Asteroid Investigation

Contents

Introduction

The term asteroid, or Minor Planet, is generally used to describe a diverse group of small bodies that drift around the Solar System in orbit around the Sun. It is thought that asteroids are the remnants of the protoplanetary disc that formed around the Sun when the Solar System was first created. Most of the small bodies came together to form the planets, but there were some left-overs that could not combine due to gravitational effects.

Asteroids are found in various locations throughout the Solar System:
* orbiting close to the Earth (Near Earth Asteroids)
* orbiting between Mars and Jupiter (in the Asteroid Belt)
* orbiting with Jupiter (Trojan Asteroids)
* orbiting between Jupiter and Neptune (Centaurs).

Hundreds of thousands of asteroids have been discovered so far, and many new discoveries are made every month!

Of particular interest are the Near Earth Asteroids that actually cross the Earth's orbit (Potentially Hazardous Asteroids) and have the potential to destroy life if they collide with the Earth. There are several programs running to find and track all Near Earth Asteroids (e.g. Spaceguard, LINEAR, NEAT). This effort must be continuous, as the orbits of the asteroids are influenced by the gravitational pull of the planets as well as other asteroids. For example, although astronomers may have determined an accurate orbit for a particular asteroid in one year, if that asteroid passes close to a planet, the gravitational pull of the planet can alter the orbit trajectory. It is important to keep an eye on these things but there are only limited resources to do it professionally.

With this project you could contribute to the effort to monitor asteroid motions by using the software program Astrometrica to discover and obtain accurate positions for selected asteroids. The positions derived will help refine the orbits of these celestial bodies and add to the growing database of information on these objects.

Complementary resource material for the Asteroid project can be found at the UK Faulkes Telescope Training Portal. To collaborate with overseas schools in this project, go to the UK Faulkes Telescope Asteroid Portal.

Downloads

From here you can download everything you need to get you started with the Asteroid Investigation project.

1. Download and install Astrometrica

You can download Astrometrica from the Astrometrica home page, or simply use the package created specifically for this project. This package is called **Astrometrica.zip** and is 21.4Mb in size. The MPCOrb database (October 2007) is already included in this package and is perfectly acceptable for the practice data here. However, if you are going to observe new asteroid data, you should update the database or download the latest version.

2. Installing Astrometrica

If you are using the package created specifically for this project, all you have to do to install is to unzip the file. You might want to move the resulting Astrometrica folder to the **C:\Program Files** directory and create a shortcut to place on your **Desktop**. Once you have placed the folder where you want it, to start Astrometrica you simply double click **Astrometrica.exe**. The first thing you should then do is set up Astrometrica so that it knows where to find the files it will need to access.

3. Downloading Practice Data

One of the best ways to learn how Astrometrica works and how to analyse your asteroid data is to practice on some real data! Please download the three data sets from the Faulkes Telescope North. Create folders **C:\DATA\FAULKES\Asteroids** and unzip the data sets to the Asteroids folder. The numbered images (EY-1.fit) are all taken through the V filter. The sequence of images in order is **asteroid-1.fit .... asteroid-n.fit**, **asteroid-V.fit**, **asteroid-B.fit**, **asteroid-R.fit**.

4. Download and install IRIS

This is only required if you wish to make a colour image of your asteroid.

Selecting an Asteroid to Observe

Note: If you plan to use the practice data or other archive data from the Faulkes Telescope, you **DO NOT** need to complete this section. If, however, you are planning to take new data, you should study this section.

If you are observing in real time, the best way to select asteroids is to visit the Asteroid and Near Earth Object portal at the Faulkes Telescope web page. The UK team have developed a web page and documentation that shows you step-by-step how to select appropriate asteroids to observe.

If you are planning for a future observing session, you will need to use the actual websites underlying this Faulkes Telescope page.

1. Select an appropriate date for your observations.

One of the key factors influencing this selection is the moon and how full it is. Asteroids are usually quite faint, so it is better to select a date and time around new moon, or when the moon is not in the sky.

2. Spaceguard Priority List for Near Earth Asteroids

http://spaceguard.rm.iasf.cnr.it/servlet/PriorityListServlet

This list prioritises asteroids into **UR**gent, **NE**cessary, **US**eful and **L**ow **P**riority. An example list is shown in Figure 1.

The columns you need to check first are:

End of Visibility – this date needs to be after the planned observations.

Decl. – this is the declination of the asteroid in the sky. For Faulkes Telescope North, this should be larger than -20; for Faulkes Telescope South, this should be smaller than +20.

Sky Uncert. in arcsec – indicates how accurately the orbit for the asteroid is known. The larger the number the more uncertain the orbit. For asteroids with very large uncertainties, there is the risk of the asteroid not falling in the image.

Last update: 2007 Jul 12, 11:54 UT

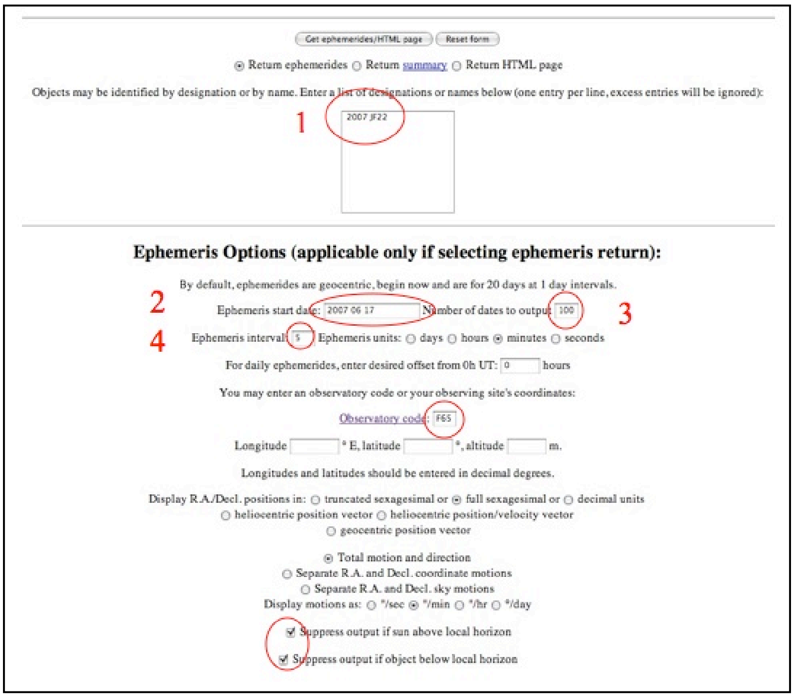
Priority	Object	Inserted in this categ.	R.A.	Decl.	Elong.	Magn.	Sky Uncert. in arcsec	End of Visibility
			Data for 2007 Jul 12, 22:00 UT					
UR	2005 XW77	2006 Mar 28	18h 43m	-00.2	156	**20.1**	2183	2006 Jan 24
UR	2005 YS165	2007 Apr 24	18h 00m	-34.5	157	**21.7**	36	2006 Jun 14
UR	2006 OZ4	2006 Jul 26	16h 15m	-18.2	135	**20.9**	8185	2006 Aug 5
UR	2006 QA31	2006 Sep 26	16h 42m	-21.0	142	**21.8**	350	2006 Oct 2
UR	2007 GS3	2007 Apr 13	02h 02m	+62.0	67	**20.2**	3	2007 Apr 26
UR	2007 KK	2007 Jul 11	18h 10m	-23.8	162	**21.6**	5	2007 Jul 17
UR	Objects from the NEO Confirmation Page Coordination on observations of NEOCP objects							
NE	2006 KE89	2007 Jun 21	11h 44m	+20.5	59	**18.0**	0	2006 Jun 14
NE	2006 VW2	2007 May 27	18h 36m	+11.1	145	**20.8**	1	2007 Jan 15
NE	2007 FH1	2007 May 28	09h 12m	-77.1	100	**21.3**	9	2007 Sep 4
NE	2007 GQ3	2007 Apr 30	01h 00m	-42.2	109	**21.6**	7	2007 Sep 4
NE	2007 JF22	2007 Jul 11	11h 57m	+05.6	67	**19.3**	4	2007 Aug 29
NE	2007 KW2	2007 Jun 29	19h 26m	+23.2	135	**21.5**	4	2007 Jul 27
NE	2007 LE	2007 Jul 1	14h 47m	-56.5	119	**19.8**	5	2007 Aug 21
NE	2007 LQ19	2007 Jul 3	03h 08m	+01.7	66	**19.6**	4	2008 Jan 18
NE	2007 LS	2007 Jul 7	15h 04m	-09.8	116	**21.3**	4	2007 Aug 11
NE	2007 LT	2007 Jun 29	19h 09m	-18.8	175	**20.0**	1	2007 Aug 4
NE	2007 LU	2007 Jun 27	21h 03m	-25.7	158	**21.1**	2	2007 Aug 4
NE	2007 LU19	2007 Jun 23	17h 19m	-30.7	150	**20.4**	3	2007 Aug 2
NE	2007 LV	2007 Jul 2	21h 56m	-58.0	135	**18.3**	12	2008 Jan 23
NE	2007 MG	2007 Jul 4	16h 13m	-01.3	129	**21.9**	2	2007 Jul 13
US	2005 SE71	2006 Dec 26	10h 46m	-81.5	106	**19.1**	1	2008 Nov 5

Figure 1: A sample extract from the Spaceguard Priority List.

3. Minor Planet Ephemeris Service

http://www.cfa.harvard.edu/iau/MPEph/MPEph.html

This site allows you to calculate an accurate position for your asteroids of interest on any date you choose. The opening page is quite long, but the important part is shown in Figure 2.



Get ephemerides/HTML page | Reset form

Return ephemerides / Return summary / Return HTML page

Objects may be identified by designation or by name. Enter a list of designations or names below (one entry per line, excess entries will be ignored):

1 — 2007 JF22

Ephemeris Options (applicable only if selecting ephemeris return):

By default, ephemerides are geocentric, begin now and are for 20 days at 1 day intervals.

2 — Ephemeris start date: 2007 06 17 — Number of dates to output: 100 — 3

4 — Ephemeris interval: 5 — Ephemeris units: days / hours / minutes / seconds

For daily ephemerides, enter desired offset from 0h UT: 0 hours

You may enter an observatory code or your observing site's coordinates:

Observatory code: F65

Longitude ° E, latitude °, altitude m.

Longitudes and latitudes should be entered in decimal degrees.

Display R.A./Decl. positions in: truncated sexagesimal or / full sexagesimal or / decimal units / heliocentric position vector / heliocentric position/velocity vector / geocentric position vector

Total motion and direction / Separate R.A. and Decl. coordinate motions / Separate R.A. and Decl. sky motions

Display motions as: "/sec / "/min / "/hr / °/day

Suppress output if sun above local horizon

Suppress output if object below local horizon

Figure 2: A sample extract from the Spaceguard Priority List.

To generate the information for your asteroid:

- Input the name of the asteroid into 1.
- Input the date you wish to observe in 2 (the 17th June, 2007 in this example). Dates should be in **YYYY MM DD** form.
- Input a large number in 3. This is how many records it will retrieve.
- Input the number '5' into the Ephemeris interval field 4 and check the **minutes** button. Each of the records will be spaced by 5 minutes.
- Input the observatory code for Faulkes Telescope North (F65) or Faulkes Telescope South (413) in 5.
- Tick both **suppress output** options since you don't want to observe the object if it is below the horizon or if the Sun is up.
- Click on the **Get ephemeris/HTML page** button.

