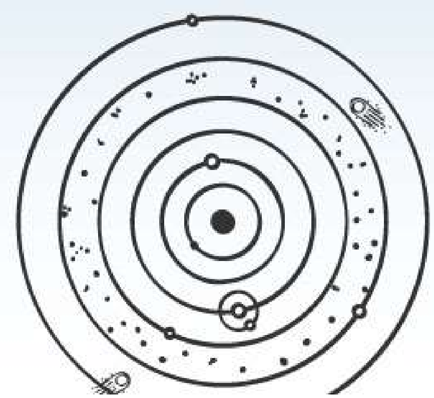
Annibale de Gasparis Workshop

La leadership italiana nello studio degli oggetti minori del Sistema Solare dall'inizio dell'Ottocento fino alle più recenti e future missioni spaziali

Napoli, 7 - 8 Novembre 2019

Auditorium INAF "Ernesto Capocci"

Annibale de Gasparis



con il patrocinio di

Annibale De Gasparis workshop, Capodimonte, 7-8 novembre 2019

Caratterizzazione fotometrica e periodo di rotazione di (6478) Gault

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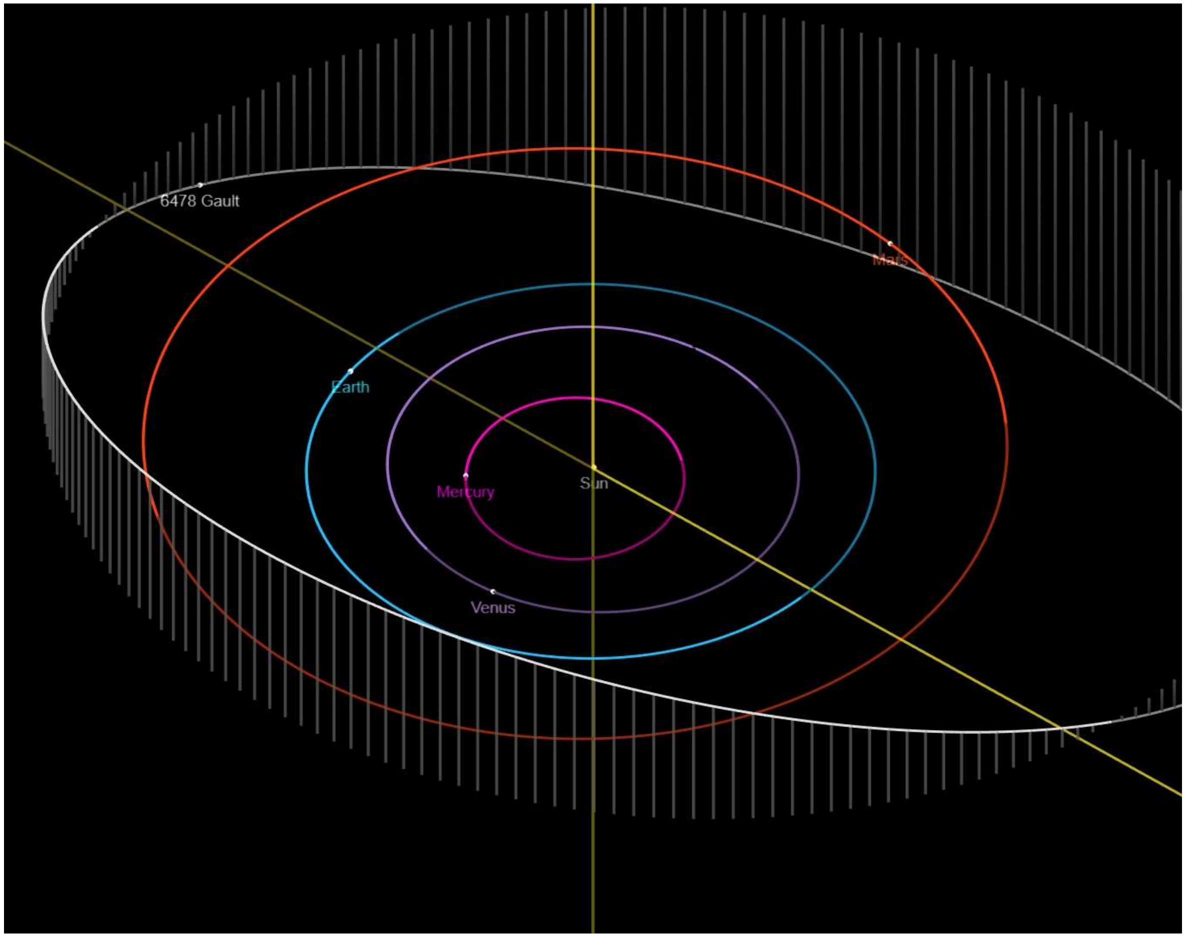
INAF OAS BOLOGNA

Orbit and family

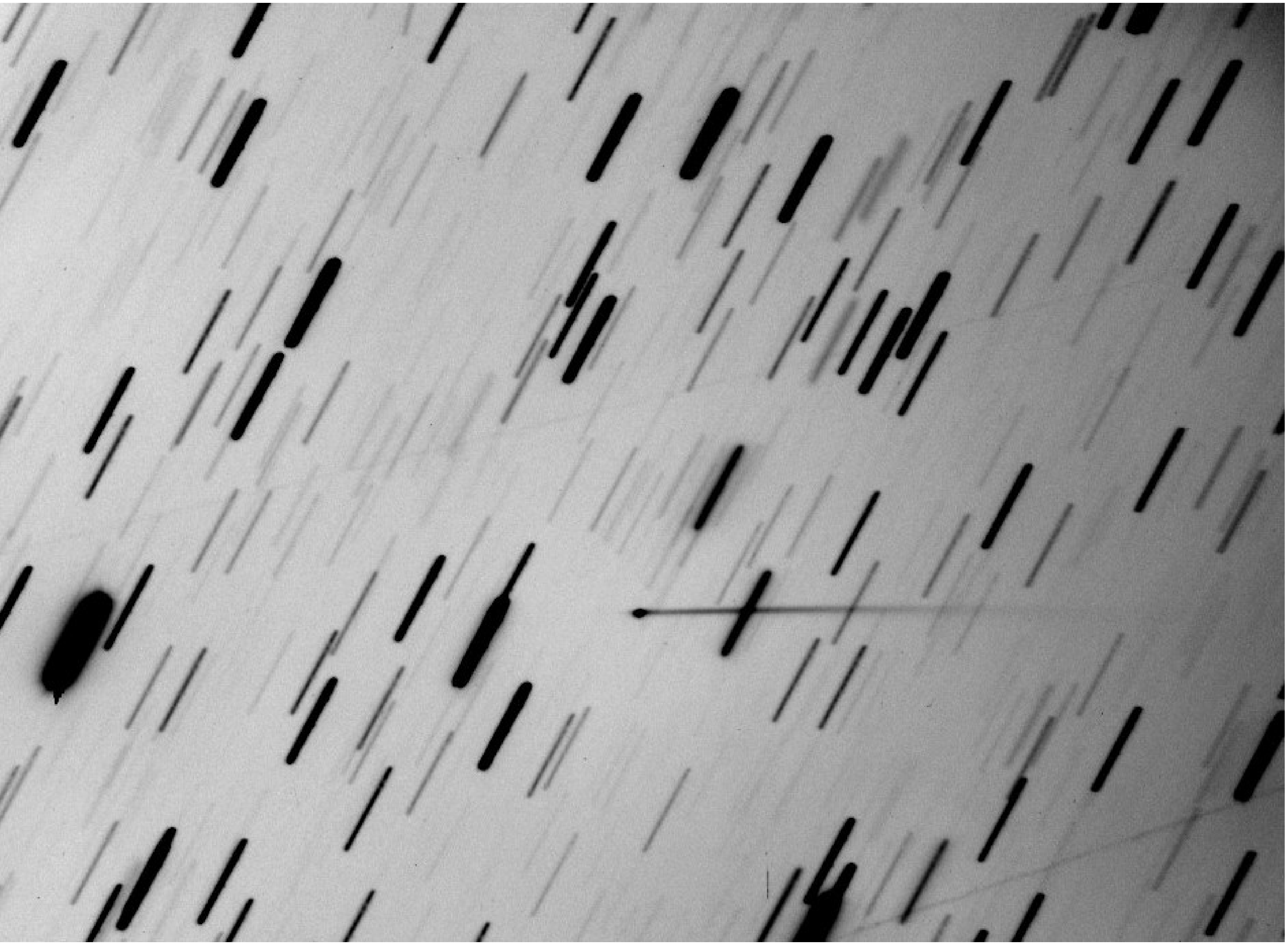
(6478) Gault is a 5-6 km diameter **inner main-belt asteroid** in the **Phocaea family** (S-type asteroids), notable for its sporadic, **comet-like ejection of dust**.

Pre-covery research in the NOAO image database allowed to trace **Gault's outbursts back to year 2013**. As the outbursts appeared along the full heliocentric orbit, even about the **aphelion distance of 2.75 AU, this feature tends to exclude the sublimation of volatile material as a cause of the activity**.

This has led to think that Gault's activity **is not due to collisions or to the emission of volatile materials** but to a phenomenon of **disintegration** due to the overcoming of the **spin-barrier** due to the **YORP effect**.



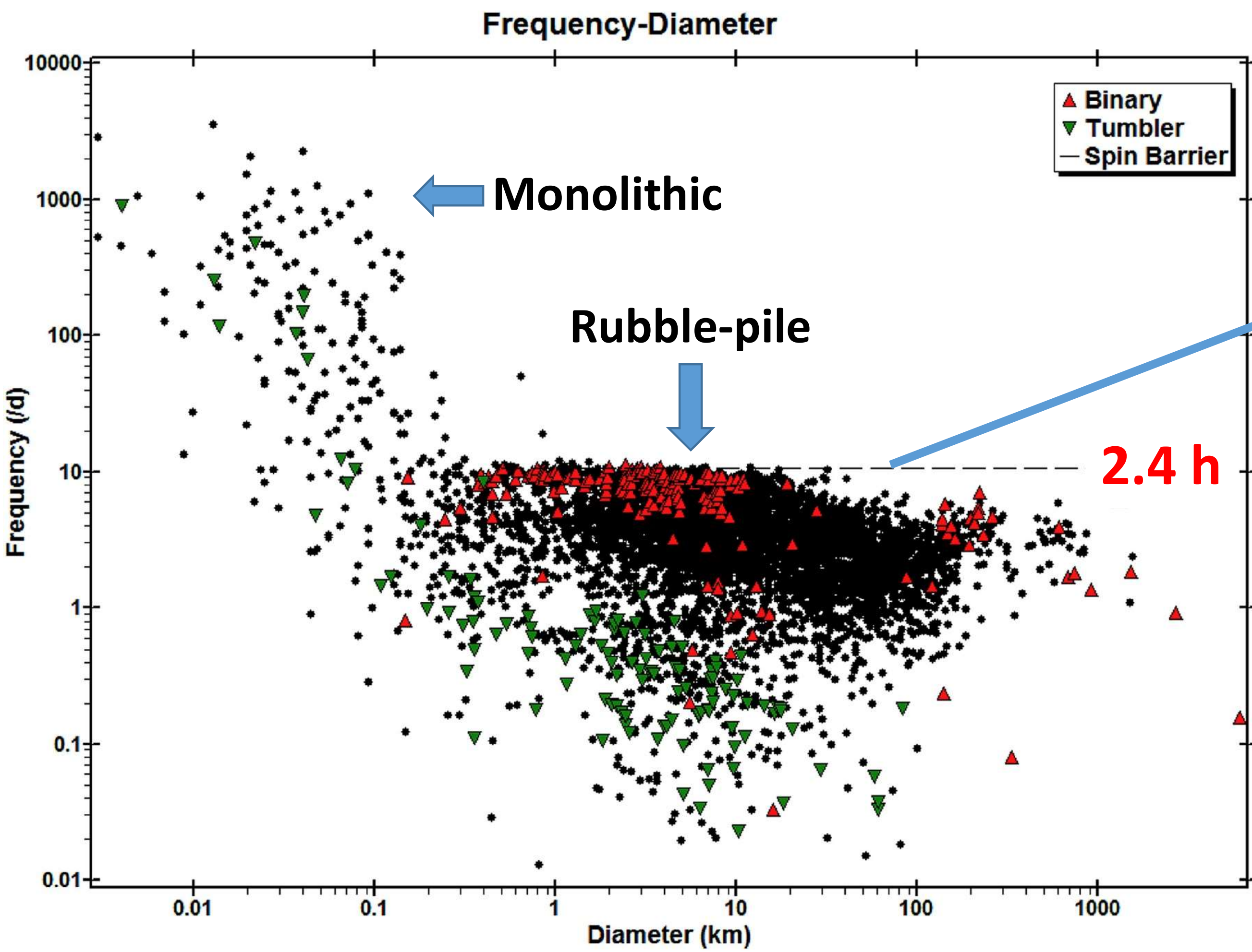
Orbital elements: a = 2.30 AU, e = 0.19, i = 22.8°, P = 3.50 y



