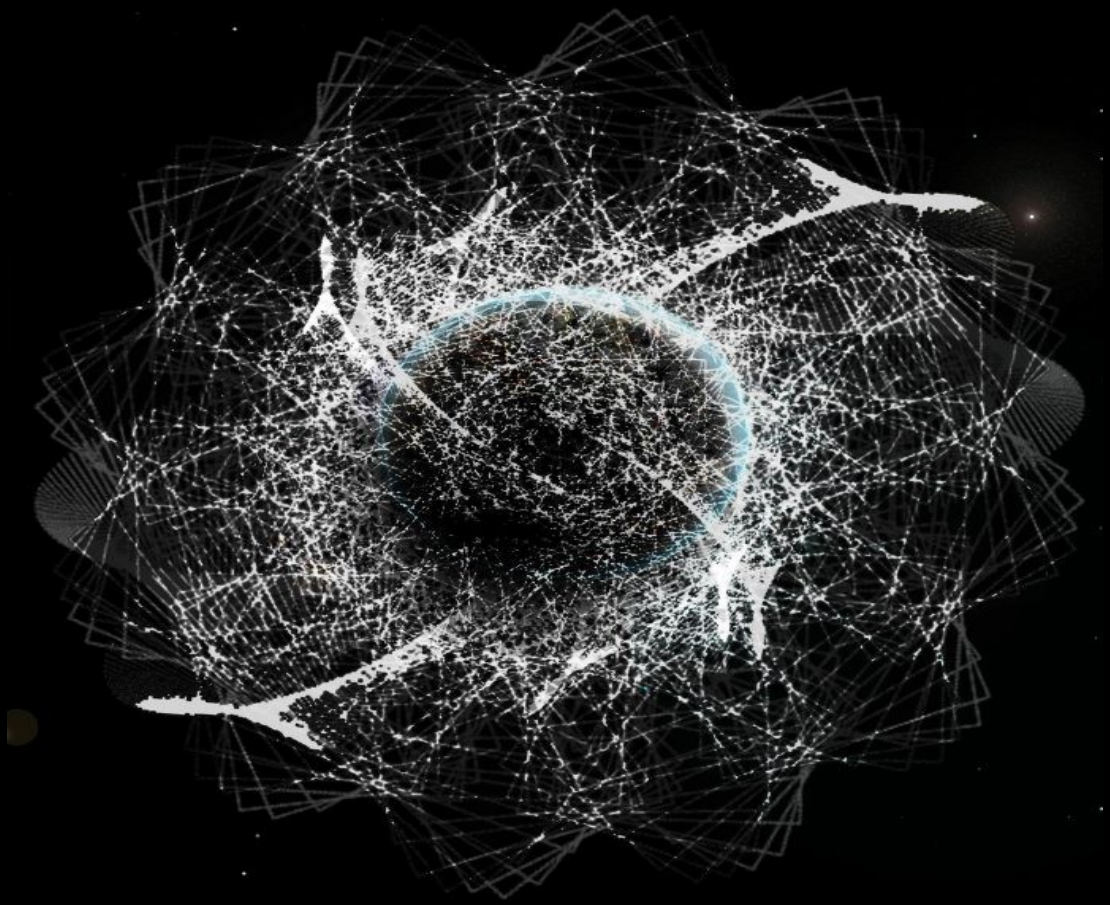
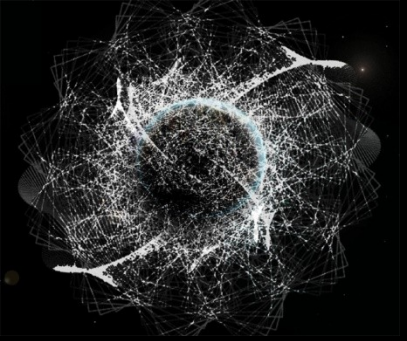
STARDUST RELOADED

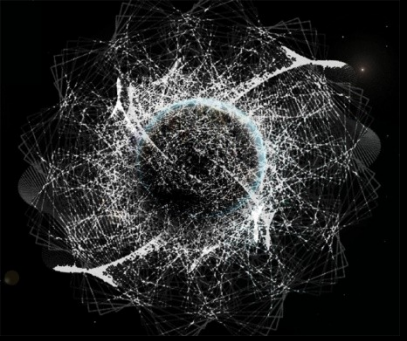


Dusan Marceta & Bojan Novakovic
University of Belgrade
Faculty of Mathematics
Department of Astronomy



What is STARDUST-R?

