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PHYSICAL FIELD

Contributions to the Knowledge of Physical Properties of Near Earth Asteroids Observed in the EURONEAR Project

PhD Thesis Summary

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Thanks

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12.25. 2014QK434 86
12.26. (90416) 2003 YK118 87
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Introduction

Asteroids are a large group of small bodies orbiting around the Sun. The oldest and most known group is the main asteroid belt that orbits between Mars and Jupiter at a distance between 2.2 and 3.3 compared to the Sun where it is estimated that there are over 750,000 objects larger than 1 km and the order of millions under that diameter. The farthest asteroids are located far beyond Pluto's orbit.

Near Earth Objects (NEOs) are asteroids and comets that have been disturbed by the gravitational pull of large planets (especially Jupiter) in orbits that allow them to be in the vicinity of the Earth. Comets originally formed in the cold outside planetary system between the orbits of Jupiter and Neptune consist mainly of water in the form of ice, rock and dust. Most rocky asteroids are formed inside the warmer interior of the solar system, between the orbits of Mars and Jupiter.

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The scientific interest in comets and asteroids is largely due to their status of relatively unchanged remains in the process of forming the solar system now around 4.6 billion years. The remnants of the formation process of the solar system, comets and asteroids, give indications of the chemical composition from which the planets were formed now 4.6 billion years. If we want to know the characteristics of this composition, then we have to determine the chemical composition of the unconsumed scraps of this formation process - comets and asteroids.

Potential Dangerous Asteroids (PHAs) are currently defined based on the orbital and physical parameters of the asteroid. Thus, all asteroids with Orbit Intersection Minimum Distance (MOID) less than 0.05 have and an absolute magnitude H lower than 22.0 are defined as PHAs.

The discovery of Ceres in 1801 and then of Eros 433 in 1898 established the existence of a population of asteroids-like bodies in orbits that intersect the orbits of the inner planets. It was only after the 1960s and 1970s that it was discovered that part of the monthly craters were caused by asteroids and not by the volcanic activity, as originally believed, so the interest in studying asteroids has gained a global reach - it has proven that the Earth system - The moon has been constantly bombarded by asteroids and comets over the last 4.5 billion years.

Over the recent history hundreds of impacts with the Earth have been reported. The best known event of this type was the Tunguska event that took place in Siberia, Russia in 1908, where a comet or asteroid with a diameter of 5 to 10 km exploded above the ground. Another recent known event took place in 2013 in Chelyabinsk, an event that resulted in a large number of wounded and significant destruction. The meteorite that hit Chelyabinsk is considered the second largest after Tunguska, who met the Earth in recent history.

Since the 1980s, some astronomy departments of the universities in the United States later supported by NASA have led six major asteroid search projects. The first SPACEGUARD project aimed at discovering at least 90% of Earth-like asteroids larger than 1 km in diameter over a 10-year period. In chronological order these programs are: Spacewatch (1980-present), LONEOS (1993-2008), NEAT (1995-2007), LINEAR (1996-2011 in collaboration with US Air Force), Catalina and Pan-STARRS present).

In the last year, the NEA's discovery rate has increased due to the Catalina and Pan-STARRS programs supported by the American Congress that mandated NASA in 2005 to discover over 90% of NEAs larger than 140m in diameter by more than 20,000 such objects are in orbit near Earth or intersect the Earth's orbit [4].

In total, up to now more than 99% of NEAs have been discovered by the six US programs.

Of the 15,000 objects discovered and cataloged less than 10%, physical properties derived from photometric and spectroscopic observations are known and at least 1000 objects require orbital corrections.

Over the last twenty years in Europe, NEA's research and discovery has been negligible. Few NEAs have been discovered in Europe and this is largely due to a few amateur scientists and astronomers and a few astronomers' associations.

EURONEAR is the European Asteroid Research Program near Earth's European Near Earth Asteroids Research (www.euronear.org). It is a research project aimed at developing a research network that will seek, discover and monitor near-Earth asteroids (NEA) and potentially dangerous asteroids (PHAs).

OPTICAL TELESCOPES USED IN OBSERVATIONS

Below we will briefly present the telescopes used to observe asteroids published in this thesis.

MERCATOR telescope

The Mercator telescope is a semi-robotic telescope located at the Roque de los Muchachos Observatory (ORM) in the island of La Palma (Canary Islands, Spain) at an altitude of 2333m. The Telescope was designed by Leuven University in collaboration with the Geneva Observatory. It was built in 2000 and began scientific activity in 2001.

The main mirror measures 1.2m in diameter and weighs 385kg and the second one 0.3m, together forming a 14.4m focal length instrument

The DANISH Telescope

Danish Telescope "Danish" has a diameter of 1.54 meters, built by Grubb-Parsons (Newcastle, England) and installed at La Silla (desert Atacama, Chile) at an altitude of 2375 meters. telescope was made on November 20, 1978. The telescope's optic is the Ritchey-Chretiencu type main mirror of 1.54 m with a main focal ratio f / 3.5 and a final f / 8.6. The focal length of the system is 13 m. It was completely upgraded in 1993 and is now equipped with diffuse astronomical astronomical spectrograph and a CCD camera with dual spectrograph / camera function.

