Tomographic inversion of gravity gradient field for a synthetic Itokawa model

This article investigates reconstructing the internal mass density of a numerical asteroid model using the gradient of a simulated gravity field as synthetic measurement data. Our goal is to advance the mathematical inversion methodology and find feasibility constraints for the resolution, noise and orbit selection for future space missions. We base our model on the shape of the asteroid Itokawa as well as on the recent observations and simulation studies which suggest that the internal density varies, increasing towards the center, and that the asteroid may have a detailed structure. We introduce randomized multiresolution scan algorithm which might provide a robust way to cancel out bias and artifact effects related to the measurement noise and numerical discretization. In this scheme, the inverse algorithm can reconstruct details of various sizes without fixing the exact resolution a priori, and the randomization minimizes the effect of discretization on the solution. We show that the adopted methodology provides an advantageous way to diminish the surface bias of the inverse solution. The results also suggest that a noise level below 80 Eotvos will be sufficient for the detection of internal voids and high density anomalies, if a sparse set of measurements can be obtained from a close-enough distance to the target.

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Contributors: Sorsa, L., Takala, M., Bambach, P., Deller, J., Vilenius, E., Agarwal, J., Carroll, K. A., Karatekin, Ö., Pursiainen, S.
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The shape of (7) Iris as evidence of an ancient large impact?

Context. Asteroid (7) Iris is an ideal target for disk-resolved imaging owing to its brightness (V ~ 7-8) and large angular size of 0.33″ during its apparitions. Iris is believed to belong to the category of large unfragmented asteroids that avoided internal differentiation, implying that its current shape and topography may record the first few 100 Myr of the solar system's collisional evolution. Aims. We recovered information about the shape and surface topography of Iris from disk-resolved VLT/SPHERE/ZIMPOL images acquired in the frame of our ESO large program. Methods. We used the All-Data Asteroid Modeling (ADAM) shape reconstruction algorithm to model the 3D shape of Iris, using optical disk-integrated data and disk-resolved images from SPHERE and earlier AO systems as inputs. We analyzed the SPHERE images and our model to infer the asteroid's global shape and the morphology of its main craters. Results. We present the 3D shape, volume-equivalent diameter D_{eq} = 214 ± 5 km, and bulk density ρ = 2.7 ± 0.3 g cm^{-3} of Iris. Its shape appears to be consistent with that of an oblate spheroid with a large equatorial excavation. We identified eight putative surface features 20-40 km in diameter detected at several epochs, which we interpret as impact craters, and several additional crater candidates. Craters on Iris have depth-To-diameter ratios that are similar to those of analogous 10 km craters on Vesta. Conclusions. The bulk density of Iris is consistent with that of its meteoritic analog based on spectroscopic observations, namely LL ordinary chondrites. Considering the absence of a collisional family related to Iris and the number of large craters on its surface, we suggest that its equatorial depression may be the remnant of an ancient (at least 3 Gyr) impact. Iris's shape further opens the possibility that large planetesimals formed as almost perfect oblate spheroids. Finally, we attribute the difference in crater morphology between Iris and Vesta to their different surface gravities, and the absence of a substantial impact-induced regolith on Iris.

