

**Osservatorio Astronomico**  
della **Regione Autonoma**  
**Valle d'Aosta**  
**Planetario di Lignan**



**Observatoire Astronomique**  
de la **Région Autonome**  
**Vallée d'Aoste**  
**Planétarium de Lignan**



# Ricerca di Large Super-Fast Rotators tra i NEAs

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Candidato: Monte Silvia

# L'Osservatorio

OAVdA, Lignan, Saint Barthélemy

Ottobre-Dicembre 2014



La struttura e la cupola del telescopio principale

A screenshot of the OAVdA website homepage. The page features a dark blue header with the observatory's name and logo. Below the header, there are several sections: a navigation menu, a 'fondazione clément filletroz ONLUS' contact box, a 'NOSTRI FACEBOOK' section with social media links, a 'TRIPADVISOR' section with a review link, an 'ASTEROID DAY' announcement for June 30, 2015, and a 'STAR PARTY a Saint-Barthélemy' announcement for September 2015. The page also includes logos for 'AMMINISTRAZIONE TRASPARENTE', '5 PER MILLE', and 'astronomical expo 2015 science &amp; technology'.

Il sito [www.oavda.it](http://www.oavda.it)

- Cosa sono i Near Earth Asteroids?
- Large Super-Fast Rotators
- Gli oggetti osservati
- Strumentazione
- Analisi dati e risultati
- Conclusioni
- Pubblicazioni

# Near Earth Asteroids

**Asteroidi:** dimensioni  $10^2$ - $10^5$  m, residuo della formazione planetaria (~ 4 miliardi di anni fa)

**Main Belt Asteroids:** tra le orbite di Marte e Giove ( $a = 2.1$ - $3.3$  UA\*)

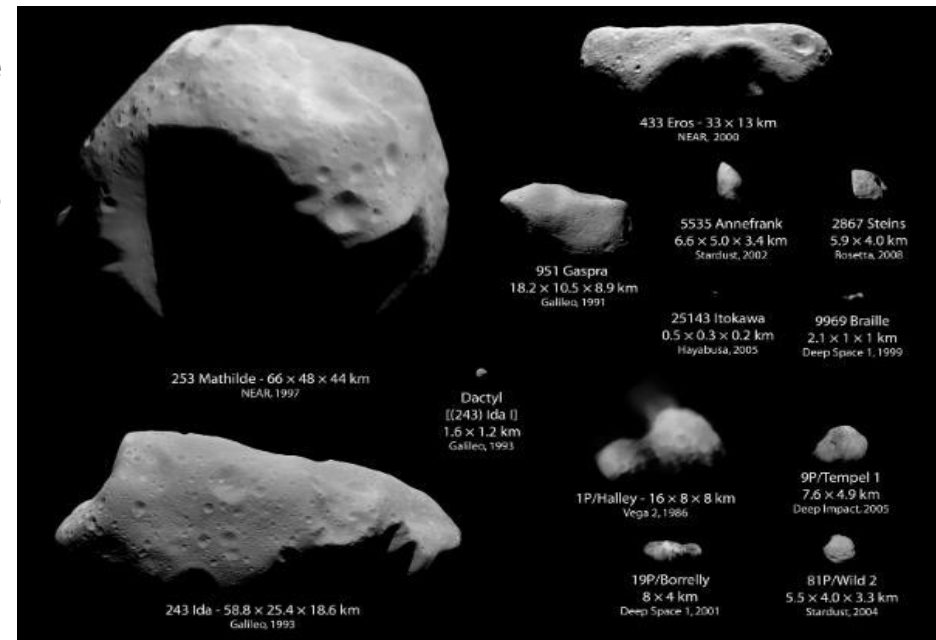
**NEA:** sono asteroidi che possono arrivare a 0.3 UA dall'orbita terrestre

**Aten-Apollo-Amor:**  $a \leq 2.1$  UA (incontri ravvicinati con i pianeti terrestri, PHA)

## Classificazione tassonomica

- **C:** somiglianza con le condriti carbonacee
- **S:** composizione rocciosa
- **V:** composizione basaltica (Vesta)
- **M:** composizione metallica

\* 1 UA ~ 150 milioni di km (distanza media Terra-Sole)

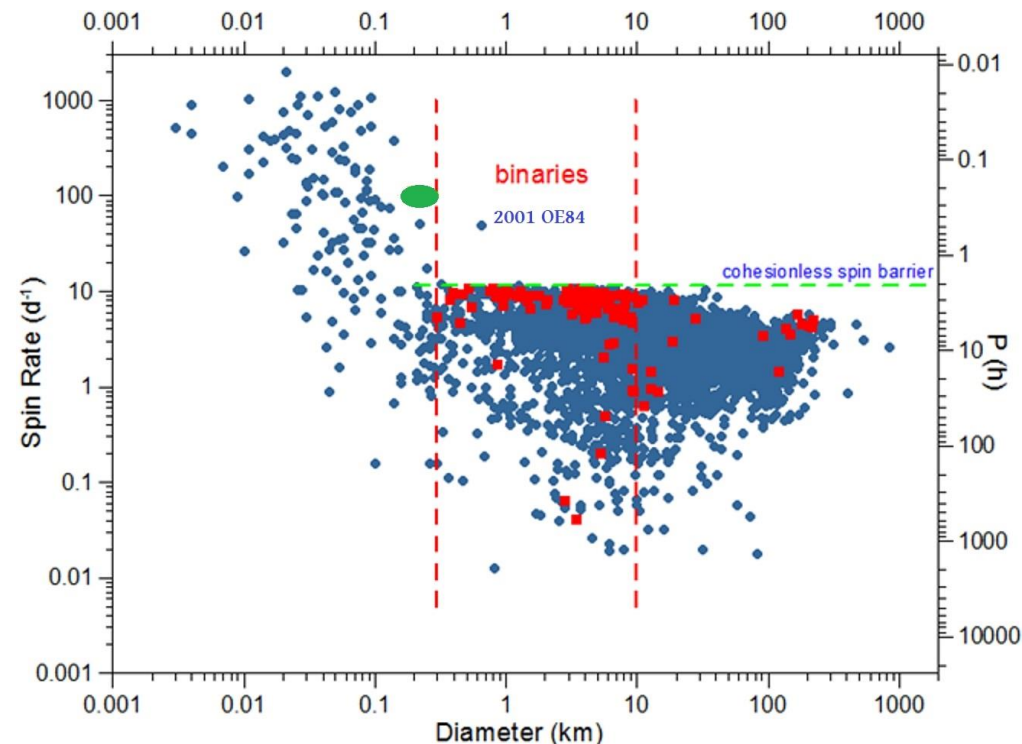


# I LSFR e la teoria dei binari

1996, Harris, **cohesionless spin-barrier**

- $d > 150$  m : struttura rubble-pile (blocchi tenuti insieme dalla forza gravitazionale mutua)  
     $P < 2.2$  h si ha rottura dell'asteroide e creazione di un sistema binario.
- $d < 150$  m : schegge monolitiche (forze di coesione interne)

2007, Holsapple, **Super Fast Rotators** (e.g. 2001 OE84 con  $P = 0.486$  h, 2005 UW163 con  $P = 1.290$  h )



# I LSFR e la teoria dei binari

2014, Sanchez e Sheeres, dipendenza del tasso di spin dalle dimensioni dell'asteroide:

$$\omega^2 \leq \omega_a^2 + \frac{\sigma\gamma}{a^2\rho}$$

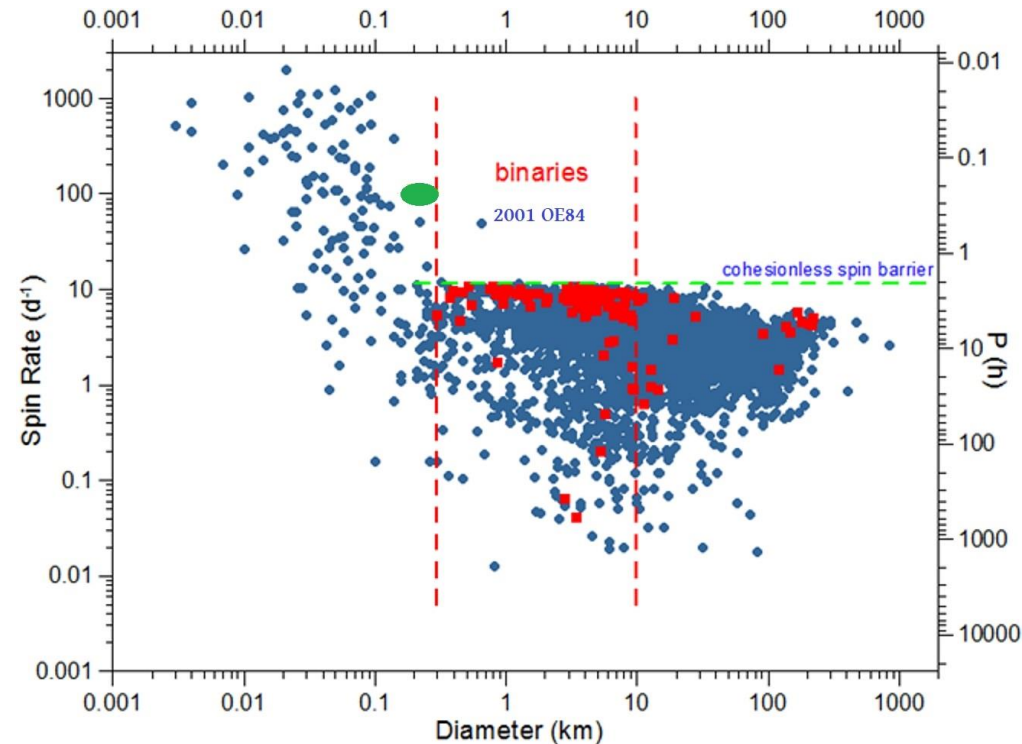
$\omega = 2\pi/P$  : tasso di spin

$\omega_a$  : valore della spin barrier

$\sigma\gamma$  : forza di coesione per area superficiale

$a$  : semiasse maggiore

$\rho$  : densità media



Si osservano asteroidi per determinarne il periodo di rotazione e verificare eventuali violazioni del valore di spin-barrier.