The INT telescope

The Isaac Newton Telescope (INT) began its work in Herstmonceux, UK in 1967, but it soon became clear that better weather conditions could make full use of the telescope's potential. Such conditions were identified at the ORM Observatory and it was therefore decided that INT would be moved to La Palma, where it resumed its activity in 1984. The INT telescope has a primary mirror of 2.5 meters in diameter. The instruments can be mounted either at the primary center point or in the Cassegrain system focus, and offer the ability to perform both broad and intermediate field imaging at low and medium resolution spectroscopy. The Wide Field CCD (WCD) is an advanced tool that offers unique opportunities to conduct broad field optical imaging studies, consisting of a mosaic of 4 CCDs covering a field of nearly half a degree.

The number of scientific research conducted with the INT telescope over the years is very high. The telescope has made many important contributions to quasars, supernovae, black holes, dwarf galaxies, Milky Way stars, planetary nebulae and stellar evolution. The first observational evidence of the existence of a black hole was brought with the INT telescope.

CTIO 0.9 m

The 0.9 meter diameter Cerro Tololo Inter-American Observatory (CTIO) telescope was originally built in 1965 by American company Boller and Chivens, located about 80 km south of La Serena, Chile, at an altitude of 2200 m.

Since 1999, CTIO 0.9 m has used a single instrument, a camera equipped with a Tek2K CCD detector of 2048 x 2046 pixels. The CCD scale is 0.4 " / pixel, providing a field of 13.1 ', or about 46% of the size of the Moon. Stability of the instrument configuration allows long-term studies that are impossible to achieve on most telescopes, including one of the world's largest astrometry programs.

PROGRAMS USED IN REDUCING AND PHOTOMETRIC ANALYSIS OF IMAGES

In this section we present briefly the photometric reduction programs.

IRAF

I.R.A.F. [59] is the abbreviation for Image Reduction and Analysis Facility. I.R.A.F. is a collection of programs written by the National Optical Astronomy Observatory (NOAO) focused primarily on the reduction of astronomical images acquired by sensors built in the form of pixel arrays. The main astronomical data is acquired by matrix image detectors, such as CCDs. The first objective of image reductions is to correct two types of errors in data collected by CCD. Additive and multiplicative errors. Primary errors have two primary causes: BIAS OFFSET and DARK CURRENT. There are two types of image calibrations that can be used to correct this kind of additive errors; BIAS frames and DARK frames.

The Dark Frame

Dark frame (or black frame in translation) is an image obtained with the closed diaphragm of the CCD or the camera covered in such a way that the light does not reach the surface of the photo sensor. Calibration using black frames is used to reduce the noise of the CCD chip.

Bias frame.

It is a frame obtained in the same way as the darker frame but the shortest exposure time of the camera (DSLR cameras would be about 1/4000 or 1/8000 seconds) with the shutter diaphragm closed. This frame is the minimum room noise level and consists of two components:

a) biased offset - the electrical charge applied to pixels by the camera electronics to be activated.

b) structure of bias due to chip reading (read out noise, en.).

Extracting the bias frame from the raw images eliminates both components. Since this noise also has a pattern after it occurs, it takes several bias frames that are combined to obtain a biased master frame that will be subtracted from the images.

Multiplicative errors

Multiplicative errors can occur for several reasons: Differential illumination, differences in quantum efficiency of the CCD sensor, dust, or various deposits on optical surfaces. All this is a pixel-to-pixel sensitivity difference in the CCD sensor, so the voltages applied by the CCD camera electronics on different pixels have to be multiplied to higher values to match more sensitive pixels. To correct this multiplier error, a calibration image called FLAT frame is used. The FLAT frame is simply a picture of a uniformly illuminated field (a white spot on the dome, clear sky, etc.).

The schematic and mathematical representation of the basic process in reducing and correcting additive and multiplicative errors is shown below. Applying to all of these calibration frames - dark, flat, bias - we get images that no longer contain camera noise and imperfections of the lens.