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Closing the gap between Earth-based and interplanetary mission observations: Vesta seen by VLT/SPHERE
Context. Over the past decades, several interplanetary missions have studied small bodies in situ, leading to major advances in our understanding of their geological and geophysical properties. These missions, however, have had a limited number of targets. Among them, the NASA Dawn mission has characterised in detail the topography and albedo variegation across the surface of asteroid (4) Vesta down to a spatial resolution of ~20 m pixel $^{-1}$ scale. Aims. Here our aim was to determine how much topographic and albedo information can be retrieved from the ground with VLT/SPHERE in the case of Vesta, having a former space mission (Dawn) providing us with the ground truth that can be used as a benchmark. Methods. We observed Vesta with VLT/SPHERE/ZIMPOL as part of our ESO large programme (ID 199.C-0074) at six different epochs, and deconvolved the collected images with a parametric point spread function (PSF). We then compared our images with synthetic views of Vesta generated from the 3D shape model of the Dawn mission, on which we projected Vesta's albedo information. Results. We show that the deconvolution of the VLT/SPHERE images with a parametric PSF allows the retrieval of the main topographic and albedo features present across the surface of Vesta down to a spatial resolution of ~20-30 km. Contour extraction shows an accuracy of ~1 pixel (3.6 mas). The present study provides the very first quantitative estimate of the accuracy of ground-based adaptive-optics imaging observations of asteroid surfaces. Conclusions. In the case of Vesta, the upcoming generation of 30-40 m telescopes (ELT, TMT, GMT) should in principle be able to resolve all of the main features present across its surface, including the troughs and the north-south crater dichotomy, provided that they operate at the diffraction limit.

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Contributors: Fétick, R. J., Jorda, L., Vernazza, P., Marsset, M., Drouard, A., Fusco, T., Carry, B., Marchis, F., Hanuš, J., Viikinkoski, M., Birlan, M., Bartczak, P., Berthier, J., Castillo-Rogez, J., Cipriani, F., Colas, F., Dudziński, G., Dumas, C., Ferrais, M., Jehin, E., Kaasalainen, M., Kryszczynska, A., Lamy, P., Le Coroller, H., Marciniak, A., Michalowski, T., Michel, P., Mugnier, L. M., Neichel, B., Pajuelo, M., Podlewska-Gaca, E., Santana-Ros, T., Tanga, P., Vachier, F., Vigan, A., Witasse, O., Yang, B.
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Homogeneous internal structure of CM-like asteroid (41) Daphne

Context. CM-like asteroids (Ch and Cgh classes) are a major population within the broader C-complex, encompassing about 10% of the mass of the main asteroid belt. Their internal structure has been predicted to be homogeneous, based on their compositional similarity as inferred from spectroscopy and numerical modeling of their early thermal evolution. Aims. Here we aim to test this hypothesis by deriving the density of the CM-like asteroid (41) Daphne from detailed modeling of its shape and the orbit of its small satellite. Methods. We observed Daphne and its satellite within our imaging survey with the Very Large Telescope extreme adaptive-optics SPHERE/ZIMPOL camera and complemented this data set with earlier Keck/NIRC2 and VLT/NACO observations. We analyzed the dynamics of the satellite with our Genoid meta-heuristic algorithm. Combining our high-angular resolution images with optical lightcurves and stellar occultations, we determine the spin period, orientation, and 3D shape, using our ADAM shape modeling algorithm. Results. The satellite orbits Daphne on an equatorial, quasi-circular, prograde orbit, like the satellites of many other large main-belt asteroids. The shape model of Daphne reveals several large flat areas that could be large impact craters. The mass determined from this orbit combined with the volume computed from the shape model implies a density for Daphne of 1.77 ± 0.26 g cm $^{-3}$ (3 σ). This densityis consistent with a primordial CM-like homogeneous internal structure with some level of macroporosity (≈ 17%). Conclusions. Based on our analysis of the density of Daphne and 75 other Ch/Cgh-type asteroids gathered from the literature, we conclude that the primordial internal structure of the CM parent bodies was homogeneous.

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DISCUS – The Deep Interior Scanning CubeSat mission to a rubble pile near-Earth asteroid

