Teaching of Astronomy in Asian-Pacific Region

Bulletin No.18

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Syuzo ISOBE

Chairman of Teaching of Astronomy
in the Asian-Pacific Region

Invitation to the JSGA's Education Project to detect asteroids using a newly developed software, Asteroid Catcher - B612

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The Japan Spaceguard Association have been developing an educational software which is now opened to the public. We sincerely invite you to use this software, to get some knowledge of asteroids, to enjoy asteroid detection from real observational data, and to have a honor of new asteroid discovery under a fortunate situation.

The Japan Spaceguard Association was set up in 1997 to work for the Near Earth Asteroids (NEA) problems, We started to build the Bisei Spaceguard Center with a collaboration of the Japan Space Forum (JSF) and a support of the National Space Development Agency (NASDA). Three telescopes with apertures of the primary mirrors, 25 cm, 50 cm, and 100 cm, have been set up. The 1 m telescope have a mosaic CCD camera with 10 times 2 k x 4 k CCD chips covering 7 square degree field which produces 160 Mbyte data for every shot.

Additionally to detect many NEOs, we decided to use these data for educational purpose, and prepare a large data storage accessible through high speed network line. Beside of these hardware, our team have developed a software to be used for educational fields such as in school classrooms, in science museums, and by individual persons.

The BATTeRS team worked and will work to prepare all the necessary data for those users. We hope you to enjoy asteroid detection and not to hesitate to send us any question, request, and suggestion for our software.

Guide to

Spaceguard Detective Agency

- Tracking down the asteroids -

Let's find asteroids !!

1st editon

JSGA The British Council JMU

Japan Spaceguard Association

Guide to Spaceguard Detective Agency

- Tracking down the asteroids -

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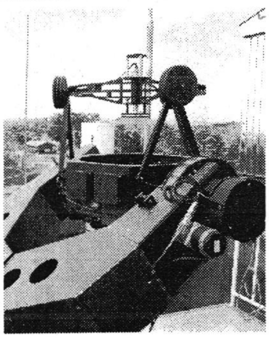
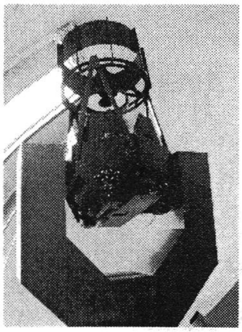


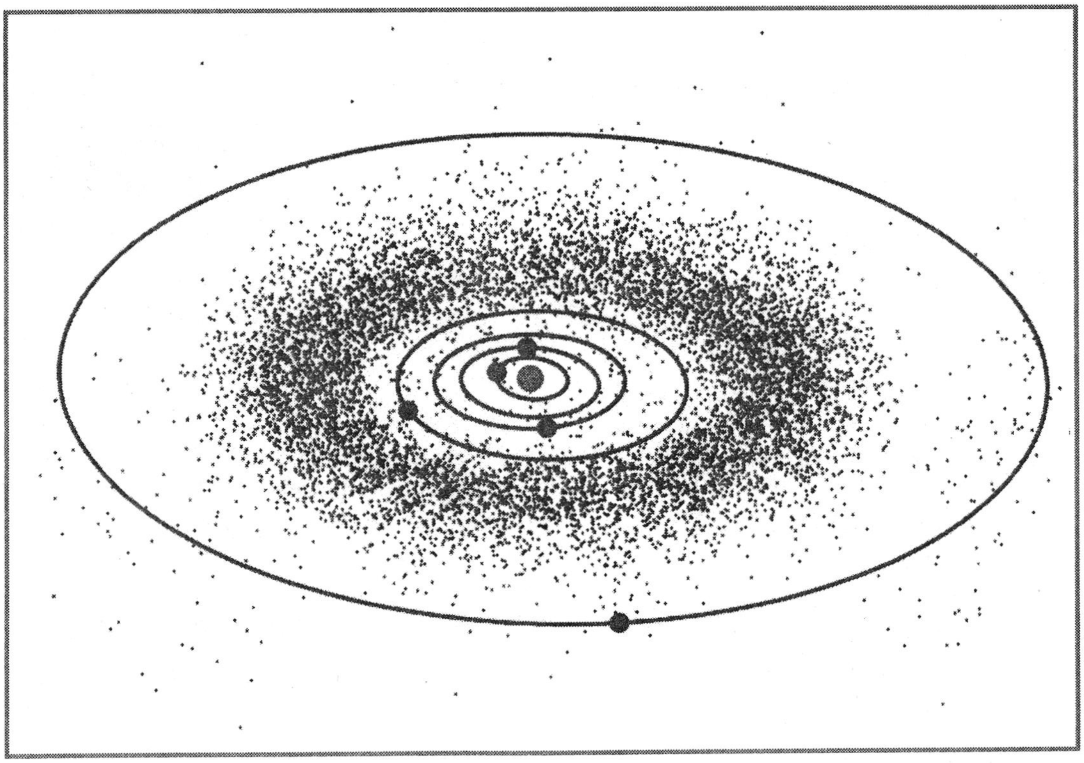
50cm *telescope in Bisei Spaceguard Center*



1.0m telescope in Bisei Spaceguard Center

1

Welcome to the world of asteroids



There are a variety of cerestial bodies in our universe. The Sun, the Moon, planets, comets, stars, nebulae and galaxies. All of them have their own unique characteristics and they are all mysteriously beautiful to look at.

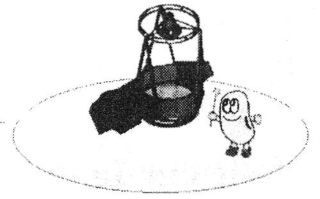
However, there are other cerestial bodies which are not readily noticeable. They are the asteroids. Asteroids are very small objects circulating around the Sun.

It is possible, however, that they may provide a clue to the birth of our solar system. They may also become very precious resources available to the human kind in future when human activities extend well into the universe.

At the same time, however, it is possible that they may collide with the Earth, leading to the end of our civilization, as we know it today.

The Japan Spaceguard Association (JSGA, http://www.spaceguard.or.jp/) invites you all to the world of asteroids. We are convinced that you will be very excited about them and find yourself looking at the new horizon which is yet to be explored by you and your friends.

2



About projects

The Japan Spaceguard Association (JSGA: http://www.spaceguard.or.jp/) is carrying out several asteroid detection projects, both independently and in association with external organisations. There are currently three such projects ongoing as follows;

Spaceguard Detective Agency - Tracking down the asteroids-

This is JSGA's own program and it is our very first program following the success of the "International Asteroid Detection Project".

International Asteroid Detection Project

This project was carried out in Japan in association with the Yomiuri Shimbun and the British Council, Japan (http://www.uknow.or.jp/bc/index_e.html). The project started in February 2001 and the results were evaluated at the end of March 2001.

International Schools' Observatory (ISO)

This web-based observatory (ISO: http://www.bciso.net/) is giving schools round the world access to professional robotic telescopes provided by Liverpool John Moores University (http://www.livjm.ac.uk/default.asp) and observational data for asteroids provided by the Japan Spaceguard Association. The ISO project is supported by the British Council (http://www.uknow.or.jp/bc/index_e.html). The ISO Observatory provides the opportunity foı young people to work together on collaborative science projects, make new friends and experience the excitement of science observation and discovery.

You do not need to worry about asteroid detection. You do not even need to have access to a telescope. You have this software specially developed by the Japan Spaceguard Association for detecting asteroids. It is called "**Asteroid Catcher B-612**" (**AstCat** in abbreviation). We will also provide you with the night sky data obtained by **the Bisei Spaceguard Center** located in the south west of Japan, either on a CD-ROM, or via Internet. Anybody who has a PC connected to the Internet can join the project for detecting asteroids.

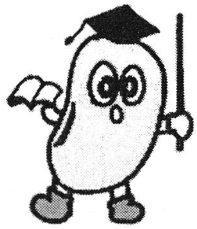
You do not need to be highly skilled in detection work. All you need is to follow this guide carefully and with a little bit of patience. This is because finding asteroids requires you to look at successive images carefully one by one. We do hope, however, that you will find it worth your time.

* Please see the web site of Japan Spaceguad Association for the current project.

NB: The Bisei Spaceguard Center (BSGC) was constructed by the Japan Space Forum (JSF: http://www2.jsforum.or.jp/) with the funds provided by the former Science and Technology Agency (STA: http://www.sta.go.jp/) of the Japanese Government and is operated by the funds of the National Space and Development Agency of Japan (NASDA: http://www.nasda.go.jp/index_e.html) . The daily observations in BSGC are carried out by the Japan Spaceguard Association (JSGA: http://www.spaceguard.or.jp/).

3

Installation and initial settings



3.1 Hardware

You need a personal computer to use **Asteroid Catcher B-612 (AstCat).** Hard disk requirement for AstCat is more than 100 MB (except for image files). **Minimum of 64 MB main memory is recommended.** Internet connection is preferable.

3.2 Operating system

Windows95/98/ME, WindowsNT/2000. **Mackintosh is not supported.** If your Macintosh has Windows emulator, AstCat may work on the emulator. But the performance may be not good.

3.3 Installation

There is a folder called NEA on your CD-ROM <A>. All you need to do is to **copy the whole of this folder on your hard disk**. NEA folder contains executable files as well as folders which contain star catalogs. All of these files will be copied to your hard disk if you copy the whole folder.

AstCat.exe can be started from your CD-ROM <A> directly. **But do not start it from CD-ROM**. Because, the system will try to write onto the CD-ROM and you will get an error message. If it happens please remove your CD-ROM and re-boot your system.

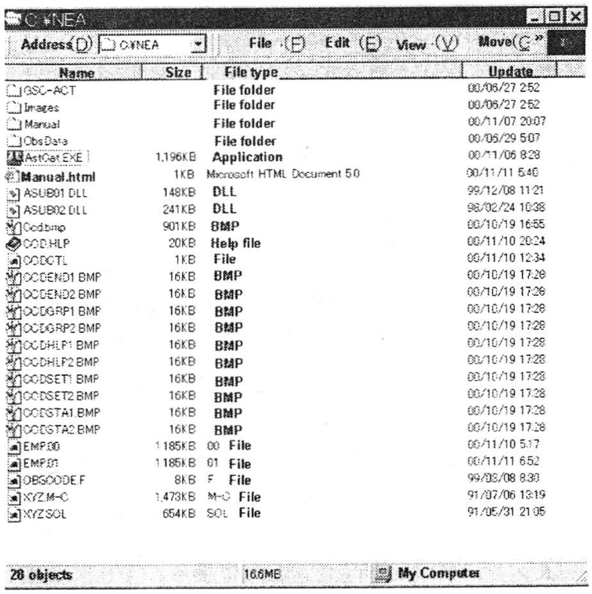
3.4 File structure

We show here the file structure of the folder NEA using. Please note that files may be a little different in practice.

NEA folder

Amongst these files there are only two user executable files, **AstCat.exe** and "**manual.html**". Please read "manual.html" through your browser. It has been confirmed that IE5 can display the manual properly. The contents of "manual.html" are the same as those of this guide,but you can see animation by "manual.html".

Please note that "ASUB01.DLL" and "ASUB02. DLL" files cannot be shown unless display option is set for "**Display all files**".

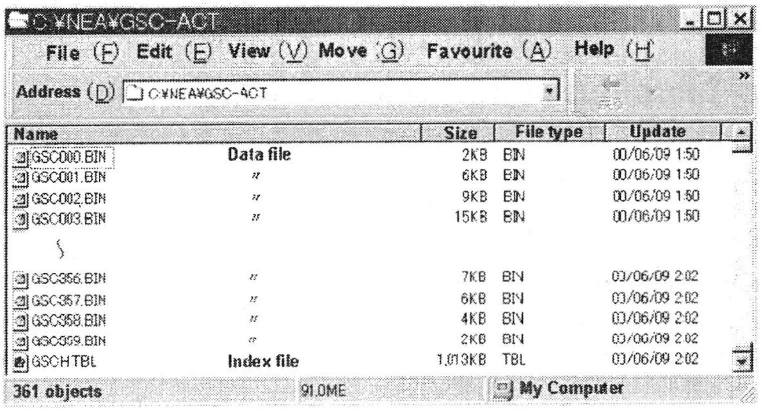


Name	Size	File type	Update
GSC-ACT		File folder	00/06/27 2:52
Images		File folder	00/06/27 2:52
Manual		File folder	00/11/07 20:07
ObsData		File folder	00/06/29 5:07
AstCat.EXE	1,196KB	Application	00/11/06 8:28
Manual.html	1KB	Microsoft HTML Document 5.0	00/11/11 5:46
ASUB01.DLL	148KB	DLL	99/12/08 11:21
ASUB02.DLL	241KB	DLL	98/02/24 10:38
Ccd.bmp	901KB	BMP	00/10/19 16:55
CCD.HLP	20KB	Help file	00/11/10 20:24
CCDCTL	1KB	File	00/11/10 12:34
CCDEND1.BMP	16KB	BMP	00/10/19 17:28
CCDEND2.BMP	16KB	BMP	00/10/19 17:28
CCDGRP1.BMP	16KB	BMP	00/10/19 17:28
CCDGRP2.BMP	16KB	BMP	00/10/19 17:28
CCDHLP1.BMP	16KB	BMP	00/10/19 17:28
CCDHLP2.BMP	16KB	BMP	00/10/19 17:28
CCDSET1.BMP	16KB	BMP	00/10/19 17:28
CCDSET2.BMP	16KB	BMP	00/10/19 17:28
CCDSTA1.BMP	16KB	BMP	00/10/19 17:28
CCDSTA2.BMP	16KB	BMP	00/10/19 17:28
EMP.00	1,185KB	00 File	00/11/10 5:17
EMP.01	1,185KB	01 File	00/11/11 6:52
OBSCODE.F	8KB	F File	99/03/08 8:30
XYZ.M-C	1,473KB	M-C File	91/07/06 13:19
XYZ.SOL	654KB	SOL File	91/05/31 21:05

28 objects | 16.6MB | My Computer

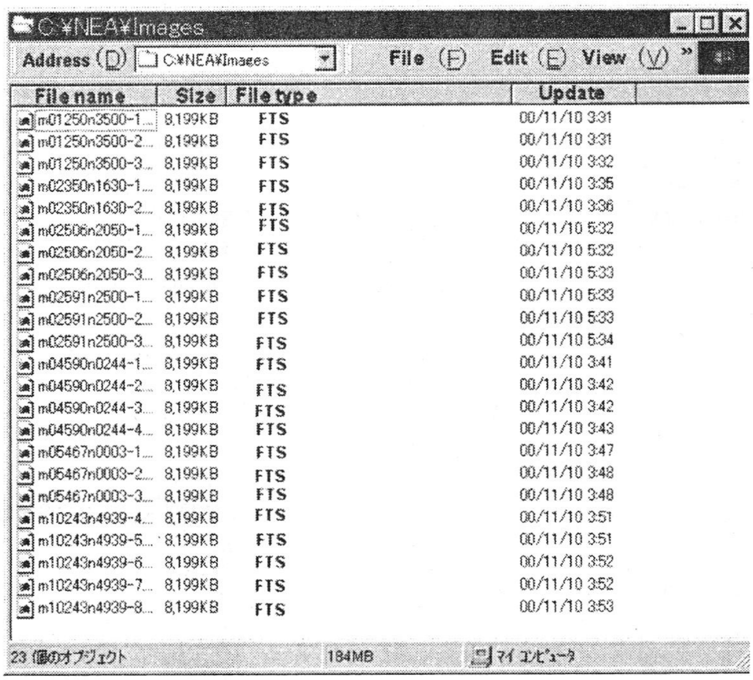
GSC-ACT folder

This contains star catalogs.



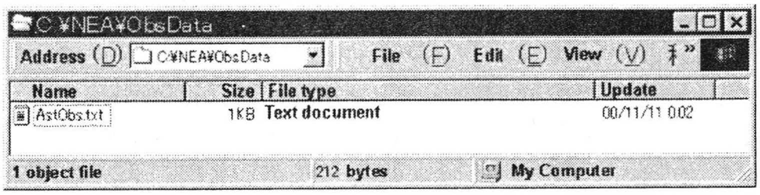
Images folder

This contains sample image data for your practice. See chapter 14.



ObsData

This is a folder for storing your measurements (in default). "AstObs. txt" is an output sample file.



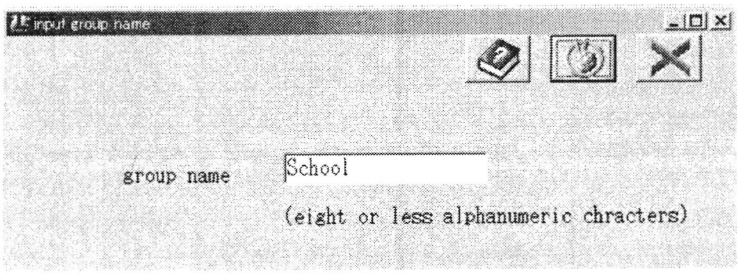
3.5 Initial settings

First, you need to start the software. In order to do so double click on  AstCat.exe in NEA folder. Then following window will open.

Start-up window

When you start up this software for the first time you cannot proceed any further by clicking on "**START**" button on the main menu. You need to register your group name by "**GROUP ENTRY**" first and do your initial settings by "**SET UP**".

Click on "GROUP ENTRY" at the lower left corner. You will then find the following window for registering your group name.

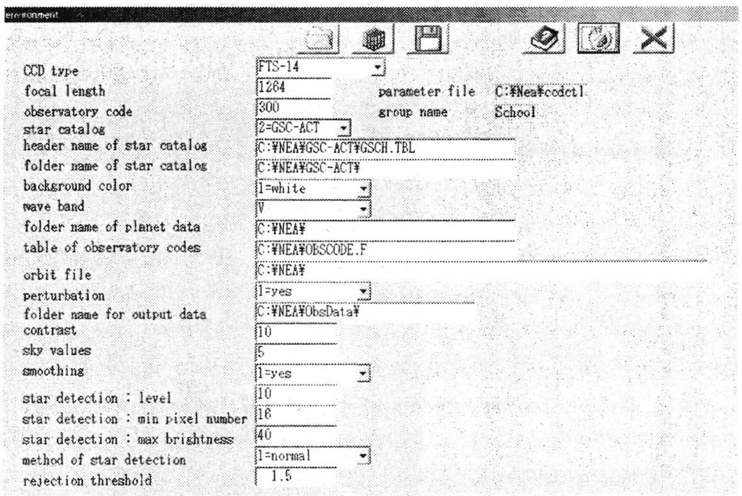


Enter your group name **within 8 alphanumeric characters**. If you are taking part in one of the projects carried out by Japan Spaceguad Association (JSGA), this group name must be a pre-registered name. Please use the group name that will be given to you by JSGA. If not, use any name as you like. The group name used here will be automatically incorporated into the report data.

In above example the group name "School" (6 alphabetical characters) is used. Please note that upper and lower characters will be differentiated. Having entered your group name please press OK icon  and return to the main menu.

NB: OK icon  is used for confirming various settings and for saving them on your hard disk. The cancel icon  is used to cancel your settings. You can also use on line help by clicking on the help icon 

Click "SET UP" and you will see the following window.



Here, you set CCD characteristics and path of various files. This setting information will be stored on a text file called **"CCDCTL"**. If you follow this manual and copy the NEA folder on your C drive such that you have C:\NEA there will be little need to change default settings.

If, for example, you copy the NEA folder on your D drive then you need to change the setting from C: to D:. If you change your settings please return to the main menu by clicking on OK icon . You can also save your new setting by clicking the icon . Since the contents of your CCDCTL have changed you will be working with these new values. If you want to cancel your settings please use the cancel icon before clicking or .

