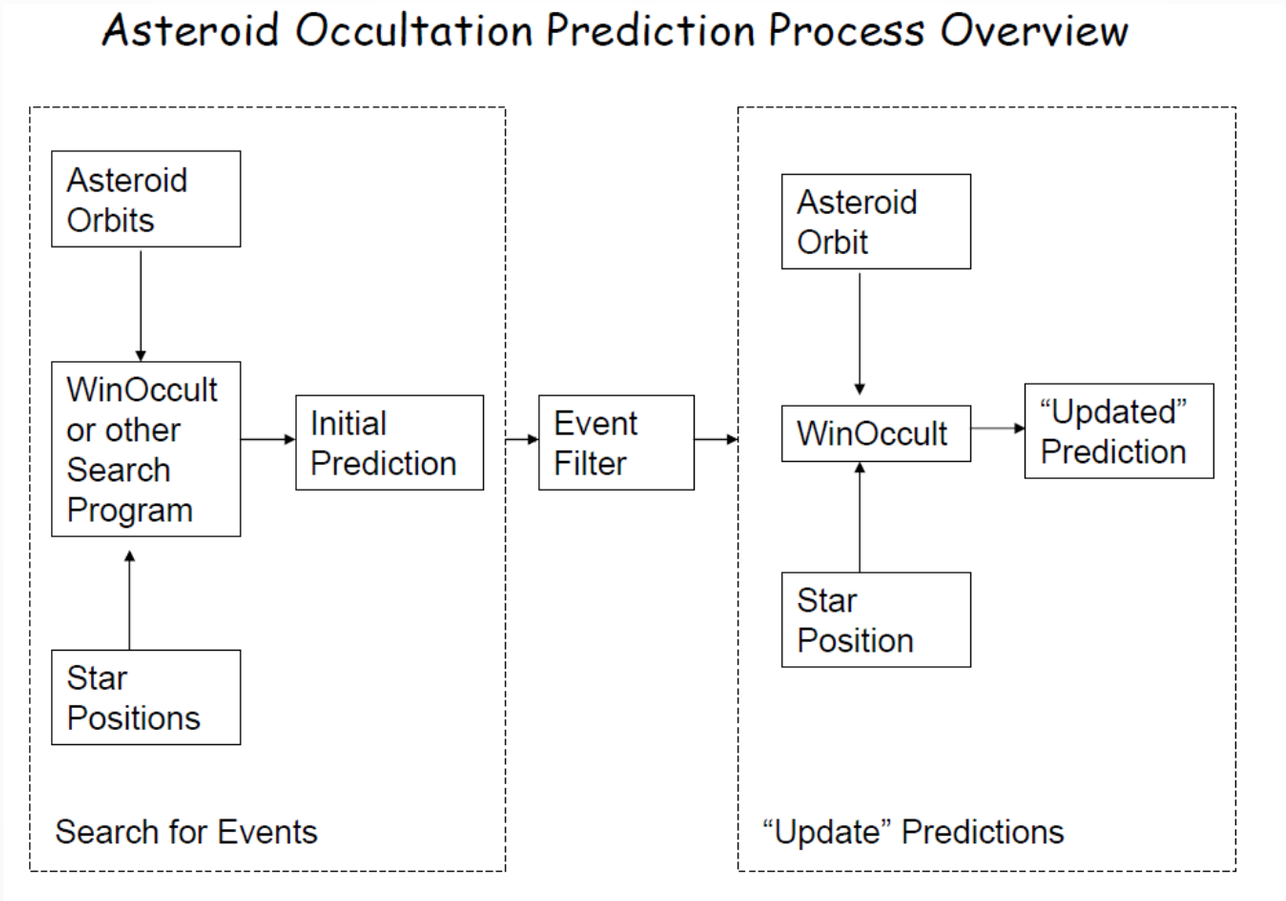
Asteroid Occultation Ephemeris

Tomasz Kluwak

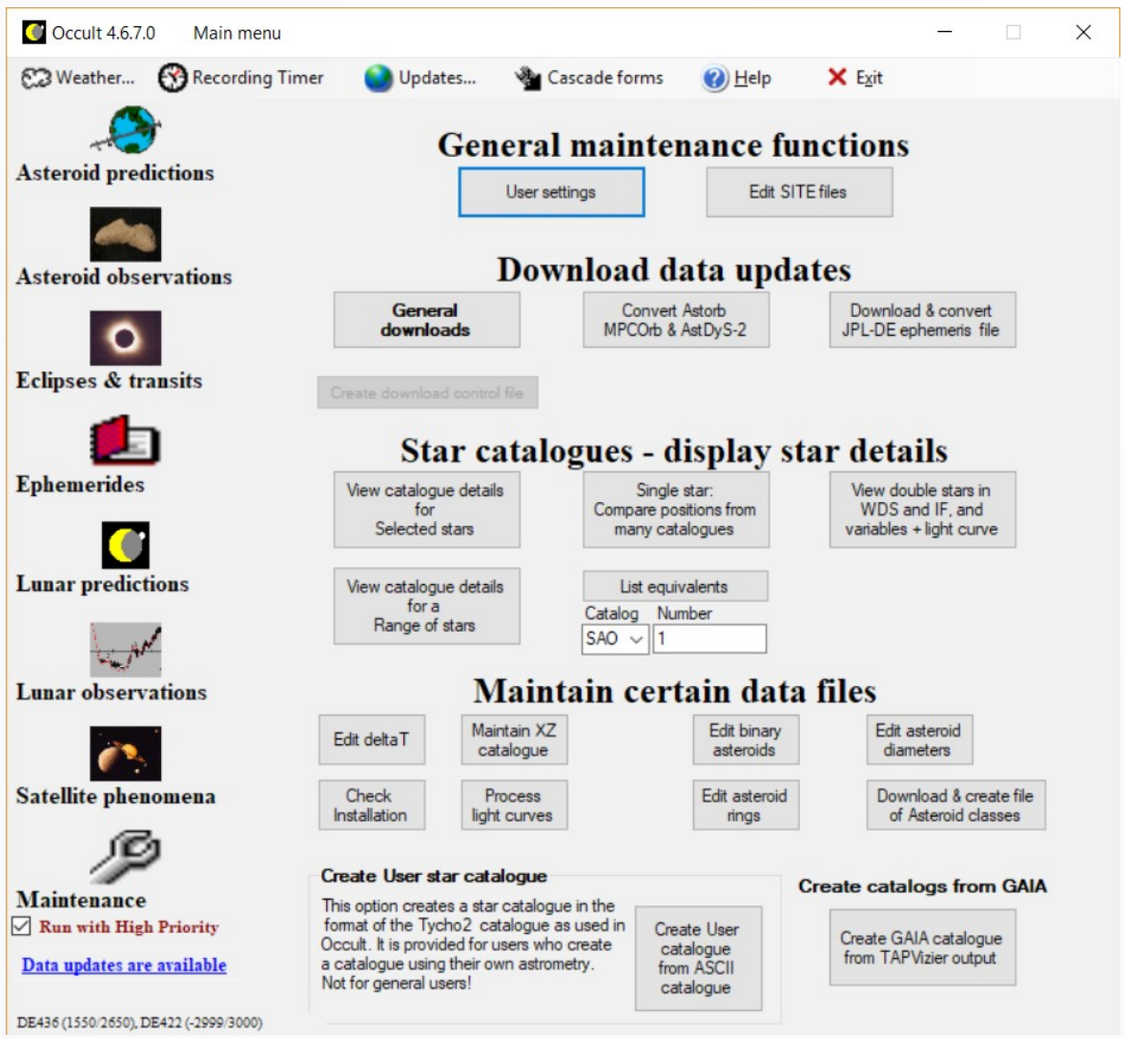
Warsaw, April 28th , 2019

Asteroid Occultation Ephemeris



Source: http://www.asteroidoccultation.com/

Occultation Prediction Software



Occult 4

Occultation Prediction Software

by David Herald

- regular update
- current version: 4.6.7.2 (21.04.2019)
- free software

http://www.lunar-occultations.com/iota/occult4.htm

Occultation Prediction Software