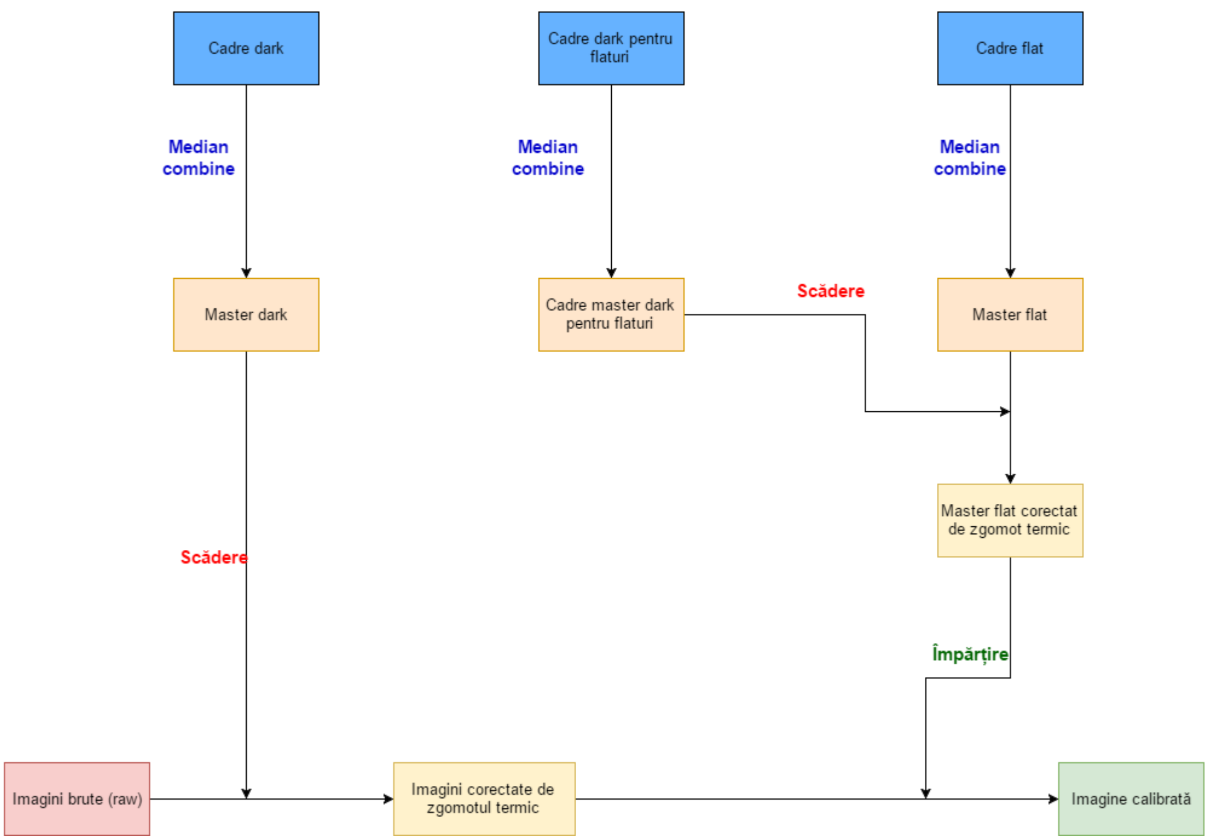


Fig. 1

$$\boldsymbol{Final\ image} = \frac{\textbf{Raw image – DARK1 frame}}{(\textbf{FLAT frame – DARK2 frame}) \,/ < \boldsymbol{FLATframe - DARK2frame} >} \qquad (1)$$

Figure 19 and Formula 27 illustrate the IRAF astronomy calibration process and other professional software used by both astronomical observers and amateur astronomers. Dark frames combine to get a dark master frame that will be subtracted from each raw image. Dark flats for flats combine to get a master dark background for flats. Flat frames combine to get a flat master. The dark master plane for flats is subtracted from the flat master, producing a flat master plane corrected by thermal noise. Next, the images corrected by the thermal noise are calibrated with the corrected flat master frame and thermal noise, resulting in calibrated images.

MPO Canopus

MPO Canopus [60] is a complete astrometry and photometry program on a Windows OS platform with features capable of delivering high precision results in both areas. With this program, it is possible to process and measure astronomical images, photometric transformations, light curves, maximum and minimum periods, both for asteroids and for variable stars, exoplanets, and much more.

More than 2,500 astrometric positions were sent by the Florissant / Palmer Divide Observatory at the Minor Planet Center using MPO Canopus. Thousands of such observations have been sent by professional astronomers and amateur astronomers around the world using MPO Canopus.

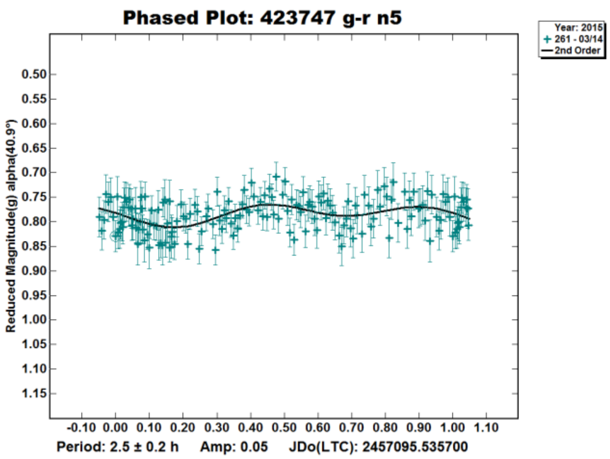
The MPO Canopus program quickly gains reputation for its unique functionality with regard to the light curves of asteroids and variable stars. Special features built into the Canopus MPO make it extremely easy to measure and analyze the images and characteristics of light curves. In just a few minutes, you can set up, measure 150-200 images, and begin analyzing data on the light curve of the observed object. They can easily combine data from multiple sets of observations and even from different observers.

