MARCOPOLO-R: ESA SAMPLE RETURN MISSION TO THE POTENTIALLY HAZARDOUS ASTEROID 2008 EV5

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(Paris Observatory – LESIA, F)

MP-R ESA SST:
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IAA-Flagstaff, 4. 16. 2013
MarcoPolo-R will rendezvous with the primitive NEA 2008 EV5:
- scientifically characterize it at multiple scales, and
- return a sample to Earth unaffected by the atmospheric entry process or terrestrial contamination.

http://www.oca.eu/MarcoPolo-R/

European Community Supporters:
682 scientists (March 1st, 2013) (25 countries)
+ USA, Japan, Brazil etc

International collaborations (junior partners) are possible

MarcoPolo-R is on Facebook:
http://www.facebook.com/pages/MarcoPolo-R-Space-Mission/40232049502
1) What are the conditions for life and planetary formation?

2) How does the Solar System work?

Mitigation
The attractive NEA 2008 EV5
Potential hazardous asteroid
The attractive NEA 2008 EV5
Potential hazardous asteroid

- Size and shape from radar: 400 +/- 50 meters oblate spheroid (Busch et al. 2011)
- Rot Period = 3.725 ± 0.001h (retrograde)
- Pole -- Ecliptic: 180°, -84° ± 10°
- Spectral type: belongs to the C complex
- Albedo: 0.10-0.12

From Reddy et al (2012) albedo, negative slope, and circular polarization ratio, EV5 could be similar to CI Orgueil (band at 0.48μm due to aqueous alteration)
- probably accreted in a volatile-rich region.

New data revealed very high interest for science & mitigation
Advantage: allows a very short & cheap mission (sample return in 4.5 years)
Arecibo delay-Doppler images of 2008 EV5 from 2008 December 23-27

Concavity of 150 meters

Few or no large blocks evident in the 7.5 m-resolution Arecibo images

Busch et al. 2011
Principal axis views of 2008 EV5 shape model

Busch et al. 2011
Thermal Inertia $\Gamma$ of about 450 +/- 100 J s$^{-1/2}$ K$^{-1}$m$^{-2}$

Using the method by Gundlach and Blum (2013) Delbo et al (2013) derived an average grain size of the regolith of the order of 0.5 - 1 cm

(Delbo et al. 2013)
Why MarcoPolo-R mission?
Tracing the origins ...
CAIs
Chondrules
Eucrites
Differentiation
Planetesimal accretion
Angrites
Mesosiderites
HED differentiation
Pallasites

△T (Myr)

100 30 20 10 0

CAIs
Chondrule
HED differentiation
Angrites
Pallasites

Planetary Formation

Planetary accretion

Earth
Mars

Absolute Time Before Present (Myr)

4558 4568
Current exobiological scenarios for the origin of life invoke the exogenous delivery of organic matter to the early Earth. The planets of the inner solar system experienced an intense influx of organic-rich material for several hundred million years after they formed. The earliest evidence for life on Earth coincides with the decline of this bombardment. Many biologically important molecules are present in the organic materials.
Laboratory investigation of returned samples

High spatial resolution and analytical precision are needed:

- High precision analyses - including trace element abundances to ppb levels and isotopic ratios approaching ppm levels of precision
- High spatial resolution - a few microns or less
- Requires large, complex instruments – e.g. high mass resolution instruments (large magnets, high voltage), bright sources (e.g. Synchrotron) and usually requires multi-approach studies
MarcoPolo-R addresses a wide range of objectives:

**Stars**
- Stellar nucleosynthesis
- Nature of stellar condensate grains

**The Interstellar Medium**
- IS grains, mantles & organics

**The proto-solar nebula**
- Accretion disk environment, processes and timescales

**Planetary formation**
- Inner Solar System Disk & planetesimal properties at the time of planet formation

**Asteroids**
- Accretion history, alteration processes, impact events, regolith

**Life**
- Nature of organics in NEOs

**The Earth**
- Impact hazard
- Evolution of life on Earth
Small bodies: a wide variety of physical & compositional properties

We do not have yet a detailed image of a primitive Near-Earth Asteroid. We need several missions to obtain a comprehensive knowledge of primitive materials.
Look different, but common origin
## NEOShield EU project:  
D2.2: Requirements for mitigation precursor reconnaissance