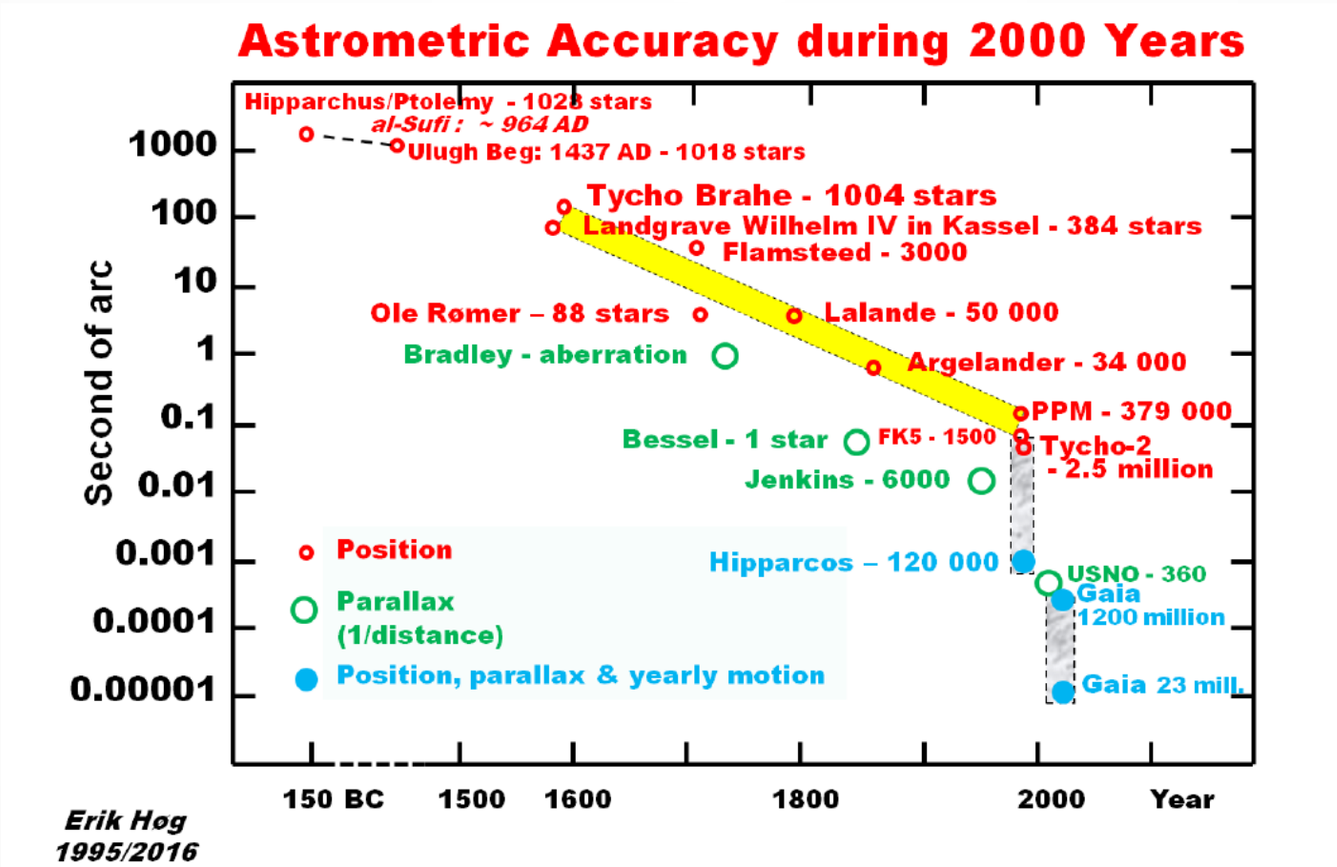
What one needs to know, to predict an occultation?

- asteroid position, movement and physical characteristic
- star position
- observer positions

Observer position

- Observer position in 3D
  - WGS-84 (World Geodetic System longitude, latitude, elevation)
  - Reference coordinate system used by GPS
  - High accuracy and easy of use
- Uncertainty of observer position is not a source of occultation uncertainty any more.

