NEO ROCKS

Near Earth Object Rapid Observation, Characterization and Key Simulations

WELCOME TO THE NEOROCKS PROJECT!

NEWSLETTER – EDITION 1

IN THIS ISSUE:

PROJECT FUNDED BY EU H2020

NEOROCKS MAGAZINE ISSUE 01 - EDITORIAL

Elisabetta Dotto, NEOROCKS Coordinator
INAF – National Institute for Astrophyiscs, Italy

Welcome to NEOROCKS, our newly launched magazine for insights into the world of Near Earth Objects (NEOs).

"NEOROCKS - The NEO Rapid Observation, Characterization and Key Simulations" is a Collaborative Research Project, funded by the European Union Horizon 2020 programme for Research and Innovation.

With our NEOROCKS magazine, we want to share knowledge being developed by our group of international research institutions and industry partners, the *Neorockers*.

Each issue will bring you updates on our work and share some key findings: carefully selected articles to bring you into the world of NEOROCKS and to learn a bit more about this fascinating field.

Not only that, our magazine will also republish some classic articles from the Tumbling Stone magazine (on-line publication of the Spaceguard Foundation, from 2001-2003), timeless pieces helping us to understand asteroids.

We will finish each issue with something for the new generation, the mini-Neorockers.

Before you dive into all of that, as the project coordinator, it is my job to tell you a bit more about what NEOROCKS is.

The NEOROCKS team joins top scientists with long-standing experience in NEO observations and physical characterization, governmental institutions able to guarantee access to large infrastructures and industrial partnerships participating in European Space Situational Awareness programmes. You can find out more about them in the *"Meet the Neorockers"* section of this issue.

NEOROCKS was designed to improve our knowledge on the physical characterization of the NEO population and the implications for their origin and evolution, as well as for planetary defence.

The challenge for physical characterization is to keep pace with the ever-increasing NEO discovery rate: at present, less than 20% of NEOs have known physical properties (shape, albedo, composition, rotation etc.) and this fraction is likely to decrease when the near-future widefield high-sensitivity NEO surveys come into operation.

Meanwhile, the challenge for planetary defence is to keep up with the fact that, due to ever increasing performance of NEO surveys, discoveries are dominated by objects that may be small in size, but would still be capable of causing damage in case of impact. Among them, we have the so-called "imminent impactors". These would allow for an extremely short warning time (hours to weeks) and limited time to determine impact location reliably and estimate the severity of the strike. In this case, we need rapid response for effective risk assessment and mitigation.

NEOROCKS offers a coordinated approach to these dual challenges. We link up expertise in performing small body astronomical observations and the related modelling needed to derive their dynamical and physical properties, to the pragmatic approach of planetary defence, which aims to provide operational loops and information systems to protect citizens and ground infrastructures from potential threats.

Our innovative approach will improve and optimize observational activities, enhance modelling and simulation tasks, foster international coordination and speed-up response times. We are doing this by:

a) building a team of European expert astronomers, able to grant access to large aperture telescopes equipped with state of the art instrumentation to perform high-quality, physical observations and foster the related data reduction process;

b) investigating the relationship between the orbit determination of newly discovered objects and the quick execution of follow-up observations, in order to provide enabling technologies to face the threat posed by the "imminent impactors";

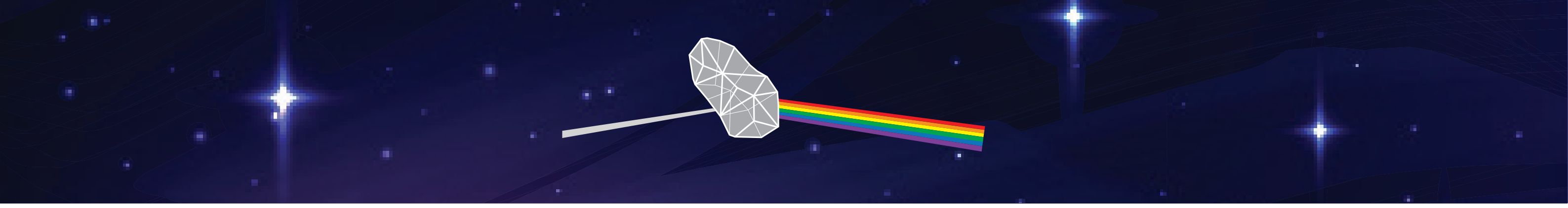
c) using European industrial expertise in ongoing SSA (Space Situational Awareness) initiatives to plan and execute breakthrough experiments foreseeing remote tasking of highly automatized robotic telescopes, in order to provide a proof-of concept rapid response system;

d) guaranteeing extremely high standards in data dissemination through agency level involvement of a data centre facility (ASI Space Science Data Centre - SSDC) already operating in a European and international context. Our European born technical web portal will host an orbital catalogue, ephemerides and physical properties database. Astronomers and observers will be able to find both dynamical and physical properties of already observed NEOs and lists of observable, but not yet characterized NEOs.

NEOROCKS has been running since January 2020. We had just got started, when the global health pandemic emerged. COVID-19 hit NEOROCKS activities hard. Critical observation facilities, the high-sensitivity, large-aperture telescopes, were closed for prolonged periods. Some major telescopes and observatories have since re-opened their facilities, but the backlog of previous commitments limits the possibility for new observation proposals.

This has also meant a reduction in data analysis and modelling tasks, due to the limited flux of input data. We have attempted remote management of astronomical observations using smaller, less-performing telescopes and, in this way, succeeded in completing some observational campaigns. However, limited telescope performances made it difficult to detect the most valuable NEOROCKS targets (small and faint objects). Luckily, the European Commission has granted us a 12-month extension, so we are now ready to make up for lost time and we'll be with you until June 2023!

All that is left for me then, is to say that I hope you enjoy this first issue of the NEOROCKS magazine and that you will follow our work over the next few years. Happy reading!



