Summer School: Natural Spatial Risks

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Space Weather

The Sun & Interplanetary medium

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The Sun is our neighbour star which activity may damage industrial infrastructures on Earth. This presentation introduces the basic concepts on the Sun activity, and interplanetary disturbances. Some details are given on the observing and simulation methods that are used to understand these Sun-Earth relationships

*Speaker

Variability of the Earth's Magnetosphere and Ionosphere and consequences for human activities

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The great variability of the Earth's space environment is mainly due to its coupling with the solar wind (a plasma carrying the Sun's magnetic field through the solar system). Magnetic merging is the major interaction process between the solar wind and the region of space occupied by the Earth's magnetic field (the 'magnetosphere'). In this process, the Sun's magnetic field lines connect (or 'reconnect') to those of the Earth, and drag the Earth's field lines antisunward across the polar high atmosphere (the 'ionosphere'), allowing transfer of momentum, mass and energy through the Earth's environment. In the nightside, on both sides of the magnetotail equatorial plane, the stretched opened field lines are anti-parallel and can reconnect mainly during violent episodes called substorms. The plasma stored in the tail is then released in the nightside ionosphere and the new closed field lines created by reconnection are dragged sunward by the magnetic tension. At the ionospheric footprints of these dayside and nightside reconnected field lines, auroral features are formed and fast ionospheric flows are excited, driving ionospheric currents and heating the thermosphere. These processes can considerably affect the state of the ionosphere and of the thermosphere and have important consequences on human activities. This presentation will mainly focus on the main processes affecting the electrodynamics of the magnetosphere-ionosphere system before detailing the consequences on several human activities (variation of ionosphere refractivity and perturbations of waves propagation, ground induced currents, thermosphere expansion causing satellites drag).

*Speaker

Space weather forecasting practical

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This session will provide a hands-on introduction to space weather forecasting. Participants will discuss the general principles behind forecasting - what is needed to make a forecast useful - and get a brief introduction to some of the relevant theory behind space weather forecasting in particular. They will then put this theory into practice, and analyse real-time (and historic) solar imagery and other space weather data, to issue their own space weather forecasts.

*Speaker

Online Tools for Space Physics

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This hand's on session will present online tools and databases dedicated to space physics. These tools are developed mainly by the CDPP (Centre de Données de la Physique des Plasmas) in France. The audience will be able to display data, search for data or events, propagate events or visualize model runs and in situ data.

*Speaker

Geomagnetically Induced Currents: an introduction

Carine Briand *† [1]

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The single most dangerous threat from space weather to human infrastructure are so called "G*eomagnetically Induced Currents*" short GICs. They are caused by fast changes in the magnetic disturbance fields caused by sudden set-up or re-organisation

of large magnetospheric or ionospheric current systems. According to Faraday's Law a fast change in the magnetic field

induces an electric field, which in turn can induce currents in any conductor, which is oriented in the direction of the electric field.
This introductory talk aims to present the basic physics at the origin of these currents and the industrial infrastructures that can be damaged by such currents

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Instrumentation for space weather

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A space weather service is based primarily on observations. The system to observe is however huge: from the whole Sun to little structures on its surface to local disurbances of the ionosphere, together with large and small scale changes of the magnetosphere. Each physical processes leading to perturbation of the space environment has its own signature, from UV to radio emission. The goal of this talk it to provide an overview of the different observing signatures and instrumetal means necessary to provide the necessary information to a Space Weather Center.

*Speaker

International Civil Aviation Organization

Luc Lapene *† [1]

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Navigation, communications, and radiation exposure issues, as affected by space weather, also extend to various degrees to other parts of the globe and to other applications. Satellite-based navigation, though most affected near the poles and the equator, can also be impacted at middle latitudes. A particularly significant space weather storm occurred during the October-November 2003 events when the FAA's WAAS system exceeded its vertical protection limit and was deemed un-useable for 15 hours and 11 hours on October 29 and 30, 2003 respectively. As satellite-based navigation has a key role in the NextGen and SESAR efforts, the need to monitor and predict space weather will grow.
Another impact of solar activity on GPS occurred in December 2006 when a solar radio burst in a solar flare was so strong that it overwhelmed the GPS signal at L-band, causing a several-minute-long interruption to geodetic-grade GPS receivers operating on the dayside of Earth.