Star catalogs accuracy



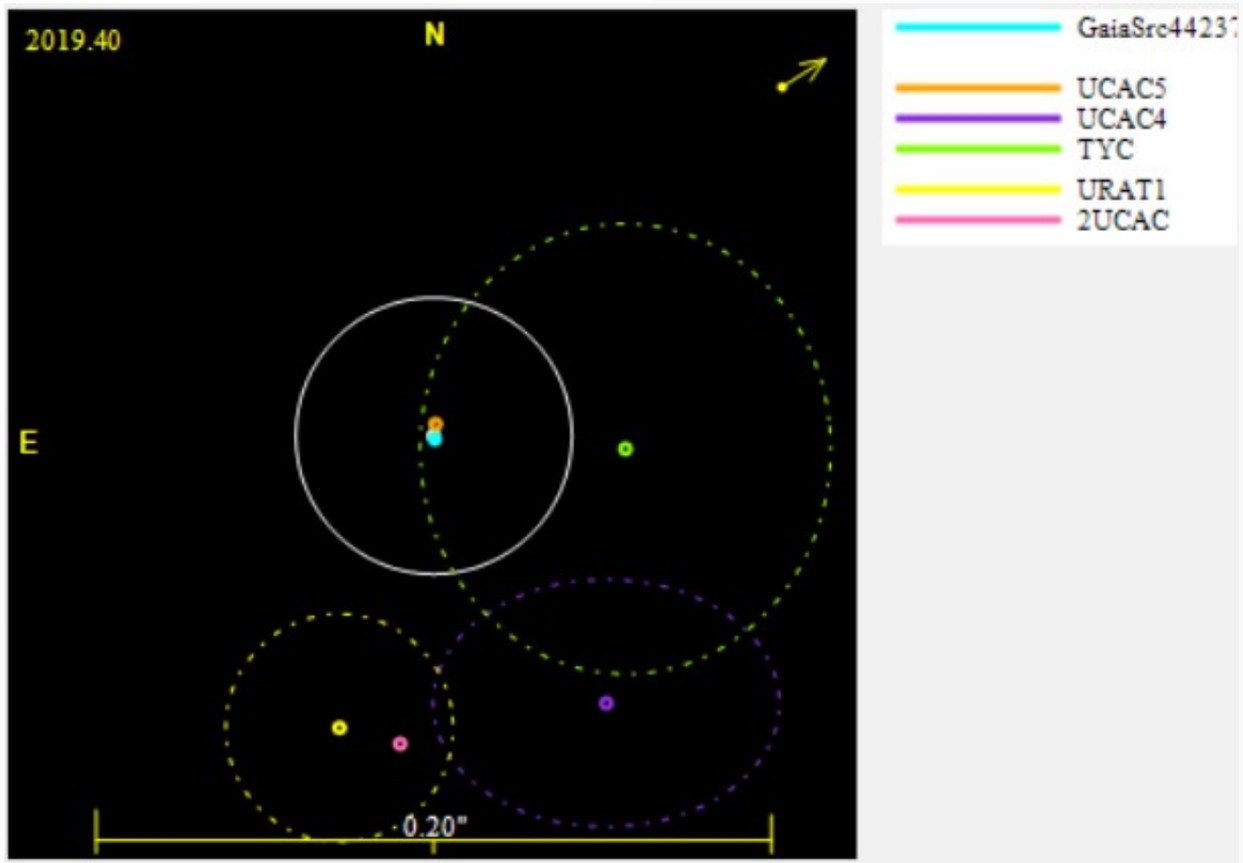
source: Astrometric accuracy during the past 2000 years, Erik Høg, Niels Bohr Institute, Copenhagen (2017)

Star catalogs accuracy

Catalog	Stars number	Limit (mag)	Mean epoch	Position uncertainty ×0.001”	Proper motion uncertainty ×0.001”/year	Parallax uncertainty ×0.001”
Tycho-2	2.5 mln	11.5	1991.5	60	2.5	
UCAC-4	113.8 mln	16.5	2000	18 (15-100)	4	
UCAC-5	107 mln	16.5	2001	10-70	1-2 (<15mag) 5 (<16mag)	
URAT-1	228.3 mln	18.5	2013.4	5-40	5-8	4.3 – 10.8
Gaia DR2	1 300 mln	21	2015.5	2 (20mag)	0.06 (<15mag) 0.2 (17mag) 1.2 (20mag)	0.04 (<15mag) 0.1 (17mag) 0.7 (20mag)

Star catalogs accuracy

- An example:
  May 28th, 2019, (225)
  Henrietta occulting TYC
  0355-00548-1 (~10mag)
- Asteroid diameter
  0.082″ (white ring)



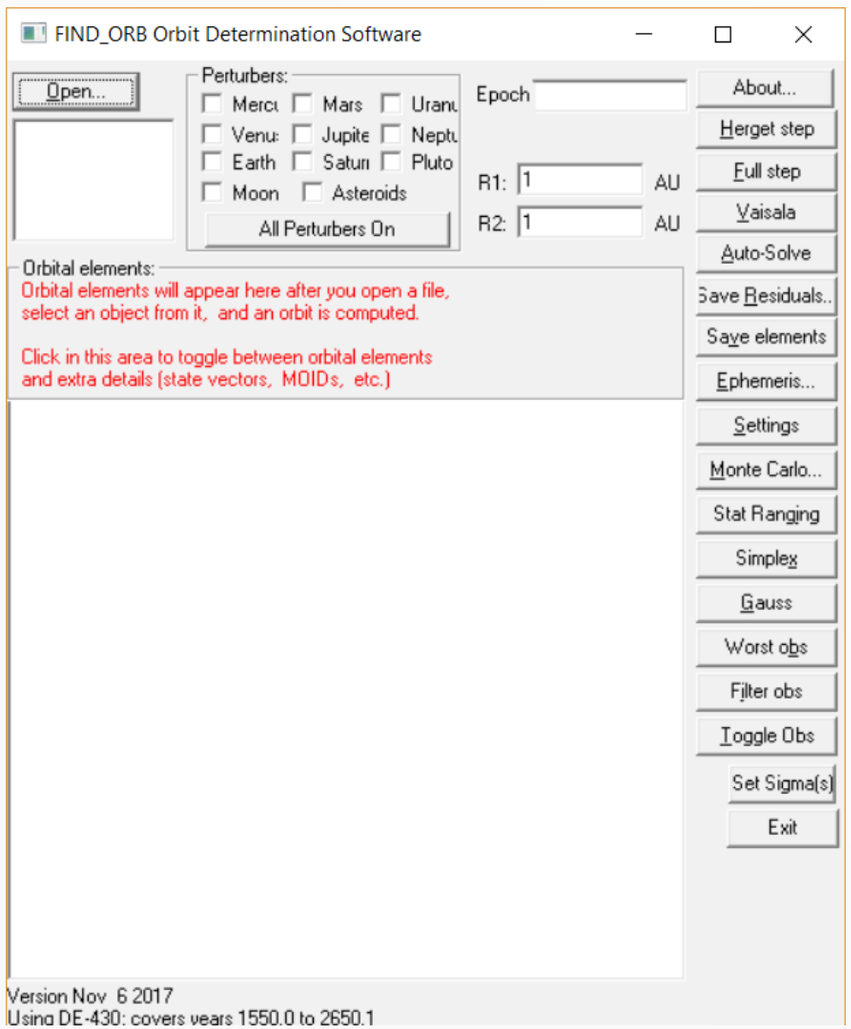
Star catalogs accuracy

- Uncertainties of Gaia DR2 (G=20 mag)
  - position 0.002″
  - Proper motion 0.0012″/year
  - parallax 0.0007″
- Observed occulting asteroid typical size: 0.01″ - 0.1″
- After Gaia DR2 release uncertainty in star position is not a significant source of occultation uncertainty any more. Exception: binary and multiple systems.