The output should look like Figure 3.

2007 JF22

Display all designations for this object (Option unavailable)

Perturbed ephemeris below is based on 153-day-arc elements from *MPO* 121367. Last observed on 2007 June 10.

Further observations? NEO : None needed at this time. Desirable between 2007 July 10-Aug. 29.

Date	UT h m s	R.A. (J2000)	Decl.	Delta	r	El.	Ph.	V	Sky Motion "/min	Sky Motion P.A.	Object Azi.	Object Alt.	Sun Alt.	Moon Phase	Moon Dist.	Moon Alt.	Uncertainty 3-sig/"	Uncertainty P.A.
... Suppressed ...																		
2007 06 17	050500	10 43 04.1	+21 59 55	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+67	+00	0.06	042	+26	2	000.8
2007 06 17	051000	10 43 04.8	+21 59 47	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+66	-02	0.06	041	+25	2	000.8
2007 06 17	051500	10 43 05.4	+21 59 39	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+65	-03	0.06	041	+24	2	000.8
2007 06 17	052000	10 43 06.1	+21 59 31	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+64	-04	0.06	041	+23	2	000.7
2007 06 17	052500	10 43 06.7	+21 59 23	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+63	-05	0.06	041	+22	2	000.7
2007 06 17	053000	10 43 07.4	+21 59 14	1.310	1.338	68.9	45.1	19.0	2.43	132.0	098	+62	-06	0.06	041	+21	2	000.7
2007 06 17	053500	10 43 08.0	+21 59 06	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+60	-07	0.06	041	+20	2	000.7
2007 06 17	054000	10 43 08.7	+21 58 58	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+59	-08	0.06	041	+19	2	000.7
2007 06 17	054500	10 43 09.3	+21 58 50	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+58	-09	0.06	041	+18	2	000.7
2007 06 17	055000	10 43 10.0	+21 58 42	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+57	-10	0.06	041	+17	2	000.7
2007 06 17	055500	10 43 10.6	+21 58 34	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+56	-11	0.06	041	+16	2	000.7
2007 06 17	060000	10 43 11.3	+21 58 26	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+55	-12	0.06	041	+14	2	000.7
2007 06 17	060500	10 43 11.9	+21 58 18	1.310	1.338	68.9	45.1	19.0	2.43	132.0	099	+53	-13	0.06	041	+13	2	000.7
2007 06 17	061000	10 43 12.6	+21 58 10	1.310	1.338	68.9	45.1	19.0	2.43	132.0	100	+52	-14	0.06	041	+12	2	000.7
2007 06 17	061500	10 43 13.2	+21 58 01	1.310	1.338	68.9	45.1	19.0	2.43	132.0	100	+51	-15	0.06	041	+11	2	000.6
2007 06 17	062000	10 43 13.9	+21 57 53	1.310	1.338	68.9	45.1	19.0	2.43	132.0	100	+50	-16	0.06	041	+10	2	000.6
2007 06 17	062500	10 43 14.5	+21 57 45	1.310	1.338	68.9	45.1	19.0	2.43	131.9	100	+49	-17	0.06	041	+09	2	000.6
2007 06 17	063000	10 43 15.2	+21 57 37	1.310	1.338	68.9	45.1	19.0	2.43	131.9	100	+48	-18	0.06	041	+08	2	000.6
2007 06 17	063500	10 43 15.8	+21 57 29	1.310	1.338	68.9	45.1	19.0	2.43	131.9	101	+47	-19	0.06	041	+07	2	000.6
2007 06 17	064000	10 43 16.5	+21 57 21	1.310	1.338	68.9	45.1	19.0	2.43	131.9	101	+45	-20	0.06	041	+06	2	000.6
2007 06 17	064500	10 43 17.1	+21 57 13	1.310	1.338	68.9	45.1	19.0	2.43	131.9	101	+44	-21	0.06	041	+05	2	000.6
2007 06 17	065000	10 43 17.8	+21 57 05	1.310	1.338	68.9	45.1	19.0	2.43	131.9	101	+43	-22	0.06	041	+04	2	000.6
2007 06 17	065500	10 43 18.4	+21 56 56	1.311	1.338	68.9	45.1	19.0	2.43	131.9	102	+42	-22	0.06	041	+03	2	000.6
2007 06 17	070000	10 43 19.1	+21 56 48	1.311	1.338	68.9	45.1	19.0	2.43	131.9	102	+41	-23	0.06	041	+02	2	000.6
2007 06 17	070500	10 43 19.7	+21 56 40	1.311	1.338	68.9	45.1	19.0	2.43	131.9	102	+40	-24	0.06	040	+01	2	000.6
2007 06 17	071000	10 43 20.4	+21 56 32	1.311	1.338	68.9	45.1	19.0	2.43	131.9	102	+38	-25	0.06	040	+00	2	000.6
2007 06 17	071500	10 43 21.0	+21 56 24	1.311	1.338	68.9	45.1	19.0	2.44	131.9	102	+37	-26	0.06	040	-01	2	000.5
2007 06 17	072000	10 43 21.7	+21 56 16	1.311	1.338	68.9	45.1	19.0	2.44	131.9	103	+36	-27	0.06	040	-02	2	000.5
2007 06 17	072500	10 43 22.3	+21 56 08	1.311	1.338	68.9	45.1	19.0	2.44	131.9	103	+35	-28	0.06	040	-03	2	000.5
2007 06 17	073000	10 43 23.0	+21 55 59	1.311	1.338	68.9	45.1	19.0	2.44	131.9	103	+34	-29	0.06	040	-04	2	000.5
2007 06 17	073500	10 43 23.6	+21 55 51	1.311	1.338	68.9	45.1	19.0	2.44	131.9	103	+33	-30	0.06	040	-05	2	000.5
2007 06 17	074000	10 43 24.3	+21 55 43	1.311	1.338	68.9	45.1	19.0	2.44	131.9	104	+32	-30	0.06	040	-06	2	000.5
2007 06 17	074500	10 43 24.9	+21 55 35	1.311	1.338	68.9	45.1	19.0	2.44	131.9	104	+30	-31	0.06	040	-07	2	000.5
2007 06 17	075000	10 43 25.6	+21 55 27	1.311	1.338	68.9	45.1	19.0	2.44	131.9	104	+29	-32	0.06	040	-08	2	000.5
2007 06 17	075500	10 43 26.2	+21 55 19	1.311	1.338	68.9	45.1	19.0	2.44	131.9	105	+28	-33	0.06	040	-09	2	000.5
2007 06 17	080000	10 43 26.9	+21 55 11	1.311	1.338	68.9	45.1	19.0	2.44	131.9	105	+27	-34	0.06	040	-10	2	000.5
2007 06 17	080500	10 43 27.5	+21 55 03	1.311	1.338	68.9	45.1	19.0	2.44	131.8	105	+26	-34	0.06	040	-11	2	000.4
2007 06 17	081000	10 43 28.2	+21 54 54	1.311	1.338	68.9	45.1	19.0	2.44	131.8	105	+25	-35	0.06	040	-12	2	000.4
2007 06 17	081500	10 43 28.8	+21 54 46	1.311	1.338	68.9	45.1	19.0	2.44	131.8	106	+24	-36	0.06	040	-13	2	000.4

Figure 3: Sample output from the Minor Planet Ephemeris Service.

The output contains a wealth of information, but the main things you need to check are:

The best dates to take observations (circled in red above). There is often a statement indicating when the greater astronomical community would like additional observations of this particular asteroid. This doesn't mean that you shouldn't observe it - all information is equally welcome in the world of asteroid tracking.

The brightness of the asteroid. This is given in the column labelled **V**. This indicates the brightness of the asteroid. For the Faulkes Telescopes it should be between 10 and 20. A magnitude less than 10 means the asteroid is too bright, a magnitude greater than 20 means that the asteroid is too faint to be imaged in an appropriate timeframe. In this example, the asteroid on this night is magnitude 19, which is doable with the Faulkes Telescope. The UK Faulkes Telescope team provide appropriate exposure times for particular magnitudes at:

http://faulkes-telescope.com/education/planning/exposures

The position of the asteroid at the time the observations will be taken. This is encompassed by the columns labelled **Date**, **UT**, **R.A**. and **Decl**.

- The **Date** is simply the date you indicated you would be taking the observations (in this example, the 17th June 2007).
- The **UT** is the Universal Time at which the object is at the given coordinates. You can see that the UT goes up by 5 minutes each time. This is what was specified earlier as the Ephemeris Interval. **Note:** in order to determine the best time to observe your asteroid in local time, you will have to convert from UT. For local time at Faulkes Telescope North, you should subtract 10 hours from the UT to determine the local time. For local time at Faulkes Telescope South, you should add 10 hours to the UT to determine the local time (11 hours during daylight saving).
- The **R.A**. and **Decl.** show the accurate position of the asteroid at that UT.

If you are observing in real time, when you are ready to observe your asteroid, you must look for the nearest **UT** and use the **R.A**. and **Decl**. given at that time.

Finding the Asteroid

By far the easiest way to find an asteroid in a series of images is to rapidly step through the sequence of images looking for an object that is moving relative to the stars. The stars appear in the same place in each of the images because the telescope is set to move at the same rate as the stars appear to move across the sky. The asteroid, however, is moving much faster and often in a completely different direction. Rapidly comparing a sequence of images in this way is known as **"blinking"**.

1. Load the required images.

Important: At this stage you should not resize any images or move them around the screen. Even though they are overlapping at the moment, leave them where they are, as in Figure 4.

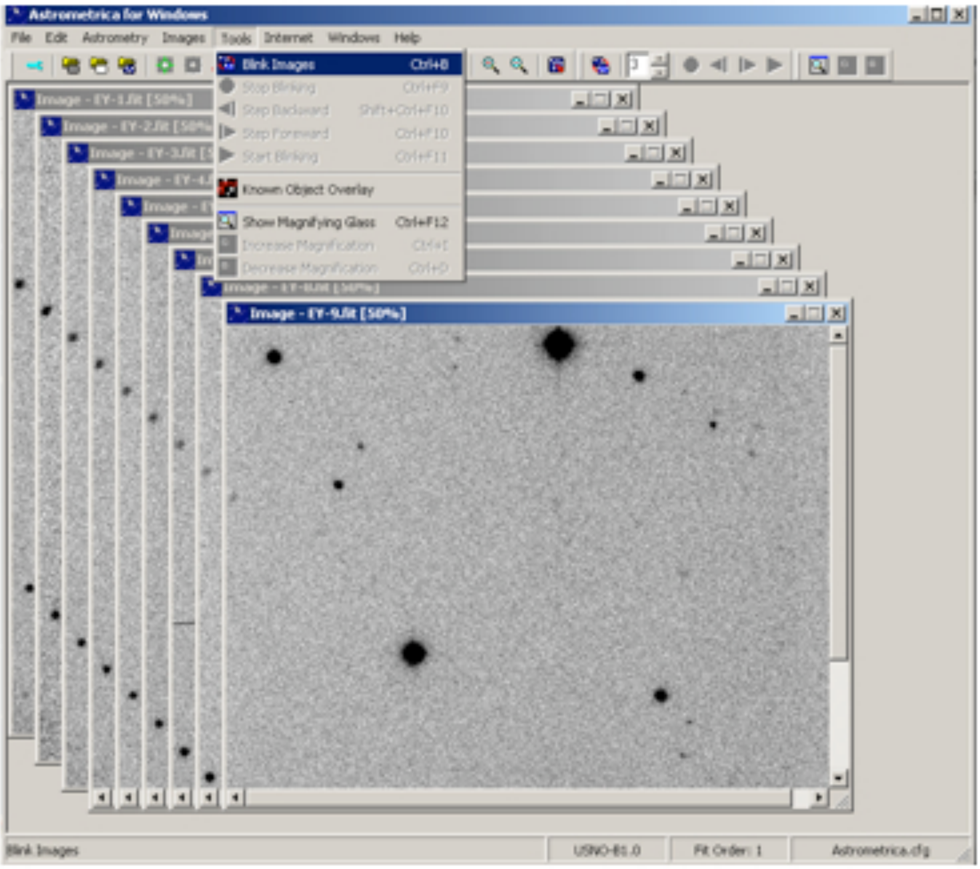


Figure 4: Images are loaded.