Gault on 2019 March 23 from OAVdA's Main Telescope (Ritchey-Chrétien, 0.81-m f/4.75 + CCD FLI 1001E, no filter).

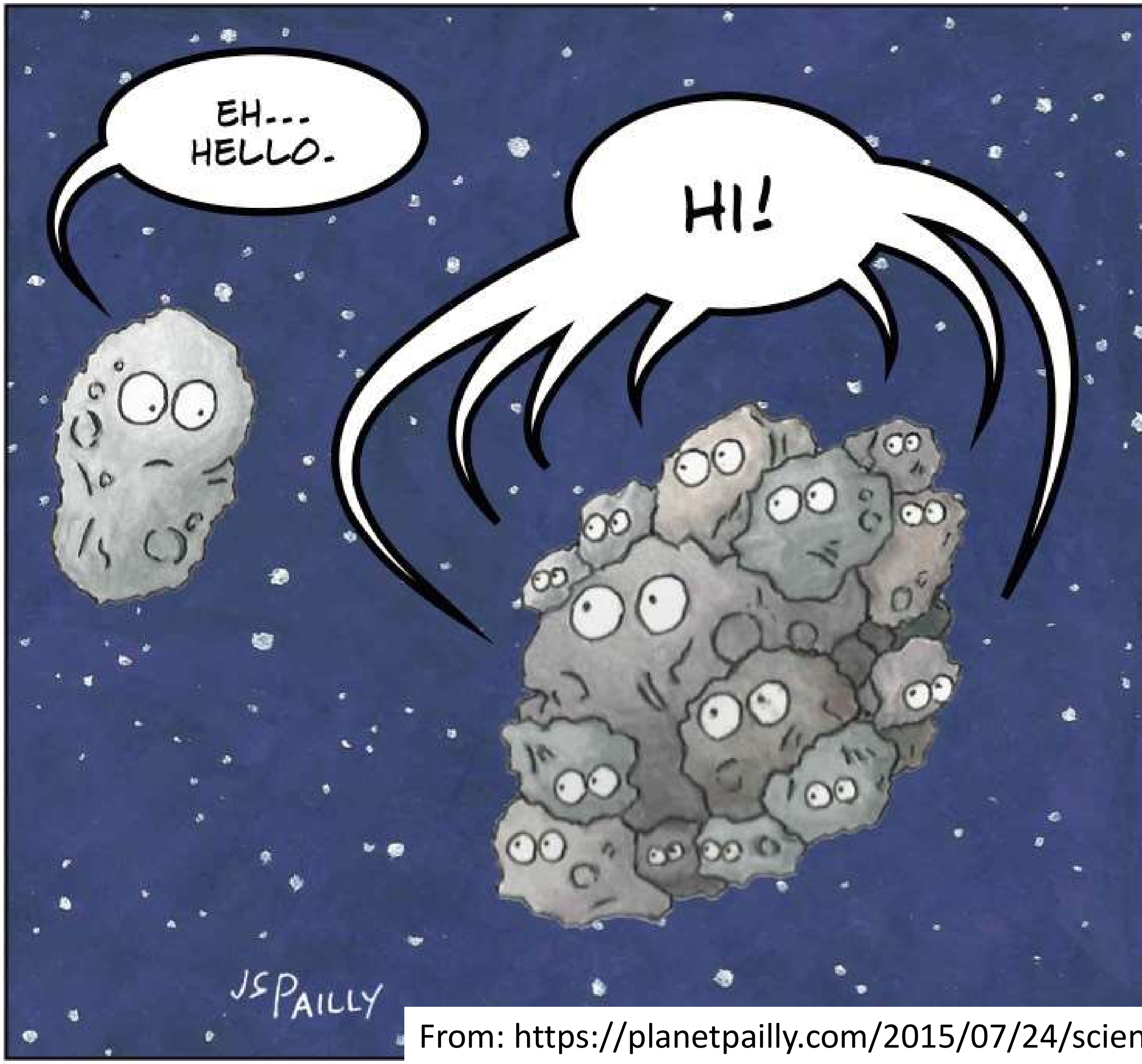
Field of view 14×11 arcmin. Tail length 5.5 arcmin at position angle 272°.

The spin-barrier and the "rubble-pile" asteroids

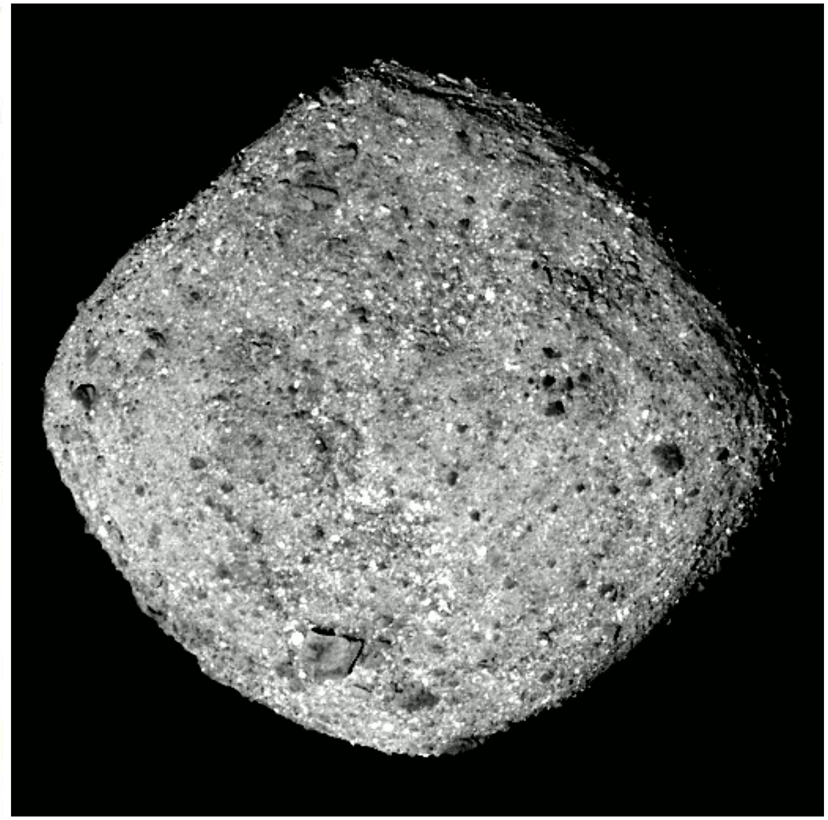


$$P_S = \sqrt{\frac{3\pi}{G\rho}} \approx \frac{3.3\text{h}}{\sqrt{\rho}}.$$

If the rotation period is at the spin-barrier value we can directly estimate the asteroid bulk density.



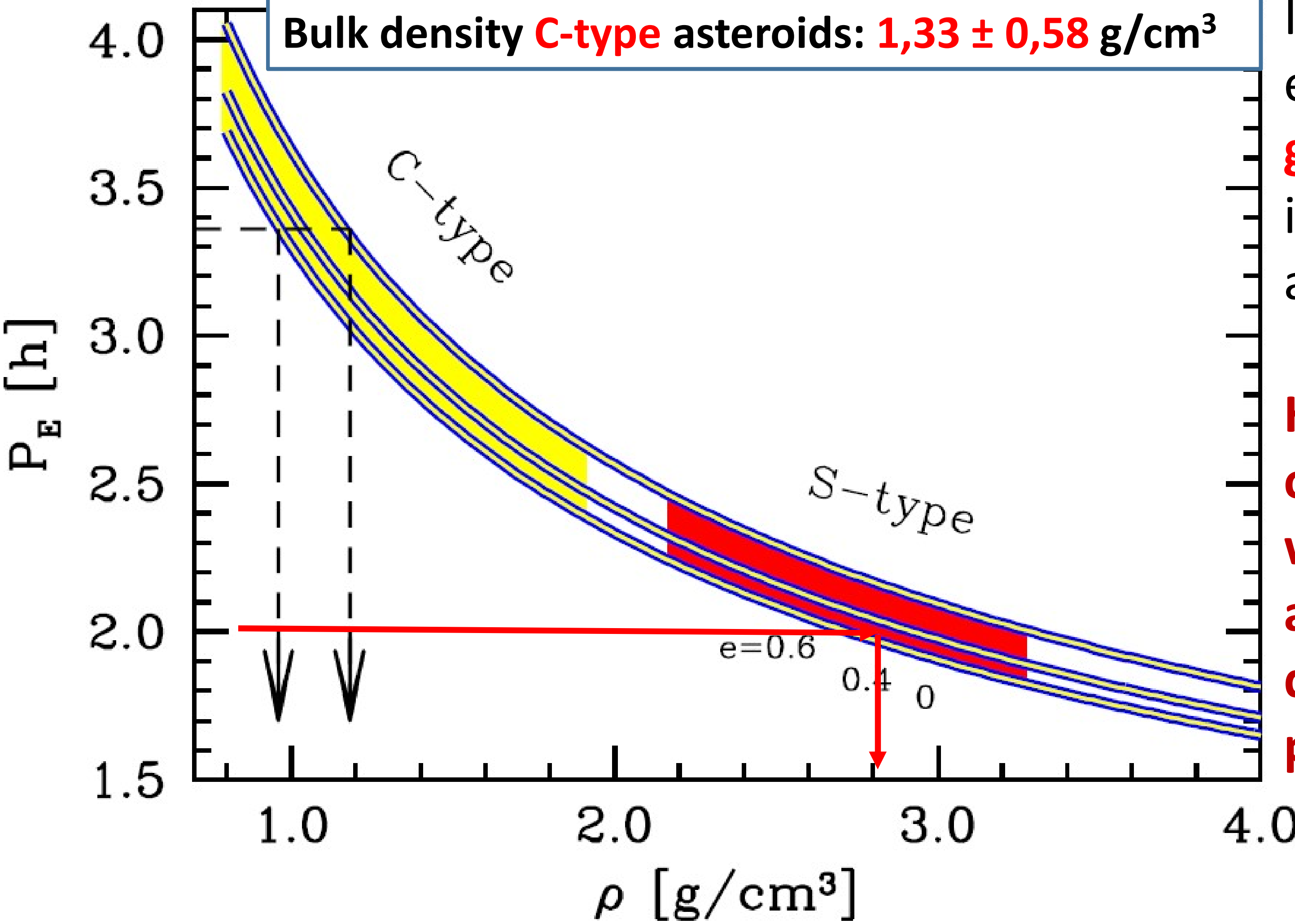
From: https://planetpailly.com/2015/07/24/sciency-words-rubble-pile/



