3122 FLORENCE: LIGHTCURVE ANALYSIS AND PRELIMINARY MODEL

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Photometric observations of 3122 Florence were carried out on 12 nights between 2017 Aug 30 and Oct 6. This allowed us to determine a synodic period range from P = 2.3568 h ± 0.0002 to 2.3576 h ± 0.0002 with amplitude ranging from A = 0.22 to 0.16 mag. Multi-band photometric sessions and low resolution visible spectrum analysis shows a taxonomic class S, according to the SMASS II classification. Using lightcurve inversion method we also obtained a preliminary shape and spin axis model of (λ = 164° ± 15, β = -86° ± 5) with a sidereal period Psid = 2.3583 h ± 0.0005.

3122 Florence is an Amor NEA (PHA) discovered on 1981 Mar 2 by J.S. Bus at Siding Spring in Australia. Collaborative observations were made over twelve nights inside the UAI (Italian Amateur Astronomers Union) group in order to observe this asteroid during its close approach to the Earth in the early of September 2017. The CCD observations were carried out between 2017 Aug 30 and Oct 6, covering wide variations in the phase angle and in the viewing geometries. The instrumentation is described in the Table I. Lightcurve analysis was made at the Balzaretto Observatory with *MPO Canopus v.10.7.7.0* (BDW Publishing, 2016). All the images were calibrated with dark and flat frames and converted to standard magnitude system using solar colored field stars from APASS catalogue. For the Rc and the Ic photometric bands were used the transformations by Munari (Munari, 2012), while for the B and V photometric bands were used the magnitude values of the catalog without any transformation. Table II shows the observing circumstances and results. Multi-band photometric sessions, acquired at Balzaretto Observatory on 2017 Aug 30 and at University of Siena (DSFTA, 2017) on 2017 Sept 4, let us determine the color indexes reported on table III and in Fig 1. These color indexes are consistent with a medium albedo S-type taxonomic class (Shevchenko and Lupishko, 1998).

There are many previously published rotation periods reported into lightcurve database (LCDB; Warner et al., 2009). The period analysis shows variations of the synodic periods and lightcurves amplitude as a consequence of the wide variations of the viewing geometry. The synodic period ranging from P = 2.3568 h ± 0.0002 to 2.3576 h ± 0.0002 and the amplitude ranging from A = 0.22 to 0.16 mag (Fig. 2). Moreover, the observed synodic period decrease respect the daily change rate of PAB Longitude (Fig. 3). This trend suggests a retrograde rotation for 3122 Florence. In addition, the intercept of the stationary point (ΔPABL/day=0) with the regression line is consistent (within the errors) with the sidereal period derived from the lightcurve inversion process.

Reflectance spectrum

Low resolution visible spectrum was observed at Balzaretto Observatory on 2017 Aug 30 with the diffraction grating SA-200 (Paton Hawksley Education) mounted inside the filter wheel, obtaining in this configuration a spectral resolution R~100. In order to increase the signal-to-noise ratio, we acquired and stacked 45 frames, each with a 30 second exposure time. In the same session we also acquired, at the same air-mass of the asteroid, the spectra of the stars HD 203893 (A0V type) and HD 203311 (solar-like G2V type), respectively for wavelength calibration and for solar reference to derive the reflectance spectrum. This was achieved by dividing the asteroid spectrum with the solar-like star and then normalized to the unity at the standard wavelength of 0.55 μm (center of the photometric V band). The resulting asteroid reflectance spectrum was compared with the SMASS II single-letter taxonomy classes (Bus and Binzel, 2002). The best fit of the 3122 Florence reflectance spectrum was achieved for the S-type taxonomic class (Fig. 4), according to the SMASS II taxonomy classification (Bus and Binzel, 2002). Moreover, a more rigorous taxonomy classification was done using the PCA analysis technique. First, we computed the principal component scores (PC1, PC2) and eigenvectors coefficients for the SMASS II single-letter taxomomy classes at discrete wavelengths (0.44, 0.50, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85 μm; Bus and Binzel, 2002). We fit the normalized spectrum of 3122 Florence using a 4th order polynomial function and computed the two component scores (PC1, PC2) with the previously determined eigenvectors. Figure 5 compare the position of 3122 Florence respect single-letter taxonomy classes in the PC1, PC2 space. The taxonomy class of 3122 Florence is close to that of S-type asteroids.

