

Investigations of asteroids in Pulkovo observatory

*Devyatkin A.V., Gorshakov D.L., Lvov V.N., Tsekmeister S.D., Petrova S.N.,
Martyusheva A.A., Slesarenko V.Yu., Naumov K.N., Sokova I.A., Sokov E.N.,
Zinoviev S.V., Karashevich S.V., Ivanov A.V., Lyashenko A.Yu., Rusov S.A.,
Kouprianov V.V., Bashakova E.A., Melnikov A.V.*



ZA-320M

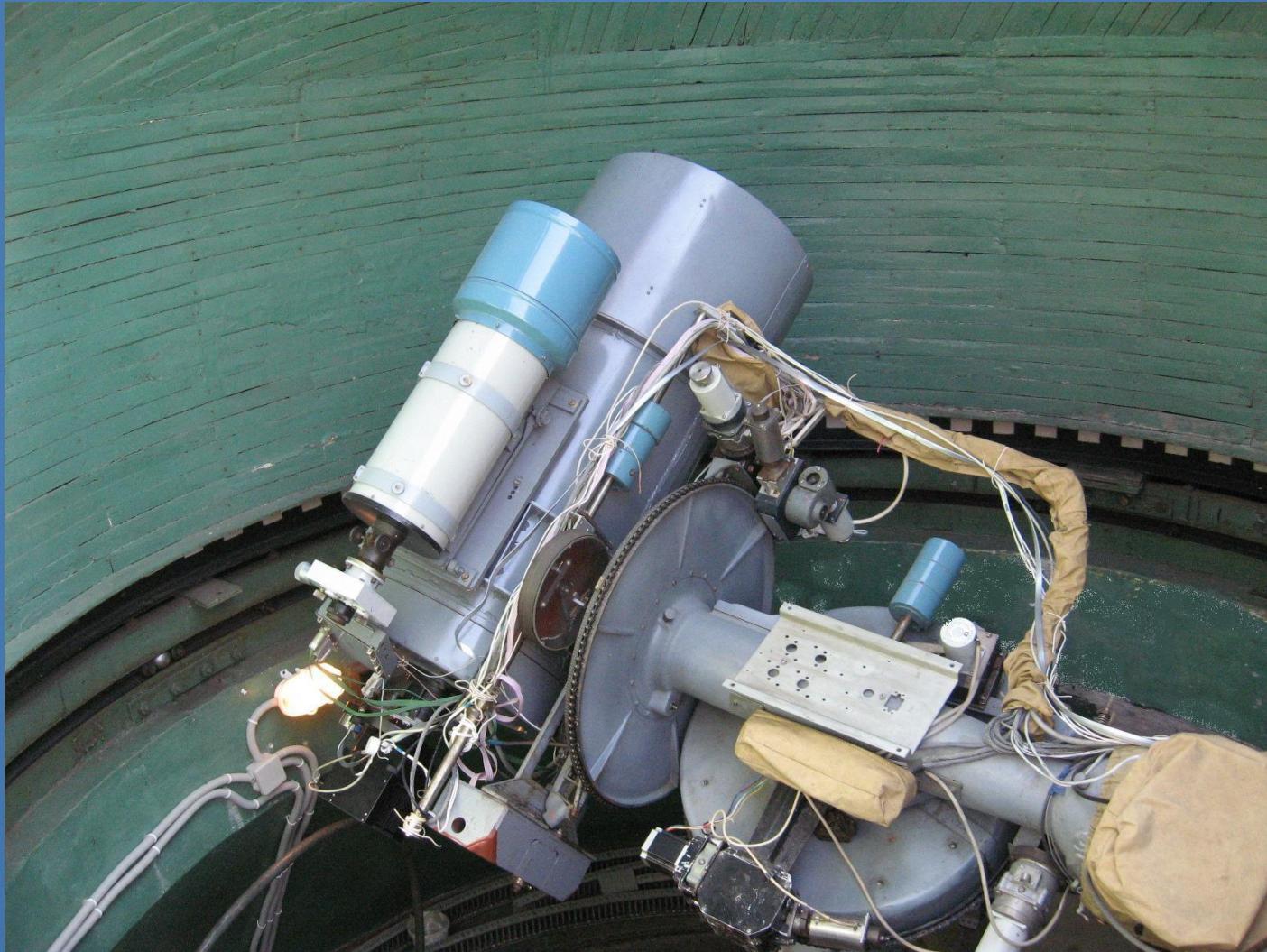
at Pulkovo observatory (Saint-Petersburg)

Cassegrain
system

$D = 320 \text{ mm}$
 $F = 3200 \text{ mm}$

CCD-camera
SBIG STX-16803
 $4096 \times 4096 \text{ pix.}$
 $9 \times 9 \mu\text{m}$
(binning $3 \times 3 \text{ pix}$)
 $\text{FoV} \approx 39' \times 39'$

BVRI filters



MTM-500M

at Mountain astronomical station of Pulkovo observatory
(Northern Caucasus, $h = 2100$ m)

Maksutov – Cassegrain

system +
extra lens corrector

$D = 500$ mm

$F = 4100$ mm

CCD-camera

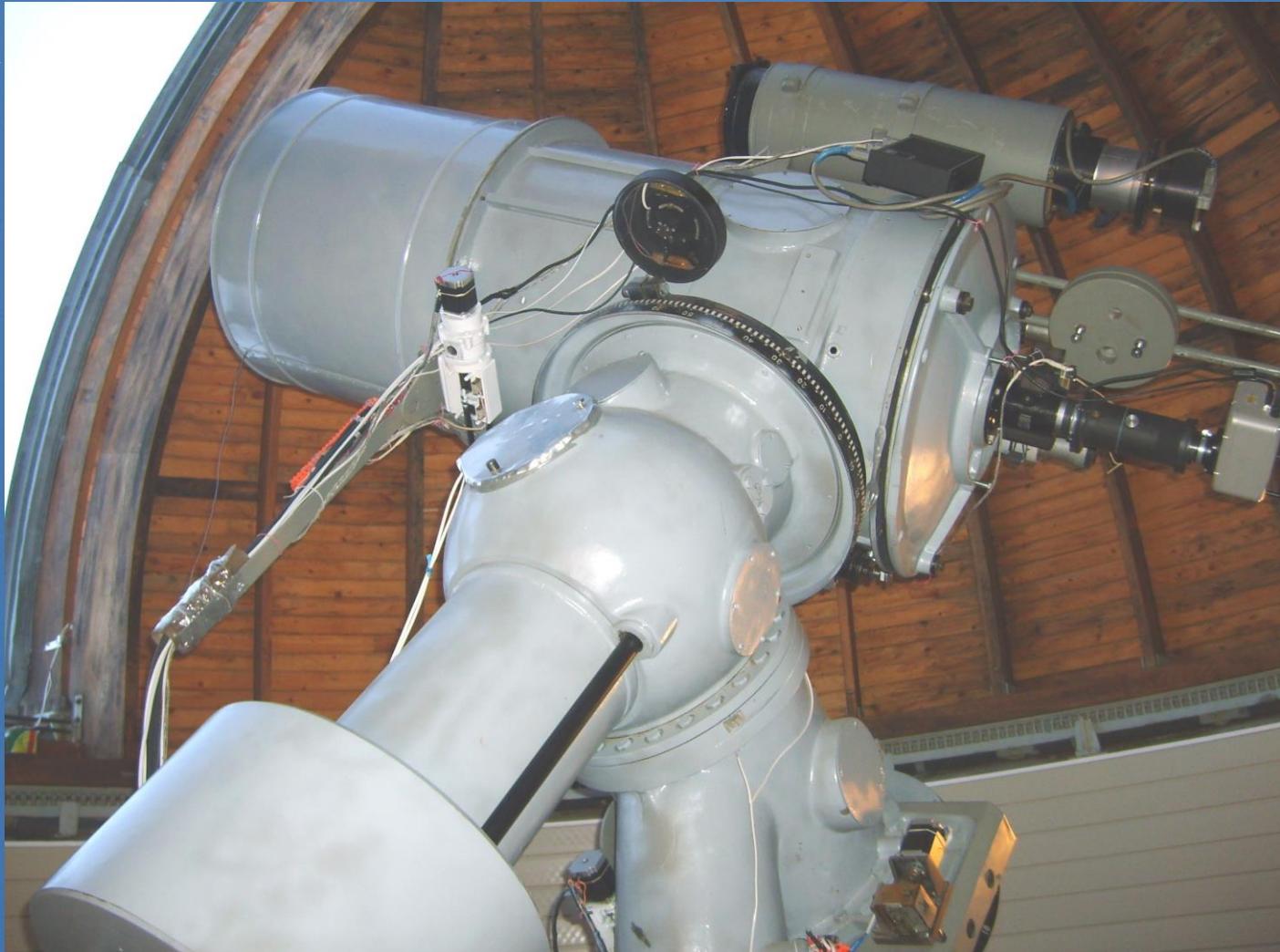
SBIG STL 1001E

1024×1024 pix.