Canopus was and is being used at the Florissant / Palmer Divide Observatory to generate and publish nearly 200 asteroid light curves and more than 400 light curves were sent by astronomers from North America, Europe, South America, Japan and Australia. Canopus was the first program that implicitly incorporates a Fourier Alan Harris analysis algorithm for determining the period in a general program for the astronomy community. It was used by global observers to publish nearly 2000 light curves in jury publications and to discover more than a dozen binary asteroids.

EXAMPLES OF ASTEROID LIGHT CURVES

In this section we will present some examples of light curves and reduced spectra.

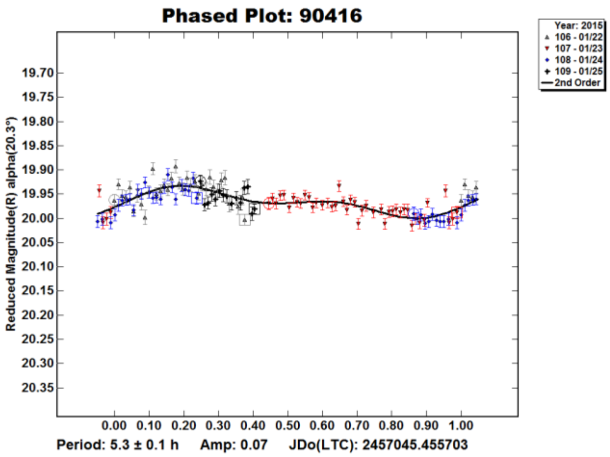
(423747) 2006CX



This NEA was discovered by the CSS-Catalina Sky surveillance program on February 3, 2006, being classified as Amor (a = 1.71 au, e = 0.29, i = 28.96 °, MOID = 0.224 au). Period, unknown taxonomic and albedo class, absolute magnitude H = 19 mag and a diameter between 500 m and 1118 m.

Based on 3 nights using the 1.2 m Mercator telescope, we reduced a period of P = 4.14 ± 0.01 h, reduced magnitude HR = 19.7 mag and an amplitude of light curve (A) of 0.06. The taxonomic class is Sv, the albedo 0.18, resulting in a diameter of 0.496 km.

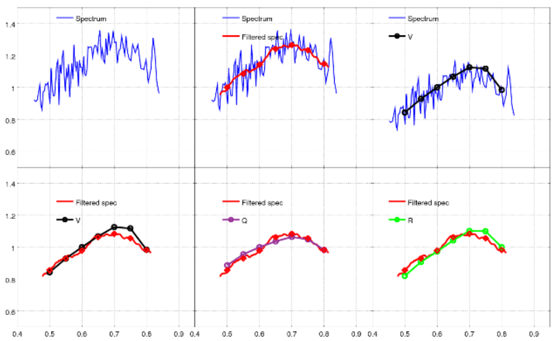
(90416) 2003 YK118



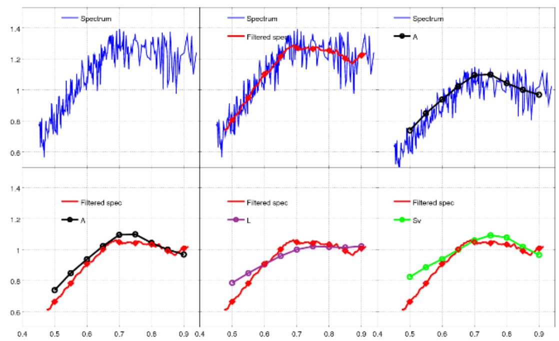
This NEA was discovered by the LINEAR surveillance program - Lincoln Lab. ETS on December 28, 2003, being classified as Apolo (a = 1.69 au, e = 0.49, i = 7.83 º, MOID = 0.00088 au). It was photometrically observed by B. Warner with a telescope of 0.35 m, f / 9.1 / STL - 100E and Veres, which solved a rotation period P = 43.58. h and the absolute magnitude H = 18.7 mag. Radar Detected by JPL's NEO Radar Detection program. The taxonomic class is unknown, the albedo is unknown, its diameter is estimated to be between 548 m and 1225 m.

Based on 3 nights using the 1.2 m telescope, we reduced a period of P = 5.3 ± 0.1 h, the amplitude of the light curve (A) of 0.07 and the reduced magnitude HR = 19.95 mag. The taxonomic class determined is Cg with associated albedo 0.05, resulting in a diameter of 1,082 km.