DATA MINING

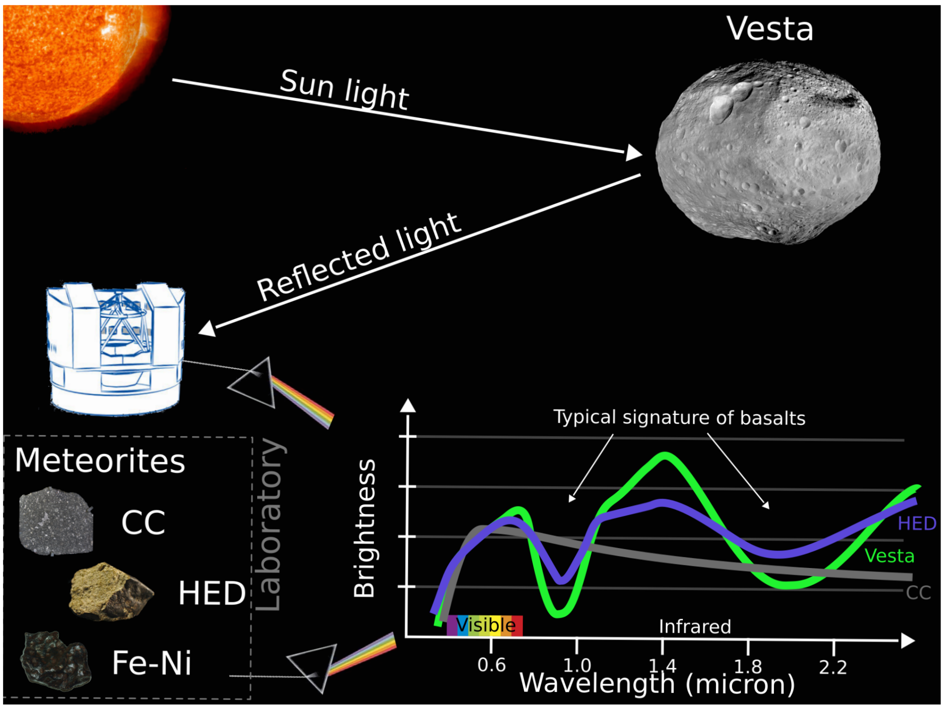
Benoit Carry
Observatoire de la Cote d'Azur

Near-Earth Asteroids (NEA) represent the vast majority of NEO: as of today, the astronomical community have discovered more than 28,000 NEOs. Owing to their orbits, they end up impacting planets or falling into the Sun. The potential threat represented by NEOs motivates discovery programmes (How many are they? Where are they?) and characterisation programmes (How big are they? What are they made of?), such as our NEOROCKS project.

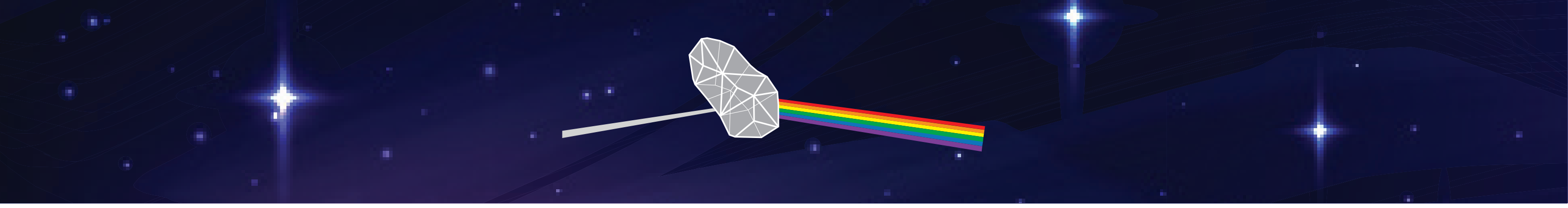
While the probability of impact with the Earth is very low, it is a natural hazard that we can predict. In the very unlikely case of an NEO heading towards us (Don't Look Up!), the mitigation strategy will depend on the characteristics of the asteroid, and in particular its diameter and its composition.

The level of threat is dictated by the mass of the asteroid, which is extremely complex to measure. We thus rely on measurement of the diameter and the density to estimate the mass. While density is also extremely complex to measure, it is closely linked with the composition of the asteroid, which can be determined from how it reflects the light of the Sun.

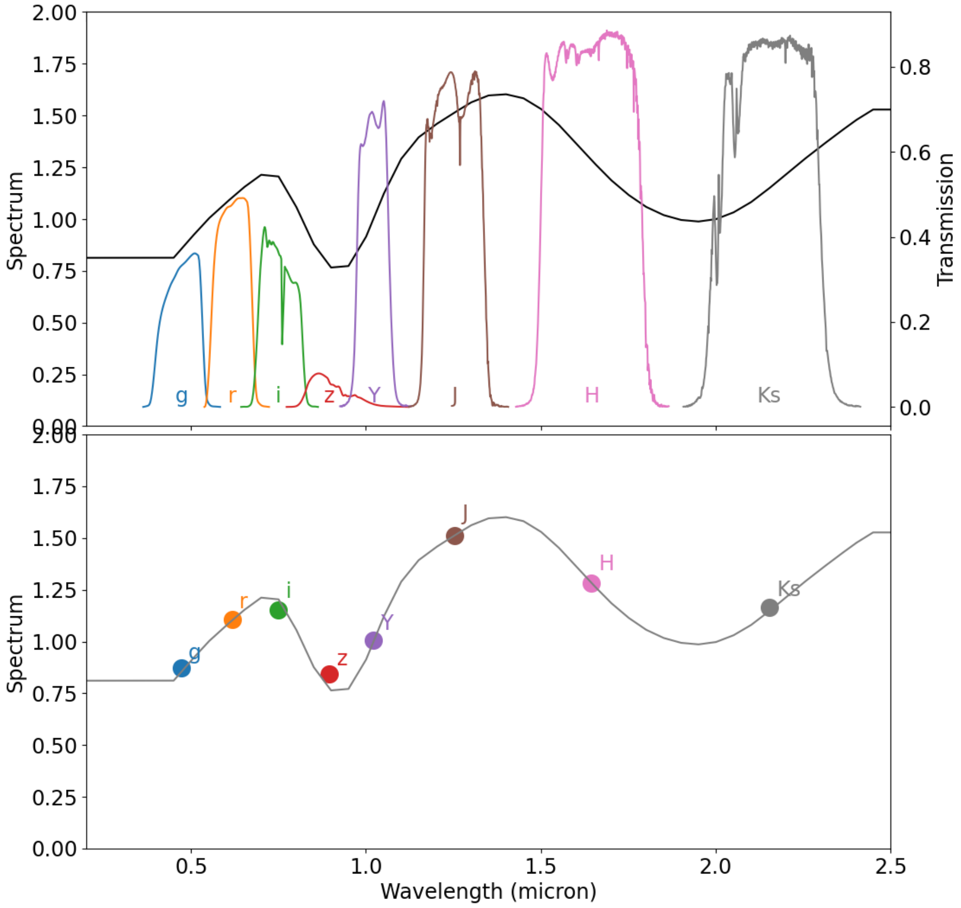
The composition of an asteroid is determined by comparing the light reflected by the surface with that of meteorites studied in the laboratory. In particular, we compare how the light spread across wavelengths (in plain English, we would say across colours). This technique is called spectroscopy. It is the most precise method to study the composition of an asteroid.