(101955) Bennu

Bulk density S-Type asteroids: 2,72 ± 0,5 g/cm³

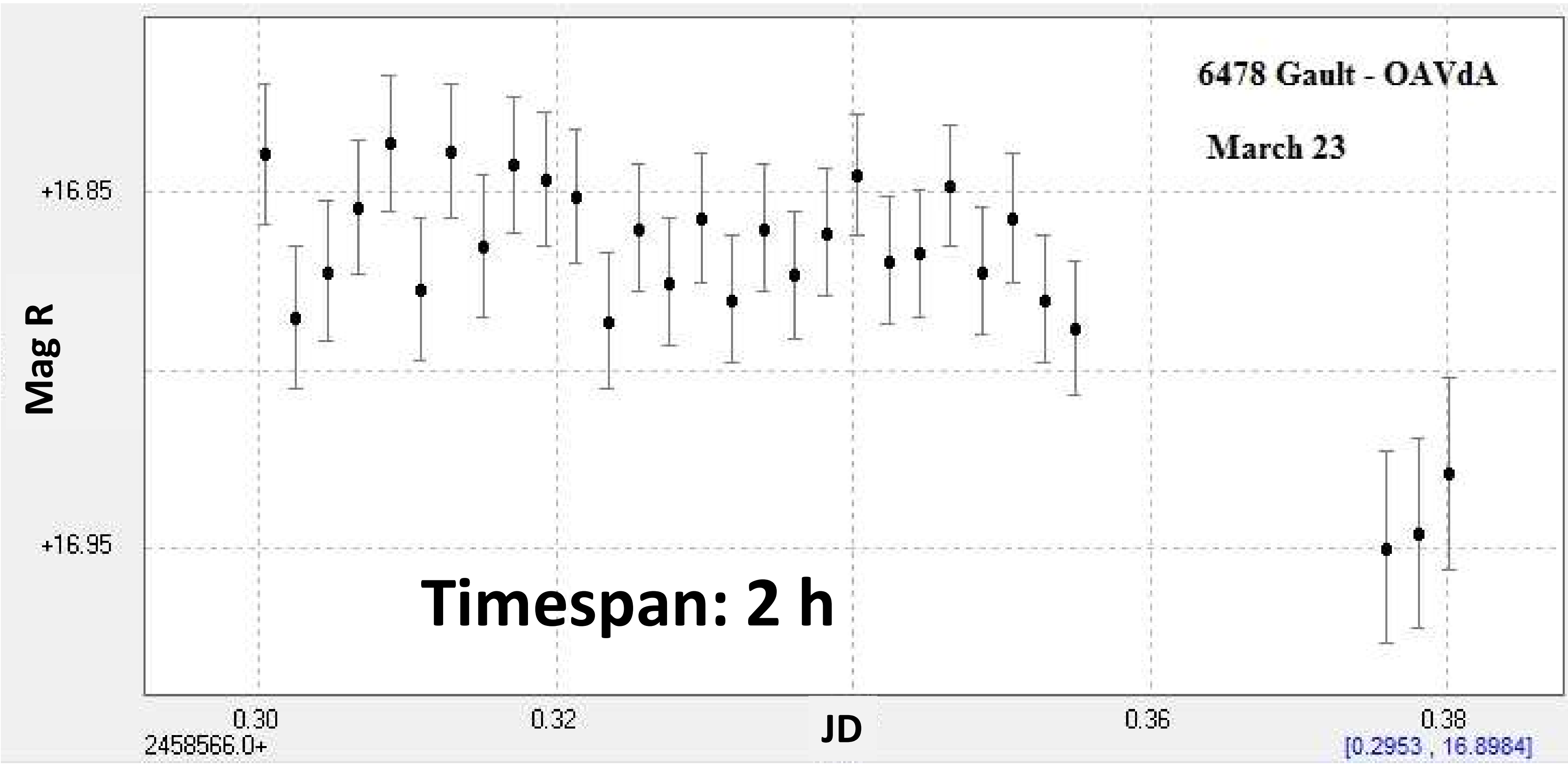
Bulk density C-type asteroids: 1,33 ± 0,58 g/cm³



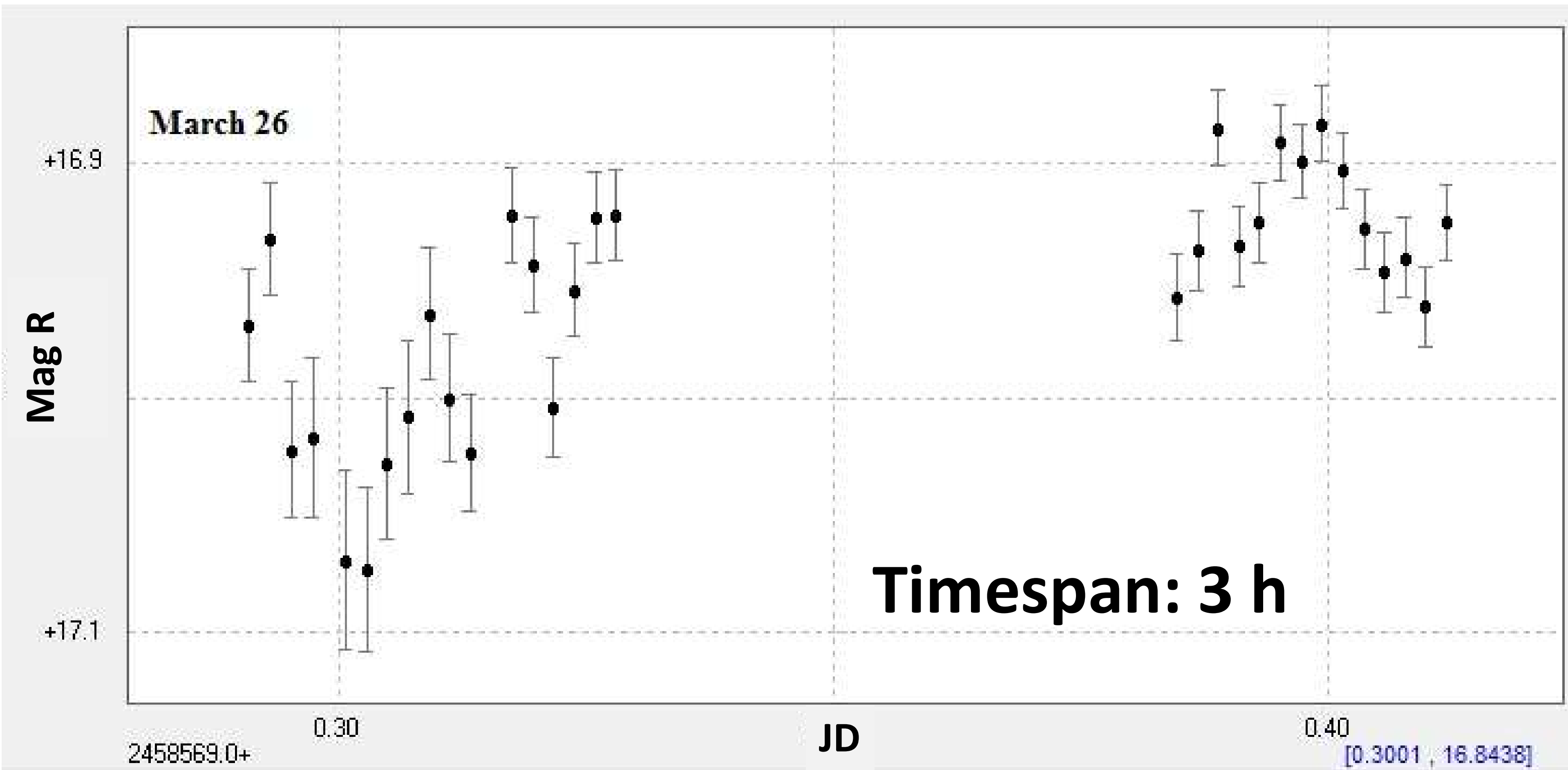
If Gault **P ≈ 2 h**, (Kleyna et al. (2019), then ρ **≈ 2.8 g/cm³** according to what is expected for an **S-type** asteroid.

However, photometric observations were made with the asteroid in full activity, so it was difficult to have a periodic light curve!