24×24 μm

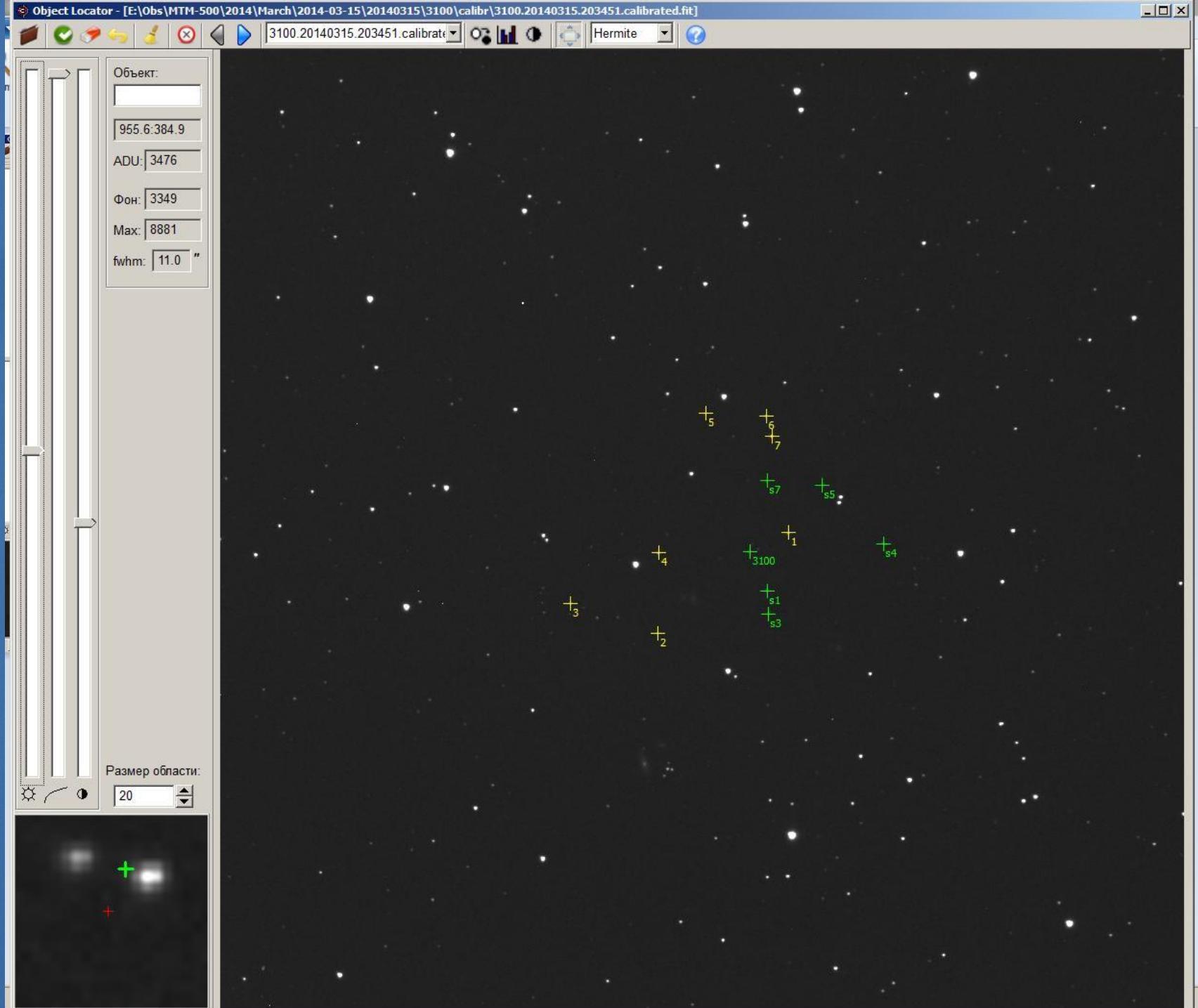
$\text{FoV} \approx 21' \times 21'$

BVRI filters



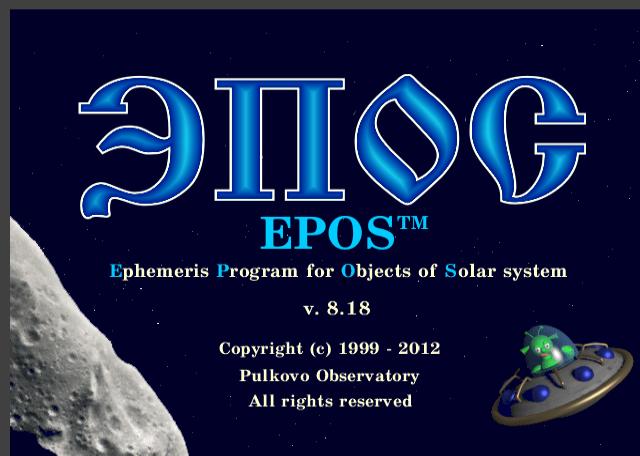
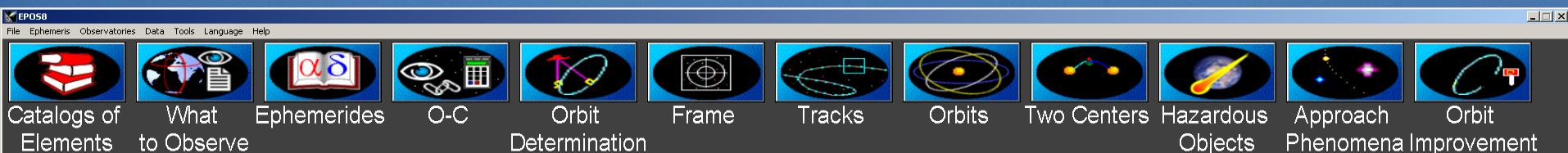
APEX-II – CCD-frame processing software

- Calibration – fitting, synthesis and application of darks and flats
- Sky background smoothing
- Object detection using threshold algorithm
- Deblending
- Object center detection using PSF method
- Flux measurement using aperture or PSF methods
- Noise rejection
- Identification of measured objects with reference catalogues (USNO-A2, USNO-B1, TYCHO-2, HIPPARCOS, UCAC-4, 2MASS, user's catalogues)
- Astrometric reduction using several methods
- Identification of unknown objects using EPOS module (asteroid and comet searching)
- Creation of report in standard format (e.g. MPC format)



EPOS

(Ephemeris Program for Objects of Solar System) software for celestial-mechanics computations and visualization



The software is available at:

<http://www.epos.gao.spb.ru/personal/neo/ENG/ESUPP/main.html>

Directions

Astrometric positions → orbit enhancement

Modeling of orbital evolution
taking into account:

- light pressure,
- Yarkovsky's effect,
- close approaches

Lightcurves → rotation parameters
m.b. shape

BVRI → color indices
m.b. taxonomy

Asteroids

NEAs

Binary asteroids

Asteroids that have close approaches to inner planets

Asteroids named by Pulkovo astronomers

And other

International observational campaigns

GAIA FUN SSO

“Project on coordinated observations of hazardous objects” (INASAN)

Triangulation of 2014 HQ124

New direction: Quasi-satellites

Some recent results

Some recent results

(367943) Duende = 2012 DA14

close approach (27700 km) to the Earth

on 15-th of February 2013

(GAIA FUN SSO training observational campaign)

**436 astrometric positions
with average accuracy**

0^{".}43 for right ascension

0^{".}26 for declination

Color indices

$$B-V = 0.86^m \pm 0.15^m$$

$$V-R = 0.39^m \pm 0.04^m$$

$$R-I = 0.36^m \pm 0.03^m$$

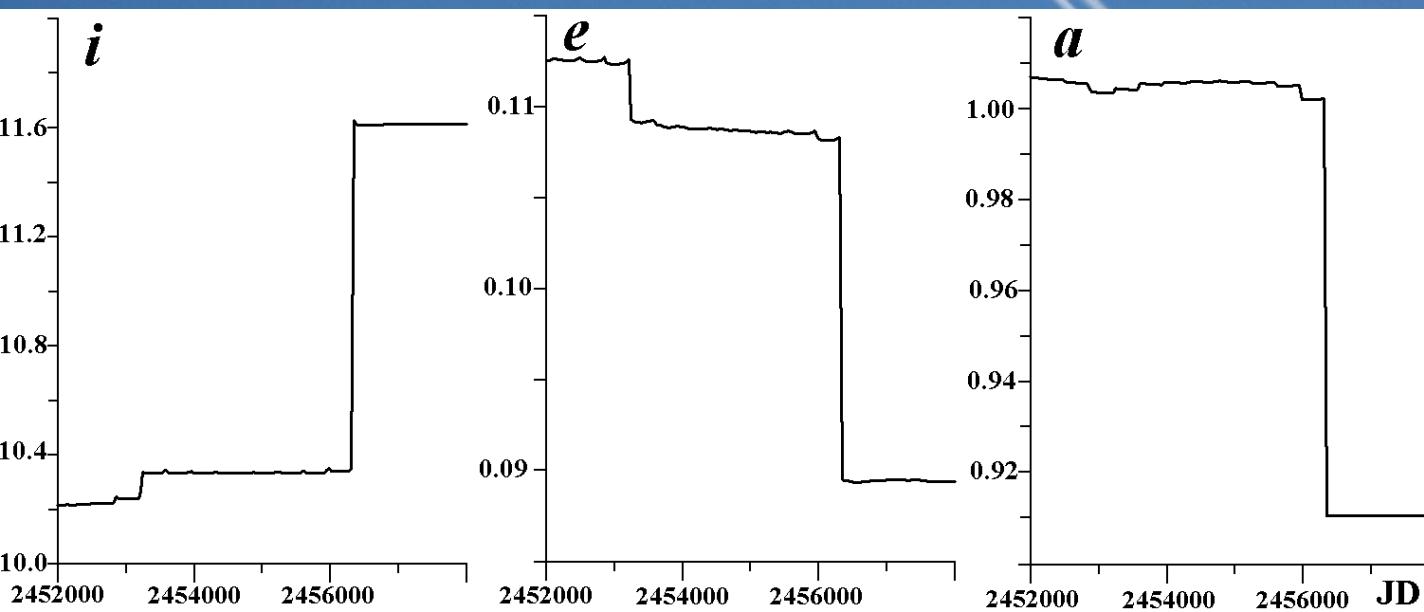
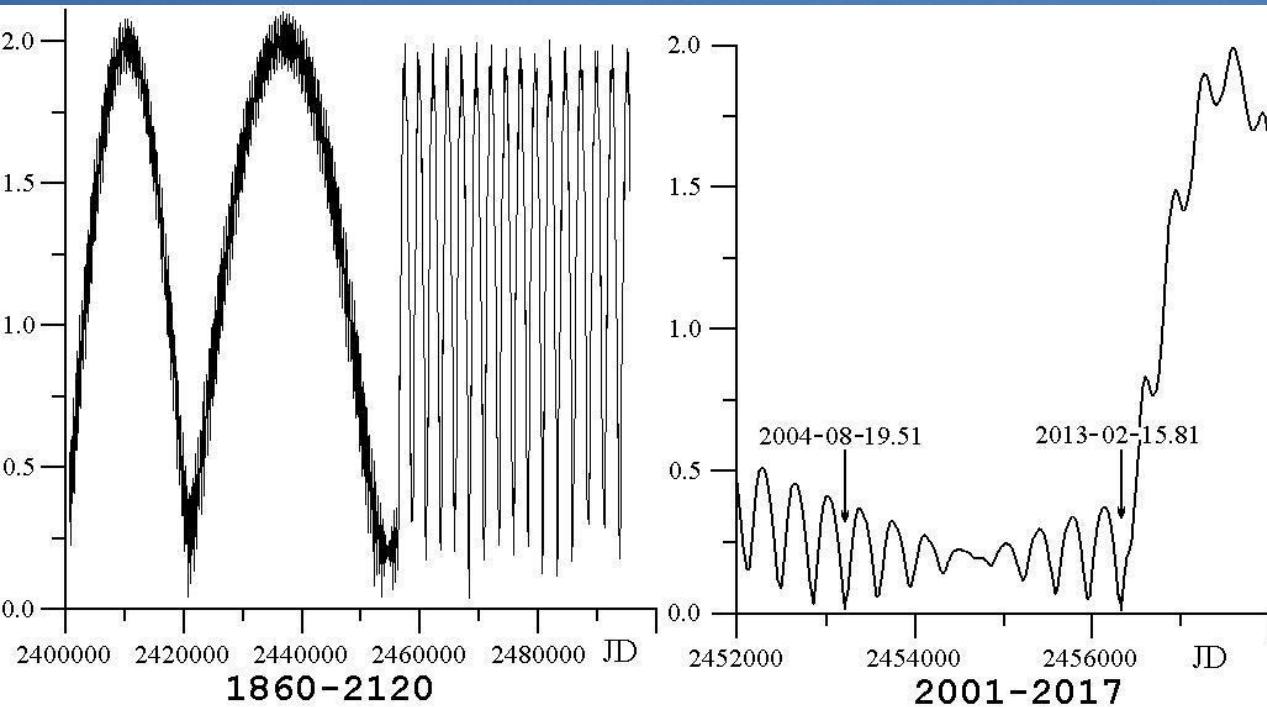
**Possible Tholen class:
G, C**