Asteroid orbit determination

- Uncertainty of asteroid's state vector (position and velocity) comes from orbit determination uncertainty and non-gravitional factors (constant or temporary)
- Source of orbit determination uncertainty:
  - Astrometry inaccuracy
    - Measurement uncertainty (position and time)
    - Star catalogs uncertainty (old observations are not re-reduced with Gaia!)
  - Small observation number
  - Short observation arc
- Non-gravitional factors
  - Difficult to foresee
  - Need fresh observations

Asteroid orbit determination



Software:

Find_Orb

Orbit Determination Software

by David Herald

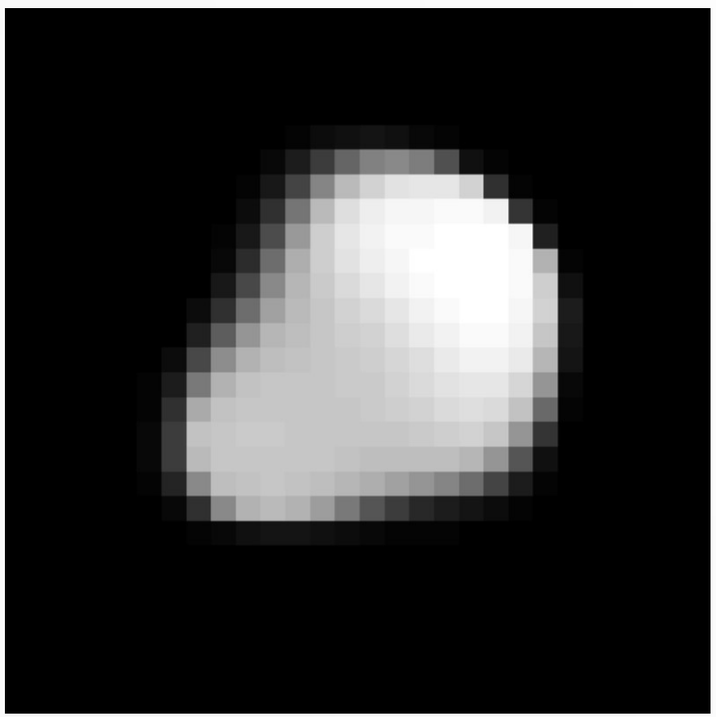
- regular update
- last update: 18.03.2019
- free

https://www.projectpluto.com/find_orb.htm

Physical properties and occultation

- Size
- Shape and rotation
- Binary and multiple systems

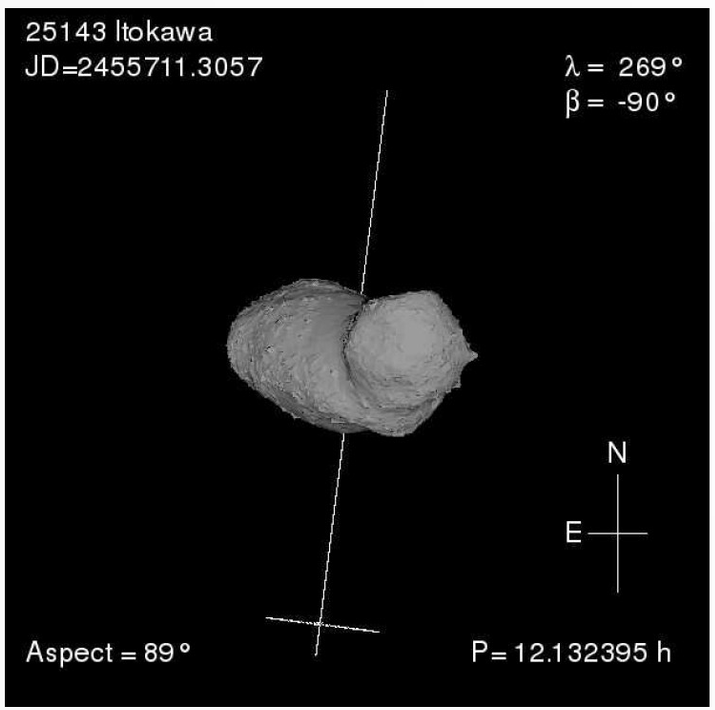
Asteroid size



(41) Daphne – image from adaptative optic (source: Durech, 2015).

- For most – no direct data exists
- Usually estimated using indirect methods, observation techniques (photometry, spectroscopy, polarimetry, thermal radiation etc.) and theoretical assumptions
- Asteroid size determines width of occultation path

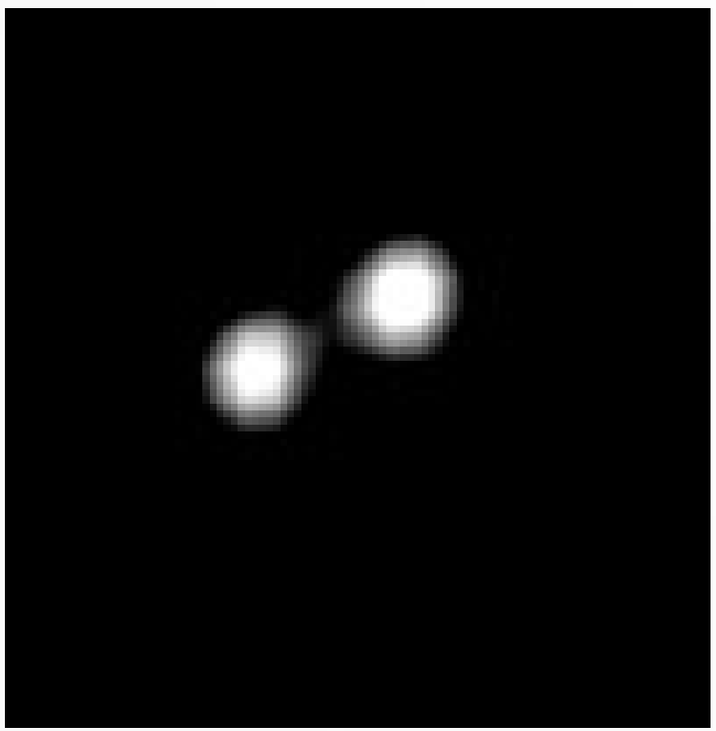
Asteroid shape and rotation



(25143) Itokawa model; Bartczak, Marciniak (2011).