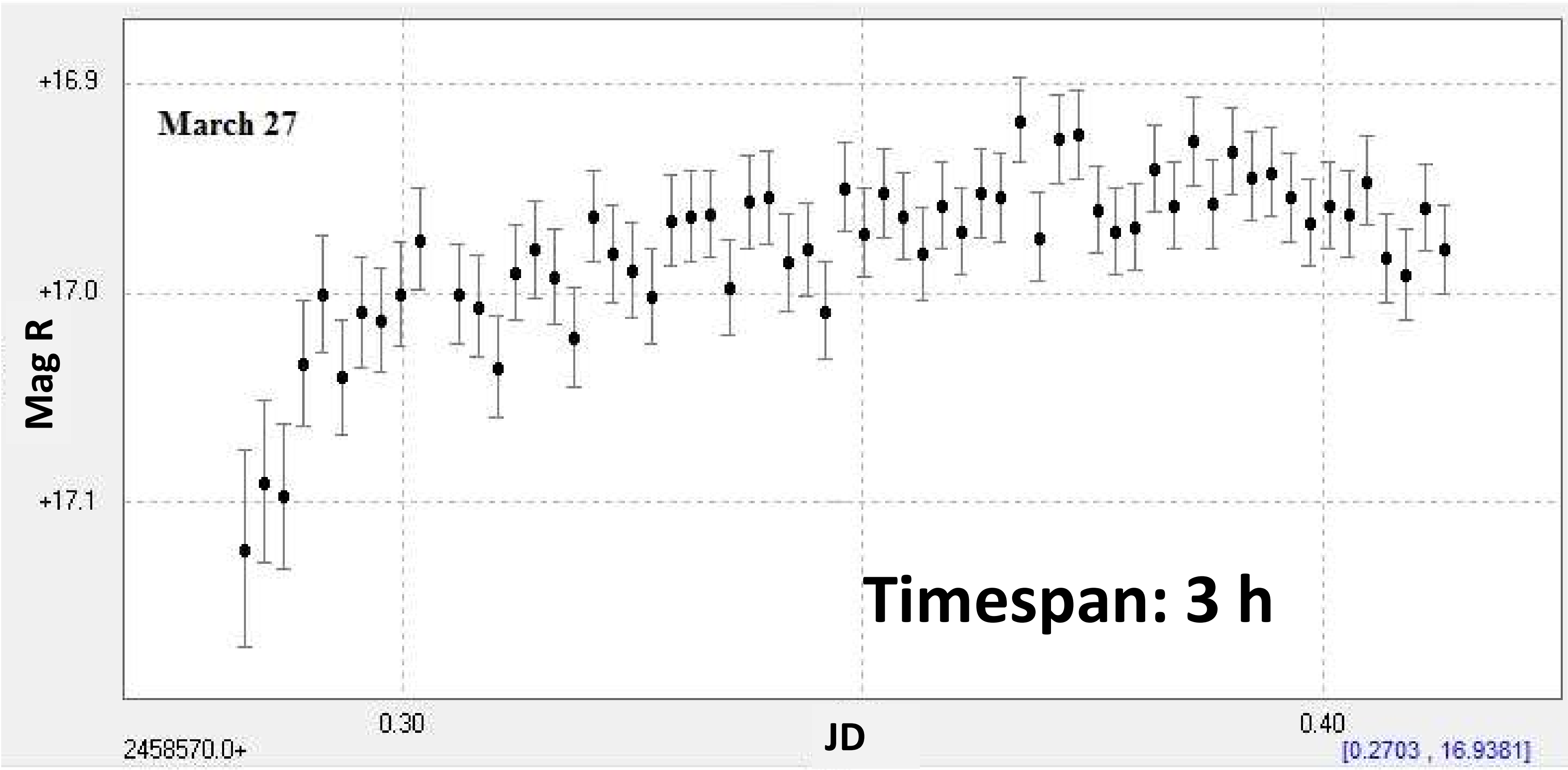
Photometric observations from OAVdA: 1/3
(Main Telescope 0.81-m, f/4.75, Ritchey-Chrétien, no filter)



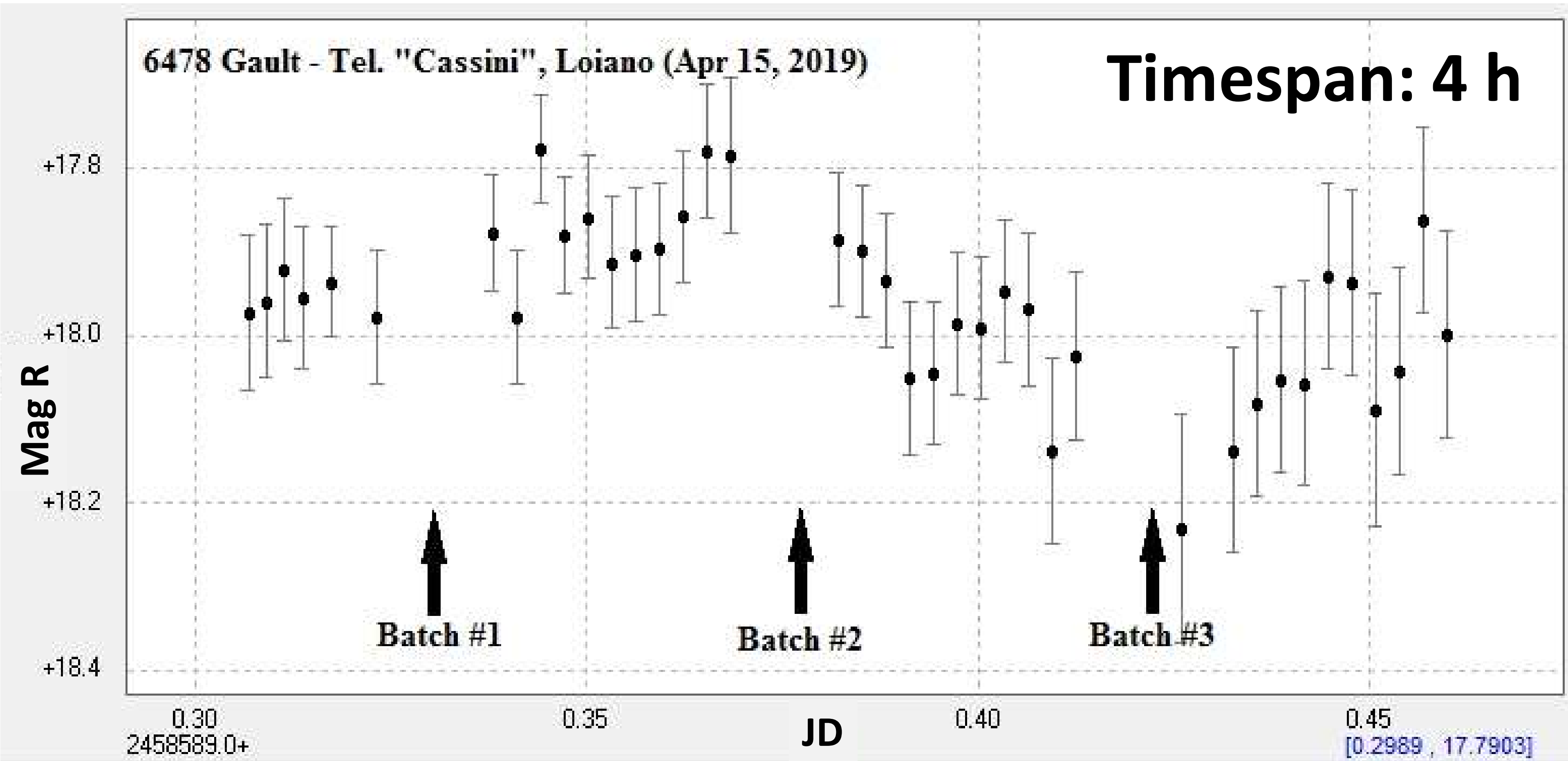
Photometric observations from OAVdA: 2/3



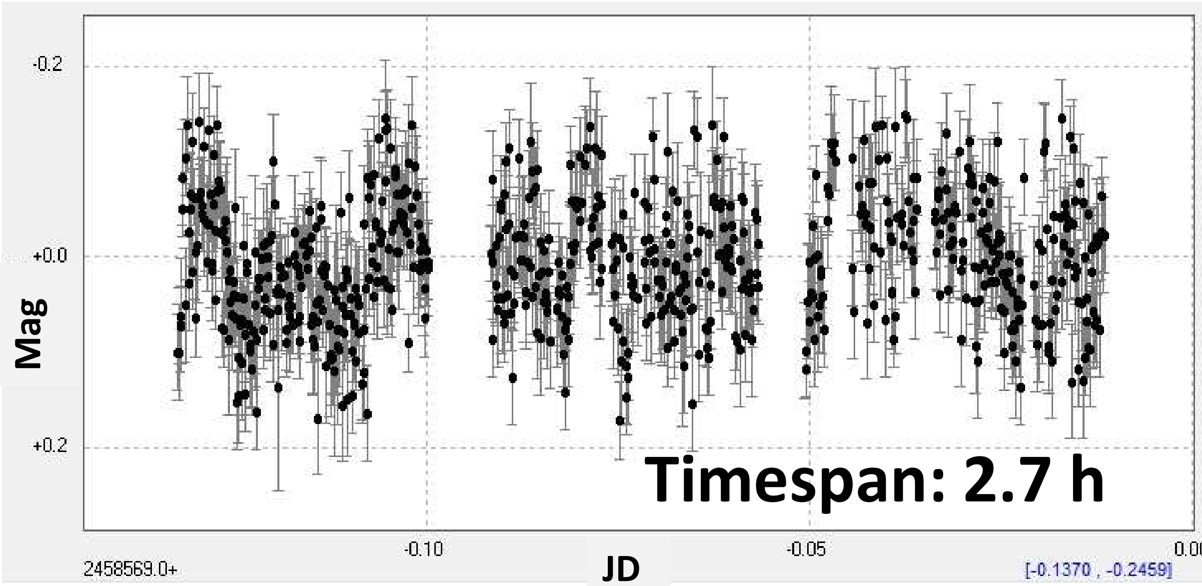
Photometric observations from OAVdA: 3/3



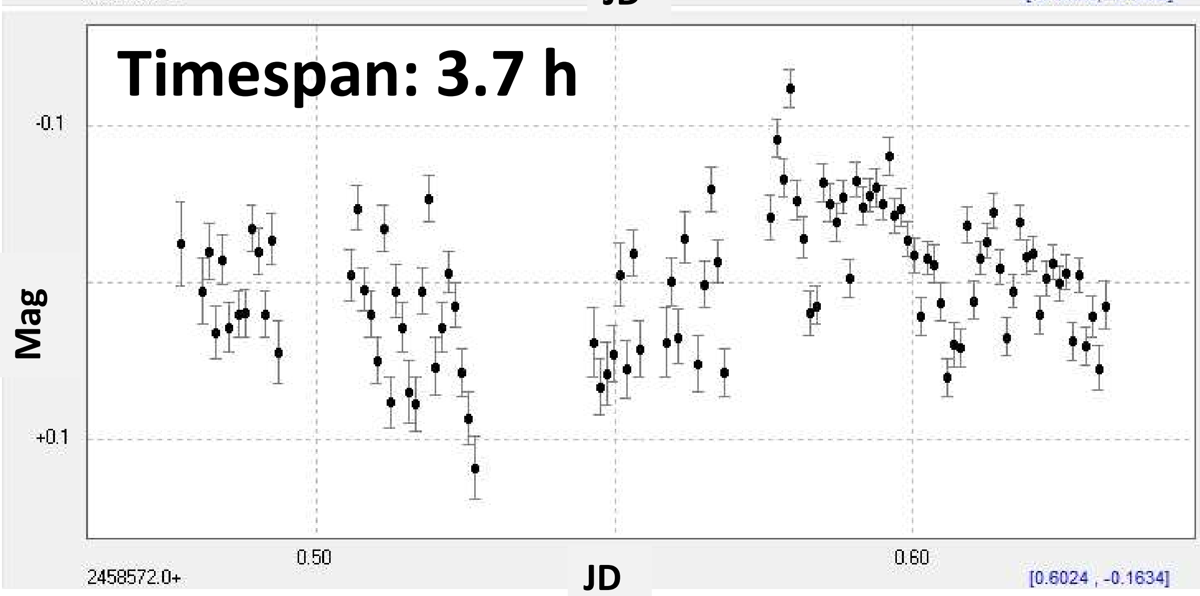
Photometric observations from Loiano (OAS)
(“Cassini” Telescope 1.52-m, f/4.6, Ritchey-Chrétien, Rc filter)