Concept of the analysis of asteroid composition

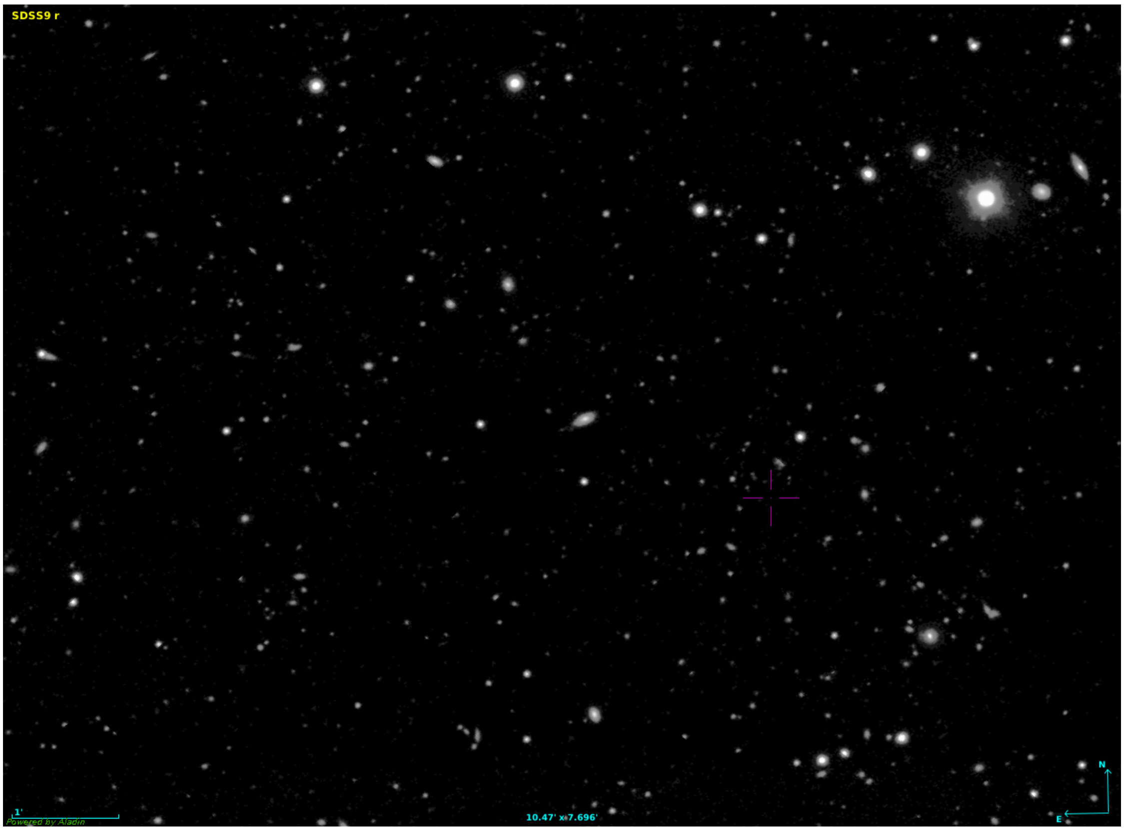


However, acquiring these spectra is time consuming. It requires nights, and nights, and nights of observations to collect a few tens or hundreds of spectra. These spectra are extremely important as they provide detailed information on the composition of an object. So, how can we increase the number of characterization of compositions?
In NEOROCKS, we decided to complement these reference spectroscopic observations with another approach: colours.
We call colours the comparison of the amount of light between two wavelengths. It is similar to the usual, daily, conception: if an asteroid reflects more light in the wavelength corresponding to the "red" than in the wavelength corresponding to the "blue", we will say that the asteroid is "red". Beyond a simple red/green/blue perception, the colours really describe the spectrum of the NEOs. They are simply a low-resolution version of the spectrum (an analogy could be a pixelized version of a portrait that still allows to recognise the person).
In astronomy, we use many different filters to take images and these select only some wavelengths. In the figure here, the g and r filters correspond to what the eye recognize as blue and red. However, we also use filter in the near-infrared, represented by the z, Y, J, H, Ks in this example. Thus, we can obtain the colour by measuring the amount of light in two images, taken with two different filters. In NEOROCKs, we also measure colours of NEOs.

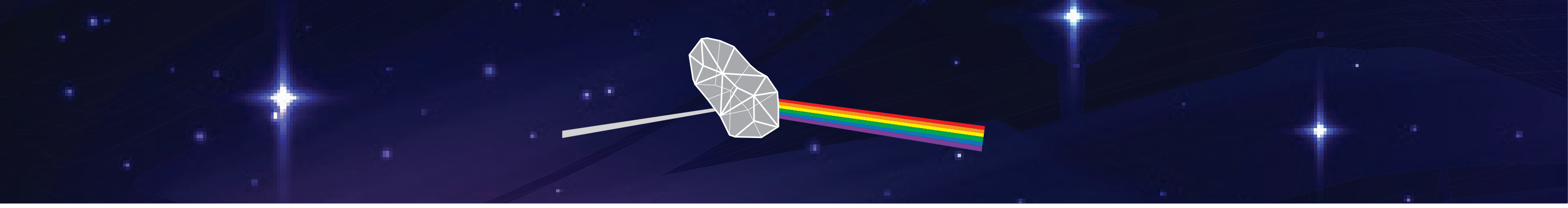


Filters select the light over some specific wavelength ranges. Combining several filters reproduce the spectrum, with less resolution

Why should we use a cruder version of the information? Why do we not acquire only spectra? The answer is that it is much faster to acquire two images in two filters than to build a complete spectrum. The filters collect the light over a broad range of wavelengths, while by essence spectroscopy spreads it. It is thus more efficient to acquire colours than spectra, but we lose spectral details. These colours can, therefore, be used to classify asteroids broadly into similar groups, the composition of which can be understood thanks to spectroscopy. By doing both spectroscopy and colours in NEOROCKS, we win on both sides: more characterised NEOs and more understanding!
We also decided to complement our own observations with another approach: mining of colours from astronomical archives. There are many different telescopes in the world. For many years, they have been observing every night and collecting data. Most of the time, the images acquired by these telescopes have other purposes than NEOs: some researchers may be studying galaxies, stars, nebulae, exoplanets... There is nevertheless a tremendous amount of images taken over many different regions of the sky every night, in many different filters.
In NEOROCKS, we are hunting for NEOs present in these images by mere chance, These could be NEOs orbiting the Sun, which are constantly moving, and usually appear starlike in a single image taken for other purposes. The complexity of this task is to be sure that it is definitely an NEO in the image. Moreover, in the vast majority of images, there will only be stars, or galaxies, but no NEOs. So, it becomes a bit like searching for a needle in a haystack.