Lightcurve inversion

The lightcurve inversion process requires at least 2-3 apparitions data and a wide range of the viewing angles in order to determine the asteroid spin axis vector. In this apparition, the wide variations of the viewing geometry let us to attempt a preliminary shape and spin axis model. For this purpose, we used only the best lightcurves, that cover the entire observing geometries of our complete sample (Fig. 6). Lightcurve inversion was performed using *MPO LCInvert v.11.7.5.1* (BDW Publishing, 2016). For a description of the modeling process see LCInvert Operating Instructions Manual and Warner et al. (2017). The search for sidereal period was started around the synodic periods found in the period analysis. For this search the "dark facet" weighting factor was set to 0.3 and the number of iterations was set to 300. We found three sidereal periods with nearly lower chi-square value below the 10% limit, where the first two produce prograde pole solutions at (λ = 224, β = 89), (λ = 269, β = 82) and the third produce a retrograde pole solution at (λ = 164, β = -86). This last one have a lower chi-square value and it is consistent with PAB calculations, so we prefer this last one (Fig. 7).

For the pole search we used the “medium” search option with the previously found sidereal period set to “float”. The “dark facet” weighting factor was set to 0.3 and the number of iterations was set to 50. Data analysis shows a rough solution with lower chi-square value at λ = 180°, β = -90°. The subsequent “fine” search, centered on this position, allowed us to further refine the position of the pole (Fig. 8). The analysis does not find a well-isolated solution for the pole position with lowest chi-square below the 3% limit, but a wide distribution of the ecliptic longitude (lambda) and a more restricted distribution for the ecliptic latitude (beta). A preliminary solution, with lowest chi-square, is located at λ = 164° ± 15 β = -86° ± 5, with a sidereal period Psid = 2.3583 h ± 0.0005. The uncertainty in the sidereal period has been evaluated as a rotational error of 30° over the total timespan of the observations. Figure 9 shows the shape model with the fit between the model (black line) and the observed lightcurves (red points). The asteroid shape is nearly spheroidal in agreement with the observed low amplitude lightcurves and with the radar observations obtained on 2017 Sept 4 from Arecibo (CNEOS, 2017; Fig. 10).

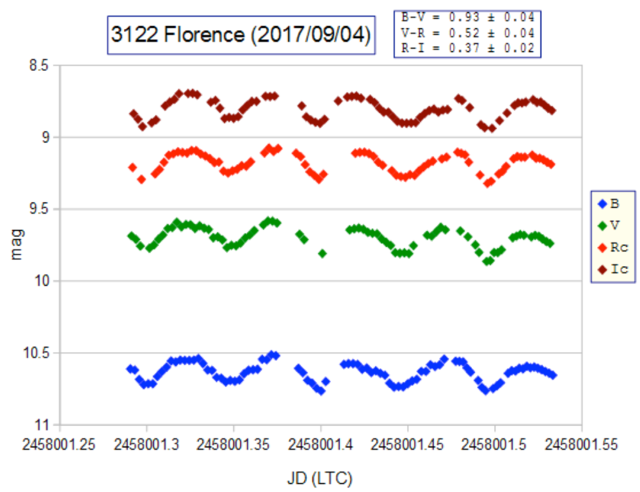

Fig. 1: Multi-band photometric lightcurves acquired on 2017 Sep 4 at DSFTA Observatory.

