

How to determine the size of an asteroid ?

André Debackère, Monistrol sur Loire, FR
andre.debackere@free.fr
<http:dbrastronomie.free.fr>



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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.¹
- 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.²
- 11) Diameter calculation for the target.

¹ [http://www.britastro.org/asteroids/JBAA 119 149-156 Dymock1.pdf](http://www.britastro.org/asteroids/JBAA_119_149-156_Dymock1.pdf)

² <http://www.britastro.org/asteroids/dymock4.pdf>

Chapter I

I) Choice of the target

1st criteria: the asteroid must be near opposition.

« Opposition » means that sun, earth, 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 website³

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

3rd criteria : the phasis 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 website⁴

« OBSERVERS »

« Other Observers Services »

« MPCChecker »

This tool gives us a list of asteroids near opposition on the date of observation.

Then the Minor Planet Center Ephemeris Services gives us the parameters of the selected asteroid.

« OBSERVERS »

« Ephemeris Service »

« designation or name »

« Ephemeris start date »

« Number of dates to output »

« Ephemeris interval »

« Observatory code »

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

³ <http://pgj.pagesperso-orange.fr/position-planetes.htm>

⁴ <http://www.minorplanetcenter.net/iau/mpc.html>

II) Images

1st search for good exposure time

At the bottom of the LCOGT home page click on « Instruments » then on « exposure_time_calculator ».⁵

Fill the form

« Magnitude » Vmag given by MPC

« ExpTime (sec) » try different value to avoid saturation

« Telescope class and detector » T1m SBIG

« Filter » V

« Moon phase »

« Airmass » 1.3 by default

Click on « Calculate », then Calculated Values are updated :

- S/N:
- Magnitude:
- ExpTime(sec):
- PkDN:

2nd Request observations

Log into your LCOGT account

At the top of the LCOGT home page click on « Observatory »

« Schedule Observations > »

Observing

« Request observations > »

« Enter request title »

« Queue schedule within »

« Add an observation »

- Add a target
- Target name
- RA
- DEC
- Use single filter ?
- Exposure time ans How many times ?
- Add

« Submit »

3rd Keep fingers crossed...

⁵ http://lcogt.net/files/etc/exposure_time_calculator.html

III) Your images are ready

At the top of the LCOGT home page click on

« Observatory »

« Schedule Observations > »

Observations

« View submitted observations »

You can download your images

IV) Convert your images to be used in Astrometrica

If we use LCOGT network 1m telescopes equipped with SBIG camera we will convert the images obtained.

We use SalsaJ⁶ software to perform this conversion.

The first thing to do after downloading the images on the LCOGT website is to open image with SalsaJ and save it in «FITS...» format, otherwise the image can not be used with Astrometrica.

Do it for each image you have downloaded.

V) Reference stars

We use ALADIN Sky Atlas⁷ which allow us to display and align our own image, a Digital Sky Survey (DSS) image and the CMC14 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 :

- $r' \text{mag} < \sim 16$
- $0.3 < J-K < 0.7$
- non-variable stars
- stars should not be saturated

⁶ <http://www.fr.euhou.net/>

⁷ <http://aladin.u-strasbg.fr/>

To measure the light intensity of each star we use Astrometrica⁸.

First fill the different form in « Edit Program Settings »

- Observing site
- CCD
- Program
- Environment
- 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.

Now you can choose the reference stars you want to use and you can calculate the V-band magnitude from r', J and K using the formula :

$$V = 0.6278 \times (J-K) + 0.9947 \times r'$$

VI) Asteroid identification in the FOV

Click on « Tools », « Known Object Overlay »

Asteroids present in the FOV are marked in red.

Click on the asteroid you have chosen to study, you can see SNR, Flux and FWHM.

VII) 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

$I = \text{FWHM} / \text{sky motion}$ (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.

⁸ <http://www.astrometrica.at/>

VIII) V mag, H mag and "diameter" calculation

Now you can calculate the V-band magnitude of the asteroid by using LCOGT spreadsheet⁹. I modified this spreadsheet to fit our work as you can see here:

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

You need this information to complete it:

- Reference stars magnitude (§ V)
- Images exposure time (§ II)
- Reference stars flux (§ VII)

- Use the formula to calculate H mag:

$$H = H(\text{Ph}) + 2.5 \log[(1-G)\varphi_1(\text{Ph}) + G \varphi_2(\text{Ph})]$$

where:

$$\varphi_i(\text{Ph}) = \exp\{-A_i(\tan 1/2 \text{ Ph})B_i\}$$

$i = 1$ or 2 , $A_1 = 3.33$, $A_2 = 1.87$, $B_1 = 0.63$ and $B_2 = 1.22$

and Ph is the phase angle in degrees given by the MPC (§ I).