High-Frequency (HF) communications, the primary and in some cases, sole, means of communicating over the poles, is well-known to be affected during space weather events. For aircraft at latitudes of roughly 82 degrees and higher, it is impossible to "see" geostationary communications satellites and to use the higher frequencies they afford. There are polar orbiting satellites available for use to mitigate the communication problems, but as yet most airlines are not equipped to take advantage of this option.

Radiation exposure is difficult to characterize. However, in general, the risk – and the dose – is greatest over the poles, and lessens at lower latitudes. It is also true that the higher the altitude, the more radiation is present, so the radiation conditions will be important for sub-orbital commercial space flights.
In order to minimize risks to civil aviation, including in cases of severe space weather events, the International Civil Aviation Organization is currently organizing global/regional space weather services for civil aviation, to be in place by November 2018.

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Space Debris

Trajectory visualization tools for artificial satellites: exercises.

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This session will be dedicated to orbit visualization tools for artificial satellites, that are publickly available through Scilab (Celestlab module provided by CNES), or through the web (IXION software, provided by LMD). Attendees will have the opportunity to learn how to use these tools to get the representation of the orbits, as seen from space, or in the terrestrial rotating frame. Part of the session wil also illustrate the theoretical part of the lectures dealing with the geometrical configuration of the orbits, where the positions of the observer to the ground, and the directions of the Moon and the Sun are also involved. This practical session will be led on computers in a suitable meeting room in Meudon, with one computer for two participants.

*Speaker

Uncontrolled reentries of manmade space objects: how to get reliable products to manage and mitigate the potential risk in the airspace and on the ground

Carmen Pardini * [1]

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In spite of decades of efforts, predicting the reentry time and location of an uncontrolled satellite remains a very problematic activity, being reentry predictions affected by various sources of unavoidable uncertainties. The experience accumulated worldwide suggests that a relative prediction error of ±20% should be adopted to compute the uncertainty windows associated with nominal reentry epoch predictions, in order to reasonably cover all possible error sources. However, in specific cases, more conservative prediction errors, up to ±30%, should be considered, in particular during the last 2-3 days of residual lifetime. Therefore, even predictions issued a few hours before reentry may be affected by a quite huge along-track uncertainty, often corresponding to more than one full orbital path. In consequence of this, the typical reentry prediction standard products, such as the nominal decay forecasts with the associated reentry uncertainty windows and corresponding sub-satellite ground tracks, are of no, or very limited, use for civil protection applications. In other words, the locations possibly at risk in a given area of the planet cannot be identified reasonably ahead of reentry using such kind of knowledge. For this reason, specific approaches and procedures have been devised and applied in Italy, since the orbital decay of the BeppoSAX spacecraft in 2003, to provide reasonable and unambiguous information useful for civil protection planning and applications.
After an introduction dealing with the reentry statistics, the reentry risk evaluation and the reentry prediction uncertainties, the main objectives and outcomes of a reentry prediction process will be pointed out. Then, the typical reentry prediction standard products will be discussed and analyzed, in order to prove their weakness and inadequacy whether applied to manage and mitigate the potential risk in the airspace and on the ground due to falling debris over specific locations of the planet. Finally, the strategy devised in Italy for civil protection applications will be described and applied to recent reentry prediction campaigns of noteworthy satellites: UARS, ROSAT, Phobos-Grunt, GOCE and Progress-M 27 M.