# Gli oggetti osservati

Ricerca di candidati LSFR usando la fotometria differenziale dei NEA.

## Caratteristiche:

- fly-by con la Terra
- magnitudine apparente  $\leq +17$
- velocità  $\leq 10$  arcsec/min
- altezza sopra l'orizzonte  $\geq 20^\circ$

([www.minorplanetcenter.net](http://www.minorplanetcenter.net))

La durata delle osservazioni è diversa a seconda della velocità dell'asteroide e della sua magnitudine.

# Gli oggetti osservati

## Target:

1355 Magoeba (MBA)

**1998 SS49**

**4401 Aditi**

**2014 VQ**

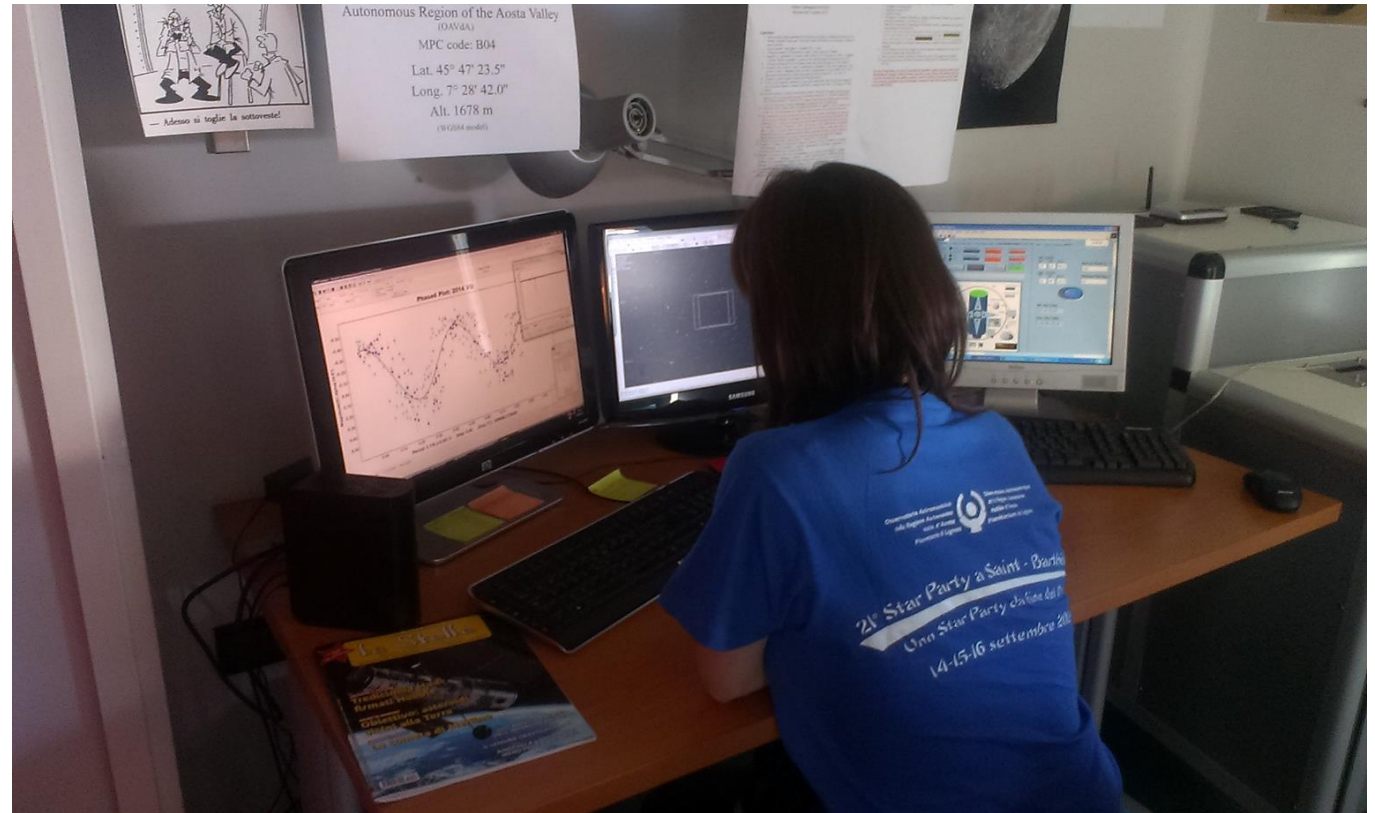
**2004 JN13**

**1998 WQ5**

2001 EA16

2001 QU159

2004 BL86



Dopo il periodo della tesi il lavoro dei ricercatori dell'OAVdA è continuato con l'osservazione di altri target:

1999 CU3 2000 BJ19 1996 FR3 2014 YM9 2012 LC1 2006 TN



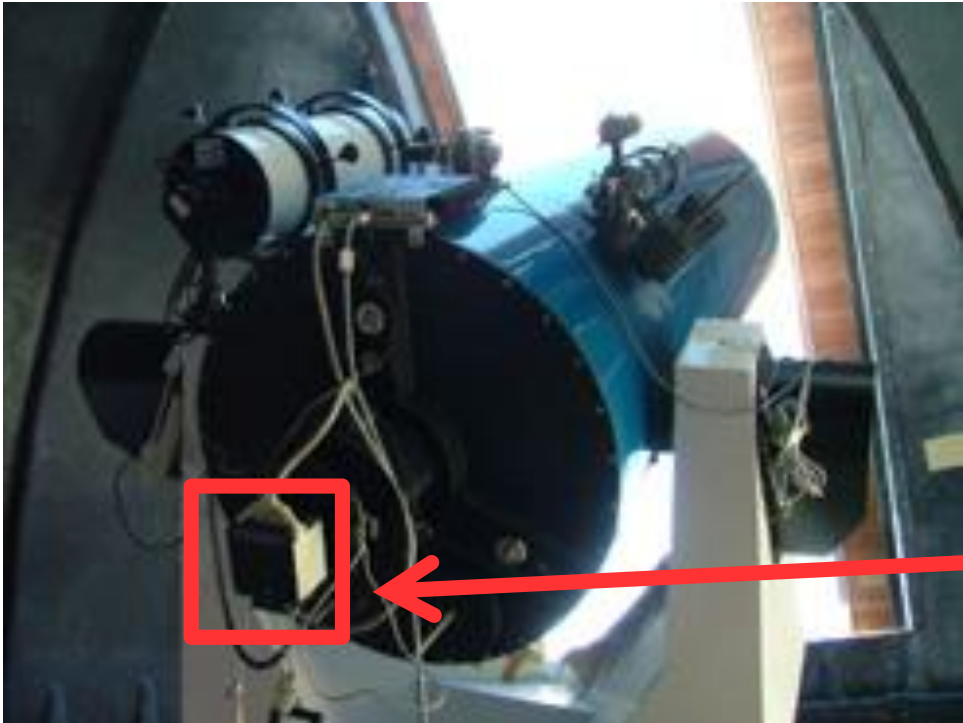
# Strumentazione



## OAVdA:

- telescopio riflettore Ritchey-Chrétien 0.81 m, f/7.9
- controllo elettronico del telescopio e della cupola
- FoV 13.1x13.1 arcmin
- camera FLI 1001E CCD (1024x1024 pixels) , plate scale 1.54 arcsec per pixel (binning 2x2)

# Strumentazione



OAVdA:

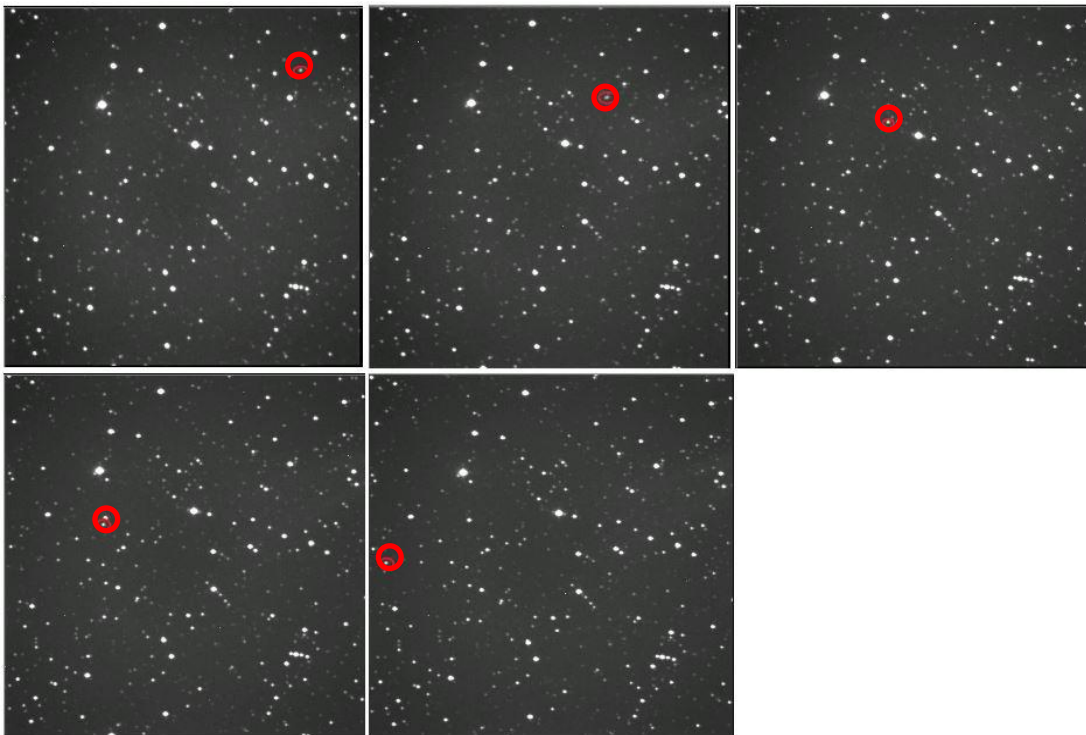
- telescopio riflettore Ritchey-Chrétien 0.81 m, f/7.9
- controllo elettronico del telescopio e della cupola
- FoV 13.1x13.1 arcmin
- camera FLI 1001E CCD (1024x1024 pixels) , plate scale 1.54 arcsec per pixel (binning 2x2)

# Osservazioni e analisi: il caso di 1998 SS49

## Presenza dati

Foto consecutive con apposito tempo di esposizione per un determinato numero di ore e giorni, in modo da determinare il periodo di rotazione

## Filtro C



$\Delta t = 2 \text{ h } 55 \text{ min}$

## Apollo-PHA

- 731 immagini
- 13.5 ore di osservazione (26 Ottobre 2014 – 19 Novembre 2014)
- Fly-by: 18 Novembre 2014

# Osservazioni e analisi: il caso di 1998 SS49

## Calibrazione

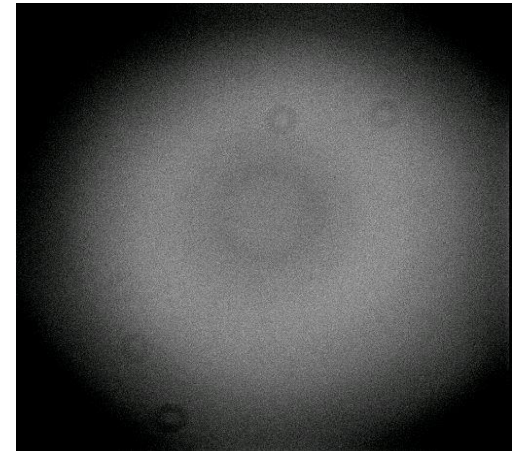
Per ricondursi al caso di CCD ideale prima di procedere con l'analisi dati: master dark e master flat



**Master dark:** no rumore termico ed elettronico  
stessa T (-30° C) e tempo di posa (60 s) dell'immagine ripresa (otturatore chiuso)

**Master flat:** immagine uniformemente illuminata

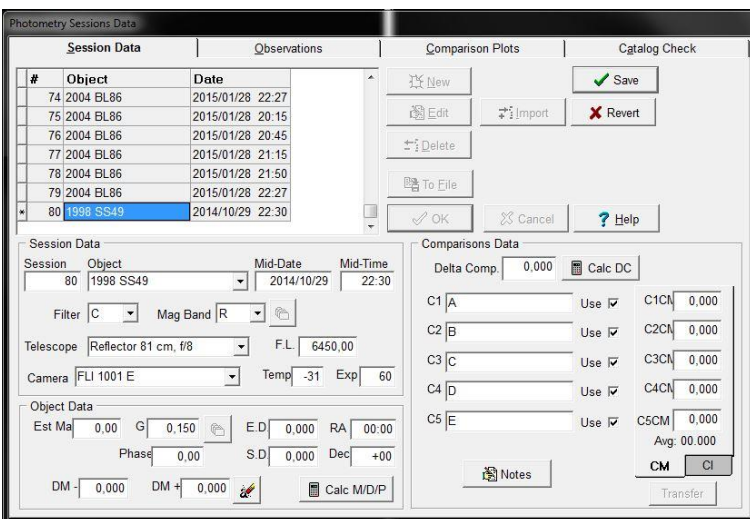
- sensibilità pixel
- grani di polvere
- vignettatura



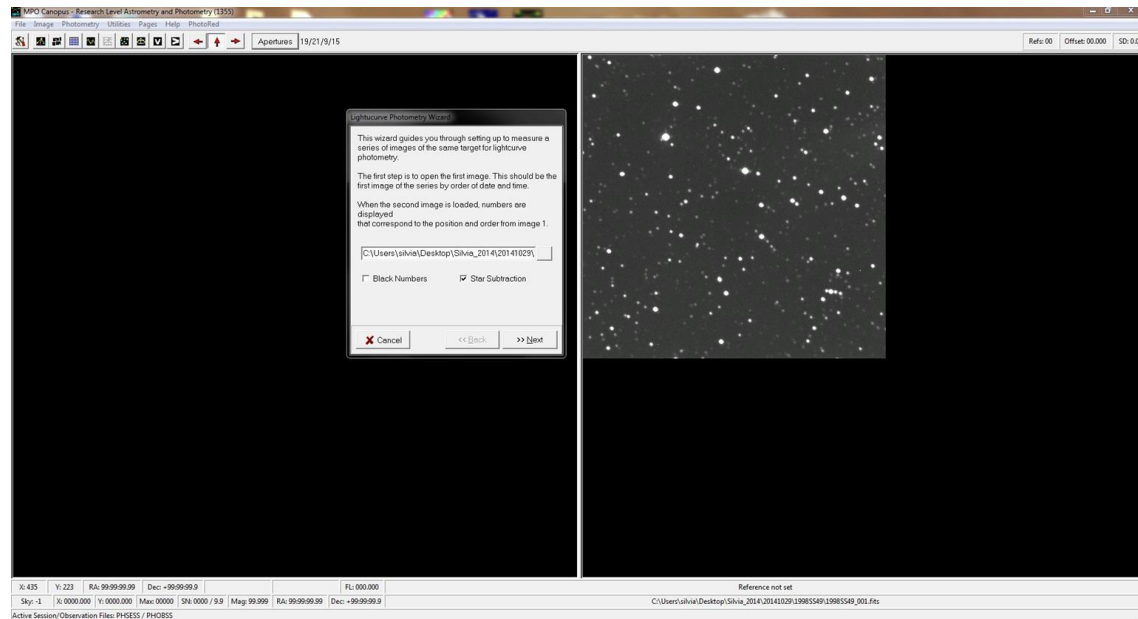
# Osservazioni e analisi: il caso di 1998 SS49

Analisi della curva di luce:

Uso del software MPO Canopus v. 10.4.7.6



Creazione sessione osservativa



Caricamento prima immagine

# Osservazioni e analisi: il caso di 1998 SS49

MPO Canvas - Research Level Astronomy and Photometry (1953)

File Image Photometry Utilities Pages Help PhotoPad

Apertures 19/21/9/15 Refs: 00 OffSet: 00.000 SD: 0.000

Image #1	X Centroid	Y Centroid
Star 1	381,8594	252,5361
Star 2	0,0000	0,0000
Star 3	0,0000	0,0000
Star 4	0,0000	0,0000
Star 5	0,0000	0,0000
Target	0,0000	0,0000

Show Path Clear Selector

Target Comp

Cancel Back Next

X: 130 Y: 200 RA: 99:99:99.99 Dec: -99:99:99.99 Fl: 000.000 Reference not set  
 Sky: 7302 X: 301,069 Y: 252,536 Mac: 41562 Mas: 5083,778 IM: -10,840 RA: N/A Dec: N/A  
 Active Session/Observation Files: PHOESS / PHOESS

Identificazione stelle di confronto

MPO Canvas - Research Level Astronomy and Photometry (1953)

File Image Photometry Utilities Pages Help PhotoPad

Apertures 19/21/9/15 Refs: 00 OffSet: 00.000 SD: 0.000

Image #1	X Centroid	Y Centroid
Star 1	381,8594	252,5361
Star 2	485,4378	411,5975
Star 3	442,9844	253,5783
Star 4	145,4785	383,7922
Star 5	194,8597	88,3198
Target	426,1875	88,3417