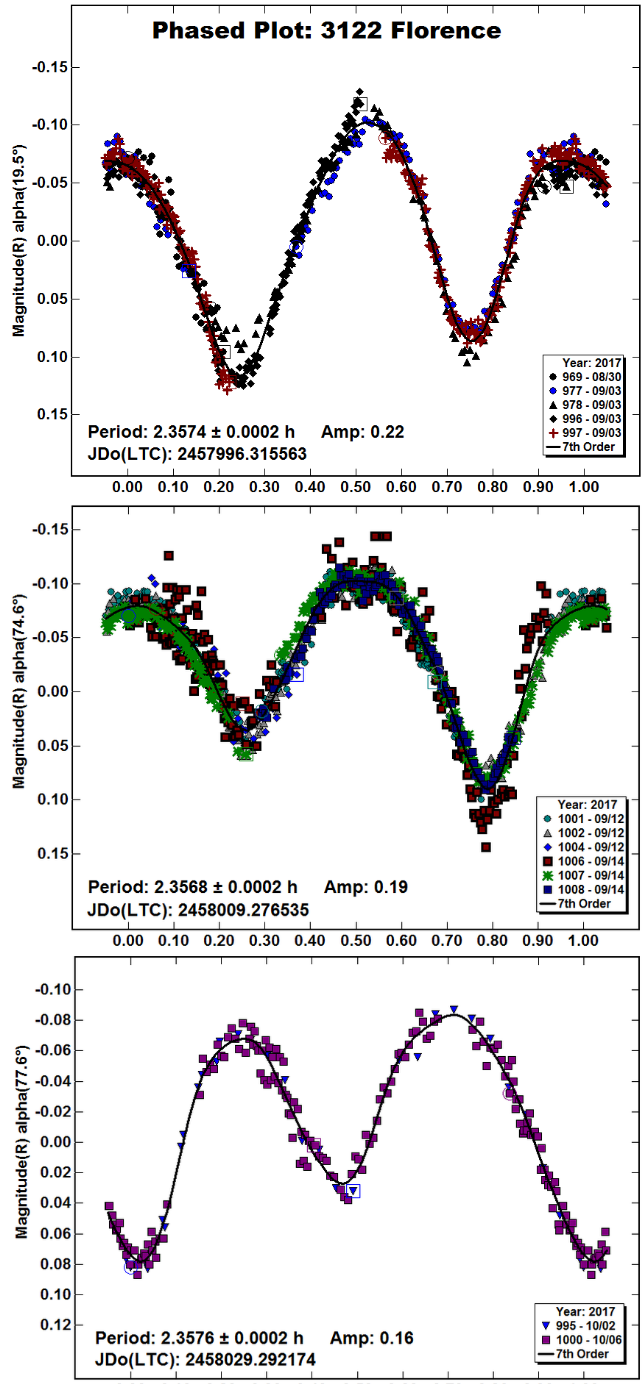

Fig. 2: 3122 Florence. The acquired lightcurves show variations in the synodic period and amplitude.

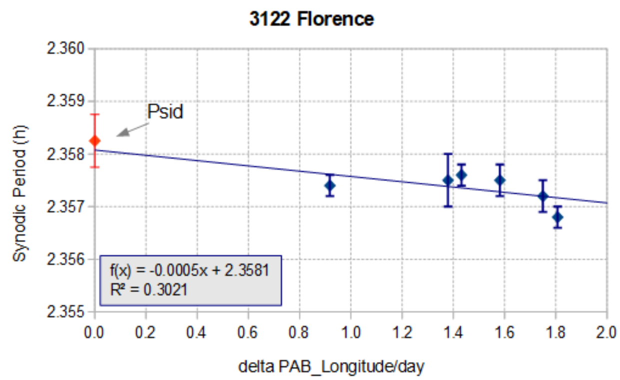

Fig. 3: The observed synodic period decreases, respect the daily change rate of the PAB Longitude, suggesting a retrograde rotation for 3122 Florence.

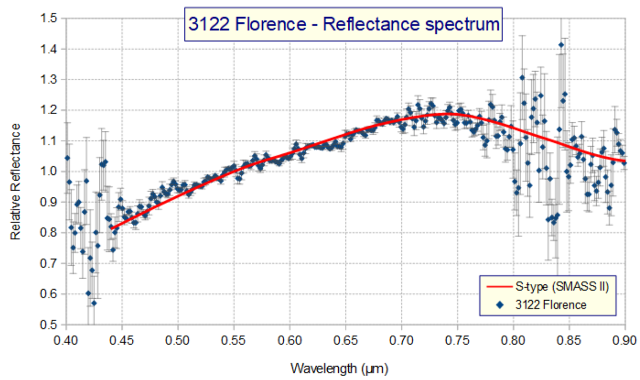

Fig. 4: The reflectance spectrum of 3122 Florence compared with S-type taxonomic class (SMASS II).