<table>
<thead>
<tr>
<th>Mitigation technique</th>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High priority</td>
</tr>
<tr>
<td><strong>Kinetic impactor</strong></td>
<td>Mass, porosity, mechanical prop., size, shape, rotation prop., multiplicity</td>
</tr>
<tr>
<td><strong>Gravity tractor</strong></td>
<td>Mass</td>
</tr>
<tr>
<td><strong>Blast deflection</strong></td>
<td>Mass, elem. and chem. composition, thermodyn. and mechanical prop., porosity, multiplicity, shape</td>
</tr>
</tbody>
</table>
Schedule for ESA M3 class mission

Advisory structure

Selection of 5 missions

- **2011**: ESA-internal studies in Concurrent Design Facility
- **2012**: Industrial studies (2 competing for each mission)
- **2013**: Phase A
- **2014**: Final selection (February 2014)
  - Phase B1 kick-off March 2014 for selected mission
  - Implementation phase in industry,
  - Launch 2022 - 2024
<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Mass</th>
<th>PI (Lead &amp; partners)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaNAC</td>
<td>Narrow Angle Camera</td>
<td>10.6 kg</td>
<td>G. Cremonese (Osservatorio Astronomico Padova, Italy)</td>
</tr>
<tr>
<td>CUC</td>
<td>Close-up Camera</td>
<td>0.8 kg</td>
<td>J.-Luc Josset (Space Exploration Institute, Switzerland)</td>
</tr>
<tr>
<td>MaRIS</td>
<td>Visible near Infrared imaging Spectrometer</td>
<td>6.2 kg</td>
<td>A. Barucci (LESIA, France)</td>
</tr>
<tr>
<td>THERMAP</td>
<td>Mid-infrared spectro imager</td>
<td>4.4 kg</td>
<td>O. Groussin (LAM, France)</td>
</tr>
<tr>
<td>RSE</td>
<td>Radio Science Experiment</td>
<td>none</td>
<td>T. Andert (Universität der Bundeswehr, Germany)</td>
</tr>
<tr>
<td>VESPA/</td>
<td>Thermogravimetric analysis (one sensor out of a larger instrument</td>
<td>1.0 kg</td>
<td>tbd</td>
</tr>
<tr>
<td>VISTA2</td>
<td>package)</td>
<td>(tbd)</td>
<td></td>
</tr>
</tbody>
</table>

**Total Mass:** 23.0 kg

+ LIDAR for navigation by JAXA
MarcoPolo-R - 2008 EV5

<table>
<thead>
<tr>
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<th>Spatial resolution</th>
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<tbody>
<tr>
<td></td>
<td>VIS imaging</td>
</tr>
<tr>
<td>Global characterisation</td>
<td>Order of dm</td>
</tr>
<tr>
<td>Local characterisation</td>
<td>Order of mm</td>
</tr>
<tr>
<td>Context measurements</td>
<td>Hundred μm</td>
</tr>
</tbody>
</table>

After a first assessment, the precise mission analysis is now available at ESA-ESOC

Primary launch opportunities:

- Launch in December 2022, 4.5-year duration, arrival at the asteroid ~ January 2025, return to Earth in June 2027
- Launch in December 2023, 4.5 year duration, arrival at the asteroid ~ December 2025, return to Earth in June 2028

Backup opportunity:

- Launch in December 2024, 6.5 year duration, arrival at the asteroid ~ November 2027.
MarcoPolo-R – 2008 EV5

Compared to the mission to 1996FG3, a 2008EV5 mission features:

- Shorter mission duration (approx. 4.5 vs. 7 years)
- Reduce required mission delta-V ([3-4] km/s vs. [5-6] km/s)
- Shorter distance between Earth and spacecraft (higher data rate and simpler communication system)
- Have a “constant” distance from the sun (good for thermal design)
- Have a lower sample capsule re-entry speed (smaller ERC)
Technology activities

MP-R is not a critical mission in terms of TRL level

- High-precision **Guidance, Navigation & Control (GNC)** was found to need more attention in the previous Marco Polo study. Phase 2, 500 k€ (completed – successful).