Show Path Clear Selector

Target Comp

Cancel Back Next

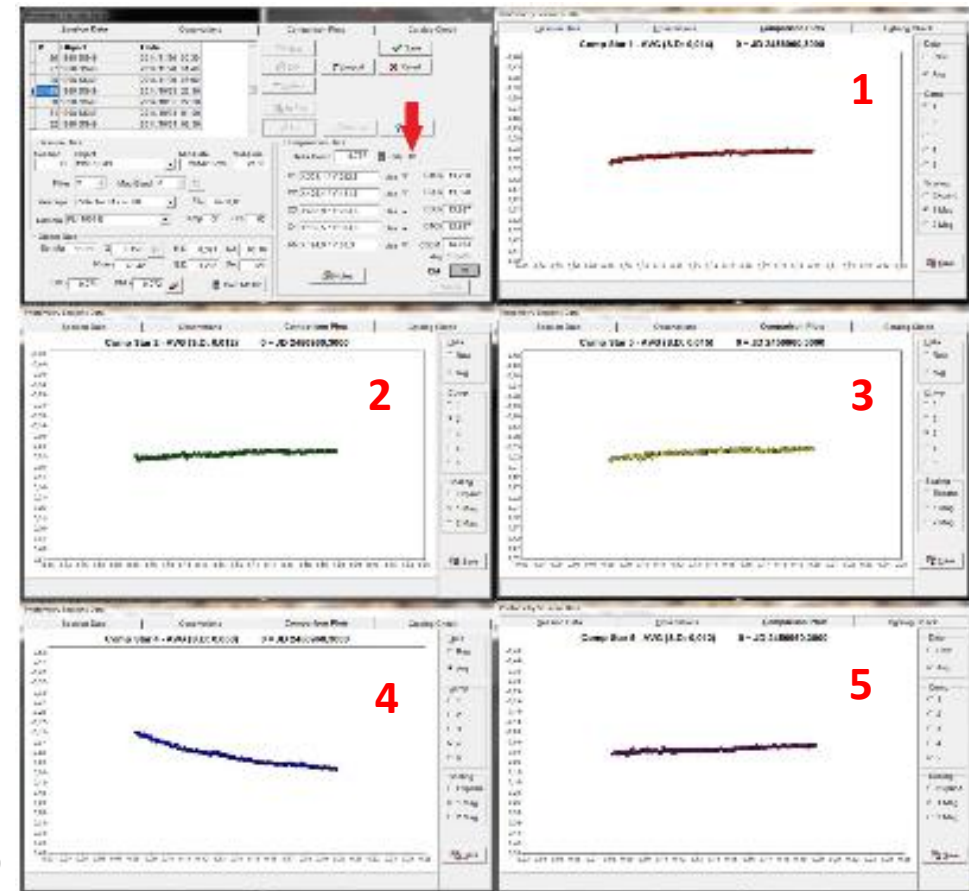
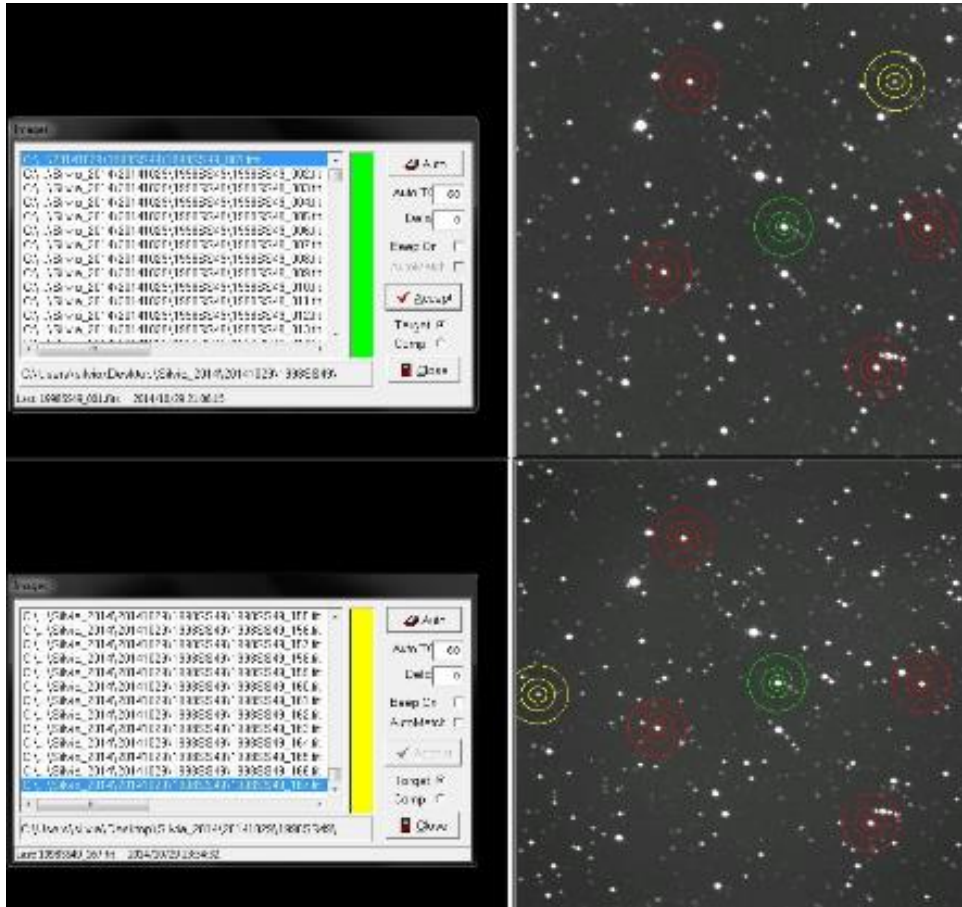
X: 15 Y: 184 RA: 99:99:99.99 Dec: -99:99:99.99 Fl: 000.000 Reference not set  
 Sky: 7291 X: 426,188 Y: 88,342 Mac: 11289 Mas: 69/4,00 IM: -8,570 RA: N/A Dec: N/A  
 Active Session/Observation Files: PHOESS / PHOESS

