| | |
|---|---|
| ***Activity title:** | Calculate the size of an asteroid |
| ***Keywords:** (list any words which you think relate to the subject, goals or audience of your activity) | Asteroids, Observing, Measurement, Data analysis. |
| ***Age range:** (choose all age categories this activity applies to) | H 16-19<br>I 19+ |
| ***Education level:** (choose one or more educational level for your activity) | D Secondary<br>E University |
| ***Time:** (how long does the activity take?) | F 2hrs in 3 steps |
| ***Group size:** | Group |
| ***Supervised for safety:** (does the activity have steps which need adult supervision for safety?) | No |
| ***Cost:** (rough cost of any materials needed for this activity in Euros) | Low (<5) |
| ***Location:** | Indoors (small, e.g. classroom) |
| ***Language:** (what language are you submitting this activity in?) | English |

***List of material:** (what items are needed for the activity? Be as thorough as possible, bearing in mind that the activity may not take place in a classroom)

Computers with Internet (the cost of computers is not included in the cost of the activity)
Softwares :
SalsaJ and Astrometrica
Excel

***Goals:** (a short list of points outlining the general purpose of the activity)

Students will have an appreciation of the size of an asteroid
Students will be aware that the size is a function of the magnitude and albedo

***Learning objectives:** (specific statements of what content students are intended to learn, in terms of how they will demonstrate that learning)

Students will learn the basic knowledge about asteroids.
Students will be able to find a list of asteroids at opposition or near at a specific date.
Students will be able to choose an asteroid according defined conditions (opposition, magnitude, avoid earth penumbra...)
Students will be able to prepare an observing session using the LCOGT network telescopes or other robotic telescope or other telescope (no moon, location of the asteroid in the sky to do good images, exposure time to avoid saturation...).
Students will be able to use astronomical software and data base.
Students will be able to turn images north up and east left (comparison with a DSS image in ALADIN software with the same field of view...).
Students will be abble to identify the asteroid in the field (using the blink tool in ASTROMETRICA,

asteroid moves on the stars background).
Students will be abble to use a star catalogue to identify and select stars for photometry in the field of images (CMC-14 catalogue).
Students will be abble to use a photometry software (SasaJ developed by EUHOU).

***Evaluation:** (how the teacher will elicit evidence of student learning, to evaluate how well students are achieving the learning objectives above)

Teachers can check the different task listed above to see if the students succeed in.
Students will be asked about:
- Their knowledge about asteroids.
- Calculation of the coordinates of an asteroid at opposition on a given date.
- How they schedule observation on the telescope.
- How they recognize the asteroid on the images and explain their choice.
- Measurement of the light flux of the stars and the asteroid on the images obtained.
- On their choice of good reference stars in the images using a specialized astronomical catalogue
- How they use and adapt a spreadsheet.

***Background information:** (information that teachers will read prior to beginning the activity)

Determine the size of a small object in the solar system that appears almost point shape even with large instruments is not easy. One way to achieve this is to use sunlight scattered by the object and captured by the telescope.
We will use the position of an asteroid opposite to the Sun relative to the Earth to determine its magnitude by comparison with field stars whose magnitudes are well known. We observe the target to the opposition or close to the opposition in order to minimize as much as possible the phase effect. The images will be shot using a photometric filter Standard V Johnson Cousins, care should be taken not to saturate the target by choosing a suitable exposure time. Finally we will have to select reference stars in the field of the images obtained for photometry. We chose to make the differential photometry rather than absolute or all-sky photometry. In fact this method is simpler because it is performed directly on the images where the target object is located. The advantage lies in the fact that atmospheric changes or variations due to the height affect in the same way all the stars of very small observed field. Then comes a phase of calculations based on mathematical formulas derived from physical laws and observational data leading to an estimate of the "diameter" of the asteroid studied.
To choose the target we will use "ephemeris" given by the Minor Planet Center.
An ephemeris gives the positions of naturally occurring astronomical objects as well as asteroids at a given time or times. The astronomical position calculated from an ephemeris is given in the spherical polar coordinate system of right ascension and declination.
This activity is complex, it is possible if desired to split it into several simple part that processed one by one will reach the final goal.

Here you can find :

- images to check the activity
- examples illustrating the activity
- useful documents to carry out the activity
- reference articles
- useful links

https://onedrive.live.com/redir?resid=62E512265D1AC767!1360&authkey=!AOOKjIl5hHIrXbA&ithint=folder%2c

| | |
|---|---|
| ***Core skills:** (core practices of doing science and thinking scientifically that student will learn from the activity. Choose as many as you like) | A Asking questions<br>B Developing and using models<br>C Planning and carrying out investigations<br>D Analysing and interpreting data<br>E Using mathematics and computational thinking |
| ***Type of learning activity:** (choose only one) | A Full enquiry |

***Brief Summary:** (one paragraph short description of the activity)

The light of celestial bodies that reaches us is often the only source of information on objects observed except in very rare cases of space probes. Is the light collected by our ground-based telescopes allows us to access the size of asteroids that we observe? This goal can be achieved if we are able to measure with accuracy the V-band magnitude (Johnson V magnitude centred on about 545nm, "V" stands for visual) of the observed asteroid.

***Full description of the activity:** (detailed steps of the activity)

Caution : this activity is not for novice students and non-expert teachers.
Astronomy workshop in schools with some experience may benefit from it but it is necessary to have a minimum knowledge in astronomy, in use of telescopes (robotic telescopes :
LCOGT net work telescopes http://lcogt.net/
GLORIA network telescopes http://gloria-project.eu
...or personal telescopes), CCD imaging and photometry.

The method presented here is directly inspired by that described by Roger Dymock & Richard Miles.

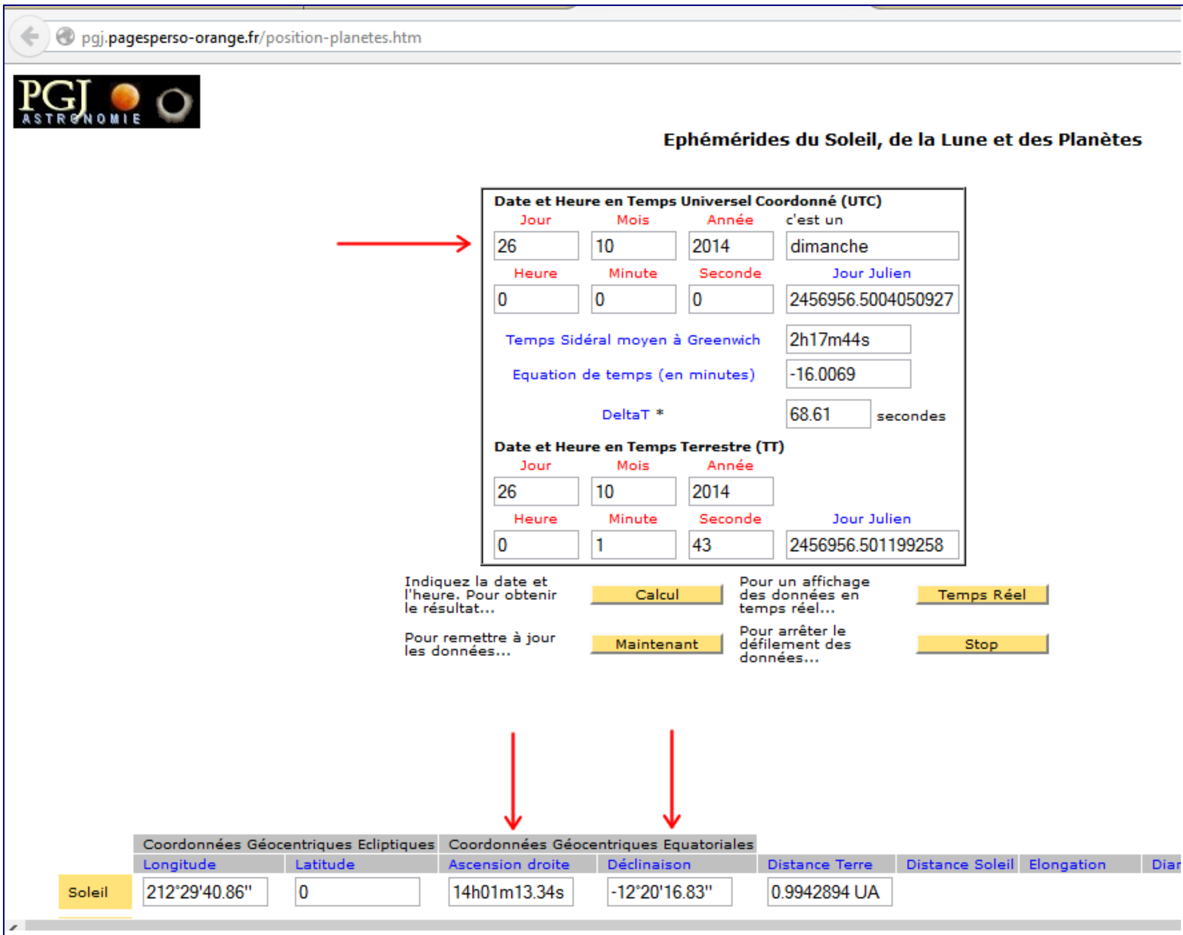
List of steps

1) Preparation of the observation: choice of the target.
2) Acquiring images.
3) Downloading images.
4) Converting images into fits format suitable for ASTROMETRICA software.
5) Study of stars in the field of view aid of ALADIN software in order to find reference stars to apply photometry.
6) Vmag calculation for each reference star from r', J and Kmag.
7) Target identification in the field.
8) Photometry of reference stars and target.
9) Vmag calculation for the target.
10) Absolute magnitude H calculation for the target.
11) Diameter calculation for the target.