Duende orbital evolution

(EPOS calculations)

1:1 resonance
with the Earth

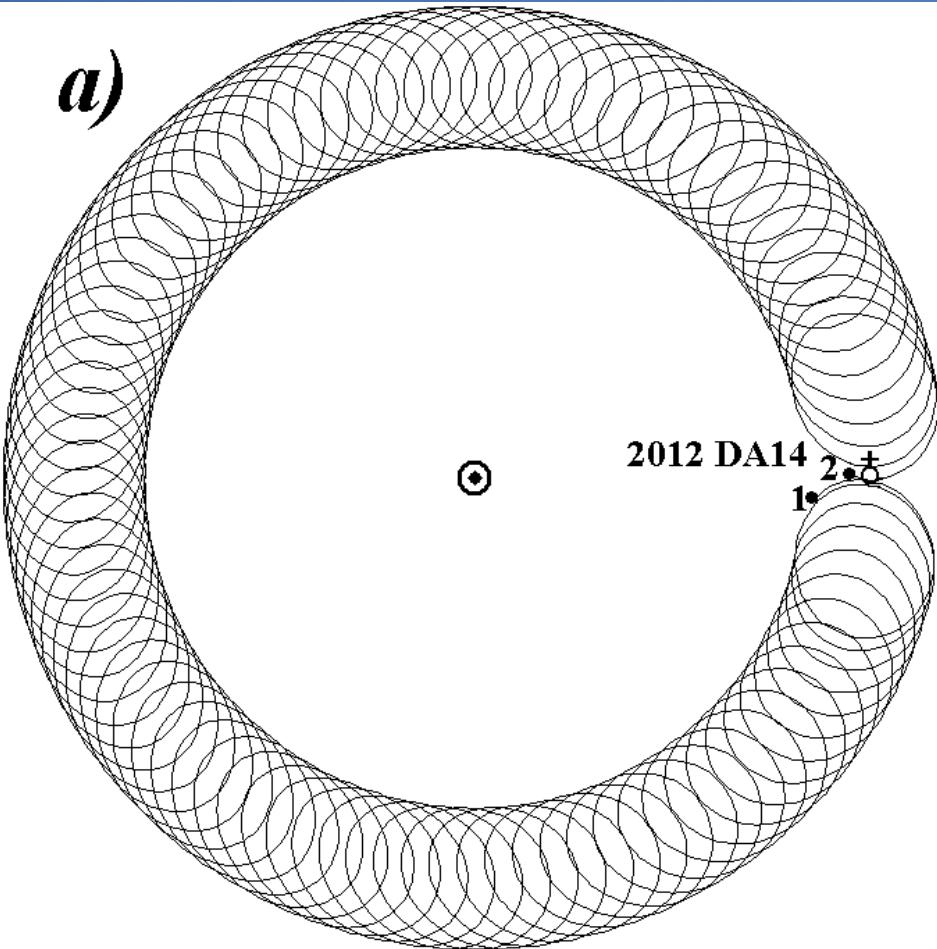
Change of
geocentric distance
in 1860 – 2120
and 2001– 2017



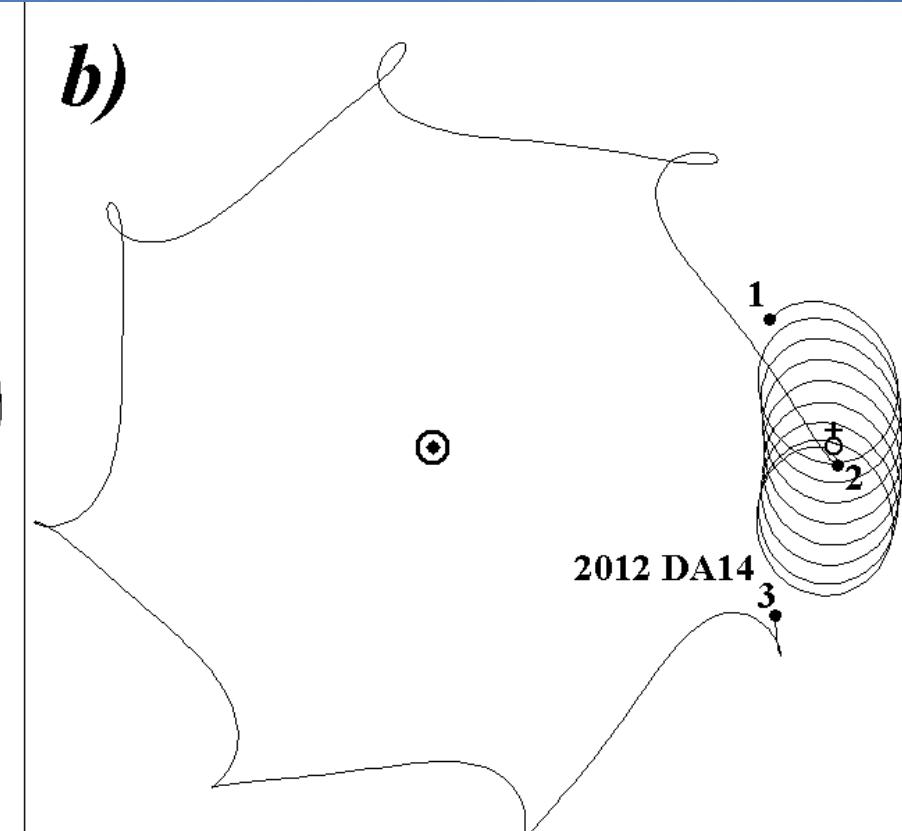
Change of 3
orbital elements
in 2001 – 2017

Duende orbital evolution (EPOS calculations)

a)



b)

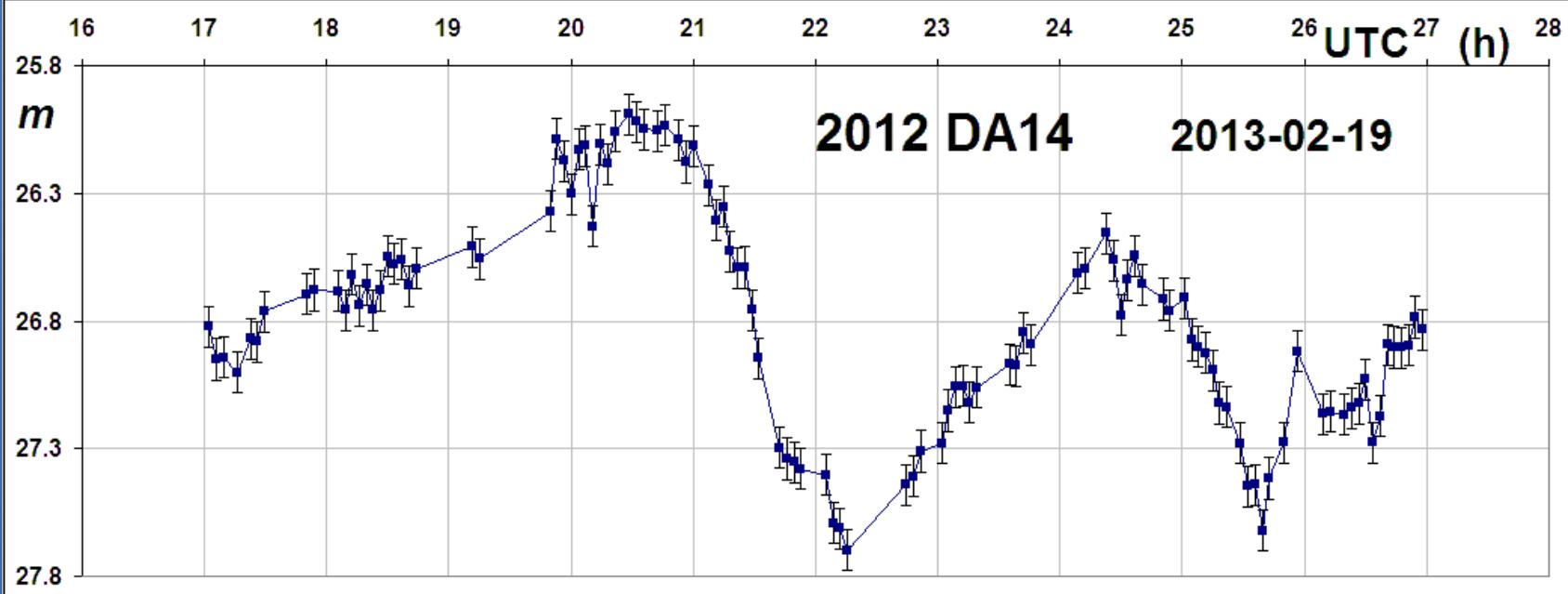
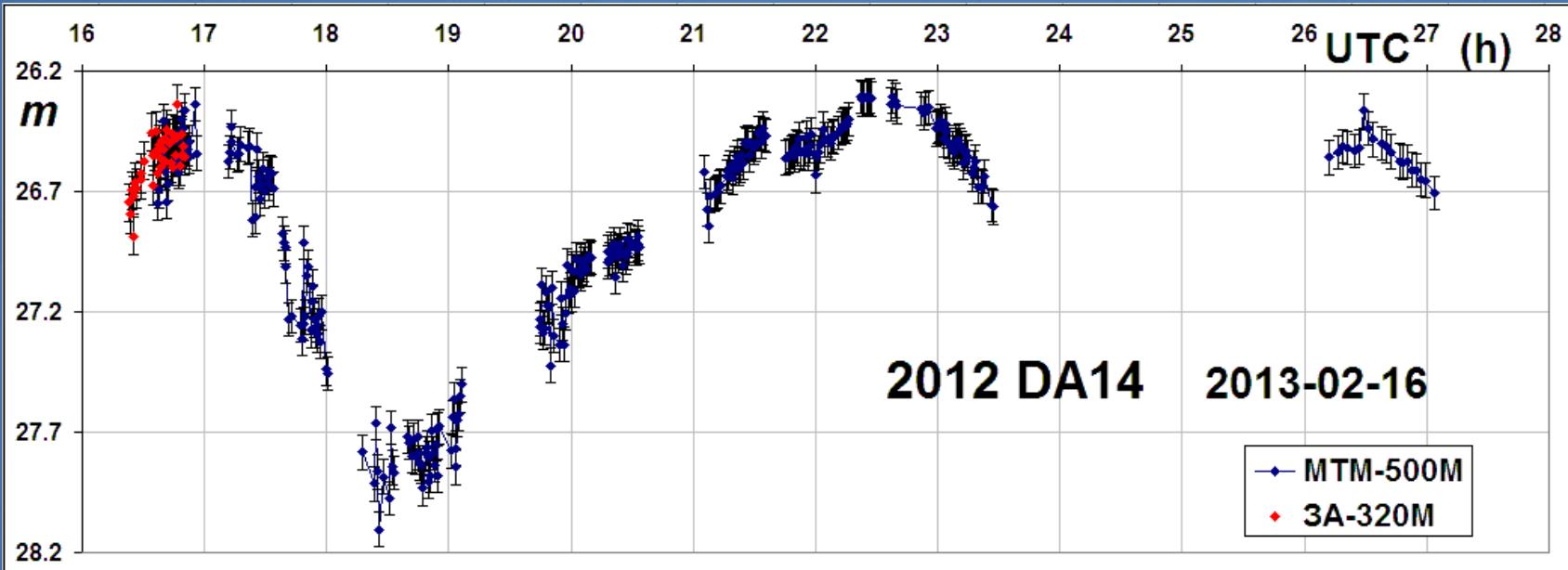