2. Select **Tools » Blink Images**.

This will extract all of the objects from each of the images and load a new window. In this case you can resize and move this new window around to make sure you can see the entire image, as in Figure 5.

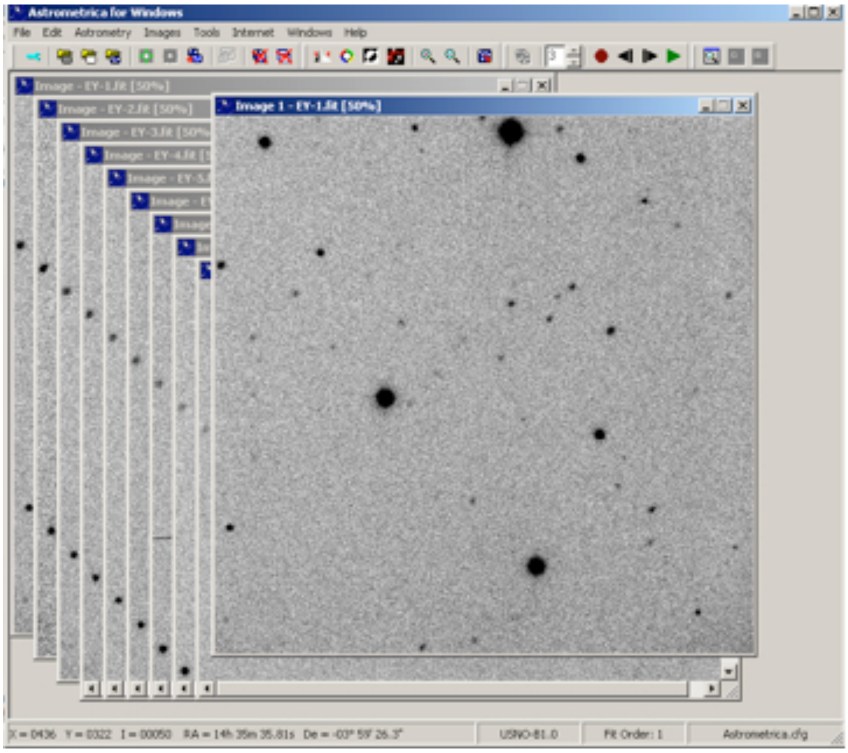


Figure 5: Files are blinked.

3. In this window that has just popped up, Astrometrica will now rapidly step through each of the images in turn.

You will notice that the stars stay pretty much in the same place but there should be an object (probably quite faint) that moves in a consistent direction as the frames are displayed. This is your asteroid! You should make a mental note of which object it is for later.

4. Once you have identified your asteroid, select **Tools » Stop Blinking** to stop the blinking.

Obtaining an Accurate Position

Although you can see the RA and Dec of objects in your images simply by moving your cursor around the image in Astrometrica (see bottom of the Astrometrica screen), the positions are based on how well the telescope is configured and therefore are not useful for the extremely accurate position determinations you are trying to obtain through this project.

A much more accurate way to determine the position of the asteroid is to triangulate on the accurately known positions of the surrounding stars. This is where the USNO-B1.0 catalogue (which you selected in the preferences) comes in as it contains accurate positions for more than a billion objects.

However, before you begin, you should make sure that your MPCOrb database is up to date.

1. Update MPCOrb database *(not necessary every time - only really necessary when you have brand new data).*

The MPCOrb database is a large database with the position information of all the known asteroids and comets. This data is constantly being updated as astronomers from around the world discover new asteroids and comets, and submit new information on known objects. The database originally downloaded through Astrometrica contains most of the information, but you should periodically download the updates so your database is current.

Once you are connected to the internet, select **Internet » Update MPCOrb**. This will pop up the following window.

Figure 6: Select Files dialog.

Select **Daily Orbital Update**, **Comets** and **Near Earth Asteroids** (the others are not necessary) and click **OK**. This will start the downloads and update the database. Depending on the speed of your internet connection and computer, this may take a little while.

If, when you try to update the MPCOrb database through Astrometrica, you receive the error message **"Connection to Host cfa-ftp.harvard.edu failed: Connection Closed Gracefully"**, please read the Software-Astrometrica: Troubleshooting web page.

2. Load the relevant image files.

Note: At this stage you should not resize any images or move them around the screen. Even though they are overlapping at the moment, leave them where they are.

3. Match the objects in the Faulkes Telescope images to objects in the USNO-B1.0 catalogue.

Once you are connected to the internet, select **Astrometry » Data Reduction**. Click **OK** when the **Coordinates** window pops up (the numbers are taken from the header info on the actual image file and should be correct. There is no need to input a name). This identifies the central coordinates of the Faulkes Telescope images.

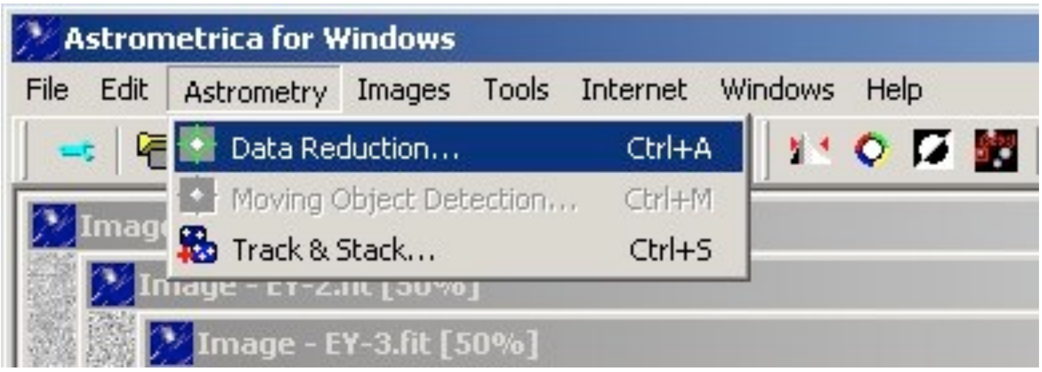


Figure 7: Click **Data Reduction** or press **Ctrl+A.**

Astrometrica will now extract all of the objects in each of the Faulkes Telescope images. It will then connect to the internet and query the USNO-B1.0 catalogue to extract all of the objects near the central position of the Faulkes Telescope images. Astrometrica will then compare the positions for the objects it found in the images with the positions it finds in the USNO-B1.0 catalogue in order to match the objects.

Once it has finished, you will see that most of the objects in the image are circled in colour (and Astrometrica pops up a table - which you can ignore). These are known objects for which the program has found a match in the USNO-B1.0 catalogue. The green circles are for stars it has correctly identified in the USNO-B1.0 catalogue, the blue circles are for objects that it hasn't been able to verify but that it believes are stars. Your asteroid should not be circled or might have a grey circle around it.

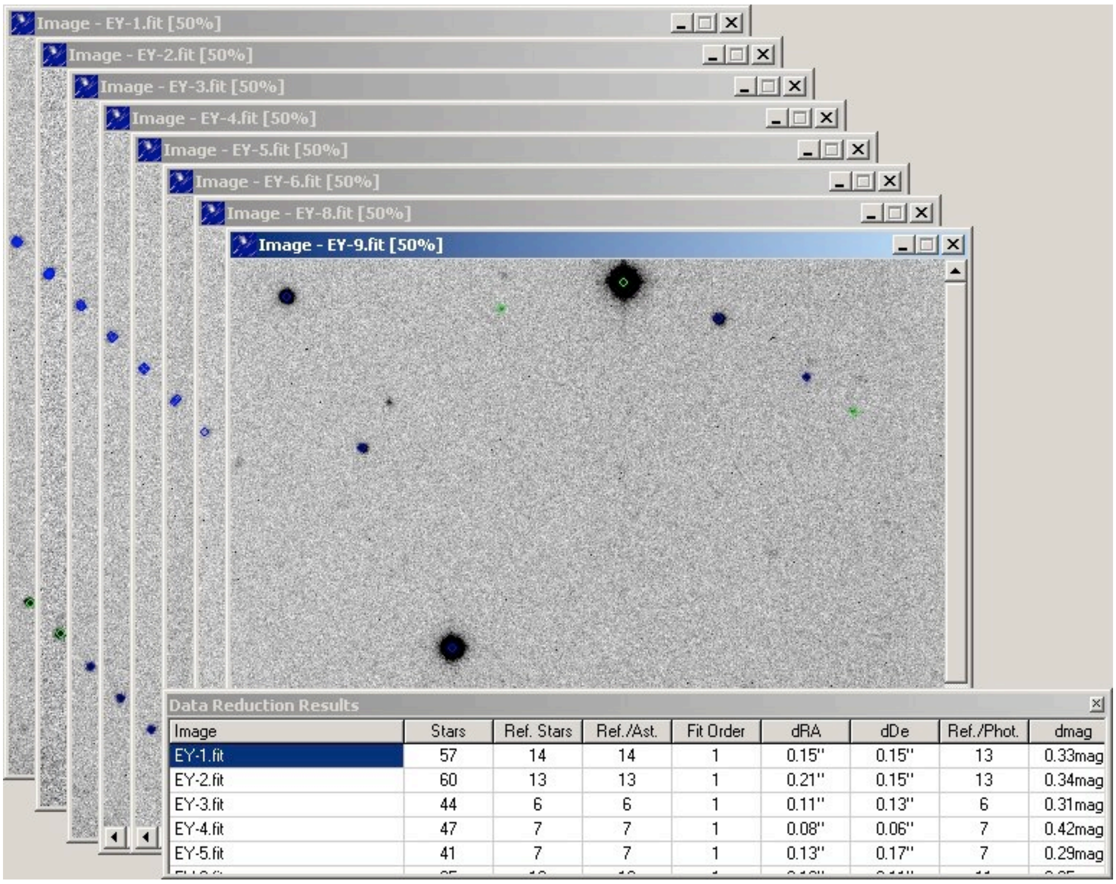


Figure 8: Data Reduction Results.