**1st module: Selecting the target(s)**

***1st criteria***: the asteroid must be near opposition.
« Opposition » means that sun, earth and target are aligned so we can calculate the coordinates of the asteroid from the coordinates of the sun at the date of observation. You can use Gilbert JAVAUX website : http://pgj.pagesperso-orange.fr/position-planetes.htm

For example




***2nd criteria*** : the magnitude of the asteroid must be below a value which depend of your device.

***3rd criteria*** : the phase angle of the asteroid must be less than 1°.

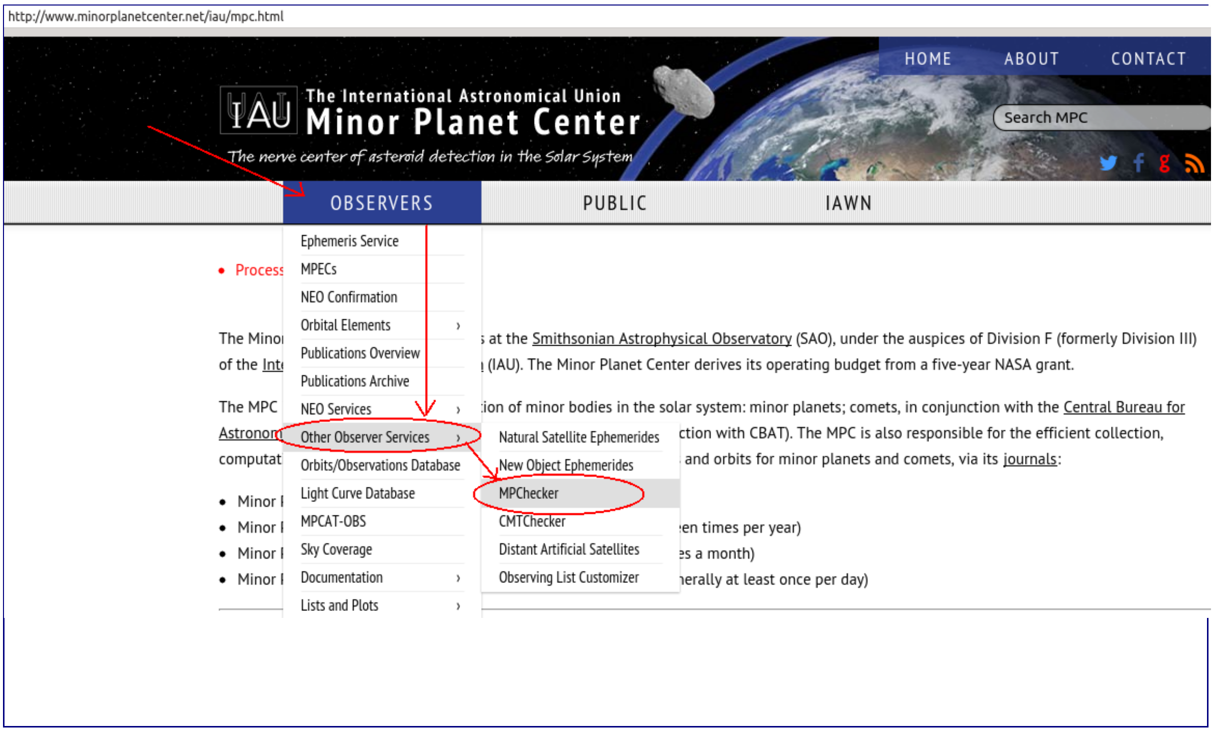
***4th criteria:*** the altitude of the asteroid must be higher than about 25°/30°.

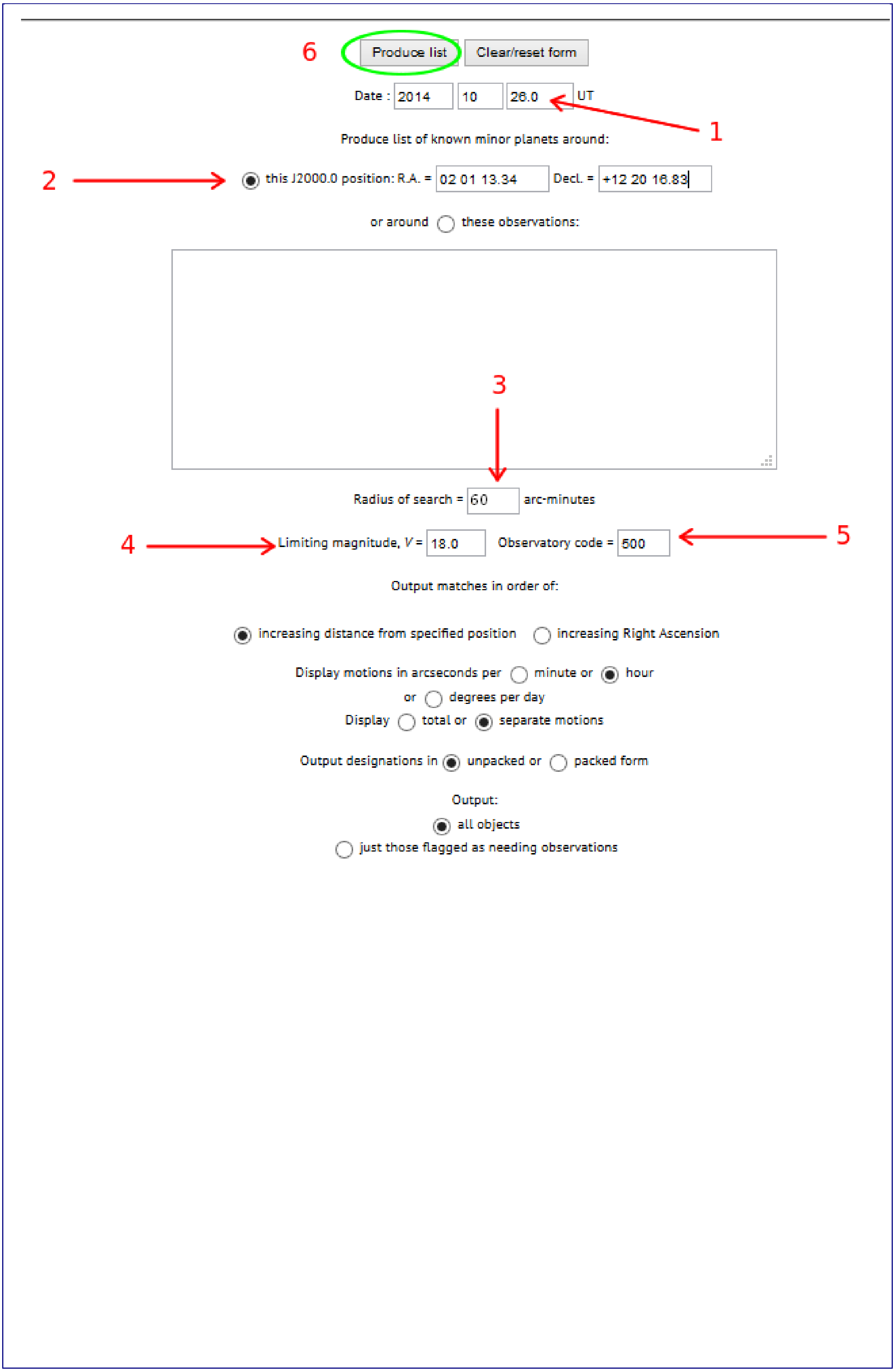
***5th criteria*** : the asteroid must be out of Earth umbra or penumbra

Now go to the Minor Planet Center website : http://www.minorplanetcenter.net/iau/mpc.html

OBSERVERS > Other Observers Services > MPChecker (this tool gives a list of asteroids near opposition on the date of observation)