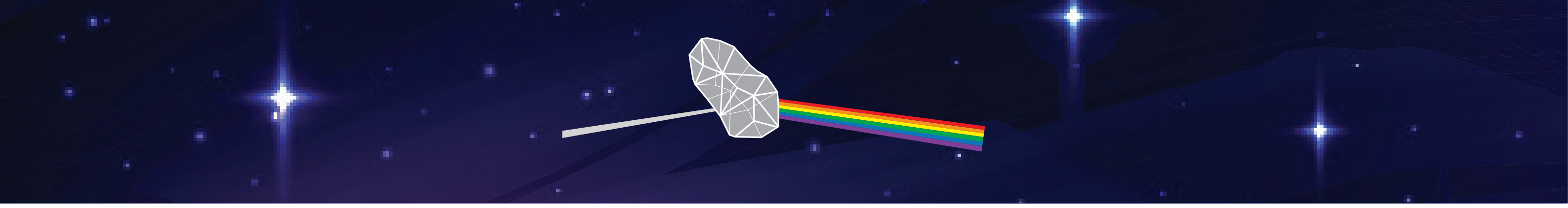
Example of an image from the SDSS. From a single image, there is a priori no way to identify the source: stars, galaxies, NEOs?



This approach, thus, requires both an analysis of many images to find NEOs and the development of tools to ascertain their identification. In NEOROCKS, we have searched NEOs in images obtained by two telescopes that have imaged very large portions of the sky: the Sloan Digital Sky Survey (SDSS) from 1998 to 2008, and the SkyMapper Southern Survey (SMSS) since 2014. We have computed the predicted positions of all asteroids for each of the 1,400,000 images of the SDSS and the 200,000 images of the CMSS. If there was a source detected on the image at the predicted position of the asteroid, we considered it was a good candidate for being a NEO.

We then checked that these candidates were genuine NEOs. Indeed, the simple match on position can lead to many false association with stars. These checks are multiple, from the motion of the candidate over several frames, to its colours, to its proximity with known stars, among others.

As a result, we have managed to measure the colours of 1652 NEOs from the SDSS (five filters each), and of 669 NEOs (two to four filters) from the SkyMapper, without actually undertaking the observation ourselves! This is a clear advantage of this mining / hunting approach: we can extract many, many observations. We benefit from hundreds of nights of observations, which were initially taken for other purposes. The drawback is that have not yet been able to choose the NEO for which we would report the colours. This is the next step, to be carried out with our own, targeted observations. This is why we combine both in NEOROCKS, so stay in touch to find out more.



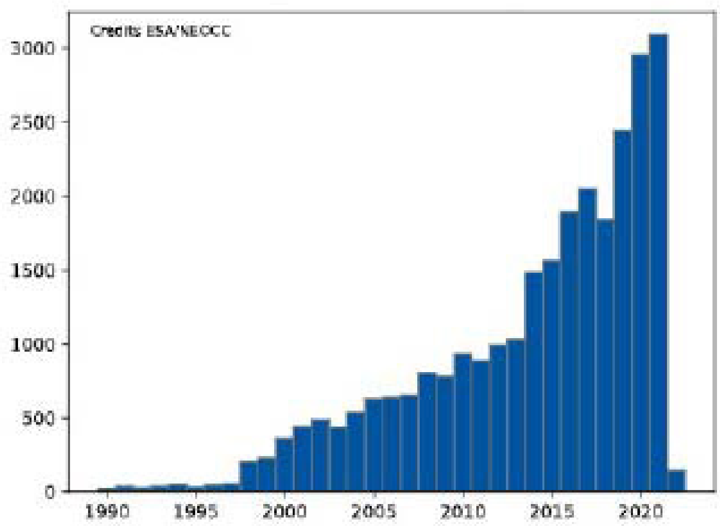
DON'T PANIC AND LOOK UP!

Ettore Perozzi
Italian Space Agency

Many of you will surely have watched Don't Look Up over your winter break. Those of you that work on NEO impact monitoring and are used to choosing every single word carefully when talking to the media, to making sure you are not accused of fostering panic, might actually have been relieved when you watched this film. Here everyone is desperately and deliberately trying to panic journalists, politicians, security officers and the citizens, with little if no success at all (at least at first).

Of course, it is clear from the very beginning that Don't Look Up is not another blockbuster on cosmic impacts: the threat posed by a newly discovered comet is the perfect choice for addressing more earthly hazards (e.g. global warming) of which initially only a restricted group of experts are aware. However, discussing the many technical details used in the film to explain how astronomers discover an NEO on a collision course with our planet and the actions undertaken to face the threat, turns out to be an interesting exercise. It allows us to show, by sheer comparison with reality, advances in terms of technical developments and international coordination achieved in the last 10 years, as well as the potential contribution of NEOROCKS.

Firstly, it is rather unlikely that the discovery of a large active comet would occur as a serendipitous event. Since the beginning of this century, the efficiency of the network of telescopes that survey the skies every night searching for NEOs has been steadily growing. In 2021, the record-breaking figure of 3000 new objects per year was hit. That means three time more than the total number of objects discovered in the whole century since 1898, when the first Near-Earth asteroid (433 Eros) was spotted in the sky.



Discovered NEOs by years from 1st January 1990 to present

Moreover, impact monitoring is no longer performed by scientists writing formulas on a whiteboard, but by sophisticated software robots running at NASA-JPL, in California, and at the ESA NEO Coordination Center at ESRIN (Frascati, Italy). It is worth mentioning that the very first impact monitoring system, NEODyS, developed at the University of Pisa, went into operation in 1999 and is actively participating in the NEOROCKS project, providing inputs to our observers.
Then, there is the question of how to act once a threat is confirmed. The solution presented in the movie (give a call to the US President!) reflects the panel discussion closing the first Planetary Defense Conference organised in Granada (Spain) in 2009. At that time, the scientific community involved in NEO studies realised that there was no established procedure in place to interface with governmental institutions. This is a particularly dangerous missing link, considering the global nature of the threat. Since then, many official steps have been taken. Early attempts, represented by the UN Action Team 14 and by establishing the Spaceguard Foundation, have evolved into the IAWN (International Asteroid Warning Network) and SMPAG (Space Mission Planning Advisory Group) committees. Both of them, under the auspices of the United Nation Office for Outer Space Affairs (UNOOSA), gather a large community of professional and amateur astronomers, as well as aerospace engineers, who meet regularly to study impact scenarios and prepare mitigation actions.
In this context, NEOROCKS's goal of improving our knowledge of the physical characterization of the known NEO population, through performing dedicated observations and advanced data processing and dissemination, is essential to carry out realistic simulations.

TNG (the Italian Telescopio Nazionale Galileo) in La Palma (Canary Islands, Spain) is part of NEOROCKS' network of collaborating telescopes, allowing visible and near-infrared spectroscopic and photometric observations.