Note: If Astrometrica fails to match the objects between the images and the USNO-B1.0 catalogue, it will pop up a **"Reference Star Match Error"**. Solutions for this are available on the Software-Astrometrica: Troubleshooting web page.

After this matching exercise is complete, Astrometrica knows the exact position of each star in each Faulkes Telescope image, and the exact RA and Dec of each of these stars from the USNO-B1.0 catalogue. This means that Astrometrica now knows the exact RA and Dec of each pixel in each Faulkes Telescope image. You can now use this information to determine the accurate position of the asteroid by selecting its central pixel.

4. Verify the asteroid.

Go to the window displaying the first image in the sequence. Move the mouse so your cursor is over the asteroid (you have to remember where it is from the blinking exercise you did earlier) and click on it as close to the centre as possible. This will pop up a new **Object Verification** window, as in Figure 9.

This window shows a zoomed-in view of the asteroid. It also gives you a measure of the **SNR** (Signal-to-Noise Ratio) of your image - this is an indication of the quality of your image. A SNR lower than 4 indicates that the image quality is not good enough to obtain an accurate position for the object and you should think carefully about whether to submit your position to the Minor Planet Centre.

You will note also that the asteroid appears slightly (or very) elongated. This is because the asteroid had been moving while the shutter of the camera taking the image was open. The length of the elongation will depend primarily on two factors:

a. the exposure time used
b. the speed of the asteroid

If the asteroid is very elongated and it is difficult to ascertain where the actual centre is, you should think carefully about whether to submit your position to the Minor Planet Centre.

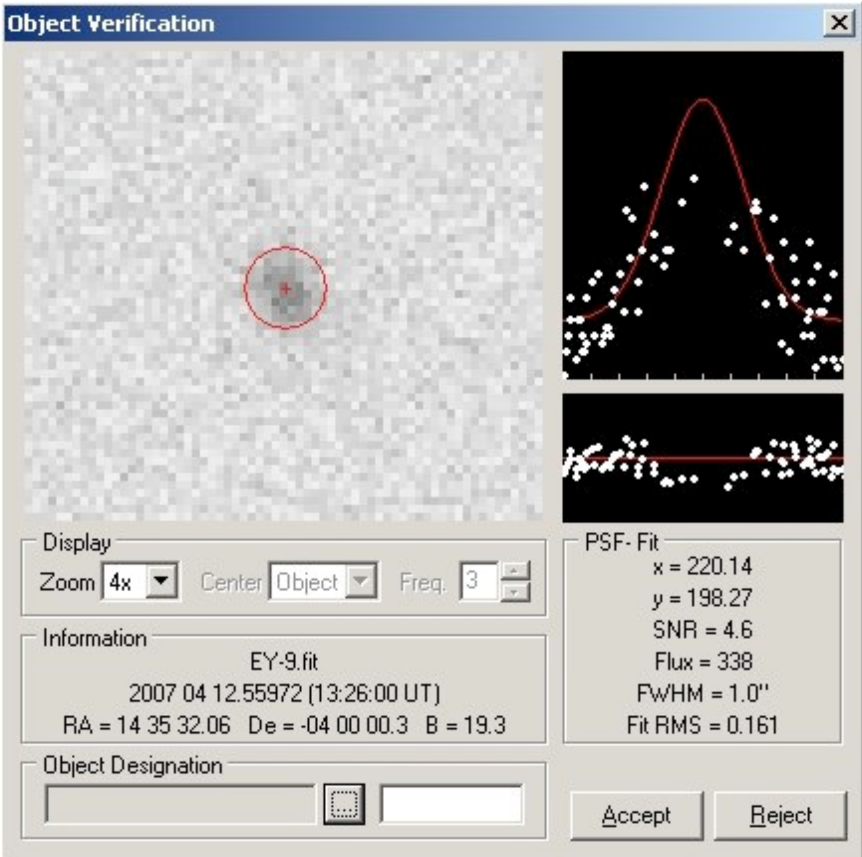


Figure 9: Zoomed in asteroid.

In this **Object Verification** window, the **Object Designation** field is currently blank. If this is a known asteroid that you are following up (i.e. one you obtained through the Spaceguard Priority List), click on the box beside this field to have Astrometrica identify it. Astrometrica will search the MPCOrb database and pop up another window (**Object Identification**, Figure 10) containing a list of asteroids in the MPCOrb database that are close to the position of the object you selected.

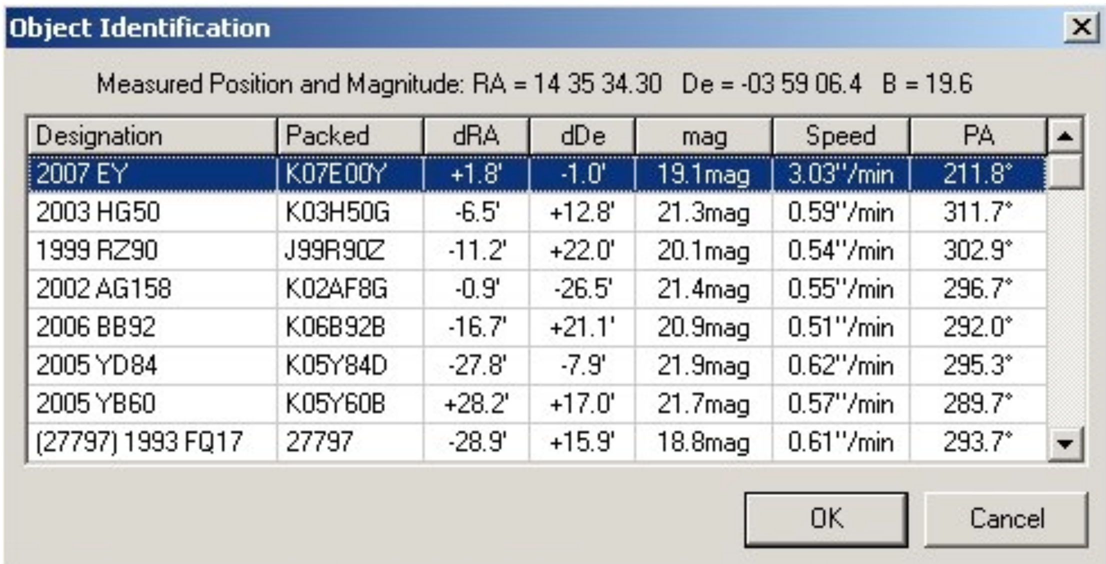


Figure 10: Object Identification.

The **dRA** and **dDec** show the difference in position between the nearest object in the database and the object you selected. The top entry in this window should be the asteroid you imaged and **dRA** and **dDec** should be very close to zero.

If this is the case, click on **OK** and the **Object Designation** box will be filled with the details of the asteroid. Then click **Accept**. Astrometrica will label the asteroid on your image and write the position of the asteroid to an **MPC report**.

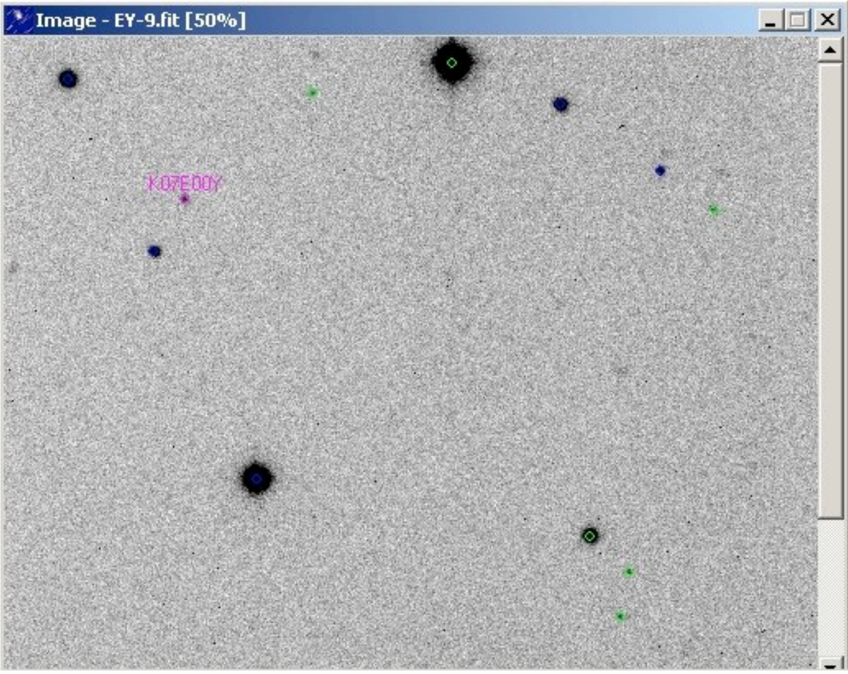
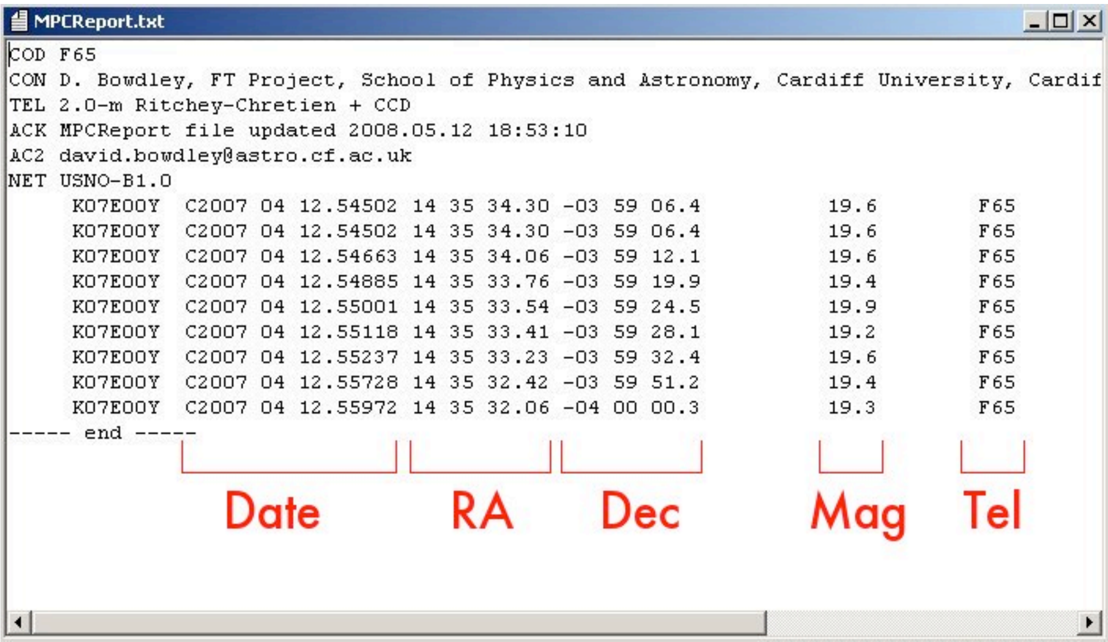


Figure 11: Labelled Asteroid.

You must repeat this process for each of your images.