Example :


http://www.minorplanetcenter.net/iau/mpc.html
HOME
ABOUT
CONTACT
IAU
The International Astronomical Union
Minor Planet Center
The nerve center of asteroid detection in the Solar System
Search MPC
OBSERVERS
PUBLIC
IAWN
Ephemeris Service
MPECs
NEO Confirmation
Orbital Elements
Publications Overview
Publications Archive
NEO Services
Other Observer Services
Orbits/Observations Database
Light Curve Database
MPCAT-OBS
Sky Coverage
Documentation
Lists and Plots
Natural Satellite Ephemerides
New Object Ephemerides
MPChecker
CMTChecker
Distant Artificial Satellites
Observing List Customizer


6
Produce list
Clear/reset form
Date : 2014 10 26.0 UT
1
Produce list of known minor planets around:
2
this J2000.0 position: R.A. = 02 01 13.34 Decl. = +12 20 16.83
or around these observations:
3
Radius of search = 60 arc-minutes
4
Limiting magnitude, V = 18.0
Observatory code = 500
5
Output matches in order of:
increasing distance from specified position
increasing Right Ascension
Display motions in arcseconds per minute or hour
or degrees per day
Display total or separate motions
Output designations in unpacked or packed form
Output:
all objects
just those flagged as needing observations

1 - the date of observation ( 2014 10 26.0 UT means 2014 October 26th at 0hUT, MPChecker use a decimal form for the date and hour, 26.875 means 26th at 21h UT)

2- rigth ascension and declination of the area of the sky you are looking for asteroids (20 01 13.34 for 20h 01m 13.34s and +12 20 18.83 for 12° 20' 18.83'' N)

3- the radius of your search in arc-minutes center on the previous position

4- magnitude limit in V-band depending on your telescope

5- MPC observatory code (500 is the code of the center of the Earth used by default)

6- Then click on “Produce list”

scully.cfa.harvard.edu/cgi-bin/mpcheck.cgi

# MPChecker/CMTChecker/NEOChecker/NEOCMTChecker

Here are the results of your search(es) in the requested field(s) :

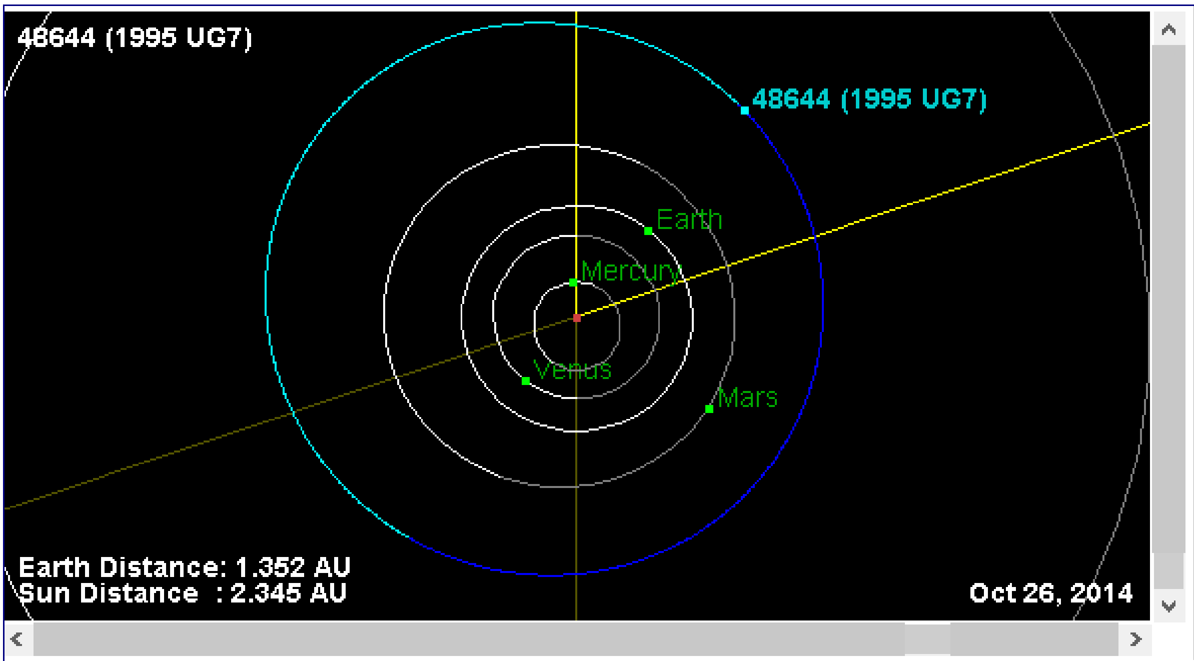
The following objects, brighter than $V$ = 18.0, were found in the 60.0-arcminute region around R.A. = 02 01 13.34, Decl. = +12 20 16.83 (J2000.0) on 2014 10 26.00 UT:

| Object designation | R.A. h m s | Decl. ° ' " | V | Offsets R.A. | Offsets Decl. | Motion/hr R.A. | Motion/hr Decl. | Orbit | Further observations? Comment (Elong/Decl/V at date 1) |
|---|---|---|---|---|---|---|---|---|---|
| (66676) 1999 TS27 | 02 00 54.5 | +12 27 45 | 17.4 | 4.6W | 7.5N | 33- | 4- | 14o | None needed at this time. |
| (10464) Jessie | 02 01 42.9 | +12 13 12 | 17.0 | 7.2E | 7.1S | 39- | 9- | 16o | None needed at this time. |
| (179973) 2002 XZ36 | 02 00 41.2 | +12 06 09 | 17.2 | 7.9W | 14.1S | 42- | 7+ | 9o | None needed at this time. |
| (8426) 1997 ST | 02 00 39.5 | +12 04 53 | 16.6 | 8.3W | 15.4S | 34- | 18- | 16o | None needed at this time. |
| (34979) 2173 T-3 | 02 02 50.4 | +12 15 36 | 16.3 | 23.7E | 4.7S | 30- | 29- | 15o | None needed at this time. |
| (48644) 1995 UG7 ← | 02 02 02.4 | +11 56 40 | 17.1 | 12.0E | 23.6S | 38- | 5- | 14o | None needed at this time. |
| (13536) 1991 RA15 | 01 59 14.8 | +12 02 45 | 17.6 | 29.0W | 17.5S | 28- | 10- | 21o | None needed at this time. |
| (54584) 2000 QC181 | 02 03 32.9 | +12 45 16 | 16.4 | 34.1E | 25.0N | 42- | 1+ | 14o | None needed at this time. |
| (9672) Rosenbergerezek | 02 04 20.8 | +12 28 12 | 17.0 | 45.8E | 7.9N | 29- | 7- | 16o | None needed at this time. |
| (17954) Hopkins | 02 04 23.0 | +12 02 34 | 17.6 | 46.3E | 17.7S | 38- | 10- | 14o | None needed at this time. |
| (82578) 2001 OS86 | 02 03 01.4 | +13 02 37 | 18.0 | 26.4E | 42.3N | 31- | 17- | 12o | None needed at this time. |
| (12224) Jimcornell | 02 00 08.0 | +11 32 28 | 17.3 | 16.0W | 47.8S | 30- | 12- | 16o | None needed at this time. |
| (14732) 2000 DX71 | 02 04 00.6 | +12 51 27 | 16.7 | 40.8E | 31.2N | 29- | 9- | 17o | None needed at this time. |
| (68233) 2001 DY35 | 02 04 41.7 | +12 08 35 | 16.7 | 50.9E | 11.7S | 30- | 12- | 12o | None needed at this time. |
| (17502) Manabeseiji | 01 58 19.7 | +12 53 37 | 17.9 | 42.4W | 33.3N | 38- | 9- | 15o | None needed at this time. |
| (38296) 1999 RD87 | 01 57 54.3 | +12 43 49 | 17.7 | 48.6W | 23.5N | 31- | 9- | 12o | None needed at this time. |
| 2010 MT42 | 01 57 34.8 | +12 04 06 | | 53.4W | 16.2S | 20- | 11- | 1d | Leave for survey recovery. |

Number of objects checked = 701339

Choice : **(48644) 1995 UG7**

You can view the orbit and the position of the asteroid using the JPL small body data base browser : http://ssd.jpl.nasa.gov/sbdb.cgi (after enter the name of the asteroid, click on “Orbit Diagram”). Note: we see that on this diagram the Sun, the Earth and the asteroid are almost aligned as the asteroid is at the opposition.




How to calculate ephemeris ?