If you want to store your setting information on another file you may do so by "save with new name" icon . If you want to use such a file in place of CCDCTL file you must open it by clicking .

Explanation:

● **CCD Type:**

Only "FTS-14" and "FTS*14(binning) can be used. FTS-14 will read the image data as its original size. "FTS*14(binning)" will use 2-pixel binning, that is to say that 2x2 pixels will be read as one pixel so the file size is reduced to one 1/4 of its original size. This will increase processing speed and leads to a lot of saving on your main memory, but measurement precision is slightly reduced.

● **Focal length:**

Enter the focal length in mm of the telescope used for data acquisition. The value of focal length must be accurate within 10 mm so that stars on the image data and those on the star catalog are matched automatically. With the Bisei telescopes their focal lengths are as follows.

1 m diameter telescope: 3,000 mm

50 cm diameter telescope: 946 mm

25 cm diameter telescope: 1,264 mm

Please note that the image data provided on your CD-ROM are those obtained using the 25cm telescope, so use 1264.

● **Observatory code:**

Enter **300** for the Bisei Spaceguard Center. Other observatory codes may be obtained from http://cfa-www.harvard.edu/iau/lists/ObsCodes.html.

● **Star catalog:**

Choose only "2=GSC-ACT". No other star catalogs are used here.

● **Header name of star catalog:**

Specify the file GSCH.TBL with full path.

The default is "C:\NEA\GSC-ACT\GSCH.TBL".

● **Folder name of star catalog:**

Specify the folder name of the star catalog.

The default is "C:\NEA\GSC-ACT\".

● **Background color:**

Black or white only.

● **Wave band:**

Use V for GSC-ACT.

● **Folder name of planet data:**

Specify the folder name which has the files of XYZ.SOL and XYZ.M-C.

The default is "C:\NEA\".

● **Table of observatory codes:**

Specify the file OBSCODE.F with the full path.

The default is "C:\NEA\OBSCODE.F".

● **Orbit file:**

We do not use this setting.

● **Perturbation:**

We do not use this setting.

● **Folder name for output data:**

Specify the folder name where the output data are written. The default is C:\NEA\ObsData\.

● **Contrast:**

The typical value is 10. Smaller values mean stronger contrast.

● **Sky value:**

Larger sky values mean dim stars appearing brighter, but with more noise.

● **Smoothing:**

Smoothing is recommended.

● **Star detection Level:**

Use the value from 10 to 50.

● **Star detection (Minimum pixel number):**

Use around 10.

● **Star detection (Maximum brightness):**

Stars will **not** be recognized if maximum pixel brightness is less than the value specified here.

● **Star detection method:**

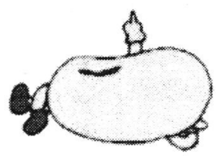
1 = Normal, 2 = Special. Use 1 here.

● **Rejection threshold:**

Use 1 to 1.5. Some of the reference stars on the star catalog may **not** be used if there are large discrepancies on comparison with those on the image data. Rejection threshold refers to angular discrepancy (unit is arc seconds).

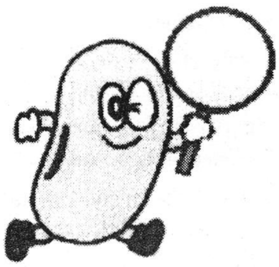
3.6 Uninstallation

Delete the whole NEA folder. **Asteroid Catcher B-612 does not interfere with Windows system files**. No alteration of the registry is made either.



4

Hints for asteroid detection



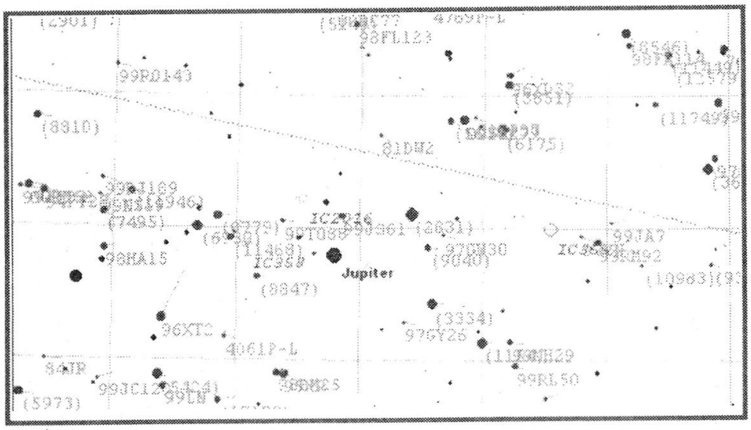
4.1 Let's find asteroids!

There is almost limitless number of stars in the night sky. However, there are many more objects, which are too dim to be viewed with naked eyes.They are asteroids. They are so dim that even the use of telescopes will not allow you to see them.

How do we detect them?

We attach cameras to telescopes and take photos. Of course, cameras used are very sensitive ones which can image dim objects. Using long exposure times we can accumulate photons from these dim objects. Being able to record dim objects does **not** immediately mean that we can find asteroids. We **must** confirm that they are moving objects. Therefore, we take successive images of the same part of the night sky and compare those images.

With this Asteroid Catcher B-612 anybody can find asteroids. We hope you will enjoy finding asteroids!

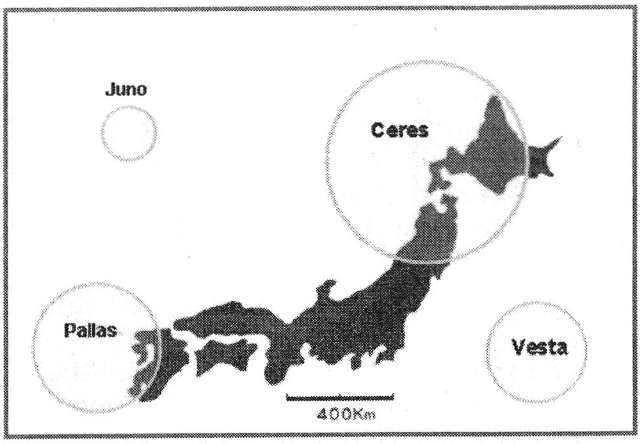


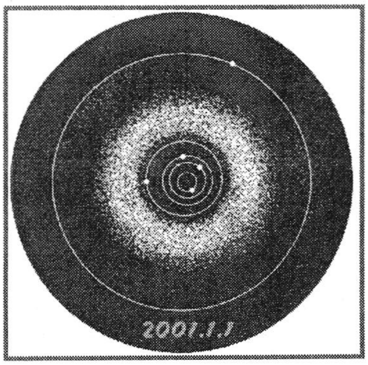
Asteroid found near the center of the Pleiades on 1 January 2001. All the numbered points are asteroids. As you can see there are so many asteroids.

4.2 What are asteroids?

They are literally small planets. The largest asteroid is the Ceres and its diameter is approximately 910 km. However, most of asteroids are much smaller in diameter and range from a mere few meters to a few kilometers. The smaller the size the greater the number of such asteroids exist.

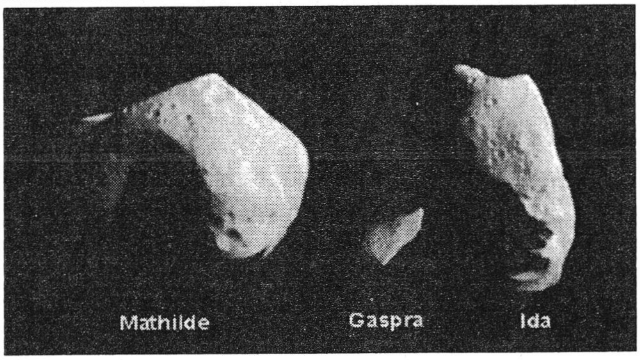
Currently, we have accurate orbital information on nearly 30,000 asteroids. In addition, we have orbital information less accurate on more than 100,000 of them. If we include those which we have observed only once, the number will jump up to more than 200,000. They are small in size, but in number they are the main players in our solar system.





(right up) Asteroids distribution on 1st January 2001. At the center is the Sun. The orbits are of Mercury, Venus, Earth, Mars, and Jupiter in radial outward order.

(left up) Size of large asteroids



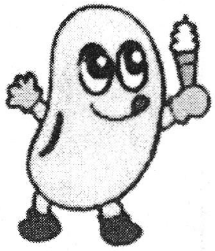
(left down)
Close up photos of asteroids taken from a NASA space probe.
(From the home page of Jet Propulsion Laboratory, Pasadena, California)

The first asteroid was found on 1st January 1801 at an astronomical observatory in Palermo on the island of Sicily in Italy. It was named after the Goddess of the island, Ceres. It was found halfway between the orbits of the Mars and the Jupiter. Subsequently, many more have been found in similar orbits.

The region in which we find most of asteroids between the Mars and the Jupiter is called the asteroid belt. However, some asteroids are found outside the belt, sometimes even outside the orbit of the Jupiter or inside the orbit of the Mars. We pay particular attention to those that orbit inside the Mars orbit as they may collide with the Earth. They are major targets for the observation at **Bisei Spacegurad Center** .

Until recently, we observed asteroids only through telescopes, but today we can send space probes to asteroids and get close up photographs. Some asteroids have been found to be shaped like potatoes. The world of asteroids is still surrounded in mystery. We remain very interested in further discoveries.

4.3 From Detection to Registration



Just as the pocket monster grows from "peechyu" to "peekachyu", then to "reichyu" asteroids are also called with different names throughout the stage of being detected. (The names of pocket monsters mentioned here are Japanese ones.)

Asteroid detection process is as follows.

Stage 1 ---- Personal designation (just discovered)

The discoverer or discovering group of the newly found asteroid can give a sorting code. Normally, it is a combination of alphabets and serial numbers.

In the project using Asteroid Catcher B-612 it is assumed that the personal designation is an alphanumeric of less than seven digits. For example, you may use any arbitrary combination of 4 alphabetical characters of your own choice followed by a 3 digit serial number.

Examples: BSGC001, BSGC002, BSGC003 etc, or UFO800, UFO801, UFO802 etc.

Stage 2 ---- Provisional designation (unnumbered asteroids)

This is the sorting code given by the **Minor Planet Center** (http://cfa-www. harvard.edu/cfa/ps/mpc. html). It is given to an asteroid whose orbit is not yet clear. Asteroids at this stage are called "unnumbered asteroids". You need a minimum of two night's observation in order to get this code.

Examples: 1998 RX25, 2000 UV13 etc.

Stage 3 ---- Registration number (numbered asteroids)

This is the registration number given by the Minor Planet Center and is given to asteroids whose orbital information is accurately known. They are called "numbered asteroids".

Examples: (1), (1862), etc.

Stage 4 ---- Unique name (numbered asteroids)

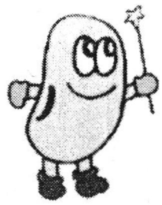
This is a unique name given by the **Minor Planet Center**. Advice on naming from the discoverer is considered. Naming can be made once a registration number has been assigned.

Examples: Ceres, Apollo, etc.

As you can see personal designation can be freely given by the discoverer or discovering group. However, beyond that stage all subsequent sorting codes will be given by the Minor Planet Center, and once given they become formal names. Unique names are also supposed to be given by the Minor Planet Center. **However, it is customary that discoverer's advice is accepted after an assessment if there is no reason for objection. This is meant to pay respect to the effort made by the discoverer.**

In early days when the number of asteroids found was small names with origins in the Greek myth were frequently used. Nowadays we encounter many unique names. Usually, those named asteroids with corresponding registration numbers are denoted like (1) Ceres, (1862) Apollo. On the other hand numbered asteroids without names are often denoted like (17286) 2000 NB6.

4.4 Finding asteroids

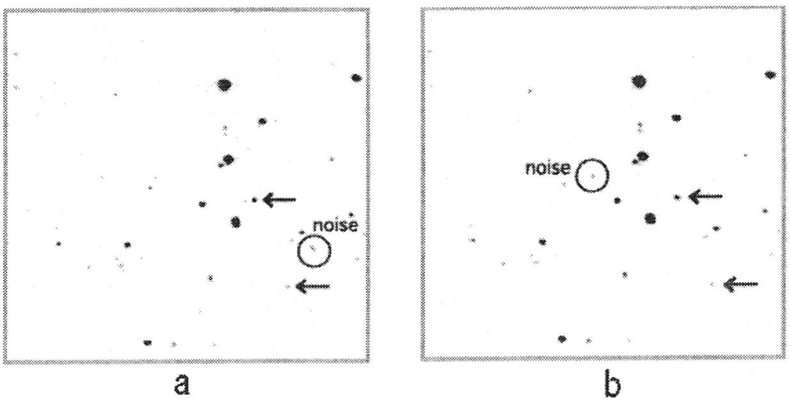


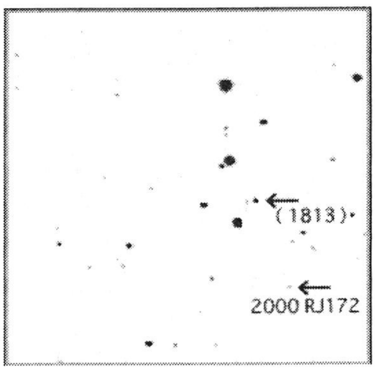
Asteroid Catcher B-612 is designed to help you find asteroids with ease. It uses more than one sky images of the same area and displays them in quick succession (blinking) alternately so that objects moving against the background of stars such as asteroids and comets can be found with accurate positional information. You can get the image data either via Internet or on CD-ROMs from Bisei Spaceguard Center. The method of obtaining data will be different from one project to another. Once you have the image data you are ready to use Asteroid Catcher B-612. Please note that the CD-ROM <A>, which contains "Asteroid Catcher B-612" also, contains sample images for your practice.

Asteroids circulate in elliptical orbits around the Sun, and when viewed from the Earth they appear to traverse the night sky against the background of stars. Thus, blinking more than one images will show up asteroids as moving objects. If you use many images you will be able to see the motion of asteroids more clearly.

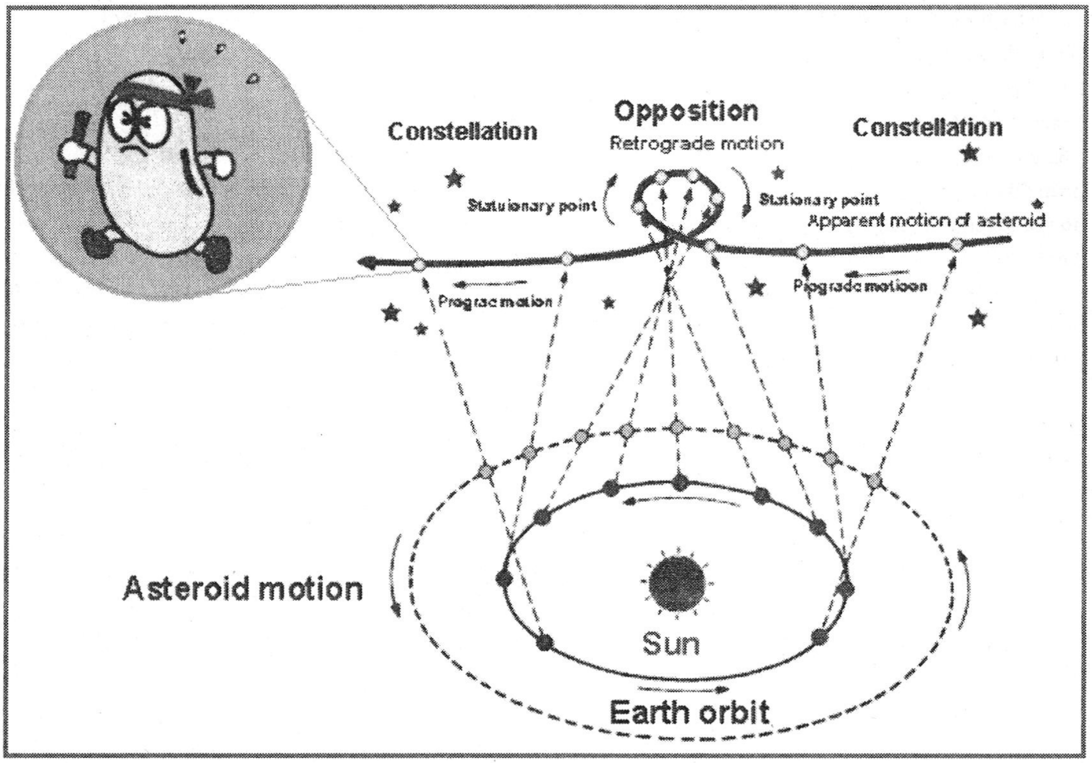
That is how **"Asteroid Catcher B-612"** works. We hope that you will be able to find as many asteroids as you can and have some fun in doing so.

Example of moving objects





Motion of asteroids (1813) Imhotep and 2000 RJ72. (The brighter one is (1813) Imhotep.)
The composite animation of "a" and "b" together (below) shows two asteroids as well as two noises.
"a" is part of the image data "m2350n1630-1.fts and "b" is part of "m2350n1630-2.fts"
in your CD-ROM <A> (See chapter. 14).



Apparent motion of asteroids

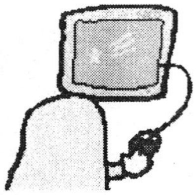
The motion of normal planets and asteroids is, when viewed from the Earth, from the west to the east. However, some may move in the opposite direction and some may even appear stationary before changing directions.

The relative motion of asteroids against the background can be very small or very large depending on the distance from the Earth, relative positions of the asteroids as well as the characteristics of the imaging device. In some cases you cannot detect motion at all due to the short time intervals used.

As you may see from the figure above the distance to an asteroid become least as the Earth overtakes them. At this stage it is located at the opposite end from the Sun. The asteroid is then fully reflecting the light from the Sun and is very visible. This is the best time for detecting usually very dim asteroids.

*** Beware of excessive viewing for your own health!**

4.5 You may find other interesting objects

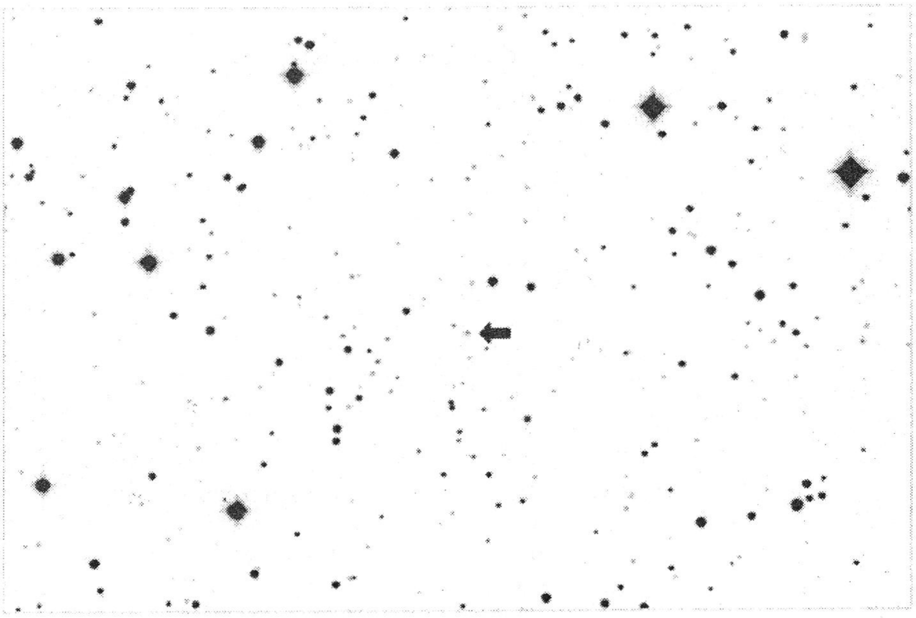


Long time ago people thought that the universe was stationary. Today, we know that it is not and in fact we know that the universe is constantly changing. It is therefore only natural that some previously undetected moving (or changing) objects are recorded on the vast amount of image data obtained by the Bisei Spaceguard Center.