5. View the MPC Report.

You can view the report written for the Minor Planet Centre and see how the RA and Dec of your asteroid has changed over the course of your observations. Select **File » View MPC Report File**.



```
MPCReport.txt
COD F65
CON D. Bowdley, FT Project, School of Physics and Astronomy, Cardiff University, Cardif
TEL 2.0-m Ritchey-Chretien + CCD
ACK MPCReport file updated 2008.05.12 18:53:10
AC2 david.bowdley@astro.cf.ac.uk
NET USNO-B1.0
     K07E00Y  C2007 04 12.54502 14 35 34.30 -03 59 06.4          19.6        F65
     K07E00Y  C2007 04 12.54502 14 35 34.30 -03 59 06.4          19.6        F65
     K07E00Y  C2007 04 12.54663 14 35 34.06 -03 59 12.1          19.6        F65
     K07E00Y  C2007 04 12.54885 14 35 33.76 -03 59 19.9          19.4        F65
     K07E00Y  C2007 04 12.55001 14 35 33.54 -03 59 24.5          19.9        F65
     K07E00Y  C2007 04 12.55118 14 35 33.41 -03 59 28.1          19.2        F65
     K07E00Y  C2007 04 12.55237 14 35 33.23 -03 59 32.4          19.6        F65
     K07E00Y  C2007 04 12.55728 14 35 32.42 -03 59 51.2          19.4        F65
     K07E00Y  C2007 04 12.55972 14 35 32.06 -04 00 00.3          19.3        F65
----- end -----
```


Figure 12: MPC Report.

This text file contains the positional information (RA, Dec) about the asteroid at the date and time each Faulkes Telescope image was taken. It also gives an estimate of the brightness (Mag) of the asteroid at that time and indicates the telescope (Tel) used.

6. Report your Findings.

Note: You should only report positions of freshly-observed asteroids (not the included archive observations).

The UK Faulkes Telescope team has set up a collaborative webpage for all schools pursuing asteroid projects. It is called the Asteroid Portal and can be found at:
http://portal.faulkes-telescope.com/asteroid/
They have also established a procedure for submitting your measured positions through this portal. You must follow these procedures if you wish to submit your findings. Please download the **Observing Asteroids using the Asteroid Portal** manual from:
http://faulkes-telescope.com/education/projects/asteroids/
and follow the instructions contained in there.

Stacking Images to show the path of the Asteroid

One interesting exercise you might like to do is to stack all the images in the sequence to show the motion of the asteroid in a single image. You could compare these stacked images for different asteroids to illustrate how each asteroid moves at a different speed and in a different direction.

1. Load the required FITS files (in this example you are only going to use the first 4 images of EL88).

2. Stack the images.
Once you are connected to the internet, select **Astrometry » Track and Stack...**

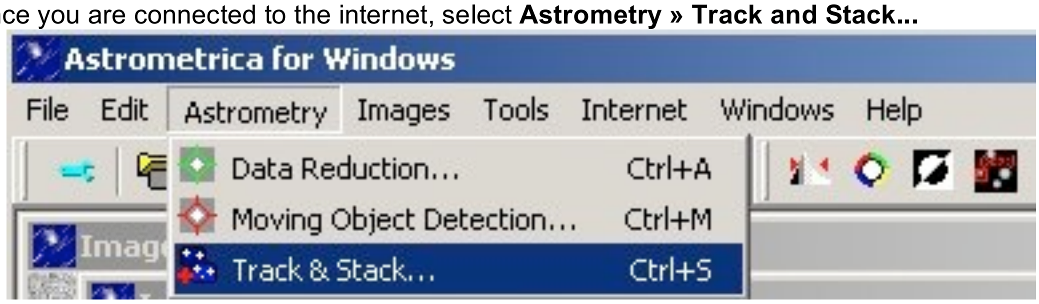


Figure 13: Track and Stack, baby.

This will pop up a **Select Images** window, as in Figure 14. Click on **Add** and select the images you wish to stack (again you can hold down the control key to select multiple images).

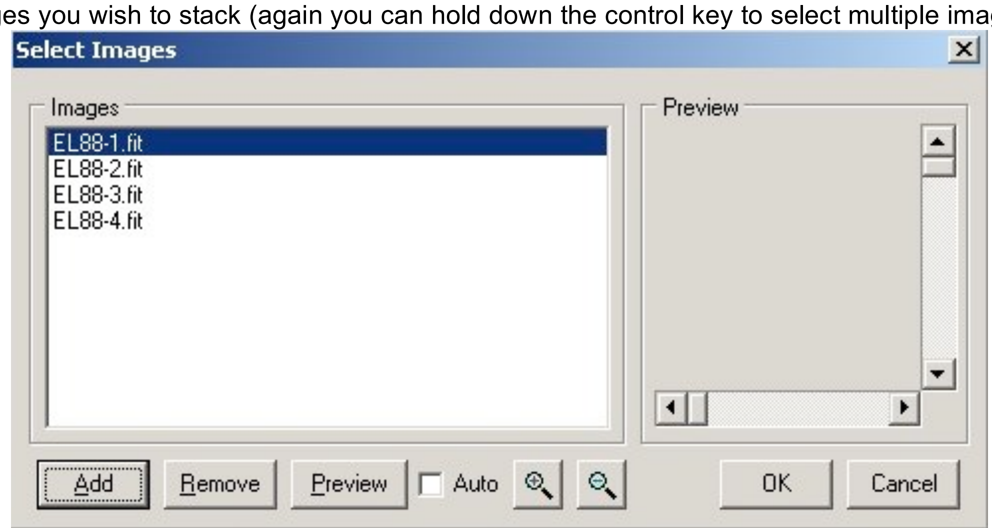


Figure 14: Select Images.

Click on **OK** once you have selected all your images. Once again, Astrometrica will pop up a small window indicating the Date and Time for each of the selected images. Click **OK** for each one as the data are taken from the image header and should be correct.

The next window to pop up is the **Coordinates, Tracking and Stacking** window (Figure 15). Here you can choose to track either the Asteroid (you will have several images of each of the stars) or the stars (you will have several images of the asteroid). It also gives you the option to Add, Average or Median your images together.

In this case you want to track the stars (you will only have one instance of each star but 4 instances of the asteroid). Click on the **Average** button and then **OK** to stack the images.

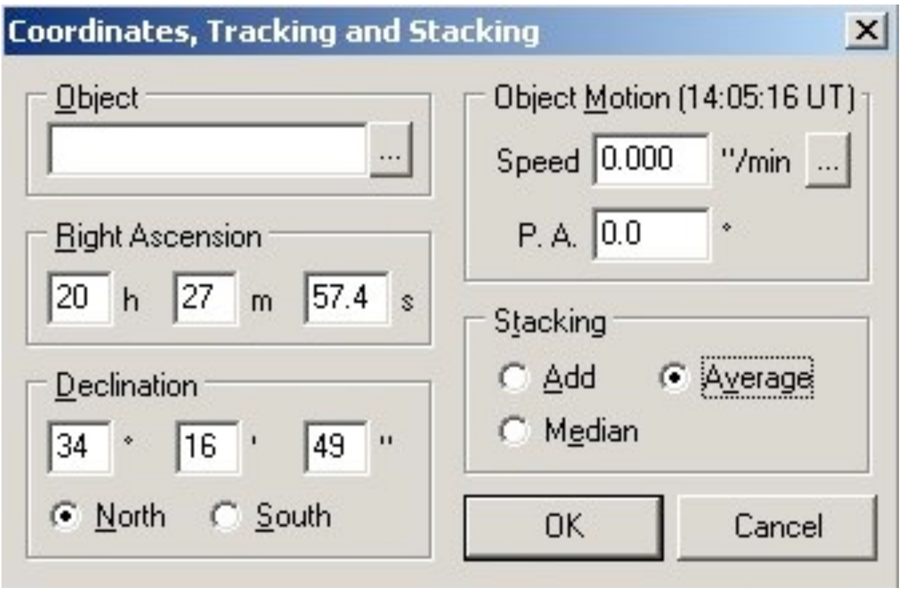


Figure 15: Settings for tracking on the stars.

Astrometrica will now go through the process of matching the objects in the Faulkes Telescope images to the objects in the USNO-B1.0 catalogue, just as it did when you were determining an accurate position for the asteroid. Once complete, it will return an image showing the matched stars and the asteroid moving against the backdrop of stars.

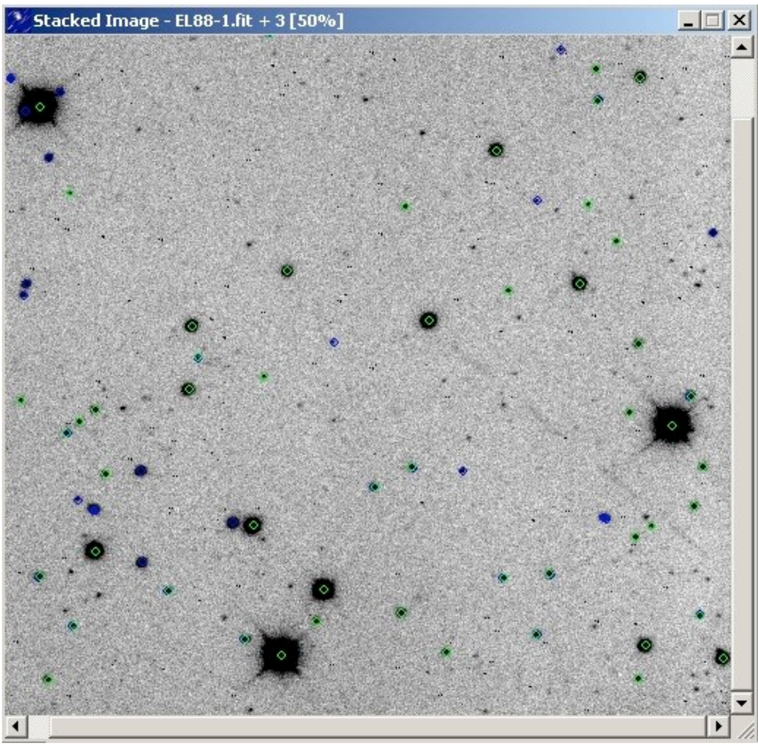


Figure 16: Stacked Image.

3. Remove the coloured identifiers.

You don't really want these in your exported image. Go to **Images » Select Markings...**

Uncheck all of the boxes and click **OK**.

Note: Astrometrica will remember that you have unchecked the boxes, so next time you identify objects in an image, it will not circle the reference objects unless you recheck all the boxes.