*Speaker

An holistic approach to the space debris mitigation

Alessandro Rossi * [1]

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Notwithstanding the recommendations and the efforts of the space agencies of the last decades, the number of space debris is still growing.
A new paradigm, including space debris mitigation as an initial requirement from the very beginning of the design of a space mission, has to be introduced.
The lecture will first make an introduction to the space debris environment.
Then it will focus on the results of a large number of simulations showing the effectiveness of the currently proposed mitigation measures.
Finally some results of the most recent studies undertaken in the framework of the Horizon 2020 project ReDSHIFT, to reduce the space debris
population by passive means (as opposed to active debris removal), will be shown.

*Speaker

Legal Aspects linked to Space Debris: The French Space Operation Act and Its Technical Regulation

Christian Cazaux *† [1]

[1] CNES – Centre National d'Etudes Spatiales - CNES (Toulouse, France) – Toulouse, France

Since the launch of Sputnik-I in 1957, the amount of space debris in Earth's orbit has increased continuously. Historically, besides abandoned intact objects (spacecraft and orbital stages), the primary sources of space debris in Earth's orbit were (i) accidental and intentional break-ups which produced long-lasting debris and (ii) debris released intentionally during the operation of launch vehicle orbital stages and spacecraft. In the future, fragments generated by collisions are expected to become a significant source as well.
The fear that the future environment growth might be dominated by collisions, rather than by launches and explosions, was expressed already decades ago. In order to avoid such situation, several responses outlining mitigation procedures, including the Inter- Agency Space Debris Coordination Committee (IADC) space Debris Mitigation Guidelines, the United Nations Committee on the Peaceful Uses of Outer Space Mitigation Guidelines, the International Organization for Standardization Space Debris Mitigation Standards and a multitude of other national and international documents have been, and continue to be, developed to limit the expected growth of the debris population.

In France, The French Space Operations Act, which came into force in 2010, ensures that the technical risks associated with space activities are properly mitigated. The Act confers CNES a central support role in providing technical expertise to government on regulations governing space operations. In this respect, CNES is in charge of proposing and developing the technical methods to be recommended to cope with the law requirements. CNES also checks compliance prior to delivery of authorizations submitted to the minister in charge of space for approval.
On this presentation, an overview of the technical regulation on which the French Space Operation Act reposes will be given. Additionally, the verification process thanks to which a French operator is granted to launch will be also presented.

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Near Earth Objects

Near Earth Objects dynamical model and ephemerides

Josselin Desmars * [1]

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Near Earth Asteroids are a population of asteroids that regularly approach the orbit of the Earth so that some of them may represent a risk of impact with Earth. In that context, the knowledge of their orbit and the estimation of their orbital uncertainty are key points for risk assessment and impact probability. The orbit determination consists in the determination of six orbital elements that fit to the observations. Due to errors on the observations, the orbital elements have an uncertainty leading to errors on their ephemeris in particular in the future. Moreover, as NEAs have regular close approaches with the Earth or planets, their orbits are perturbated and even small perturbations have to be taken into account.

In this presentation, I will detail the dynamical model used for NEA, the orbit determination process and the methods to estimate the precision of their orbit. I will also present the current limitations in the estimation of uncertainty and the expected improvements brought by several scientific missions such as Gaia in the NEA risk assessment.

*Speaker

Introduction to Near-Earth Objects

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Contrarily to the major part of the asteroids which are orbiting between Mars and Jupiter, Near Earth Asteroids have orbits which drive them close to the Earth orbit and eventually across it. Due to the potential risk of impact involved, they are intensively observed and studied, but only since the 80's. The improvement of the observing techniques and the increase of the number of ground based or space dedicated telescopes, gives us now a more realistic image of this population. In this introductory talk, we will give a general description of the context of Near-Earth Objects study, we will describe some dynamical and physical aspects, we will discuss the need of their monitoring and will shortly describe the risks that they represent.

