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On the application of 3D asteroid models to occultation work

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Photometry is one of the most important remote sensing techniques in order to get information about basic physical properties of asteroids. In the past decade the inversion of asteroid light curves was successfully applied to many asteroids and has provided shape models (3D) for currently about 200 asteroids. While a successful observed occultation led to a projection of the asteroid's shape on the fundamental plane for one moment (a so-called profile), the light curve inversion gives us a complete 3D model of the physical object (Fig. 1), but without an information about the absolute dimensions (size in km). Obviously, the occultation method can be used to a) check the reliability of the inversion result and b) as constrain during the inversion process itself (Durech et al., 2011)

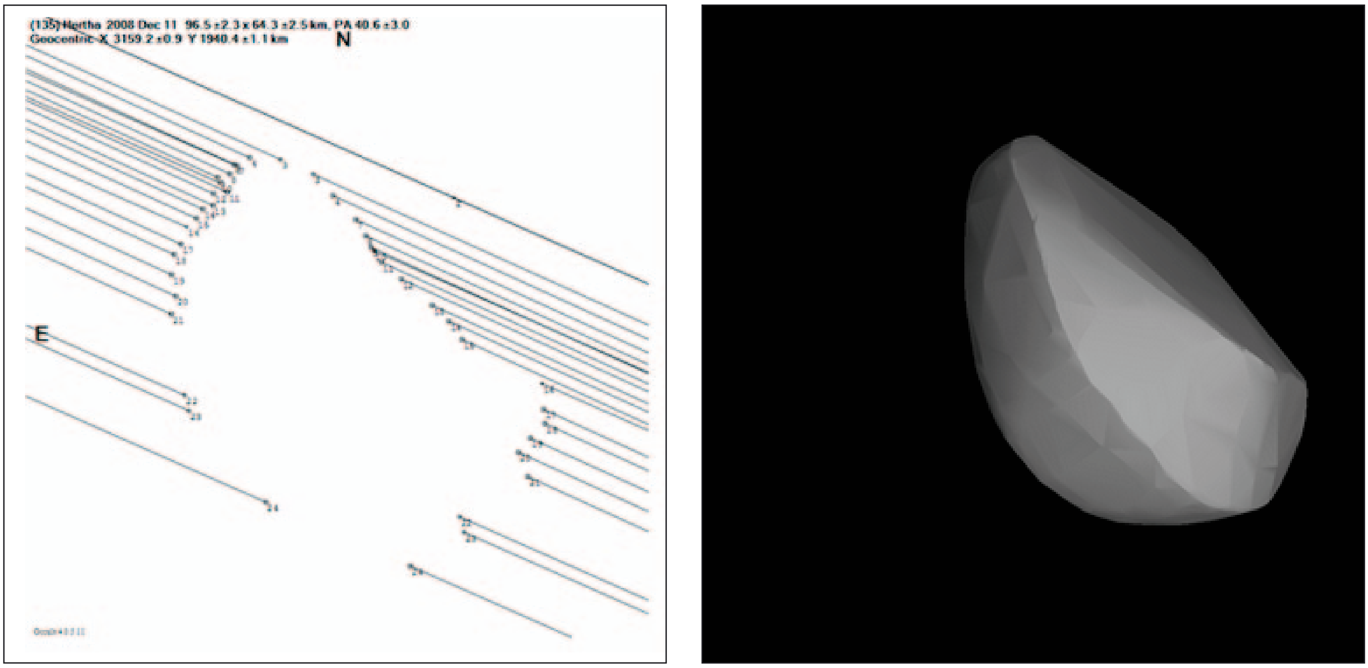

Fig. 1 The occultation of HIP 13021 by (135) Hertha on 2008-12-11 was well observed in the US. On the left side the shape profile on the fundamental plane is outlined from the occultation chords. The right side shows the DAMIT 3D model as seen from the Earth for the time of occultation (by Durech).

In this paper I do not go into the light curve inversion method itself, i.e. deriving 3D shape models from observed light curves. The method is described in Kaasalainen et al. (2002) and papers cited there. Rather, it is shown, that just using existing shape models helps to understand and prepare occultations by these objects and -btw- is also helpful to prepare light curve observations runs.