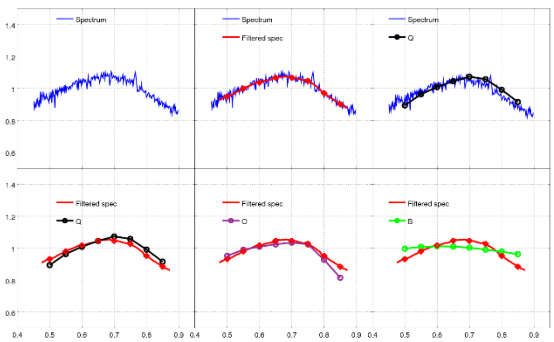
EXAMPLES OF REFLECTION SPECTRA



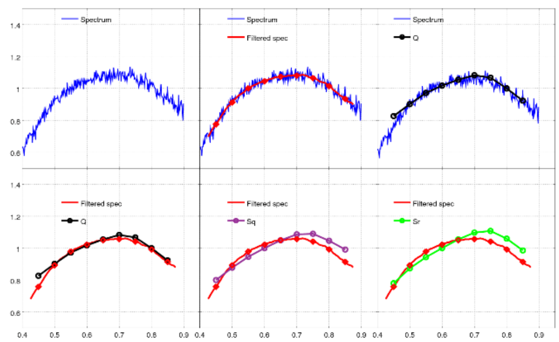
39796 vs 1997TD



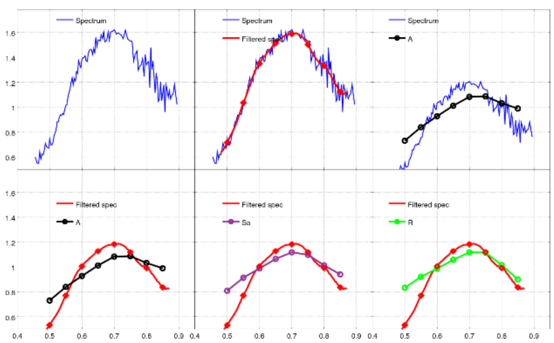
67367 vs 2000LY27



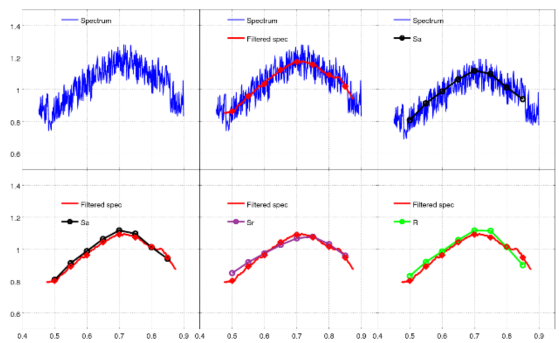
68031 vs 2000YK29



68063 vs 2000YJ66



68348 vs 2001LO7



86067 vs 1999RM28

GENERAL CONCLUSIONS

In NONE's EURONEAR surveillance program, more than 200 asteroids [61] [63] [62] were analyzed using photometry and reflection spectroscopy.

In this paper I presented photometrically a number of 46 asteroids and from a spectroscopic point of view a number of 44 asteroids. A total of 14 asteroids are analyzed both photometrically and spectroscopically. Thus we have defined the taxonomic class for 40 asteroids whose class is missing in literature. Based on this and the albedo associated with the taxonomic class, we have calculated the diameter of over 30 asteroids that are also missing from the literature or have a very high error rate. From the photometric point of view we improved light curves, we calculated the rotation period and its amplitude to more than 30 asteroids, in some cases for the first time. From the preliminary analysis of photometric data, at least two asteroids appear to have at least one satellite and a number of 7 asteroids have the characteristics of a multi-axis rotating body.

The characteristics of the physical properties of 76 observed asteroids from the literature are presented in parallel with the new data obtained through observations. Another result is the development of the LiDAS Preliminary Reduction Program, which provides very short assistance in planning the next observations. It has been used successfully in most of the observations in this sentence and in most of the EURONEAR observations.

In particular, on the Mercator telescope we simultaneously observed for the first time NEAs asteroids in two bands r and / or g with the MAIA room (room developed for space missions ESA). This allowed us to study the color variation g-r along the light curve. Obvious variations in color have been highlighted in several asteroids in this paper. In particular, the color curves of at least three asteroids may be associated with the determined periods in the individual g or / and r bands, which proves a different mineralogical component on the visible surface of the asteroids. This study was done for the first time in the world.

I am currently working with an EURONEAR team, where we will first train students from the University of Craiova to four international scientific publications, two of which will be sent for publication in the near future [61] [63] [62] and the other two later this year.

REFERENCES

[1] „NASA JPL,” Februarie 2017. [Interactive]. Available: http://neo.jpl.nasa.gov/neo/groups.html.

[2] „Wikipedia,” [Interactiv]. Available: https://en.wikipedia.org/wiki/Near-Earth_object. [Accessed February 2017].

[3] „NEODyS-2,” [Interactiv]. Available: http://newton.dm.unipi.it/neodys/. [Accesed January 2017].

[4] A. Mainzer, T. Grav, J. Masiero, J. Bauer, R. S. McMillan, J. Giorgini, T. Spahr, R. M. Cutri, D. J. Tholen, R. Jedicke, R. Walker, E. Wright și C. R. Nugent, „CHARACTERIZING SUBPOPULATIONS WITHIN THE NEAR-EARTH,” *The Astrophysical Journal,* 20 June 2012.