Such objects other than asteroids are usually comets, supernovae and variable stars.

Comets move around the Sun just like asteroids, and usually they appear as fuzzy objects like galaxies at a large distance. As they approach the Sun and become brighter they appear to have long tails. If you find fuzzy moving objects on your image data please suspect that they are new comets.

However, it is possible that they are known comets or simply noise due to the cryogenic CCD camera. You must be careful. You can obtain orbital information on known comets from magazines on astronomy. You can also obtain information from the home page of the Minor Planet Center.



Animation of the comet LINEAR (C/2000 U5) moving to the northwest in the Orion. Magnitude is approximately 14 to 15. You can see a faint tail in the direction of the south. (Top of the image is the north.)

Supernovae are explosive phenomena at the end of evolution of stars. They are rare and are found on average once in a few hundred years within any one galaxy. In fact, with our own galaxy no supernova has been detected since 1604 when a supernova called Kepler's supernova was detected in Ophiuchus.

However, there is almost limitless number of galaxies on your image data. Even if, with any one galaxy, it is rare to observe supernovae you can still expect to find them with other galaxies. Checking for supernovae is easy. All you need to do is to compare the images of the same galaxy taken at different times and look out for a new bright star in or around the galaxy. You can find the images of galaxy, for example, by clicking here (http://dss.mtk.nao.ac.jp/).

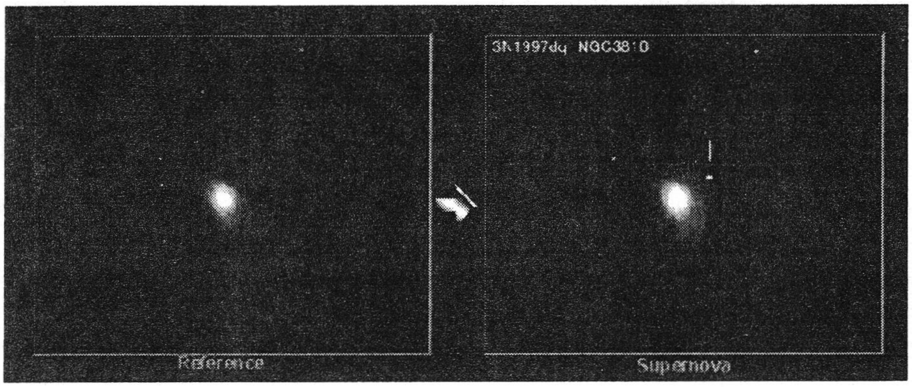
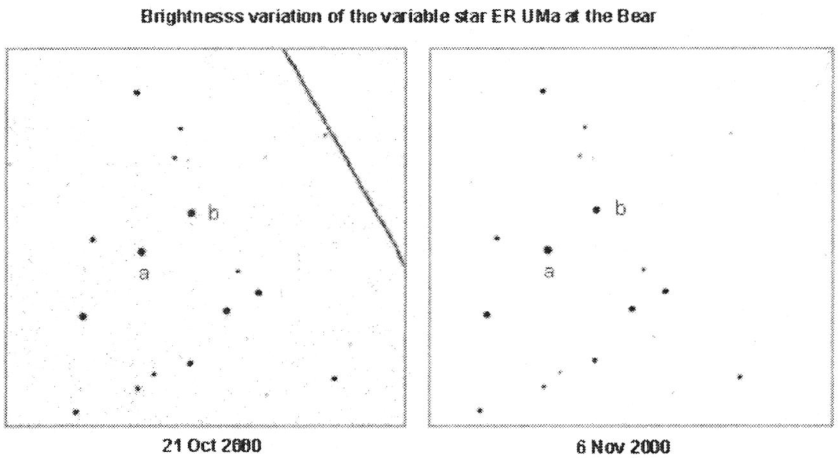


Image of the supernova SN1997dq found by Mr Masakatsu Aoki (Toyama-city, Japan).
(From his home page, http://www.tam.ne.jp/aoki/pages/novamain.html)



Above two images contain a variable star ("a" on the image) called "Ursa Major ER" found by Mr Shin Iida of Nagano prefecture, Japan.
On 21st October its brightness was similar to that of "b".
You can see, however, that its brightness is greater on 6th November than "b".
For your information, the line going across the image on the left is the orbit of an artificial satellite.

Variable stars are the stars whose apparent brightness changes with time. There are different reasons for changing brightness. In some cases stars are periodically swelling and shrinking. In other cases they may be a binary with one star rotating around the other so that they appear like eclipsing when viewed from the Earth.

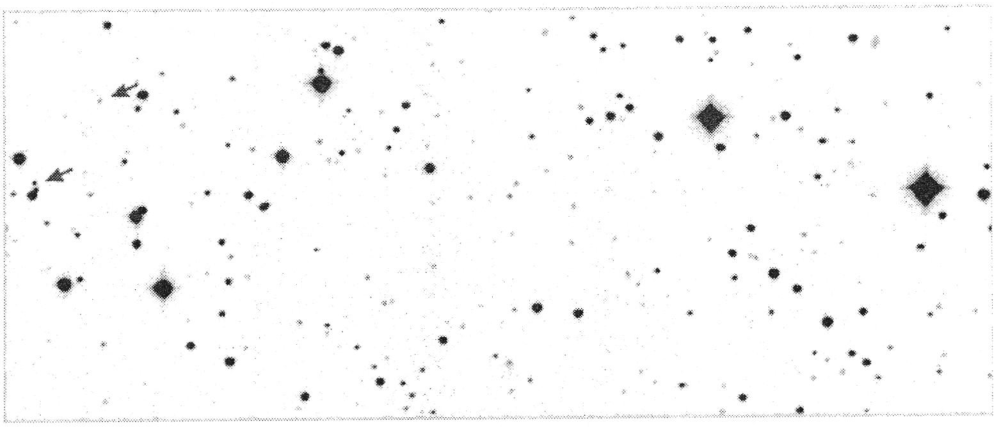
Their brightness usually do not change overnight. Therefore it is not easy to find them from a series of images taken at short time intervals. However, with care and patience you may find them if you compare images separated by a few days.

4.6 Beware of noise

Digital CCD cameras are very popular these days. For astronomical use we also use cryogenic CCD cameras so that we can record astronomical objects over a long exposure time. Long exposure leads to an increased amount of noise. However, cooling the CCD chip reduces noise.

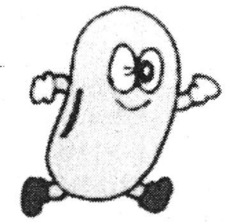
Unfortunately, cooling does not completely remove the noise. CCD chip consists of a large number of photo receptors called "pixels". For example, each image on your CD-ROM consists of a collection of some 4.19 million pixels. Some of these pixels are more photosensitive than others. Some may be faulty and do not respond to light at all.

These may be regarded as "noise". Noise is a nuisance when we examine our image data. Sometimes they appear just like asteroids. We need to be very careful.



This animation shows examples of noises. At the tip of arrow is the noise.

5



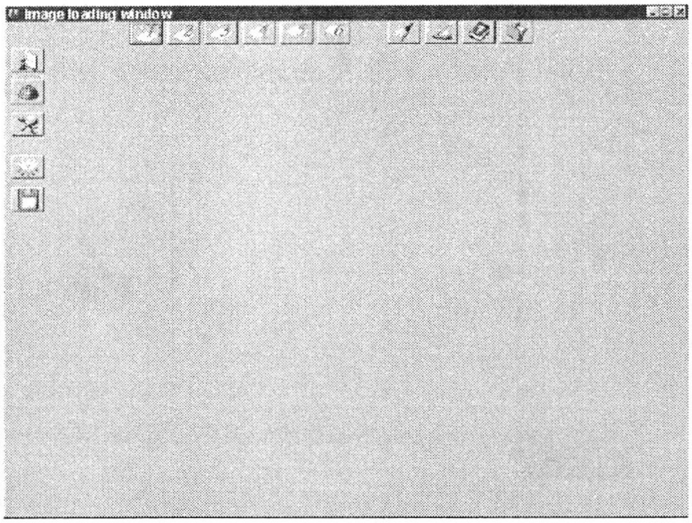
How to use AstCat.exe -1-

Loading image files

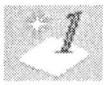
In this chapter and the next we will explain how you can use the **Asteroid Catcher B-612 (AstCat)** in order to detect asteroids. Please also refer to the list of icons in chapter 10.

First of all, double click on  "AstCat.exe" in NEA folder to start the program. If you have not yet registered your group name and setting initial values please do so first (refer to 3.5) before you proceed any further.

Next, Click on  "START" button. You will see the following window. This is the window for loading image data.

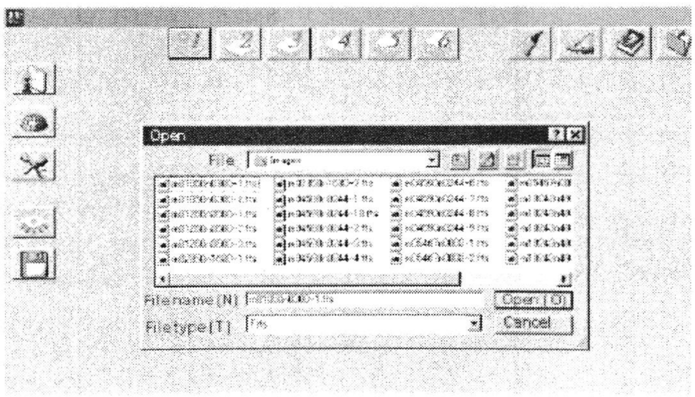


NB: There is a "return" icon  on most of your windows. Alternatively, you can use the close button ☒at the upper right corner of your window to close your current window.

5.1 Loading reference image 

Load the first image (Reference image) by clicking on  at the top of your window. An image loading dialogue will be displayed. Choose your target image file and click on it, or alternatively type in the file name directly.

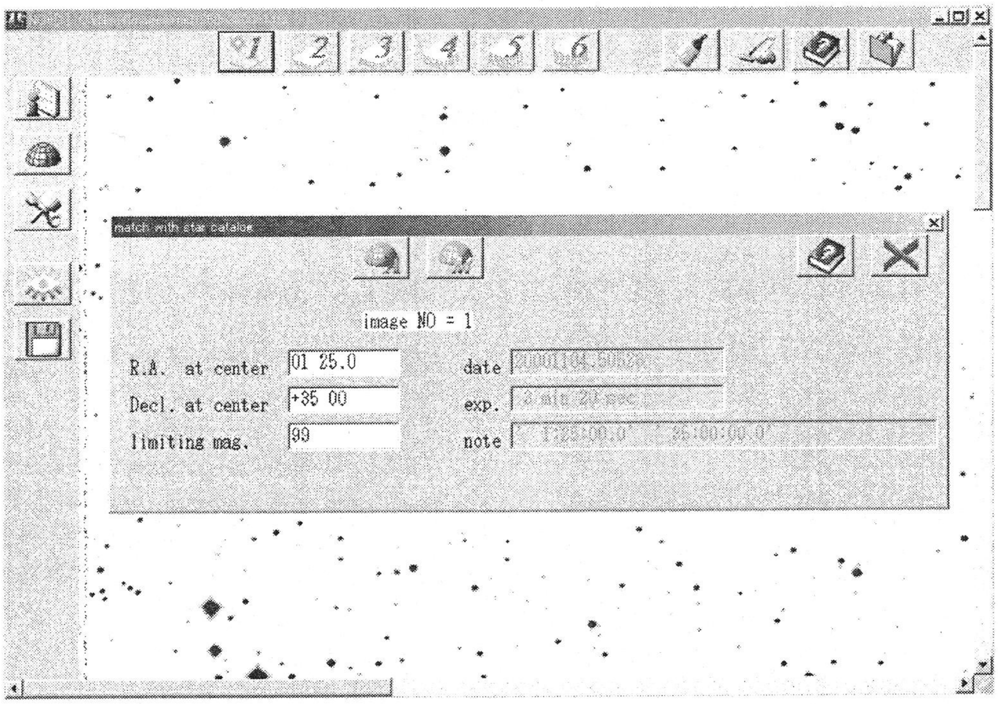
Image loading window



> **NB:** Loading image files takes a lot of time, as they are all large files. It may take a few minutes to load one image depending on the processing speed of your PC. Please be patient even if the screen appears to be stopping.

Once the first image is loaded, the following window will be displayed.

Window for matching with the star catalog



The coordinates (right ascension and declination) of the center of the image and other information are displayed. Click on "automatic matching" and match your image with the star catalog.

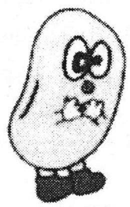
Automatic matching with the star catalog is the process whereby stars on your image data are checked with the reference stars on the star catalog and the exact location of your image on the night sky is determined.

If this automatic matching is successful with the first image data, then please load images 2, 3 etc. Automatic positioning of these images with reference image (the first image) will be carried out.

If you want to delete a loaded image click either on icon (currently displayed image is deleted), or on icon (all loaded images are deleted). If your image currently on display is the image 1, then clicking on icon will delete all currently loaded images.

> **NB:** You can output the image currently on display as a BMP (bit map) file by "output image as BMP" icon . Original images are of FITS format and some of image processing software may not be able to handle them. In that case this is a useful function.

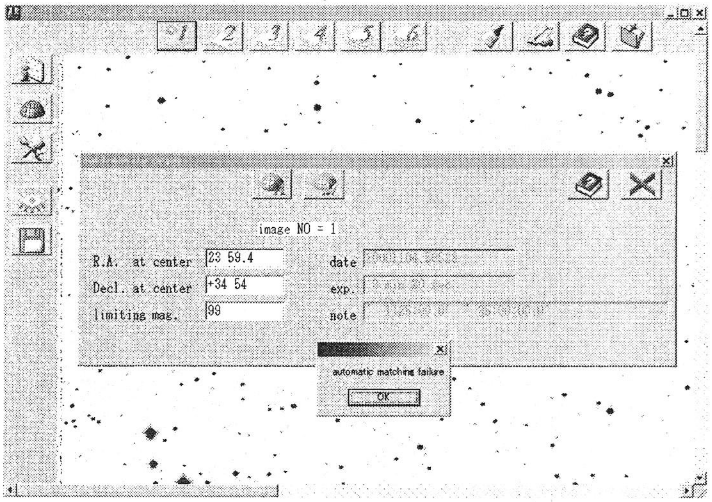
5.2 Manual matching with star catalog 



If automatic matching with the star catalog fails, you must do manual matching. It rarely necessary to do this. However, occasionally if images are taken around the Polar Star (right ascension larger than +89 degrees) , or if images are not very good, automatic matching may fail.

In that case you must compare your image with the star map (map of the star catalog data) in the following way so that both are matched.

Window when automatic matching fails



If automatic matching fails, you will see a window shown left. You click on the OK button on the message box and a new window (below) will show up. It is within this window that you do your manual matching. This window shows your image on the left and the star map on the right.

Manual matching Window

First of all, you must check if both images are of the same area of the night sky by the resemblance between the image and that of the star catalog. It is possible that the values of right ascension and declination are wrong if there is no resemblance between the two images.

The star catalog is partitioned with a blue square that indicates the field of view. This is for your ease of operation and you should not differentiate the inside from the outside. You should select 4 pairs (or more) of the same stars. These pairs should be evenly located over the entire area of your image.

Having decided on these paired stars you then must click on them both on the image and the star catalog in the same order. Therefore, you are advised to click on your target stars alternately between the image and the star catalog. Clicked reference stars will turn red. If you wish to cancel your selection you only need to click again on the selected pair. After the selection of pairs, clicking on "manual matching" icon will start the process of matching the image file and the star catalog.

If you click on "reference stars" icon after your matching operation, those pairs with good matching accuracy will appear red and those with significantly less accuracy will turn blue. If there are red pairs evenly across the screen, your manual matching is a success and click on "return" .

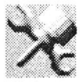
If you click on table of residuals icon you will be able to know the amount of residual between your image and the star catalog. Even on this manual matching window you still have "Automatic matching" icon . This has nothing to do with manual matching and it starts automatic matching, but it allows you to know the result of automatic matching.

If you click on "initialize" icon selected (or marked) stars are all cancelled. You may use it for selecting your reference stars all over again.

If you click on "Match with star catalog" icon in the image loading window then a window for this operation will appear. Normally, images are automatically matched with the star catalog when they are loaded. You may use this icon in case automatic matching fails to take place.

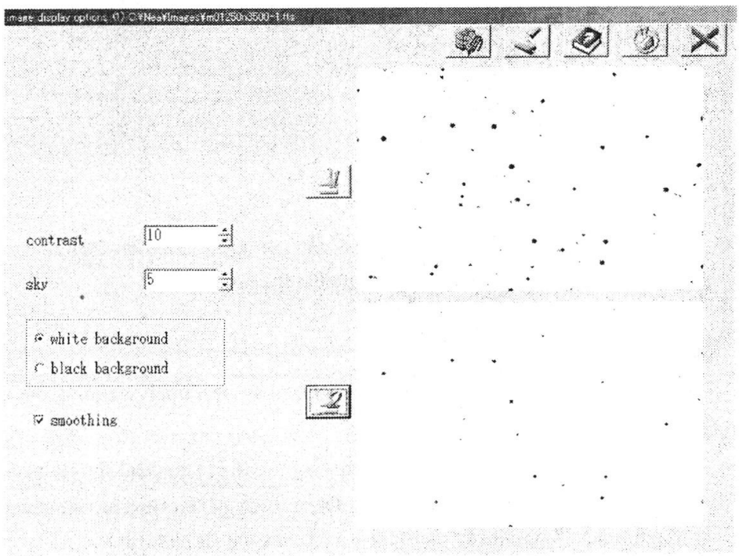
5.3 Display option

- getting good images to analyze-



You may use icon for adjusting contrast and others.

Display option window



● Contrast:

Default value is 10. Larger values will lead to smaller contrast.

● Sky Value:

Larger values of "Sky Value" will brighten up stars, but also increase noise level.

● Test display:

This is done by "Show test display 1" or "Show test display 2" icons. At first, "Test display 1" will display currently adopted setting values, but you can change them. If you click anywhere on either display you can use values set for that display.

● Apply to all images:

Setting values will be applied to all images and redrawing of images will be made.

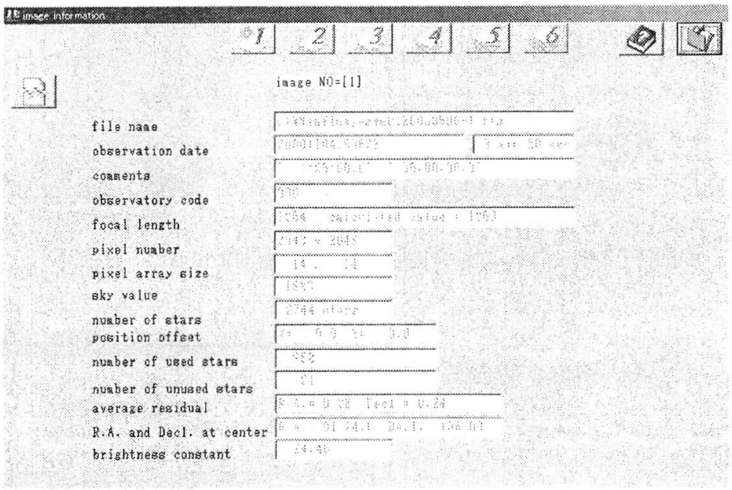
● Use default setting values:

This is used to return to default values.