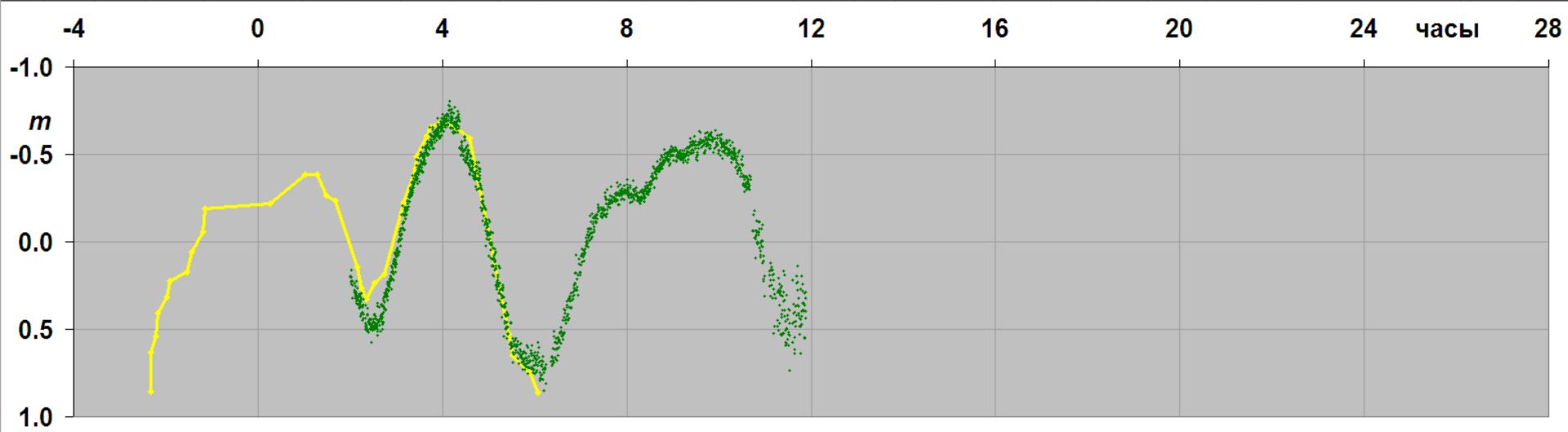
Horseshoe-shaped
orbit in 1916 – 2004

(before 1916 – circulatory orbit)

1-2 – quasi-satellite orbit
in 2004 – 2013
2-3 – circulatory orbit
after 2013-02-15

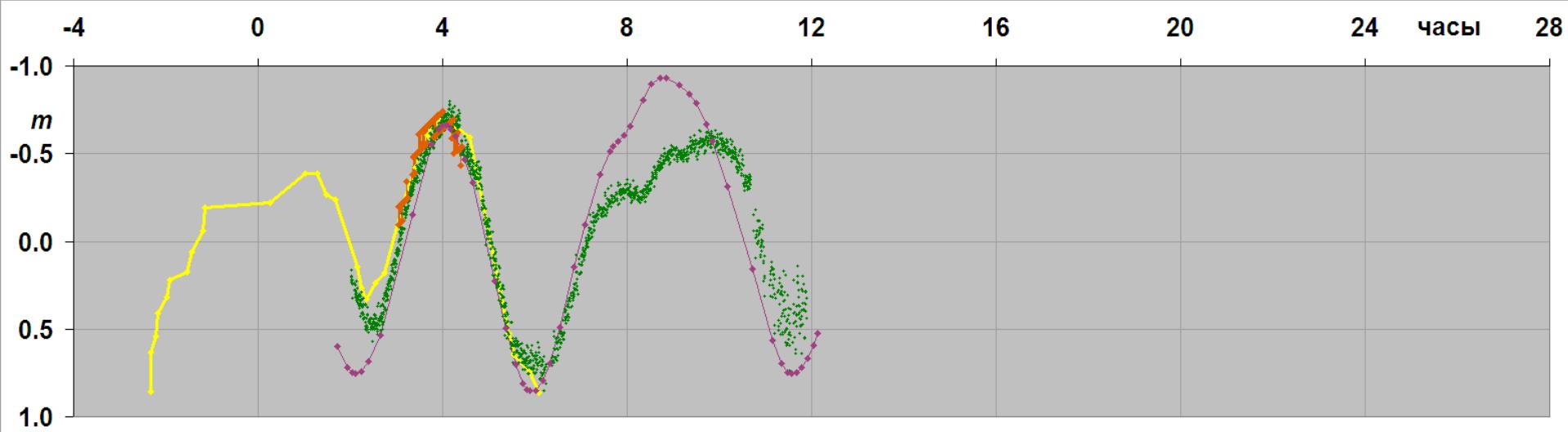
Duende light-curves



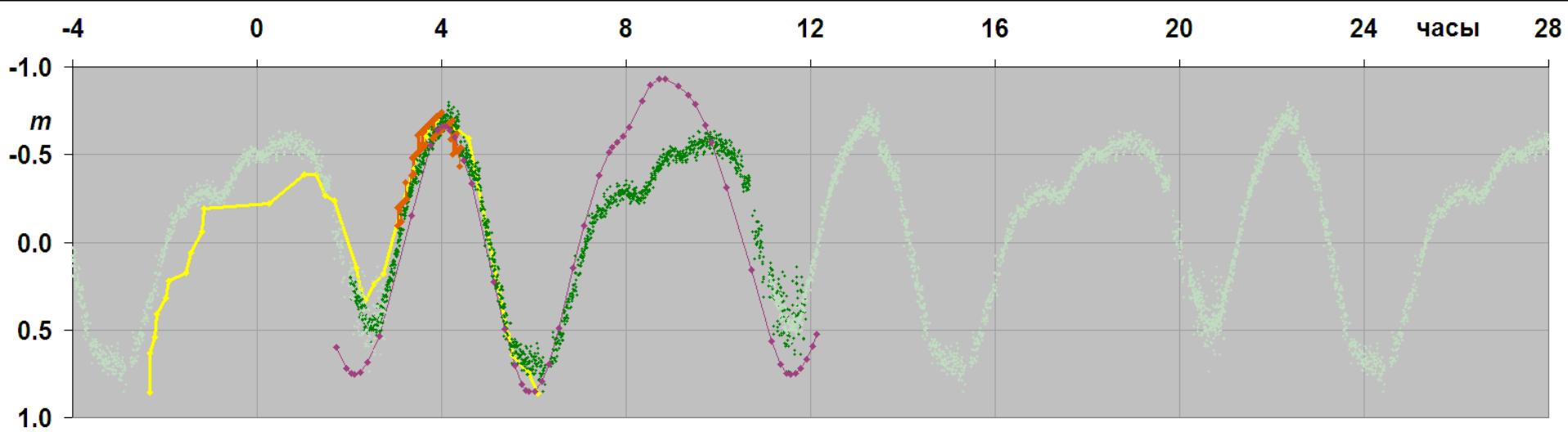


- ◆ *de Leon J. et al.*, Astronomy & Astrophysics, 2013, vol. 555, id. L2.
“La Hita” observatory, Spain, 15-16 febr. (Graphical data)
- ◆ *Gary B.* <http://brucegary.net/2012DA14>
Arizona, USA, 16 febr. (Digital data)