It is considered an asteroid and the Sun in a fixed coordinate system in relation to distant stars. The force exerted by the Sun on the asteroid is:

$F = G \times m_a \times M_s / r^2$

with

G = universal gravitational constant

$m_a$ = asteroid mass

$M_s$ = Sun mass

r = distance between the centers of mass of the asteroid and the sun (orbit radius)

The asteroid's velocity is constant, only the direction of the velocity vector changes (circular motion). Acceleration is in this case given by:

$a = v^2/r$

We apply Newton's 2nd law:

$F = m_a\ v2/r$

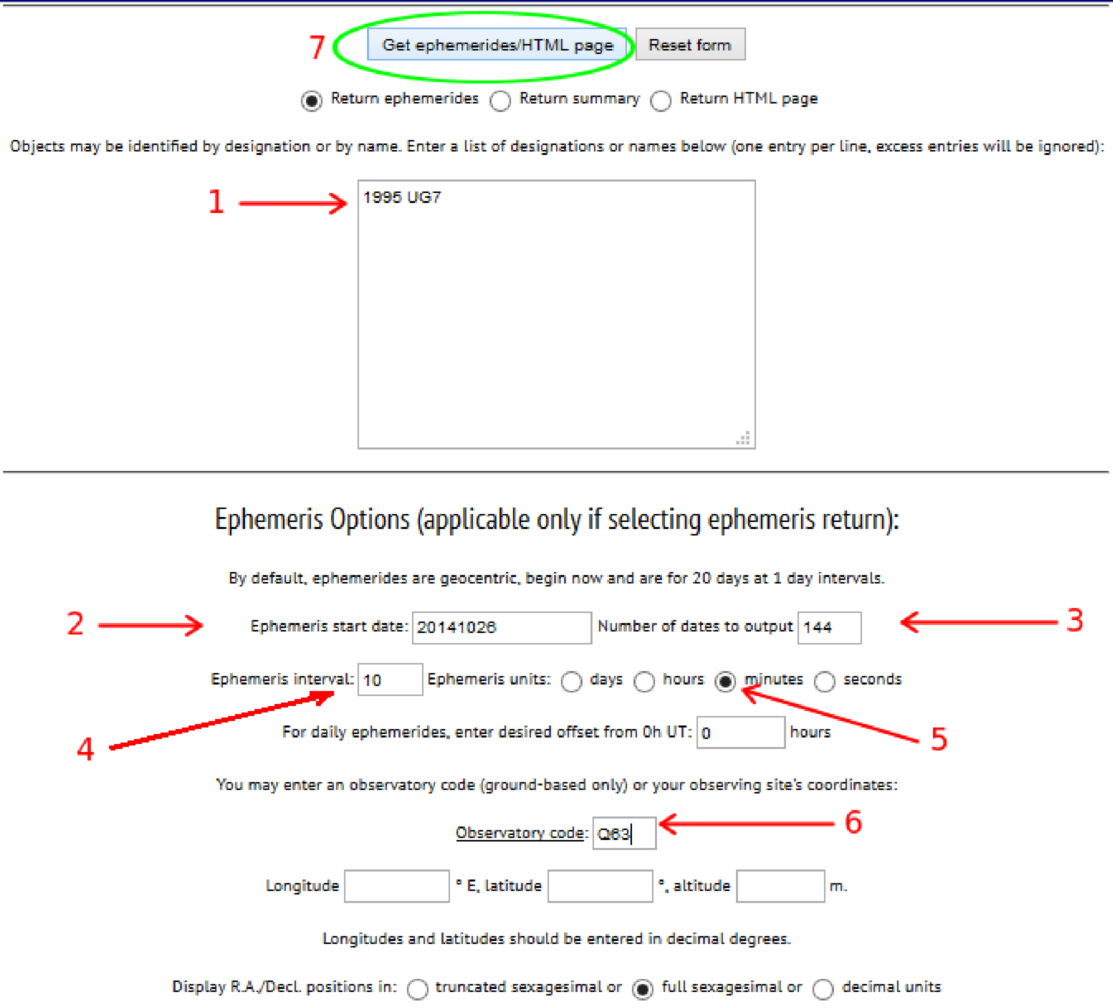
$G \times m_a \times M_s / r^2 = m_a\ v2/r$

$G\ M_s/r = v^2$

$\mathbf{r = G\ M_s/v^2}$

Conclusion: the radius of the orbit depends only on the mass of the Sun and the speed of the asteroid. It is the same for elliptical orbits. It is possible to compute the position of an asteroid in the sky at a given date. To do that MPC used a method that is called O-C . This is in fact to establish the better path from different observations (O) and to minimize a predetermined orbit and calculated (C) by minimizing all O-C data obtained during an observational campaign. To determine an orbit, it must give the osculatoires elements, basically giving a set of parameters to learn about his time at the ascending node, its perihelion passage, etc... To find exactly an object in time, the MPC uses no less than ten elements (http://ssd.jpl.nasa.gov/?sb_elem). By the play of O-C, the MPC therefore refines the different elements. Basically we need more observations than unknowns initially to set a preliminary orbit and then increasing the number of observations may help to minimize errors relating to observers and thus redefine more specific elements.

Example of completed form




1- designation or name (1995 UG7 in this example)
2- start date (the date of observation YYY MM DD)
3- Number of dates to output (144 in the example)
4 & 5- Ephemeris interval (choose the step of the calculations of position; 10 minutes in the example)
6 - Observatory code (MPC observatory code, Q63 is the MPC code of one of the two LCOGT T1m located in Siding Spring, Australia)
You can get Observatory code here:
http://www.minorplanetcenter.net/iau/lists/ObsCodesF.html
7- Click on this button to obtain the ephemeris

You get a list from which you can choose the time of observation that gives you position and Vmag of the asteroid.

www.minorplanetcenter.net/cgi-bin/mpeph2.cgi

# Minor Planet Ephemeris Service: Query Results

Below are the results of your request from the Minor Planet Center's Minor Planet Ephemeris Service. Ephemerides are for observatory code Q63.

**(48644) 1995 UG7**

Display all designations for this object / # of variant orbits available = 3

Perturbed ephemeris below is based on 14-opp elements from *MPO* 313782. Last observed on 2014 Oct. 29.

Discovery date : 1995 10 27
Discovery site : Kushiro
Discoverer(s) : Ueda, S., Kaneda, H.

48644 [H=14.5]