5.4 Display image information

If you want to know information on your image please click on icon.

Image information window



By clicking on image 1 to image 6 you get information on each image. Clicking on an image number that has not been loaded will not cause any change in the display.

● Number of stars

This is the total number of objects recognized as stars upon scanning the image.

● Brightness constant

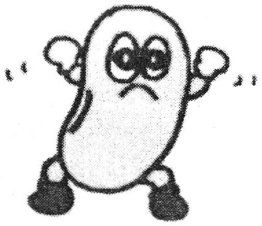
This is a constant used to calculate the magnitude of stars and is obtained from the magnitude listed on the star catalog and the CCD brightness. From this you can calculate the magnitude of your target star as:

Magnitude = Luminosity constant - 2.5 times log (brightness)

● Table of residuals

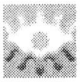
With this table you can find the residual of matching between the images and the star catalog.

6



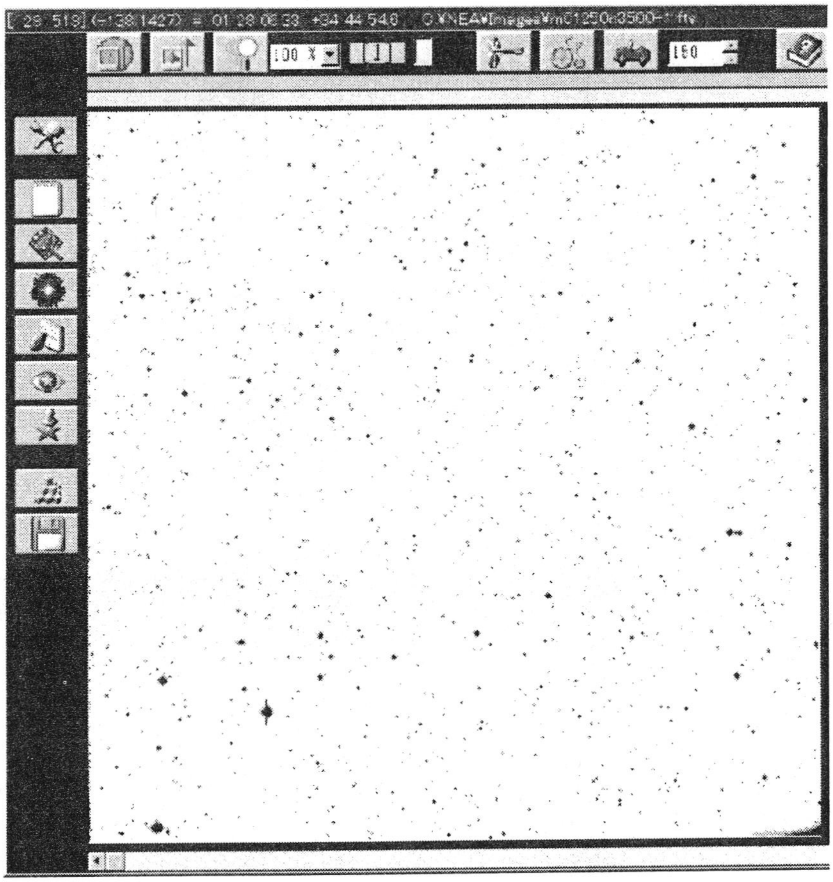
How to use AstCat.exe -2-

Blinking and measurements

6.1 Blinking 

Once you have successfully matched your first image data with the star catalog you can load other image data files. Automatic matching is made with image data 2 and beyond. If you have loaded all image files you can now proceed to blinking stage by clicking on blink icon  . **You are now ready for detecting asteroids.**

Blinking window

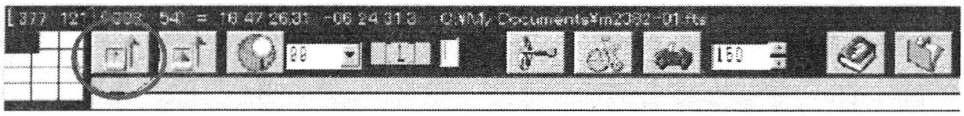


Clicking on "**Automatic blinking**"  will start the process of blinking (alternate showing of all images). Blinking speed can be changed by the up and down icon 150 found to the right of  . If you click on "**Manual blinking**" icon  you can see images one by one. Look at blinking images very carefully and try to find moving objects.

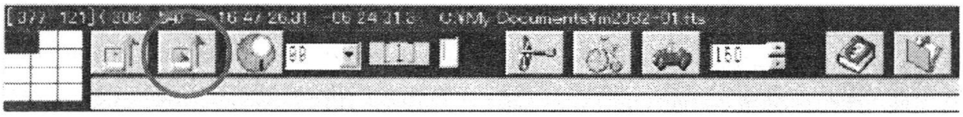
You must not be confused by noise. For details on noise please refer to chapter 4.6.

You may find it easier to work with enlarged images. Use following icons.

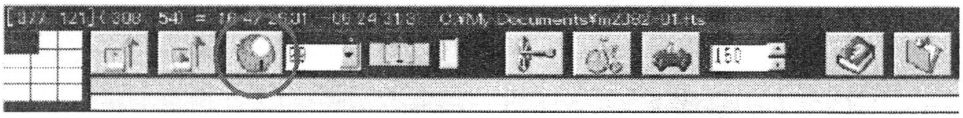
● **Display whole image :** Whole image is displayed (This is the default setting)



● **True scale :** One pixel on the CCD is displayed as one pixel on the screen.



● **Set image size :** Display will enlarge or shrink. Choose the value from the combo list to the right of the icon . Direct keyboard input is also possible.



Please note that the displayed area may be limited by the display of your PC. If one whole image cannot be accommodated within your screen you can scroll your image by one of the following methods.

(1) Direct clicking on scroll bar or by dragging the bar itself.

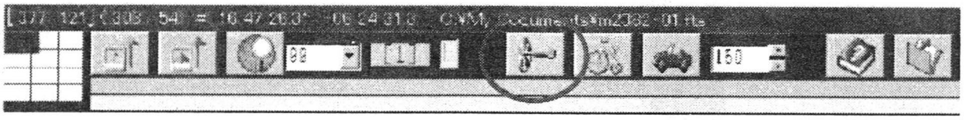
(2) Pressing space bar will move the image across.

(3) Clicking in the grid which is shown upper left

(4) Use arrow keys.

On the blinking window itself you also have a display option icon . Use it when trying to find dim objects. You can selectively blink your images. Use following icon .

● **Select images for blinking:**



On the blinking window you can see the values of the right ascension and declination where your cursor is currently positioned. You can move your cursor about to see the scale of your images.

NB: Some examples of angular distance are as follows.
From the horizon to the Zenith : 90 degrees
Size of the Plough : Approx. 15 degrees
Three stars of the Orion : Approx. 2.5 degrees
Apparent diameter of the Sun and the Moon: Approx. 0.5 degrees (= 30 minutes)
Daily movement of asteroids : Approx. 0.2 degrees (= 12 minutes)
Apparent diameter of the Jupiter : Approx. 0.7 degrees (= 42 seconds)
Apparent diameter of Pluto : Approx. 0.1 second

6.2 Useful functions

● Search for known asteroids

You cannot use these function in this edition. This is because we would like you to enjoy detecting even known asteroids. Followings in this paragraph are just for your information.

If there are known asteroids within your image their predicted positions will be displayed in a red frame and their names and predicted magnitudes will be displayed in red.

You can search for known asteroids by clicking on . Also, if you click on detailed information about the known asteroids will be displayed.

NB 1: Asteroids' names are displayed as follows:

(1862)	Asteroid registered as one thousand and eight hundred and sixty second
2000UV13	Asteroid registered with provisional designation 2000 UV13
3040P-L	Asteroid registered with provisional designation 3040 P-L
5778T-3	Asteroid registered with provisional designation 5778 T-3

NB 2: Accuracy of predicted positions of asteroids

The accuracy of predicted positions of numbered asteroids is pretty high to within a few arc seconds. However, with asteroids with provisional designation numbers you may not find them at predicted locations because information on their orbits is insufficient for accurate prediction. The accuracy differs from one asteroid to another. All astronomical objects in our solar system are under mutual gravitational influence and their orbits are constantly changing by perturbation. Therefore, positional accuracy decreases with time.

● Search for moving objects

If you click on this icon moving objects will be marked blue. However, it is **you** who must decide if they really are moving objects. Sometimes this function fails to mark moving objects. Use your own eyes to find them. (This function can only be used when you have loaded more than one image files.)

● About stars

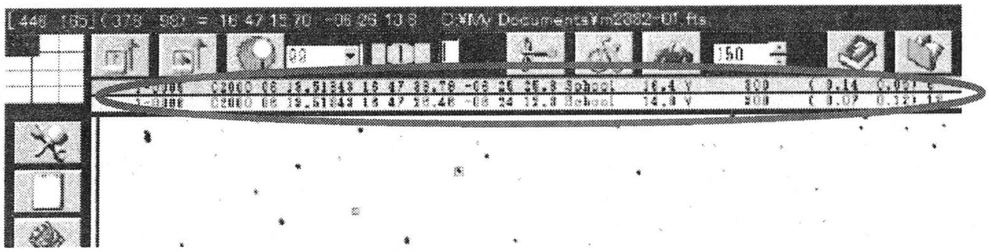
If you click on objects recognized as stars will be marked red. If you click on then the objects recognized as stars and those that match with the star catalog will be marked. If matched properly marking will be in red and if matching is not very good marking will be in blue.

● Delete markings

All markings will be deleted if you click on this icon .

6.3 Measuring positions

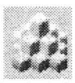
If you find an object moving relative to stars in the background, you should measure its position. **It is necessary to measure the position of the same asteroid for all the blinking image files.** In order to measure the position, put the cursor at the center of the object and click. Its positional information will be displayed immediately at the top of your screen (Following figure).



Of the two lines displayed the lower line shows the positional information you just clicked for and its contents are as follows (From left to right):

Measurement serial number
Time of observation (Universal Time "UT"). (Hour, minute, second is converted into decimals in units of day)
Right ascension (Hour/minute/second. Year 2000 equinox)
Declination (Hour/minute/second. Year 2000 equinox)
Group name
Magnitude (V= Visual magnitude)
Observatory code
Standard deviation etc.

The position of the selected objects are determined by using several sets of reference stars. The numbers such as (0.07 0.12) 12 in the right show the standard deviation and the number of times of determinations.

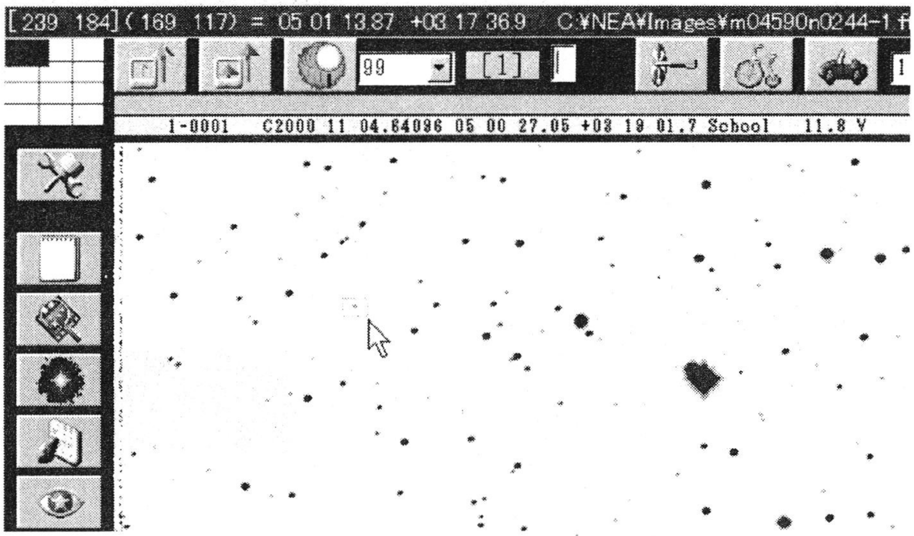
Pixel brightness map 

The pixel brightness map is a sky brightness distribution of the objects and the surrounding sky recorded on the CCD camera. You may use the pixel brightness map in one of the following two cases.

(1) Objects are too dim and clicking on them does not give measurements (No red frame appears, which means that automatic measurements is impossible.)

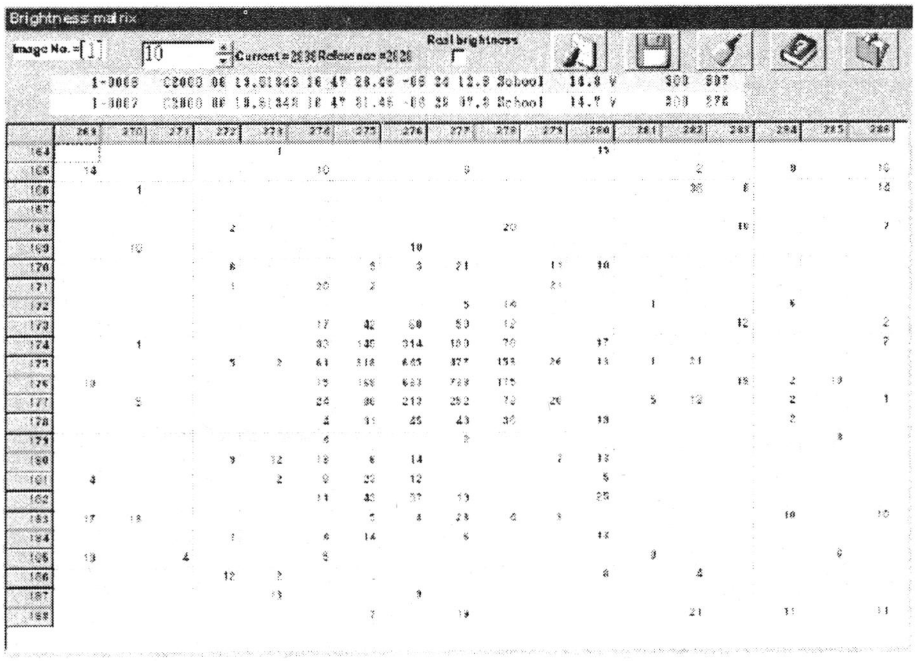
(2) When you want to know detailed information on the pixel brightness and to determine the position manually.

In the case of (1) drag your mouse and draw a blue frame around the object you selected (Next figure), and release the right button of your mouse. It will show the pixel brightness map around the selected object.



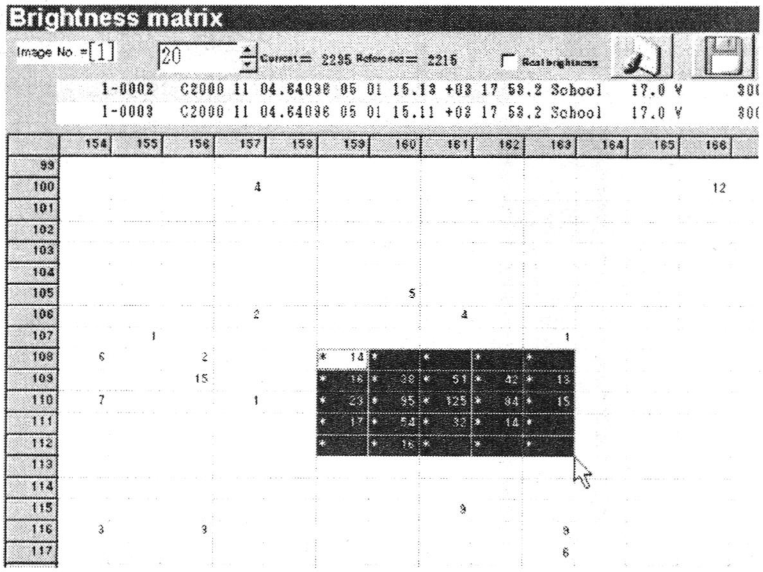
In the case of (2) after clicking your object, click on "pixel brightness map" icon  .
Following figure is the pixel brightness map.

Pixel brightness map window



Each number within the cells gives the amount of light that fell on each pixel. Large numbers are bright stars and their surrounding areas. When the pixel brightness map is displayed drag your mouse, with the left mouse button pressed down, to draw an area which you wish to recognize as a star. Selected area will turn blue and an asterisk is placed in front of the brightness value (following figure). This is the area you select as your star candidate. As soon as dragging stops the center coordinates of the star are calculated and the result will be shown above the matrix.

Brightness matrix

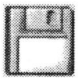


Your drag will initially select a square, but you can make fine adjustments by clicking the left button of the mouse on each pixel (Each clicking corresponds to "on" and "off"). Just after each clicking, the star position will be calculated and the result will be displayed at the top.

You can also make automatic star recognition while on the pixel brightness map itself. Put your cursor at the center of your target star and click the right button on it. It will show the result. If you want to cancel all pixel selection just click on the clear icon .

This is how you make measurements on the blinking window or on the pixel brightness map. If you are satisfied with the results you then save them on a file.

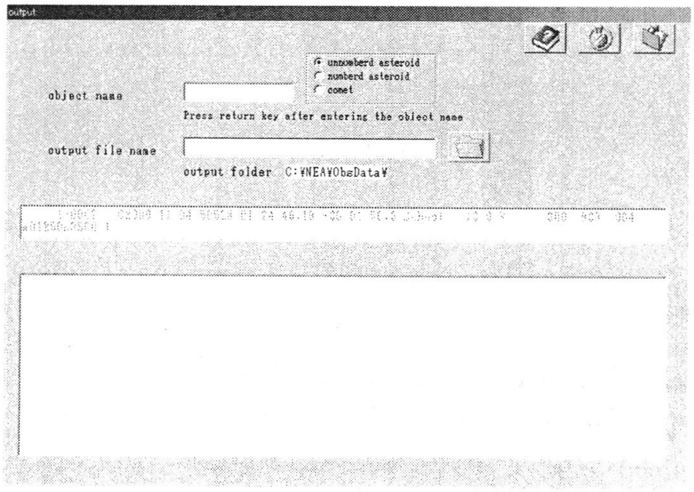
6.4 Saving measured results on a file



In order to save the result of your measurements on a file, you click on "Output measured data" icon . Display will change to the following.

Observed data saving window

You will see the lastly measured data in the frame at the data will be saved on a



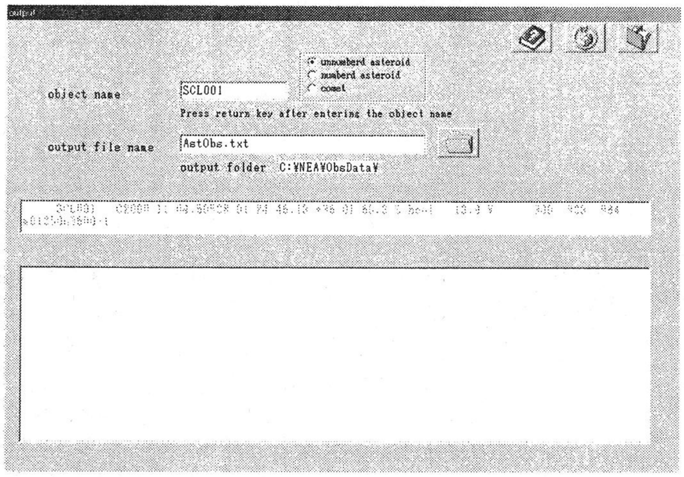
Followings are how to save the measured results.