We have performed an initial stage conceptual design study for the Deep Interior Scanning CubeSat (DISCUS), a tandem 6U CubeSat carrying a bistatic radar as the main payload. DISCUS will be operated either as an independent mission or accompanying a larger one. It is designed to determine the internal macroporosity of a 260–600 m diameter Near Earth Asteroid (NEA) from a few kilometers distance. The main goal will be to achieve a global penetration with a low-frequency signal as well as to analyze the scattering strength for various different penetration depths and measurement positions. Moreover, the measurements will be inverted through a computed radar tomography (CRT) approach. The scientific data provided by DISCUS would bring more knowledge of the internal configuration of rubble pile asteroids and their collisional evolution in the Solar System. It would also advance the design of future asteroid deflection concepts. We aim at a single-unit (1U) radar design equipped with a half-wavelength dipole antenna. The radar will utilize a stepped-frequency modulation technique the baseline of which was developed for ESA's technology projects GINGER and PIRA. The radar measurements will be used for CRT and shape reconstruction. The CubeSat will also be equipped with an optical camera system and laser altimeter to support navigation and shape reconstruction. We provide the details of the measurement methods to be applied along with the requirements derived from the known characteristics of rubble pile asteroids. Additionally, an initial design study of the platform and targets accessible within 20 lunar distances are presented.

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(16) Psyche: A mesosiderite-like asteroid?

Context. Asteroid (16) Psyche is the target of the NASA Psyche mission. It is considered one of the few main-belt bodies that could be an exposed proto-planetary metallic core and that would thus be related to iron meteorites. Such an association is however challenged by both its near- and mid-infrared spectral properties and the reported estimates of its density. Aims. Here, we aim to refine the density of (16) Psyche to set further constraints on its bulk composition and determine its potential meteoritic analog. Methods. We observed (16) Psyche with ESO VLT/SPHERE/ZIMPOL as part of our large program (ID 199.C-0074). We used the high angular resolution of these observations to refine Psyche's three-dimensional (3D) shape model and subsequently its density when combined with the most recent mass estimates. In addition, we searched for potential companions around the asteroid. Results. We derived a bulk density of 3.99 ± 0.26 ± cm^{-3} for Psyche. While such density is incompatible at the 3-sigma level with any iron meteorites (~7.8 ± cm^{-3}), it appears fully consistent with that of stony-iron meteorites such as mesosiderites (density ~4.25 ± cm^{-3}). In addition, we found no satellite in our images and set an upper limit on the diameter of any non-detected satellite of 1460 ± 200 m at 150 km from Psyche (0.2% × R_{Hill}, the Hill radius) and 800 ± 200 m at 2000 km (3% × R_{Hill}). Conclusions. Considering that the visible and near-infrared spectral properties of mesosiderites are similar to those of Psyche, there is merit to a long-published initial hypothesis that Psyche could be a plausible candidate parent body for mesosiderites.

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The impact crater at the origin of the Julia family detected with VLT/SPHERE?
Context. The vast majority of the geophysical and geological constraints (e.g., internal structure, cratering history) for main-belt asteroids have so far been obtained via dedicated interplanetary missions (e.g., ESA Rosetta, NASA Dawn). The high angular resolution of SPHERE/ZIMPOL, the new-generation visible adaptive-optics camera at ESO VLT, implies that these science objectives can now be investigated from the ground for a large fraction of D 100 km main-belt asteroids. The sharp images acquired by this instrument can be used to accurately constrain the shape and thus volume of these bodies (hence density when combined with mass estimates) and to characterize the distribution and topography of D 30 km craters across their surfaces. Aims. Here, via several complementary approaches, we evaluated the recently proposed hypothesis that the S-type asteroid (89) Julia is the parent body of a small compact asteroid family that formed via a cratering collisional event. Methods. We observed (89) Julia with VLT/SPHERE/ZIMPOL throughout its rotation, derived its 3D shape, and performed a reconnaissance and characterization of the largest craters. We also performed numerical simulations to first confirm the existence of the Julia family and to determine its age and the size of the impact crater at its origin. Finally, we utilized the images/3D shape in an attempt to identify the origin location of the small collisional family. Results. On the one hand, our VLT/SPHERE observations reveal the presence of a large crater (D 75 km) in Julias southern hemisphere. On the other hand, our numerical simulations suggest that (89) Julia was impacted 30-120 Myrs ago by a D 8 km asteroid, thereby creating a D 60 km impact crater at the surface of Julia. Given the small size of the impactor, the obliquity of Julia and the particular orientation of the family in the (a,i) space, the imaged impact crater is likely to be the origin of the family. Conclusions. New doors into ground-based asteroid exploration, namely, geophysics and geology, are being opened thanks to the unique capabilities of VLT/SPHERE. Also, the present work may represent the beginning of a new era of asteroid-family studies. In the fields of geophysics, geology, and asteroid family studies, the future will only get brighter with the forthcoming arrival of 30-40 m class telescopes like ELT, TMT, and GMT.