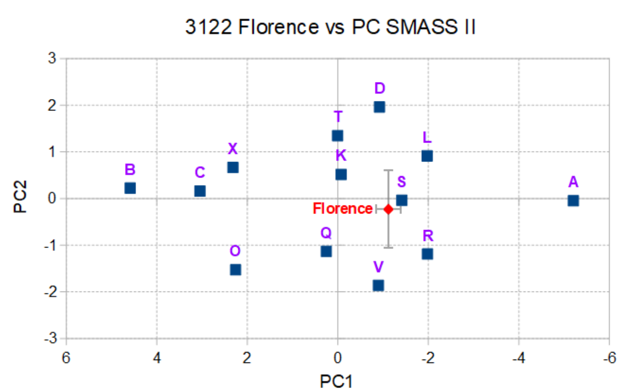

Fig. 5: The position of 3122 Florence respect single-letter taxonomy classes in the PC1, PC2 space. The error bars indicate the 1-sigma uncertainty.

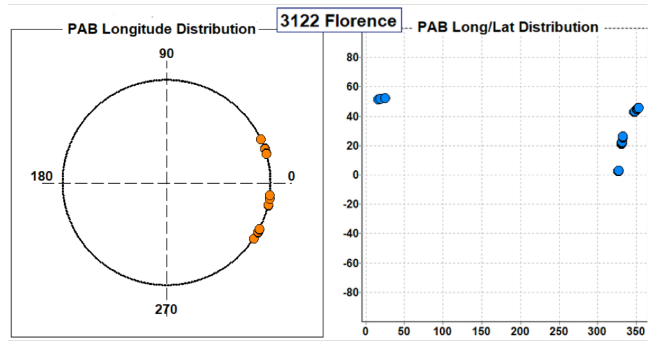

Fig. 6: Phase angle bisector (PAB) longitude/latitude distribution of the data used for the lightcurve inversion model.

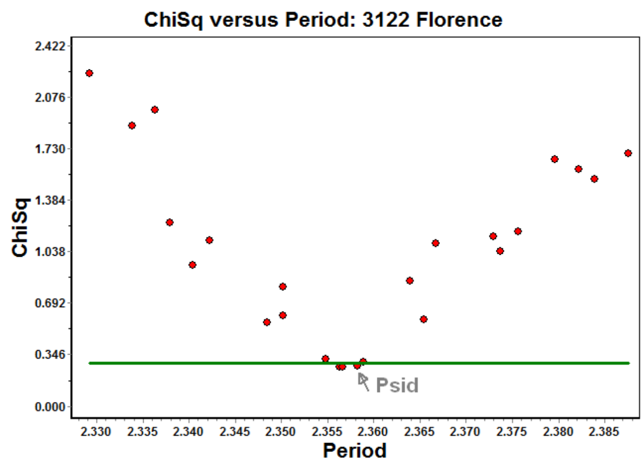

Fig. 7: The period search do not find a unique solution with lowest chi-square, but three solutions with a similar low chi-square reside below the 10% limit (green line).

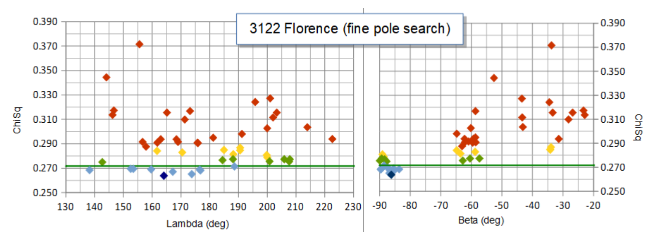

Fig. 8: The “fine” pole search shows a distribution of the ecliptic coordinates. The colors from dark blue to maroon indicates the better solutions (lower chi-square) and the worst ones. The better solutions are located below the 3% limit (green line).