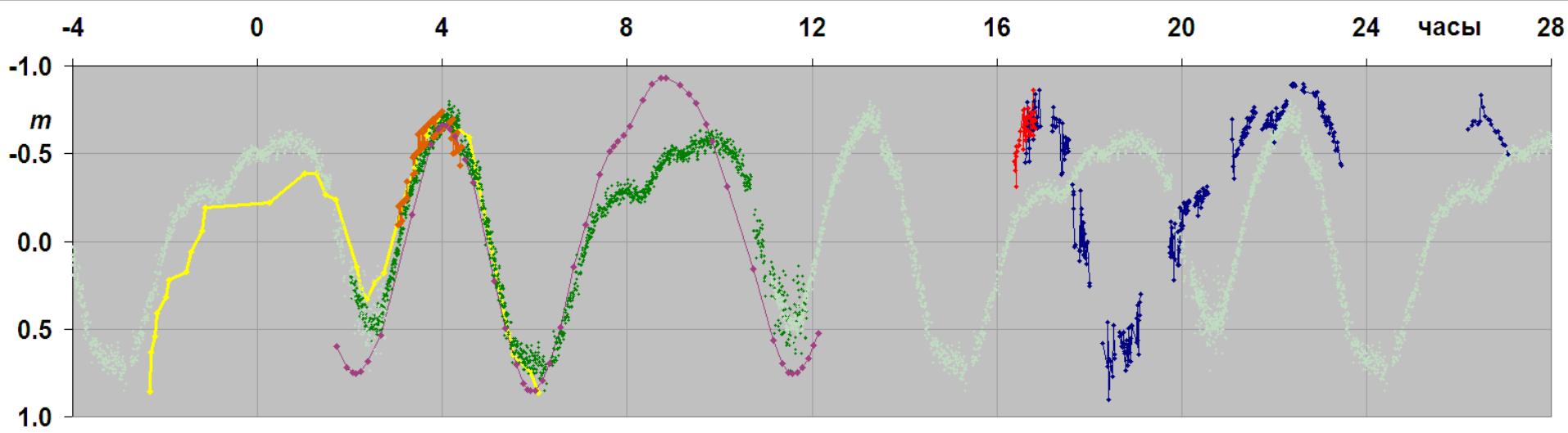




- ◆ *de Leon J. et al.*, *Astronomy & Astrophysics*, 2013, vol. 555, id. L2.
“La Hita” observatory, Spain, 15-16 febr. (Graphical data)
- ◆ *Gary B.* <http://brucegary.net/2012DA14>
Arizona, USA, 16 febr. (Digital data)
- ◆ *MPC (MPS 456432)*
NAO Rozhen, Smolyan, Bulgaria, 16 febr. (Digital data)
- ◆ *Elenin L., Molotov I.*, *The Minor Planet Bulletin*, 2013, vol. 40, no. 4, p. 187-188.
New-Mexico, USA, 16 febr. (Graphical data)



- ◆ *de Leon J. et al.*, *Astronomy & Astrophysics*, 2013, vol. 555, id. L2.
“La Hita” observatory, Spain, 15-16 febr. (Graphical data)
- ◆ *Gary B.* <http://brucegary.net/2012DA14> ◆ $P = 9.22^h$
Arizona, USA, 16 febr. (Digital data)
- ◆ MPC (MPS 456432)
NAO Rozhen, Smolyan, Bulgaria, 16 febr. (Digital data)
- ◆ *Elenin L., Molotov I.*, *The Minor Planet Bulletin*, 2013, vol. 40, no. 4, p. 187-188.
New-Mexico, USA, 16 febr. (Graphical data)



◆ *de Leon J. et al.*, *Astronomy & Astrophysics*, 2013, vol. 555, id. L2.

“La Hita” observatory, Spain, 15-16 febr. (Graphical data)

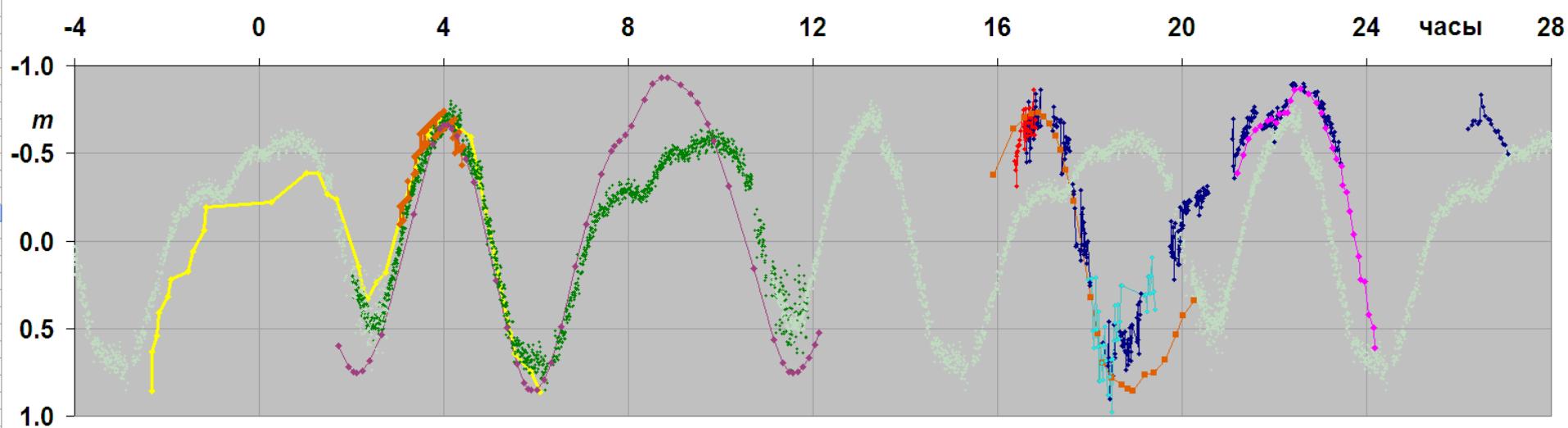
◆ *Gary B.* <http://brucegary.net/2012DA14> ◆ $P = 9.22^h$
Arizona, USA, 16 febr. (Digital data)

◆ *MPC* (MPS 456432)
NAO Rozhen, Smolyan, Bulgaria, 16 febr. (Digital data)

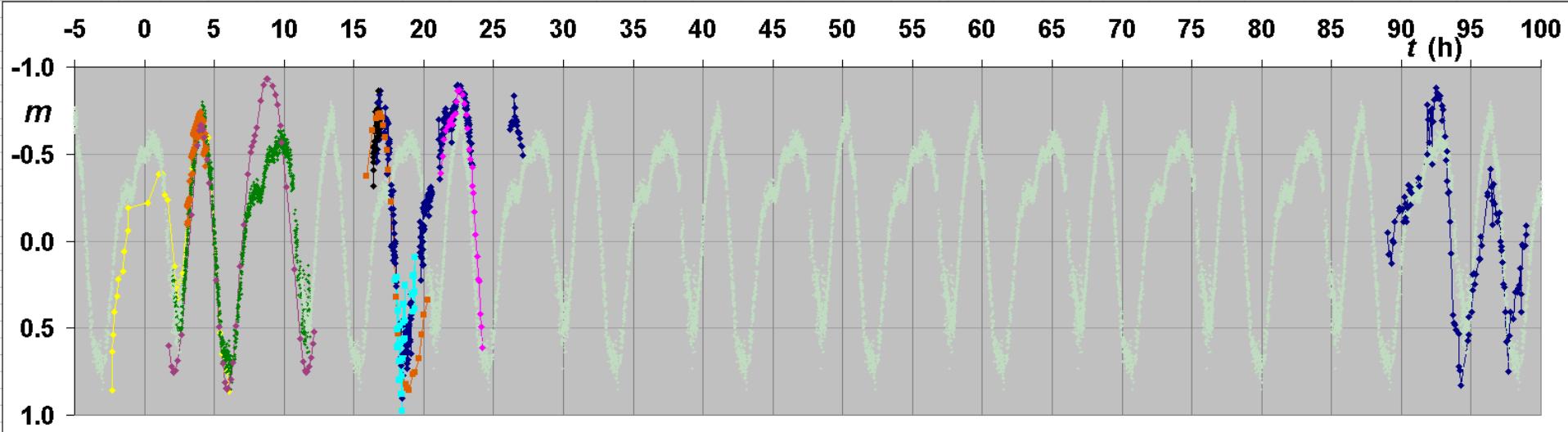
◆ *Elenin L., Molotov I.*, *The Minor Planet Bulletin*, 2013, vol. 40, no. 4, p. 187-188.
New-Mexico, USA, 16 febr. (Graphical data)

◆ **ZA-320M**
Pulkovo, Russia, 16 febr.

◆ **MTM-500M**
Northern Caucasus, Russia, 16-17 febr.