The main source for these asteroid models is DAMIT (Database of Asteroid Models from Inversion Techniques). DAMIT is a database of asteroid shape models which is operated by The Astronomical Institute of the Charles University in Prague, Czech Republic (Durech et al., 2010).

The web frontend provides an easy access to the data. You can display and download rotational parameters, observed light curves and shape models derived from light curve inversions plus associated information like references, light curve fit results etc. You can even dump the whole database, giving you the possibility to use the data in your own research and programs.

The shape model is provided in a proprietary format (an easy to code facet-vertex-mesh, see below) and meanwhile also in the Wavefront .obj 3D geometry definition file format which can be read and visualized by many model viewer and scientific plotting programs. Even smart phone apps are available to display this .obj models.

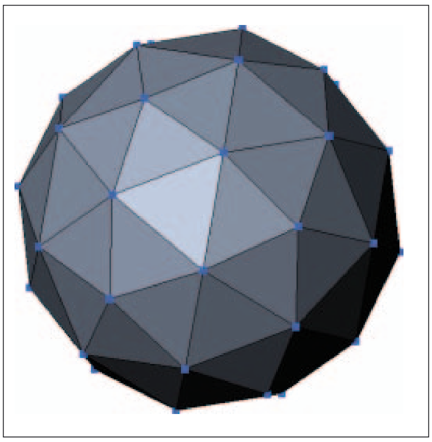

Fig. 2 Representing a body by a triangle mesh (blender.org)

Basically, the object is represented by a mesh of triangles, the small surfaces build from a triangle are called facet, each point of the triangle is called vertex and is represented by a 3D vector in a planetocentric coordinate system (Fig.2).

In simple words, the disc integrated brightness of the asteroid for a time t is computed by applying a reflection / scattering law (here: Lambert's law) to each facet considering the perspective geometry (angle of incidence and viewpoint) and the phase angle function. The summation over all facets visible to the observer for the given time t leads to the relative (and usually normalized) brightness.

While the DAMIT website offers also some C and Fortran programs for processing the data, I decided to implement this algorithms into my own software project which I started a while ago. Furthermore the resulting code can be used in another project, i.e. an Occultation Reports Database[1], automatically providing the perspective view on the asteroids model for the time of a successful observed occultation. Python[2] as programming language was chosen because a lot of scientific grade modules (like scipy and matplotlib) are available, thus avoiding to spend time with programming basic routines, and a lot of graphic packages (like OpenGL) and GUI toolkits are also available or even part of the language standard[3].

As a first step, all data were parsed into a SQLite[4] DB, to provide an easy access from within the software. Secondly a script was written which reads all light curves from DAMIT which were used to derive the 3D model of a specific asteroid[5]. For all observed light curves corresponding synthetic light curves are computed, to verify the result of the light curve inversion. Fig. 3 outlines the result for one of these observed nights. It is also possible to predict and plot the light curve for an arbitrary date (Fig. 4). Currently in progress is to put this code into a GUI based program which allows to handle with observed and computed light curves and to display the 3D model in different perspectives including the resulting light curves. Aim of this paper was to give the reader an idea about how the results of asteroidal occultation observations and light curve inversion can support each other.