*Speaker

Near Earth Asteroids: spectroscopic observations

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The Minor Planet Center databse contains noadays more than 15,400 Near Earth Asteroids (NEA). A fraction of NEAs are the most accessible objects by the space missions in terms of propulsion requirements. Another fraction of NEAs are investigated in terms of risk and natural hazards, with an important interest in developing threatening space technologies and orbital mitigation of these bodies. On average five favorable geometries per century for groundbased observation occurs for NEAs. Thus, the scheduling of observations for these observational windows is crucial for the physical and mineralogical characterization of NEAs. The presentation objective is to give an overvieww of spectral observations of NEAs as well as their mineralogical interpretations.

*Speaker

Post Deflection Impact Risk Assessment and Avoidance

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Even after decades of large-scale near-Earth asteroid discovery and observation programs the census of objects that can collide with our planet is not complete. As the well documented case of the Chelyabinsk boldie has shown in 2013, even relatively small objects have the potential to cause infrastructure damage and harm the local population. Impacts of hundred-meter-sized asteroids on our planet are one of the few natural desasters that can - in theory - be averted, however. Deflecting the trajectories of near-Earth asteroids is deemed technically feasible. Several methodologies have been envisaged to achieve such goals. Kinetic impactors are among the most mature concepts in this respect. Hyper-velocity collisions between kinetic impactors and asteroids are expected to produce a significant amount of ejected material that can rival that of the impactor itself, thus improving the deflection performance. Uncertainties in magnitude and direction of the momentum carried by the ejected material are substantial, however, and weaken predictions on the asteroid's post-impact orbit. This makes it difficult to guarantee that the deflection does not cause the target asteroid to enter a secondary gravitational keyhole. Such a scenario would lead to a high probability of the same object to collide with the Earth at a later date. This contribution deals with the question how to best target an asteroid during an impulsive deflection maneuver so as to avoid creating concerns for planetary safety in the future. The proposed methodology promises a more efficient and safe application of deflection actions via kinetic impacts.

*Speaker

Mitigation projects

Daniel Hestroffer * [1]

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Some of the asteroids orbiting around the Sun in the vicinity of the Earth show probabilities of having an impact trajectory. Given the risk assessment, and the characterisation of the impact, measures to reduce our vulnerability are taken. In some cases a space mission to deviate the threatening asteroid from its dangerous orbit is the best option. One should ensure that any deviation does not put the asteroid on another impact trajectory.

*Speaker

Meteoroid streams

Auriane Egal * [1]

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Meteoroid streams are formed by the outgassing of comets approaching the sun or by asteroidal collisions. The dynamical evolution of the rocks compouning the streams is similar to the evolution of their parent body. When such a stream crosses the Earth's orbit, it can represent a real threat for space missions and for the scientific and industrial satellites. Destruction of satellites, and impacts on the wings of space shuttles and on the International Space Station highlight the need to predict future collisions between the meteoroids streams and the Earth. Many efforts are currently employed to dynamically characterized the evolution of meteoroids streams in order to securize the launch and the course of space missions.

*Speaker

Territorial vulnerability and resilience - part 2

Laurie Boschetti * [1]

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In the first part " Territorial Vulnerability and Resilience ", we talked about what is a risk, and how could be define the main concepts, which are vulnerability and resilience. In order to complete what we saw and to go further, in that second part we are going to treat the existing methodologies that permitted to realize vulnerability analyses, and risk analyses. Methodologies that are well known and that have been reproduced many times. We are also going to look at the different tools that we can use to realize those studies. Finally, we will take our interest on resilience, which is a difficult concept to implement because the scientific community does not agree about its definition and how to analyze it on a practical way. We will see what is done in different field of research and how it is possible to deal with it.

*Speaker

ESA-SSA & risk assessment

Ettore Perozzi * [1]

[1] Agenzia Spaziale Italiana, Italy

At the 2008 European Space Agency's Ministerial Council Meeting, a new optional programme was started, called 'Space Situational Awareness" (SSA). The aim of the SSA programme is to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space surrounding our planet. As such it foreseen three major elements: SST - Space Surveillance (monitoring space-debris and satellites); SWE – Space Weather (knowing the radiation and plasma environment); NEO – Near Earth Objects (addressing the asteroid hazard). The current status of the SSA Programme, just entered in the realization Phase 3, is presented, with special focus on the SSA-NEO Coordination Centre operations.