- Asteroid shape and rotation
  - In most cases unknown
  - For some shape model has been determined based mainly on many years' photometry observations
  - Only few are with direct observations (spacecraft, radar, adaptative optic)
  - Typical rotation period (for size>150m): 2 to hundreds hours
- Non-spherical shape can affect an occultation.

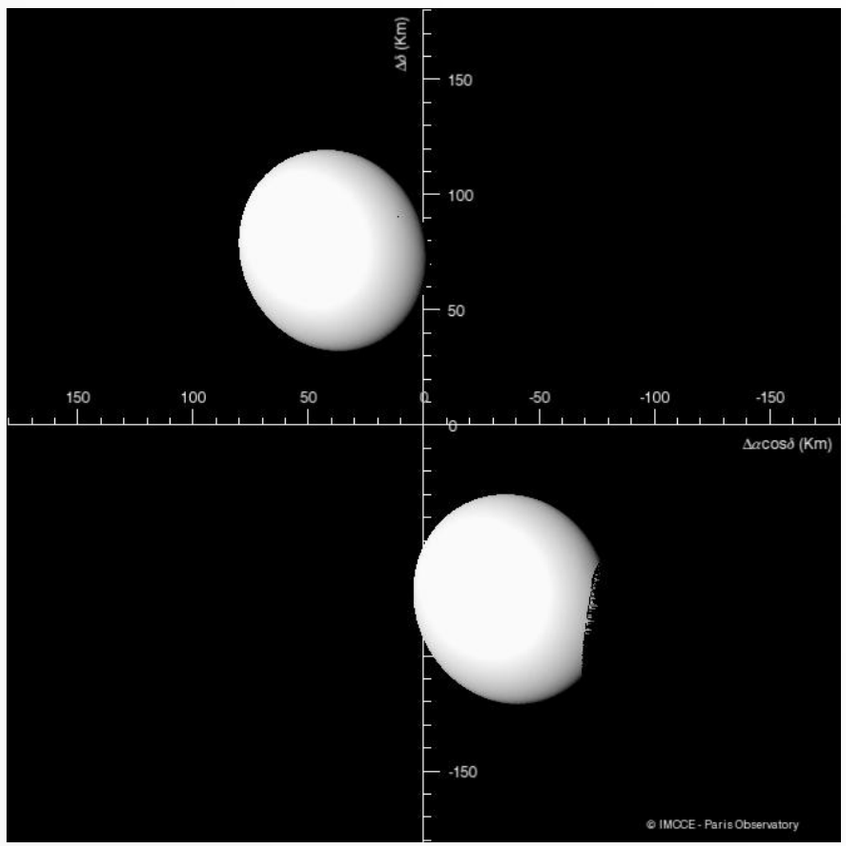
Binary and multiple asteroids

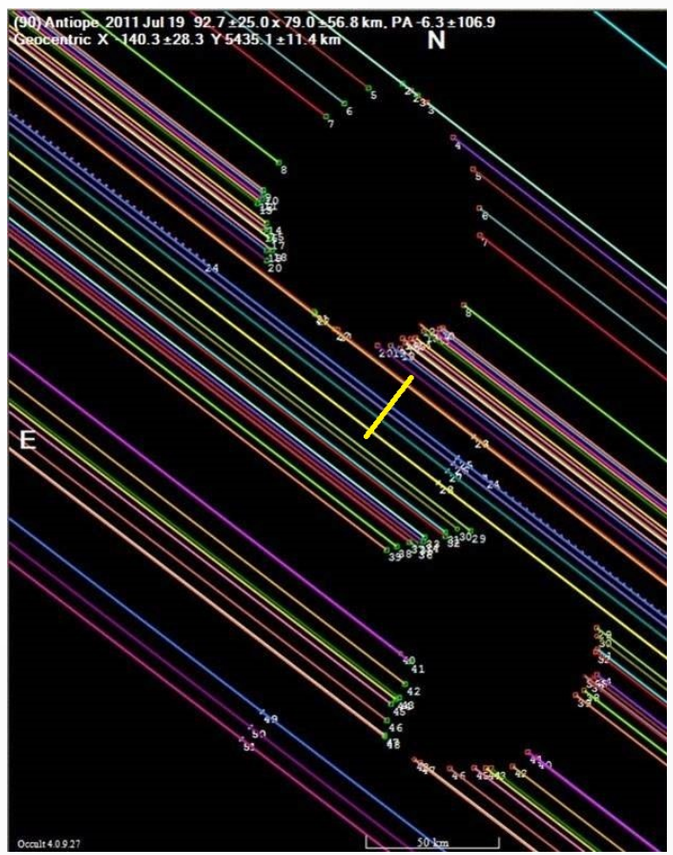


(90) Antiope – double asteroid consisting of two almost-equally sized bodies (phot. W.M. Keck Observatory, 2000).

- As of Feb 2019, 352 asteroids (and TNOs) are confirmed multiple systems
- An estimated 2% Main Belt asteroids and 11% have satellite or satellites
- In most of the known multiple systems satellites are much smaller then main body
- However… see left. Where is photometry center?
- (90) Antiope both components max. separation is 0.14″.

Binary and multiple asteroids





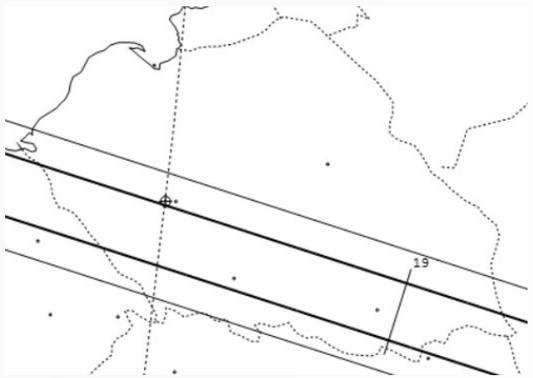
(90) Antiope – occultation on July 19th, 2011. Non-occultated belt (yellow) between both components is app. 28 km wide. (phot. wikipedia)