Additional light curves



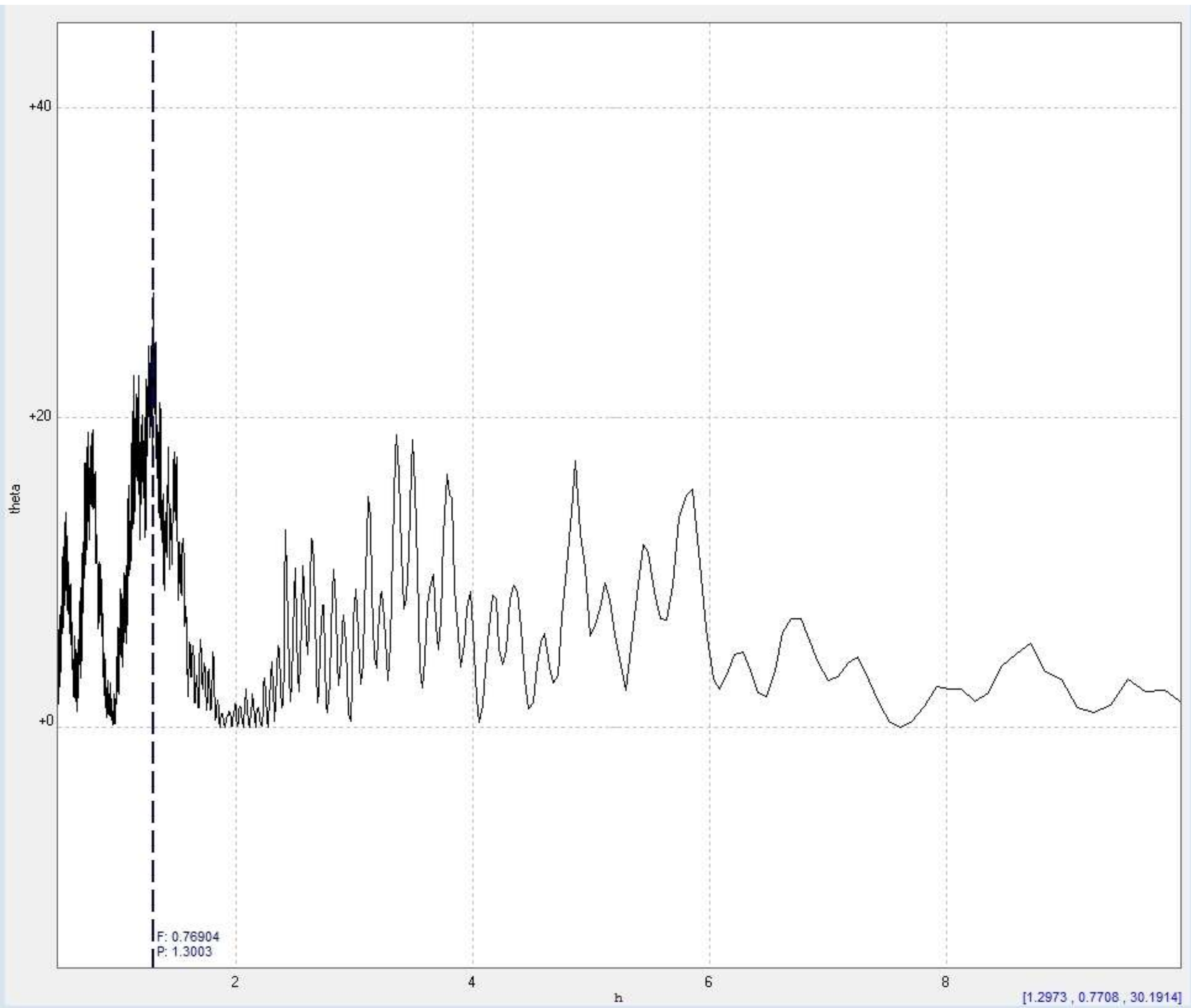
Sanchez, 2019 March 26
(IRTF Moris)



Sanchez, 2019 March 30
(SMARTS CTIO)

(Sanchez et al., The Astrophysical Journal Letters, 2019)

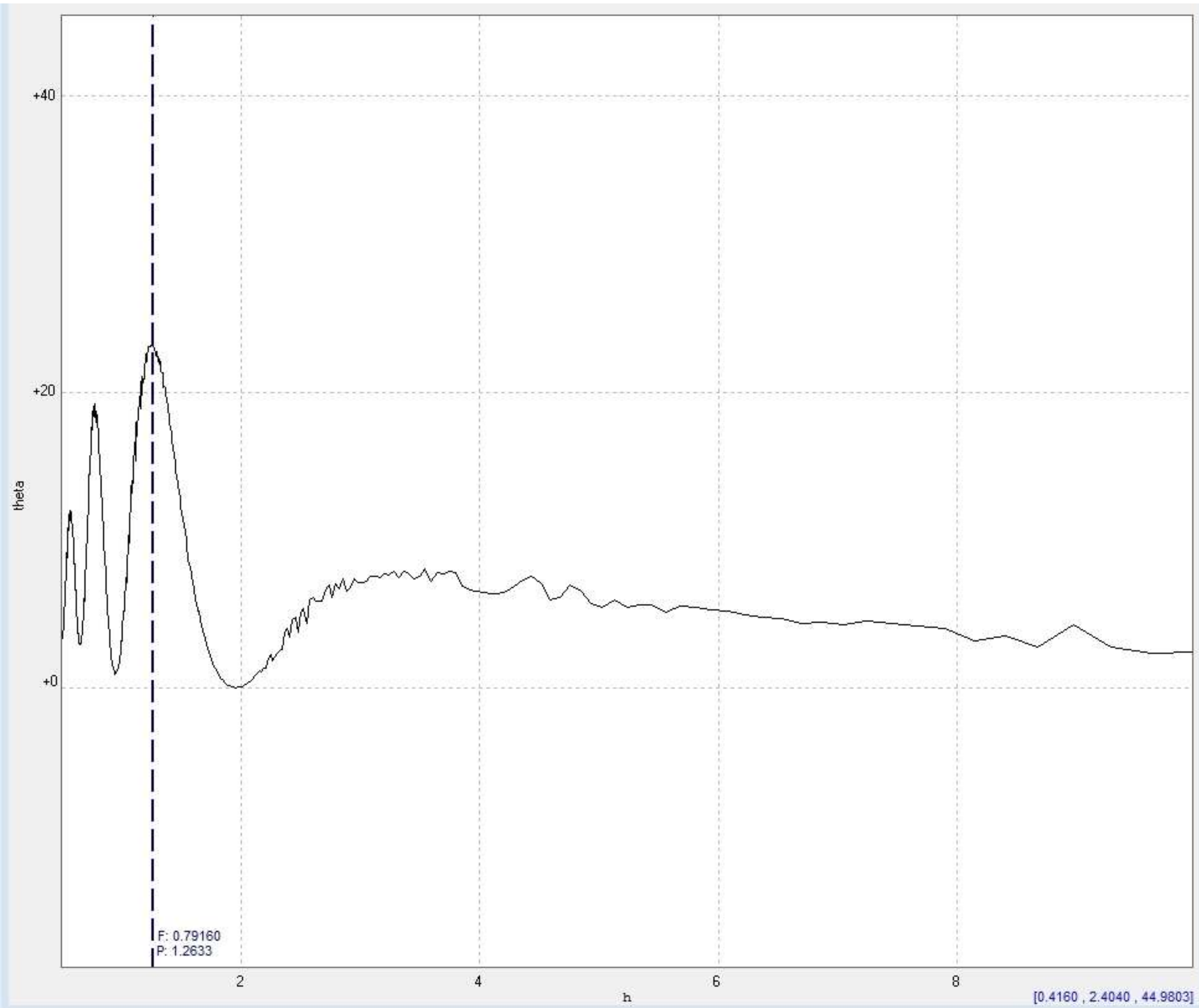
In search of the period with Lomb-Scargle periodogram: 1/3



All March sessions (OAVdA+Sanchez)

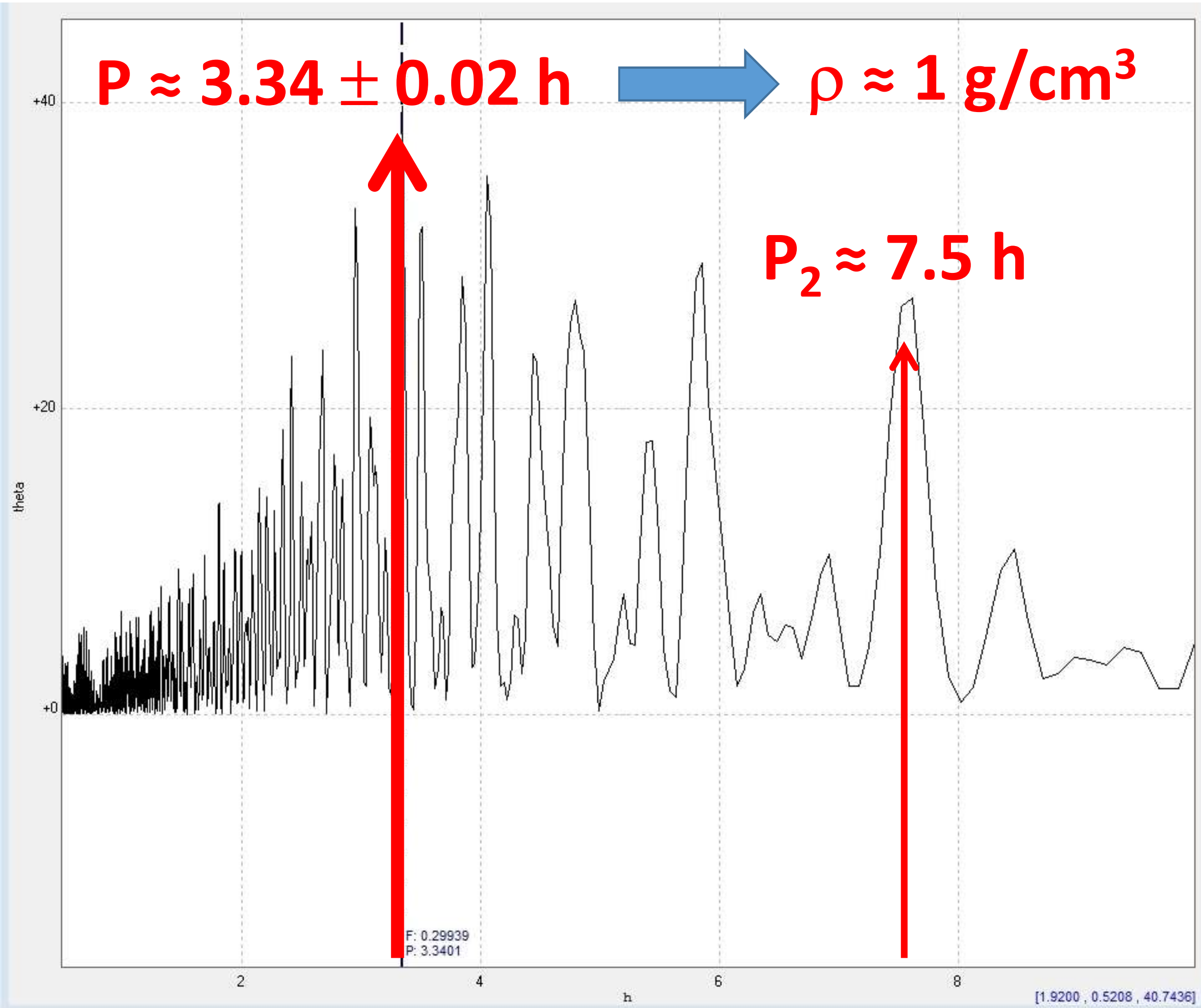
The Lomb-Scargle periodogram is a well-known algorithm for detecting and characterizing periodic signals in unevenly-sampled data.