Identificazione target



# Osservazioni e analisi: il caso di 1998 SS49

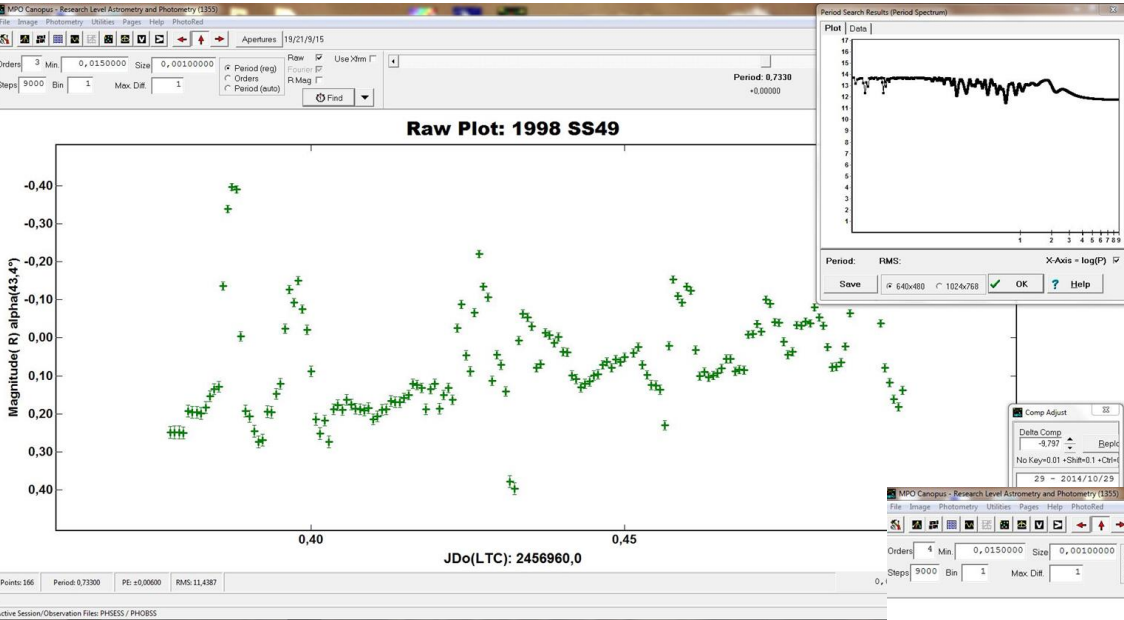
Fotometria differenziale



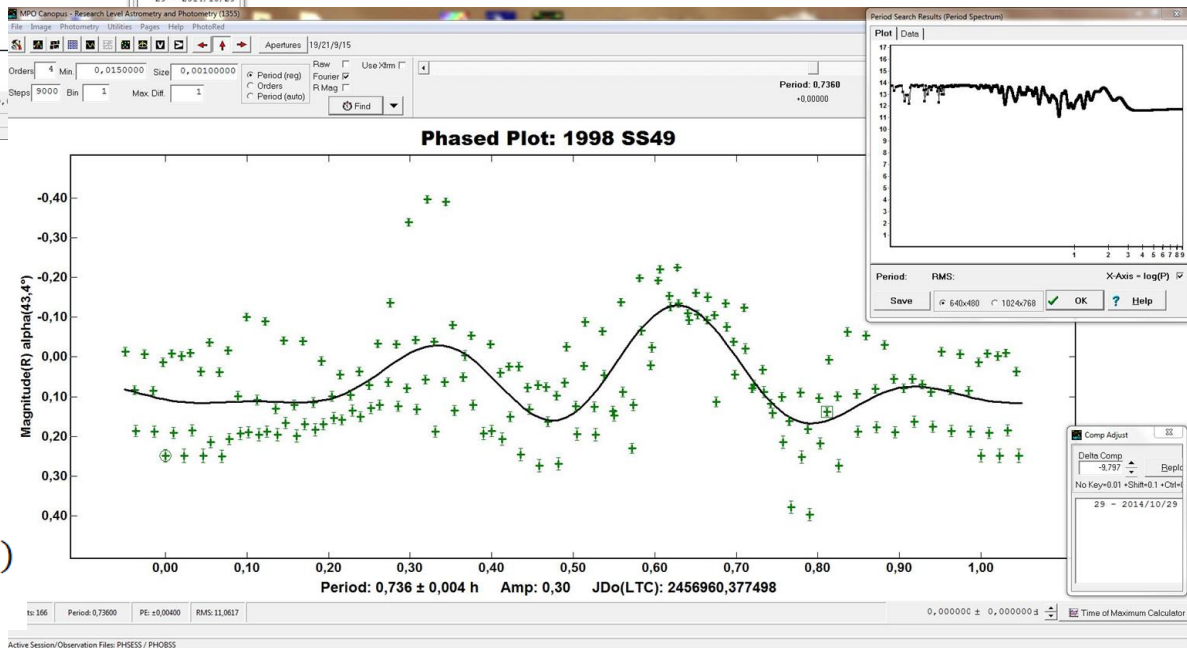
Regolarità delle stelle di confronto

# Osservazioni e analisi: il caso di 1998 SS49

Spettro Raw



Spettro di Fourier

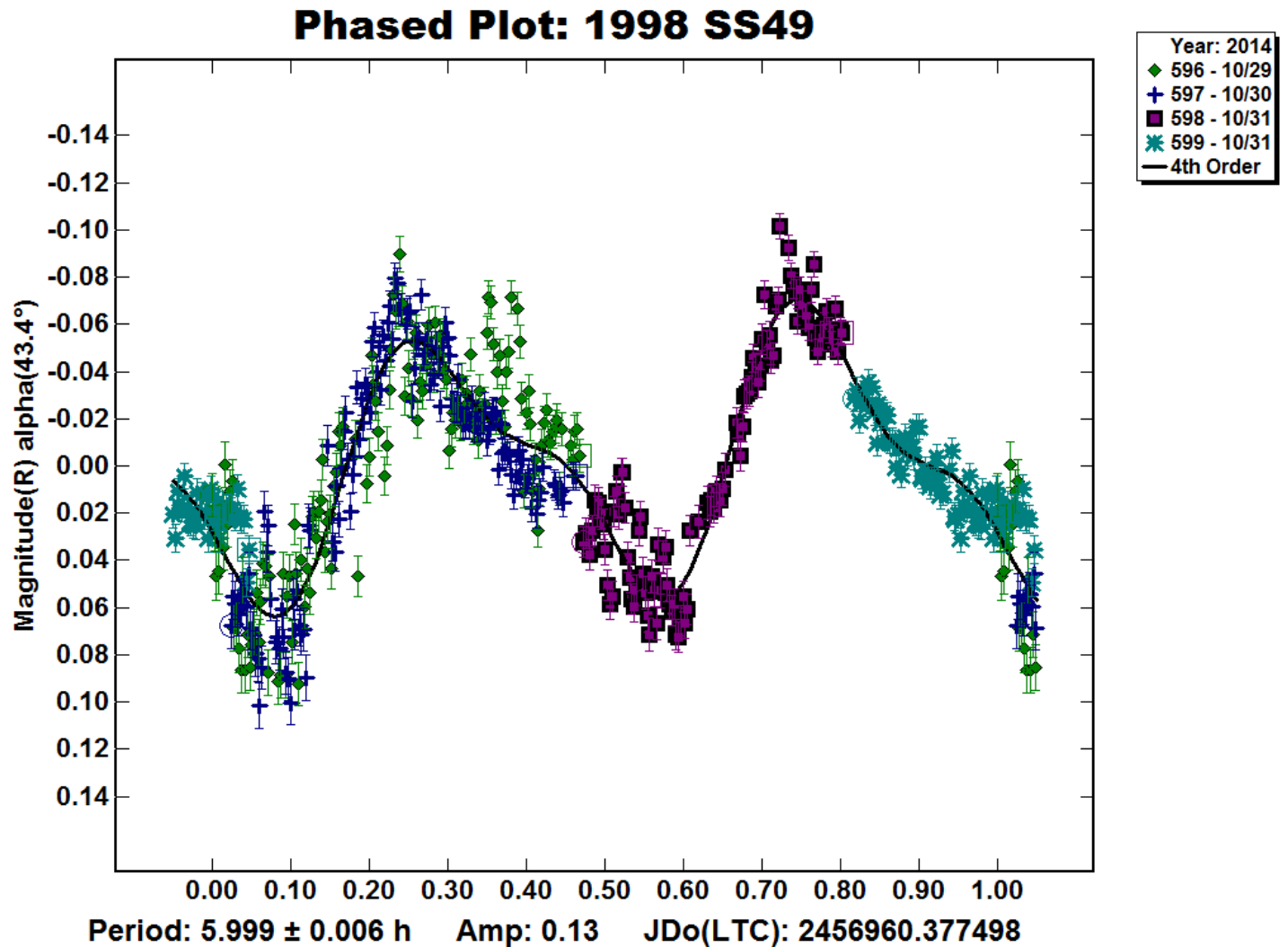


$$H(\alpha, t) = \bar{H}(\alpha) + \sum_{l=1}^m A_l \sin \frac{2\pi L}{P} (t - t_0) + B_l \cos \frac{2\pi L}{P} (t - t_0)$$

U	#	F	Start Date
<input type="checkbox"/>	25	c	2014/11/20
<input type="checkbox"/>	27	c	2014/11/20
<input type="checkbox"/>	28	c	2014/11/20
<input checked="" type="checkbox"/>	29	c	2014/10/29
<input type="checkbox"/>	30	c	2014/10/30
<input type="checkbox"/>	31	c	2014/10/31
<input type="checkbox"/>	32	c	2014/10/31

Select by Filter	
<input type="radio"/> B	<input type="radio"/> R
<input type="radio"/> C	<input type="radio"/> r
<input type="radio"/> V	<input type="radio"/> I
<input type="radio"/> g	<input type="radio"/> i
<input checked="" type="radio"/> All	



4 sessioni (6.5 ore di osservazioni) usate per la curva di luce

Il periodo di rotazione è quasi un sottomultiplo esatto del periodo di rotazione della Terra

H=15.7    D=2-3 km

# 1998 WQ5

Amor

- 317 immagini
- 11 ore di osservazione (18-19 Dicembre 2014)
- Fly-by: 25 Gennaio 2014

H=15.3

D=3-5 km

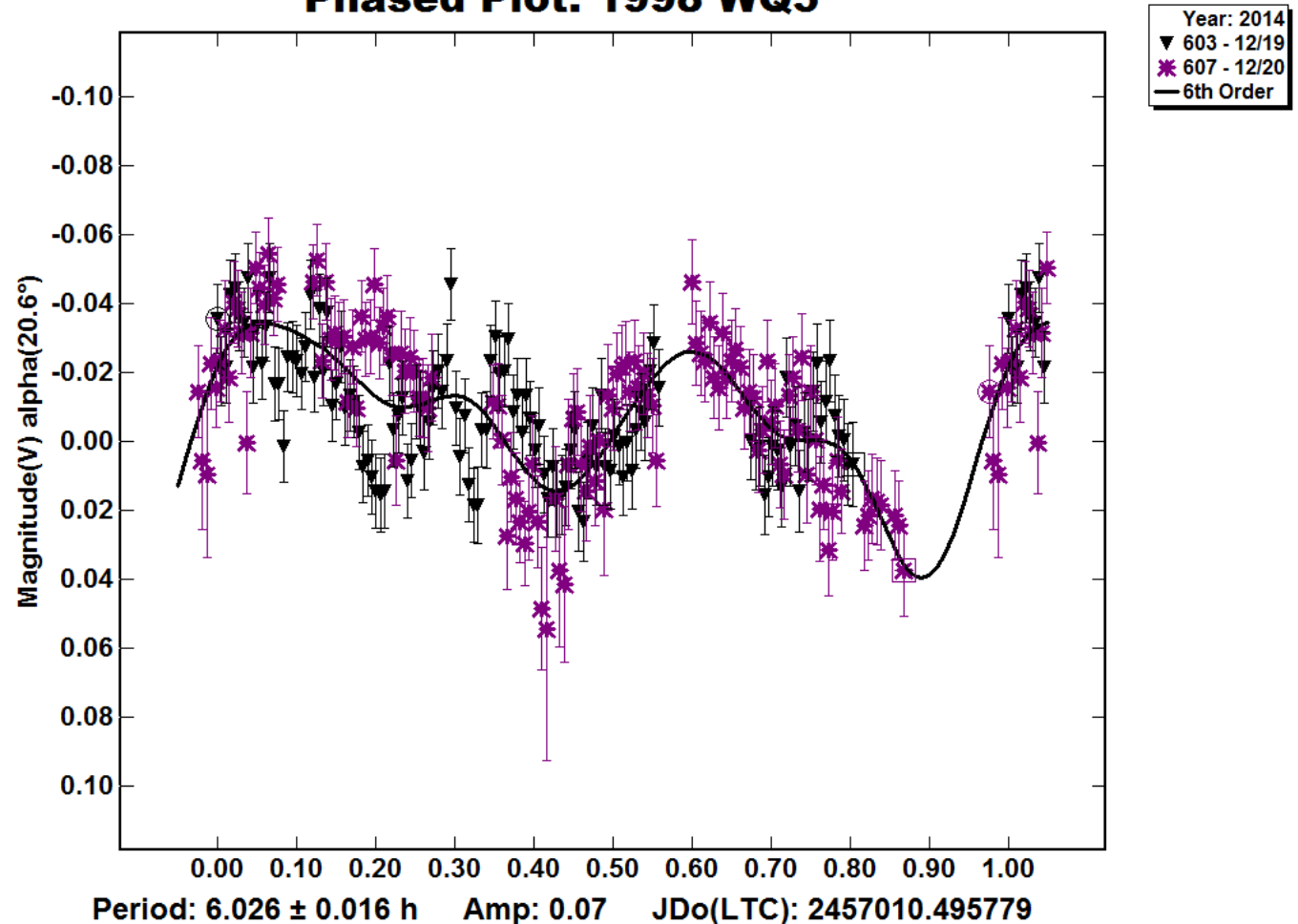
Oey, 2006 :