(1) Selecting astronomical object type

First, select unnumbered asteroid, numbered asteroid, or comet. However, it may be difficult to know what your discovery is. If you want to check the type of the object please use the method explained in chapter 7. If you find it difficult to check, you may just select "Unnumbered asteroid" and give it a personal code as follows.

(2) Naming your object

Once you have selected an object type the next step is to name it and you may do so according to the format as follows.



Above is the case of unnumbered asteroids. In this case a personal code of "**SCL001**" is being given. Here, you can arbitrarily choose the portion corresponding to "**SCL**". "**001**" is a serial number. You can choose any name as you wish such as **SCL001** when you cannot identify your object as one of the known astronomical objects.

If your discovery is an unnumbered asteroid with a temporary code just enter that code as the name of your discovery. If, for example, it is the asteroid **2001 AS** you enter "2001 AS" or you can also enter just "**01AS**" and hitting the Enter key will convert that into a proper format.

In the case of a numbered asteroid you enter its registration number such as 1 or 2382. In the case of a comet you should enter the name of the comet according to the IAU formal format. This format is used by the Minor Planet Center (http://cfa-www.harvard.edu/cfa/ps/mpc.html).

NB: Please hit the return key (CR) after you have entered the object name. It will insert that name into the top of the data string.

(3) Entering the file name

After you have entered the object name you must also enter a file name. You can use any file name as long as it makes sense to you. Unless you specify your own folder the file will be stored in the folder that was specified when you made your initial setting. You may also use a full path specification such as "C:\NEA\ObsData\AstObs.txt". (You find this file in your CD-ROM. This is a sample file for measurements.)

Finally, clicking on "OK" icon  will save the result on the specified file. If a file already exists with the same name, then data will be added and if not a new file will be created.

```
Examples of measurements  [IAU format]

>         1         2         3         4         5         6         7         8
>12345678901234567890123456789012345678901234567890123456789012345678901234567890
>
>numbered asteroids ------------
>02382        C2000 06 19.51343 16 45 18.68 -07 01 35.3                      300
>02382        C2000 06 19.51860 16 45 18.36 -07 01 28.6                      300
>
>unnumbered asteroids ----------
>     J87K00L C2000 06 19.50797 15 32 50.88 -19 36 34.3                      300
>     J87K00L C2000 06 19.51601 15 32 50.25 -19 36 45.7                      300
>     AB001  * C2000 06 04.66535 18 28 01.17 -10 47 47.9          17.3 V      300
>     AB001   C2000 06 04.66762 18 28 00.11 -10 47 49.7                      300
>
>periodic comets --------------
>0047P        C2000 06 04.74766 20 50 14.30 -34 58 18.1          15.6 T      300
>0047P        C2000 06 04.75455 20 50 14.41 -34 58 19.6                      300
>
>non-periodic comets ------------
>    CJ99S040 C2000 06 04.76306 02 08 06.90 +33 05 53.7                      300
>    CJ99S040 C2000 06 04.76645 02 08 07.10 +33 05 56.4                      300
>    CJ99S040 C2000 06 04.76747 02 08 07.07 +33 05 56.7                      300
```

The data format used in **AstCat** is quite similar to the IAU format. IAU format consists of 80 columns of text with alphanumeric characters. However, with AstCat we added extra columns from 81 to record X and Y coordinates of the object and the name of the image file.

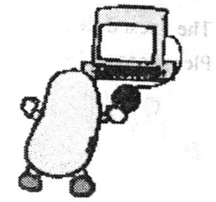
The first 80 columns from the left are as follows.

(1) Name of the celestial body
(2) Asterisk at the 13th column indicates the new observation
(3) Date of image acquisition (Time as a fraction of one day)
(4) Right ascension and declination
(5) Magnitude
(6) Color band (V if CCD is used)
(7) Observatory code

Please take care that the same objects are measured more than once in the above example. This is because you must measure the position of the same object for every images that you blink to show that the objects that you find are moving objects.

7

Identifying detected objects



- for advanced users -

If you find a moving object please do check whether it is a newly discovered object or an already known object. There are a lot of new discoveries everyday and you need to check your object with latest information. Here we show you how to use the home page of the Minor Planet Center.

First of all, you need to determine the position of your moving object. Please refer to chapter 6.3. At this stage you need not determine its position very accurately. An accuracy of one arc minute is enough and note down its right ascension and declination.

NB: Position and accuracy of an astronomical object

In determining the position of an astronomical object its accuracy must be appropriate for the purpose. For example, if the brightness of the Space Shuttle in orbit is something like that of magnitude 1 star, you may simply describe the motion of the Shuttle like "moving from the low altitude in the south western part of the sky to right above our heads." Then other people can find it.

However, you need much more accurate information on the position of an asteroid. The accuracy required is less than 0.1 arc second. Since the diameter of the full Moon as viewed from the Earth is approximately 0.5 degrees, determining the position of an asteroid with such accuracy is equivalent to measuring it with an accuracy of 1 in 18,000 of the full Moon.

Examples of positional accuracy

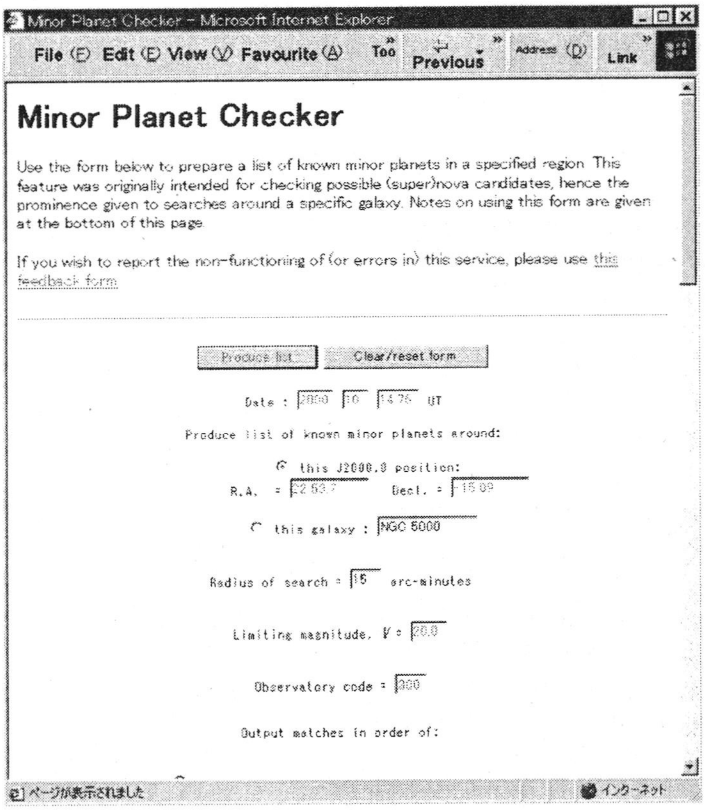
	α	δ
0.1 arc second	13h 30m 42.84s	-22° 49' 18.2"
1 arc second	13h 30m 42.8s	-22° 49' 18"
1 arc minute	13h 30.7m	-22° 49'
0.1 degree	13h 31m	-22° 8

α; 13h 30m 42.84s and δ; -22° 49' 18.2" are respectively equivalent to the right ascension 13 hours 30 minutes 42.84 seconds and the declination -22 degrees 49 minutes and 18.2 seconds.

Let us now check your data (time of observation, the right ascension, the declination) with the latest data.

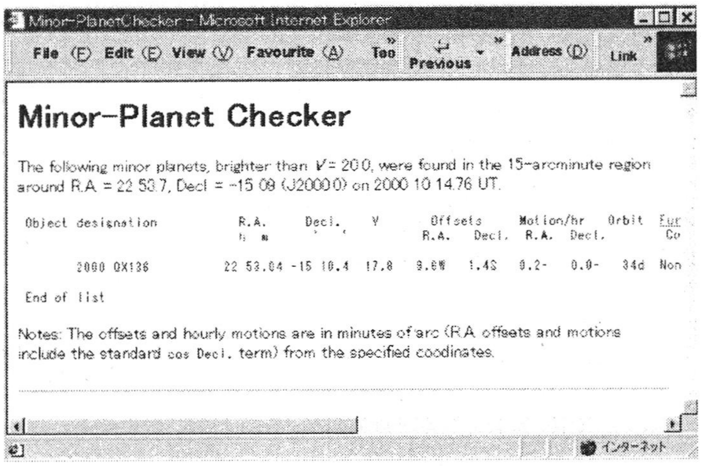
Here, for the sake of explanation we assume that the time of observation is day 14.76 of October 2000 (UT) and you found a moving object at the right ascension 22h 53.7m and declination -15° 09' with a magnitude of 18.5. Let us now check if this is a known astronomical object or not.

The latest data are available at the **Minor Planet Center (MPC)** of the **IAU**.
Please access "MPChecker" in MPC (http://cfa-www.harvard.edu/iau/ps/mpc.html).



You will find right window. Then enter your data and finally click on "Produce list" icon. After a few seconds you will see the following window. (These Web pages o MPC may be changed.)

According to this window you know following things:



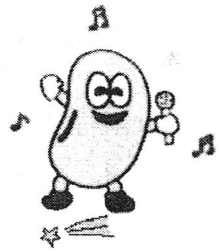
"At the time and in the vicinity of the position you specified, there is an asteroid named 2000 QX136, with a magnitude of 17.8. The position is 6.6 arc minutes to the west and 1.4 arc minutes to the south from the position that you input. This asteroid is moving due west at 0.2 arc minutes per hour with no movement in the north-south direction."

This is very similar to your object in magnitude and direction of its movement. Its position is similar to less than 0.1 degree. It is therefore very likely that your object is not a new discovery. On the other hand, if there is no object in the vicinity it is likely that your object is a new one. However, we cannot be sure because right at this moment somebody, somewhere out there, may be writing up a report on exactly the same object!

Yes, race is on for new discoveries!!

8

Reporting



If you are taking part in a project, please send your data of asteroids to the coordinator of the project. The data format must be the one that Asteroid Catcher B-612 produces. Otherwise, your report cannot be recognized by the checking software.

How to make your reports:

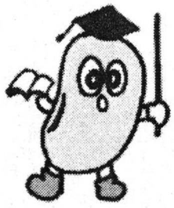
Please send your reports by e-mail. If other informations are announced to you from your coordinator, please follow them. **You must use exactly the same format that this software uses.** In doing so, please **copy-and-paste** the data to your e-mail in order to prevent transcription mistakes. Please add following information in your report.

(1) Group name or registration number
(2) Your name (or group leader's name)
(3) E-mail address
(4) Telephone number
(5) FAX number An example of reporting (Expand)
(6) Other information that your coordinator requires

NB: E-mail software setting:

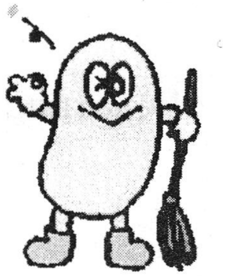
(1) Please do not use HTML format. **Use only text format.** HTML format is not accepted.

(2) Ensure that a long line is not carriage returned and disrupted in transmission. Please ensure that **at least 110 characters are not disrupted**.

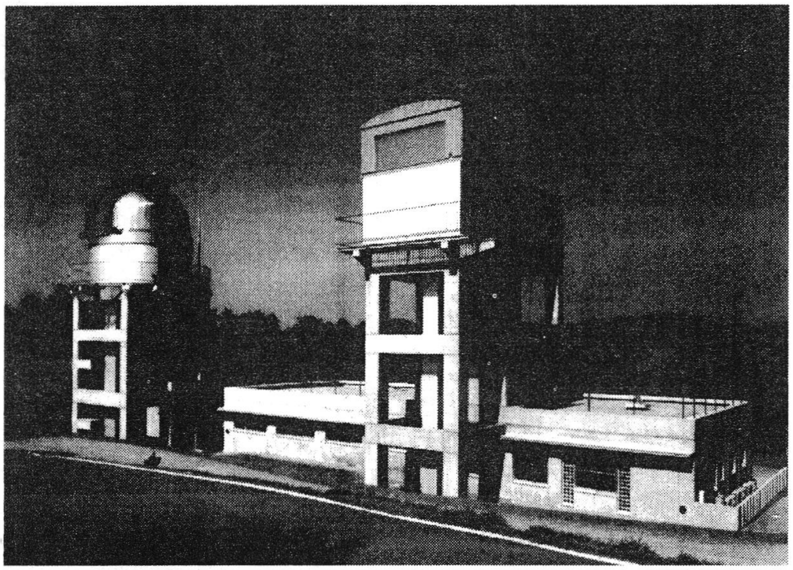


9

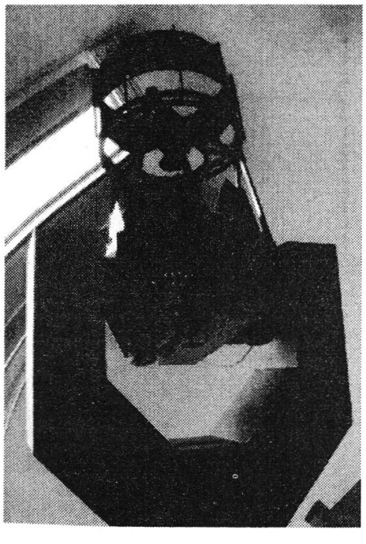
Latest information



Japan Spacegurd Association provides you information about the projects, Asteroid Catcher B-612, and the image data, etc. Please see the homepage **http://www.spaceguard.or.jp/**.

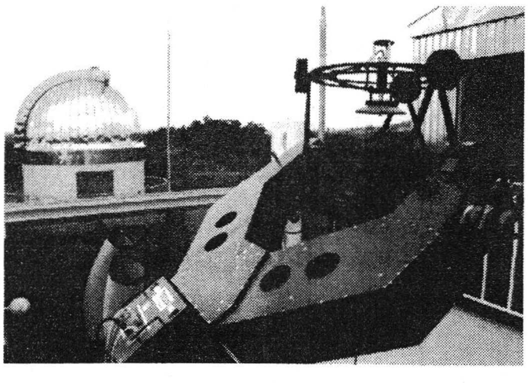


Bisei Spaceguard Center
The 1m telescope is in the left dome, and 50cm telescope is in the right sliding roof.



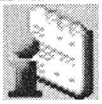
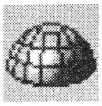
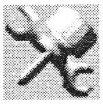
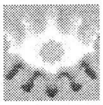
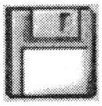
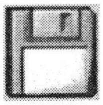
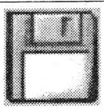
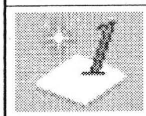
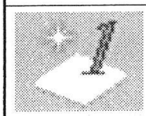
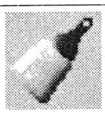
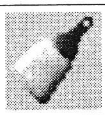
⬅ 1m telescope

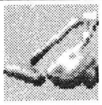
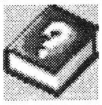
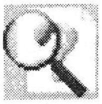
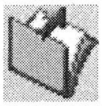
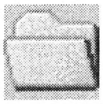
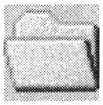
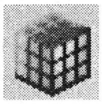
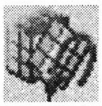
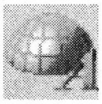
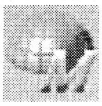
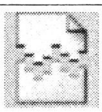
⬇ 50cm telescope

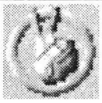
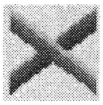
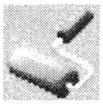
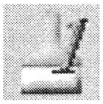
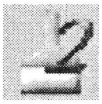
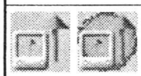
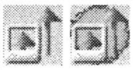
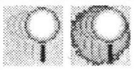
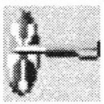
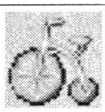


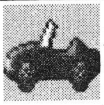
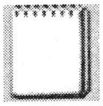
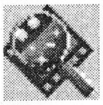
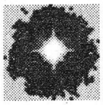
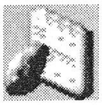
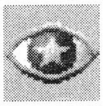
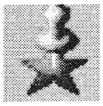
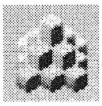
10

ICONs

	**image information** Clicking this icon will display information about the image.
	**match with star catalog** Shows a window, where you can re-input the center coordinates of the image in order to match with the star catalog. It is the same window which appears upon loading the first image file.
	**image display option** Modifies contrast and sky brightness of the image.
	**blink** Moves to the blink window, where loaded images will be displayed in succession.
	**save with new name** [on SET UP window] This allows you to save your current setting on a new file.
	**output image as BMP** [on window for loading image files] This allows you to save your current image in BMP format.
	**output measured data** [on blinking and pixel brightness map windows] This allows you to save the result of your measurement on a file.
	**read image (1) - (6)** [on window for loading image files] This allows you to load the images into memory. Load them in order of data acquisition.
	**images NO.1 - 6** [on window for image information and table of residuals] This icon selects images and displays their properties. The display will not be changed if you select the number of image that you have not yet loaded.
	**clear** [on window for loading images] This icon clears the image currently being displayed. However, if it is the image NO.1 then all of the images will be cleared from memory.
	**clear** [on window for pixel brightness map] This icon clears pixel selection.

	**clear all** Clears all of the images from main memory.
	**help** Displays information relevant to the current window.
	**index** If this icon is clicked whilst in the help display mode it will display help index. Use this icon in order to get information on another window.
	**return** Return to previous display without saving the result of your last operation.
	**open** [on SET UP window] This reads parameters from the user-specified file.
	**reference** This will show existing paths and files when you save your data or images on a file.
	**default values** Current setting values are saved as the standard setting, and they are used when the program is next executed.
	**default values** Changes user set values to default values.
	**automatic matching** Stars on the image are automatically matched with those on the star catalog. There are occasional errors. If an error occurs please use manual matching.
	**manual matching** This allows you to match manually stars on the image with the star catalog. Please mark stars by clicking on them which, you think, are the same stars on both. You must mark more than three pairs both on the image and the star catalog so that they form a polygon as large as possible on your display. After selecting stars, click this icon once again.
	**table of residuals** This shows you the amount of discrepancy in the positions between stars on the image and the data on the star catalog.

	**OK** Click on this icon if you are satisfied with your current setting. Your current setting becomes effective and the display returns to that of just before this operation.
	**cancel** Click on this icon when you wish to invalidate your currently chosen setting on your current window. Once you select default setting you will not be able to cancel it.
	**apply to all images** Click on this icon if you are satisfied with your current setting and want to apply it to all other images.
	**show test image 1** The sample image to the right of this icon will be redrawn according to your current setting.
	**show test image 2** The sample image to the right of this icon will be drawn or redrawn according to your current setting. You can use this icon in order to compare images by leaving the sample image on the Test Display 1 as it was.
	**display whole image** Whole of the picture will be shown on your display. When this mode is selected, the icon will change to one with the Sun in the background (right).
	**true scale** In this mode, one pixel of the image corresponds to one pixel of your display. When this mode is selected, the icon will change to one with the Sun in the background (right).
	**set image size** Choose scaling % of your preference to enlarge/shrink your image on your display. Upon choosing the scale in the box to the right of this icon, click on this icon. When this mode is selected, the icon will change to one with the Sun in the background (right).
	**Select images** Currently loaded images are shown with image numbers. You can choose images that you want to blink by checking those you want to blink. If you remove checking marks then they will not be displayed on the blinking window.
	**manual blink** Click on this icon, then images will be displayed one by one each time you click on this icon. You may use this in order to check objects you find with automatic blinking.

