# The potential of combined sparse photometric data in asteroid shape modeling

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Solar System science before and after Gaia

# Lightcurve inversion

- Kaasalainen & Torppa 2001; Kaasalainen et al. 2001, 2002
- Method for a convex shape determination of an asteroid from a set of lightcurves
- Parameters of the rotational state and the scattering law can be also determined
- Uses all available data, we can use dense or sparse photometry alone or their combination
- Shape is general, parametrized by the coefficients of the expansion into the spherical harmonics

# A convex shape model of asteroid (312) Pierretta

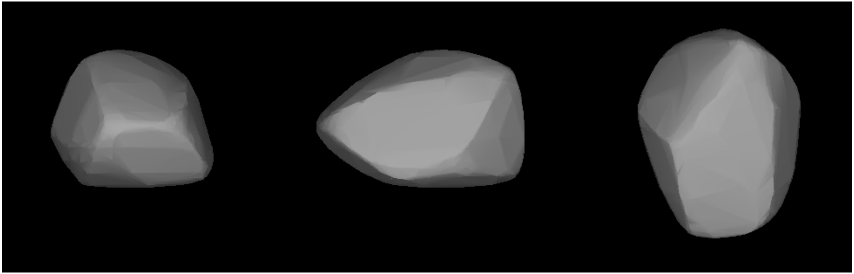

Figure: The first two figures are shown at equatorial view with rotational phases 90° apart, the third one is pole-on view. $P = 10.20764$ h, ecliptic pole coordinates (82°,−39°), mirror solution (256°,−58°). Based on 4 dense lcs from UAPC and three sparse lcs (689, 703, E12).

# Models from “classical” lightcurves

- $\sim$100, stored in DAMIT
- Typically, we need data from at least three apparitions and a good coverage of the solar phase angle (i.e., different viewing geometries)
- We search the model near the known synodic period, with a step of $\Delta P = \frac{P^2}{T}$
- Limited amount of these data (for $\sim$2 500 asteroids), only few models per year are published, demanding on observational time
- If a period for a particular object is secure, people do not need to observe this object any more
- Sometimes hard to get these data, often in different formats, a lot of work to process such data
- Important in testing the results for sparse data

# Models from a combination of dense and sparse data

- Ďurech et al. 2009, sparse data from U.S. Naval Observatory in Flagstaff
- Tested on multiple-apparition lightcurve inversion models
- 24 models, typical pole uncertainty 10–20°
- Sparse photometry from USNO is of a low quality (8-10%)
- Almost for free, you just need to download them from the AstDyS

# Typical sparse lightcurve

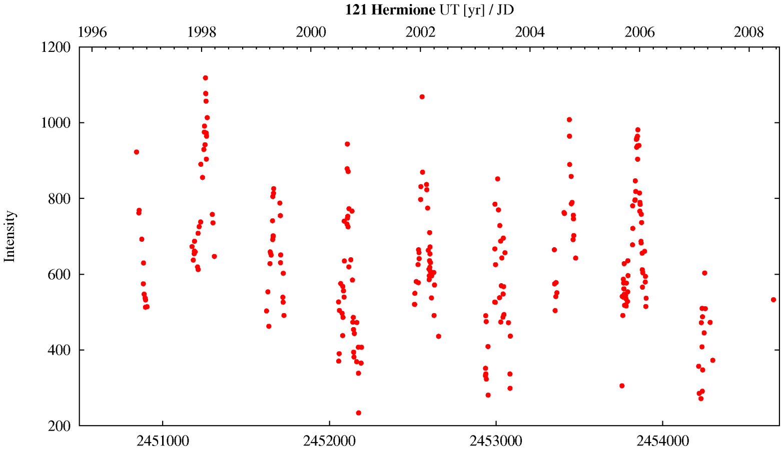


Figure: Sparse lightcurve of 121 Hermione, brightness vs. time, USNO in Flagstaff.