[5] O.Vaduvescu, M. Birlan, A. Tudorica, M. Popescu, F. Colas, D. Asher, A. Sonka, O. Suciu, D. Lacatus, A. Paraschiv, T. Badescu, O. Tercu, A. Dumitriu, A. Chirila, B. Stecklum, J. Licandro, A. Nedelcu, E. Turcu, F. Vachier, L. Beauvalet, F. Taris și L. Bouqu, „739 observed NEAs and new 2–4 m survey statistics,” *Planetary and Space Science,* vol. 85, pp. 299-311, 2013.

[6] D. Koschny și M. Busch, „The Teide Observatory Tenerife Asteroid Survey,” *Planetary and Space Science,* vol. 118, p. 305–310, 2015.

[7] „IAU Minor Planet Center,” [Interactiv]. Available: http://www.minorplanetcenter.net/iau/mpc.html. [Accessed Februarie 2017].

[8] „NASA JPL (Jet Propulsion Laboratory) HORIZONS Web-Interface,” [Interactiv]. Available: http://ssd.jpl.nasa.gov/horizons.cgi. [Accessed Februarie 2017].

[9] „L'INSTITUT DE MÉCANIQUE CÉLESTE ET DE CALCUL DES ÉPHÉMÉRIDES,” [Interactiv]. Available: https://www.imcce.fr/fr/presentation/presentation_imcce.html. [Accessed Februarie 2017].

[10] „E.A.R.N. The Near-Earth Asteroids Data Base,” [Interactiv]. Available: http://earn.dlr.de/nea/. [Accessed Februarie 2017].

[11] „Planetary Spectroscopy at MIT," [Interactiv]. Available: http://smass.mit.edu/. [Accessed Februarie 2017].

[12] „M4AST (Modeling for Asteroids)," [Interactiv]. Available: http://cardamine.imcce.fr/m4ast/.

[13] O. Vaduvescu, *Studiul unor fenomene dinamice în Sistemul Solar, Teză de doctorat, Universitatea Babeș-Bolyai, Prof. îndrumător Dr. Arad Pal,* Cluj-Napoca, 1997.

[14] E. Bowell, B. Hapke, D. Domingue, K. Lumme, J. Peltoniemi și A. W. Harris, „Application of photometric models to asteroids," *Asteroids II; Proceedings of the Conference,* pp. 524-556, 1989.

[15] Y. Batrakov, „Ephemerides of Minor Planets for 1997," *Institute of Theoretical Astronomy, St. Petersburg,* p. 110, 1996.

[16] D. W. Hughes, „Comets and asteroids," *Contemporary Physics,* nr. 35, pp. 75-93, 1994.

[17] A. Dollfus, „Diameter measurements of asteroids," *Physical Studies of Minor Planets,* p. 25, 1971.

[18] R. P. Binzel, T. Gehrels și M. S. Matthews, Asteroids II (Space Science Series), Univ of Arizona Press, 1989.

[19] J. Schubart și D. Matson, „Masses and densities of asteroids," *Asteroids, ed. T. Gehrels (Univ. of Arizona Press, Tucson),* p. 84, 1979.

[20] M. Hoffmann, Asteroids II, R. P. Binzel, T. Gehrels și M. S. Matthews, Ed., The Univ. of Arizona Press, Tucson, 1989.

[21] A. W. Harris și D. F. Lupishko, „Photometric lightcurve observations and reduction techniques.," *Asteroids II,* pp. 39-53.

[22] E. M. Standish, „Dynamical reference frame — Current relevance and future prospects," *Towards Models and Constants for Sub-Microarcsecond Astrometry,* pp. 120-126, 2000.

[23] A. Harris, J. Young, E. Bowell, L. Martin, R. Millis, M. Poutanen, F. Scaltriti, V. Zappala, H. Schober, H. Debehogne și K. Zeigler, *Icarus,* nr. 77, p. 171, 1989.

[24] J. Rahe, V. Vanysek și P. Weissman, „Properties of cometary nuclei," *Hazards due to comets and asteroids,* pp. 597-634, 1994.

[25] P. Pravec, A. W. Harris și B. D. Warner, „NEA rotations and binaries,” *Proceedings of the International Astronomical Union,* vol. 2, nr. S236, 2007.

[26] P. Pravec, A. W. Harris și D. e. a. Vokrouhlicky, *Icarus,* 2008.

[27] S. Mottola, A. Erikson, A. W. Harris, G. Hahn, G. Neukum, M. W. Buie, W. D. Sears, A. W. Harris, D. J. Tholen, R. Whiteley, P. Magnusson, J. Piironen, T. Kwiatkowski, E. Howell, M. Hicks, Y. N. Krugly, N. M. Gaftonyuk, F. P. Velichko și d, „Physical Model of Near-Earth Asteroid (6489) 1991 JX from Optical and Infrared Observations,” *American Astronomical Society, DPS Meeting #27,* vol. 27, p. 1055, 1995.

[28] Y. N. Krugly, I. N. Belskaya, V. G. Chiorny, V. G. Shevchenko și N. M. Gaftonyuk, „CCD photometry of near-Earth asteroids in 2001,” *Proceedings of Asteroids, Comets, Meteors - ACM 2002. International Conference, 29 July - 2 August 2002,* pp. 903 - 906, 2002.

