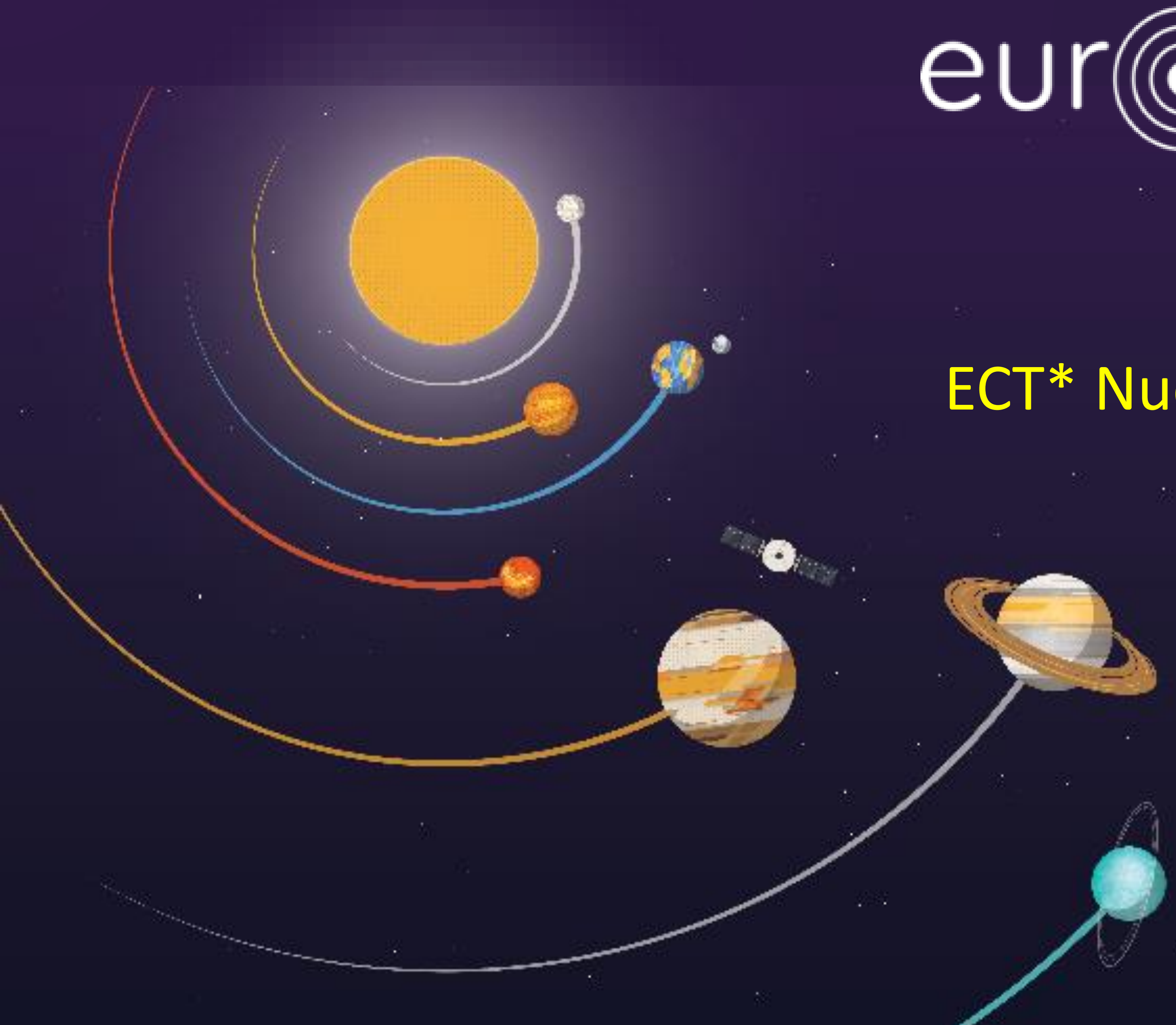

europlanet 2024
Research Infrastructure

ECT* Nuclear Astrochemistry

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ECT* Nuclear Astrochemistry

February 26 to March 1, 2024

Welcome

Thanks to ECT*

Particularly Barbara Gazzoli

Supported by

ChETEC-Infra – Daniel Bemmerer & Eliana Masha

Europlanet Duncan Mifsud

EMMI

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Theory Alliance FACILITY FOR RARE ISOTOPE BEAMS

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Why this meeting?

Two major scientific questions still requiring answers

How (why) did life begin on Earth?

Is there life elsewhere in the Universe?

- These questions/challenges are highlighted in many strategic fora for space
- Space Agencies – NASA/ESA
- Astronet roadmap .. ESFRI landscape

ESA decadal programme

- Solar system exploration and Human and Robotic Exploration Strategy to 2030 (and beyond) is focused on 'Astrobiology' : Key topic in Science Programme.