# Available sparse data – AstDyS

- Astrometric database – data for $\sim$ 400 000 objects from $\sim$ 1 500 observatories (November 11, 2010)
- Hiparcos, Catalina Sky Survey, La Palma, LONEOS, USNO in Flagstaff, PS1, ...
- 7 observatories with a “good” photometry
- Different quality between observatories => weights
- For 75 000 asteroids we have at least 20 sparse data points
- For 4 300 asteroids we have at least 100 sparse data points and do not know the period
- For 2 500 asteroids we have data and also know the period

# Deriving models

- We combined dense and sparse data together and gathered data sets for ∼2 500 asteroids, for ∼1 000 there were only sparse data available
- Period guess based on the Minor Planet Lightcurve Database (Warner et al., 2009)
- 161 new unique models, 47 based only on sparse data (Hanuš et al., 2011: 80 models, the rest is unpublished)
- Currently, we are computing models for 4 300 asteroids on period interval 2–100 hours

# Tests of the sparse data models relevance

- Inertia tensor
- Half and double period values
- Reduction of the number of sparse photometric data
- Comparison with models based only on dense data
- Creating data sets for “mock” objects and deriving their convex models

# Example of a “mock” object

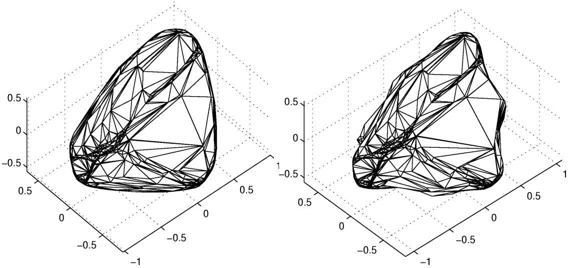


Figure: Asteroid (810) Atossa: shape model (left) and an example of a “mock” shape model (right).

# Are sparse data sufficient for a unique period determination?

- For most asteroids we do not know the period
- Search on a large interval of 2–100 hours, a lot of computational time
- Problems to solve: can we trust these periods and models? the amount of data and its accuracy, testing on asteroids with known periods
- After adding some data, we do not want to recompute the model again on the 2–100 hours period interval!

# (5647) 1990 TZ

- P = 6.141 h (Warner et. al., 2009)
- Catalina: 87 points, P = 6.13867 h, a unique model

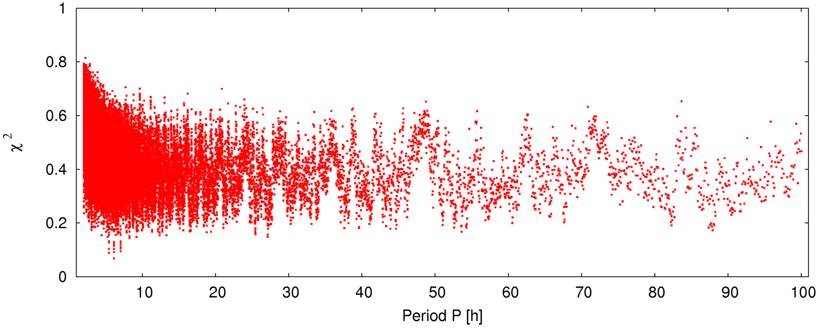


Figure: Periodogram of asteroid (5647) 1990 TZ.

# Relevance to Gaia

- For a unique model from the Gaia data alone, we will need all the ∼60 data points, the amount of new models will be dependent on the real quality of the photometry
- Already ∼20 data points from Gaia could be combined with existing photometric data (Catalina, Pan-STARRS, relative data)
- Using this approach, we will be able to derive as many new models as possible
- We have to determine the quality of the photometry => weight
- Our routines are ready

# Conclusions

- We showed that reliable asteroid models can be also derived when we use only sparse data
- We found current valuable sparse data and used them either alone or in combination with dense lightcurves in lightcurve inversion
- We derived 161 new models, 47 are based only on sparse data
- This amount of new models could not be achieved from neither dense nor sparse data alone, the most efficient approach is to combine all available photometric data together
- Data from Gaia should be investigated in order to estimate its weight and used together with other photometric data in lightcurve inversion method
- Unique periods can be determined from sparse data, more careful analysis is needed

# Thank you for your attention!