The ASI Space Science Data Center (SSDC) takes care of the NEOROCKS data dissemination; it already hosts an impressing collection of astronomical data and guarantees their availability to the scientific community.

The outcome of an impact in fact depends strongly not only on the trajectory and the size of the impacting body, but equally on its chemical composition and internal structure. This is particularly true, rather than the extremely improbable event of an impacting 10-km Oort cloud comet as in Don't Look Up, for the much more frequent "imminent impactors". These are tiny (10-m class) bodies on a collision trajectory, discovered with short warning times.

We know that a rocky, loosely-bound NEO of that size almost completely burns up upon entering the atmosphere. On the other hand, if it is of iron composition, it is capable of reaching the ground and forming an impact crater. Should such a threat materialise, a key issue for planetary defense is to react in a matter of hours, or days at the latest, coordinating observations aimed at both astrometry and physical characterisation. The former is needed to shrink the so-called "impact corridor" down to a precise location on the surface of the Earth, the latter to estimate ground damage reliably. Only upon receiving these basic inputs, can civil protection authorities determine the level of alert and put into place the necessary mitigation actions. With this is mind, it becomes clear why NEOROCKS focuses on characterising small, recently discovered NEOs. But the Neorockers have decided to move even farther. Presently, the observational and data-analysis effort described above is performed on a voluntary basis and with a high level of human intervention. Why not profit from the expertise in our project to check how far we can go in automatising this process? This can be considered the very first step toward a fully operational, rapid response system. Just in case of panic....

THE FIRST NEO AND THE ORIGIN OF CHAOS

Giovanni Valsecchi
INAF – National Institute for Astrophyiscs, Italy

Many of the ideas at the heart of our current understanding of the motion of NEOs date back to the XVIIIth and XIXth century. They were started by the discovery of a comet on the night between 14 and 15 June 1770 by Charles Messier, one of the most famous comet hunters of all times.

The comet was heading right towards the Earth: in hindsight, it can be considered the very first observation of a NEO approaching our planet. Within a few days, starting from 21 June, it became visible to the naked eye, reaching the second magnitude three days later. The minimum distance from the Earth was reached on 1 July, at about six times the lunar distance, and in a few more days the comet became no longer visible due to its proximity to the Sun. Yet Messier was able to see the comet again starting from the beginning of August and it was observed until the first days of October.

"Portrait of Charles Messier
by Jean Henri Cless (1774–1812)"

A serious problem soon became clear to astronomers: the ephemerides used to recover the comet after its perihelion passage, based on a parabolic orbit, were incapable of accounting for the entire set of observations. It was the Swedish astronomer Anders Lexell who showed that the comet was on an elliptical orbit, such that of Comet Halley (the only other case known at the time). However, it had a period of revolution of 5.5 years, far shorter than Halley's (76 years). Messier then questioned why the comet had not been observed during previous returns, given its short orbital period and its small perihelion distance. The answer by Lexell was that in May 1767, the comet and Jupiter had been very close to each other and the action of the gravity of the giant planet had greatly transformed the orbit

Photo available through creative commons) Adam Christian Gaspari, Christian Gottlieb Reichard (1802) Allgemeine geographische Ephemeriden, Band 10, Weimar: Landes - Industrie - Comptoir Retrieved on 25 November 2011.

of the comet. In fact, before 1767 the comet had a much larger perihelion distance, which meant that it could not become very bright. This explained the fact that it had not been observed before.Lexell did not content himself with these findings. He went on to say that in 1779 the comet would encounter Jupiter again and would be expelled from the inner solar system into an orbit of large perihelion distance and period. This would make it invisible again for the telescopes available at that time. The comet, in fact, was not observed in 1782, as it should have been if it had remained in its 1770 orbit.

In recognition of his findings, the comet, although discovered by Messier, was given Lexell's name.

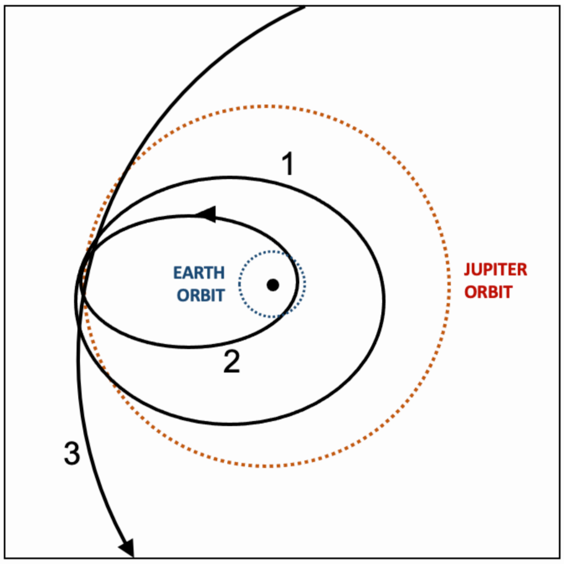
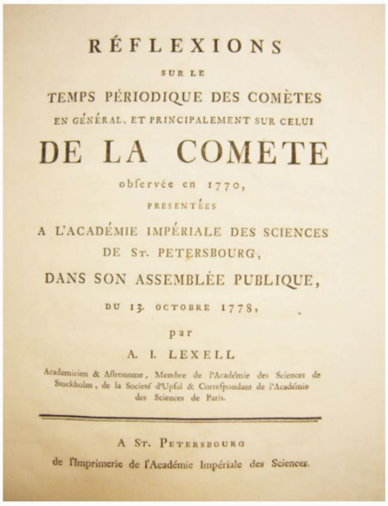


Figure caption: Comet Lexell orbits:
1) before the 1767 Jupiter encounter;
2) during the 1770 discovery apparition;
3) after the 1779 encounter with Jupiter.



RÉFLEXIONS
SUR LE
TEMPS PÉRIODIQUE DES COMÈTES
EN GÉNÉRAL, ET PRINCIPALEMENT SUR CELUI
DE LA COMETE
obſervée en 1770,
PRESENTÉES
A L'ACADÉMIE IMPÉRIALE DES SCIENCES
DE ST. PETERSBOURG,
DANS SON ASSEMBLÉE PUBLIQUE,
DU 13. OCTOBRE 1778,
par
A. I. LEXELL
Académicien & Aſtronome, Membre de l'Académie des Sciences de Stockholm, de la Société d'Upſal & Correſpondant de l'Académie des Sciences de Paris.

A ST. PETERSBOURG
de l'Imprimerie de l'Académie Impériale des Sciences.

Lexell's original publication on the comet

But this is not the end of the story. About seventy years later, Urbain Le Verrier – who was soon to become a celebrity for predicting where to search for planet Neptune – critically re-examined the case for Lexell. He concluded that it was not possible to determine a reliable orbit of the comet because the observations were insufficient.