In search of the period with Lomb-Scargle periodogram: 2/3

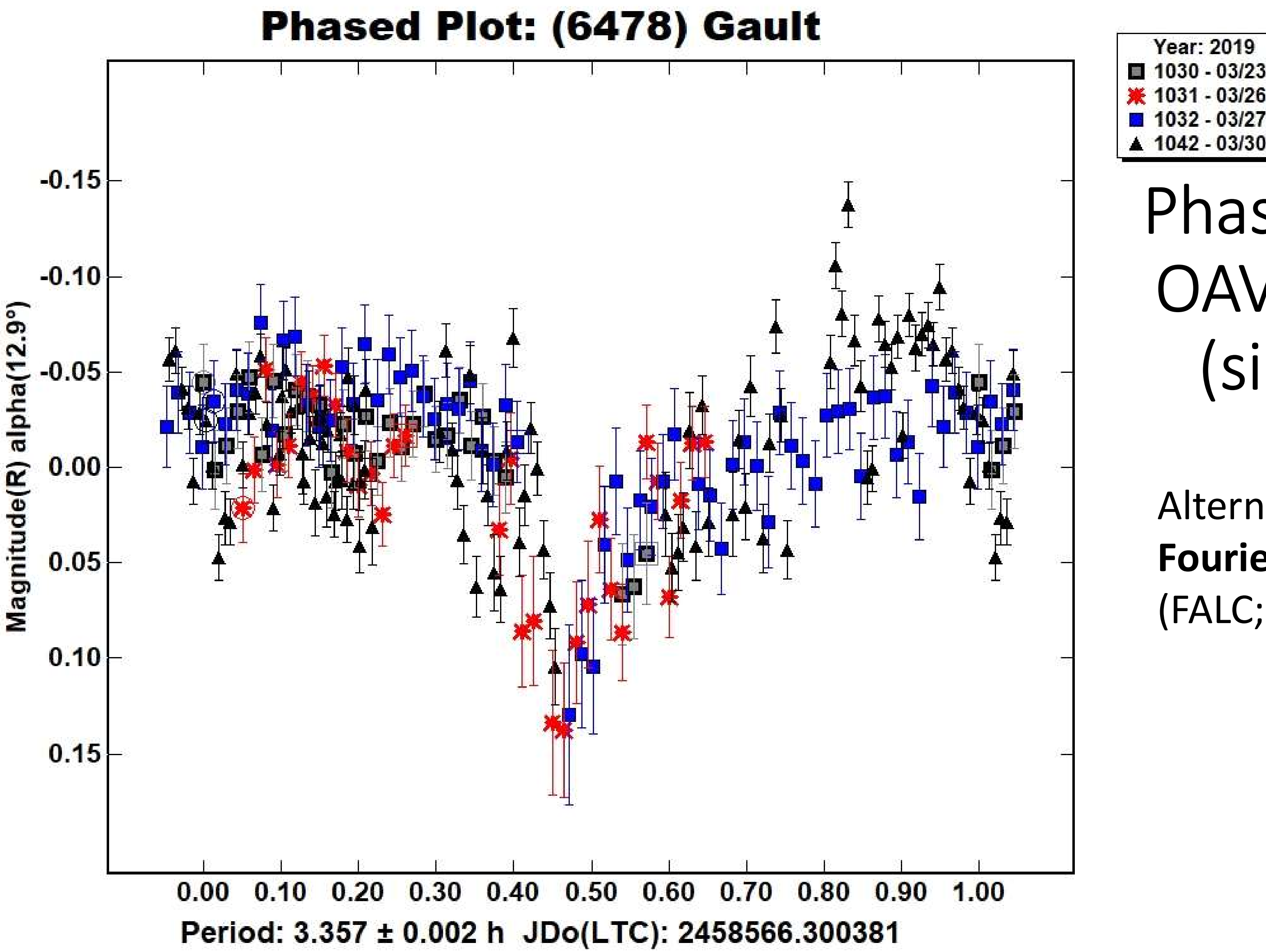


2019 March 26 session, Sanchez

In search of the period with Lomb-Scargle periodogram:3/3

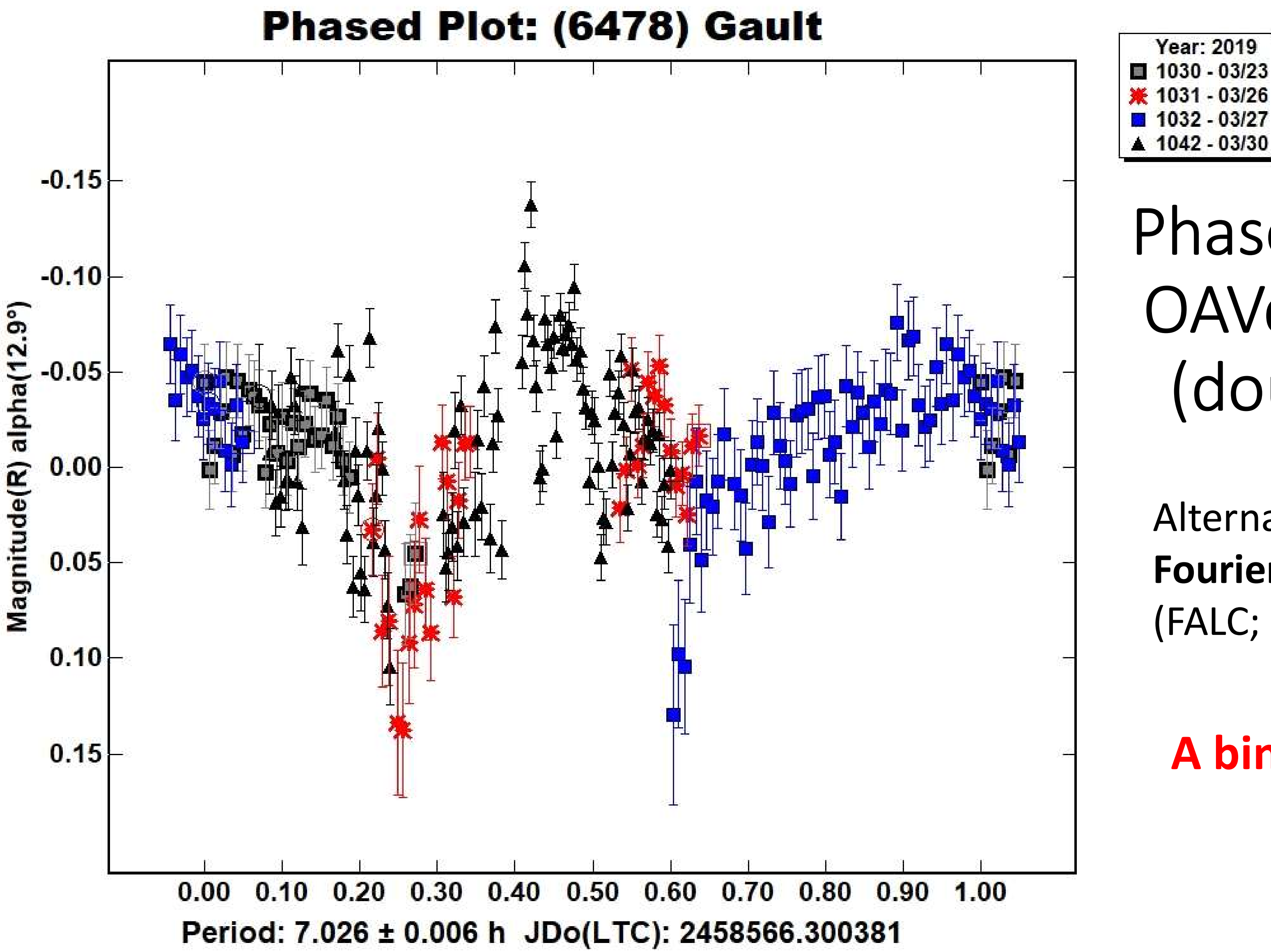


Remaining sessions:
(OAVdA+2019 March 30, Sanchez)



Phased light curve OAVdA + Sanchez (single period)

Alternative analysis with the **Fourier analysis algorithm** (FALC; Harris et al., 1989)



Phased light curve OAVdA + Sanchez (double period)

Alternative analysis with the **Fourier analysis algorithm** (FALC; Harris et al., 1989)

A binary system?