Occultation uncertainty

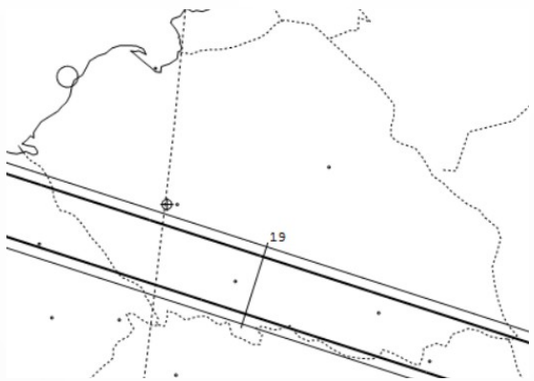
Example 1:

- Occultation on May 11th, 2019; asteroid: (449) Hamburga
- Main Belt asteroid
- Observed since Oct 1899 (120 years, 49 oppositions)
- 2797 astrometry observations in MPC, including:
  - 1589 since 2010
  - 356 for last 12 months

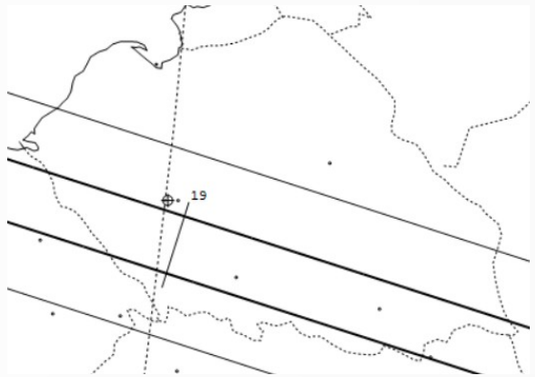
Predictions for May 11th, 2019; (449) Hamburga



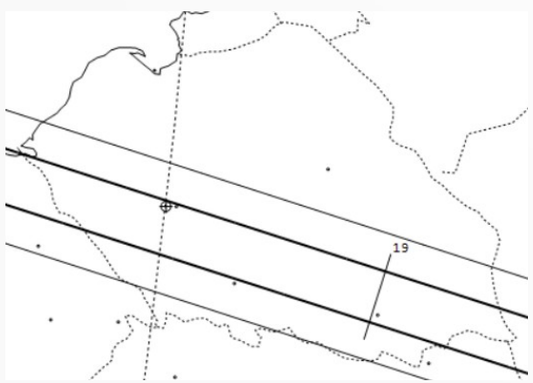
FO: all observations



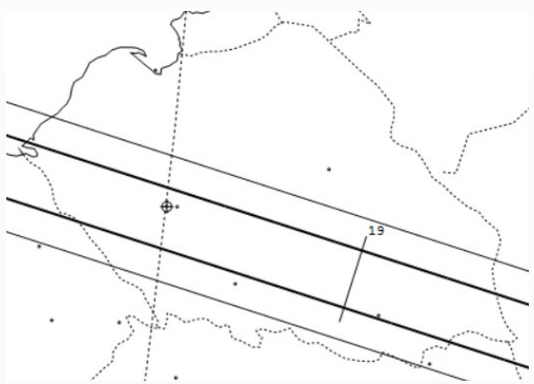
FO: obs. since 2010



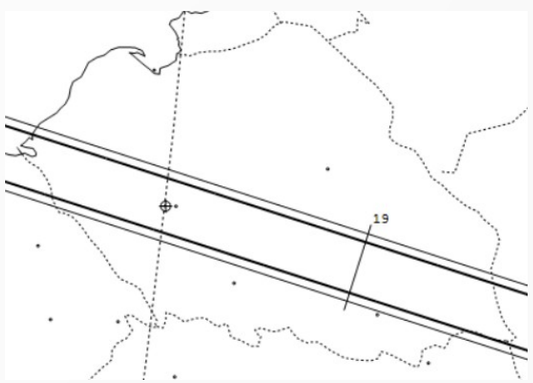
FO: obs. Last 12 mnths



Minor Planet Center



JPL Horizon



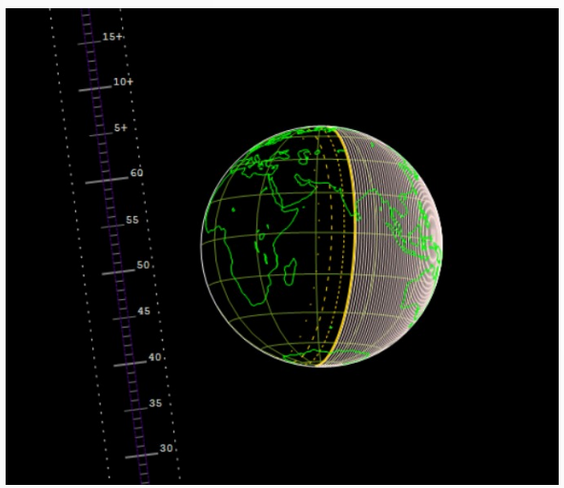
S. Preston

Occultation uncertainty

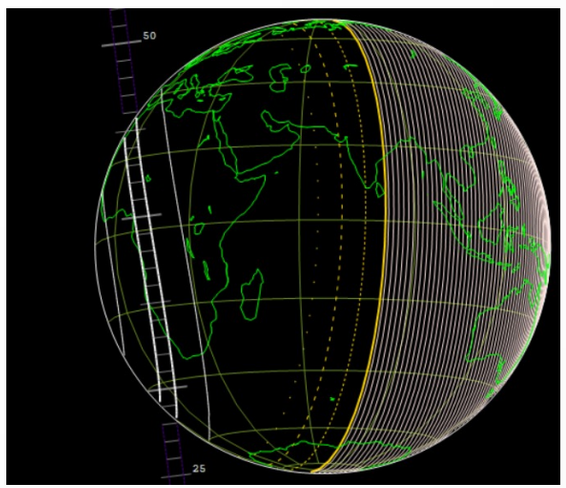
Example 2:

- Occultation on March 18th, 2019, TNO (38628) Huya
- Trans-Neptunian Object
- Observed since April 1996 (23 years, 19 oppositions)
- 316 astrometry observations in MPC, including:
  - 166 since 2010 roku
  - 30 for last 12 months
- Additional 179 observations in 2013-2019 by LuckyStar (not published earlier)