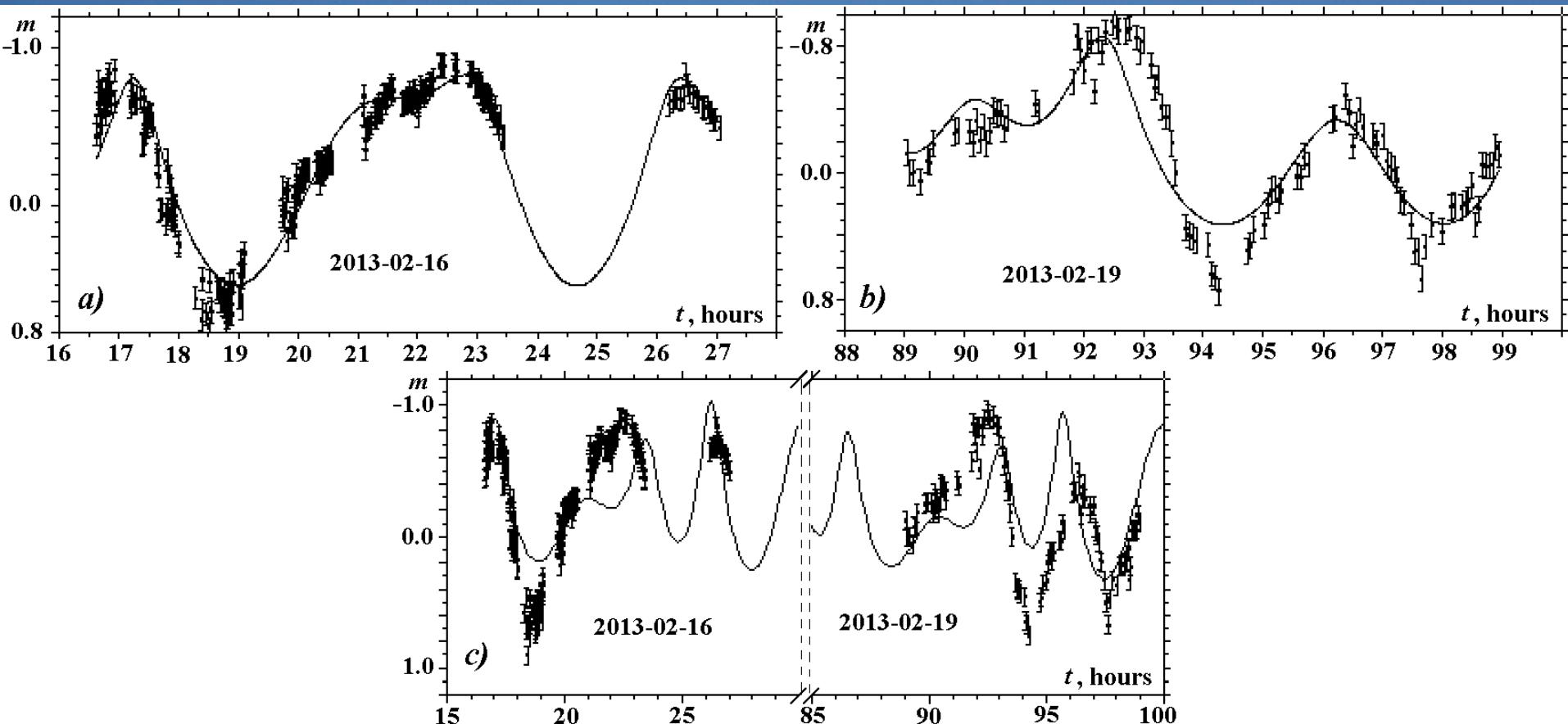


- ◆ *de Leon J. et al.*, *Astronomy & Astrophysics*, 2013, vol. 555, id. L2.
“La Hita” observatory, Spain, 15-16 febr. (Graphical data)
- ◆ *Gary B.* <http://brucegary.net/2012DA14> ◆ $P = 9.22^h$
Arizona, USA, 16 febr. (Digital data)
- ◆ *MPC* (MPS 456432)
NAO Rozhen, Smolyan, Bulgaria, 16 febr. (Digital data)
- ◆ *Elenin L., Molotov I.*, *The Minor Planet Bulletin*, 2013, vol. 40, no. 4, p. 187-188.
New-Mexico, USA, 16 febr. (Graphical data)
- ◆ **ZA-320M**
Pulkovo, Russia, 16 febr.
- ◆ **MTM-500M**
Northern Caucasus, Russia, 16-17 febr.
- ◆ *Terai T. et al.*, *Astronomy & Astrophysics*, 2013, vol. 559, A106.
Saitama Univ. observatory, Japan, 16 febr. (Graphical data)
- ◆ *MPC* (MPS 456433)
Galati observatory, Romania, 16 febr. (Digital data)
- ◆ *Birtwhistle P.* <http://peter-j95.blogspot.ru/2013/02/partial-lightcurve-for-2012-da14.html>
England, 16-17 febr. (Graphical data)



◆ MTM-500M (19 febr.)
Northern Caucasus, Russia

Preliminary results of modeling of Duende rotation



Semi-axis of body ellipsoid (NASA radar data) – 4:2:1,
semi-axis of “photometrical” ellipsoid – 10:2:1
⇒ heterogeneous albedo and/or non-ellipsoidal form

Rotation of rotational axis (tumbling)

2014 HQ124

Close approach (0.0086 a.u.) on 2014-06-08.

- GAIA FUN SSO training observational campaign
- Campaign of Lohrman observatory (Dresden) for triangulation (synchronous observations)

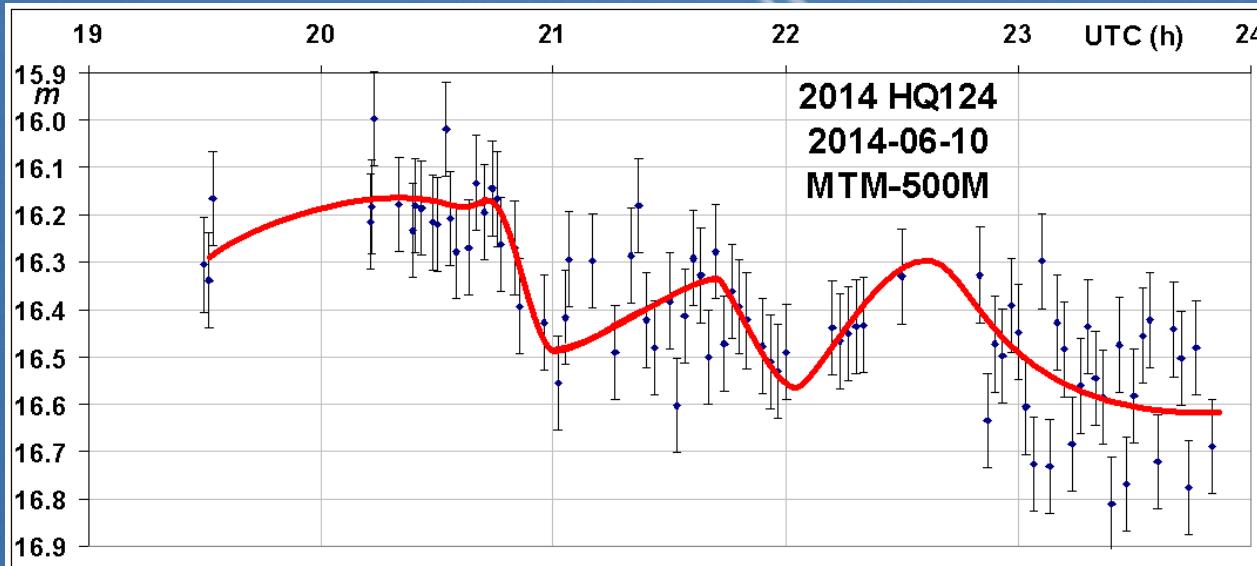
84 astrometric positions with average accuracy