"Portrait of Urbain Le Verrier"

However, the situation was not totally desperate. Le Verrier was able to constrain the possible trajectories of the comet by expressing them as a function of a single unknown parameter, that he called mu: outside a certain range of mu values, the path of the comet on the sky would have been measurably different from the observed one. Note that his reasoning is surprisingly modern as it can be considered the direct ancestor of the determination of the so-called “confidence region” for the orbit of a near-Earth object. Finally, Le Verrier computed the effects of the 1767 and 1779 encounters with Jupiter undergone by comet Lexell for the admissible values of mu. In this way, he obtained a global view of all the possible outcomes. This procedure, again, was very similar to the systematic computations carried out nowadays by modern NEO impact monitoring systems.
Le Verrier concluded that in 1779 the comet could have approached Jupiter as close as less than three and a half radii of the planet from its centre, but could not have become a satellite for any allowed value of mu. The post-1779 trajectories included even the possibility, for the comet, to leave the solar system on a hyperbolic orbit, thus becoming what we call today an “Interstellar Object”.

The reason for the wide range of possible outcomes found by Leverrier was the extreme sensitivity of the orbital evolution to the precise value adopted for mu. This sensitivity is a crucial part of the modern concept of chaos (small changes result into large differences), and in fact Le Verrier’s computations probably represent the first instance of this concept in scientific literature. The studies of the dynamics of small solar system bodies on chaotic orbits, such as NEOs, had entered the modern era.

TUMBLING STONE REVISITED

This article first appeared on the on-line journal “Tumbling Stone”, published by the Spaceguard Foundation. Historically, this was the first entity addressing planetary defense in the early 2000s. Luckily for us, some of the Neorockers were involved with Tumblingstone and with the kind permission of the journal editors, Nanni Riccobono and Livia Giacomini, we have the pleasure to revisit some of their excellent articles in our newsletter.

Photo available through creative commons) Commons upload by File Upload Bot (Magnus Manske) 13:07, 22 May 2006 (UTC).

GLOSSARY

What is the Magnitude?

The brightness of any celestial body (stars, asteroids, planets, etc) is measured by a quantity called magnitude. The modern magnitude scale relies on a mathematica exponential law which allows a precise expression of the brightness and extends to both extremely bright and very dim objects. The lower the magnitude (including negative values), the brighter the object. Naked-eye objects can reach up to magnitude 6 on an extremely dark night. The magnitude of the Moon is -12.5.

Who is Messier?

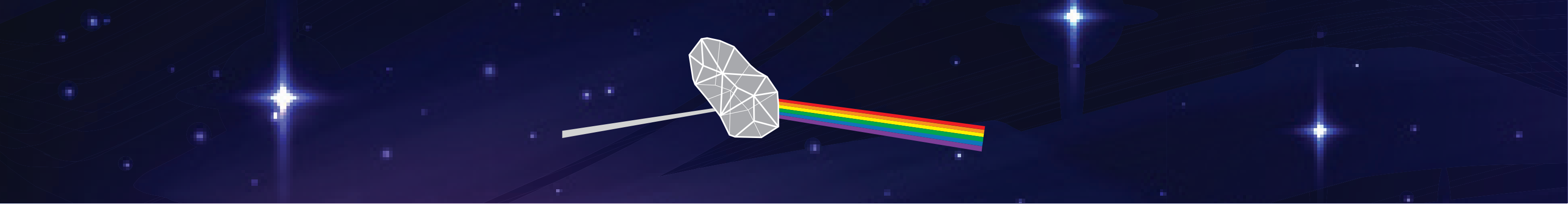
Charles Messier (1760-1817) became an astronomer, inspired by childhood sightings of comets and a by a solar eclipse visible from his home town of Badonvillier, in France. As a celebrated comet hunter, he kept careful records of his observations while hunting for comets which resulted in a detailed list of approximately 100 diffuse objects that were difficult to distinguish from comets but they were notsince they did not move with respect to the background stars. This list became famous as the "Messier Catalog" and is still well known as a collection of the most beautiful objects in the sky including nebulae, star clusters and galaxies.

Who is Lexell?

Anders Lexell (1740 – 1784) was born, studied and graduated in Sweden, where he became appointed professor of mathematics. He was then invited to the St Petersburg Academy of Science, where he started working from 1769 with Euler and other high quality scientists, becoming appointed professor of astronomy in 1771. Lexell stayed in St. Petersburg until his death, working mainly in the area of analysis and geometry. In astronomy, Lexell is famous for having computed the orbits of several comets, including the comet of 1770, that was named after him and for having recognized that the celestial body discovered by William Herschel in 1781 was actually a new planet (later named Uranus).

Who is LeVerrier?

Urbain Jean Joseph Le Verrier (Saint-Lô, 11 marzo 1811 – Parigi, 23 settembre 1877) was an oustanding celestial mechanician of his time. He is remembered worldwide for having contributed to the discovery of Neptune by predicting its position in the sky - a major result since until then discoveries were obtained only through extended sky surveys. He was director of the Observatory of Paris for almost 20 years.



Neorocks4kids

ONCE UPON A TIME....

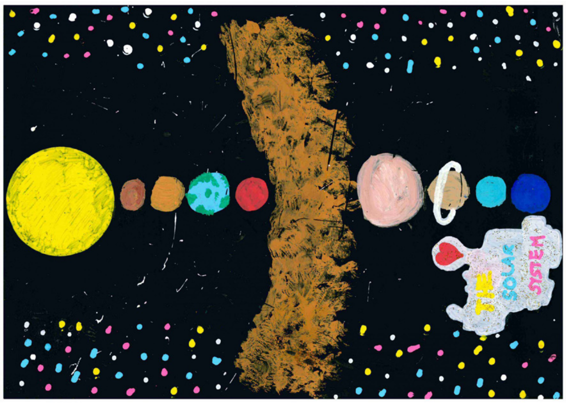
No, don't worry this is not a fairy tale about princesses and evil stepmothers and dragons...!! Let's start again...

Once upon a time, nearly 5 BILLION years ago, there was a big bang and the solar system was created: the planets, the stars, the sun...but also those small, rocky bodies that fly about in the sky.

These are the asteroids. Bits of stone and even metal left over from the formation of the planets or produced by catastrophic collisions between celestial bodies. They orbit around the sun, just like our planet Earth. Most travel in the asteroid belt, between the planets of Jupiter (the biggest planet in the solar system) and Mars (the Red planet).

BUT, some of them can cross the orbits of the planets. The buttered surface of the Moon tells us that asteroids keep on raining near Earth after planet formation. They likely brought some of the elements that we find on our planet, including precious metals like gold!