  Conclusion: high-precision landing on a small body works

- **For touch and go:** Sampling tool mechanism for low-gravity bodies activity funded by MREP, 700k€, split into two phases. Phase 2 will test sampling tool in microgravity, i.e. parabolic flight (Study Kick-Off in July 2012): various concepts

- **Earth re-entry** - in various technology activities
In total, **ESA is investing close to 11M€** in activities directly relating to MP-R and other technologies developed in other programmes which are indirectly related to MP-R

in addition **nationally funded activities** regarding the ESA selected scientific instruments are going on

**NASA financed (Aug.14, 2012)** APL-JHU, for a study of a possible Sample mechanism for MP-R

**Possible contribution by JAXA** *(LIDAR-GNC)*
A new ERA of Sample Return

MarcoPolo-R (ESA)
- different primitive object
- particular C-type
- different sampling
MP-R mission will

- allow Europe to contribute in a timely manner to the international sample return effort
- allow scientists to unravel mysteries surrounding the birth and evolution of the solar system
- retain samples for future advances through a Curation and Distribution Facility

Support mitigation strategies
Next MarcoPolo-R meeting
Juin 3rd-4th, 2013
ESA-ESTEC, The Netherlands

http://www.sciops.esa.int/The_science_of_MarcoPolo-R
2008 EV5

1 asteroid with albedo 0.10-0.12 (possibly from a distinct primitive population)

2 asteroids with albedo < 0.07 to be sampled by OSIRIS-REx (NASA) and Hayabusa 2 (JAXA)

~5 carbonaceous/primitive ones

~350 accessible for sample return

More than 8000 Near Earth Asteroids
We need

- more than one sample return mission
- an European NEA return mission

and even if $2+1=3$

HY2 + O-Rex + MP-R $>> 3$

Spin-up by YORP

1. Even sunlight, such as the “YORP” effect, can spin-up and disrupt asteroids.
2. Depends on body size and distance from Sun.
3. Spin-up timescale ~Myr.

Taylor et al. (2007)

54509 YORP: 12.2-minute rotation and speeding up!

Asteroid must be nearly strengthless to disrupt.
Both EV5 and FG3 have Top Shapes and a Ridge and same rotation period ...

Binary 1999 KW₄ radar model, Ostro et al. 2005

YPORP spinup sims, Walsh et al. 2008

Single asteroid 1999 RQ₃₆
Howell et al. 2008, ACM

Binary 2004 DC
Taylor et al. 2008, ACM

Šteins (Rosetta Images)

Single 2008EV5
Busch et al. 2011
Amino Acids in Meteorite Extracts

1. D-Aspartic Acid
2. L-Aspartic Acid
3. L-Glutamic Acid
4. D-Glutamic Acid
5. D,L-Serine
6. Glycine
7. β-Alanine
8. γ-Amino-n-butyric Acid (γ-ABA)
9. D,L-β-Aminoisobutyric Acid (β-AIB)
10. D-Alanine
11. L-Alanine
12. D,L-β-Amino-n-butyric Acid (β-ABA)
13. α-Aminoisobutyric Acid (AIB)
14. D,L-α-Amino-n-butyric Acid (α-ABA)
15. D,L-Isovaline
16. L-Valine
17. D-Valine
X: unknown

Ehrenfreund et al. 2001
Why NEA?

Compositional Variation Across The Solar System

Temperature (K)

- 270
- 220
- 190
- Ice Line
- 160
- 140
- 120
- 100
- 90
- 80
- 70
- 60
- 50
- 40

Albedo

Spectral Types

- Typical
- X
- C
- Q
- V
- M
- K
- E
- P
- D
- S
- C

Dominant

Approximate Distribution

Unstable Population

Density of Objects (a v. i)

Silicate-rich

- Earth–Moon
- NEOs
- Mars Crossers
- Inner Belt
- 3:1
- 5:2

Ice-rich

- Trojans
- Centaurs
- Kuiper Belt 3:2

Heliocentric Distance (AU)

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 20
- 30
- 40
- 50
- 1000

(DeMeo F. PhD thesis)
A new ERA of sample return

Apollo 11, US 1969

Luna 16, US 1970
Geopotential mapped as equivalent velocity over the surface of the 2008 EV5 shape model (assuming a bulk density of 3 g/cm$^3$)