0 ″.19 for right ascension

0 ″.26 for declination

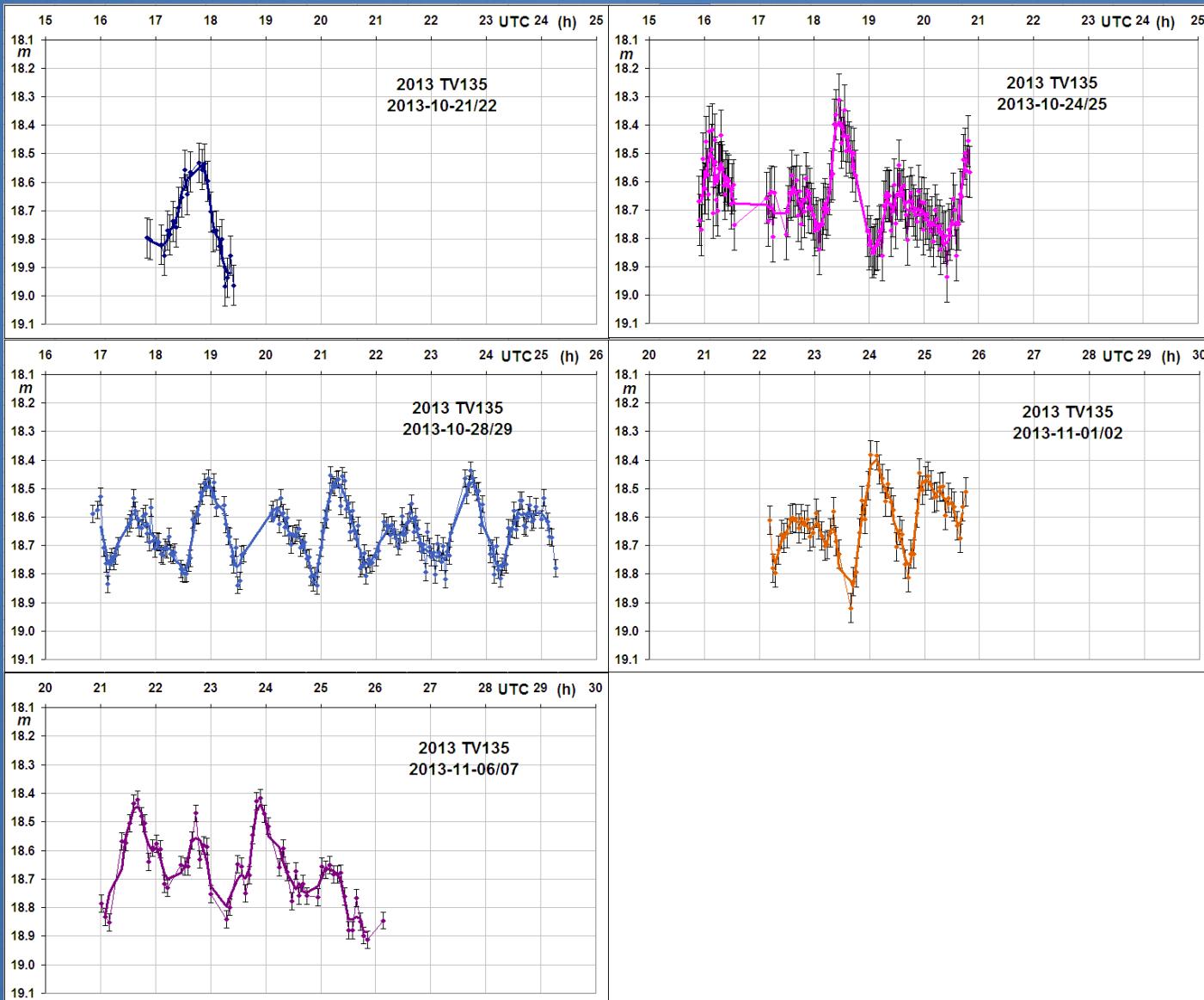
including 18 positions

at appointed time moments for triangulation

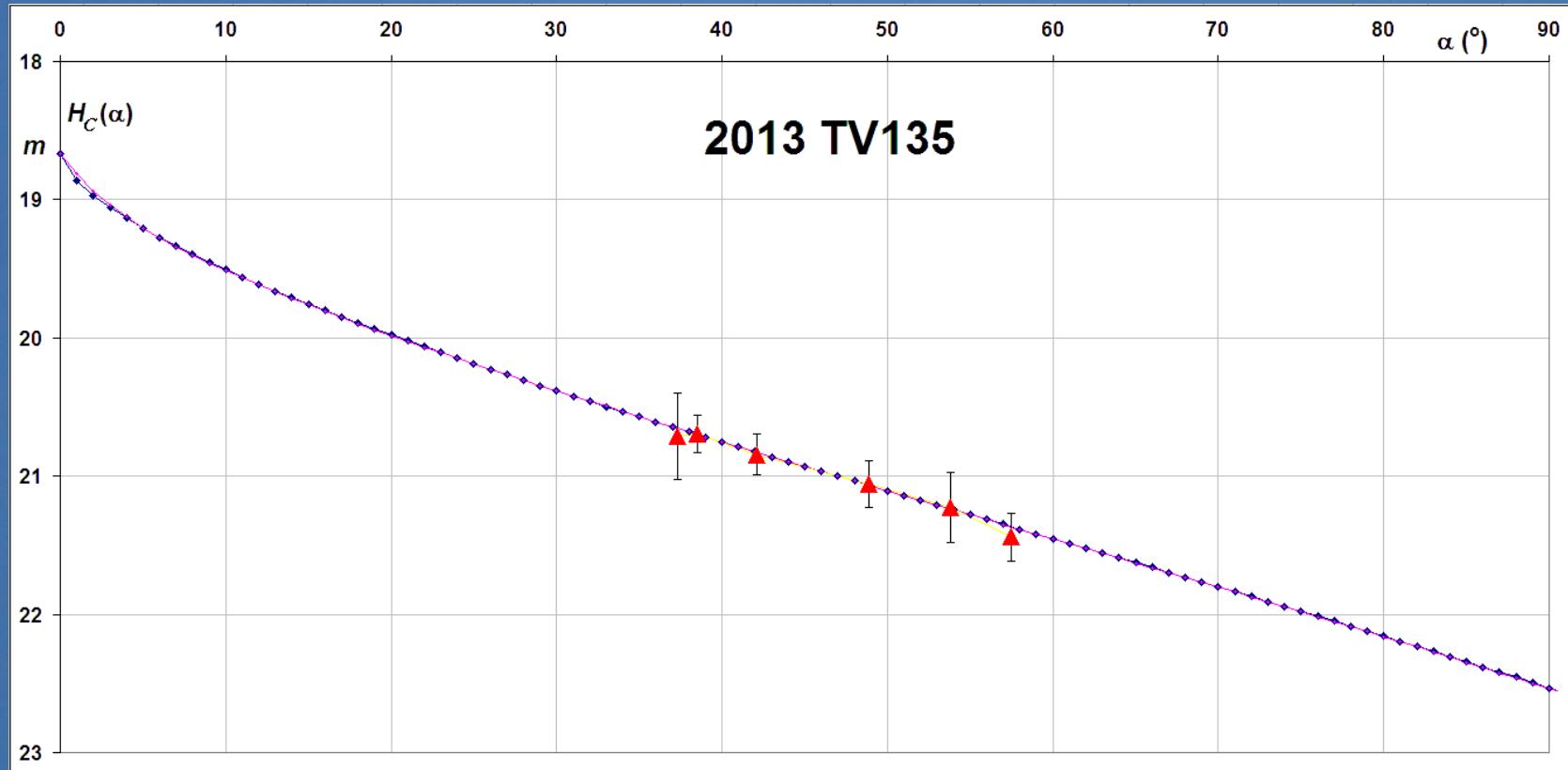


2013 TV135

Approach (0.045 a.u.) on 2013-09-17.
(GAIA FUN SSO training observational campaign)