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, Berthier, J., Castillo-Rogez, J., Cipriani, F., Colas, F., Dumas, C., Urech, J., Kaasalainen, M., Kryszczynska, A., Lamy, P. , Le Coroller, H., Marciniak, A., Michalowski, T., Michel, P., Pajuelo, M., Tanga, P., Vachier, F., Vigan, A., Warner, B., Witasse, O., Yang, B., Asphaug, E., Richardson, D. C., Ševeček, P., Gillon, M., Benkhaldoun, Z.
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Distribution of shape elongations of main belt asteroids derived from Pan-STARRS1 photometry

Context. A considerable amount of photometric data is produced by surveys such as Pan-STARRS, LONEOS, WISE, or Catalina. These data are a rich source of information about the physical properties of asteroids. There are several possible approaches for using these data. Light curve inversion is a typical method that works with individual asteroids. Our approach in focusing on large groups of asteroids, such as dynamical families and taxonomic classes, is statistical; the data are not sufficient for individual models.Aim. Our aim is to study the distributions of shape elongation ba and the spin axis latitude β for various subpopulations of asteroids and to compare our results, based on Pan-STARRS1 survey, with statistics previously carried out using various photometric databases, such as Lowell and WISE.Methods. We used the LEADER algorithm to compare the ba and β distributions for various subpopulations of asteroids. The algorithm creates a cumulative distributive function (CDF) of observed brightness variations, and computes the ba and β distributions with analytical basis functions that yield the observed CDF. A variant of LEADER is used to solve the joint distributions for synthetic populations to test the validity of the method.Results. When comparing distributions of shape elongation for groups of asteroids with different diameters D, we found that there are no differences for D < 25 km. We also constructed distributions for asteroids with different rotation periods and revealed that the fastest rotators with P = 0 - 4 h are more spheroidal than the population with P = 4-8 h.

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What's inside a rubble pile asteroid? DiSCUS - A tomographic twin radar Cubesat to find out

A large fraction of asteroids with diameter d > 240 m are suspected to be loose piles of rocks and boulders bound together mainly by gravity and only weak cohesion. Still to date the size and distribution of voids and monolithic fragments inside these "rubble-piles" are not known. To perform a full tomographic interior reconstruction a bistatic CubeSat configuration has been investigated by Tampere University of Technology (TUT), Radar Systemtechnik GmbH (RST) and the Max Planck Institute for Solar System Research (MPS). The concept is based on two 6U CubeSats, both carrying an identical 1U sized stepped frequency radar. As stepped frequency radars can be built compact, require less power and generate less data volume compared to other radar applications they are well-suited for small satellite platforms. In 2017 the Concurrent Design Facility of ESA/ESTEC conducted two studies relevant for DISCUS. In the Small Planetary Probes (SPP) study DISCUS served as a reference payload for a piggyback mission to a Near-Earth Asteroid (NEA) or even a Main Belt Asteroid (MBA). The M-ARGO study investigated a stand-alone mission to a NEA, with a DISCUS sized instrument. Based on the spacecraft design of SPP and M-ARGO we could prove the instrument requirements as feasible and evaluate our science case from the orbits and mission duration that have been identified by these studies. Using inversion methods developed for medical tomography the data would allow to reconstruct the large scale interior structure of a small body. Simulations have shown that the measurement principle and the inversion method are robust enough to allow full reconstruction of the interior even if the orbits do not cover the entire surface of the asteroid. The measurement results of the mission will help to gain a better understanding of asteroids and the formation mechanisms of the solar system. In addition, the findings will increase the predictability of asteroid impact consequences on Earth and improve future concepts of asteroid deflection.