$T=3.0089 \pm 0.0001$  h

ampiezza 0.35 mag

Periodo difficile da determinare per  $SNR \approx 100$

**Phased Plot: 1998 WQ5**



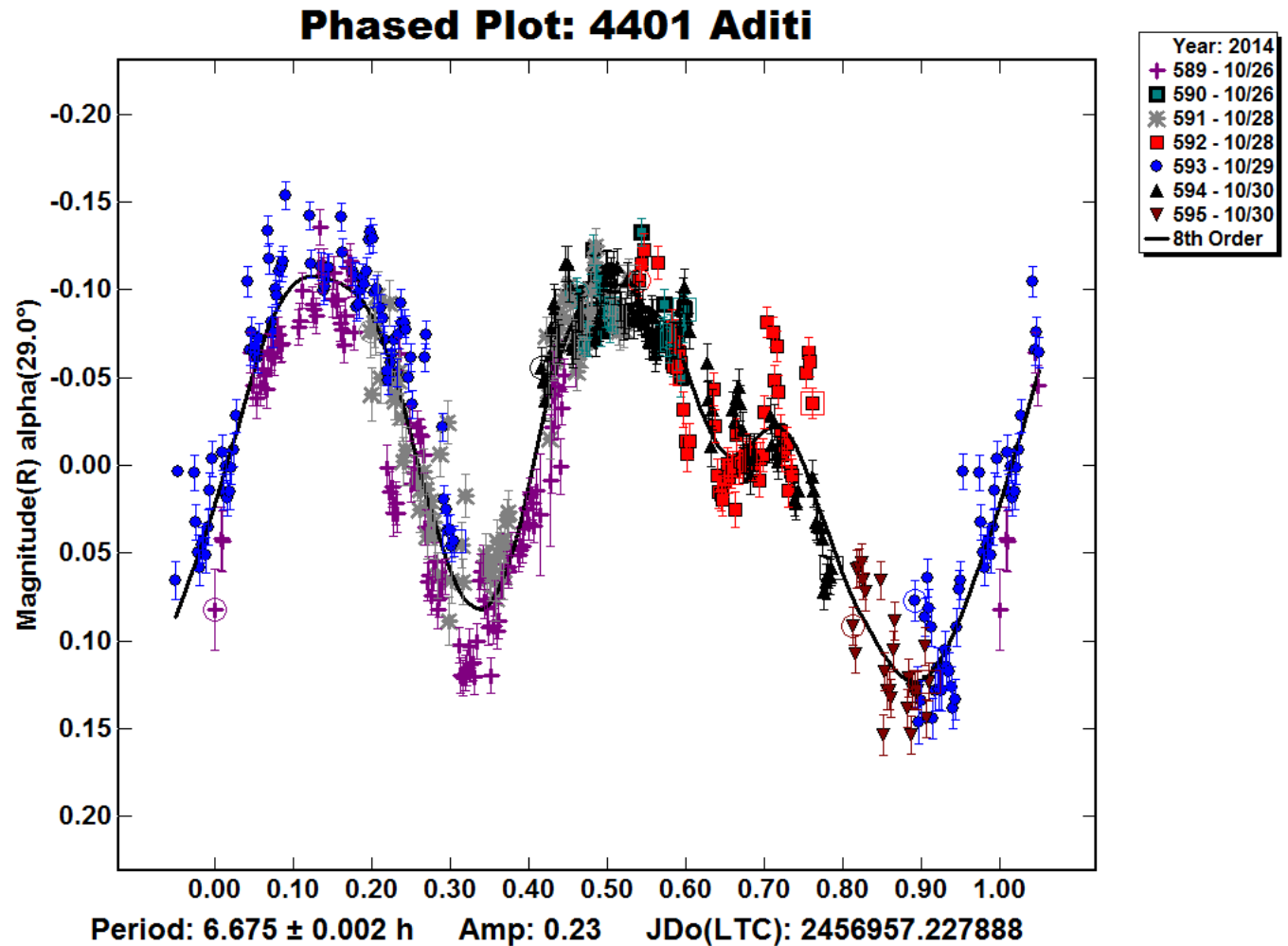
# 4401 Aditi

NEA-Amor

- 823 immagini
- 14.5 ore di osservazione (26-28-29-30 Ottobre 2014)
- Fly-by: 06 Novembre 2014

H=15.9

D=1.2-3.7 km

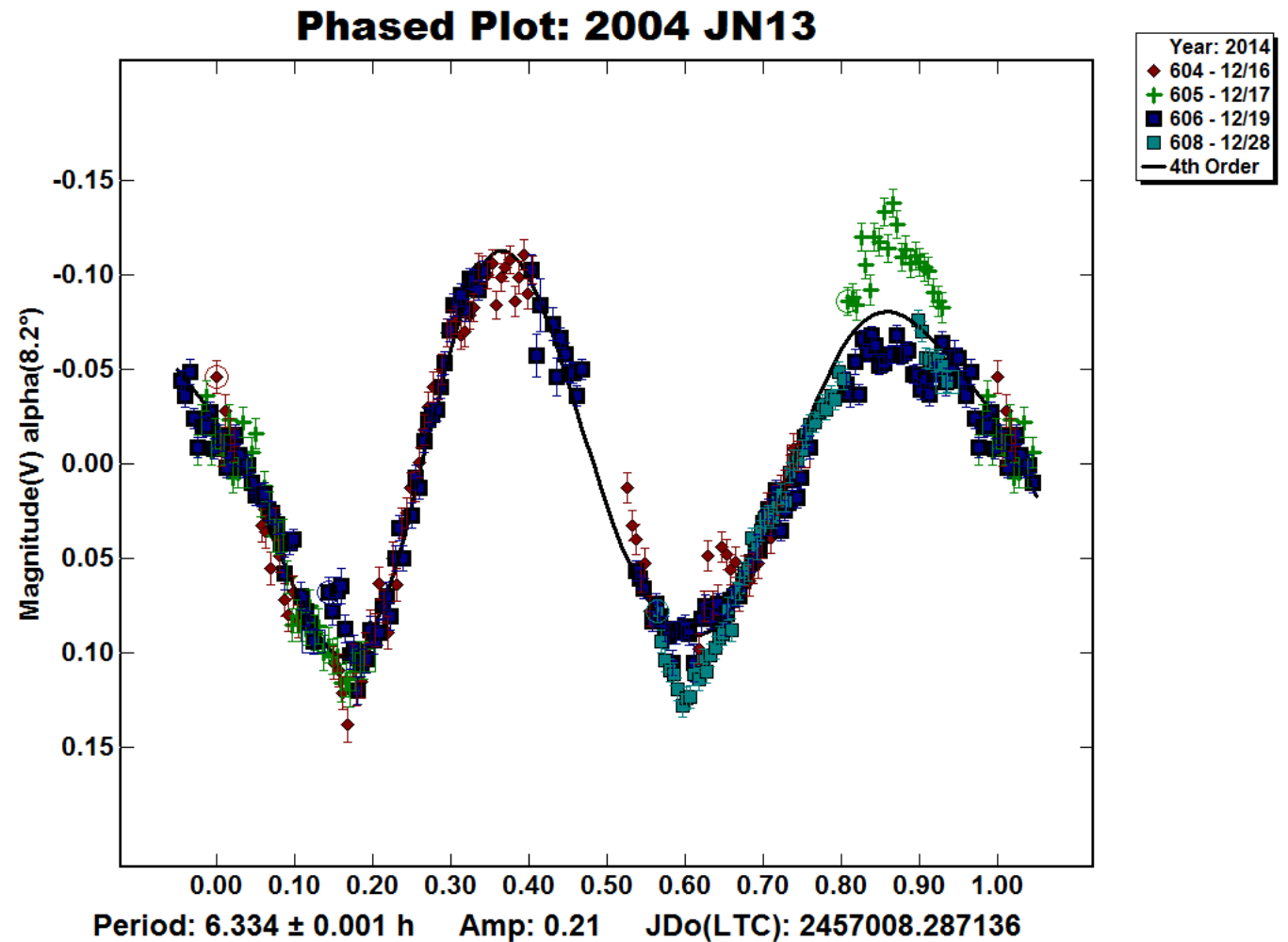


# 2004 JN13

## Apollo

- 887 immagini
- 17 ore di osservazione (16-19-28 Dicembre 2014)
- Fly-by: 18 Novembre 2014