| 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 info 3-sig/" | Uncertainty info P.A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2014 10 26 | 000000 | 02 02 02.1 | +11 56 42 | 1.351 | 2.345 | 179.5 | 0.2 | 17.1 | 0.63 | 261.7 | 059 | -58 | +59 | 0.05 | 155 | +41 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 001000 | 02 02 01.7 | +11 56 41 | 1.351 | 2.345 | 179.5 | 0.2 | 17.1 | 0.63 | 261.7 | 055 | -60 | +61 | 0.05 | 155 | +43 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 002000 | 02 02 01.3 | +11 56 41 | 1.351 | 2.345 | 179.5 | 0.2 | 17.1 | 0.63 | 261.7 | 052 | -62 | +62 | 0.05 | 155 | +45 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 003000 | 02 02 00.8 | +11 56 40 | 1.351 | 2.345 | 179.5 | 0.2 | 17.1 | 0.63 | 261.7 | 048 | -64 | +64 | 0.05 | 155 | +47 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 004000 | 02 02 00.4 | +11 56 39 | 1.351 | 2.345 | 179.5 | 0.2 | 17.1 | 0.63 | 261.7 | 043 | -65 | +66 | 0.05 | 155 | +49 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 005000 | 02 02 00.0 | +11 56 38 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.8 | 038 | -67 | +67 | 0.05 | 155 | +51 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 010000 | 02 01 59.6 | +11 56 37 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.8 | 033 | -68 | +68 | 0.05 | 155 | +53 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 011000 | 02 01 59.1 | +11 56 36 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.8 | 027 | -69 | +69 | 0.05 | 155 | +55 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 012000 | 02 01 58.7 | +11 56 35 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.8 | 020 | -70 | +70 | 0.05 | 154 | +57 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 013000 | 02 01 58.3 | +11 56 34 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.8 | 013 | -70 | +71 | 0.05 | 154 | +59 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 014000 | 02 01 57.9 | +11 56 33 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.9 | 006 | -71 | +71 | 0.05 | 154 | +61 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 015000 | 02 01 57.4 | +11 56 32 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.9 | 359 | -71 | +71 | 0.05 | 154 | +62 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 020000 | 02 01 57.0 | +11 56 32 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.9 | 351 | -71 | +71 | 0.05 | 154 | +64 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 021000 | 02 01 56.6 | +11 56 31 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.9 | 344 | -70 | +70 | 0.05 | 154 | +66 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 022000 | 02 01 56.2 | +11 56 30 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 261.9 | 337 | -69 | +70 | 0.05 | 154 | +68 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 023000 | 02 01 55.7 | +11 56 29 | 1.351 | 2.346 | 179.5 | 0.2 | 17.1 | 0.63 | 262.0 | 331 | -69 | +69 | 0.05 | 154 | +69 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 024000 | 02 01 55.3 | +11 56 28 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.0 | 325 | -67 | +68 | 0.05 | 154 | +71 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 025000 | 02 01 54.9 | +11 56 27 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.0 | 320 | -66 | +66 | 0.05 | 154 | +72 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 030000 | 02 01 54.5 | +11 56 26 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.0 | 315 | -65 | +65 | 0.05 | 153 | +73 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 031000 | 02 01 54.0 | +11 56 25 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.0 | 311 | -63 | +63 | 0.05 | 153 | +74 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 032000 | 02 01 53.6 | +11 56 25 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.1 | 307 | -61 | +61 | 0.05 | 153 | +75 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 033000 | 02 01 53.2 | +11 56 24 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.1 | 303 | -60 | +60 | 0.05 | 153 | +75 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 034000 | 02 01 52.8 | +11 56 23 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.1 | 300 | -58 | +58 | 0.05 | 153 | +75 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 035000 | 02 01 52.3 | +11 56 22 | 1.351 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.1 | 297 | -56 | +56 | 0.06 | 153 | +75 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 040000 | 02 01 51.9 | +11 56 21 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.2 | 295 | -54 | +54 | 0.06 | 153 | +74 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 041000 | 02 01 51.5 | +11 56 20 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.2 | 292 | -52 | +52 | 0.06 | 153 | +74 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 042000 | 02 01 51.1 | +11 56 19 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.63 | 262.2 | 290 | -50 | +50 | 0.06 | 153 | +73 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 043000 | 02 01 50.6 | +11 56 18 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.2 | 288 | -48 | +48 | 0.06 | 153 | +71 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 044000 | 02 01 50.2 | +11 56 18 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.3 | 286 | -46 | +46 | 0.06 | 153 | +70 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 045000 | 02 01 49.8 | +11 56 17 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.3 | 284 | -44 | +44 | 0.06 | 152 | +68 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 050000 | 02 01 49.3 | +11 56 16 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.3 | 282 | -42 | +42 | 0.06 | 152 | +67 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 051000 | 02 01 48.9 | +11 56 15 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.3 | 281 | -40 | +40 | 0.06 | 152 | +65 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 052000 | 02 01 48.5 | +11 56 14 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.3 | 279 | -38 | +38 | 0.06 | 152 | +63 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 053000 | 02 01 48.0 | +11 56 13 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.4 | 278 | -35 | +36 | 0.06 | 152 | +61 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 054000 | 02 01 47.6 | +11 56 13 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.4 | 276 | -33 | +33 | 0.06 | 152 | +59 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 055000 | 02 01 47.2 | +11 56 12 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.4 | 275 | -31 | +31 | 0.06 | 152 | +57 | N/A | N/A / Map / Offsets |
| 2014 10 26 | 060000 | 02 01 46.7 | +11 56 11 | 1.352 | 2.346 | 179.6 | 0.2 | 17.1 | 0.64 | 262.4 | 273 | -29 | +29 | 0.06 | 152 | +55 | N/A | N/A / Map / Offsets |

What information is provided by this MPC page?

The designation of the asteroid, the discovery date, the discovery site, and discoverer(s). Then in the different columns we find from left to right:

Date: YYYY MM DD

Time: hh mm ss (UT)

Position: Right Ascension (R.A.) and Declination (Decl.) for the equinox J2000.

Delta: the distance from the observer to the asteroid (AU)

r : the distance from the Sun to the asteroid (AU)

El: the solar elongation of the asteroid (Sun-Earth-Asteroid angle) (°)

Ph: the phase angle of the asteroid (Sun-Asteroid-Earth angle) (°)

V: the predicted magnitude , for the MPC it is the visual magnitude

Sky Motion: the angular velocity of motion of the asteroid relative to the sky background (arcseconds per minute) and direction of motion (P.A. Position angle counted from the direction of north and turning east).

Object : the Azimut (°)and Altitude (°) for the asteroid

Sun : the Altitude(°) for the Sun

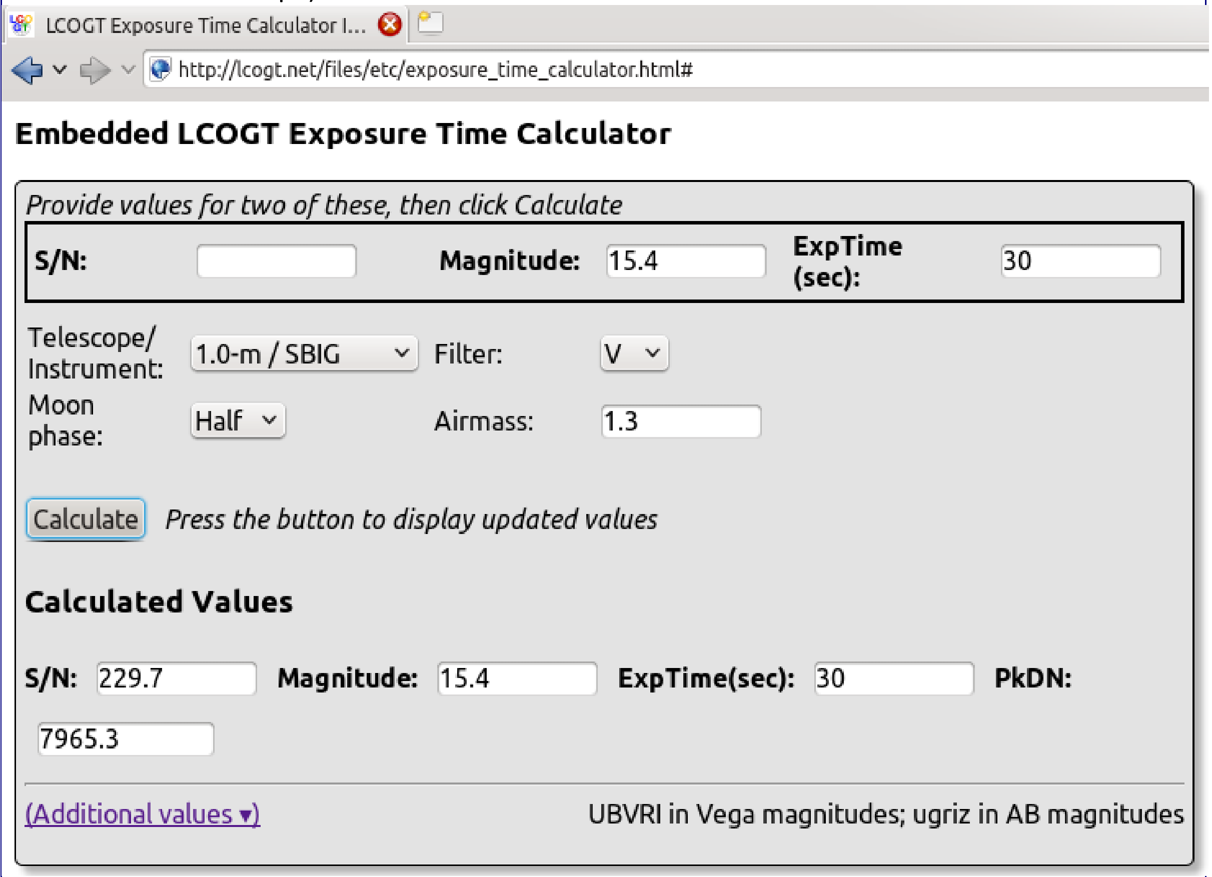
Moon : the Moon phase, Asteroid-Earth-Moon angle (°) and Altitude (°)

**2nd module: Defining the observations**

*1st* search for good exposure time

For photometric measurements we need, you must use standard photometric V filter Johson-Cousins.

You must avoid saturation (http://lcogt.net/files/etc/exposure_time_calculator.html if you use LCOGT network telescope)




*2nd* Request observations with a robotic telescope or make your observations with your own equipment

*3rd* Keep fingers crossed…

4th Your images are ready

You can download your images

If you have not been able to acquire images but you still want to do the activity, you can download 9 images here:
https://onedrive.live.com/redir?resid=62E512265D1AC767!1353&authkey=!AAG1xyA7-fvw2vA&ithint=folder%2c

## 3rd module: Processing the observations

*1st Convert your images to be used in Astrometrica*

This is not always necessary but if you use LCOGT network 1m telescopes equipped with SBIG camera you will convert the images obtained.

For example use SalsaJ software to perform this conversion. You can download SalsaJ software here : http://www.euhou.net/index.php/salsaj-software-mainmenu-9/download-mainmenu-10

Save all your images in «FITS...» format, otherwise the image can not be used with Astrometrica.