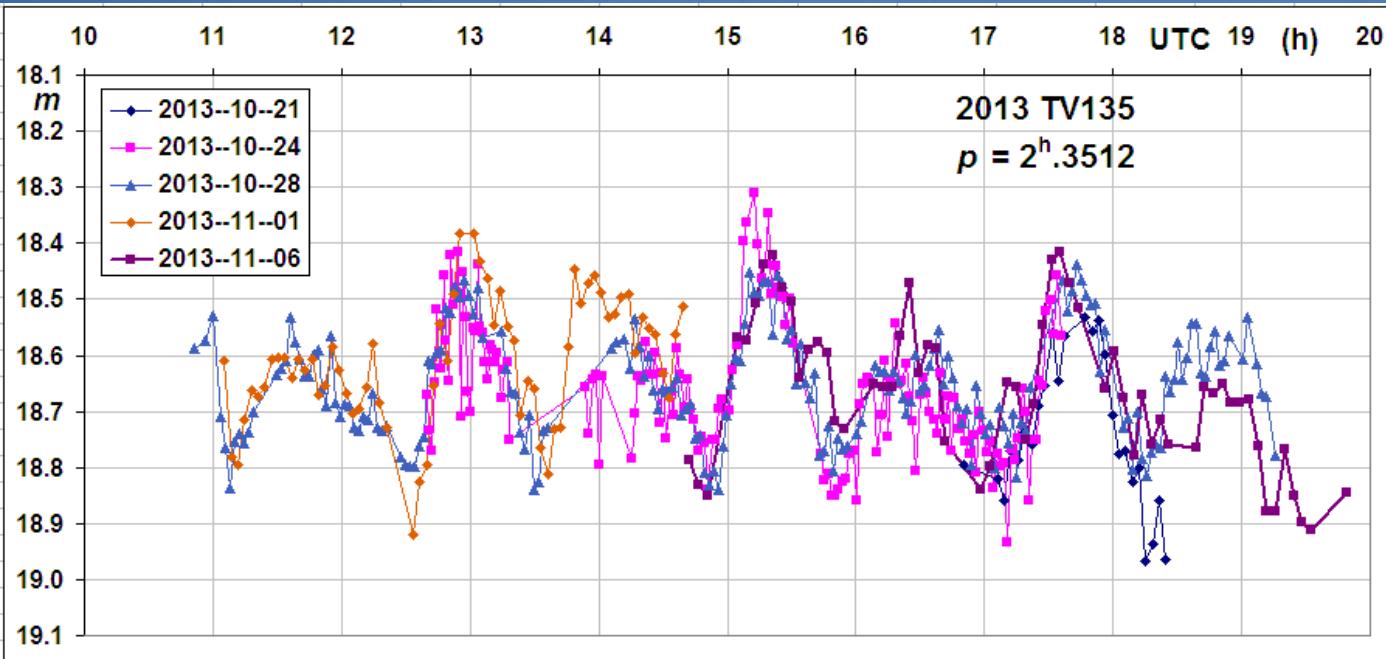


2013 TV135

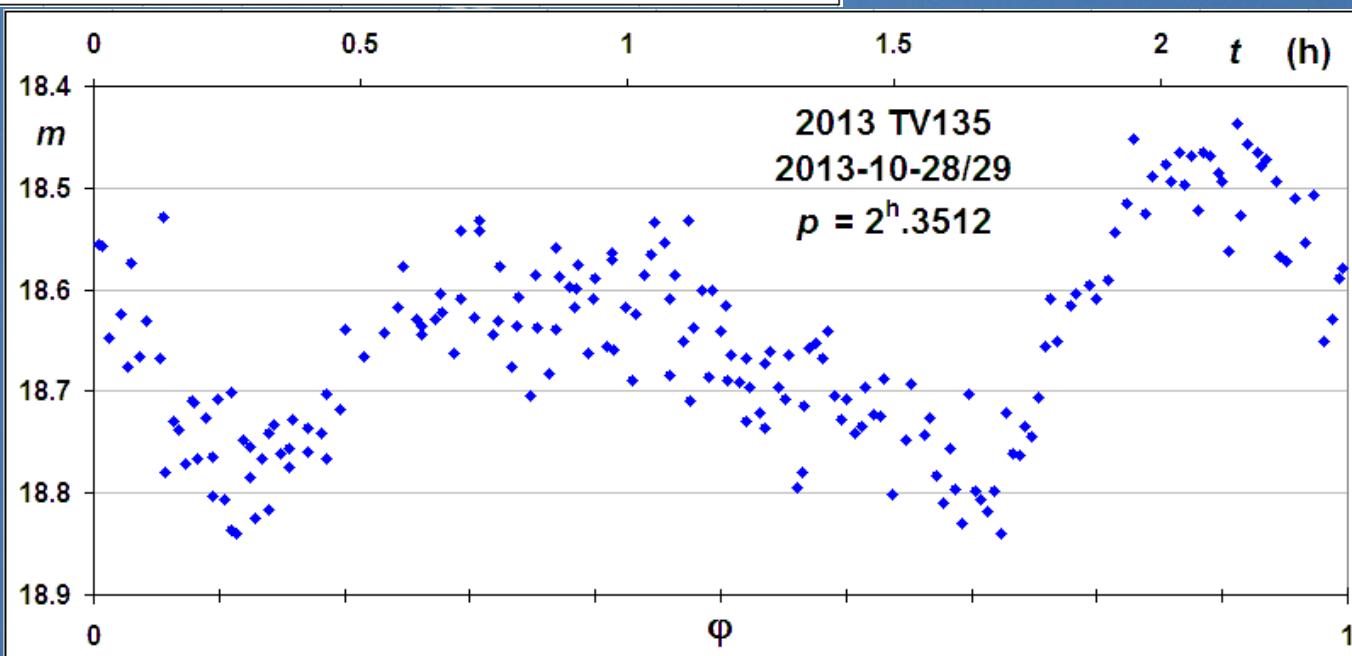


$$G = -0.06 \pm 0.03$$
$$H_R \approx 18.7^m \pm 0.2^m$$

2013 TV135

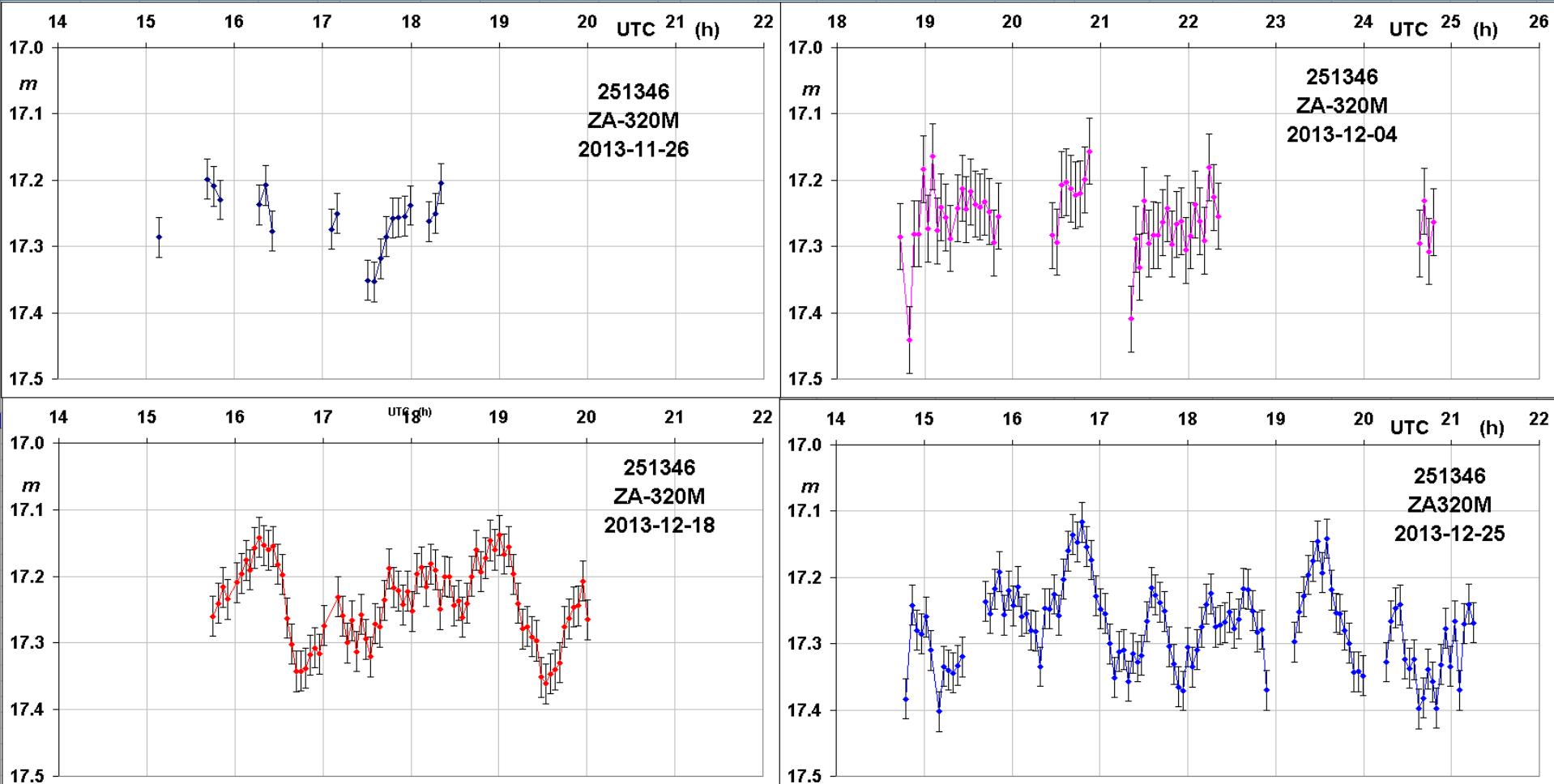


$$p = 2.3512^h \pm 0.0004^h$$

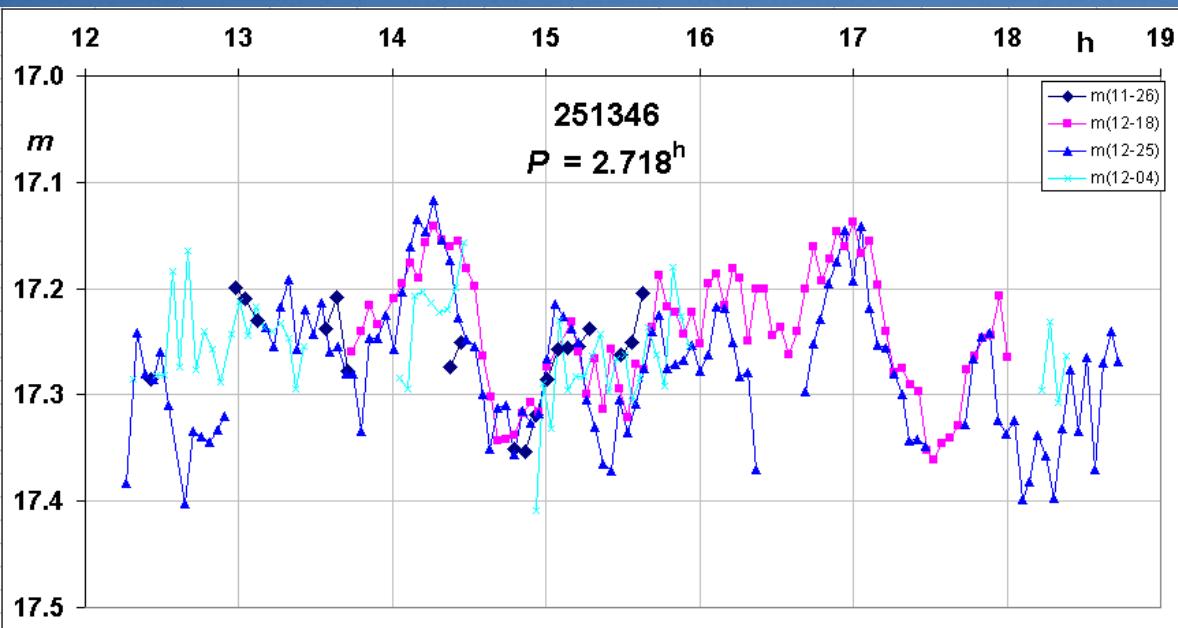


251346

Approach (0.049 a.u.) on 2014-01-22.



251346



251346
 $P = 2.718^h$

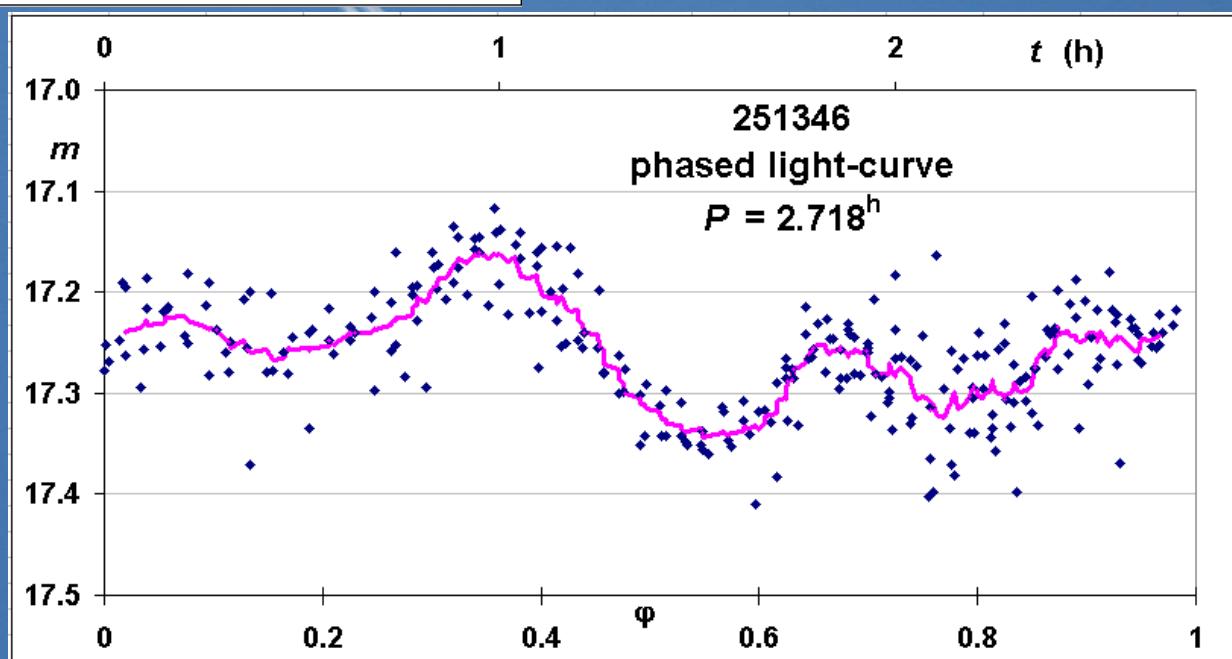
$P = 2.718^h$

[<http://ssd.jpl.nasa.gov/sbdb.cgi#top>]

[Hicks, M.; Ebelhar, S.. (2014) Astronomer's Telegram

5801. <http://www.astronomerstelegram.org>]

[Warner, B.D. (2014) Minor Planet Bul. 41, 113-124.]



285263	2013-06-01	0.039 a.u.	P = 4.749h
2010 XZ67	2013-12-30	0.064 a.u.	P = 15.05h
(388188) 2006 DP14	2014-02-11	0.016 a.u.	P = 5.77h

...

...



AZT-16

(Cerro El Roble, Chile)

**Double-meniscus
Maksutov system**

$D = 1.0 \text{ m (mirror)}$
 $D = 0.7 \text{ m (meniscus)}$
 $F = 2.06 \text{ m}$

**Astrometric
FoV $\approx 5^\circ \times 5^\circ$**

CCD-camera
SBIG STX-16803
 $4096 \times 4096 \text{ pix.}$
 $9 \times 9 \mu\text{m}$
FoV $\approx 1^\circ \times 1^\circ$

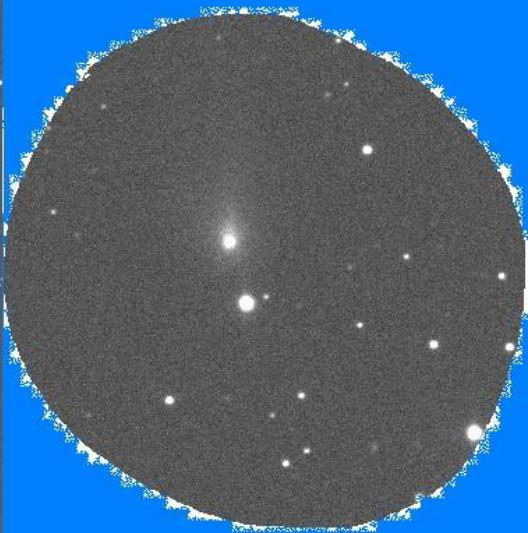
Up to 22^m



AZT-16



**Comet Loneos
AZT-16
2013-04-18
04:31:21.29 UTC**



**Thank you
for your attention!**