$$D = 2.7 \pm 0.6 \text{ km}$$

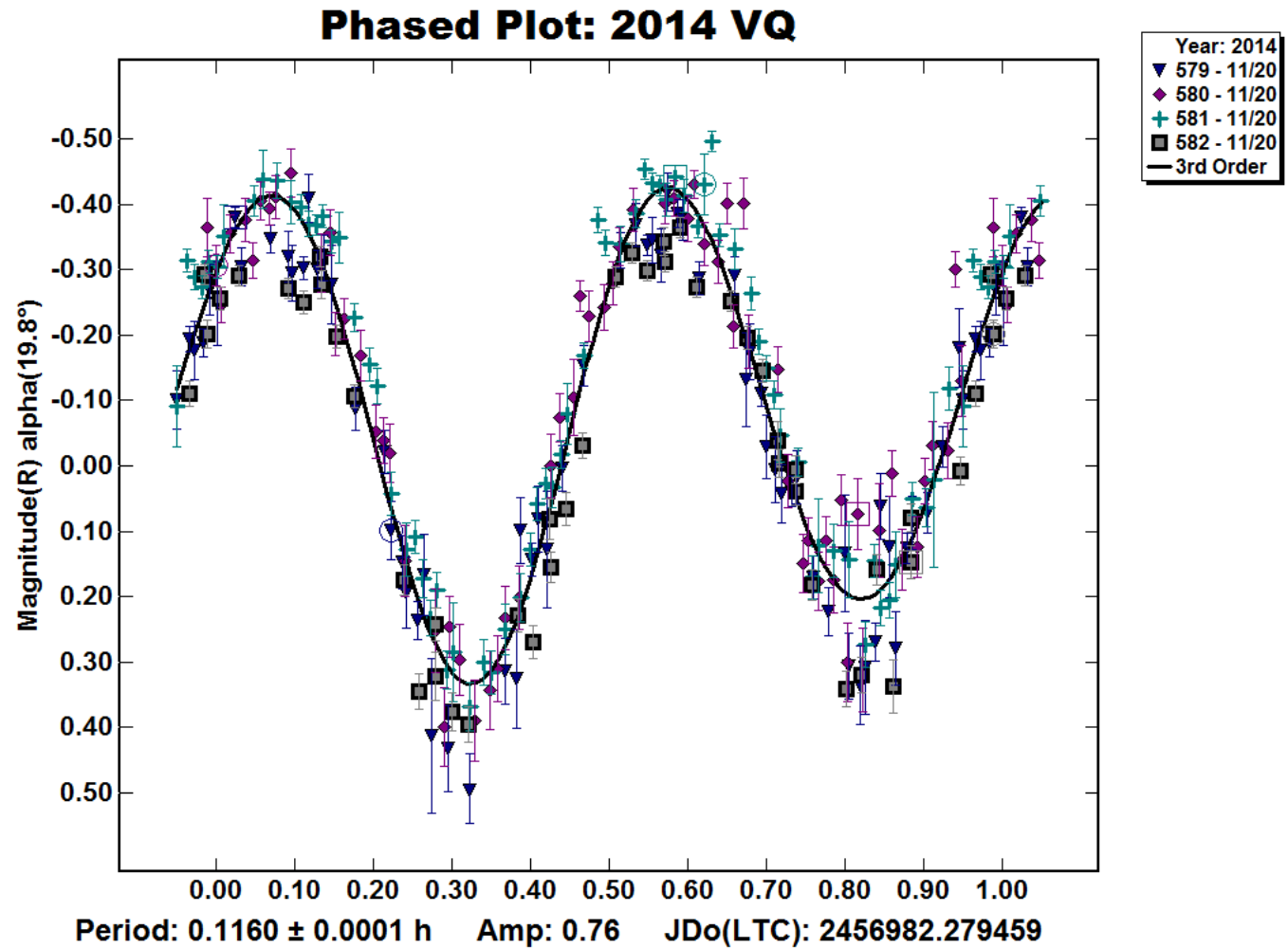




# 2014 VQ

NEA-Amor

- 325 immagini
- 5.5 ore di osservazione (20 Novembre 2014)
- Fly-by: 13 Novembre 2014



# 2014 VQ

Collaborazione con Pravec P. et coll. (Ondrejov Observatory)

$P = 0.116032 \pm 0.000001$  hours

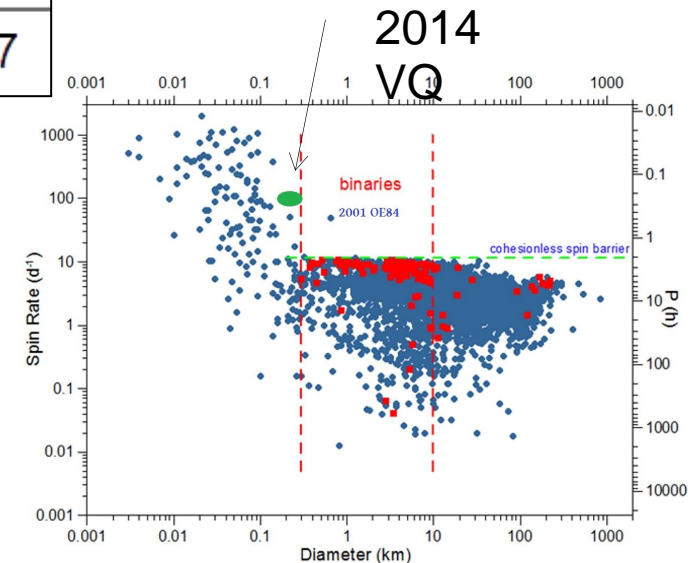
Misura indici V-R. (La Silla, Chile)

Color index (V-R) =  $0.483 \pm 0.01$  mag

tipo	G	$H_V$ (mag)	$p_V$	D (km)
S	$0.24 \pm 0.11$	$20.23 \pm 0.20$	$0.20 \pm 0.05$	$0.267 \pm 0.043$
V	$0.43 \pm 0.08$	$20.52 \pm 0.11$	$0.40 \pm 0.05$	$0.165 \pm 0.027$

La misura dell'indice B-V non è stata effettuata

E' un possibile candidato a LSFR!



# Conclusioni

Asteroide	Notti di osservazione	Periodo (h)	A (mag)	H <sub>V</sub> (mag)	D (km)
2014 VQ	1	0.116032 ± 0.000001	0.75	20.23 ± 0.20	0.267 ± 0.043
				20.52 ± 0.11	0.165 ± 0.027
1998 SS49	4	5.999 ± 0.008	0.13	-	-
1998 WQ5	2	6.026 ± 0.016	0.07	-	-
2004 JN13	3	6.334 ± 0.001	0.21	15.20 ± 0.4	2.7 ± 0.6
4401 Aditi	4	6.675 ± 0.002	0.23	-	-

# XII Congresso Italiano di Planetologia, Bormio (02-06 febbraio 2015)

## Search of Large Super-Fast Rotator Between NEAs

XII Congresso Italiano di Planetologia, Bormio 2-6 Febbraio 2015  
 A. Carhognani<sup>1</sup>, P. Pravec<sup>2</sup>, P. Kušnirák<sup>3</sup>, K. Hornoch<sup>2</sup>, A. Galád<sup>4</sup>,  
 S. Mouté<sup>5</sup>, M. Bertina<sup>6</sup>

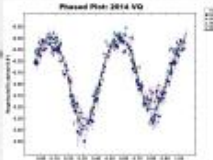
<sup>1</sup>Astronomical Observatory of the Autonomous Region of Aosta Valley (DAVdA), Aosta - Italy,  
<sup>2</sup>Astronomical Institute, Academy of Sciences of the Czech Republic, Ondřejov - Czech Republic,  
<sup>3</sup>Physics Department, Tezno University - Italy

### Introduction

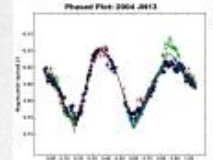
Asteroids were subject to strong collisional destruction. Harris (1994), in its studies of the rotation periods, discovered that objects of size larger than 0.1 km probably do not have periods smaller than 2.2 hours (sub-stationary synchronous). This spin barrier can be explained by the rubblepile structure on which the asteroids are made up of rubble cemented together by mutual gravitational forces. Rotators with periods exceeding this critical value will cause mutual leakage and the formation of a binary system (Pravec & Harris, 2007; Jacobson et al., 2010). However, there are exceptions to this rule, as the NEAs 2004 (1214) (Pravec, 2002) and the NEAs 2008 UJ30 (Cesna, 2013), both with the dimensions of about 0.4 km and rotation rates of 0.60 and 1.20 h, respectively. The presence of these objects, called *super-fast rotators* (SFRs), have been discussed by Holsinger (2007) as an effect of anisotropic material strength for small bodies (0.1-10 km) due to rubblepile structure, the presence of some very small amount of strength allows such small bodies to spin at super-stationary synchronous values. To verify the predictions, it is interesting to measure the rotation periods of the asteroids in the range 0.17 km < D < 0.3 km, looking for the violation of the synchronous value.

### The Observations

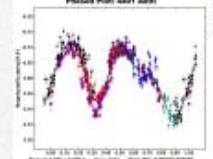
Here we present the results obtained with NEA differential photometry from 13/07/04 to the period October/December 2014 as search of SFR candidates. NEAs are an average small bodies, and it is not difficult to find them in the range of sizes of large SFRs. These observations have the best of our NEAs. Among the observed 70 NEAs, we did the light curve analysis for the range of the synchronous value, 2.0 h V in the most interesting because with a rotation period of only few minutes and an absolute magnitude around +20 in a potential large SFR. After the discovery of this short object, a collaboration was started with P. Pravec and colleagues of the Ondřejov Observatory that made further photometric observations on this asteroid that led to the determination of the color index (V-I) as a better measure of the spin period and an estimate of albedo and size. For these observations we used the LHA 140 telescope at La Silla (Chile).