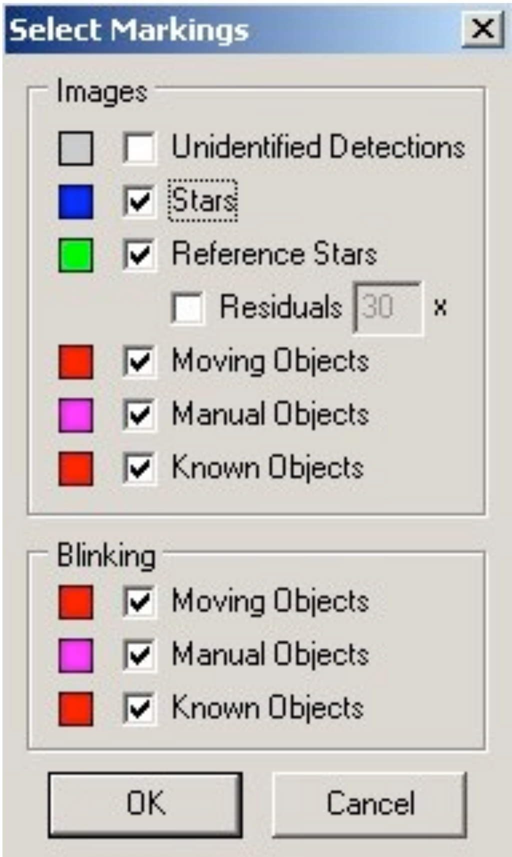
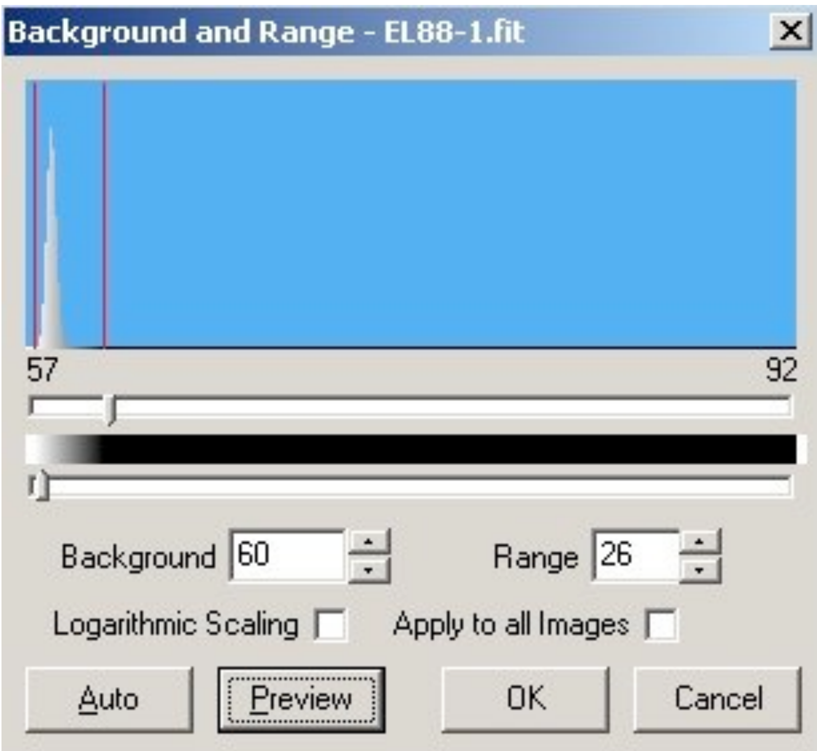


Figure 17: Remove the coloured identifiers

4. Adjusting the contrast.

An optional step you might like to try before exporting is to adjust the contrast in your image to really bring out all the features. Select **Images » Background and Range...** This pops up the **Background and Range** window, as in Figure 18.



From here it is a bit of an art, but basically you play around with the sliders in this window to achieve the desired effect. Use the **Preview** button to see what effect the changes you are making are having on your image. Once you are happy with how your image looks, click **OK**.

Figure 18: Background and Range window.

5. Export the final image.

Now you have your stacked image showing the motion of the asteroid you should export it for use in other programs. Select **File » Export Image to... » JPEG...** and click **Save**.

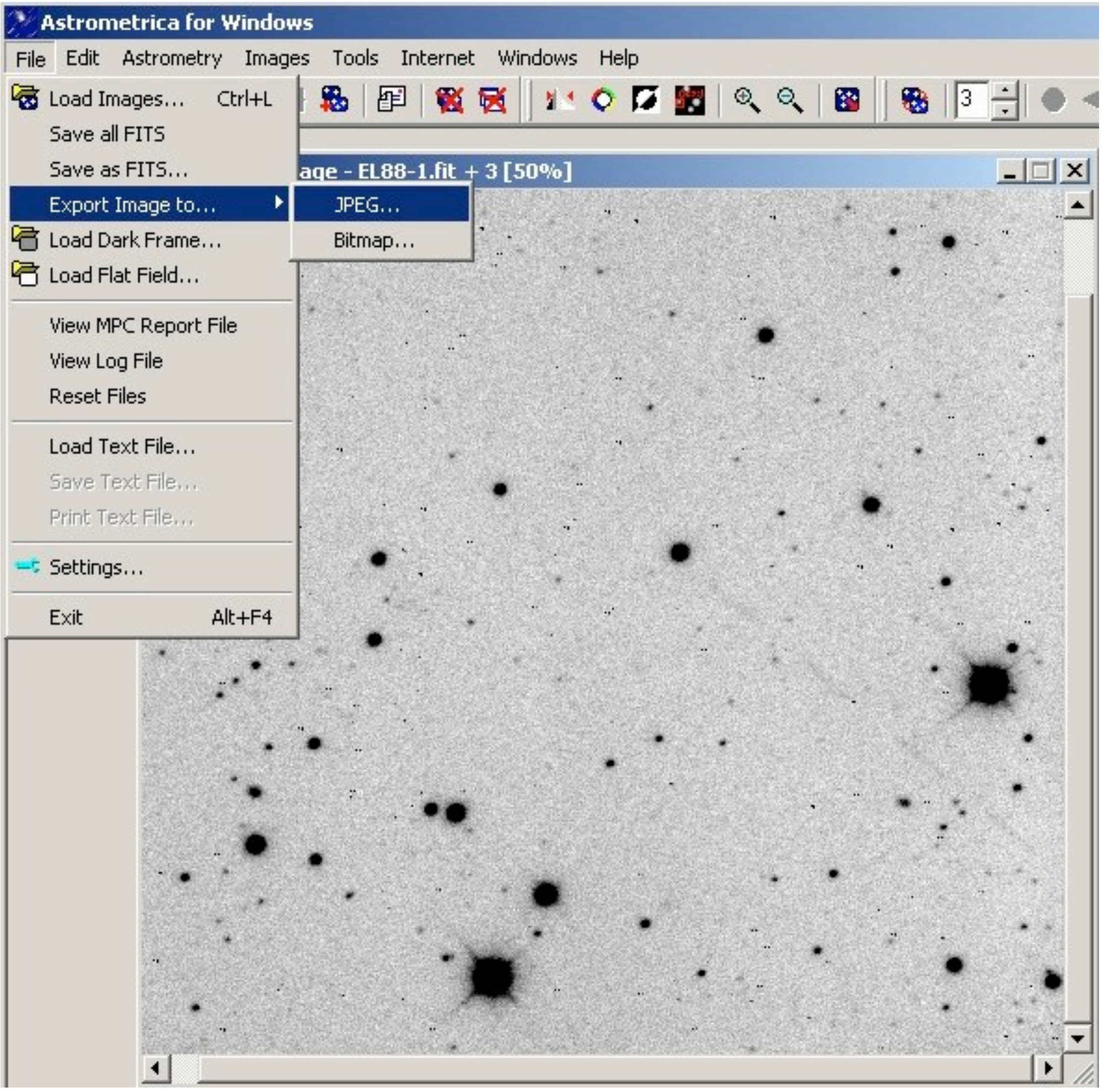


Figure 19: Save the final image.

Making a Colour Image with IRIS

Another activity you might like to undertake is to create a colour image with your data. Not only will you produce a stunning colour image, you can use this exercise to teach students about what happens when different coloured light combines. It can be used (depending on the data) to show that stars have different colours and lead on to a discussion of why this is so. You can use this exercise to show the direction the asteroid is moving, provided you know which colour was observed first.

Note: In order to do this, you **must** have 3 successive images of the same object in the same field, one taken through the B filter, one through the V (green) filter and one through the R filter.

1. Start IRIS by double-clicking on the program icon.

2. Change the settings.

Select **File » Settings...** In particular, you must indicate in the **Working Path** where your data is located. Your data files must have the extension **.fit**, **.fts**, or **.pic** for IRIS to find them **AND** the names must only contain lower-case letters. If your data files have capitals in the filename or the extension .fits (this is likely if you have used the Faulkes Telescope), you need to rename them using lower-case letters and replacing the **.fits** with **.fit**.

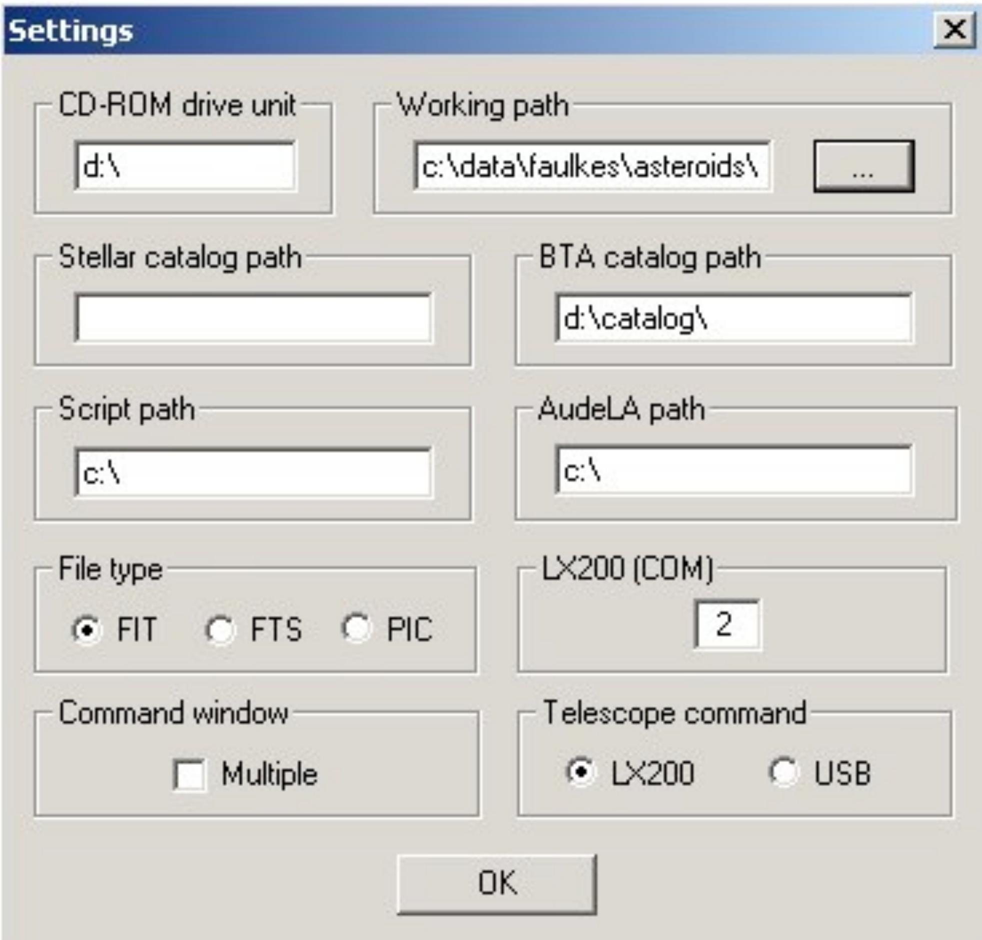


Figure 20: IRIS Settings.

3. Load and superimpose the images taken through the B, V and R filters.

Select **View » (L)RGB...** You need to put the filename (drop the .fit extension) in the appropriate box and click **OK**.