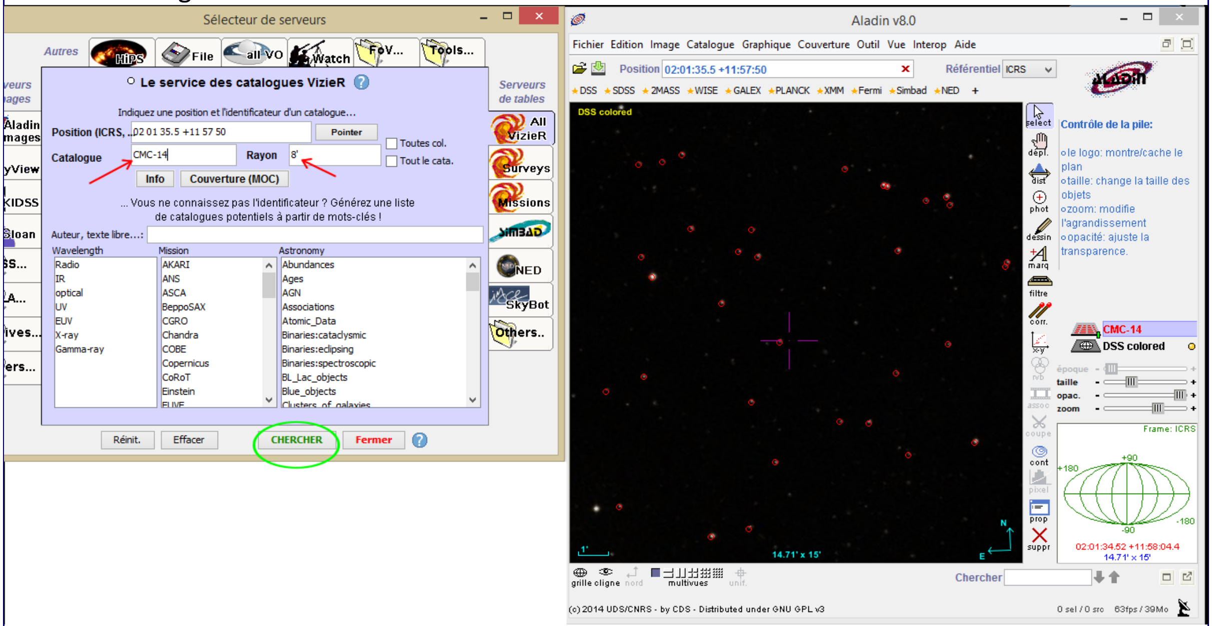
You can download Astrometrica software here :

[http://www.astrometrica.at/default.html?/download.html](http://www.astrometrica.at/default.html?/download.html)

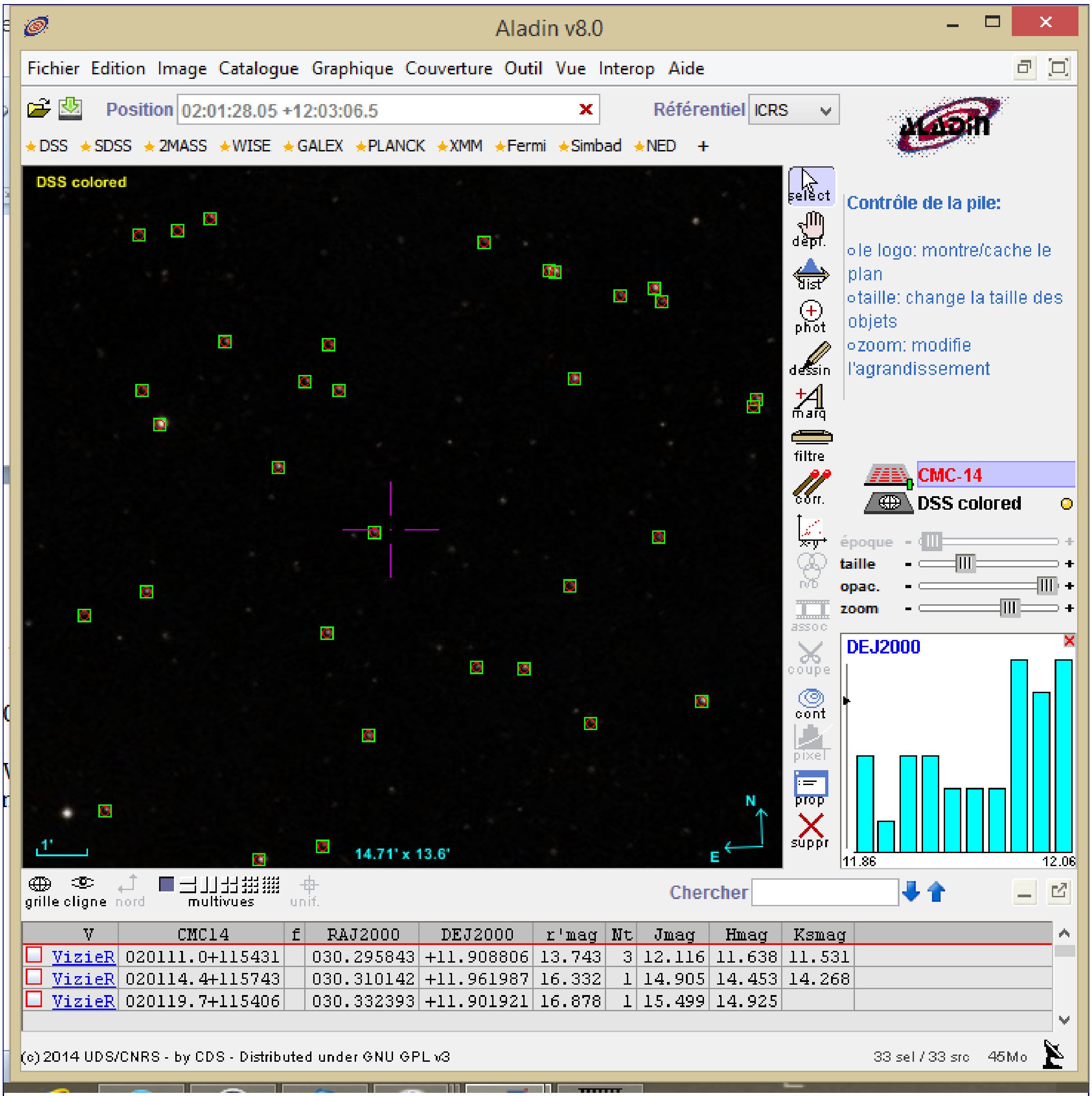
*2nd Reference stars*

Use ALADIN Sky Atlas ([http://aladin.u-strasbg.fr/](http://aladin.u-strasbg.fr/))

This software allows us to display and align our own image, a Digital Sky Survey (DSS) image and the CMC-14 catalogue.




– Edition « Select all objects »
– Copy all measures (to Excel).
– Open an Excel spreadsheet and then paste the list.
– Now looking for possible variable stars in the FOV using the catalogue : I / 280B.




**Criteria** for selection of stars from the previous list :

- ☐ r 'mag <~ 16
- ☐ 0.3 <J-K <0.7
- ☐ non-variable stars
- ☐ stars should not be saturated