	**automatic blink** Click on this icon, then blinking will start automatically. The number shown in the box on the right can control the blinking period. The minimum blinking period is 1/1000 second. Pictures will be replaced every one second if you select the number 1,000. Please use this automatic blinking when you try and detect objects such as asteroids. Automatic blinking is stopped if manual blinking icon is clicked.
	**reset, initialize** This will remove all markings on the image.
	**find moving objects** This will mark objects in blue which are suspected as moving objects. More than two images must be loaded in the main memory.
	**find known asteroids** Clicking on this icon will mark known asteroids in red. However, this function does not work in the current project.
	**table of known asteroids** Detailed information on known asteroids will be displayed. However, this function does not work in the current project.
	**detect stars** Objects that are recognized as stars will be marked red.
	**stars used for analysis** Stars on the image that are correctly matched with those on the star catalog will be marked red. Stars with large discrepancies will be marked blue.
	**pixel brightness map** Click on this icon after you have marked your target object in the blinking window. The area around the selected object will be enlarged. The pixel numbers are shown on the upper end and left side. Numbers in the cells indicate the brightness. The greater the numbers the brighter the stars. Use this map in order to determine star positions manually with high accuracy.

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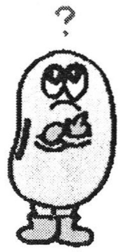
FAQ



Q	Display on screen appears to stop when loading images. Why?
A	It takes a lot of time to load images. It depends on your CPU speed. Sometimes it takes a few minutes.
Q	None of the icons functions in the blink mode. Why?
A	AstCat sometimes does not function properly when the Japanese character input system, MS-IME, is used. Put it in the task bar.
Q	Moving the cursor on the blinking screen does not show up the position (right ascension/declination) at the cursor. Why?
A	Position matching between the image and the star catalog has not been made.
Q	No blinking takes place. Why?
A	You need more than two images covering the same area of the sky. Load them in turn and click on blink icon.
Q	Blinking does occur, but some areas are not well matched. Why?
A	Either the subsequent images are rotated with respect to the first image, or they are partially distorted. This happens when the time interval is large and atmospheric conditions change over that period.
Q	There is no asteroid. Why?
A	Asteroids are not evenly distributed across the sky. Try other images.
Q	I can see a star on and off, but it is not moving. Why?
A	We think it is noise. It may also be the effect of a cosmic ray.

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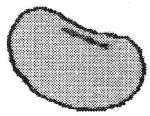
A little more about asteroids



Bean

Asteroid

What is the difference between asteroids and minor planets?

Small planets are called "asteroids" or "minor planets" in English. The former originates from the usage of the word meaning "something like stars" at the start of the 19th century. This is because they looked like points even if viewed through a telescope. The latter simply means "small planets". Both are correct ways of calling asteroids. According to a British astronomer, Dr D.J. Asher, there are a little more astronomers who use the term "asteroids".

Where are they found?

Most of asteroids are found in the orbit between that of Mars and Jupiter. It is called "asteroid belt". However, an increasing number of asteroids have been found in the inside of Martian orbit. They are called **Near Earth Objects** (NEO) and pose potential threats to the Earth. Also, a lot of them have been found in the vicinity of the orbit of thePluto. They are called "Edgeworth-Kuiper Belt objects". As you can see they are distributed all across our solar system.

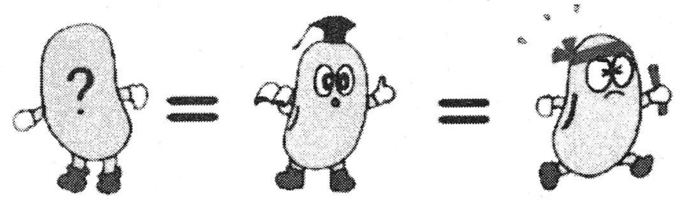
Orbital calculation

On 1st January 1801 the first asteroid was found in the vicinity of the constellation Taurus. It was named "Ceres". However, it quickly went missing. Then, a German astronomer and mathematician, C.F. Gauss, calculated its expected orbit using known positions of the first few days of its discovery. Ceres was found again according to hisprediction near the constellation Virgo, about one year later on 31st December 1801. It was confirmed for the first time that Ceres was an asteroid circulating the Sun (It was much smaller than any other known planets).

If we can measure the apparent positions of an asteroid over a few nights we will then be able to calculate its orbit. Young Gauss, the mathematical genius, was the first astronomer to do so.

Identification

An asteroid often goes missing without giving us its accurate orbital information. Some years later another observatory may detect it and report it as a new discovery.



That means that the same asteroid can be found many times over and each time it is "discovered" it is given a new provisional designation.

In the same way you may well find an asteroid, using Asteroid Catcher B-612, one that was detected in the past and went missing. One day, a more accurate orbital calculation can be made and an asteroid with different provisional designations may be identified as the same single asteroid. In that case the asteroid may be described as something like **2000 SD7 = 1997 YW18 = 1999 JY85** . We call this process "**identification**".

Who discovered it? The difference between "saw" and "discovered"

Did you notice that in the above example the order of detection is irregular?

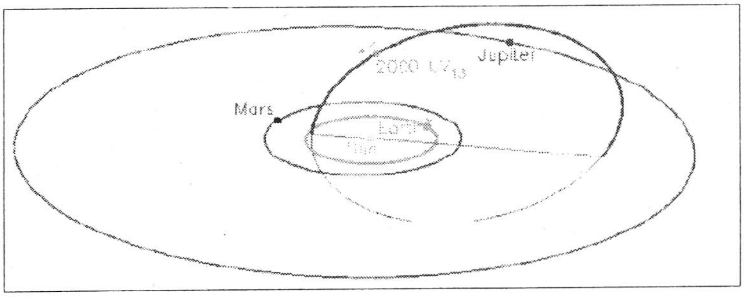
The fact that the same asteroid can be found many times means that there are many discoverers of the same asteroid. However, **IAU** (http://www.iau.org/) only recognizes one person (or one group) as the true discoverer. The glory goes to the person who calculated its elliptical orbit for the first time. You cannot calculate elliptical orbits from observations over a few nights. So, we will not be able to predict their future positions. If we know the elliptical orbits of asteroids, then we can predict their future position. Therefore, in order to say we have discovered asteroids, we need to have its elliptical orbital information as a minimum condition.

In the above example the person who discovered **2000 SD7** is the true discoverer and other people only **"saw"** the same asteroid.

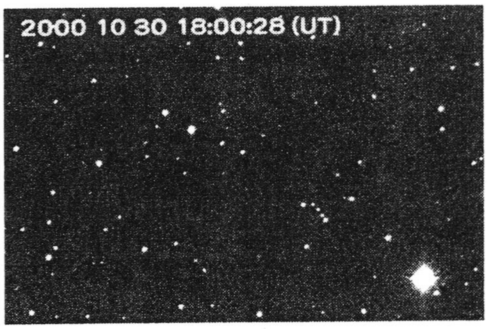
Unusual asteroids

Most of asteroids are found in semi-circular orbits between the orbits of the Mars and the Jupiter. However, some follow narrow elliptical orbits and there are others that even cross Earth and Martian orbits. On the other hand, there are others that circulate near the orbit of the Jupiter and some even go out as far as the Pluto. These are called **"unusual asteroids"**. Some approach the orbit of the Earth and they are called **Near Earth Asteroids** (NEA), or **Near Earth Objects** (NEO).

An asteroid discovered at **BSGC** on 21st October 2000 is one of the **"Apollo"** type asteroids. Its orbit crosses that of the Mars and approaches the Sun closer than the Earth. Its diameter is assumed to be between 5 to 12 km. It is similar to the asteroid which collided with the Earth at the Yukatan Peninsular some 6.5 million years ago, wiping out most of the species on this planet. **It is getting a lot of attention for that reason**. This asteroid is called 2000 UV13.



The figure depicts the orbits of the Mars, Jupiter, and the Earth at the time of 2000 UV13 discovery. (An illustration drawn by Dr D. J. Asher). Its orbit inclines to the Earth orbit at an angle of 32 degrees. The portion of its orbit below the line linking the Sun and the intersection with the orbit of the Earth is located below (south) the plane of the Earth orbit.



Animation of unusual asteroid 2000 UV13 moving across the constellation Ursa Major. (Photo: Bisei Spaceguard Center)

Exploration of Asteroids

Asteroids were not very well known until recently. However, they are becoming topical now. For instance, we can now send space probes to asteroids to get more detailed information. In 1991 and 1993 Galilleo approached the asteroids called Gaspra and Ida respectively and sent photos back to the Earth. In 1997 a space probe called "NEA" approached asteroid "Mathilde" and was placed in the orbit around asteroid "Eros".

A Japanese space probe is expected to be launched in 2002. It is called **"MUSES-C"** and it is a **sample return mission**. It will no doubt unveil even more information on asteroids.

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References

- Japan Spaceguard Association (http://www.spaceguard.or.jp/)

- IAU Minor Planet Center (http://cfa-www.harvard.edu/cfa/ps/mpc.html)
- Find asteroid names (http://cfa-www.harvard.edu/cfa/ps/lists/MPNames.html)

- Dictionary of Minor Planet Names : Lutz D. Schmadel, Springer
- Minor Planet Circular (http://cfa-www.harvard.edu/iau/services/MPC.html)
- Minor Planet Electronic Circular (http://cfa-www.harvard.edu/iau/services/MPEC.html)

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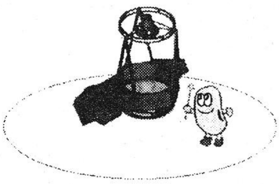
Sample images

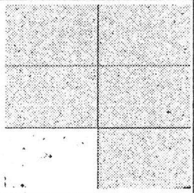
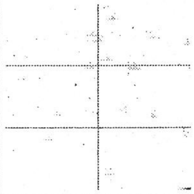
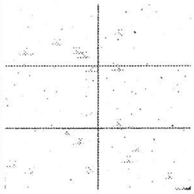
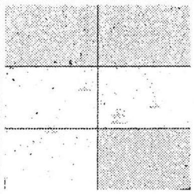
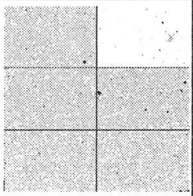
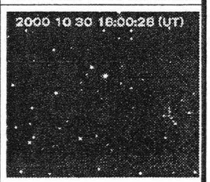


In your CD-ROM <A>, you will find several sample images that the 25-cm reflective telescope with CCD camera at the **Bisei Spaceguard Center** took. The size of these images is 2,048 X 2,048 = approx. 419 million pixels. This corresponds to an angular area of the night sky of about 1.3 degrees by 1.3 degrees.

What follows is the list of images.
If the first 11 characters of the file names are the same it means they are of the same area of the night sky. The numbers that follow characters denote the number of order in which images were taken. For your information, ".fts" means that the images are of FITS format.

● **Please try to find asteroids using these images.**

For your convenience, the blinking animations are alsoattached.

Set	File name	Date	time (End of exposure)	Exposure (sec)	Note	Blink
(1)	m01250n3500-1.fts	2000 11 04	12:09:16	200	m01250n3500-?.fts	
	m01250n3500-2.fts	2000 11 04	12:34:21	200		
	m01250n3500-3.fts	2000 11 04	12:58:47	200		
(2)	m02350n1630-1.fts	2000 11 03	13:17:37	240	m02350n1630-?.fts	
	m02350n1630-2.fts	2000 11 03	13:41:33	240		
(3)	m02506n2050-1.fts	2000 11 05	13:22:16	300	m02506n2050-?.fts	
	m02506n2050-2.fts	2000 11 05	14:14:09	300		
	m02506n2050-3.fts	2000 11 05	15:04:11	300		
(4)	m02591n2500-1.fts	2000 11 04	13:47:07	300	m02591n2500-?.fts	
	m02591n2500-2.fts	2000 11 04	14:34:24	300		
	m02591n2500-3.fts	2000 11 04	15:07:53	300		
(5)	m04590n0244-1.fts	2000 11 04	15:24:39	200	LINEAR comet C/2000 U5 (animationin Chap.4)	
	m04590n0244-2.fts	2000 11 04	15:36:13	200		
	m04590n0244-3.fts	2000 11 04	15:43:57	200		
	m04590n0244-4.fts	2000 11 04	15:51:40	200		
(6)	m05467n0003-1.fts	2000 11 04	16:01:16	200	m05467n0003-?.fts	
	m05467n0003-2.fts	2000 11 04	16:12:55	200		
	m05467n0003-3.fts	2000 11 04	16:28:22	200		
(7)	m10243n4939-4.fts	2000 10 30	18:40:01	240	2000 UV13 (animation in Chap.12)	
	m10243n4939-5.fts	2000 10 30	18:44:27	240		
	m10243n4939-6.fts	2000 10 30	18:48:52	240		
	m10243n4939-7.fts	2000 10 30	18:53:17	240		
	m10243n4939-8.fts	2000 10 30	18:57:43	240		

(Time used is Universal Time (UT).)

● Next, measure the positions of asteroids.

After finding asteroids, please try to measure their positions. If you measure the positions of asteroids for above image files, the results would be like as follows. You should send this kind of result data to your coordinator.

Results of the position measurments of asteroids in the sample images

02444	C2000 11 04.50528	01 26 18.42	+34 35 37.1	School	15.1 V	300	448	1663	m01250n3500-1
02444	C2000 11 04.52270	01 26 17.54	+34 35 27.7	School	15.1 V	300	451	1672	m01250n3500-2
02444	C2000 11 04.53966	01 26 16.66	+34 35 18.5	School	15.1 V	300	460	1680	m01250n3500-3
K00R51D	C2000 11 03.55251	02 34 34.51	+17 04 54.4	School	17.2 V	300	1179	145	m02350n1630-1
K00R51D	C2000 11 03.56913	02 34 33.44	+17 04 50.1	School	17.5 V	300	1185	148	m02350n1630-2
K00U06Q	C2000 11 03.55251	02 35 10.57	+16 58 19.4	School	17.8 V	300	956	322	m02350n1630-1
K00U06Q	C2000 11 03.56913	02 35 09.70	+16 58 13.9	School	17.4 V	300	961	325	m02350n1630-2
K00O09A	C2000 11 03.55251	02 32 23.15	+16 53 44.2	School	16.1 V	300	2009	422	m02350n1630-1
K00O09A	C2000 11 03.56913	02 32 22.26	+16 53 39.2	School	16.5 V	300	2014	425	m02350n1630-2
18557	C2000 11 03.55251	02 34 43.16	+17 09 57.3	School	18.4 V	300	1123	13	m02350n1630-1
18557	C2000 11 03.56913	02 34 42.28	+17 09 50.9	School	17.8 V	300	1127	17	m02350n1630-2
K00V07S	C2000 11 03.55251	02 34 58.34	+16 55 58.8	School		300	1034	382	m02350n1630-1
K00V07S	C2000 11 03.56913	02 34 56.88	+16 55 57.2	School		300	1042	384	m02350n1630-2
02436	C2000 11 03.55251	02 37 12.58	+16 40 15.2	School	16.6 V	300	198	808	m02350n1630-1
02436	C2000 11 03.56913	02 37 11.83	+16 40 10.6	School	16.8 V	300	201	811	m02350n1630-2
K00U06R	C2000 11 03.55251	02 36 13.60	+16 25 07.6	School	18.3 V	300	575	1199	m02350n1630-1
K00U06R	C2000 11 03.56913	02 36 12.74	+16 25 04.7	School	18.3 V	300	579	1201	m02350n1630-2
K00U38N	C2000 11 03.55251	02 36 28.64	+16 14 39.6	School	18.6 V	300	484	1475	m02350n1630-1
K00U38N	C2000 11 03.56913	02 36 27.68	+16 14 38.2	School	18.9 V	300	489	1477	m02350n1630-2
K00U35T	C2000 11 03.55251	02 34 43.81	+16 48 00.4	School	18.7 V	300	1129	590	m02350n1630-1
K00U35T	C2000 11 03.56913	02 34 43.10	+16 47 52.4	School	18.4 V	300	1132	594	m02350n1630-2
K00U73P	C2000 11 03.55251	02 33 22.70	+16 56 52.9	School	19.1 V	300	1634	347	m02350n1630-1
K00U73P	C2000 11 03.56913	02 33 21.52	+16 56 52.4	School		300	1640	348	m02350n1630-2
K00V07R	C2000 11 03.55251	02 35 12.48	+16 44 41.6	School		300	950	680	m02350n1630-1
K00V07R	C2000 11 03.56913	02 35 11.54	+16 44 34.1	School		300	955	684	m02350n1630-2
23214	C2000 11 03.55251	02 34 02.56	+16 44 15.2	School	18.7 V	300	1390	683	m02350n1630-1
23214	C2000 11 03.56913	02 34 01.62	+16 44 13.1	School	18.7 V	300	1394	685	m02350n1630-2
K00U66B	C2000 11 03.55251	02 33 53.91	+16 43 39.8	School	18.9 V	300	1444	698	m02350n1630-1
K00U66B	C2000 11 03.56913	02 33 53.29	+16 43 37.2	School	18.9 V	300	1447	700	m02350n1630-2
K00U35X	C2000 11 03.55251	02 34 15.20	+16 26 39.2	School	18.1 V	300	1319	1146	m02350n1630-1
K00U35X	C2000 11 03.56913	02 34 14.25	+16 26 36.3	School	17.7 V	300	1323	1149	m02350n1630-2
21069	C2000 11 03.55251	02 33 26.89	+16 23 43.2	School	18.0 V	300	1624	1218	m02350n1630-1
21069	C2000 11 03.56913	02 33 26.01	+16 23 38.6	School	18.5 V	300	1628	1221	m02350n1630-2
01813	C2000 11 03.55251	02 32 33.71	+16 17 00.1	School	15.3 V	300	1963	1388	m02350n1630-1
01813	C2000 11 03.56913	02 32 32.74	+16 16 58.2	School	15.3 V	300	1968	1389	m02350n1630-2
K00U35U	C2000 11 03.55251	02 34 46.27	+16 00 00.4	School	18.2 V	300	1136	1849	m02350n1630-1
K00U35U	C2000 11 03.56913	02 34 45.52	+15 59 54.1	School	18.6 V	300	1139	1853	m02350n1630-2
K00R72J	C2000 11 03.55251	02 32 29.96	+16 14 34.4	School	17.3 V	300	1988	1451	m02350n1630-1
K00R72J	C2000 11 03.56913	02 32 28.87	+16 14 31.3	School	17.6 V	300	1993	1453	m02350n1630-2
K00U72X	C2000 11 05.55539	02 52 28.36	+21 08 06.3	School	19.3 V	300	215	526	m02506n2050-1
K00U72X	C2000 11 05.59142	02 52 25.75	+21 08 06.9	School	19.5 V	300	233	535	m02506n2050-2
K00U72X	C2000 11 05.62617	02 52 23.29	+21 08 07.9	School	19.2 V	300	256	545	m02506n2050-3
K00U71K	C2000 11 05.55539	02 51 29.46	+21 11 54.8	School		300	574	420	m02506n2050-1
K00U71K	C2000 11 05.59142	02 51 27.44	+21 11 36.5	School	18.4 V	300	589	438	m02506n2050-2
K00U71K	C2000 11 05.62617	02 51 25.65	+21 11 21.3	School		300	607	455	m02506n2050-3
K00V46D	C2000 11 05.55539	02 50 55.27	+21 08 21.6	School	19.1 V	300	785	510	m02506n2050-1
K00V46D	C2000 11 05.59142	02 50 53.00	+21 08 09.2	School	19.2 V	300	801	526	m02506n2050-2
K00U95M	C2000 11 05.55539	02 50 42.99	+21 06 20.3	School		300	861	562	m02506n2050-1
K00U95M	C2000 11 05.59142	02 50 40.90	+21 06 06.4	School		300	876	578	m02506n2050-2
K00U95M	C2000 11 05.62617	02 50 39.01	+21 05 54.6	School		300	895	593	m02506n2050-3
K00U95N	C2000 11 05.55539	02 50 31.01	+21 00 39.4	School		300	937	710	m02506n2050-1
K00U95N	C2000 11 05.59142	02 50 29.07	+21 00 26.3	School		300	951	726	m02506n2050-2
K00U95N	C2000 11 05.62617	02 50 27.09	+21 00 18.0	School		300	970	739	m02506n2050-3