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Adaptive optics and lightcurve data of asteroids: Twenty shape models and information content analysis

We present shape models and volume estimates of twenty asteroids based on relative photometry and adaptive optics images. We discuss error estimation and the effects of myopic deconvolution on shape solutions. For further analysis of the information capacities of data sources, we also present and discuss ambiguity and uniqueness results for the reconstruction of nonconvex shapes from photometry.

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Organisations: Mathematics, Charles University in Prague, SETI Institute
Contributors: Viikinkoski, M., Hanuš, J., Kaasalainen, M., Marchis, F., Ďurech, J.

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Source ID: 85035125736
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3D shape of asteroid (6) Hebe from VLT/SPHERE imaging: Implications for the origin of ordinary H chondrites
Context. The high-angular-resolution capability of the new-generation ground-based adaptive-optics camera SPHERE at ESO VLT allows us to assess, for the very first time, the cratering record of medium-sized (D ~ 100-200 km) asteroids from the ground, opening the prospect of a new era of investigation of the asteroid belt's collisional history. Aims. We investigate here the collisional history of asteroid (6) Hebe and challenge the idea that Hebe may be the parent body of ordinary H chondrites, the most common type of meteorites found on Earth (~34% of the falls). Methods. We observed Hebe with SPHERE as part of the science verification of the instrument. Combined with earlier adaptive-optics images and optical light curves, we model the spin and three-dimensional (3D) shape of Hebe and check the consistency of the derived model against available stellar occultations and thermal measurements. Results. Our 3D shape model fits the images with sub-pixel residuals and the light curves to 0.02 mag. The rotation period (7.274 47 h), spin (ECJ2000 λ, β of 343°, +47°), and volume-equivalent diameter (193 ± 6 km) are consistent with previous determinations and thermophysical modeling. Hebe's inferred density is 3.48 ± 0.64 g cm^{-3}, in agreement with an intact interior based on its H-chondrite composition. Using the 3D shape model to derive the volume of the largest depression (likely impact crater), it appears that the latter is significantly smaller than the total volume of close-by S-type H-chondrite-like asteroid families. Conclusions. Our results imply that (6) Hebe is not the most likely source of H chondrites. Over the coming years, our team will collect similar high-precision shape measurements with VLT/SPHERE for ~40 asteroids covering the main compositional classes, thus providing an unprecedented dataset to investigate the origin and collisional evolution of the asteroid belt.

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Organisations: Mathematics, Research group: Inverse Problems, Queen's University, Belfast, Northern Ireland, CNRS, IMCCE - Institut de Mecanique Celeste et de Calcul des Ephemerides, TMT Observatory, Charles University in Prague, Laboratoire d'Astrophysique de Marseille, Max-Planck-Institut für Extraterrestrische Physik, Université de Liège, Open University, European Southern Observatory (ESO), ONERA - The French Aerospace Lab, Planetary Science Institute, Universite de Geneve
Contributors: Marsset, M., Carry, B., Dumas, C., Hanuš, J., Viikinkoski, M., Vernazza, P., Müller, T. G., Delbo, M., Jehin, E., Gillon, M., Grice, J., Yang, B., Fusco, T., Berthier, J., Sonnett, S., Kugel, F., Caron, J., Behrend, R.
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Dynamic, data-driven processing of multispectral video streams

Video analytics plays an important role in a wide variety of defense-, monitoring- and surveillance-related systems for air and ground environments. In this context, multispectral video processing is attracting increased interest in recent years, due in part to technological advances in video capture. Compared with monochromatic video, multispectral video offers better spectral resolution, and different bands of multispectral video streams can enhance video analytics capabilities in different ways. For example, the infrared bands can provide better separation of shadows from objects, and improved spatial resolution in scenes that are impaired by fog or haze [16].