[29] S. J. Ostro, „Radar Observations of Earth-Approaching Asteroids,” *Engineering and Science,* 1997.

[30] P. Pravec, P. Scheirich, P. Kušnirák, L. Šarounová, S. Mottola, G. Hahn, P. Brown, G. Esquerdo, N. Kaiser, Z. Krzeminski, D. Pray, B. Warner, A. Harris, M. Nolan, E. Howell, L. Benner, J.-L. Margot, A. Galád, W. Holliday, H. M.D și Y. Krugly, „Photometric survey of binary near-Earth asteroids,” *Icarus,* 2006.

[31] V. Reddy, R. Dyvig, P. Pravec și P. Kusnirak, „Report on detection of binary nature of NEA 2005 AB,” *IAU Circ. 8483,* 2005.

[32] V. Reddy, M. J. Gaffey, P. A. Abell și P. S. Hardersen, „COMPOSITIONAL INVESTIGATION OF NEAR-EARTH ASTEROIDS 6456 Golombek, (5660) 1974 MA,(13553) 1992 JE.,” *Lunar and Planetary Science XXXVII ,* 2006.

[33] A. W. Harris, A. Galvez, W. Benz, A. Fitzsimmons, S. F. Green, P. Michel, G. Valsecchi, M. Paetzold, B. Haeusler și I. Carnelli, „Mitigation-relevant science with Don Quijote - a European-led mission to a near-Earth asteroid,” *36th COSPAR Scientific Assembly. Held 16 - 23 July 2006, in Beijing, China.,* 2006.

[34] M. J. L., P. P., N. M. C., H. E. S., B. L. A. M., G. J. D., J. R. F., O. S. J., S. M. A., M. C., T. P. A., N. P. D. și a. C. D. B., „Hermes as an exceptional case among binary near-Earth asteroids.,” *IAU General Assembly,* 2006.

[35] R. Behrend, L. Bernasconi, R. Riy, A. Klotz, F. Colas, P. Antonini, K. Augustesen, E. Barbotin, N. Berger, H. Berrouachdi, E. Brochard, A. Cazenave, C. Cavadore, J. Coloma, S. Deconihout, C. Demeautis, J. Dorseuil, G. Dubos și R. Durkee, „Four new binary minor planets: (854) Frostia, (1089) Tama, (1313) Berna, (4492) Debussy. Astron.," *Astrophys.,* nr. 446, p. 1177–1184, 2006.

[36] J. Richardson, H. Melosh, R. Greenberg și D. O'Brien, „The global effects of impact-induced seismic activity on fractured asteroid surface morphology," *Icarus,* vol. 179, p. 325–349.

[37] K. Holsapple, „Equilibrium Configurations of Solid Cohesionless Bodies," *Icarus,* vol. 154, p. 432, 2001.

[38] „Equilibrium figures of spinning bodies with self-gravity," *Icarus,* vol. 172, pp. 272-303, 2004.

[39] P. Pravec, L. Šarounová, M. D. Hicks, D. L. Rabinowitz, M. Wolf, P. Scheirich și Y. N. Krugly, „Two Periods of 1999 HF1—Another Binary NEA Candidate," *Icarus,* 2002.

[40] P. Pravec, A. Harris, P. Scheirich, P. Kušnirák, L. Šarounová, C. Hergenrother, S. Mottola, M. Hicks, G. Masi, Y. Krugly, V. Shevchenko, M. Nolan, E. Howell, M. Kaasalainen, A. Galád, P. Brown, D. DeGraff și J. e. a. Lambert, „Tumbling asteroids," *Icarus,* vol. 173, p. 108–131, 2005.

[41] M. Kaasalainen, „Interpretation of lightcurves of precessing asteroids," *Astron. Astrophys,* vol. 376, pp. 302-309, 2001.

[42] B. G. J., N. P. D., B. W., B. J. A. și H. A. W, „On a Possible Rotation State of (433) Eros," *Icarus,* vol. 140, nr. 1, pp. 239-242, 1999.

[43] B. J. A și S. V. S, *MNRAS,* nr. 165, p. 403, 1973.

[44] R. Hudson și S. Ostro, „Shape and non-principal axis spin state of Asteroid 4179 Toutatis," *Science,* nr. 270, p. 84–86, 1995.

[45] A. Harris, „Tumbling asteroids," *Icarus,* nr. 107, pp. 209-211, 1994.

[46] P. Pravec, M. Wolf și L. Šarounová, „Lightcurves of 26 Near-Earth Asteroids," *Icarus,* 1998.

[47] A. W. Harris, J. W. Young, E. L. G. Bowell și T. D. J., „Asteroid lightcurve observations from 1981–1983," *Icarus,* nr. 142, p. 173–201.

[48] A. Harris, J. Young, F. Scaltriti și V. Zappala, „Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis,” *Icarus,* nr. 57, pp. 251-258, 1984.