Synthetic light curves of binary asteroids

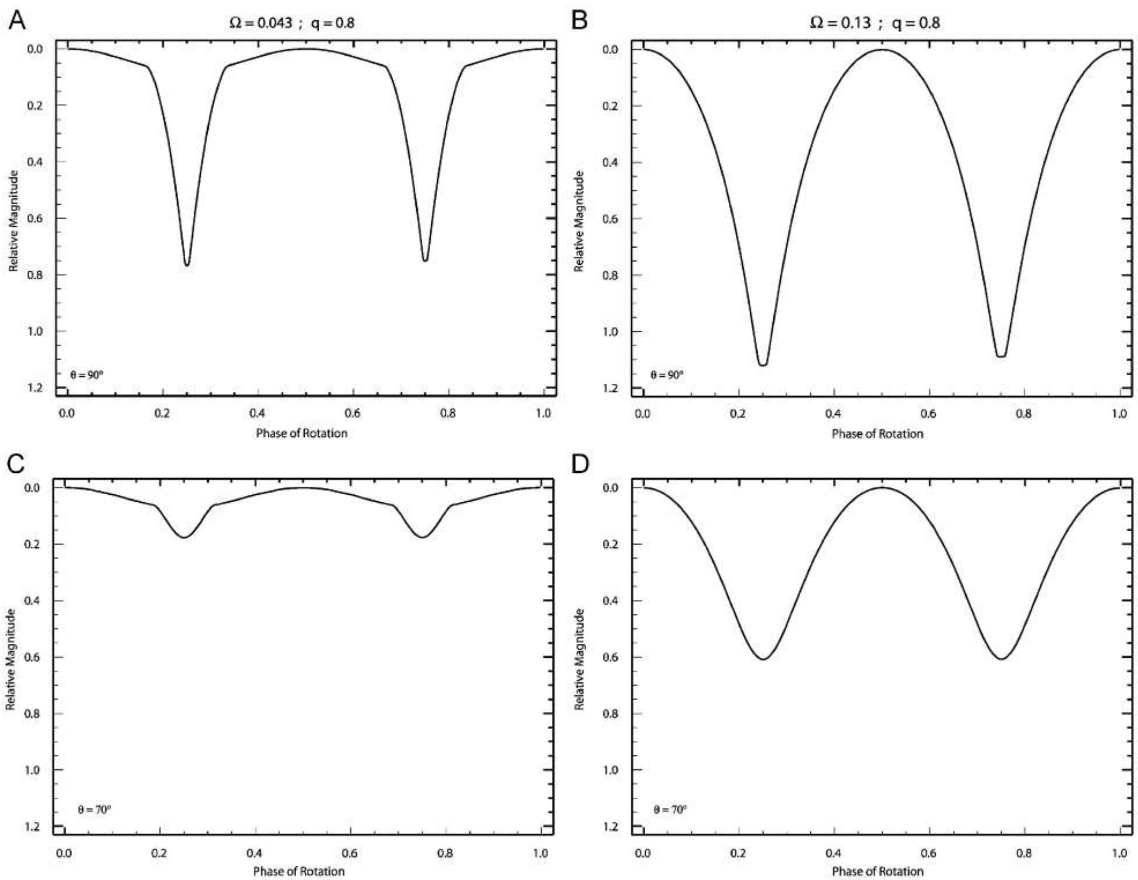


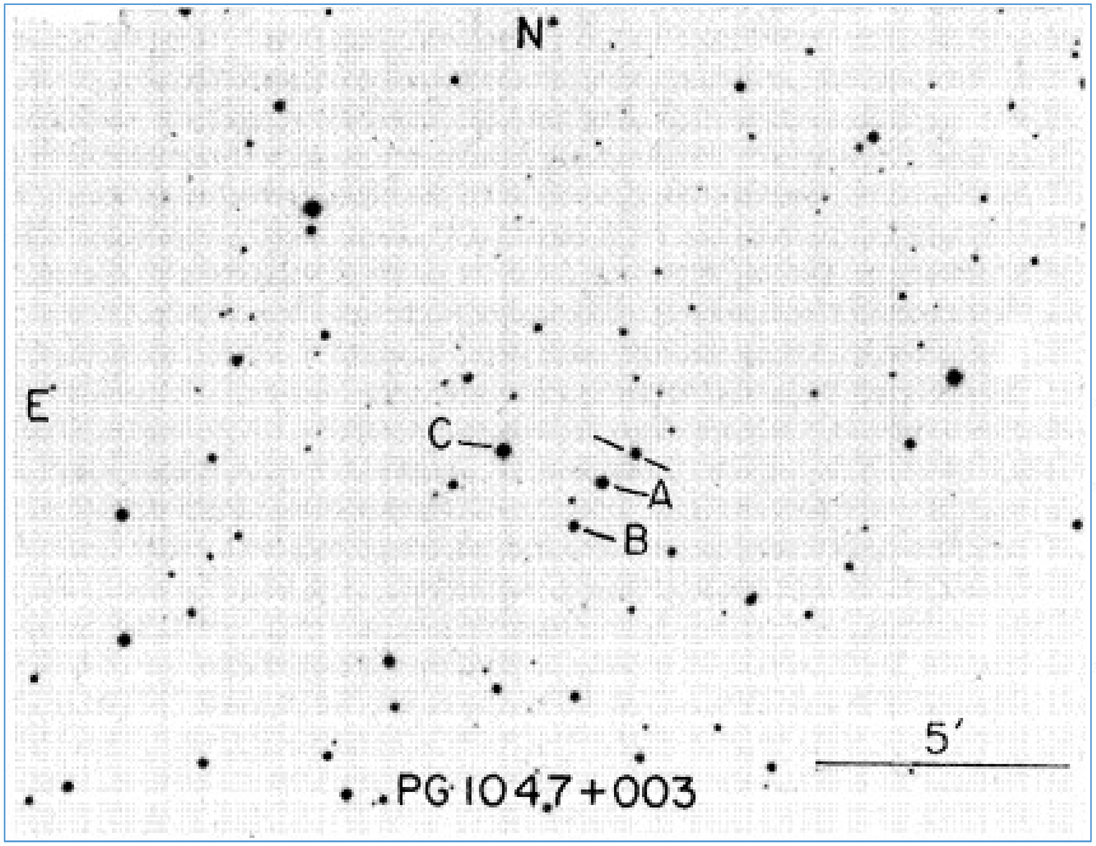
Fig. 1. General morphology of lightcurves of two Roche systems viewed under two aspect angles (θ). The equatorial aspect ($\theta = 90^{\circ}$) gives highest amplitudes. (A) and (B) are obtained for a well-detached pair of nearly spherical bodies, whereas (B) and (D) derive from a contact binary composed of two highly elongated bodies.

Spherical components

Elongated componets

(Descamps, Planetary and Space Science **56**, 2008)

Magnitude calibration with Landolt stars

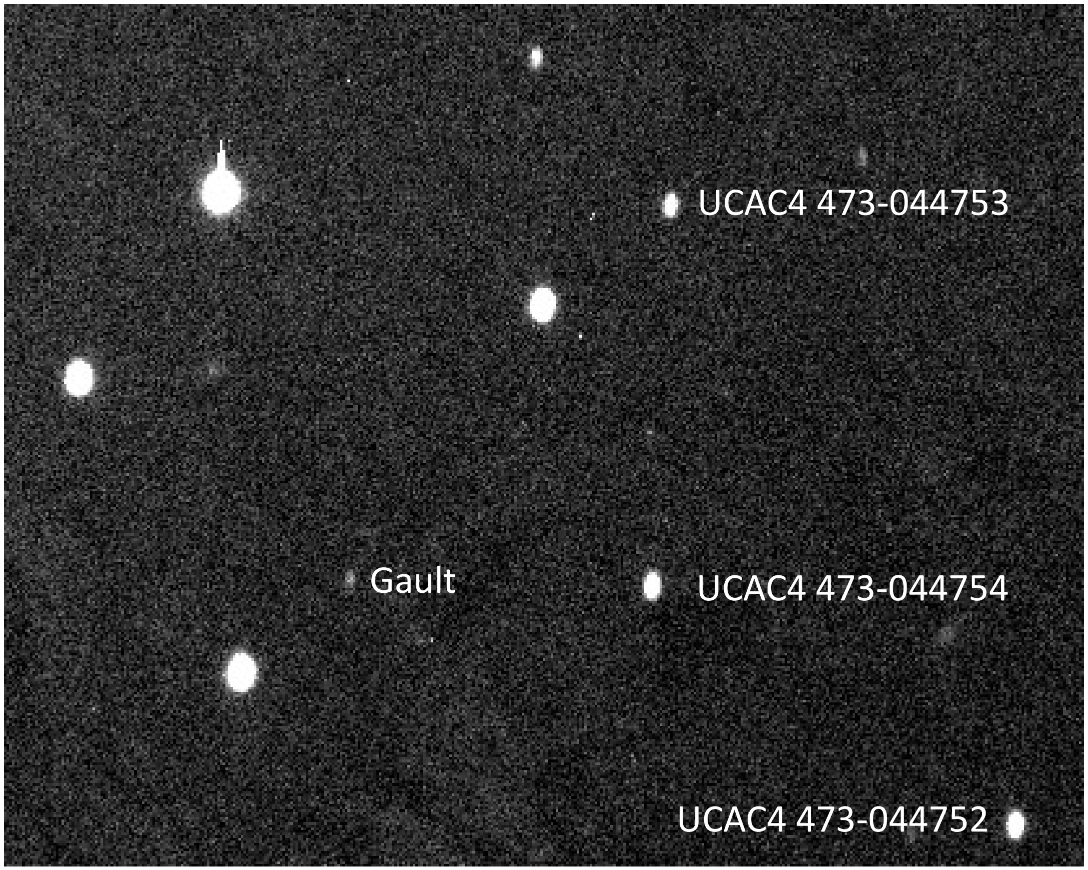


$$B = b - k_B X + c_B(B - V) + ZP_B,$$
$$V = v - k_V X + c_V(B - V) + ZP_V,$$
$$R_c = r - k_R X + c_R(V - R_c) + ZP_R,$$

Band	k^*	c	ZP
B	0.20	$+0.16_{\pm 0.03}$	$22.22_{\pm 0.02}$
V	0.10	$-0.04_{\pm 0.02}$	$22.70_{\pm 0.01}$
R_c	0.08	$-0.08_{\pm 0.03}$	$22.84_{\pm 0.01}$

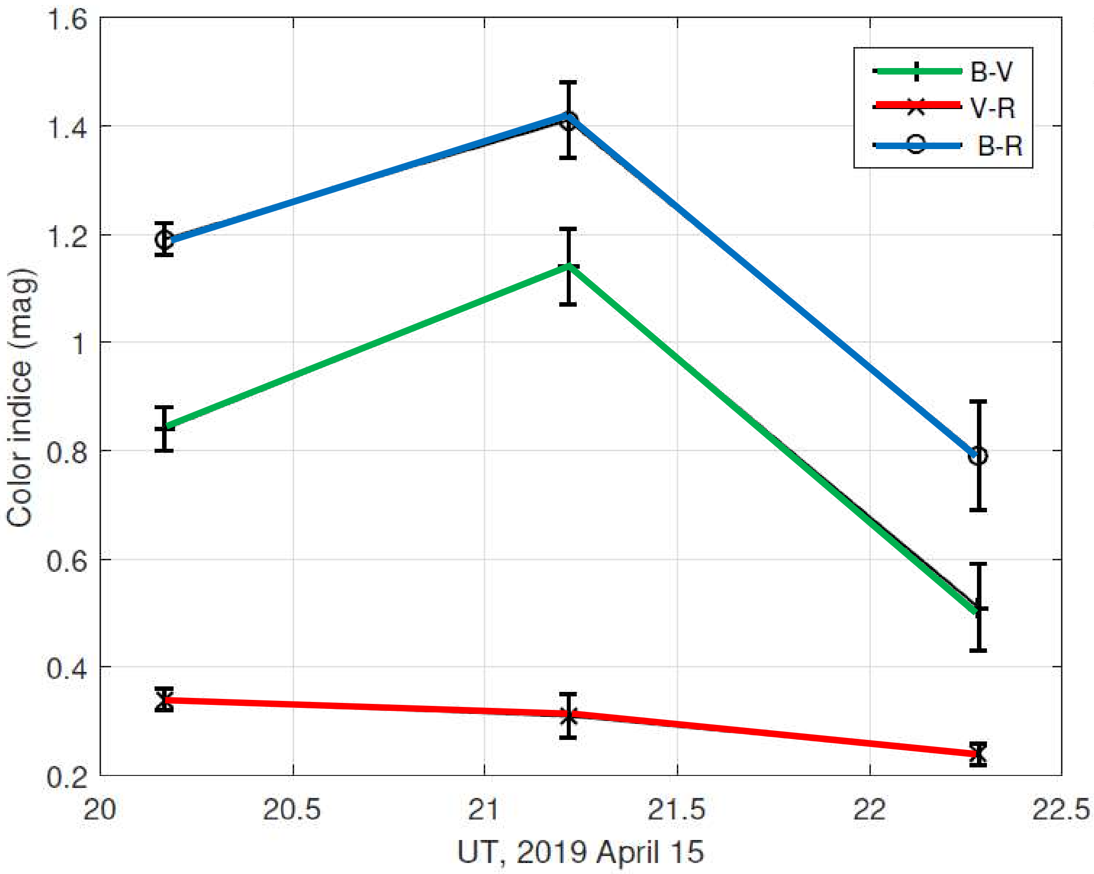
† $M_{std} = m_{instr} - k\,X + c\,(\text{Color}) + ZP$, as from eq. (5).
* Assumed