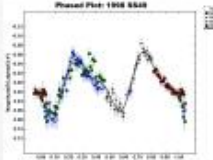
**Phased Plot 2014 VO**  
 The phased lightcurve of the NEA Asteroid (2014) VO from OSIRIS. The period was known for this object before. According to the observations made by P. Pravec and colleagues, the period is considered 0.71022 ± 0.00001 hours. The color index is (V-I) = 0.02 ± 0.01 mag, which is typical for large asteroids. Assuming a  $Q = 0.25$  a typical value for S-type asteroids, the mean absolute magnitude is  $H = 21.21 ± 0.25$  mag. If we assume the geometric albedo  $p_v = 0.22 ± 0.25$ , which is a typical range for large asteroids (Pravec et al., 2012), we get the diameter  $D = 0.24 ± 0.04$  km. It is an S-type, S(Ch) asteroid above the "stationary or" of about 0.2 km for S-type asteroids.



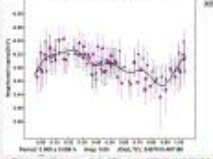
**Phased Plot 2004 1013**  
 The phased lightcurve of the NEA Asteroid (2004) 1013 from OSIRIS. The period was known for this object before. This object was observed with OSIRIS and OSIRIS-Prime, which have provided the calculation of the color index (V-I) = 0.24 ± 0.01 mag, (V-I) = 0.27 mag, with a 0.30 mag spread. The corresponding mean absolute magnitude is  $H = 17.0 ± 0.3$  mag and the diameter, using  $p_v = 0.22 ± 0.25$ , is  $D = 4.4 ± 0.6$  km.



**Phased Plot 2008 0401**  
 The phased lightcurve of the NEA Asteroid (2008) 0401 from OSIRIS. The period was known for this object before. This object was observed with OSIRIS and OSIRIS-Prime, which have provided the calculation of the color index (V-I) = 0.24 ± 0.01 mag, (V-I) = 0.27 mag, with a 0.30 mag spread. The corresponding mean absolute magnitude is  $H = 17.0 ± 0.3$  mag and the diameter, using  $p_v = 0.22 ± 0.25$ , is  $D = 4.4 ± 0.6$  km.



**Phased Plot 1998 0348**  
 The phased lightcurve of the NEA Asteroid (1998) 0348 from OSIRIS. The period was known for this object before. This object was observed with OSIRIS and OSIRIS-Prime, which have provided the calculation of the color index (V-I) = 0.24 ± 0.01 mag, (V-I) = 0.27 mag, with a 0.30 mag spread. The corresponding mean absolute magnitude is  $H = 17.0 ± 0.3$  mag and the diameter, using  $p_v = 0.22 ± 0.25$ , is  $D = 4.4 ± 0.6$  km.



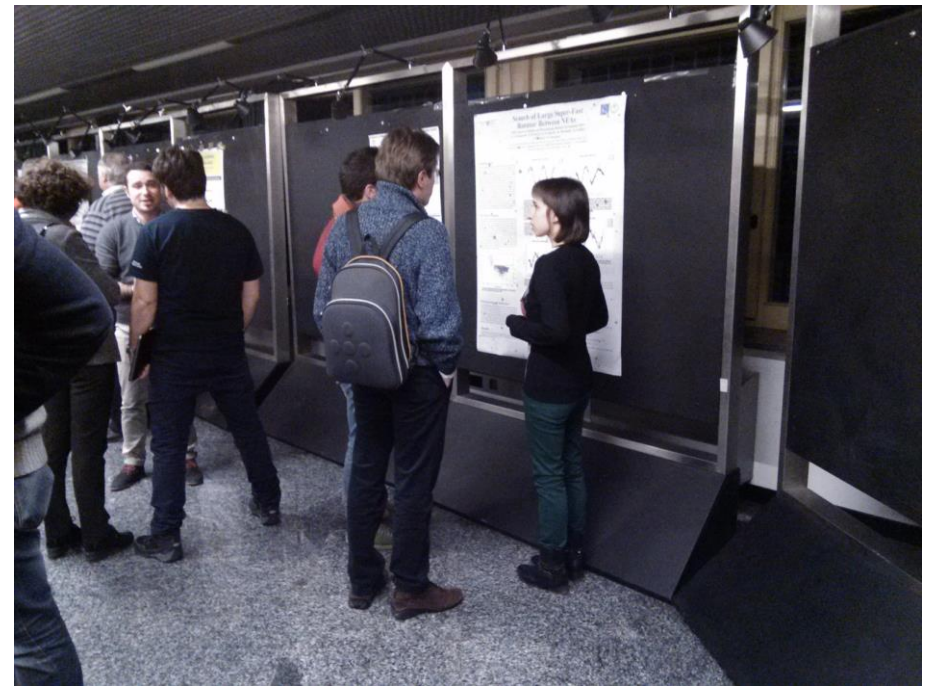
**Phased Plot 1998 0920**  
 The phased lightcurve of the NEA Asteroid (1998) 0920 from OSIRIS. The period was known for this object before. This object was observed with OSIRIS and OSIRIS-Prime, which have provided the calculation of the color index (V-I) = 0.24 ± 0.01 mag, (V-I) = 0.27 mag, with a 0.30 mag spread. The corresponding mean absolute magnitude is  $H = 17.0 ± 0.3$  mag and the diameter, using  $p_v = 0.22 ± 0.25$ , is  $D = 4.4 ± 0.6$  km.

### Acknowledgements

This research has made use of the NEAOS, Asteroid Light Curve System and IAU Asteroid Light Curve System. Thanks to the Primary Society for the 2013 Observing 1017 Class in OSIRIS which made it possible to observe the rubblepile used to observe the NEAs.

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 Warner, B. D., 2009, *LPI Science Conference*, 40, 104.



# Proceedings di Bormio (memorie SAIt)

Mem. S.A.It. Vol. 75, 282  
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Memorie della



## Search of Large Super-Fast Rotator Between NEAs

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**Abstract.** Asteroids of size larger than 0.15 km generally do not have periods smaller than 2.2 hours, a limit known as cohesionless spin-barrier. This barrier can be explained by the rubble-pile structure in which the asteroids are made up of collisional breakup fragments bound together by mutual gravitational force. The exceptions to this rule, called Large Super-Fast Rotators (LSFRs), are very few as 2001 OE84 and 2005 UW163. Preliminary results of some NEAs (Near Earth Asteroids) photometric observations, are presented. We report, in addition to the determination of new rotation periods for these elusive asteroids, the discovery of a new candidate LSFR, the Amor 2014 VQ.

**Key words.** Minor planets, near Earth asteroids, rotation periods.

### 1. Introduction

Asteroids were subject to strong collisional interaction. Harris (1996), in its studies of the rotation periods, discovered that objects of size larger than 0.15 km generally do not have periods smaller than 2.2 hours (cohesionless spin-barrier). This spin barrier can be explained by the rubble-pile structure in which the asteroids are made up of collisional breakup fragments bound together by mutual gravitational force (Figure ??). Rotation with periods exceeding this critical value will cause asteroid breakup and the formation of a binary system (?), (?). However, there are exceptions to this rule, as the NEA 2001 OE84 (?) and the MBA 2005 UW163

(?), both with diameters of about 0.6 km and rotation periods of 0.486 and 1.290 h, respectively. The presence of these objects, called Large Super-Fast Rotators (LSFRs), have been theorized by ? and others as an effect of size-dependent material strength: for small bodies ( $D < 10$  km), also with rubble-pile structure, the presence of even a very small amount of strength allows much more rapid spins than the simple cohesionless spin-barrier value. Therefore, to verify the predictions, it is interesting to measure the rotation periods of asteroids in the range  $0.15 \text{ km} < D < 10 \text{ km}$ , looking for spin-barrier value violations. Here we present the first results obtained with NEAs differential photometry from the Astronomical Observatory of the Aosta Valley



# Articolo per “Planetary Space Science” (risultati completi)

## A New Candidate Large Super-Fast Rotator, the Near Earth Object 2014 VQ

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### Abstract

Asteroids of size larger than 0.15 km generally do not have periods smaller than 2.2 hours, a limit known as cohesionless spin-barrier. This barrier can be explained by the cohesionless rubble-pile structure model. According to this model, the asteroids are made up of collisional breakup fragments bound together only by mutual gravitational force. The exceptions to this rule, called Large Super-Fast Rotators (LSFRs), are very few: 2001 OES4, (335433) 2005 UW163 and 2011 XA3 are the best known examples. Results of photometric observations of some NEAs (Near Earth Asteroids), made during the period October 2014 - May 2015 are presented. We report, in addition to the determination of new rotation periods for these elusive asteroids, the discovery of a new candidate LSFR, the Amor 2014 VQ spinning with a period of  $0.116032 \pm 0.000001$  hours, a lightcurve amplitude of 0.75 mag and a diameter of  $0.165 \pm 0.027$  km (if V-type) or  $0.267 \pm 0.043$  km (if S-type).

*Keywords:* Minor planets, near Earth asteroids, rotation periods.

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### 1. Introduction

Asteroids were subject to strong collisional interaction and the population that we see today is the result of billions of years of evolution. Harris

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