General information

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Contributors: Li, H., Sudusinghe, K., Liu, Y., Yoon, J., Der Schaar, M. V., Blasch, E., Bhattacharyya, S. S.
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Shape and spin distributions of asteroid populations from brightness variation estimates and large databases

Context. Many databases on asteroid brightnesses (e.g. ALCDEF, WISE) are potential sources for extensive asteroid shape and spin modelling. Individual lightcurve inversion models require several apparitions and hundreds of data points per target. However, we can analyse the coarse shape and spin distributions over populations of at least thousands of targets even if there are only a few points and one apparition per asteroid. This is done by examining the distribution of the brightness variations observed within the chosen population. Aims. Brightness variation has been proposed as a population-scale rather than individual-target observable in two studies so far. We aim to examine this approach rigorously to establish its theoretical validity, degree of ill-posedness, and practical applicability. Methods. We model the observed brightness variation of a target population by considering its cumulative distribution function (CDF) caused by the joint distribution function of two fundamental shape and spin indicators. These are the shape elongation and the spin latitude of a simple ellipsoidal model. The main advantage of the model is that we can derive analytical basis functions that yield the observed CDF as a function of the shape and spin distribution. The inverse problem can be treated linearly. Even though the inaccuracy of the model is considerable, databases of thousands of targets should yield some information on the distribution. We employ numerical simulations to establish this and analyse photometric databases that provide sufficiently large numbers of data points for reliable brightness variation estimates. Results. We establish the theoretical soundness and the typical accuracy limits of the approach both analytically and numerically. We propose a robust brightness variation observable η based on at least five brightness points per target. We also discuss the weaker reliability and information

content of the case of only two points per object. Using simulations, we derive a practical estimate of the model distribution in the (shape, spin)-plane. We show that databases such as Wide-field Infrared Survey Explorer (WISE) yield coarse but robust estimates of this distribution, and as an example compare various asteroid families with each other.

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Organisations: Mathematics, Research group: Inverse Problems, Charles University in Prague, Max-Planck-Institut für Extraterrestrische Physik
Contributors: Nortunen, H., Kaasalainen, M., Ďurech, J., Cibulková, H., Ali-Lagoa, V., Hanuš, J.
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Volumes and bulk densities of forty asteroids from ADAM shape modeling

Context. Disk-integrated photometric data of asteroids do not contain accurate information on shape details or size scale. Additional data such as disk-resolved images or stellar occultation measurements further constrain asteroid shapes and allow size estimates. Aims. We aim to use all the available disk-resolved images of approximately forty asteroids obtained by the Near-InfraRed Camera (Nirc2) mounted on the W.M. Keck II telescope together with the disk-integrated photometry and stellar occultation measurements to determine their volumes. We can then use the volume, in combination with the known mass, to derive the bulk density. Methods. We downloaded and processed all the asteroid disk-resolved images obtained by the Nirc2 that are available in the Keck Observatory Archive (KOA). We combined optical disk-integrated data and stellar occultation profiles with the disk-resolved images and use the All-Data Asteroid Modeling (ADAM) algorithm for the shape and size modeling. Our approach provides constraints on the expected uncertainty in the volume and size as well. Results. We present shape models and volume for 41 asteroids. For 35 of these asteroids, the knowledge of their mass estimates from the literature allowed us to derive their bulk densities. We see a clear trend of lower bulk densities for primitive objects (C-complex) and higher bulk densities for S-complex asteroids. The range of densities in the X-complex is large, suggesting various compositions. We also identified a few objects with rather peculiar bulk densities, which is likely a hint of their poor mass estimates. Asteroid masses determined from the Gaia astrometric observations should further refine most of the density estimates.