PLS6695	C2000	11	05.55539	02 50 52.39	+20 30 14.4	School	19.2	V	300	819	1510	m02506n2050-1
PLS6695	C2000	11	05.59142	02 50 50.49	+20 30 10.6	School	19.3	V	300	833	1522	m02506n2050-2
PLS6695	C2000	11	05.62617	02 50 48.59	+20 30 07.7	School	19.0	V	300	852	1533	m02506n2050-3
K00U11Q	C2000	11	05.55539	02 52 52.07	+20 21 03.0	School	18.5	V	300	87	1763	m02506n2050-1
K00U11Q	C2000	11	05.59142	02 52 49.81	+20 20 48.8	School	18.0	V	300	103	1779	m02506n2050-2
K00U11Q	C2000	11	05.62617	02 52 47.62	+20 20 35.2	School	17.6	V	300	124	1795	m02506n2050-3
11423	C2000	11	05.55539	02 52 19.83	+20 17 54.1	School	17.1	V	300	286	1843	m02506n2050-1
11423	C2000	11	05.59142	02 52 17.77	+20 17 40.4	School	16.8	V	300	301	1859	m02506n2050-2
11423	C2000	11	05.62617	02 52 15.73	+20 17 26.8	School	16.9	V	300	321	1875	m02506n2050-3
19825	C2000	11	05.59142	02 50 33.60	+20 17 47.4	School	18.3	V	300	943	1845	m02506n2050-2
19825	C2000	11	05.62617	02 50 31.77	+20 17 30.5	School	18.0	V	300	961	1862	m02506n2050-3
J97X01K	C2000	11	05.55539	02 49 37.32	+21 15 38.3	School	17.3	V	300	1258	311	m02506n2050-1
J97X01K	C2000	11	05.59142	02 49 34.78	+21 15 33.9	School	17.2	V	300	1276	323	m02506n2050-2
J97X01K	C2000	11	05.62617	02 49 32.25	+21 15 29.2	School	17.3	V	300	1299	334	m02506n2050-3
K00V42U	C2000	11	05.55539	02 49 40.21	+21 00 49.3	School	19.3	V	300	1248	700	m02506n2050-1
K00V42U	C2000	11	05.59142	02 49 38.35	+21 00 45.3	School	19.1	V	300	1261	712	m02506n2050-2
K00V42U	C2000	11	05.62617	02 49 36.39	+21 00 41.2	School			300	1280	723	m02506n2050-3
K00U71G	C2000	11	05.55539	02 49 42.68	+20 37 39.4	School	19.0	V	300	1244	1308	m02506n2050-1
K00U71G	C2000	11	05.59142	02 49 40.48	+20 37 37.2	School	18.9	V	300	1260	1319	m02506n2050-2
K00U71G	C2000	11	05.62617	02 49 38.25	+20 37 34.2	School			300	1281	1330	m02506n2050-3
19530	C2000	11	05.55539	02 49 09.54	+20 26 37.2	School	17.7	V	300	1453	1594	m02506n2050-1
19530	C2000	11	05.59142	02 49 07.15	+20 26 26.3	School	17.6	V	300	1470	1608	m02506n2050-2
19530	C2000	11	05.62617	02 49 04.74	+20 26 14.5	School	17.9	V	300	1492	1623	m02506n2050-3
K00U71F	C2000	11	05.55539	02 49 25.53	+20 22 08.1	School			300	1357	1713	m02506n2050-1
K00U71F	C2000	11	05.62617	02 49 21.26	+20 21 49.5	School			300	1393	1741	m02506n2050-3
19535	C2000	11	05.55539	02 48 13.64	+20 15 03.5	School	17.5	V	300	1803	1890	m02506n2050-1
19535	C2000	11	05.59142	02 48 11.49	+20 14 54.1	School	17.6	V	300	1819	1904	m02506n2050-2
19535	C2000	11	05.62617	02 48 09.36	+20 14 44.2	School	18.0	V	300	1840	1919	m02506n2050-3
K00WH4Y	C2000	11	04.64096	04 57 43.69	+02 16 45.2	School	18.6	V	300	1572	1693	m04590n0244-1
K00WH4Y	C2000	11	04.64899	04 57 43.37	+02 16 44.6	School			300	1574	1696	m04590n0244-2
K00WH4Y	C2000	11	04.65436	04 57 43.27	+02 16 45.1	School	19.3	V	300	1576	1697	m04590n0244-3
K00WH4Y	C2000	11	04.65972	04 57 43.05	+02 16 44.2	School	19.0	V	300	1575	1699	m04590n0244-4
17769	C2000	11	05.59142	02 51 13.78	+20 34 17.0	School	17.5	V	300	688	1416	m02506n2050-2
17769	C2000	11	05.62617	02 51 11.40	+20 34 15.3	School	17.6	V	300	710	1427	m02506n2050-3
K00U95W	C2000	11	04.57265	02 59 19.04	+25 03 49.8	School	17.3	V	300	863	910	m02591n2500-1
K00U95W	C2000	11	04.60549	02 59 17.19	+25 03 45.4	School	17.7	V	300	870	921	m02591n2500-2
K00U95W	C2000	11	04.62874	02 59 15.99	+25 03 42.5	School	17.5	V	300	877	929	m02591n2500-3
J99J25H	C2000	11	04.57265	03 00 19.00	+24 46 13.6	School	17.1	V	300	514	1378	m02591n2500-1
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K00V51K	C2000	11	04.62874	02 57 00.63	+24 55 56.3	School	18.7	V	300	1685	1117	m02591n2500-3
K00U95Y	C2000	11	04.57265	02 58 14.71	+24 52 43.1	School	18.4	V	300	1250	1194	m02591n2500-1
K00U95Y	C2000	11	04.60549	02 58 12.34	+24 52 42.7	School	18.3	V	300	1261	1204	m02591n2500-2
K00U95Y	C2000	11	04.62874	02 58 10.76	+24 52 42.7	School	19.0	V	300	1270	1210	m02591n2500-3
K00SH9V	C2000	11	04.57265	02 58 16.86	+24 49 30.4	School	17.8	V	300	1239	1279	m02591n2500-1
K00SH9V	C2000	11	04.60549	02 58 14.25	+24 49 26.3	School	18.3	V	300	1251	1290	m02591n2500-2
K00SH9V	C2000	11	04.62874	02 58 12.67	+24 49 23.8	School	17.8	V	300	1260	1297	m02591n2500-3
00893	C2000	11	04.66639	05 44 41.04	+00 27 11.0	School	15.0	V	300	1841	358	m05467n0003-1
00893	C2000	11	04.67448	05 44 40.87	+00 27 08.8	School	15.0	V	300	1843	361	m05467n0003-2
00893	C2000	11	04.68521	05 44 40.65	+00 27 05.9	School	15.0	V	300	1844	365	m05467n0003-3

15

Dawn of the 21st Century

Did you enjoy finding asteroids?
How did you find the Asteroid Catcher B-612?
Perhaps, your eyes may be pretty strained by now.
Either way, you must be feeling that there are so many tiny astronomical objects in our solar system.

It will be our greatest pleasure if you remain interested in the vast expanse of the universe, all starting from this asteroid detection project. You may even reverse your views and reflect on the life on Earth, its environment, and fellow humans. That will be an added bonus, we think.

As we entered the new century we ask ourselves where we are heading for. How much progress in science and technology is expected during this new century? We are not sure. However, it is certain that time will move on with a lot of changes in its wake.

Beyond the horizon of space and time lie dreams.

Copyrights

Acknowledgments

We are grateful to Mr. Hiroshi Kaneda, Ms.Akemi Ogura and Mr. Misao Sato for their help to this astreoid detection software and this guide. We also thank to Mr. Tadashi Tsuji for his help to the English translation of this guide. We are particularly obliged to Japan Space Forum for their tremendous contribution to the project. Star catalogs used in the program derive from GSC-ACT and Tycho-2. Asteroid orbital data derive from the Minor Planet Center. We are most grateful to NASA, ESA, and MPC for the provision of these data.

Health issue

You should be careful about your eye strains. Please rest your eyes from time to time.

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Major Dynamical, Physical And Technological Concepts Of Space Science: An Educational Approach Via Concepts

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Abstract

The major dynamical & physical concepts and their associated technological concepts of space science are identified and discussed. A conceptual approach to space science education is developed and recomended. The concepts; which are built within the frameworke of the suggested educational scheme; are shown as a way to teach different theories and applications. The computational, experimental and technical training techniques that are needed in space science are described at which steps may be introduced through the suggested educational scheme. Different jobs description are designed to correspond different educational structures (modules).

1. Introduction

Any educational process is made up of several components. These include **teachers, students, curriculum and teaching methodology**. The standered method in building an educational scheme (**curriculum**) for any specialization is to divide the knowledge (scientific material) to **major subjects** and then divide each subject into **major topics**. However, education of any specialization through its major concepts is, relatively, a new trend in developed world which may be called **"conceptual approach"**. The approach is based on considering the **major building blocks** of any specialization to be its **major concepts**. It possesses several advantages that can be summarized as follows:

1. develops an integrated specialist who knows, applies and uses several concepts in different subjects and specializations,

2. improves the capabilities of lecturers in understanding and teaching parts from several subjects and specializations using well known concepts to them in one subject and specialization,

3. saves time in order to impart more educational materials to students.

These advantages can be tested and verified by using any suitable **"lecture feedback project"** (cf. Hodgson and Mc Connell (1980)).

In this article, a conceptual approach is developed for space science education on the undergraduate level. In general, there should be several educational structures (modules) on the undergraduate level that should aim to have graduates with certain specifications which will cover several job descriptions in space science institutional structures. To fulfil the objective, the paper will discuss the major dynamical & physical concepts and the associated technological counterparts are exposed with the required credits in the proposed educational scheme. Hence, one can choose the needed building blocks out of the major concepts, for certain job description in a certain position in the matrix of space science organisations.

2. Major Concepts Of Space Science

Space science is a good example of a science in which many concepts of different sciences are integrated and used to build up its educational scheme. The major building blocks; **concepts**; of space science are discussed in the following sub-sections.

2.1 Concept Of An Object Orbiting Around A Source Of Gravity

This concept is dealing with the choice of an orbit for a space mission to move arround any celestial body; belonging to the solar system; to fulfil definite objectives. In this context, students should learn different types of orbits and determine which type will conveniently preform the specified aim of the mission. Also, they should learn different types of space missions, e.g. remote sensing; meteorological; geophysical; environmental; communications; scientific; astrophysical...etc. They should realize that any space mission has six degrees of freedom, which are its position and velocity in three dimensional space. To enable the students to do such job; i.e. choosing the most siutable (optimal) orbit; they should learn the relevant kinematical and dynamical concepts of astronomy and how to use them in this context (cf. Roy (1978), Kaufmann (1994) and Melek (2001)). While students are learning this concept, it is necessary to introduce to them the influence of:
1. the earth's oblatness at the equator, 2. the earth's atmospheric drag force,
3. the earth's magnetic field and 4. the direct and indirect solar radiation pressure; on the chosen orbit.

2.2 Concept Of Optimization

In the context of this concept, students should learn how to use the optimization techniques in the following issues:

1. determination of the best latitude for launching the mission,
2. determination of the best time (month, day and hour) to launch the mission,
3. determination of the best initial launching angle,
4. determination of the best maneuvering angles within the mission's trip to its chosen final orbit,
5. determination of the best geometrical shape for the mission, e.g. sphere, cylinder, hexagonal shaped surface, ... etc,
6. determination of the minimum payload will suit the mission's objectives, designed initial trajectories and chosen final orbit.

While teachning the students how to determine all of the previous parameters; they should also learn how to calculate the minimum amount of energy (fuel) to put the mission on its final orbit.

2.3 Concept Of The Needed Energy Budget To Put A Space Mission On Its Chosen Orbit And For The Payload Instruments

In the frame work of this concept, students should study how to calculate the needed energy (fuel) for the carrier of the mission; whether it is single stage or multistage carrier. Also, they should learn how to calculate the needed electrical power for the payload instruments; using solar energy cells panel which can serve the mission during its life time.

2.4 Concepts Of Designing And Choosing The Mission's Shape And Materials

These concepts are dealing with the physical and chemical properties of different materials used in constructing the mission and its payload instruments. For example, properties like rigidity, elasticity, conductivity, resistivity against high temperature differences and all existing hazards in space. In this context, students should study space physics in a way to know almost all different hazards that can meet the mission. Therefore, they should study material science and failure analysis for different materials under different conditions, for the purpose of getting the best performance either of the mission structure or of the used instruments. Also, they should learn vibrational mechanics and aerodynamics.

2.5 Concept Of Stability And Life Time

This concept is dealing with different factors affecting the mission life time and the order of magnitude of each factor in relation to the others. The theory of stability of differential equations and the catastrophe theory are usefull to be taught, in this context.

2.6 Concept Of Guidance And Automatic & Attitude Control

Given emphasis in this sub-section is the role of communication science, electronics, software and hardware engineering to transmit orders and information from the mission to the ground stations and vice versa (up and down links). Students should learn how to find the difference between the actual orbital elements; via tracking stations; and the calculated (theoretical) ones. They should then learn how to design a software for the mission and the ground tracking stations that can be used to modify the orientation (attitude) and the position of the mission to the desired values.

2.7 Concept Of Transmission Of Information And Their Analysis

In the frame work of this concept, students should learn finite mathematics and its applications in digital technology that can be used to transmit information from the mission to the ground stations and viceversa (up and down links). They should study different factors causing possible distorsions of the transmitted information and how to avoid them or to correct the received distorted information. They should also learn how to analyse the obtained information from the mission.

3. Designing Different Educational Structures (Modules)

It is clear from the previous section, that the major concepts of space science do represent a mixture between concepts of basic dynamical & physical sciences as well as basic and applied engineering sciences. Therefore, when one wants to fix the one to one correspondence between different job descriptions and different educational modules; he has to start, firstly, with designing all possible job descriptions that will cover all the needed functions of space organizations. Then, one has to choose the relevant major educational building blocks; major concepts; to construct different modules correspond to different jobs. Moreover, one may look upon space institutional structures (the matrix of relevant space science organizations) as composed of two main divisions namely: the space segment organizations and the ground segment organizations. Therefore, using this kind of division; one may divide the relevant jobs as follows:

1. **mission analysis job:** determining mission objectives and demands,
2. **mission dynamics job:** designing the initial trajectories, choosing the final orbit and choosing the controle attitude method,
3. **mission structure job:** choosing the geometrical shape, type of antena and the used materials & sensors,
4. **mission payload job:** choosing the optimal needed instruments to be fixed on the mission's board,
5. **mission carrier job:** choosing the most suitable carrier and calculating the optimal needed energy & its type and source to be fixed on the board,
6. **mission hardware and software job:** choosing and designing the needed software and hardware to be fixed on the board & on the ground segment,
7. **mission tracking and control job:** correcting the mission dynamics to its desired orientation and orbit,
8. **mission information analysis job:** analysing the received data and information.

At the end of this section, it is worth to point out that by the end of the undergraduate studies; students choosing any educational module should be familiar with the relevant applications of the following theories:
1. Newtonian Mechanics, **2.** Aerodynamics, **3.** Special and general relativity, **4.** Electromagnetic radiation, **5.** Propulsion and energy transformations (thermodynamics), **6.** Optimization, **7.** Automatic control and **8.** Stability.

4. Equivalent Credits To Each Concept

In this prototype scheme, the required mathematics, physics and chemistry to be taught during the first two semesters in the full educational programme is not specified. In the next table, it is suggested the needed lectures, theoretical exercises, experimental & technical training and the equivalent credits for each concept.

Concept	Lectures (hrs.)	Exercises (hrs.)	Training (hrs.)	Credits
orbiting	12	8	–	16
energy	4	4	–	6
optimization	6	4	–	8
shape	10	–	12	16
stability	6	6	–	9
control	8	4	8	14
information	10	–	10	15
sum	56	26	30	84

References

1. Hodgson V. and Mc Connel D., Institute of educational technology, University of Surry, Great Britain, 1980.
2. Roy A. E., "Orbital Motion", Adam Hilger Ltd, Bristol, 1978.
3. Kaufmann W. J., "Universe", Freeman and company, New York, 1994.
4. Melek M., Proceedings of the **IAU Symp. # SPS**, 2001, and to appear in **"Teaching of Astronomy in Asian- Pacific Region"**, published by the national observatory of Japan, Mitaka, Tokyo, vol. 17, January 2001.

LAWS OF THE MOTION OF PLANETS - KEPLER (1571-1630)
INTERDISCIPLINARY ACTYVITY

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The Kepler's laws describe the motion of planets around the Sun. They usually justify Newton's law of universal gravitation, but the procedure was the other way round: first Kepler derives his famous laws from accurate data of Brahe, and Newton about a century late formulates his law of universal gravitation.

The Earth whit Copernicus lost part of its importance or protagonism, but it is still working in circles and epicycles, deferents and eccentrics, and hasn't lost the idea of a uniform circular motion of the planets.

With the first law, Kepler gave up the circular motion, with the second he removed the uniformity of motion. He thought the Sun was the reason of the motion of planets, although he wrongly associated a motive power with the Sun and with the third law he tries associating their ideas of harmony and perfection of Universe.

That's why, we propose an interdisciplinary essay for students 17-18 years old, the objective will be the study and analyses of the process followed by Kepler until finding the three laws of planetary motion. This way we obtain a natural form implicating the subjects of Astronomy-Physic, Mathematics, Music and History in the essay.

We can summarise in the reasoning of Kepler:

First explanation of the radius of the orbits and the eccentricities of the planets are determinated values and no other

Kepler explained it with the theory:

- *The values of the radius of the planet orbits belong to the radius of a set of spheres (six) circumscribes and inscribes in the convex regular polyhedrons (five) or platonic solids.*

MATHEMATICS: STUDY OF REGULAR OR PLATONIC SOLIDS.

There are only six convex regular polyhedrons: cube tetrahedron, icosahedron, octahedron and dodecahedron. All they are made up of regular polygons and their faces and their vertex are the same. There is symmetry (good proportions, *concordance*, equilibrium,...) harmony, regularity and beauty.

We can study the polyhedrons on the whole, classify them and centre in the convex regular polyhedrons:

- Their properties
- Symmetries
- Regularities
- Relations between their elements
- Relations between the regular polygons...........

Kepler could not justify their values, and

He wonders, if the centre is the centre of the Earth's orbit just as Copernicus supposed or if it was the Sun.

- *He determines the correct orbit of theEarth and he fixes the position of the Sun.*
- *He calculates the orbit of Mars.*

MATHEMATICS: STUDY OF CONICS.

Plain curves result from cutting the surface of a cone of revolution whit a plain: elliptic, hyperbolic and parabolic. Which are their equations?. Which is their form?. How are obtained?....
We can study:

- What is their form?
- How is it obtain?
- Equations
- Relations among their elements. ......