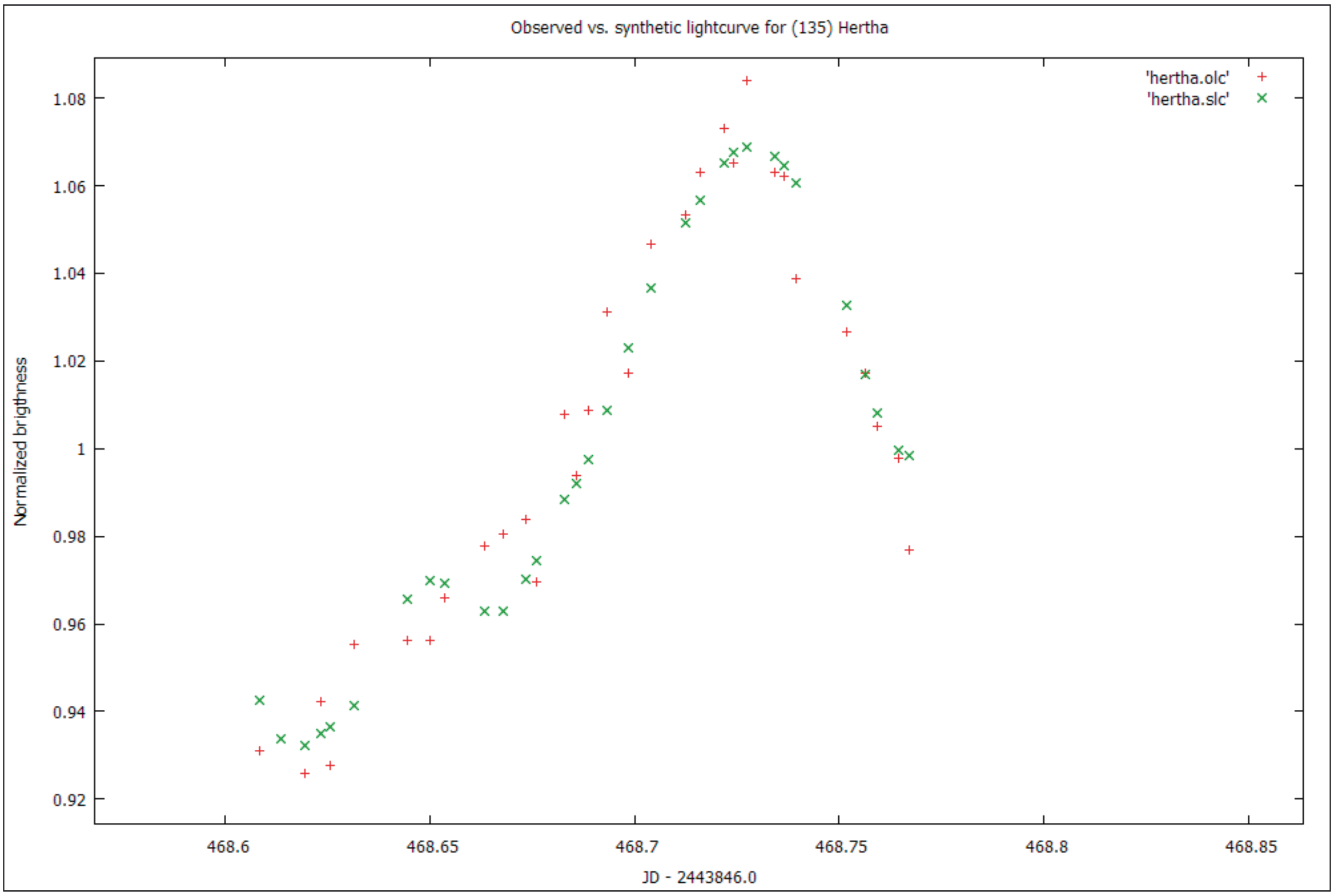

Fig. 3 Comparison between an observed light curve (red) and the synthetic light curve derived from the shape model (green) for (135) Hertha.

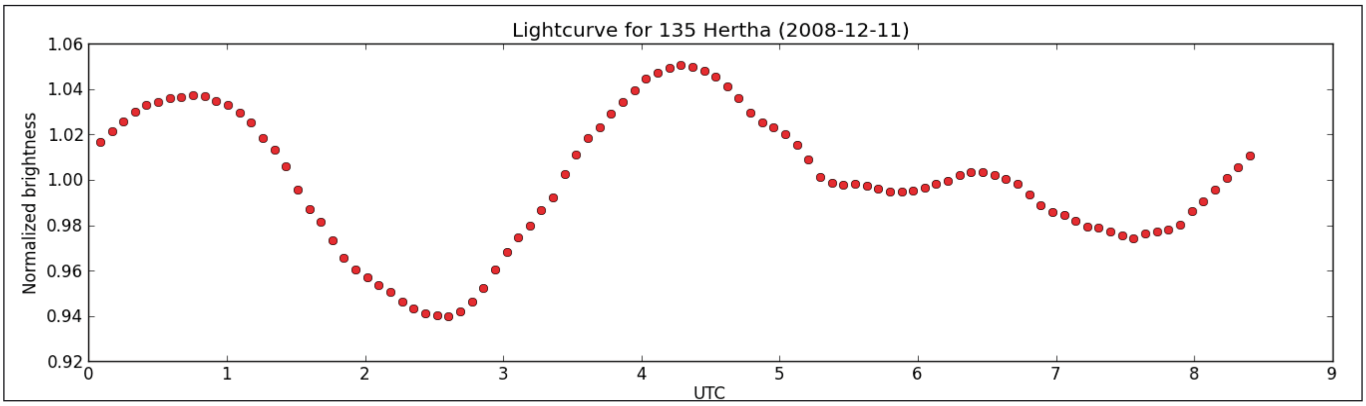

Fig. 4 Predicted light curve for (135) Hertha for the occultation shown in Fig. 1. Observed occultation time was around 07:44 UTC.