- **European research project to explore and exploit asteroids and make the use of space sustainable**
- **Led by Professor Massimiliano Vasile of the University of Strathclyde**
- **Awarded 4 million Euros through the European Commission's Horizon 2020 programme.**



BENEFICIARIES

University of Strathclyde Engineering

Università di Roma Tor Vergata

TU Delft

DEK

UAM Universidad Autónoma de Madrid

DLR

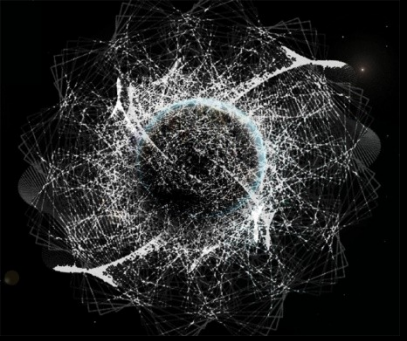
HYPERION TECHNOLOGIES

POLITECNICO MILANO 1863

deimos elecnor group

IN SUPREMÆ DIGNITATIS 1343

ΑΚΑΔΗΜΙΑ ΑΘΗΝΩΝ



PARTNERS

AIRBUS DEFENCE & SPACE

esa

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

KYOTO UNIVERSITY
KYOTO JAPAN
FOUNDED 1897

THE UNIVERSITY OF ARIZONA

TEXAS
The University of Texas at Austin

uc3m | Universidad Carlos III de Madrid

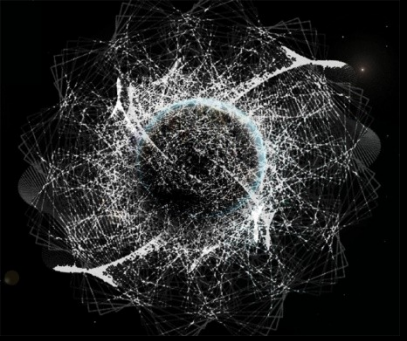
Universität Bremen

LAAS CNRS

Stanford University

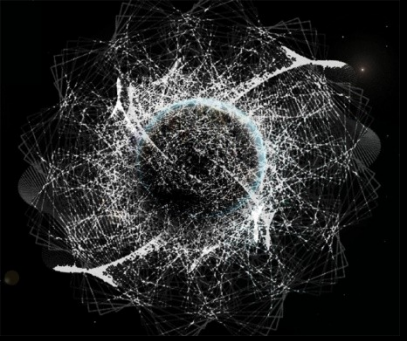
EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

ARISTOTLE UNIVERSITY OF THESSALONIKI



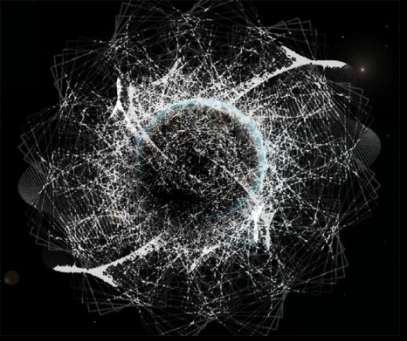
Contribution of the participants

- Engineering
- Mathematics
- Physics
- Computer science
- Training



OBJECTIVES

- RESEARCH
- TRAINING
- OUTREACH



RESEARCH

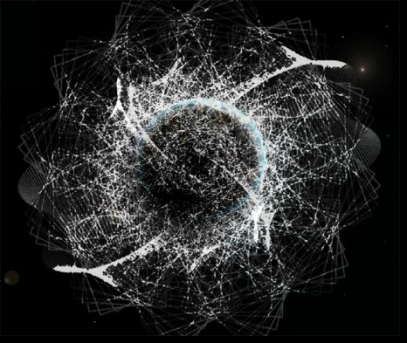
Four major innovative aspects:

1. Combining computational intelligence, dynamical systems theory and orbital mechanics to quantify the uncertainty of rare, high risk events

2. Space Traffic Management to improve the resilience of the space environment

3. Concept of the criticality of asteroids in view of future exploration, exploitation and deflection

4. Asteroids and comets exploration with small spacecraft



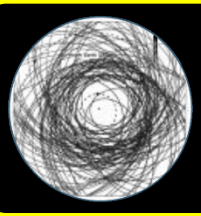
8 WORK PACKAGES (WPs)