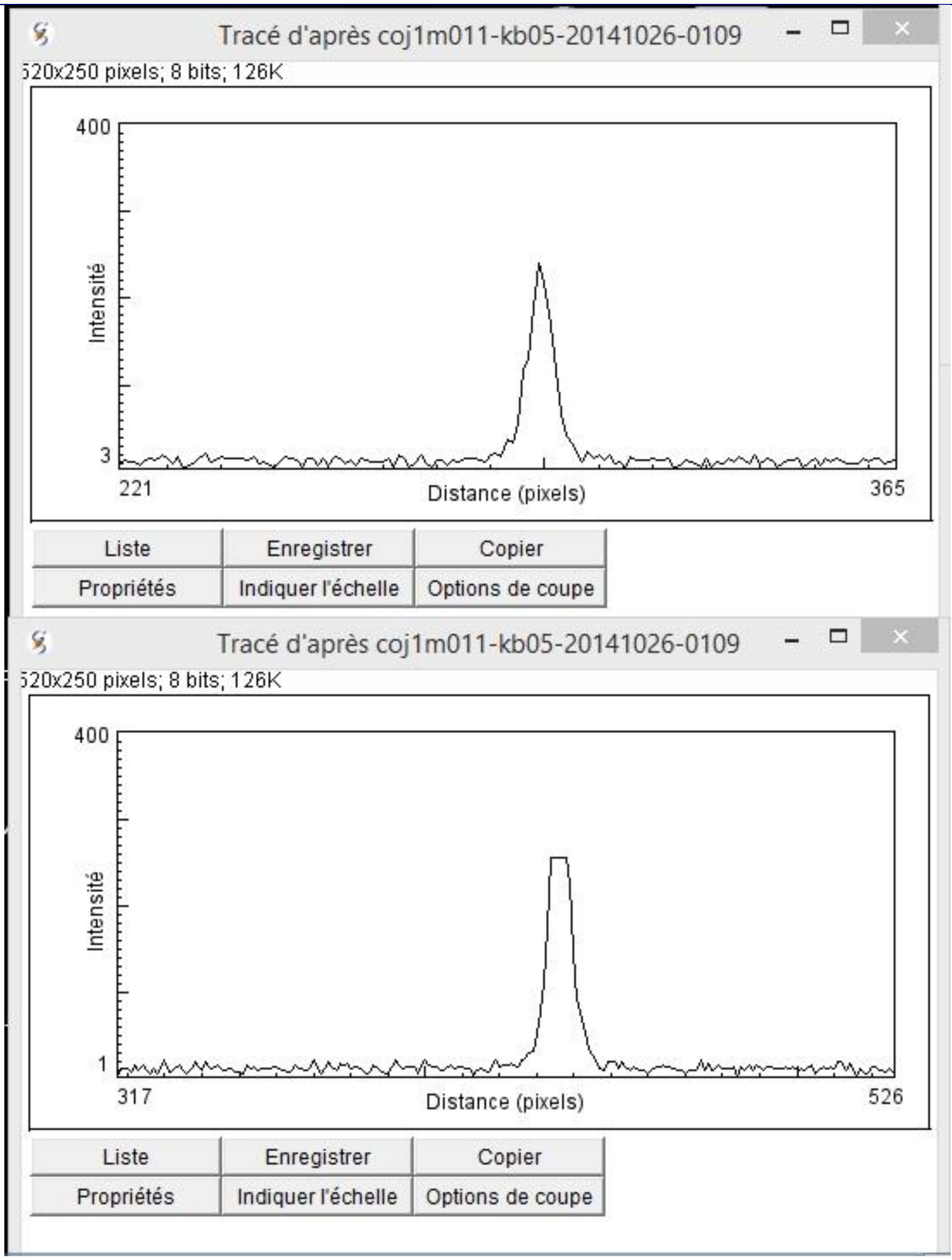
To measure the light intensity of each star use Astrometrica.

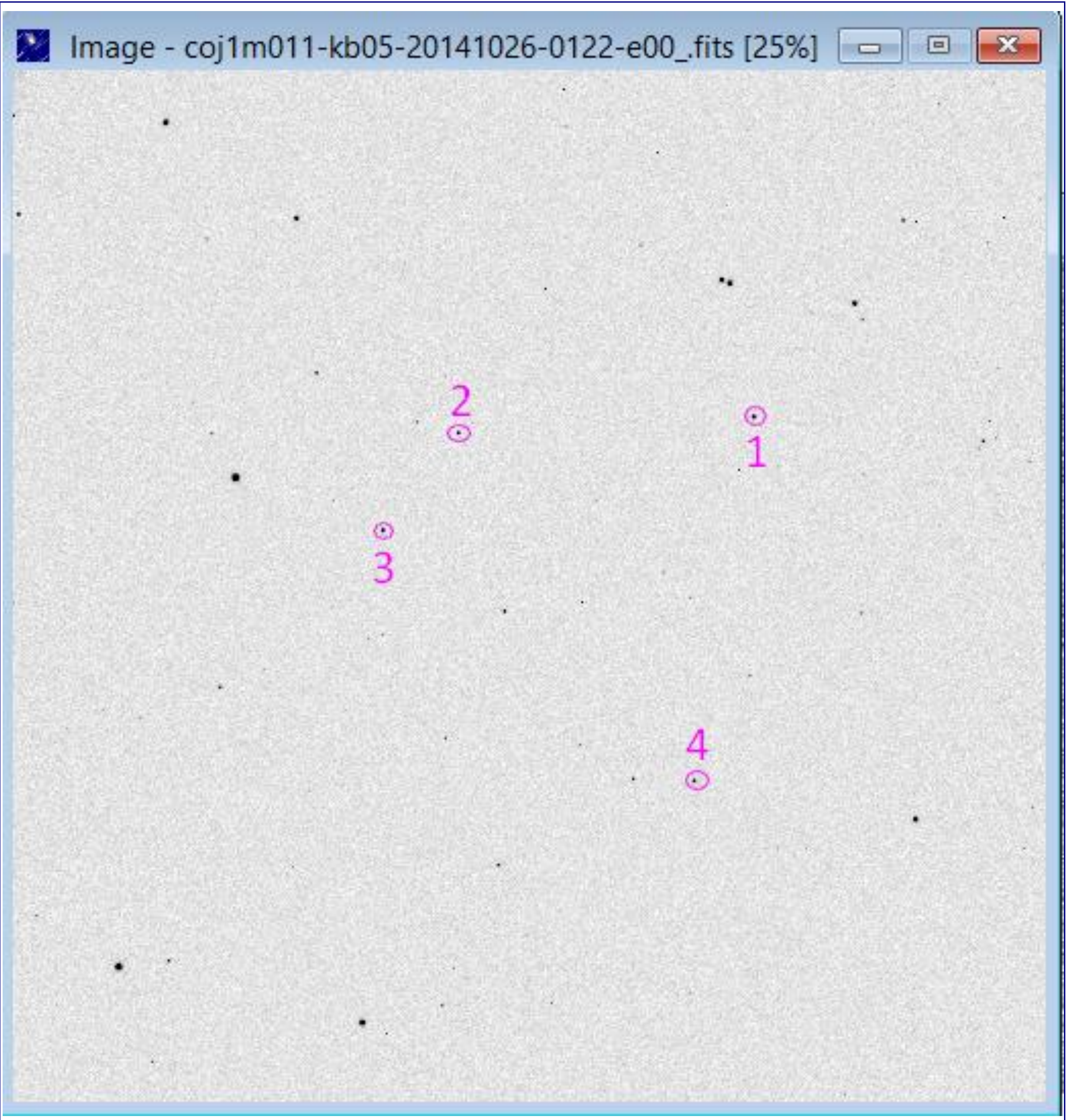
First fill the different forms in « Edit Program Settings »
- Observing site
- CCD
- Program
- Environnment
- Catalogs
- Internet

Then you download your images and click on « Astrometry », « Data Reduction... ».
Click on a selected star, a window opens « Object Verification » and you can see SNR, Flux, FWHM.

Do that for all the stars of the previous list.

Astrometrica provides the light intensity of stars in the field. This intensity should be below the saturation point of the camera CCD. For example, saturation is reached at 46000 ADU for the Kodak sensor 16803 of SBIG camera that equips the T1m of the LCOGT network. If you do not know this value you can select the unsaturated stars in the field using SalsaJ


Tracé d'après coj1m011-kb05-20141026-0109
520x250 pixels; 8 bits; 126K
400
Intensité
3
221
Distance (pixels)
365
Liste
Enregistrer
Copier
Propriétés
Indiquer l'échelle
Options de coupe
Tracé d'après coj1m011-kb05-20141026-0109
520x250 pixels; 8 bits; 126K
400
Intensité
1
317
Distance (pixels)
526
Liste
Enregistrer
Copier
Propriétés
Indiquer l'échelle
Options de coupe




You can complete the spreadsheet with the measured intensity values

For example :
https://onedrive.live.com/redir?resid=62E512265D1AC767!1357&authkey=!AJfooDA4XRWCjjI&ithint=file%2cxlsx

Magnitudes :
We use the Carlsberg Meridian Catalogue 14 (CMC14) it is an astrometric and photometric catalogue.
A VizieR query of the CMC14 catalogue returns the r' band (about 623 nm in the red part of the spectrum), the Two-Micron All-Sky Survey (2MASS) with J band (1250 nm), H band (1650 nm) and K band (2170 nm) magnitudes.
http://vizier.u-strasbg.fr/viz-bin/VizieR
To be able to convert the known r' magnitude of a star into a standard V magnitude, we must know the colour of the star. The difference J – K provides such a measure of star colour.