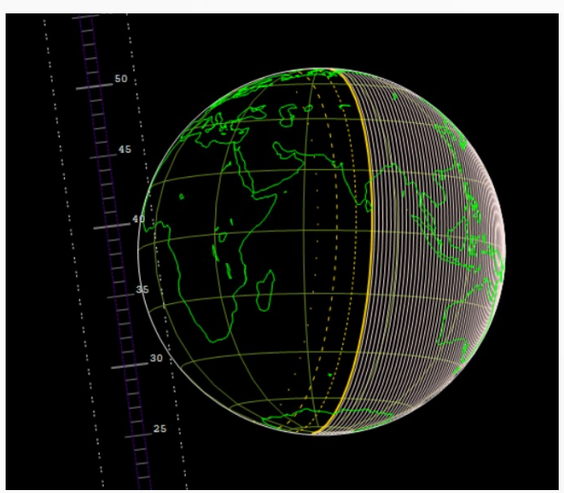
Predictions for March 18th, 2019; (38628) Huya



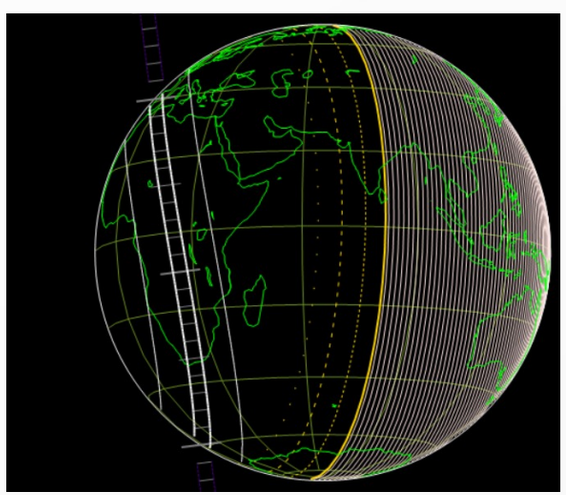
Orbit determined from last year astrometry only.



Orbit determined from all available astrometry.

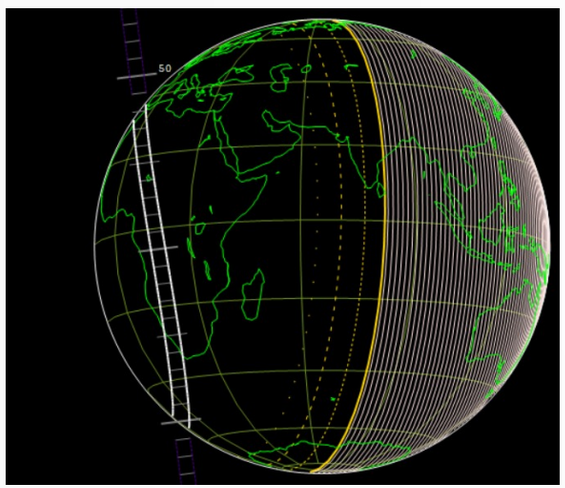


Orbit determined from 2010-2019 astrometry.

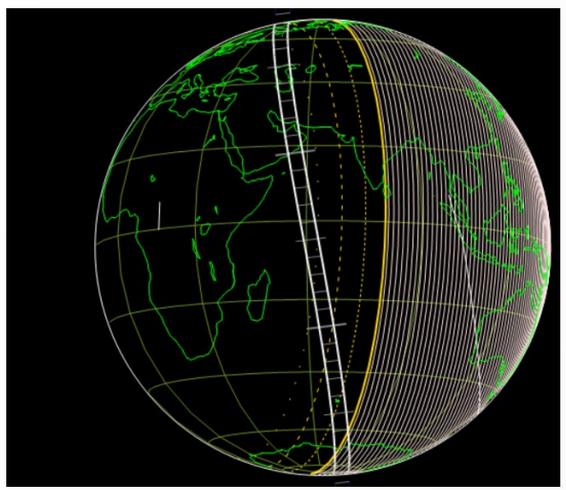


Orbit determined from all available astrometry with outliers rejected.

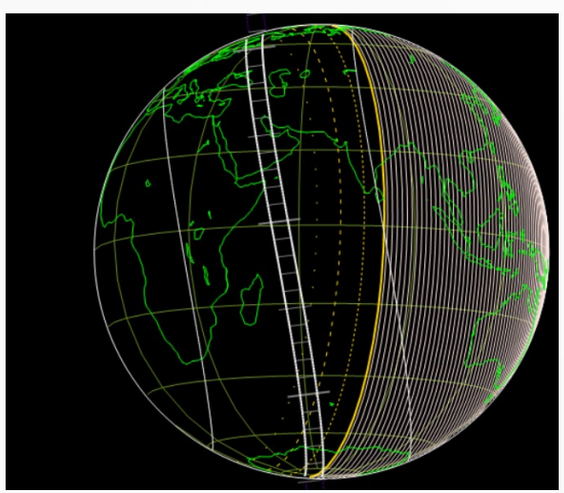
Predictions for March 18th, 2019; (38628) Huya



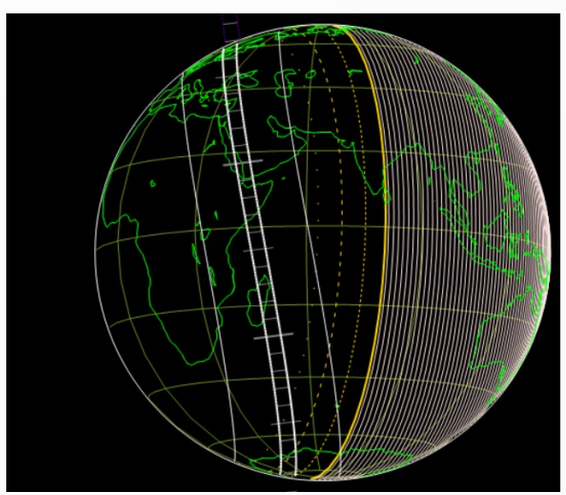
Orbit according to JPL Horizon.



Orbit according to LuckyStar – October 2018.