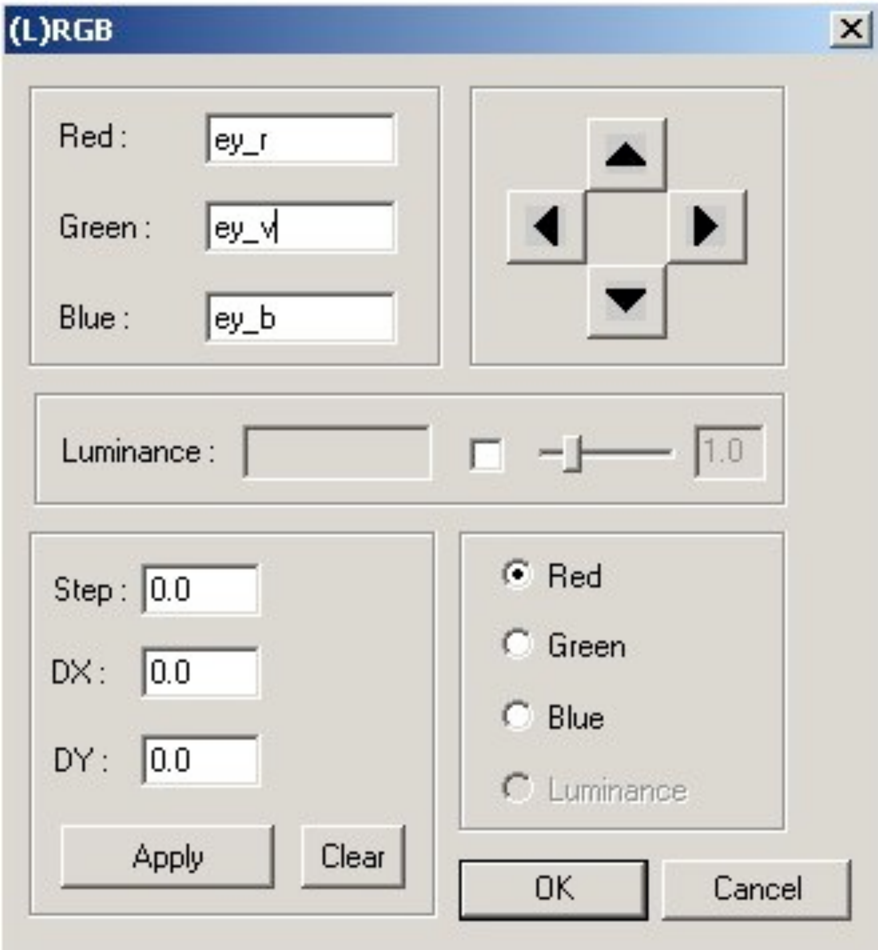


Figure 21: (L)RGB control panel.

This will load and superimpose the images. The screen will probably appear black initially and in order to see the resultant image more clearly, click **Auto** in the **Threshold** window. **DO NOT** at any point click on any of the four coloured buttons in this **Threshold** window. Alternatively, you might want to play with the sliding bars in the **Threshold** window to obtain a clear view of the objects in the image. (Note: the **Threshold** window sets the brightness at which the pixels in the image are shown to be white — in this case at a brightness of 32767 — and the brightness at which the pixels in the image are shown to be black — in this case a brightness of 0).

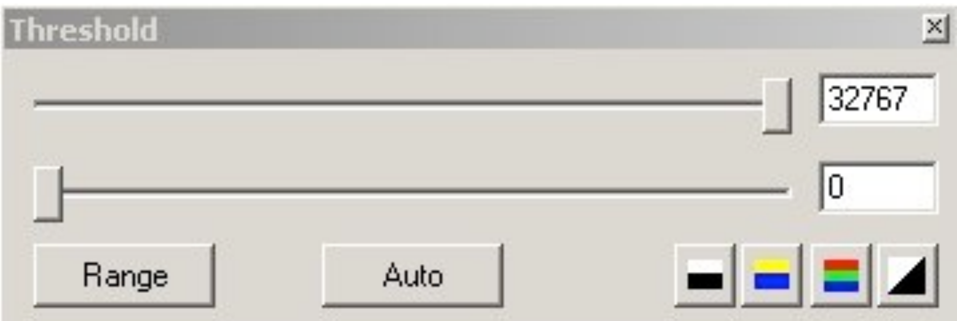


Figure 22: Threshold window.

If you look closely at the stars in this superimposed image, you may be able to distinguish the image of the stars taken through the red filter (red dots), the image of the stars taken through the visual filter (green dots) and the image of the stars taken through the blue filter (blue dots). How much the telescope has moved between each image will determine how closely aligned the stars are at this stage. You may also notice that the image itself has a general hue (i.e. the background is not black - in this case it has a reddish hue). This will depend on how much light was let through each filter (in this case, the light coming through the red filter was stronger than that coming through the green or blue filters) and may not be the case if you have previously selected **Modified Equalization** (refer to the Colour Images teaching module).

We are now going to shift each of these individual images (red, green, blue) so that they line up on top of each other. This process is quite subjective but you should be able to obtain a reasonable result.

4. Line up the images.

Select **View » (L)RGB...**

Panel A indicates which image you are manipulating (red, green or blue). **Panel B** is the controller where you move the image. The **Step** field in **Panel C** is where you indicate by how much you want the image to move at once.

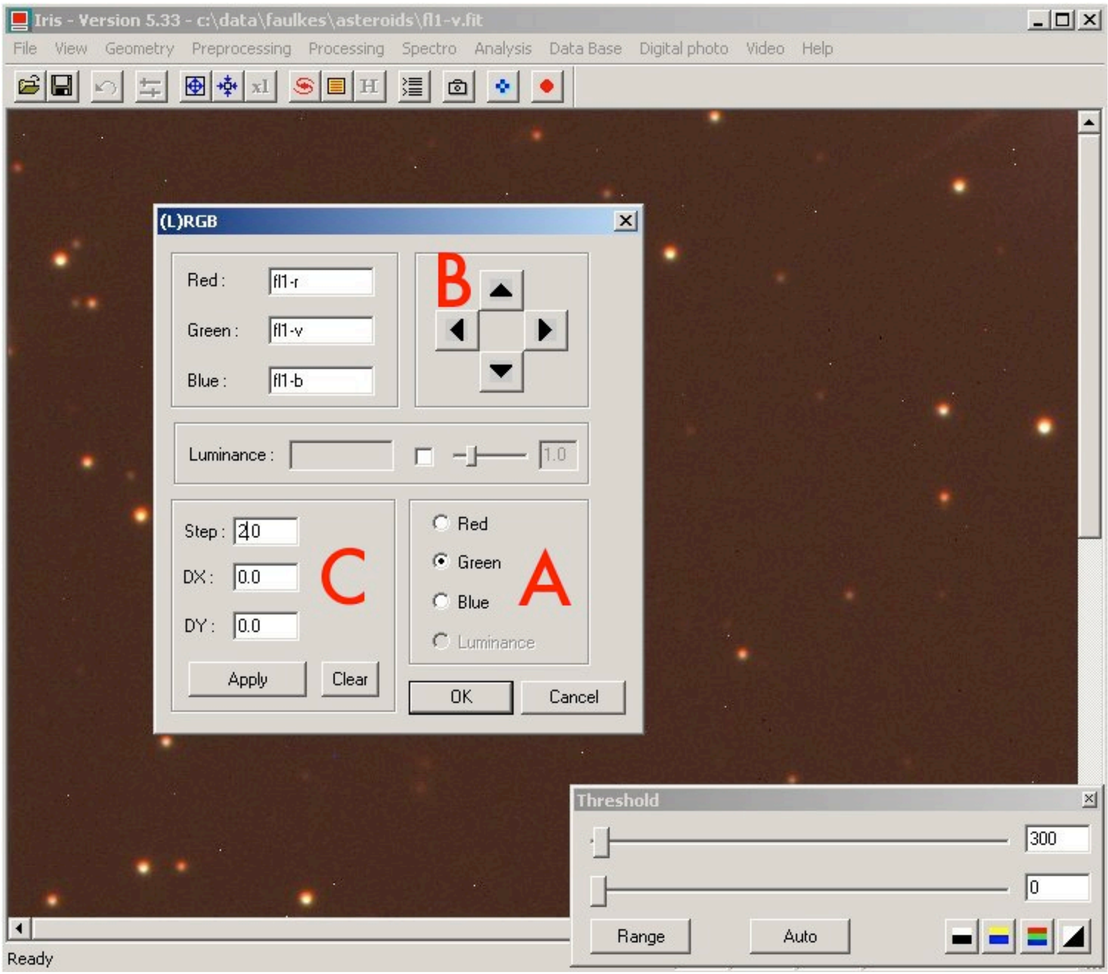


Figure 23: Lining up the images.

Start with the visual (green) image (**Green** is checked in Panel A) and try to align it with the red image. Do a coarse adjustment to begin with of 2 pixels (input 2.0 into the **Step** field in Panel C). Now, using the controls in Panel B, move the green image until it lines up better with the red image. What you are trying to do is make the stars round and their centres white (when you combine red, green and blue light — you end up with white light). You will need to adjust the **Step** to be much smaller as the alignment improves. Repeat this for the Blue image. **Do not click OK until after you have completely finished lining up the images.**

Once you are satisfied with your alignment, click **OK**.

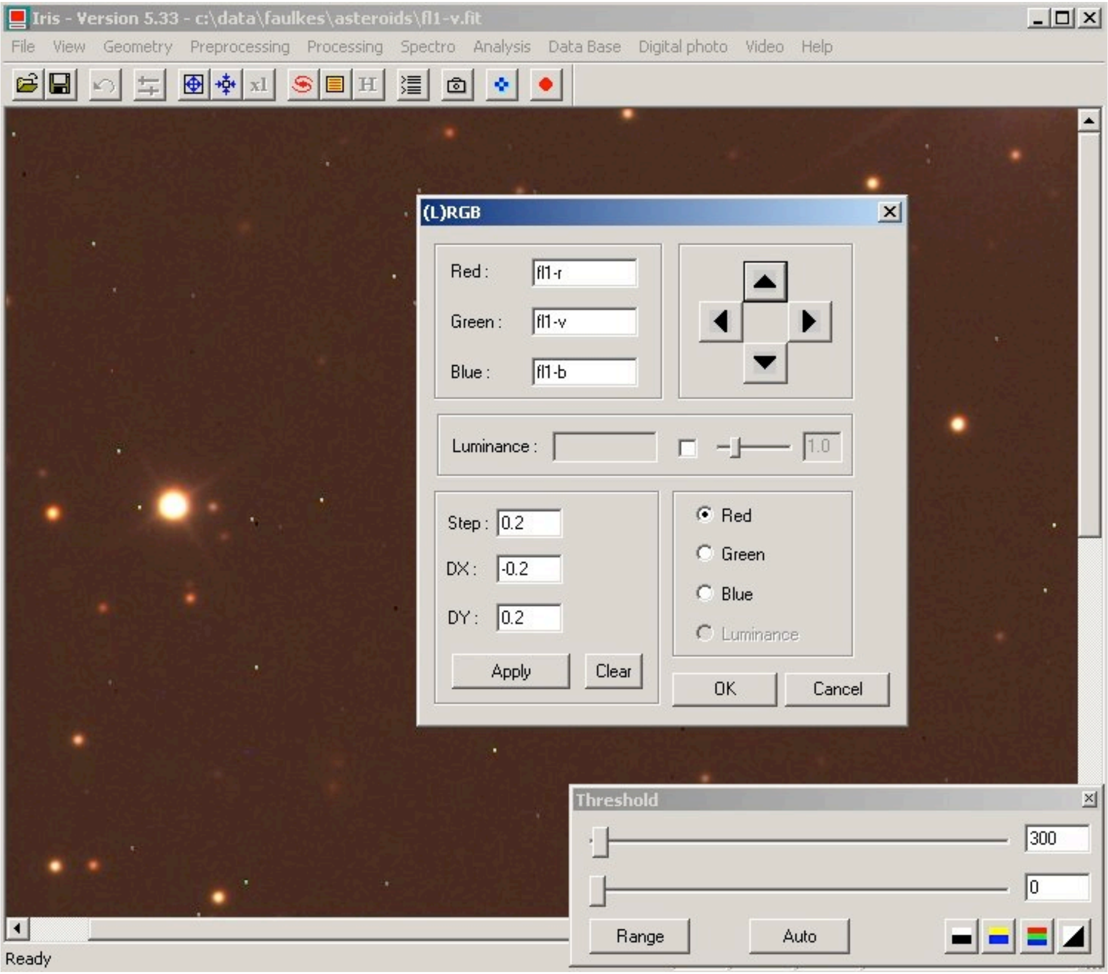


Figure 24: Aligned!