WP2 - COMPUTATIONAL INTELLIGENCE AND THE QUANTIFICATION OF UNCERTAINTY

WP3 - THE ART OF DEMISE

WP4 - THE DYNAMICS OF CHAOS AND THE DISPOSAL OF SPACE DEBRIS

WP5 - THE LINKAGE PROBLEM



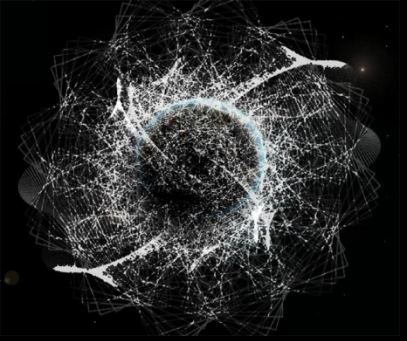
WP6 - THE CRITICALITY OF SMALL ASTEROIDS

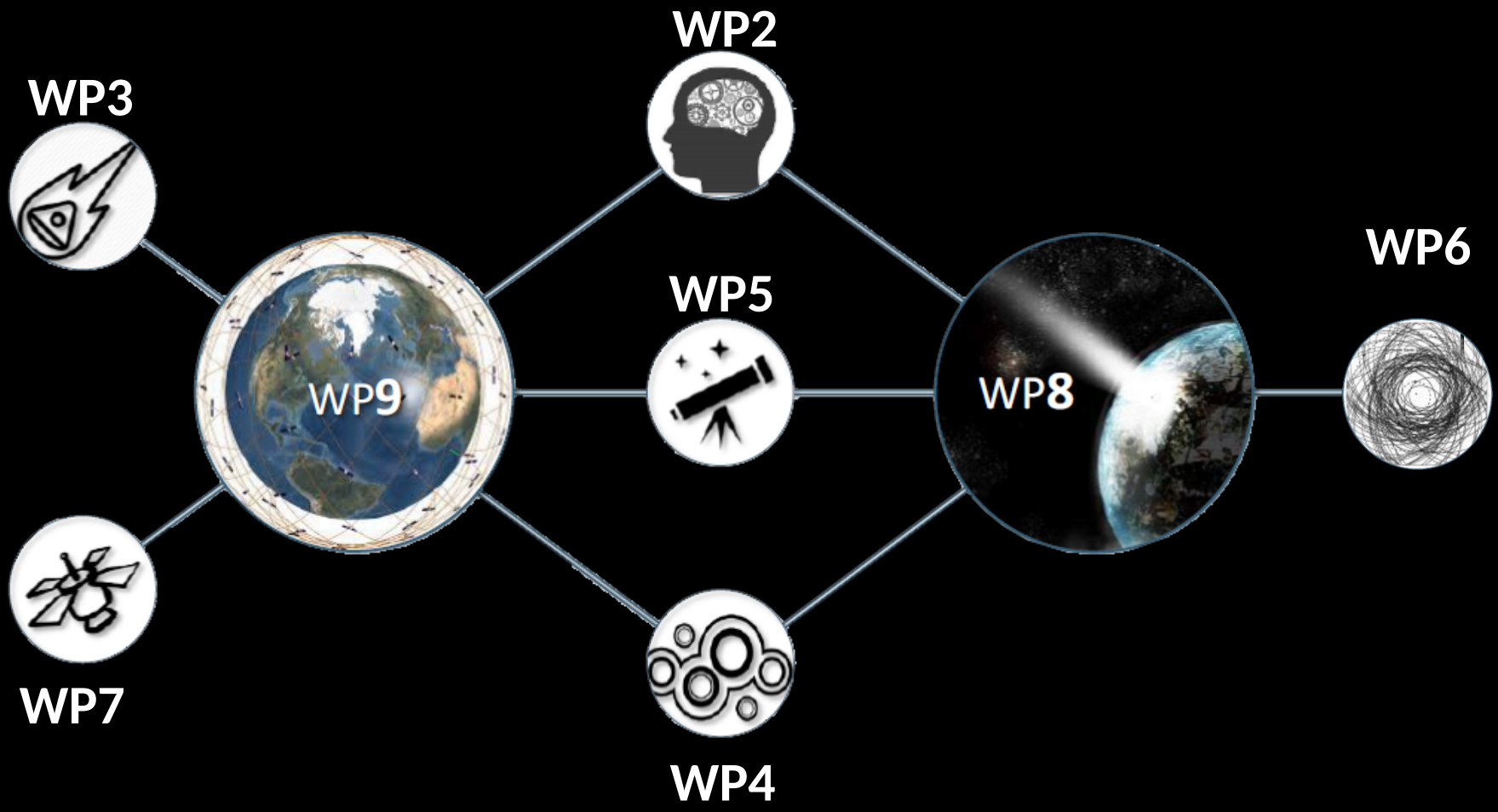
WP7 - THE MANIPULATION OF NON-COOPERATIVE TARGETS AND ON ORBIT SERVICING

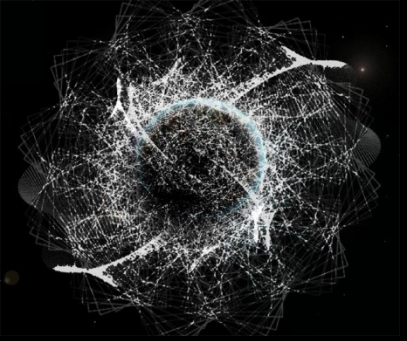
WP8 - EXPLORATION AND EXPLOITATION OF MINOR BODIES

WP9 - SPACE TRAFFIC MANAGEMENT AND THE RESILIENT SPACE ENVIRONMENT

Overall logic of the research programme







WP2 - COMPUTATIONAL INTELLIGENCE AND THE QUANTIFICATION OF UNCERTAINTY

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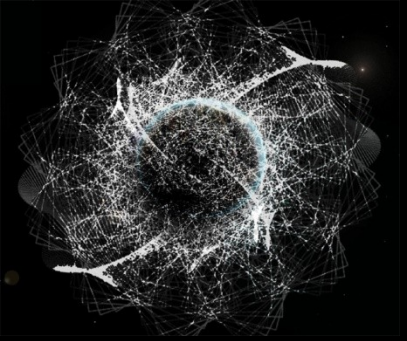
- **combining mathematical modelling with artificial and computational intelligence**
- **Quantifying uncertainty in orbital mechanics**
- **Predicting and correlating rare events, anomalies and singularities**
- **Supporting decision making and operation planning**

MAJOR INNOVATIONS

Development of key enabling computational tools in support to other WPs, and computational intelligence techniques to quantify the probability of rare, high risk events and correlate spatially and temporally distant events.

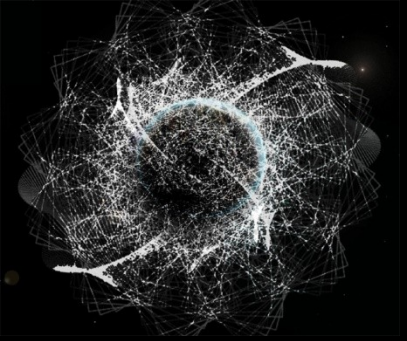


WP 3 - THE ART OF DEMISE