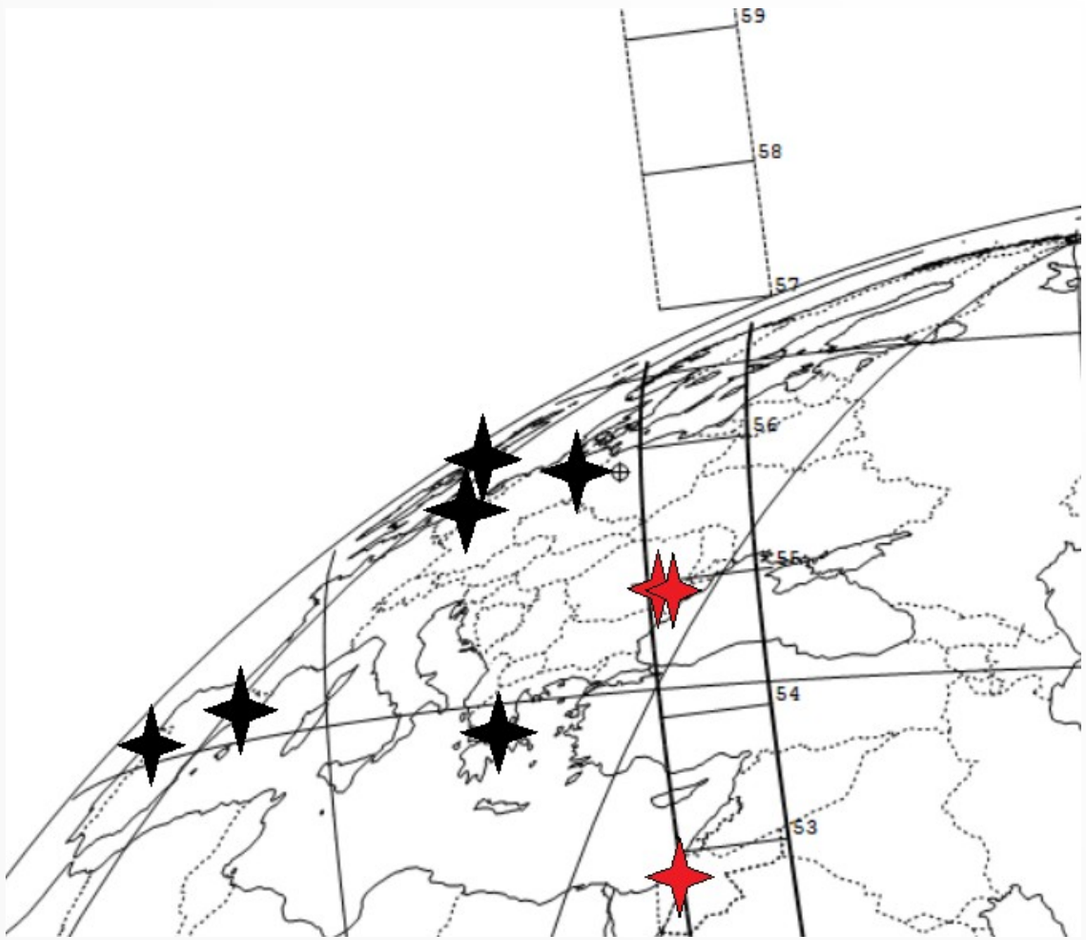


Orbit according to Minor Planet Center.



Orbit according to LuckyStar – March 13th, 2019.

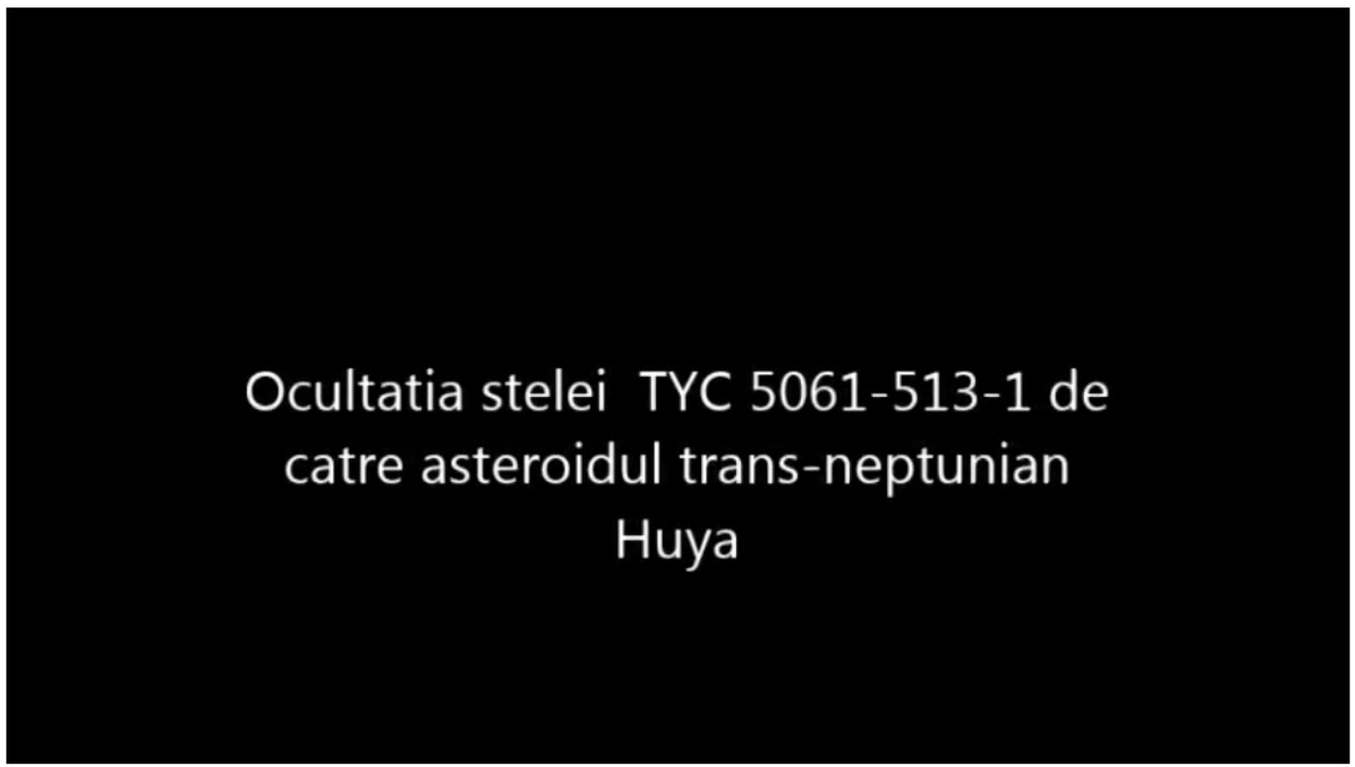
Predictions & results for March 18th, 2019 (38628) Huya



Occultation prediction based on orbits elements derived by LuckyStar (March, 13th).

Red star – positive results
Black star – negative results

March 18th, 2019 occultation; (38628) Huya



Huya occultation 18.03.2019

265 wyświetleń 9 0 UDOSTĘPNIJ ZAPISZ

https://www.youtube.com/watch?v=jOFC_637jmo