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Contributors: Hanuš, J., Viikinkoski, M., Marchis, F., Durech, J., Kaasalainen, M., Delbo, M., Herald, D., Frappa, E., Hayamizu, T., Kerr, S., Preston, S., Timerson, B., Dunham, D., Talbot, J.
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Volumes and bulk densities of forty asteroids from ADAM shape modeling
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Shape model of asteroid (130) Elektra from optical photometry and disk-resolved images from VLT/SPHERE and Nirc2/Keck

Context. Asteroid (130) Elektra belongs to one of the six known triple asteroids in the main belt, so its mass has been reliably determined.
Aims. We aim to use all available disk-resolved images of (130) Elektra obtained by the SPHERE instrument at VLT and by the Nirc2 of the Keck telescope together with the disk-integrated photometry to determine its shape model and its size. The volume can be then used in combination with the known mass to derive the bulk density of the primary.
Methods. We have applied the All-Data Asteroid Modeling (ADAM) algorithm to the optical disk-integrated data, two disk-resolved images obtained by the SPHERE instrument, and 13 disk-resolved images from the Nirc2 of the Keck telescope. We have also derived the shape model and size of Elektra.
Results. We present the shape model, volume-equivalent diameter (199 ± 7 km) and bulk density (1.60 ± 0.13 g cm^{-3}) of the C-type asteroid Elektra.

General information

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Organisations: Mathematics, Research group: MAT Inverse Problems, Charles University in Prague, SETI Institute, European Southern Observatory (ESO)
Contributors: Hanuš, J., Marchis, F., Viikinkoski, M., Yang, B., Kaasalainen, M.
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Radar observations and shape model of asteroid 16 Psyche

Using the S-band radar at Arecibo Observatory, we observed 16 Psyche, the largest M-class asteroid in the main belt. We obtained 18 radar imaging and 6 continuous wave runs in November and December 2015, and combined these with 16 continuous wave runs from 2005 and 6 recent adaptive-optics (AO) images (Drummond et al., 2016) to generate a three-

dimensional shape model of Psyche. Our model is consistent with a previously published AO image (Hanus et al., 2013) and three multi-chord occultations. Our shape model has dimensions $279 \times 232 \times 189$ km ($\pm 10\%$), $D_{eff} = 226 \pm 23$ km, and is 6% larger than, but within the uncertainties of, the most recently published size and shape model generated from the inversion of lightcurves (Hanus et al., 2013). Psyche is roughly ellipsoidal but displays a mass-deficit over a region spanning 90° of longitude. There is also evidence for two ~50–70 km wide depressions near its south pole. Our size and published masses lead to an overall bulk density estimate of 4500 ± 1400 kgm^{-3}. Psyche's mean radar albedo of 0.37 ± 0.09 is consistent with a near-surface regolith composed largely of iron-nickel and ~40% porosity. Its radar reflectivity varies by a factor of 1.6 as the asteroid rotates, suggesting global variations in metal abundance or bulk density in the near surface. The variations in radar albedo appear to correlate with large and small-scale shape features. Our size and Psyche's published absolute magnitude lead to an optical albedo of $p_V = 0.15 \pm 0.03$, and there is evidence for albedo variegations that correlate with shape features.

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Contributors: Shepard, M. K., Richardson, J., Taylor, P. A., Rodriguez-Ford, L. A., Conrad, A., de Pater, I., Adamkovics, M., de Kleer, K., Males, J. R., Morzinski, K. M., Close, L. M., Kaasalainen, M., Viikinkoski, M., Timerson, B., Reddy, V., Magri, C., Nolan, M. C., Howell, E. S., Benner, L. A. M., Giorgini, J. D., Warner, B. D., Harris, A. W.
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VLT/SPHERE- and ALMA-based shape reconstruction of asteroid (3) Juno
We use the recently released Atacama Large Millimeter Array (ALMA) and VLT/SPHERE science verification data, together with earlier adaptive-optics images, stellar occultation, and lightcurve data to model the 3D shape and spin of the large asteroid (3) Juno with the all-data asteroid modelling (ADAM) procedure. These data set limits on the plausible range of shape models, yielding reconstructions suggesting that, despite its large size, Juno has sizable unrounded features moulded by non-gravitational processes such as impacts.