So, Asteroids had already been up there for a long, long time, but they were too small to be seen with the naked eye. Then, a couple of hundred years ago a clever Astronomer (a scientist who studies the universe: planets, stars, galaxies, black holes...) finally managed to spot one using a very powerful telescope. His name was Giuseppe Piazzi and he had the honour of naming this asteroid. He called



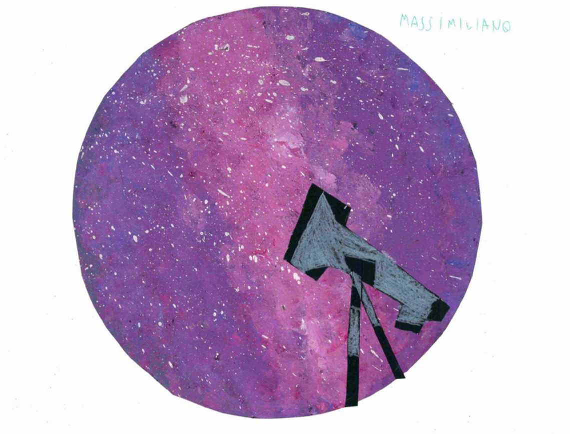
it CERES, after the Roman goddess worshipped in Sicily, Italy, where he made his discovery.

What happened next? Well, astronomers kept on looking at the sky, using more and more advanced technologies. They found and named

many more asteroids. We now know of around 1 million asteroids and there are many more out there. Giuseppe Piazzi used the "Ramsden Circle" to spot CERES. This telescope was very advanced for its time, but still much smaller than what we have now. Today, our astronomers use HUGE optical telescopes, up to 100 times as wide as Piazzi's. These amazing telescopes help them to see asteroids in the sky, to study them and take pictures of them. We can characterise them: find out about their size, their shape, the way they move and where they are heading.

This is part of Planetary Defence, which means protecting Earth from asteroid impact. Asteroids seem tiny, because they are so far away, but they can be larger than a whole building or even a town! That means if they manage to fall through the atmosphere and impact the Earth's surface (with the smallest of the becoming "meteorites"), they could cause a LOT of damage. The asteroids most likely to do this are Near Earth Objects (NEOs), because they come closer to our planet than the other ones.
I guess we could call these NEOs the baddies in our story...and the astronomers are like the heroes, working their magic to keep us safe. Only, they don't used magic. They use science, technology and international cooperation... Telescopes all over the world are watching the sky. They are tracking asteroids, sharing information and characterising them very quickly. Like in all the best fairy tales, the key to defeating the baddy is to work together.
So...we can't say yet that we all live happily, ever after...but we can say that we don't need to be up at night worrying about the asteroids under our bed! Sleep well, mini-Neorockers!

Drawings courtesy of CRISP University of Perugia and ASI Italian Space Agency "Disegniamo l'Universo" https://crisp.unipg.it/universo/



MEET THE NEOROCKERS

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INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

INAF is the public research organisation that promotes, performs, and coordinates astrophysics and astronomy research in Italy.
INAF has 16 research centres distributed over the country and observing facilities in Italy and abroad. The main ones are the Sardinia Radio Telescope, located in Sardinia, Italy, the National Telescope Galileo (TNG), located in La Palma, Canary Islands and a 25% share of the Large Binocular Telescope (LBT) in Arizona.
OAR (Astronomical Observatory of Rome) is in charge of the NEOROCKS project and is closely involved in global gravitational wave observations.

ITALIAN SPACE AGENCY ITALY

www.asi.it

ASI Agenzia Spaziale Italiana

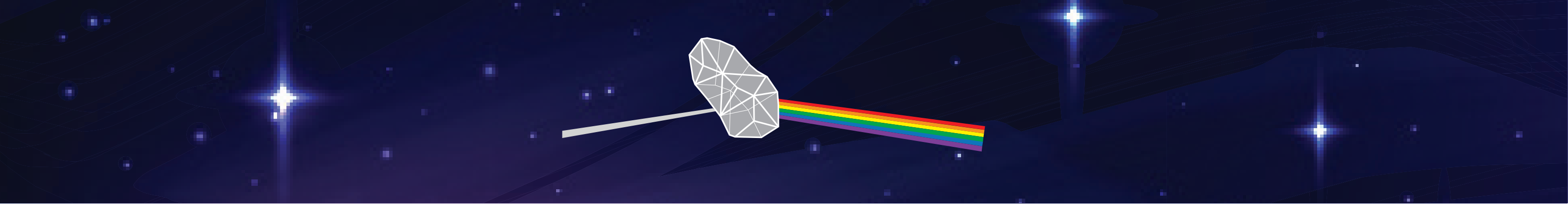
The Italian Space Agency was founded in 1988 to coordinate national efforts and investments in the space sector. ASI is one of the most significant players in the world in space science and satellite technologies, with strong interests in exploration of the Solar System and observation of the Universe from space. For over 20 years, ASI has supported the management of the data collected by scientific satellites operating its Space Science Data Center (SSDC), hosted at the agency headquarters in Rome. SSDC serves the scientific community, by promoting dissemination and exploitation of high-quality data products related to space.

UNIVERSITY OF PADOVA ITALY

www.dfa.unipd.it

Dipartimento di Fisica e Astronomia Galileo Galilei UNIVERSITÀ DEGLI STUDI DI PADOVA

Founded in 1222, Padova University is among the foremost Italian universities, in terms of research, size and of educational quality. It is composed of 43 Research and Service Centres across the spectrum of sciences, medicine, social sciences and humanities. The Department of Physics and Astronomy provides scientific and technical expertise on many of the principal fields of the modern physics and astronomy. The partner makes available the Copernicus 1.82 m and the Galileo 1.20 m telescopes, both located at the Asiago Observatory (Italy).



LESIA-OBSERVATOIRE DE PARIS
FRANCE

http://lesia.obspm.fr

Paris Observatory is a national research centre in astronomy and astrophysics. It is the largest astronomy centre in France and is structured into 5 laboratories, 1 scientific unit and 1 institute covering all fields of astronomy and astrophysics.
LESIA's scientific activities cover four research themes: Planetology, Astronomy, Plasma Physics and Solar Physics. Planetology includes physical characterization of the small bodies of the Solar System.
ObsPM makes available a 1-m telescope located at the at the Pic du Midi observatory (France).