How calculate the V-band magnitude from r ', J and K ?
Is there a relationship between these magnitudes?
This is to adjust the coefficients to link the V magnitude to the colour of stars (J-K) and the r' magnitude from a large number of stars with known accurately magnitudes.
To find this link, John Greaves analysed in 2006 data for 696 stars selected in the LONEOS photometric data base giving the V magnitude (9.9 < V < 14.8). He then merged these data with those of Carlsberg Meridian Catalogue giving the magnitude r 'and those of the 2MASS catalogue providing magnitudes J and K which enabled him to establish the relationship :
**V = 0.641 x (J-K) + r '**
This relationship predicts the V mag accurately (+/- 0.038 mag) compared with V mag provided by the LONEOS.
Note: The experimentation shown that this relationship is not valid for very red stars which led John Greaves and Richard Miles to limit the color of the stars (J-K) in the range between 0.3 to 0.7
Thereafter Richard Miles has sought to improve the relationship based on one hundred standard Landolt stars for photometry, he obtained the following more precise relationship
**V = 0.6278 x (J-K) + 0.9947 x r '**

*3rd Asteroid identification in the field of view*
The problem is to recognize the asteroid which as the name suggest “starlike” it looks just like a star. Most asteroids are only afew kilometers in size often less. Asteroids are small rocky objects that orbit the Sun just like olanets. Like the planets, they reflect sunlight but because they are so small, they appear only as points of light on images of the sky. How then can we tell which point of light on an image is an asteroid and which points are stars ? If we consider 2 images of the same field of the sky a few minutes apart the stars will not have moved with respect to one another, but asteroid will have moved because it is orbiting the Sun. Often there are so many stars on an image that you can't easily remenber the pattern when you look at another image and therefore you can't tell which dot of light has moved...Fortunately computers come to the rescue !
You can load and display alternately 2 images of the same field taken with your telecope a few minutes appart and instruct the computer to switch the display quickly back and forth from one image to another, this technique is called “blinking”.
To do that you can use Astrometrica
File
Load Images... (for example the first and last of the 9 previous images: coj1m011-kb05-20141026-0**109**-e00_.fits and coj1m011-kb05-20141026-0**117**-e00_.fits)
Tools
Blink Images

The asteroid appears to jump, making it easy to spot !

*4th Image optimization*

If the SNR of your images is smaller than 20, you can stack several images to increase the SNR but to avoid trailing when stacking images you should not exceed a maximum time value given by
I = FWHM/sky motion (Stephen Laurie law)
with
- I in minutes
- FWHM in arcseconds
- sky motion in arcseconds per minute.

You can stack your images with Astrometrica according the number above.
- « Astrometry »
- « Track & Stack... »
- « Data Reduction... »
- « Tools »
- « Known Object Overlay »
- Click on the reference stars and on the asteroid to know the flux of each object.

**4th module : calculation**

1) Now you are able to calculate the V-band magnitude of the asteroid by using LCOGT spreasheet I modified to fit our work as you can download here:

https://onedrive.live.com/redir?resid=62E512265D1AC767!1331&authkey=!AEhgaszEbSYzAfQ&ithint=file%2cxlsx

2) Absolute magnitude H of an asteroid.
At the apparent brightness E (as seen from Earth) of the star is what astronomers call the visual magnitude m.
A real radiance L (intrinsic luminosity or radiant power of the star) is the absolute magnitude M.
Note: To compare these stars do as if they were all the same distance from Earth. An arbitrary distance of 10 parsecs was chosen, which allows to define M.
b) The concept of magnitude:
Since ancient times, the stars were classified according to their brightness to the naked eye in 6 "sizes" of the brightest 1 to 6 for those at the limit of visibility.
In the nineteenth century, Fechner formulated the so-called physiological law of "Weber-Fechner" that the sensation varies as the logarithm of the stimulus.
In other words, for visual impressions which increase in arithmetic progression, the brightness are increasing in geometric progression
Suppose a star of the first magnitude 100 times brighter than a star of 6th magnitude, we have:

| "Size" | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Brightness | 100 | | | | | 1 |

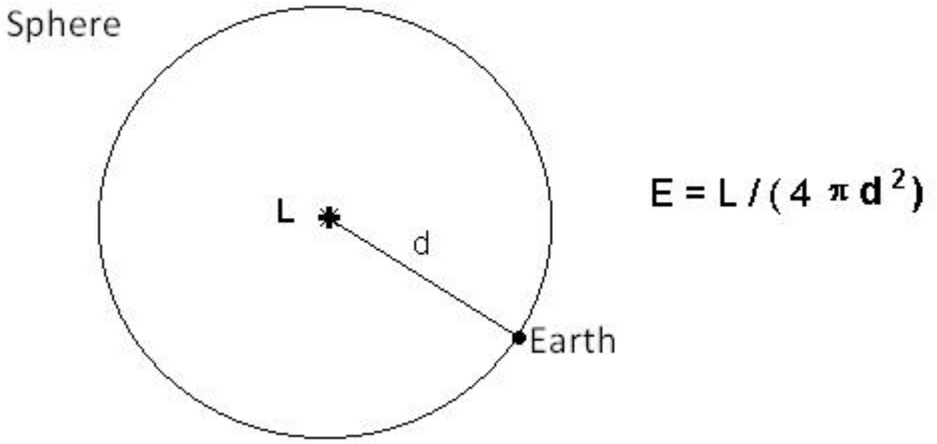
There has 5 steps to go from 1 to 100 so we must search by which number multiplied.
The fifth root of 100 gives about 2.5.

$2.5^5$ $2.5^4$ $2.5^3$ $2.5^2$ $2.5^1$ $2.5^0$

Pogson's law : Pogson formulated in 1856 the law that bears his name and which reflects the situation inherited from Hipparchus (II $^{th}$ century BC)

$m = - 2.5 \log E + const$
or for 2 stars named A and B
$m_A - m_B = 2.5 \log E_B / E_A$

For a given star, visual magnitude m is the apparent brightness seen from the earth, and the absolute magnitude M with the brightness $E_0$ is the brilliance of the star if it was at the arbitrary distance of $d_0$ = 10 parsecs. (1parsec = 3.26 light years = $3.09\ 10^{16}$ m)




$M - m = - 2.5 \log E_0 - (- 2.5 \log E) = - 2.5 (\log E_0 - \log E)= - 2.5 \log (E_0 / E)$

$M - m = - \log(L / 4\pi d_0^2 / L / 4\pi d^2 ) = - 2.5 \log (d^2 / d_0^2) = - 2.5 \log (d^2 / 100)$

$M - m = - 2.5 \times \log 2 d - 2.5 \times - \log 100$

**$M - m = -5 \log d + 5$**
if we know m and M we can calculate d (distance from the star to the Earth).

Application to an asteroid.
H absolute magnitude instead of M, distance to the Sun Δ
Visual magnitude V instead of m, distance to the Earth r

$H – V = - 2.5 \times \log 2r – 2.5 \times \log 2 \Delta$

$H – V = - 5 \log r – 5 \log \Delta$

$H – V = - 5 (\log r + \log \Delta)$

**$H – V = - 5 \log (r \times \Delta)$**

We will use this relationship without considering the phase effect which is insignificant in the case of an asteroid at opposition or near to calculate the absolute magnitude H.

In our example (48644) 1995 UG7

Ph = 0,2°
r = 2.346 AU
and
Δ = 1.352 AU
given by the MPC.
1AU = 1 Astronomical Unit

3) What is the albedo ?

To carry out this activity we have only the light emitted by the Sun and scattered by the observed asteroid. But how is this light reflected by the surface of the asteroid? This of course depends on the characteristics of the surface. A physical variable was defined called "albedo" which measures the ratio of the luminous flux emitted by a body and the luminous flux incident. This quantity was introduced by the astronomer WC Bond (1789-1859). It is expressed as a number between 0 and 1. The higher the number is to 1, the more the body is brilliant. The Moon has an albedo of 0.07 (7%), the Earth of 0.39 and 0.72 Venus; making it the brightest of the planets of the Solar System. A black body has zero albedo.

The geometric albedo is noted pV

There are many types of asteroids, but the most common are:

- type C (75%) -> pV=0.4
- types S (17%) and M -> pV=0.15

4) How to connect distance, magnitude and albedo ?

The luminous flux decreases with the distance. The magnitude provides information directly with diameter$^2$ x albedo. On the other hand, the light reflected from an object is proportional to the size and to the albedo of the object.

The formula

**$D(km) = 1329 \times 10^{(-H/5)} / pV^{1/2}$**

to calculate the diameter of an asteroid results of the work of Fowler and Chillemi (1992).

Fowler, JW and Chillemi, JR, (1992), IRAS asteroid data processing. in
The IRAS Minor Planet Survey (ed. EF Tedesco), pp. 17-43. Tech. Rep.
PL-TR-92-2049, Phillips Laboratory, Hanscom Air Force Base, Massachusetts,
USA.

Note that the diameter we get is an “equivalent photometric diameter” since it is unlikely that the asteroids studied are perfectly spherical.

You can now complete the spreadsheet given example and you can change it as needed.

https://onedrive.live.com/redir?resid=62e512265d1ac767!1373&authkey=!AEkJu_mFpsqRPgc&ithint=file%2cxlsx

**Connection to school curriculum:** (if this activity applies to a specific country, please indicate)

| **Additional information:** (related to the activity) |
| --- |
| Extend the activity further by making more observations.<br>Compare your observation to values given by the MPC.<br>http://www.casleo.gov.ar/c15-wg/index-tgh.html |
| **Conclusion:** (summary of the activity and what students learn) |
| The activity is complete when students have correctly completed the worksheet and obtained the size of the observed asteroid. They then compare the absolute magnitude and size calculated to those provided by the MPC or JPL Horizons when known. They can then repeat the activity to other asteroids. |