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Contributors: Viikinkoski, M., Kaasalainen, M., Durech, J., Carry, B., Marsset, M., Fusco, T., Dumas, C., Merline, W. J., Yang, B., Berthier, J., Kervella, P., Vernazza, P.
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Source ID: 84941207014
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ADAM: A general method for using various data types in asteroid reconstruction

We introduce ADAM, the All-Data Asteroid Modelling algorithm. ADAM is simple and universal since it handles all disk-resolved data types (adaptive optics or other images, interferometry, and range-Doppler radar data) in a uniform manner via the 2D Fourier transform, enabling fast convergence in model optimization. The resolved data can be combined with disk-integrated data (photometry). In the reconstruction process, the difference between each data type is only a few code lines defining the particular generalized projection from 3D onto a 2D image plane. Occultation timings can be included as sparse silhouettes, and thermal infrared data are efficiently handled with an approximate algorithm that is sufficient in practice because of the dominance of the high-contrast (boundary) pixels over the low-contrast (interior) pixels. This is of particular importance to the raw ALMA data that can be directly handled by ADAM without having to construct the standard image. We study the reliability of the inversion, using the independent shape supports of function series and control-point surfaces. When other data are lacking, one can carry out fast non-convex lightcurve-only inversions, but any shape models resulting from it should only be taken as illustrative large-scale models.

General information

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Organisations: Department of Mathematics, Research group: MAT Inverse Problems, Mathematical modelling with wide societal impact (MathImpact), Astronomical Institute, Faculty of Mathematics and Physics, Charles University in Prague
Contributors: Viikinkoski, M., Kaasalainen, M., Durech, J.
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ASJC Scopus subject areas: Astronomy and Astrophysics, Space and Planetary Science
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DOIs:

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Research output: Contribution to journal › Article › Scientific › peer-review

Investigating dynamical complexity in the magnetosphere using various entropy measures

[1] The complex system of the Earth's magnetosphere corresponds to an open spatially extended nonequilibrium. (input-output) dynamical system. The nonextensive Tsallis entropy has been recently introduced as an appropriate information measure to investigate dynamical complexity in the magnetosphere. The method has been employed for analyzing D_{st} time series and gave promising results, detecting the complexity dissimilarity among different physiological and pathological magnetospheric states (i.e., prestorm activity and intense magnetic storms, respectively). This paper explores the applicability and effectiveness of a variety of computable entropy measures (e.g., block entropy, Kolmogorov entropy, T complexity, and approximate entropy) to the investigation of dynamical complexity in the magnetosphere. We show that as the magnetic storm approaches there is clear evidence of significant lower complexity in the magnetosphere. The observed higher degree of organization of the system agrees with that inferred previously, from an independent linear fractal spectral analysis based on wavelet transforms. This convergence between nonlinear and linear analyses provides a more reliable detection of the transition from the quiet time to the storm time magnetosphere, thus showing evidence that the occurrence of an intense magnetic storm is imminent. More precisely, we claim that our results suggest an important principle: significant complexity decrease and accession of persistency in D_{st} time series can be confirmed as the magnetic storm approaches, which can be used as diagnostic tools for the magnetospheric injury (global instability). Overall, approximate entropy and Tsallis entropy yield superior results for detecting dynamical complexity changes in the magnetosphere in comparison to the other entropy measures presented herein. Ultimately, the analysis tools developed in the course of this study for the treatment of D_{st} index can provide convenience for space weather applications.

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Organisations: National Observatory of Athens, University of Athens, Section of Solid State Physics
Contributors: Balasis, G., Daglis, I. A., Papadimitriou, C., Kalimeri, M., Anastasiadis, A., Eftaxias, K.
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