- More than 100 kg of orbital debris has been re-entering every day
- Fragments may survive and reach the ground where they pose a risk to people
- Improvement of models used to predict the aero-thermal performance and thermomechanical response of objects

MAJOR INNOVATIONS

Development and implementation of uncertainty based multi-fidelity approaches for the effective and efficient prediction of re-entry demisability and in-orbit survivability performance, compared to current approaches, which are either not really effective nor efficient.



WP4 - THE DYNAMICS OF CHAOS AND THE DISPOSAL OF SPACE DEBRIS

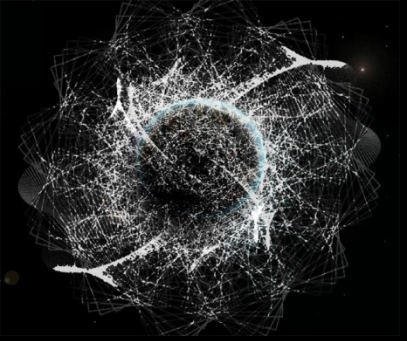
- **Plethora of dynamical phenomena: the overlapping of resonances and the onset of chaos, web-like structure of luni-solar resonances, chaotic variation of the orbital elements, bifurcations of equilibria, libration regions which lead to excursions in the eccentricity, chaotic transport in the phase space…**

- **No internationally agreed mitigation guidelines for MEO**

- **A complete investigation for every Earth orbital region is still incomplete**

MAJOR INNOVATIONS

Analysis of the dynamics of space debris, exploiting the regular and chaotic character to devise disposal orbits and classification of debris according to suitably defined orbital elements.