OBSERVATOIRE DE LA COTE D'AZUR
FRANCE

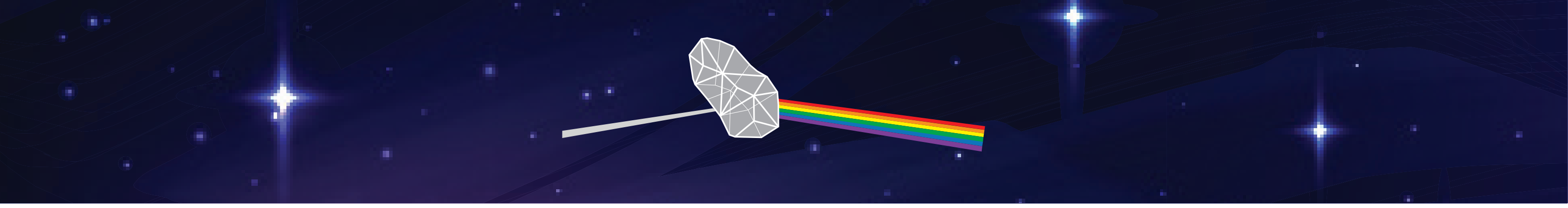
www.oca.eu

OCA is an astronomical observatory and public administrative institution, with 450 staff located in four sites. OCA is one of 25 French astronomical observatories responsible for the continuous and systematic collection of observational data on the Earth and the Universe.
The Theories and Observations in Planetology team work on topics such as collisional processes between small bodies, discovery and characterisation of small bodies, impact hazard mitigation, origin and evolution of planetary systems, formation of the Solar System and exoplanets.

UNIVERSITY OF EDINBURGH
UNITED KINGDOM

www.roe.ac.uk

The University of Edinburgh is a large research-focused university. Founded in 1582, it is one of the oldest universities in the English-speaking world. The Institute for Astronomy, within the School of Physics and Astronomy, is one of the largest astronomy groups in the UK, based at the Royal Observatory Edinburgh. The institute has particular strengths in large astronomical surveys, with a great deal of expertise in image processing software. Through University of Edinburgh, member of the 'MiNDSTEp' consortium, NEOROCKS has access to the 1.54m Danish telescope at La Silla Observatory, Chile.



ASTRONOMICAL INSTITUTE OF THE CZECH ACADEMY OF SCIENCES CZECH REPUBLIC

www.asu.cas.cz

Astronomical Institute of the Czech Academy of Sciences

The Astronomical Institute of the Academy of Sciences of the Czech Republic is the leading institution in astronomical and astrophysical research in the Czech Republic.
Research covers 4 scientific departments (Solar, Stellar, Interplanetary Matter, Galaxies and Planetary Systems). One key activity is the study of asteroids and meteors that represent a certain hazard for humankind. They focus on physical characterisation of the small bodies and understanding their formation and evolutionary processes, with an emphasis on their impacts on the Earth and its atmosphere.
Thanks to ASU, NEOROCKS has access to the 1.54m Danish telescope at La Silla station of the European Southern Observatory, Chile.

INSTITUTO DE ASTROFISICA DE CANARIAS SPAIN

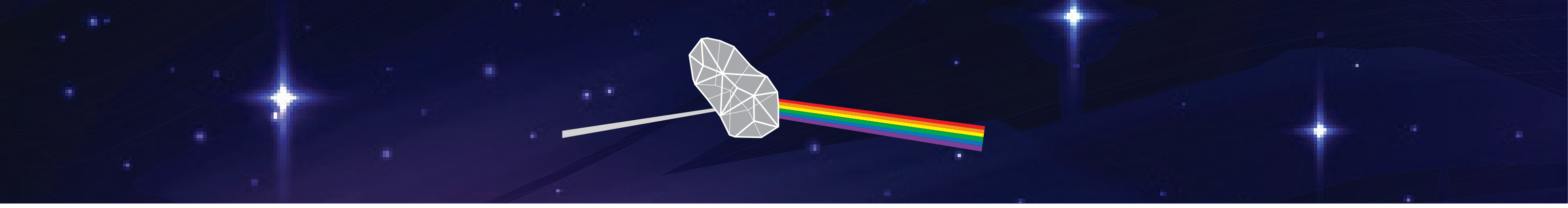
www.iac.es

The Instituto de Astrofísica de Canarias is an internationalised research centre aiming to achieve major advances in the understanding of the laws that govern the origin and evolution of the various forms of matter/energy in the Universe.
Researchers in the Solar System Group study the physical and compositional properties of near-Earth asteroids, in particular those that are accessible to spacecraft and considered as potentially hazardous.
IAC has two Observatories: Observatorio del Roque de los Muchachos (La Palma) and Observatorio del Teide (Tenerife), home to a complete variety of telescopes and instruments, of sizes.

SPACEDYS ITALY

www.spacedys.com

SpaceDyS is a spin-off of the Celestial Mechanics Group of the University of Pisa. SpaceDyS team of experienced researchers in have backgrounds in Mathematics, Physics, Astronomy and advanced skills in Flight Dynamics, Mission Design and Computer Science.
SpaceDyS's expertise focuses on orbit determination of Main Belt Asteroids, of NEOs and of space debris objects, data processing and management of data centers, satellite re-entry and gravimetry experiments in space missions.
The SpaceDyS team manages and maintains the web services NEODyS and AstDyS.



DEIMOS GROUP
SPAIN & ROMANIA

www.deimos-space.com

NEOROCKS involves three branches of the DEIMOS group.
DEIMOS Space S.L.U. has long expertise in space programmes, in fields related to Ground Segment Software, Flight Dynamics, GNSS, Satellite Systems and SSA.
DEIMOS Space S.R.L. has developed software for space situational awareness (SSA), ground segment and flight segment systems.
DEIMOS Castilla La Mancha focuses on integration of satellite systems, operations of satellites and telescope observations and processing in the NEO and SST Fields. DCM operates the DEIMOS Sky Survey Observatory, located in the South of Spain, with four telescopes.

NEOSPACE
POLAND

www.neospace.pl

NEOSpace was established in response to the Polish Space Strategy guidelines that consider SSA as one of the most important fields of involvement of the Polish space sector. The company focuses on NEO (data acquisition, processing and dissemination). The company also takes on activities that require deep knowledge of celestial mechanics and orbit calculations, as well as programming skills.
NEOSpace's shareholders all of them have a PhD in physics or astronomy and 3 in particular have dedicated their scientific careers to asteroid dynamics and physics

RESOLVO
ITALY

www.resolvo.eu

Resolvo specialises in cooperation to promote responsible economic development.
Resolvo is expert in designing and implementing communication strategies for European projects.
They are committed to communication of research results to the wider public.
Resolvo's staff are trained in business plan development and exploitation of research results.
They have extensive knowledge and expertise on the concept of Responsible Research and Innovation, which runs through the NEOROCKS project activities.

NEO ROCKS

Near Earth Object Rapid Observation, Characterization and Key Simulations

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www.neorocks.eu