with

$$H(\text{Ph}) = V - 5 \log(r \cdot \Delta) \quad r \text{ and } \Delta \text{ given by the MPC (§ I)}$$

- Choose the geometric albedo 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

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

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

⁹ <http://resources.faulkes-telescope.com/course/view.php?id=39>

Chapter II: Example

I) Observation date: 20141026

- Coordinates of the Sun (PGJ, chapter I, § I, 1st criteria)
14h01m13.34s -12°20'16.83"

← pgj.pagesperso-orange.fr/position-planetes.htm

PGJ ASTRONOMIE

Ephémérides du Soleil, de la Lune et des Planètes

Date et Heure en Temps Universel Coordonné (UTC)

Jour: 26 Mois: 10 Année: 2014 c'est un: dimanche

Heure: 0 Minute: 0 Seconde: 0 Jour Julien: 2456956.5004050927

Temps Sidéral moyen à Greenwich: 2h17m44s

Equation de temps (en minutes): -16.0069

DeltaT *: 68.61 secondes

Date et Heure en Temps Terrestre (TT)

Jour: 26 Mois: 10 Année: 2014

Heure: 0 Minute: 1 Seconde: 43 Jour Julien: 2456956.501199258

Indiquez la date et l'heure. Pour obtenir le résultat... **Calcul** Pour un affichage des données en temps réel... **Temps Réel**

Pour remettre à jour les données... **Maintenant** Pour arrêter le défilement des données... **Stop**

	Coordonnées Géocentriques Ecliptiques		Coordonnées Géocentriques Equatoriales		Distance Terre	Distance Soleil	Elongation	Dia
	Longitude	Latitude	Ascension droite	Déclinaison				
Soleil	212°29'40.86"	0	14h01m13.34s	-12°20'16.83"	0.9942894 UA			

- Opposition
RA= 14h01m13.34s + 12h = **02h01m13.34s**
DEC = **+12°20'16.83"**
- MPChecker (chapter I, § I, 5th criteria)
Vmag limit = 18.0
60.0 arcminutes

Date :

Produce list of known minor planets around:

this J2000.0 position: R.A. = Decl. =

or around these observations:

Radius of search = arc-minutes

Limiting magnitude, V =
 Observatory code =

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

MPChecker generates a list of asteroids near opposition
 Choice : **(48644) 1995 UG7**

- MPC OBSERVERS Ephemeris Service (chapter I, § I, 5th criteria)
 designation : 48644
 Ephemeris start date : 20141026
 Number of dates to output : 144
 Ephemeris interval : 10 minutes
 Observatory code : 500 (center of the Earth by default)