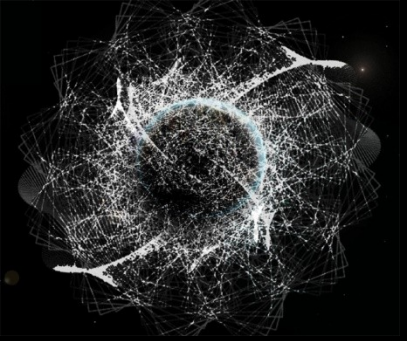


WP5 - THE LINKAGE PROBLEM

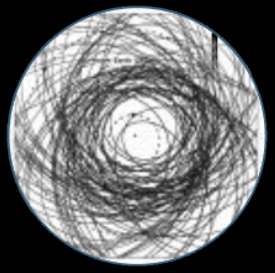
- **The current surveys, like Pan-STARRS, produce an always increasing number of asteroid observations (and not only asteroids)**
- **If more efficient algorithms for OD are not developed, the new observation technologies will surpass the capability of processing the collected data**
- **New algorithms have been recently introduced but they must be verified on large data sets**

MAJOR INNOVATIONS

Application of new OD methods to large data sets and creation of a complete OD pipeline which is able to deal with very large database of observations.



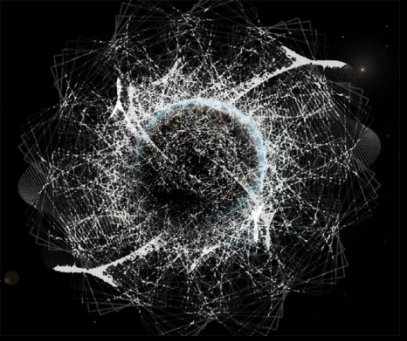
WP6 - THE CRITICALITY OF SMALL ASTEROIDS



- Observational knowledge of the asteroid populations is incomplete. Models are the main source of information for small object.
- Transport mechanisms between MB and NEA
- Main belt escape rate does not match very well the observed flux of NEAs
- Orbital distributions may vary significantly over different size ranges

MAJOR INNOVATIONS

Modelling of the population distribution of small size asteroids and their transport process from main belt to NEO including available constraints. The new model will be validated using historical data on the impact rate on Earth, Moon and Mars.



WP7 - THE MANIPULATION OF NON-COOPERATIVE TARGETS AND ON ORBIT SERVICING

- **Robotic manipulators for capturing and repairing satellites or removal of space debris**
- **Proximity navigation to a noncooperative orbiting object is one of the key technologies required to realize on-orbit-servicing and active debris removal**
- **Multi-sensors' close-range relative navigation systems demand for the development of dedicated algorithms, with special focus on Low Earth Orbits**

MAJOR INNOVATIONS

Development of autonomous navigation and control solutions for proximity operations and the manipulation of debris and satellites in view of future on orbit servicing and their experimental validation in a laboratory environment.

WP8 - THE EXPLORATION AND EXPLOITATION OF COMETS AND ASTEROIDS

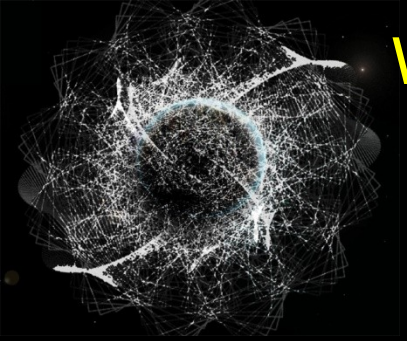
deimos
elecnor group

- Interplanetary cubesats
- Development of guidance, navigation and control (GNC), power and propulsion systems for deep space missions with small spacecraft
- Landing on a rotating object in microgravity

MAJOR INNOVATIONS

Novel methodologies to approach, orbiting, and landing on minor bodies by using new space platform characterized by limited resources in terms of mass and power.

Criticality index for each asteroid to assess the possibility to explore, exploit or deflect.