[49] A. Kryszczyńska, K. T., B. S. şi M. T., „Relation between rotation and lightcurve of 4179 Toutatis,” *Astron. Astrophys.,* nr. 345, p. 643–645, 1999.

[50] J. Buchanan și P. Turner, „Numerical Methods and Analysis.,” *McGraw-Hill, New York,* p. 363, 1992.

[51] W. Bottke, D. Vokrouhlicky, D. Rubincam și D. Nesvorny, „The Yarkovsky and YORP effects: Implications for asteroid dynamics,” *ANNU REV EARTH PL SC,* vol. 34, pp. 157-191, 2006.

[52] D. J. Tholen, *ASTEROID TAXONOMY FROM CLUSTER ANALYSIS OF PHOTOMETRY,* The University of Arizona, 1984.

[53] S. J. Bus și R. P. Binzel, „Phase II of the Small Main-Belt Asteroid Spectroscopic Survey. A Feature-Based Taxonomy,” *Icarus,* vol. 158, nr. 1, pp. 146-177, 2002.

[54] F. E. DeMeo, R. P. Binzel, S. M. Slivan și S. J. Bus, „An extension of the Bus asteroid taxonomy into the near-infrared,” *ELSEVIER,* vol. 202, nr. 1, pp. 160-180, 2009.

[55] S. J. Bus, *Compositional structure in the asteroid belt: Results of a spectroscopic survey, Ph.D. thesis,* 1999.

[56] S. P. Naidu, L. A. M. Benner, J.-L. Margot, M. W. Busch și P. A. Taylor, „CAPABILITIES OF EARTH-BASED RADAR FACILITIES FOR NEAR-EARTH ASTEROID OBSERVATIONS,” *UCLA Previously Published Works,* 2016.

[57] L. A. M. Benner, M. W. Busch, J. D. Giogini, P. A. Taylor și J.-L. Margot, „Radar observations of near-Earth and main-belt asteroids,” în *Asteroids IV,* Univ. of Arizona, Tucson, 2015.

[58] D. Vokrouhlicky, W. F. C. S. R. Bottke și D. J. a. S. T. S. Scheeres, „The Yarkovsky and YORP Effects,” în *Asteroids IV,* Univ. Arizona Press, Tucson, 2015, pp. 509-532.

[59] „Image Reduction and Analysis Facility,” [Interactiv]. Available: Image Reduction and Analysis Facility. [Accessed Februarie 2017].

[60] „MPO Canopus,” [Interactiv]. Available: http://www.minorplanetobserver.com/MPOSoftware/MPOCanopus.htm. [Accessed 2017].

[61] A. Aznar, M. Predatu, O. Vaduvescu și e. al, „EURONEAR - First light curves and physical properties of NEAs,” 2017, accepted

[62] O. Vaduvescu, M. Popescu, M. Predatu și e. al, „The EURONEAR Lightcurve Survey of Near Earth Asteroids,” *Earth, Moon and Planets,* 2017, accepted
pending.

[63] M. Popescu, O. Vaduvescu, M. Predatu și e. al, „Visible spectra of near-Eath asteroids obtained with INT: setting up the framework and the results of a small survey,” *Astron. & Astrophys;,* 2017, pending.

[64] O. Vaduvescu, M. Predatu, M. Popescu și e. al, „Insights in NEA asteroids observed by EURONEAR and other MBA asteroids and families,” *Icarus, A&A, Earth Moon Planets,* 2018. pending.

[65] O. Vaduvescu, Cornea și M. Predatu, „EURONEAR NEAs Lightcurve Survey Tenerife 2015,” *Earth Moon and Planets,* 2017, pending.

LIST OF OUR CONTRIBUTIONS

1. **EURONEAR – First light curves and physical properties of NEAs**- Aznar, Predatu, Vaduvescu et al, 2017 - accepted in the Romanian Journal of Physics (http://www.nipne.ro/rjp/2017_62_7-8.html)

2. **The EURONEAR Lightcurve Survey of Near Earth Asteroids**- Vaduvescu, Popescu, Predatu et al, 2017 - accepted at Earth, Moon and Planets (https://link.springer.com/article/10.1007/s11038-017-9506-9)

3. **Visible spectra of near-Eath asteroids obtained with INT: setting up the framework and the results of a small survey**- Popescu, Vaduvescu, Predatu et al, 2017 (Aug 2017), sent to Astronomy & Astrophysics

4. **Insights in NEA asteroids observed by EURONEAR and other MBA asteroids and families**
   authors: Vaduvescu, Predatu, Popescu et al., 2017-2018

   to send Icarus, A & A or Earth Moon Planets (2018)

5. **EURONEAR NEAs Lightcurve Survey Tenerife**
   authors: Vaduvescu, Cornea, Predatu, (aprilie-mai 2017)

   to send Icarus, A & A or Earth Moon Planets

6. **THE JOINT MEETING ON QUANTUM FIELDS AND NONLINEAR PHENOMENA**

   09-13 March 2016, Sinaia, Romania

   Predatu, Vaduvescu et al. 2016 -Light curves of Near Earth Asteroids through computational methods