*Speaker

Space weathering effects on space dust dynamics

Christoph Lhotka *† [1], Philippe Bourdin [1]

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Dust in space is subject to various non-gravitational forces due to the solar wind, the Poynting-Robertson effect, and interactions with magnetic fields and space plasmas. The orbital motion of space dust strongly depends on the the order of magnitude of these effects, i.e. the ratio of gravitational and non-gravitational forces. This session is devoted to the role of space weathering effects on perturbed Keplerian motions with applications to dust and space debris dynamics in the vicinity of the Earth and the Heliosphere. We will derive and investigate the equations of motions for space dust in the Newtonian, Gaussian, and near Hamiltonian framework by means of numerical simulations, and analytical estimates.

*Speaker

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Risks and society

Territorial vulnerability and resilience - part 1

Laurie Boschetti * [1]

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Human history had been punctuated by catastrophes, and human being had to face many disasters like Santorin's eruption (-1500 BC), Constantinople's earthquake (557), Seine's flooding, Sumatra's tsunami (2004), hurricane Katrina (2005) or the Japan's "triple disaster" (2011). These disasters had different origins and could appear as a single event or more often as a combination of events. They could affect local population or impact at the international scale, and they could generate major economic consequences. However, natural disaster fascinates, by the event suddenness, its strength and what it implies on a scientific purpose. Nowadays, human pressure is so important, that many people are currently living on a territory that is exposed to different type of disasters, most of time not only one but many of them, without knowing that they are exposed. It is therefore essential to obtain an overview of the risk. That is why it is important to study these events from a physical point of view, in order to understand the mechanisms that created those natural hazards, and ideally to be able to predicting them; and from a human point of view, by studying the territory and the exposed issues. It is that second point that is interesting us here. To do so, we are going to deal with some notions, mainly with the vulnerability and the resilience, which are key concepts on natural hazard studies.

*Speaker

Communication on risks

Ettore Perozzi * [1]

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The Chelyabinsk superbolide event of Feb 15, 2013 and the re-entry of the alleged Apollo-10 Command Module in November 2015 have clearly demonstrated that communication skills must be part of the background of those involved in the frontline of monitoring the space hazards. Whether addressing the scientific and/or technological community, the journalists and the press or the public at large, communication plays a crucial role in order to guarantee the correctness of information and to avoid the spreading of unjustified alarms. Motivating the tax payers and making them always aware of the latest achievements is also essential in sustaining the governmental programs devoted to monitoring the space hazards. An overview of the historical backround, a discussion of study cases and a roadmap for the future is presented.

*Speaker

Risk and Insurance Economics for Small-Probability-High-Impact Events

Bertrand Villeneuve * [1,2]

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The lecture explains the principles of risk management and insurance. The theory exposes a stylized yet rich view of ideal arrangements. The development explains the practical limits and solutions.
Main themes :

1/ Risk aversion, willingness to pay to avoid risk, expected utility and alternative models.

2/ Risk sharing, Pareto-optimal risk sharing, Borch principles, Wilson theory of syndicates.

3/ Actual institutions : insurance markets, reinsurance, derivatives, cat bonds, special purpose vehicles, superfunds, etc.

The special case of spatial risks (small probabilities, limits of insurability, uncertainty, unknowns, liabilities forsatellite debris) is discussed all along the lecture.

Bertrand Villeneuve

Professor of economics at Université Paris-Dauphine
https://sites.google.com/site/bertrandvilleneuvedauphine/home?pli=1

*Speaker

List of sponsors

LESIA: The Laboratory of Space Studies and Instrumentation in Astrophysics is a department of the Observatoire de Paris. It is also a research unit of the CNRS (UMR-8109), the Pierre et Marie Curie University and the Paris-Diderot university.
From the design of instruments for astrophysics to the exploitation of results, the scientific topics developed at LESIA cover many fields of astrophysics. The activities are organised around the projects (ground-based, space or modelling) of which numerous instrumental achievements make the reputation of the laboratory.