Then click on
 « Get ephemerides »
 Note the different parameters

11h20 UT

R.A. (J2000) = 02 :01 :32.5

Decl. (J2000) = +11 :55 :44

Delta = 1.352 AU

r = 2.346 AU

El. = 179.5°

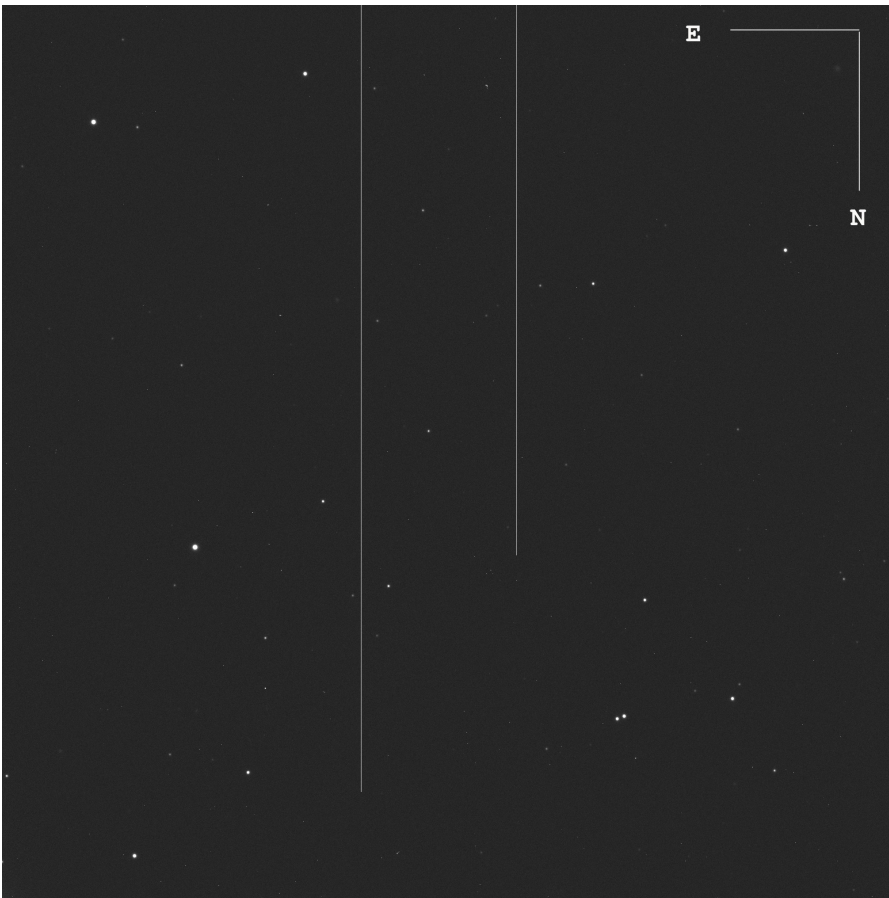
Ph. = 0.2°

V = 17.1

Sky Motion = 0.67 "/min

Alt. = +34°

- Request observation settings
 - « Enter request title » : aster size
 - « Queue schedule within » : 24 hours
 - « What size telescope ? » : 1-meter
 - « Target name » : 48644
 - « RA » : 02 01 35.5
 - « DEC » : +11 57 50.0
 - « Filters » : Bessell-V
 - « Exposure time » : 40 s
 - « How many times ? » : 14



Aladin and CMC-14 catalog

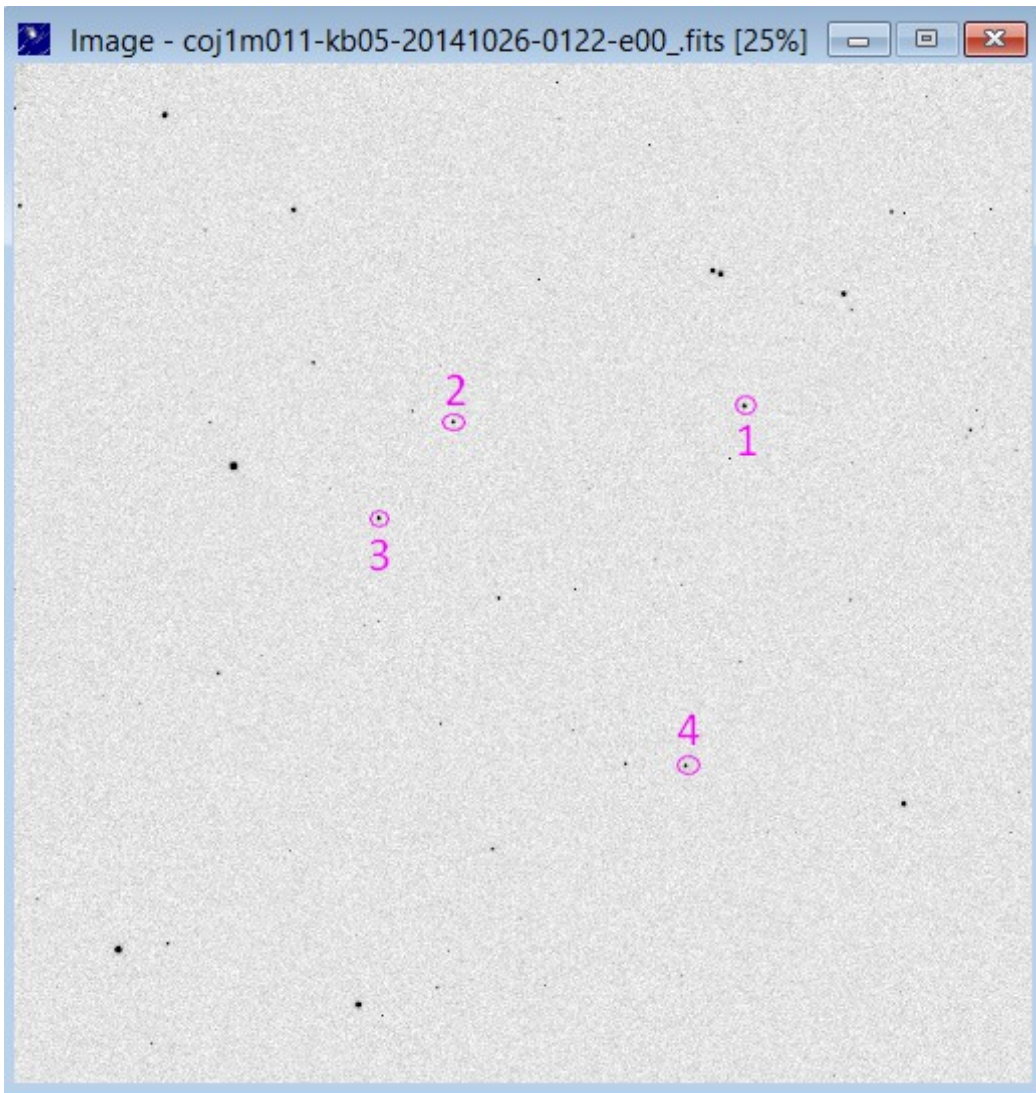
There are 4 stars that meet the selection criteria.