References:

Durech et al., 2010: http://cdsads.u-strasbg.fr/abs/2010A%26A...513A..46D
Durech et al., 2011: http://arxiv.org/pdf/1104.4227v1.pdf
Kasaaleinen et al., 2003: Asteroid Models from Disk-integrated Data. In Asteroids III.

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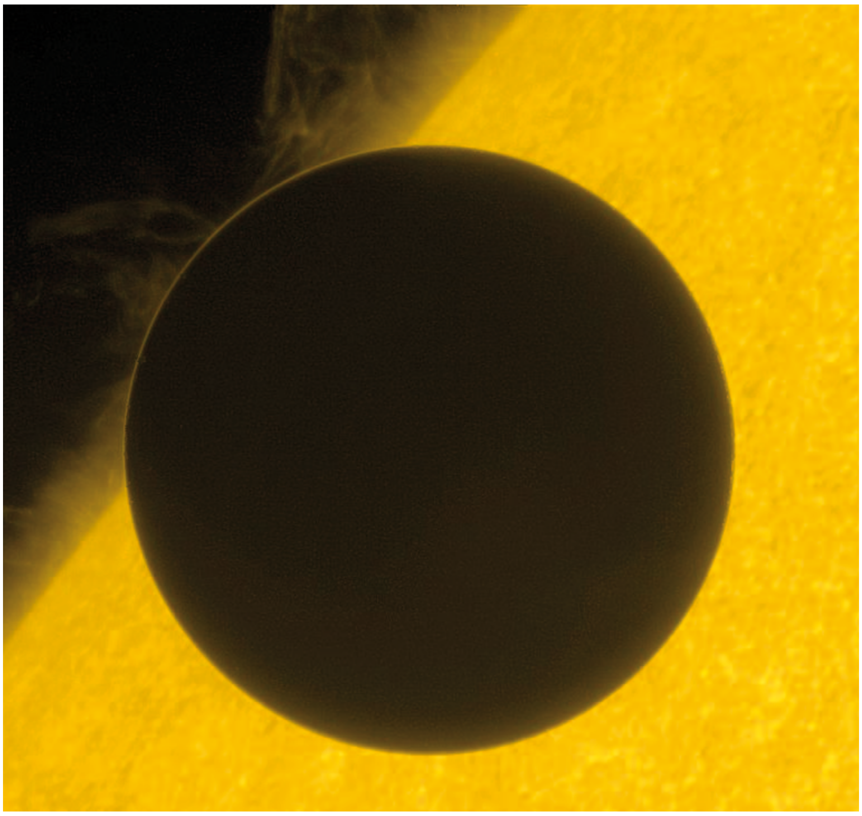
1 This paper is based on a presentation given at the annual German minor planets meeting in Berlin, June 2012
2 http://astro.troja.mff.cuni.cz/projects/asteroids3D
3 http://people.sc.fsu.edu/~jburkardt/txt/obj_format.txt
4 http://sky-lab.net/occrep/
5 http://www.python.org
6 Tkinter is the standard GUI toolkit of Python.
7 http://www.sqlite.org/
8 Similar to lcgenerator.c which is provided by Durech / DAMIT.



Venus at the Edge

Image Credit: NAOJ, JAXA, NASA, Lockheed Martin

Explanation:

As its June 6 2012 transit begins Earth's sister planet crosses the edge of the Sun in this stunning view from the Hinode spacecraft. The timing of limb crossings during the rare transits was used historically to triangulate the distance to Venus and determine a value for the Earth-Sun distance called the astronomical unit. Still, modern space-based views like this one show the event against an evocative backdrop of the turbulent solar surface with prominences lofted above the Sun's edge by twisting magnetic fields. Remarkably, the thin ring of light seen surrounding the planet's dark silhouette is sunlight refracted by Venus' thick atmosphere.

Credit: Astronomy Picture of the Day, 2012 June 9