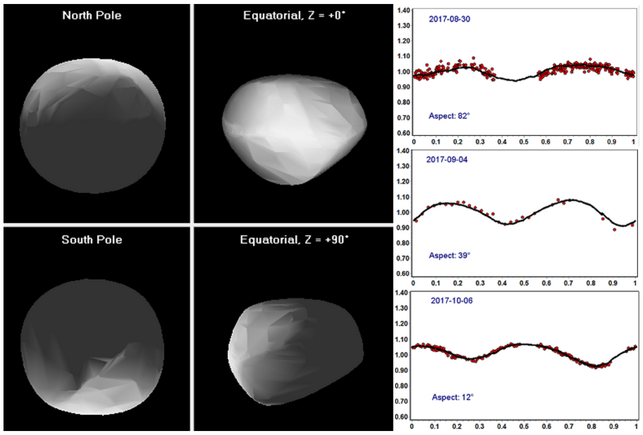

Fig. 9: The shape model for 3122 Florence (λ = 164°, β = -86°) and the fit between the model (black line) and the observed lightcurves (red points).

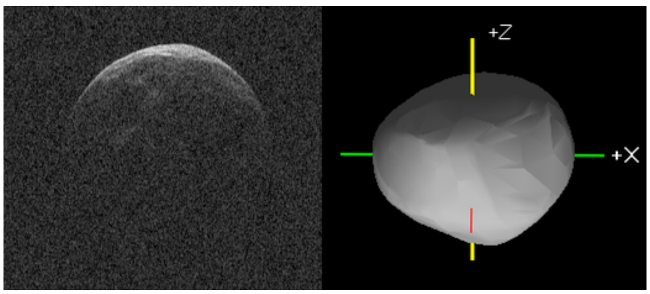

Fig. 10: Comparison between the radar image obtained on 2017 Sept 4 from Arecibo and the model obtained from lightcurve inversion process.

Observatory (MPC code)	Telescope	CCD	Filter
M57 (K38)	0.30-m RCT f/5.8	SBIG STT-1603	Rc
Balzaretto (A81)	0.20-m SCT f/5.5	SBIG ST7-XME	V,Rc
GiaGa (203)	0.28-m SCT f/10	SBIG ST8XME	Rc
Eurac (C62)	0.30-m NRT f/4	QHY9	Rc
Univ.Siena (K54)	0.30-m MCT f/5.6	SBIG STL-6303e (2x2)	B, V, Rc,Ic
Salvatore di Giacomo(L07)	0.50-m RCT f/8	FLI-PL4240	Rc
AAB	0.40-m SCT f/10	KAF 1603 ME	C
San Marcello Pistoiese (104)	0.60-m NRT f/4	Apogee Alta	C

Table I. Observing Instrumentations. MCT: Maksutov-Cassegrain, NRT: Newtonian Reflector, RCT: Ritchey-Chretien, SCT: Schmidt-Cassegrain.

Date (MPC code)	Color Indexes
2017 Aug 30 (A81)	(V-Rc) = 0.48 ± 0.05
2017 Sept 4 (K54)	(B-V) = 0.93 ± 0.04
	(V-Rc) = 0.52 ± 0.04
	(Rc-Ic) = 0.37 ± 0.02

Table III. The color indexes acquired for asteroid 3122 Florence.

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Number	Name	2017 mm/dd	Pts	Phase	LPAB	BPAB	Period(h)	P.E	Amp	A.E.
3122	Florence	08/30-09/03	723	19.5,43.2	329	12	2.3574	0.0002	0.22	0.03
3122	Florence	09/12-09/14	1156	74.5,76.8	349	44	2.3568	0.0002	0.19	0.03
3122	Florence	10/02-10/06	186	77.5,76.0	22	52	2.3576	0.0002	0.16	0.03

Table II. Observing circumstances and results. Pts is the number of data points. The phase angle values are for the first and last date. LPAB and BPAB are the approximate phase angle bisector longitude and latitude at mid-date range (see Harris et al., 1984).