Colors B-V, V-R and B-R: test with field stars



473-044752	Batch #1	Batch #2	Batch #3	Average	Cat.
$B-V$	$0.33_{\pm0.03}$	$0.34_{\pm0.03}$	$0.52_{\pm0.03}$	$0.40_{\pm0.06}$	0.43
$V-R_c$	$0.23_{\pm0.02}$	$0.27_{\pm0.02}$	$0.27_{\pm0.02}$	$0.26_{\pm0.01}$	0.25
$B-R_c$	$0.56_{\pm0.02}$	$0.61_{\pm0.02}$	$0.79_{\pm0.02}$	$0.66_{\pm0.07}$	0.68
473-044753					
$B-V$	$0.75_{\pm0.04}$	$0.76_{\pm0.04}$	$0.96_{\pm0.04}$	$0.82_{\pm0.07}$	0.90
$V-R_c$	$0.39_{\pm0.02}$	$0.46_{\pm0.02}$	$0.44_{\pm0.02}$	$0.43_{\pm0.02}$	0.41
$B-R_c$	$1.14_{\pm0.03}$	$1.22_{\pm0.03}$	$1.40_{\pm0.03}$	$1.25_{\pm0.08}$	1.32
473-044754					
$B-V$	$1.42_{\pm0.06}$	$1.37_{\pm0.06}$	$1.49_{\pm0.06}$	$1.43_{\pm0.04}$	1.49
$V-R_c$	$0.90_{\pm0.04}$	$0.96_{\pm0.04}$	$0.95_{\pm0.04}$	$0.94_{\pm0.02}$	0.93
$B-R_c$	$2.32_{\pm0.05}$	$2.33_{\pm0.05}$	$2.45_{\pm0.05}$	$2.37_{\pm0.04}$	2.42

Gault's colors (from «Cassini» Telescope)

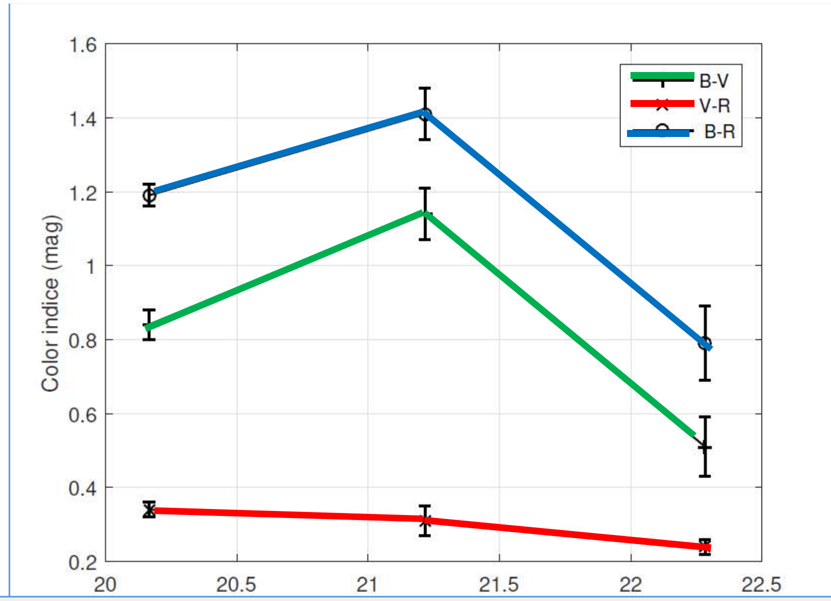


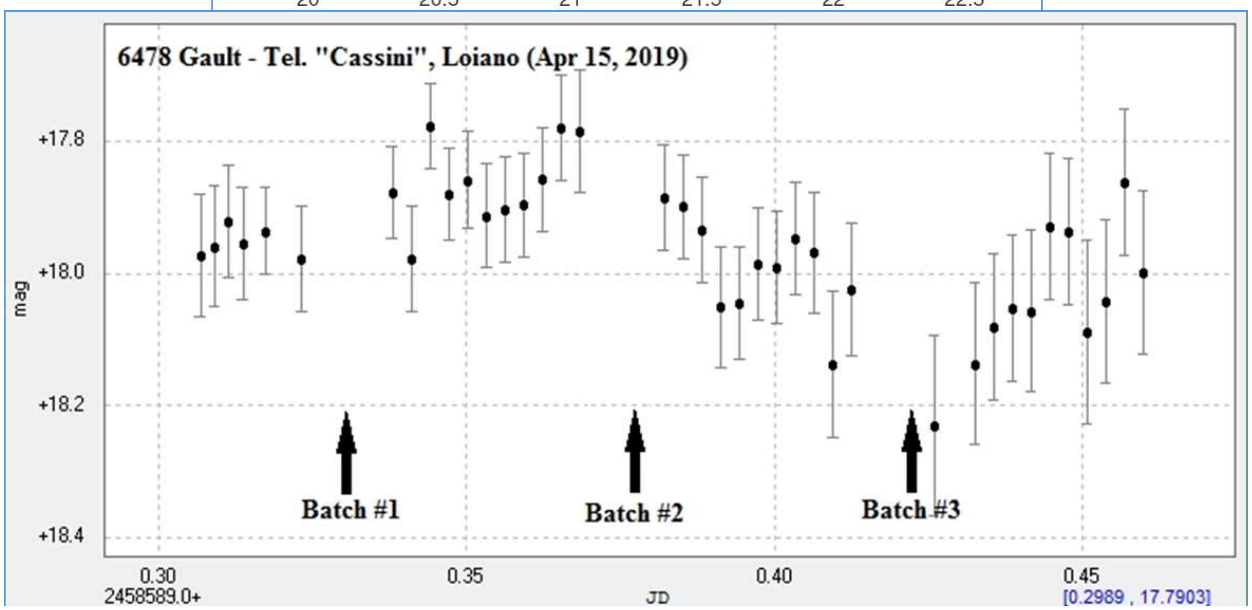
	Batch #1[a]	Batch #2[a]	Batch #3[a]	Average	MT19[b]
$B-V$	$0.84_{\pm 0.04}$	$1.14_{\pm 0.07}$	$0.51_{\pm 0.08}$	$0.83_{\pm 0.3}$	$0.79_{\pm 0.06}$
$V-R_c$	$0.34_{\pm 0.02}$	$0.31_{\pm 0.04}$	$0.24_{\pm 0.02}$	$0.30_{\pm 0.05}$	$0.31_{\pm 0.02}$
$B-R_c$	$1.19_{\pm 0.03}$	$1.41_{\pm 0.07}$	$0.79_{\pm 0.10}$	$1.13_{\pm 0.3}$	$1.10_{\pm 0.06}$

[a] After cloud veils correction, as discussed in the text
[b] As from Man-To et al. (2019)

During the 2019 April 15 session from Loiano, changes in the B-V and B-R colors are visible: **the asteroid, after a couple of hours, has become significantly bluer**.

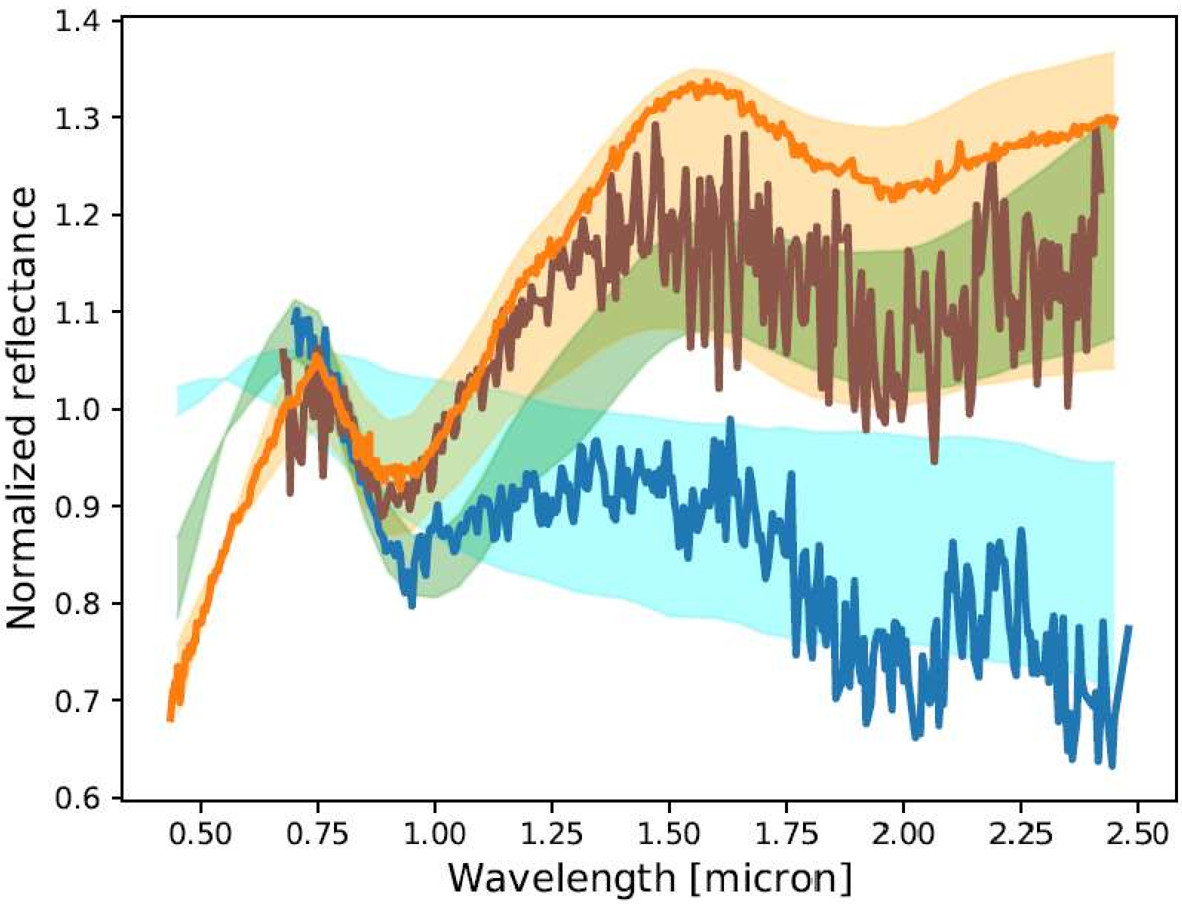
This color variation can be a consequence of the dust emission activity that has exposed a new, non-reddened substrate.





Most likely, some of the brightness changes are due to albedo patches on the surface.

What about the NIR spectrum?



Phocaea, S-type asteroid (orange)

Gault, 2019 April 8 (brown)

Gault, 2019 March 31 (blue)

(Marsset et al., The Astrophysical Journal Letters, 2019)

Conclusions

1. Gault presents a **bluer area** than the surrounding, probably linked to the dust emission activity in space.

2. The rotation period is **not 2 hours**, the data are compatible with a value of **about 3.3 hours**.

3. If point 2 is true and Gault is at the spin-barrier, the **bulk density** of the asteroid is **about 1 g/cm^3**

4. If point 3 is true, **Gault's bulk density** is lower than the average value of S-type asteroids, so **large interior voids** are possible because of the very low gravity of the asteroid.

5. Gault remains an **extremely interesting object** to follow.