WP9 - SPACE TRAFFIC MANAGEMENT AND THE RESILIENT SPACE ENVIRONMENT

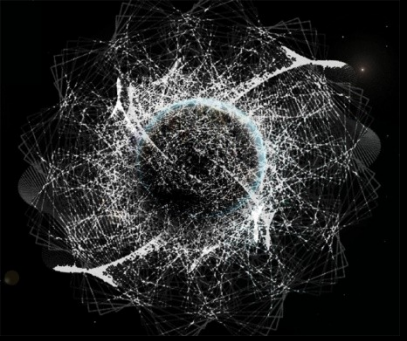
- **A viable Space Traffic Management program faces a great barrier caused by the increasing number and variety of orbiting objects from a few microns to several meters and the planned future large constellations**

- **Most debris objects cannot be tracked and motion cannot be accurately measured or simulated**

- **Long term orbit prediction, debris removal, re-entry risk assessment**

MAJOR INNOVATIONS

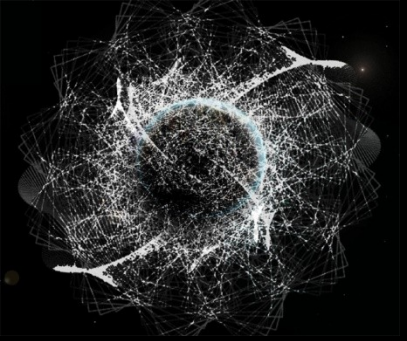
Development of the concept of Space Traffic Management and the related technologies required to detect and avoid collisions, increase of resilience of the space environment and implement preventive actions including active and passive disposal with particular focus on future large constellations.



Early Stage Researchers (ESR)

- **540 person-months of ESR split between 15 people**
- **11 based in academic entities and 4 in non-academic entities**

Researcher	Recruiting Participant	Start Month	Duration (months)
ESR1, 2	SU	10	36
ESR3, 4	UTV	10	36
ESR5	AA	10	36
ESR6	UAIC	10	36
ESR7, 8	UniPi	10	36
ESR9	UoB	10	36
ESR10	DFKI	10	36
ESR11	DLR	10	36
ESR12	UAM	10	36
ESR13	PoliMi	10	36
ESR14	DMS	10	36
ESR15	HT	10	24
ESR15	TUD	35	12



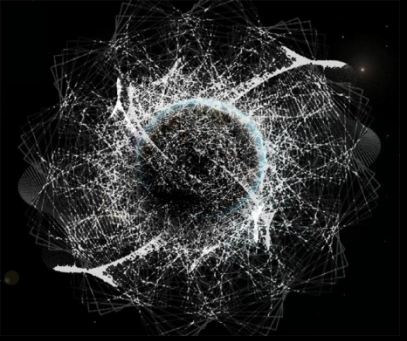
ESR 9

Project title:

Modelling and simulation of small asteroid populations

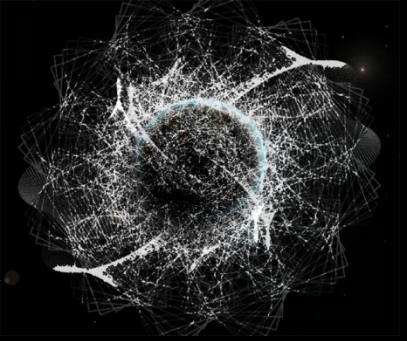
Objectives:

- **Size-frequency distribution of asteroid families in the main belt, and its evolution with time**
- **Systematic search for asteroid families younger than a few Myr**
- **Distribution of objects <100m across the asteroid belt**
- **Modelling the transport of objects <100m from MB to NEA region accounting for the gravitational perturbations of large asteroids**
- **Comparison of the size-frequency distribution of objects <100m transported to the NEO region with observational constrains**