- *Kepler extends to the Earth and the other planets the results found in Mart,*

Kepler's enunciate:

- **1st Law of the planetary motion**
  The planets move in elliptical orbits with the Sun as one of the focus

- **2nd Law of the planetary motion**
  The area is swept out by a line joining any planet to the Sun and is equal in equal intervals of time, which are equal areas in equal intervals of time. If the area is double the time is double.

Kepler didn't give up their idea about the harmony creation, and he thinks a new theory: the maximum and minimum velocity of planets in their orbits has to be harmonic in the musical sense. The planets broadcast a special harmony, where as the value of the note is proportional to the velocity of planet

MUSIC: STUDY OF BARROC MUSIC AND THE DIFERENTS ASPECTS OF MUSICAL SCALE.

Kepler didn't give up their idea about the harmony and perfection of the Universe: He thinks that planets give off a range of melodies, they are determinated by the relation into apparent diurnal motion of the aphelion and the perihelion. He uses the size of the planet orbits, their eccentricities and their periods to obtain a system of notes: to Saturn a thirty major (4:5), to Jupiter a thirty minor, a fifth to Mart, a semitone to the Earth, ... We can study this intervals of entonation, his characteristics, play these melodies,.., how they have developed?. Difference between a major third and a minor third, ...

- *Kepler enunciates*

    - **3rd law of the planetary motion**
      The squares of the periods of revolution of the planets are directly proportional to the cubes of their mediums distances from de Sun.

On the whole, Kepler stands out because of his singular personality; he is the first one that openly agreed with the heliocentric theory of Copernicus. He was Lutheran and his mother was charged of witchcraft.

HISTORY- PHILOSOPHY: STUDY OF KEPLER'S PERSONALITY AND COMPARE THEIR IDEAS WHIT THE GENERAL ORDINARY. CHRONOLOGIC TABLE.

A possible plan could be:

- Kepler's personality and factors that could have determinated
- Place Kepler in their time and compare his ideas, which the general trends
- Make a chronological table or at least find the historical facts happening in the years he published his laws.
    - 1609, year of publication 1st and 2nd law. Rudolf II assures Bohemia's Protestants the confessional freedom. Expulsion of the Spanish Moslems.
    - 1618, year of publication 3rd law. The 30 years war starts. W.Harvey discovered the circulation of the blood. J.R. Cysat discovered the Orion nebular
- What happened in our country?

We must realise the way followed by Kepler in all his reasoning and great work carried out and the mistakes made.

PHYSICS - ASTRONOMY: STUDY OF LAWS OF MOTION, VALIDITY AND LIMITATIONS. ANALYSIS OF THE PROCESS FOLLOWED.

Some observations we can point out:

- If there is a problem of two bodies the three laws of planetary motion are correct, but their aren't because we have a multiplebody
- According to the theory of Einstein, the mass of the bodies, they move with great speed, increasing by proportion to it. Mercury is the fastest planet of the solar system and we must consider it in the calculation of the position of the planets.
- The third law is an approximation to true law. Actually this law only it applies when the planets are some mass:

$$\frac{P^2}{P'^2} = \frac{R^3}{R'^3}\;\frac{\mu}{\mu'}$$

  Where:

  P and P' are the periods of revolution

  R and R' are the mean distances from the Sun to planet, and

  μ and μ' are the sum of the mass of the primary (sun) and the secondary (planet), $\mu = m_{sun} + m_{planet}$ and $\mu' = m_{sun} + m'_{planet}$

  If we make $\mu/\mu' = 1$ in the System Solar, the error made is smaller than 0,001.
- The square of the period is proportional to the cube of mean distances:

$$P^2 = K \cdot R^3$$

If R is in A.U. (astronomical units) an P is in years:
(We are making $\mu/\mu' = 1$)

- The orbit described to artificial satellites is calculated in basis to the movement of a body with regard to other carrying out Kepler laws (basic value, the Kepler's way, it joins two planets for a time).
- Kepler formulates and shows a theory in basis to observation. Kepler associates a circular motion to Mart, but this doesn't coincide with the observations of Brahe, and the positions can have a difference in an 8' of arch. He calculates the orbit; he finds an oval and determinates an ellipse.
- The same year, which he publishes the two first laws, he writes a book "Lunar Astronomy", he wonders: how are for a resident of the moon, the rest of the heavenly bodies and the Earth?, also he explains the problems of a travel to the Moon: destructive effects of the Sun outside of the atmosphere (for this reason he suggests travel during an eclipse of the moon), orbital flight, resistance the astronauts on leaving the Earth, outside earthly attraction of propulsion is not necessary and must brake for not to crash on the surface of the moon, hardness of the travel, coldness of the lunar nights. ....
- A mistake made by Kepler is the belief that the Sun supports the planets in motion.
- ....

The activity is thought for a group of students, this way we can work it on the whole, although we don't disregard a single student, that can work someone aspect, is enough captivating to attract and interest to pupil, because behind of the enunciate the three laws of the planetary motion of Kepler, it's not questioned, we can discover a great project: process, ideas, personality, crevices, form to work,....

BIBLIOGRAPHY:

- "*Johannes Kepler 1571/1971*" – 1971 Inter Nationes Bonn-Bad Godesberg
- Hoyle F. "*Astronomia*" – Ed. Destino 1967
- J.J.de Orús Navarro y M.A.Catalá Poch - *Apuntes de Astronomía* - Departamento de Física de la Atmósfera, Astronomía y Astrofísica, Universidad de Barcelona Facultad de Física, 1986-1987.
- "*Johannes Kepler, El secreto del Universo*" - Ed. Alianza Editorial , Madrid 1992

Education in Astronomy. The creation of an astronomical culture in the information globalization era.

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We live in an epoch signed by enormous scientifical and technological advances wich are provoking colosal sociocultural transformations, whose influence reach in one way or another all the humankind. The impetuous development of communications and the easy access to information that we enjoy today thanks to Internet, have situate us in the information globalization era.

In the educational context is clear that not only the goals and methods but also the ways of work and the teaching contents are changing. This is happening in the teaching of astronomy too. Activities that before seem only to the reach of professionals, can be developed today by the students themselves, using computers and the adequate software.

In October, 1998, three high-school students from Northfield Hermon School in Northfield, Massachussets, made a remarkable finding; in fact they were the first amateurs discovering a Kuiper Belt Object, studying images taken with the 4-meter reflector telescope in the Inter American Observatory in Cerro Tololo, Chile. Undoubtely, this is an outstanding discovery because it was made by students, nevertheless would be absurd to think that all the students will be astronomers, or even scientists. What is it about, as the the indian astrophysicist Jayant Narlikar have pointed out, is to make science reachable to everyone, since we should understand that science is part of the culture.

The main goal of the International Astronomical Union Commission 46 "Teaching of Astronomy", is to promote an astronomical culture at a worldwide scale. This idea was aforesaid by the mexican astronomer Julieta Fierro, president of the Commission 46, in a paper delivered at the Special Workshop on Education during UNISPACE III, last August 1999. Besides this, she pointed out that after a secondary education, concerning astronomy, every person should, at least:

1. Know her or his spatial and temporal place in the Universe.

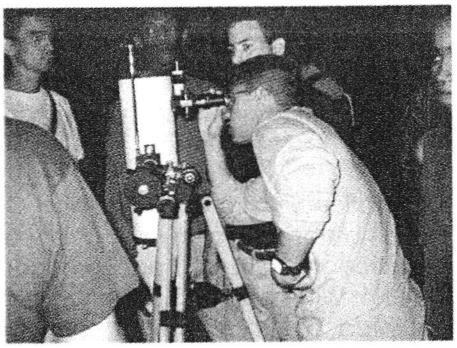
2. Be aware of cosmic evolution.
3. Know the uniqueness of Earth in the universal context and the need for life preservation.
4. Understand the way in wich astronomical knowledge is achieved.
5. Be able to understand a popularization article on astronomy and grasp its importance.

Today is recognized that the educational activity requires to form cultured citizens, more and more informed, able to orientate themselves in the historical framework in wich they have to live in, because as José Martí, the most remarkable exponent of the Cuban culture said;

> *to educate is to store in each man all the previous humankind work: is to make each man a summary of the living world, untill the day he is living on: is to put him at the level of his time to make him floatate over it.*

The teaching of astronomy can contribute to achieve this goal, since with its remarkable interdisciplinary character and its deep cultural roots, let the students to penetrate in the essence of the knowledge of several natural phenomena, to understand the laws of the world around, and to familiarize with the sense of nature historicity.

Pablo Valdés and Rolando Valdés, from the Pedagogical University of Havana, have pointed out that the methodological idea of the cultural orientation of teaching, suposse the treachers to planify, organize and actuate in the teaching-learning process, taking into consideration the objective links between concepts like science, culture, society and education.



Undergraduate students during an outdoors astronomy class, at the Pedagogical University of Havana Campus.

In this didactic context, the teaching of astronomy must be conceived starting from cualitative, open and contextualized problematic situations, of an appropiated level to the students cognoscitives capabilities, to foster their interest in studying every topic and creating a good atmosphere for revealing their misconceptions.

Althought, is not possible to conceive the cultural orientation of the teaching of astronomy in the narrow outlook and limited framework of the traditional pedagogical framework, based on the transmission-reception of information. More participative methods of teaching are needed, in correspondance with an student-centered learning, revealing besides, the characteristics of the contemporary scientifical activity: boundary mark of open problematic stituations, collaborative work, hypothesis emission and strategy design, results presentation in scientifical activities (the class in the didactic conditions), the use of computer software for data adquisition and process of the scientifical information, etc.

To achieve that the astronomical culture reaches every corner of the planet, Internet is undoubtely, the most effective way. The educational possibilities of remote controlled telescopes that can be accessed via the World Wide Web, are invaluable. Internet can also provide, access to current astronomical data, otherwise unavalilable to students and teachers, and could be the better way to enable and update the educators who teach the astronomical issues at the elementary and secondary levels. An international network for astronomy cultural education will make easier the teacher´s work by supplying them specially designed didactic materials in order to fulfill the proposed goals.

Thinking in a cultural approach to the teaching of astronomy, we should not forget the important contribution that a subject like this can provide to the moral values formation, an issue internationally recognized as a weakness of today´s educational systems all over the world.

The educators have to reflect about the educational challenges we are facing today and work together to achieve an astronomical culture at a worldwide scale in the information globalization era.

Bench-testing of Interferometric Principles at Microwave Frequencies

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Abstract

We report on tests for the detectability of coherent interference effects in the microwave range using commercially available "off the shelf" components. We comment on the applicaibility of such components to astronomical interferometry.

1. Introduction

There are various facts about contemporary availabilities of technical commodities, particularly relating to telecommunication electronics, which are making practical facilities for radio observations of astronomical objects very much more easy to obtain for the smaller-scale, lower-budget astronomer; especially in the 'microwave' (cm) region of the spectrum. The present article reports steps in educative experimentation aimed at bringing these facilities into use in interferometry and thence radio astronomy.

Modern radio astronomy relies very heavily on interferometry. The main reason for this is that, in principle, astronomical sources are very much weaker in the radio region relative to background or local emissions than at optical, or higher, frequencies. It is therefore important that full angular resolution capabilities be extracted from any device ('telescope') used to detect remote emissions. Such sources will often have high surface brightness, but over a very small angular range. If they are not resolved, this brightness then becomes smeared out over an 'Airy disk' of usually much greater size, reducing the contrast proportionately. Since many astronomically remote sources are of very small angular dimensions, loss of resolution will then inevitably entail poor *S/N* statistics in their detection and consequent information loss for their study.

2. Materials and Methods: Dual Emitter

An antenna was designed to emit simultaneously a 4 GHz signal from two dipoles positioned approximately 1 wavelength apart (Figure 1). A 400 mm length of coaxial cable (RG213/U) was modified by trimming the shielding and insulation away from the center core so approximately 38 mm of core was exposed. The exposed core was bent to form a 90° angle with the long axis of the cable, thus forming a half-wave emitter at the terminus of the signal-bearing cable tuned to 4 GHz.

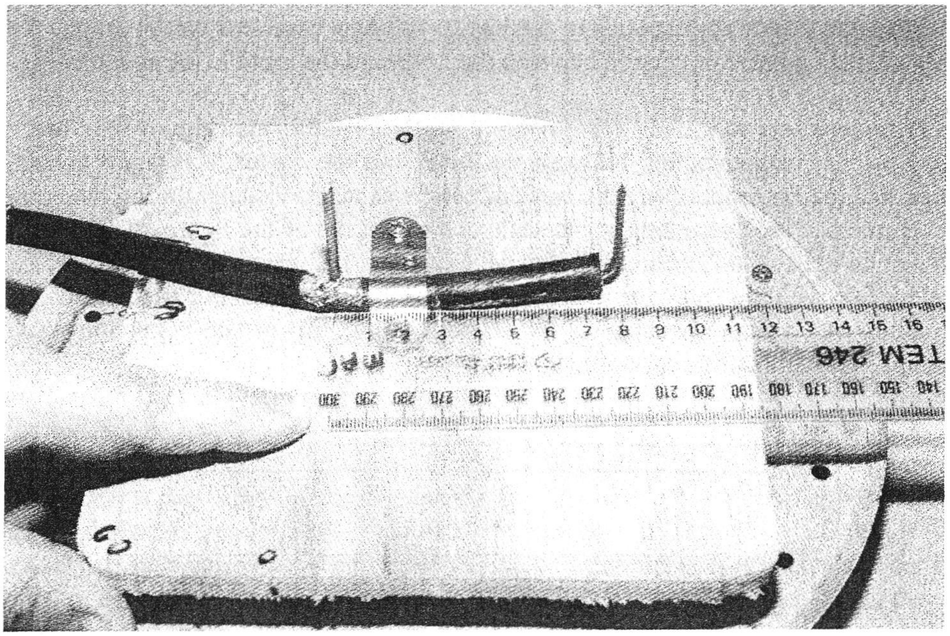

Figure 1. Dual emitter mounted on a turntable. The uprights are positioned approximately 1 wavelength apart. A protractor was used to mark the 0, 60 and 90° positions relative to the line between the center of rotation on the turntable and the LNB dipole.

The second emitter was located approximately 78 mm from the terminal emitter by soldering a 38 mm brass rod perpendicular to the core of the cable. First the outer insulation and shielding were sliced away to expose approximately 2 cm of the center conductor. Then the brass rod was soldered to the conductor. Upon cooling, the two emitters were visually aligned and fixed to a turntable.

The turntable was then positioned approximately 30 cm from a commercial 4 GHz low noise block (LNB) downconverter (Echostar model 0950). The amplified signal was then connected to an Icom-7000 radio receiver tuned to 1160 MHz. The Icom-7000 acted as a second LNB by shifting the 1160 MHz input down to audio frequencies that were accessed through the auxiliary speaker output of the radio receiver. This signal was connected to the sound card (Vibra 16, Creative Labs) of a Pentium 75 PC. The signal was analyzed using Skypipe software from Radio-Sky Publishing (PO Box 3552, Louisville, KY 40201-3552 U.S.A; http://www.radiosky.com).

3. Experimental Procedure

All electronic equipment was allowed to equilibrate for at least 20 minutes before data collection commenced. The signal generator (HP model 8620C sweep oscillator) was adjusted manually to emit a narrow band signal centered on 4 GHz. The dual emitters were positioned by rotating the turn-table until they were aligned with the LNB probe. After a steady baseline was established, the data collection software was activated and the table was manually rotated though 90° relative to the LNB. In these experiments, total power was logged as a function of time. The power curves, as observed, are inverted, so that maximum power corresponds to the lowest ordinate positions on the graph. This is simply due to a polarity inversion between the LNB and the input to the sound card.

This procedure was repeated 2 times for a total of 3 data sets (Figure 2). The angle formed by the imaginary line between the LNB and the center of rotation of the dual emitter, and the line connecting the two emitters, was noted visually during the course of the experiment. It corresponds to the scale across the top of the figure. The 0° position was taken to exist when all three dipoles were aligned, i.e. when the two emitters were in a straight line with the receiving probe in the LNB. The dual emitter was returned to the 0° position by rapidly reversing to the starting point, hence data collection remained continuous throughout this experiment.

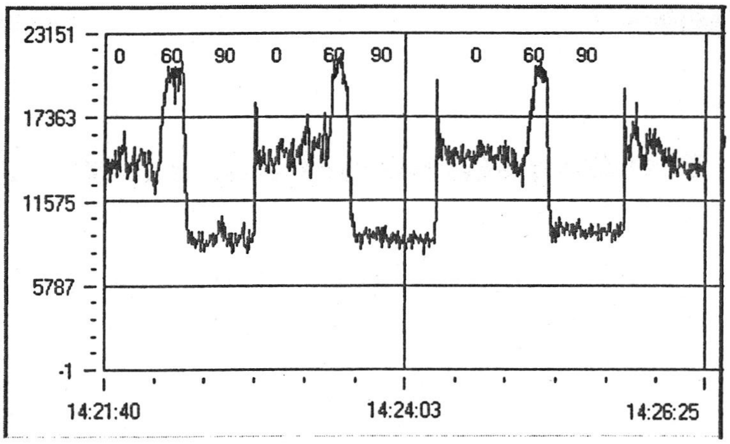

Figure 2. Interference data for 0 to 90 ° rotations. The dual emitter was rotated through 90° manually and the signal intensity relative to 0, 60 and 90° was noted visually and recorded. The antenna was rapidly repositioned to 0° prior to each repetition.

A second experiment, performed in duplicate, extended the rotation though 180° (Figure 3). In this case the turntable was rotated continuously to the 180° position and then reversed slowly back to the 0° position. Both experiments involved manual rotation of the table and, although effort was made to keep the turning rate uniform, there are small variations in the time frame between and within data collection periods.

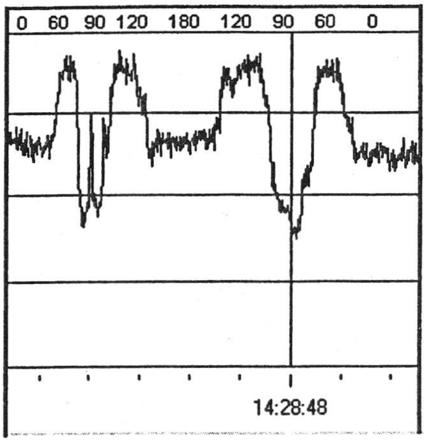

Figure 3 Interference data for 0 to 180° rotations. The antenna was first rotated from 0 through 180° and then reversed back to the 0° position as indicated by the scale at the top.

4. Discussion

Figure 2 clearly shows the expected quasi-sinusoidal variations expected as the path difference between the two signals allows the wavefronts to reinforce (aspect angle zero) or cancel (aspect angle 60°). The pattern in Figure 3 duplicates that in Figure 2 for the first 90° of rotation. The remaining data, from 90 to 180 degrees mirrors that of the former. In other words, the interference pattern is symmetrical about the 90° position as would be expected.

The principles that this experiment is demonstrating are (a) that coherent microwave signals over a frequency band $\Delta\lambda/\lambda \sim 0.00025$ behave according to a classical Huygens representation of their propagation and (b) that a single, commercially available, 'off-the-shelf' LNB is capable of receiving and passing on such effects in amplified form to a suitable recorder to allow their study. An alternative arrangement with two LNBs and a single emitter will not behave in this simple way. This is probably due to lack of phase coherence in the output from the LNBs, associated with their frequency downconversion. We are considering this point in a separate study. From the foregoing, however, we conclude that a single LNB detection arrangement would be capable of producing similar effects from astronomical signals at a comparable flux density, e.g. from the Sun, and over a similar bandwidth (cf. Lonc, 1996).

5. References

Lonc, W., 1996, *Radioastronomy Projects*, Radio Sky Publishing, ISBN 1889076007.