PROPOSAL TO CREATE A COMMISSION UNDER IAU DIVISION F:

Title: "Asteroids, comets and transneptunian objects"

Task group members:

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Rationale

We propose an IAU commission that will have the responsibility for *promoting scientific progress and research achievements* in the study of *asteroids, comets, transneptunian objects (TNOs), interstellar objects, and dwarf planets* in our solar system and their relationship to many other astronomical domains.

These studies *are interdisciplinary*, including applications of different theoretical approaches, making use of a variety of observing techniques and laboratory analyses, devoted to improve our understanding of the origin, evolution and current physical properties of small bodies orbiting the sun at very different heliocentric distances. They are *fundamental* for understanding the evolution of the protoplanetary nebula and the processes that led to the formation of our solar system and of other exoplanetary systems. Small bodies are believed to be the remnants - either fragments or "survivors"- of the swarm of planetesimals from which the planets formed. As such, they are primitive building blocks of the solar system left over from formation processes that offer clues to the chemical mixture from which the planets formed some 4.6 billion years ago. In contrast to the planets, which have experienced major alteration during their history, most asteroids, comets and TNOs (due to their small sizes) have retained a record of the original composition and volatile content of our solar system's proto-planetary disk. Abundant within the inner solar system, small bodies may have been the principal contributors of the water and organic material essential to create life on Earth. Thus, small bodies can be considered to be equivalent to DNA for unravelling our solar system's history, offering us a unique window to investigate both the formation of planets and the origin of life. Moreover, in the current epoch, these small bodies also represent both a potentially rich resource for future space exploration and a threat to the very existence of humankind on Earth. By investigating in detail the physical and chemical properties of asteroids, comets, TNOs, interstellar objects and dwarf planets, one can characterize the conditions and processes of the solar system's earliest epoch.

We are currently witnessing a *golden age of space exploration* of small solar system objects, and the efforts of many countries have resulted in the investment of billions of Euros in spacecraft missions to investigate small bodies. Major observatories routinely allocate significant amounts of observing time and major support is committed by laboratory facilities to study small bodies. Some of the main highlights from these missions include:

- The Rosetta ESA mission on the comet 67P/Churyumov-Gerasimenko revealed a dehydrated comet with refractory organic matter.
- Detection of water vapor was finally reported by Herschel around the dwarf planet Ceres and the presence of water ice was confirmed by the NASA Dawn space mission.
- The New Horizons NASA mission provided our first close-up view of both the Pluto-Charon system as well as the TNO Arrokoth.
- The two sample return missions Hayabusa2 by JAXA and OSIRIS-REx by NASA visited the primitive asteroids Ryugu and Bennu, respectively, assembling a large amount of data.

The Hayabusa2 mission will deliver pristine samples to the Earth at the end of 2020, while OSIRIS-REx will return the sample in 2023. New sample curation facilities will develop around the world. By returning primitive materials from the two primitive asteroids, these missions will offer the possibility of distinguishing between effects of solar-nebula processing and effects of alteration from asteroidal parent-body processing. The sample analysis will also permit abundance determination for a number of short-lived radionuclides present at the time of formation and for a variety of early solar-nebula components. In the near future, the ESA Gaia Mission will deliver comprehensive spectroscopic data on hundreds of thousands of asteroids and comets. Significant progress in the characterization of small solar system bodies and dwarf planets is expected from Earth-based large surveys with large observing facilities like ALMA and LSST and 30-40m class optical telescopes (GMT, TMT, ELT), as well as space-based characterization from JWST and NEO Surveyor.

The commission activities in the next triennium are for facilitating the use of the latest results to understand the complex and rich evolution of the diverse populations of small bodies.

Many new missions to visit small bodies are also currently in development, including:

- Lucy by NASA: the first space mission to the Jupiter's Trojans planned to be launched in 2021 with fly-bys in 2027-2033.
- Psyche by NASA: planned to visit the metallic asteroid Psyche with launch in 2022 and entering in orbit in 2026.
- MMX by JAXA: sample return mission to Phobos with launch in 2024 and retuned sample to Earth on 2029.
- DART, NASA mission to demonstrate asteroid deflection with launch in 2021.
- HERA ESA (launch 2024) mission to observe Didymos binary system after the impact.
- CAST-Zhenghe, planned to be launched by CNSA on 2024 for a sample return from a near-Earth asteroid 2016 HO_3 and exploration of a main-belt Comet 133P/288P.
- JAXA's DESTINY+ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLy-by and dUst Science) mission will be launched in 2023 to conduct at least one high-speed fly-by of active asteroid (3200) Phaethon in the mid-2020's, followed by a flyby of NEA (155140) 2005 UD.

These missions will provide a wealth of new results that will lead to a better understanding of these objects.

The differences between the various classes of small solar system objects are much subtler than previously believed. Recent discoveries about comets and asteroids indicate that the boundary between these two populations is not distinct, but rather these objects exist on a continuum of activity levels. Theoretical studies on dynamical evolution including planet migration show various mixing scenarios during the formation of the solar system that can bring water and other volatiles into the inner regions. The large-scale mixing in the early solar system seems to be a major phenomenon that can explain the *absence of sharp boundaries among populations*. Thanks to improvements in ground-based observations and associated more sophisticated data analysis, as well as recent space missions like AKARI, NEOWISE, Herschel, and Gaia, the *number of objects with quantified physical properties in the small body population has grown substantially* in recent years and will grow in the future. It is important to foster discussions between researchers working on different aspects of small bodies study, a goal of the new Commission. **At present, small bodies are not explicitly represented under division F.**

The small bodies scientific community has historically represented a very *broad geographical distribution of researchers*. Since the space age, almost all space-faring nations have sent probes to small bodies. In addition, cursory searches of publication databases (i.e. ADS) show the internationally diverse community engaged in small bodies research as well as the volume of publications. Although we are proposing a regular commission, *our new commission will have strong synergies with several other commissions*. Physical study of small bodies has important implications for astrobiology (Comm. F3), meteors, meteorites and interplanetary dust (Comm. F1), exoplanets and the solar system (Comm. F2) and Inter-Division A-F (Comm. Celestial Mechanics and Dynamical Astronomy) and to the Cross-Division A-F (Comm. Solar System Ephemerides). This demonstrates that our new commission will provide great service to the society and to the astronomical community at large.

The public is keenly aware of these small body investigations through educational and public outreach programs and has demonstrated significant interest in new results appearing in the news. For example, the Asteroid Day is now an international day around the world, as proclaimed in 2016 by United Nations General Assembly. The spectacular images taken by the space missions will be a wonderful means to pique the interest of the public, especially children who are the next generation of astronomers. The questions of the formation of the solar system and origin of life have always sparked enthusiasm in the general public. *The new commission will play the important role of fostering discussions by providing forums on small body topics that connect the international community of astronomers, both professional and amateur*.

The commission will

- promote progress in the determination of physical and chemical properties of small solar system bodies, their interrelations and evolutionary paths,
- support the merging of observational, experimental, and theoretical approaches, to provide a better understanding of the formation and evolution of our solar system,
- organize meetings and forums, and support IAU Symposia, encouraging suitable data standards for small bodies,
- provide various services to the community, including scientific reports,
- highlight scientific progress to the larger public audience concerning the spectacular results of space missions to small bodies,
- encourage and promote the IAU public outreach activities related to small bodies.