You will notice in this example that the stars have a reddish ring around the outside. The red images are slightly larger than the others. This may be due to observing conditions, different exposure times for the different coloured images or variations in the transmission of light through the different filters. Unfortunately, there is not a lot we can do about this.

5. Adjust the White Balance.

In an effort to eliminate the reddish cast the image has, select **View » White Balance Adjustment...** to bring up the **White Balance** window as in Figure 25. Here again it's a matter of playing with the controls until you achieve the look you want. You may also want to play with the **Gamma Adjustment**, **Contrast adjustment** and **Saturation adjustment** under this **View** menu. There is no rule about how to make the image look its best, it really is a matter of you tweaking the controls. It's best to be able to see your asteroid as you are making the adjustments.

6. Save your colour image.

Once you are satisfied with your image and you are ready to save it, select **File » Save...** This gives you multiple options for your save format, as shown in Figure 26. If you want to use the coloured image in IRIS (e.g. to make a mosaic out of several images) then you need to select .pic format. Otherwise, you must save it in a format compatible with your other software (e.g. tif, jpg). **DO NOT** save it as a FITS file or your work will be lost.

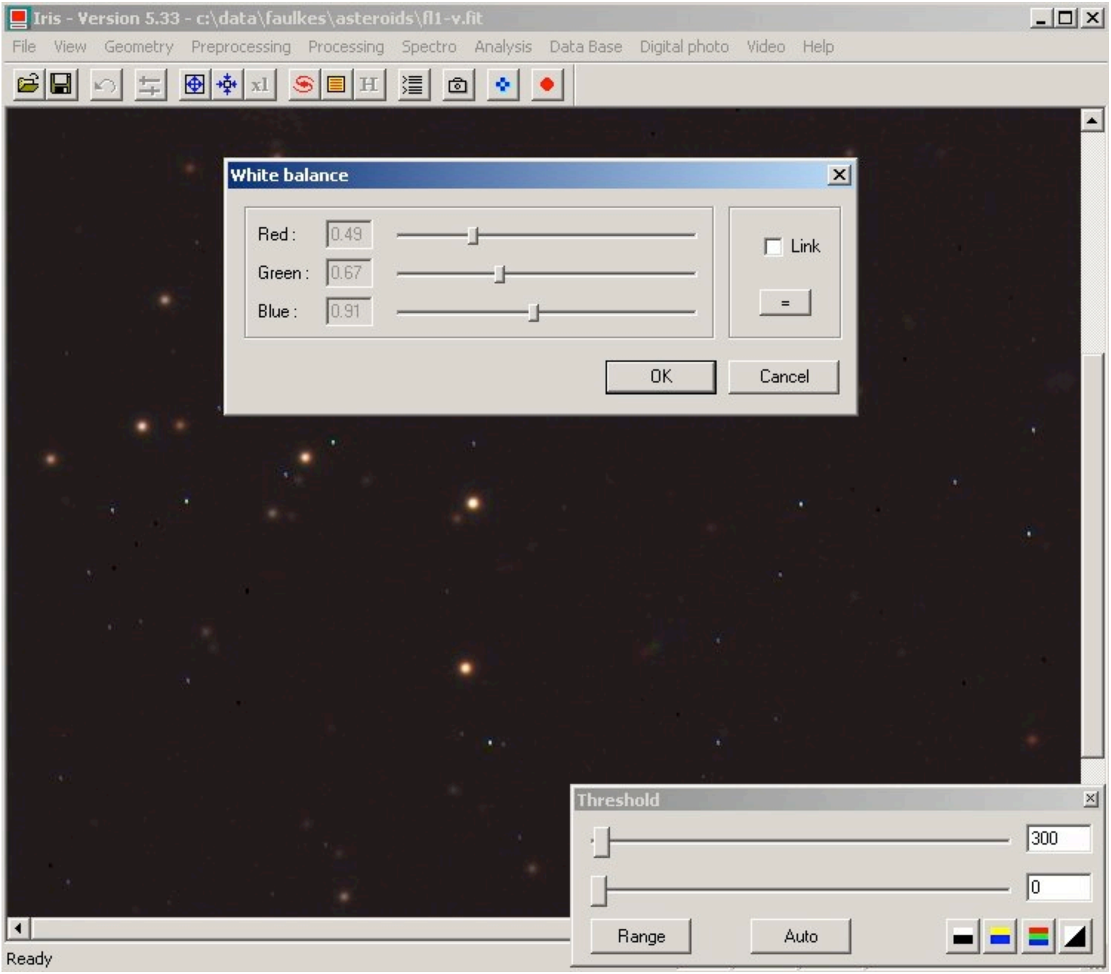


Figure 25: White Balance window

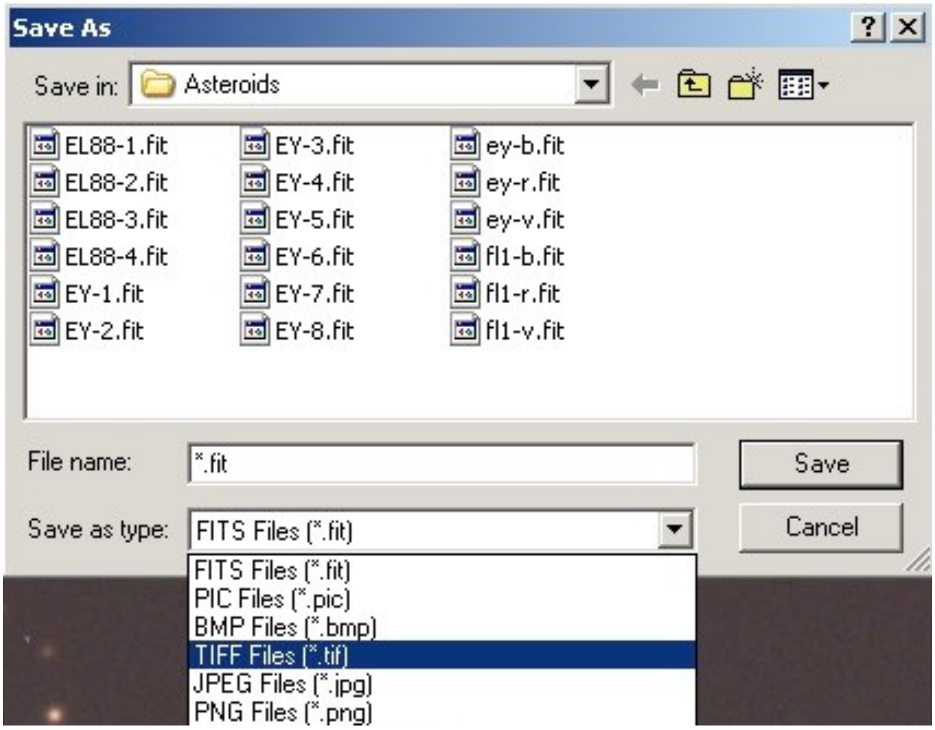


Figure 26: Saving your image.

Here is the final image showing the asteroid (one blue image, one green image and one red image) moving against the backdrop of stars.

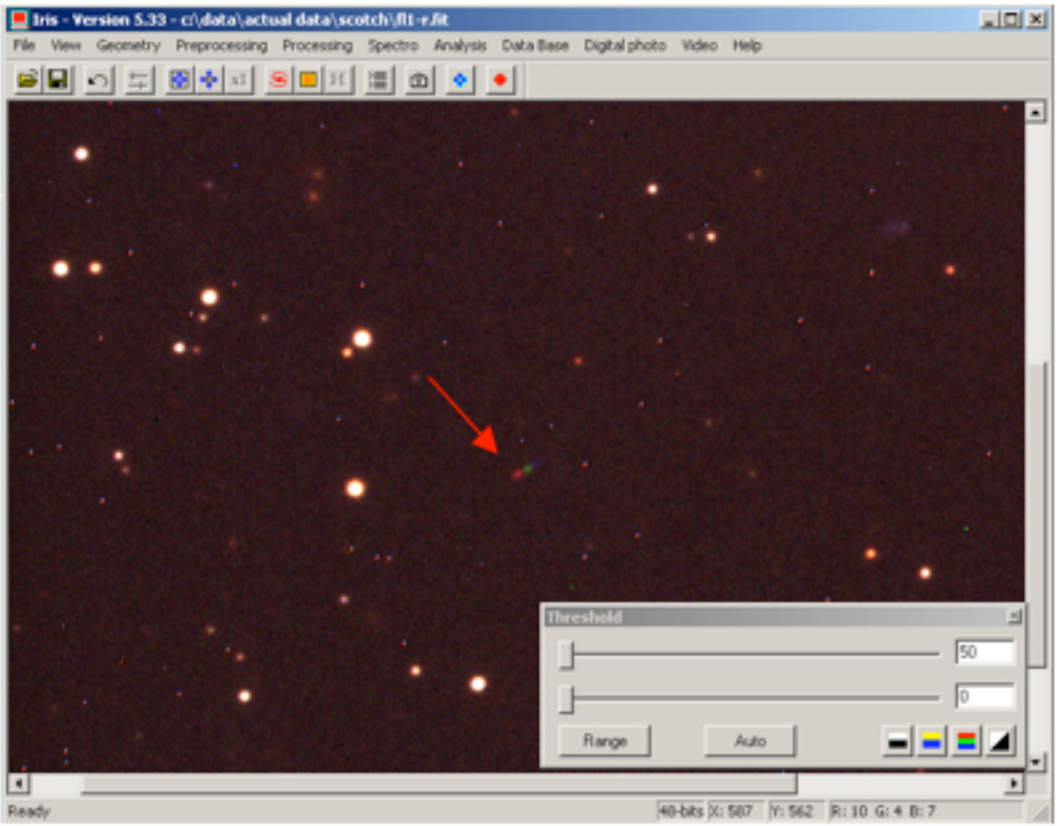


Figure 27: The final image.