Inititative de Recherche "Evaluation des Modèles Mathématiques": This project aims to respond to a deficiency, which is itself the result of a lack of exchange between the world of banking and that of the university, whose consequences have been heavily felt in this financial crisis. The use of mathematical models to evaluate market assets first, then to make theoretical market assets in a second stage, has spread, at the initiative of the trading and sales teams of the banks, without Quality control, comparable to that practiced by industries traditionally consuming mathematical models (such as aeronautics, public works or classical insurance), is put in place. This project is supported by the Credit Agricole & the Collège de France.

Observatoire de Paris: Founded in 1667, the Observatoire de Paris is the largest national research center for astronomy. 30 % of all French astronomers are working in it five laboratories and its institute. Situated on the Paris, Meudon and Nançay campuses, they are all "Unités Mixtes de Recherche (UMR)" associated with the CNRS and, in many cases, with the major scientific universities in the Paris area. The work of the Observatoire is also carried out in two

major scientific services. The Observatoire de Paris is an academic centre (Grand établissement) under the aegis of the Ministère de l'Enseignement supérieur et de la Recherche.

IMCCE : The Institut de Mécanique Céleste et de Calcul des Ephémérides provides and publishes ephemerides of solar system bodies. It serves as the official and public source of ephemerides devoted to regulate calendars.
It performs theoretical research activities in the fields of celestial mechanics, planetology and mathematics. It initiates and coordinates observing campaigns of rare and specific celestial events.

CNES: The French national Space Agency.

Institut Louis Bachelier: Founded in 2008, the Louis Bachelier Institute is a networking organisation that works for the financing, dissemination and enhancement of research excellence in economics and finance.

ESEP: The mission of LABEX ESEP is to network 9 laboratories that want to pool their skills, their long experience in the field of global environments and their know-how in the space sector. The research within ESEP revolves around three themes: space meteorology, planetology and the study of exoplanets. Focusing on the preparation of space instrumentation for future missions, LABEX ESEP should facilitate the development of tomorrow's instruments on future space missions.

PNST: The National Sun-Earth Program (PNST) of the Astronomy-Astrophysics division of INSU CNRS is centered on study of the solar atmosphere, of Sun-Earth relations as well as of the ionized environment of the Earth. This program also includes studies of planetary magnetospheres that enhance our understanding of the physical processes at work.
The scientific themes of PNST encompass a large number of questions concerning the plasma environment of the Sun-Earth-heliosphere system. On the one hand, the aim is to understand physical processes, viz., (i) Generation and transport of the Sun magnetic field, (ii) Coupling between different regions of plasma, (iii) Impulsive and explosive processes that convert and transport energy on different scales, characterisation of plasma turbulence and particle acceleration up to high energies.
On the other hand, the aim is to develop a global understanding of this Sun-Earth-heliosphere system, viz.,(i) Impact of the solar wind and solar activity on the plasma environment (magnetosphere, ionosphere) of the Earth as well as that of other planets, (ii) Coupling between plasma environment and neutral atmosphere, (iii) Interaction between the heliosphere and the interstellar medium.

SUMMER SCHOOL on
NATURAL SPACE RISKS

August 28, 2017 to September 1st, 2017
PARIS OBSERVATORY - FRANCE

Fall of space debris, asteroid impacts on Earth, damages on industrial infrastructures due to solar activity: these are hazardous threats on Earth.
This summer school, dedicated to master students, aims at learning more about these space risks, how to predict the events & to estimate and manage the risks.

For more information: https://nsr-2017.sciencesconf.org

Maquette : Sylvain Cnudde @ SIGAL

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