- 1- 020121.0+120045 → Vmag = 14.63
- 2- 020139.6+120032 → Vmag = 15.27
- 3- 020144.4+115902 → Vmag = 15.15
- 4- 020124.9+115509 → Vmag = 15.10

The screenshot shows the Aladin v8.0 software interface. The main window displays a star field with several stars highlighted in green. The interface includes a menu bar, a toolbar, and a control panel on the right. The control panel has sliders for 'époque', 'taille', 'opac.', and 'zoom', and a histogram for 'DEJ2000'. Below the star field, there is a table of selected stars.

V	CMC14	f	RAJ2000	DEJ2000	r'mag	Nt	Jmag	Hmag	Ksmag
<input type="checkbox"/>	VizieR 020111.0+115431		030.295843	+11.908806	13.743	3	12.116	11.638	11.531
<input type="checkbox"/>	VizieR 020114.4+115743		030.310142	+11.961987	16.332	1	14.905	14.453	14.268
<input type="checkbox"/>	VizieR 020119.7+115406		030.332393	+11.901921	16.878	1	15.499	14.925	

(c) 2014 UDS/CNRS - by CDS - Distributed under GNU GPL v3 33 sel / 33 src 45Mo



Improvement of S/N

- FWHM average 1.74"
- max time interval 2.59 minutes
- full duration 12.7 minutes
- nb images 4 (4x3 stacked and 2 rejected)

Star 1 is saturated on 2 images -> calculation with 3 reference stars (stars 2,3 &4)

Average Vmag for the asteroid : 17.214

Hmag : 15.4531131

With albedo 0.4 (type C)

D = 1.7 km

With albedo 0.15 (type S or M)

D = 2.8 km

II) Observation date: 20141111

PGJ website : enter the date: Day 11 ; Month 11 ; Year 2014, you can see the coordinates of the sun RASun = 15h07m13.41s and DECSun= -17°32'13.55"

Then the coordinates of the target are :

RATarget = RASun + 12h RATarget = 03h07m13.41s

DECTarget = opp(DECSun) DECTarget = +17°32'13.55"

Now, open MPChecker a tool of the Minor Planet Center

« OBSERVERS »

« Other Observers Services »

« MPChecker »

then fill the form :

Date : year month day (UT)

2014 11 11.50 means 2014 November 11th at 12h UT

Produce the list of known minor planets around :

this J2000.0 position: R.A. = 03 07 13.41 Decl. = +17 32 13.55

Radius of search in arc-minutes 120

Limiting magnitude, V = 16 Observatory code =500

Click on « Produce list »

we get 6 asteroids

You can modify the radius of search (decrease for less asteroids), with a radius of 60 arc-minutes we get only one asteroid :

(12735) 1991 VV1

Now, open the Minor Planet Center webpage

« OBSERVERS »

« Ephemeris Service »

and fill the form

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):

12735

Ephemeris start date:

20141111

Number of dates to output

144

Ephemeris interval:

10 minutes

Observatory code : V37 (we choose to observe from Mac Donald Observatory)

then click on « Get ephemerides/HTML page »

this is the result :

Date : 2014 11 11 UT 120000

R.A (J2000) 03 05 45.1 Decl. +17 27 33

Delta : 1.066 r : 2.057

El. : 179.9

Ph : 0.0

V :15.4

Sky motion : 0.78 "/min

Object Alt. : **+17**

..... **In Earth's penumbra**

It's not a good choice !!!