Structure of the training programe

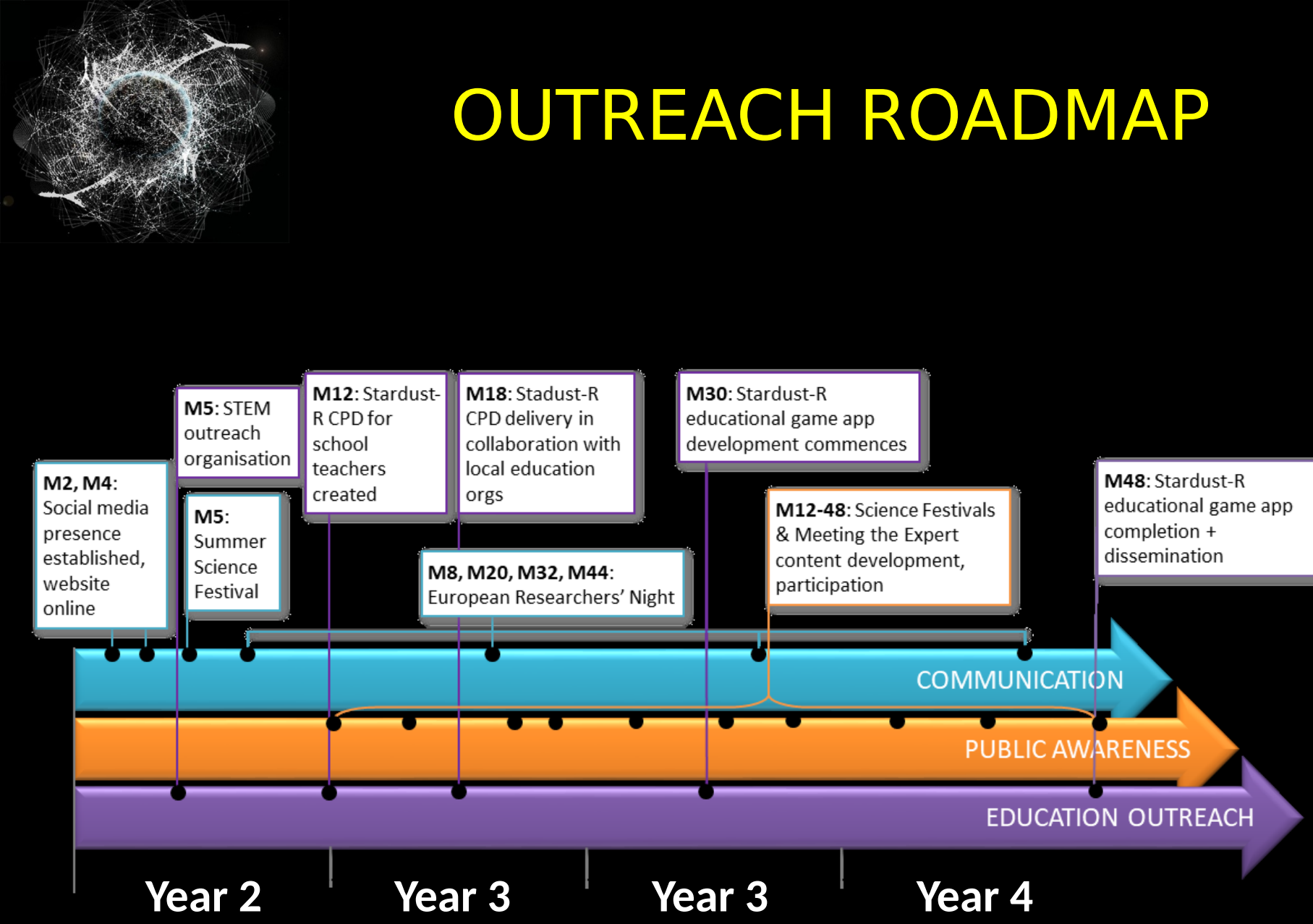
- Training through research
- Project working groups
- Tutorials and webinars
- Secondments
- Training schools
- Workshops
- Design Challenge

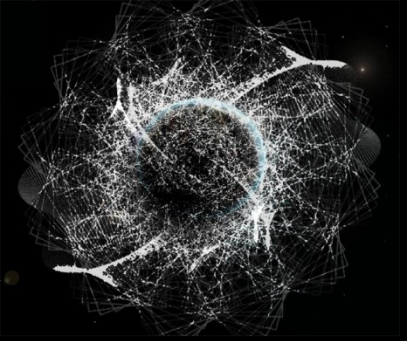


STARDUST CHALLENGE

- Open to any post graduate and under graduate student around the world
- Each ESR will have to lead a team of students not belonging to Stardust-R
- Development of mission concept either to remove space debris or to deflect asteroids
- The two best solutions for each category will be invited to attend the Global Virtual Workshop where they will compete for the final prize of best mission concept
- The panel will be composed of representatives of the companies and space agencies within Stardust-R who will also provide support for the final prize

OUTREACH ROADMAP





Thank you for your attention