- Humans in space. Space exploitation, ISS and lunar orbital stations and lunar base.
- Search for extinct or extant life on Mars.
- Habitability of ice moons (JUICE) and now Venus (Envision)
- Study of exoplanets and search for biomarkers. (Ariel)

Requires an inter/cross disciplinary approach

- Life is based/emerges from the evolution of the Universe
- From emergence of elements, to formation of (prebiotic) molecules to biomolecules and 'life'
- Star and planet formation - habitats

Astrobiology/Astrochemistry/Astrophysics/Cosmology

- The expanding universe creates an interval of cosmic history during which biochemical observers, like ourselves, can expect to be examining the Universe.
- A universe that is billions of years old and hence billions of light years in size is a necessary pre-requisite for observers based upon chemical complexity.
- We need to know the timescale and rate of expansion to understand how life evolves

Astrobiology/Astrochemistry/Astrophysics/Cosmology

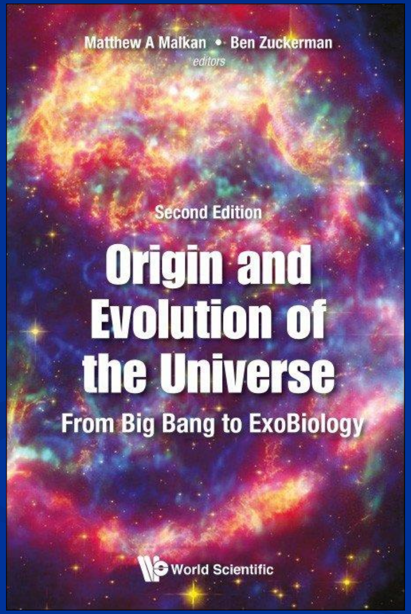
- Chemical complexity requires basic atomic building blocks which are heavier than the elements of hydrogen and helium which emerge from the hot early stages of the universe.
- Heavier elements, like carbon, nitrogen, and oxygen, are made in the stars, as a result of nuclear reactions that take billions of years to complete.
- Then, they are dispersed through space by supernovae after which they find their way into dust grains, planets, and ultimately, into people.
- This process takes billions of years to complete and allows the expansion to produce a universe that is billions of light years in size.

Astrobiology/Astrochemistry/Astrophysics/Cosmology

- The inevitability of universes that are big and old as habitats for life also leads us to conclude that they must be rather cold because expansion to large size reduces the average temperature inversely in proportion to the size of the universe.
- They must also be sparse, with a low average density of matter and large distances between different stars and galaxies

Astrobiology/Astrochemistry/Astrophysics/Cosmology

- Many aspects of our Universe which explain its birth and development appear hostile to the evolution of life but are necessary prerequisites for the existence of any form of biological complexity in the Universe.



Origin and Evolution of the Universe
From Big Bang to ExoBiology
Matthew A Malkan and Ben Zuckerman

The Physical Universe (TPU)	The Chemical Universe (TCU)	The Search for Life (SFL)
Origin & evolution of the Universe – Early universe and cosmological parameters – Dark Ages, Cosmic Dawn & Epoch of Reionisation – The formation of large-scale structure **Formation & Evolution of Galaxies** – Physical properties of early galaxies – Properties of the first stars – Formation & Evolution of Stars – Accretion processes and upper mass limits of stars – Properties of nascent planetary systems and their early evolution – Chemical pathways for the production of complex organics **Formation & Evolution of Planets** – Formation of planets and planetary systems – Composition of planets – Evolution & ultimate fate of planetary systems – Diversity of planets & planetary system architectures – The Solar System – Heliospheric plasmas, solar physics & space weather – The early history of our Solar System – Properties of small bodies – Exploration of the planets	**Creation of the Elements** – Astrophysical sources of chemical elements – Properties of isotopes effect on nucleosynthesis **Molecular Synthesis** – Role of gas phase & surface chemistry in synthesis of ISM molecules – Relative importance of formation routes of molecules – Limits on molecular complexity in ISM/circumstellar shells. **Planetary atmosphere chemistry** – Formation & evolution of planetary atmospheres – Causes of contrasting development of Earth/Venus & impacts on habitability – Exoplanetary climates & chemistry **Terrestrial Origins of Life & Prebiotic Chemistry** – Rarity vs ubiquity of chemical processes that lead to life – Delivery & evolution of chemical building blocks on Earth – Potential lunar chemical record of molecular seeds of life on Earth – Systems chemistry & interdisciplinary approaches for determining origins of life.	**The Origins & Evolution of Life** – Timescale of first emergence of on Earth – Influence of the geological evolution of the Earth-Moon system on the occurrence & evolutionary direction of life – Possible scenarios for evolution of life, and (microbial) metabolisms for the earliest form of life **Boundaries & Habitability** – Physiological/metabolic adaptation of life to extreme physicochemical conditions & variations in energy sources – Physical and chemical limits to sustain life & impact on the definition of habitability beyond the Earth – Ability of life to survive & proliferate in putatively habitable extraterrestrial environments **The search for life on exoplanets** – Chemical, morphologic, or metabolic signatures prevalent on Earth that could be used as evidence of life – Potential for life in different celestial environments (from micron to macron scale) – Evolution and preservation of biosignatures over time within different physicochemical environments (e.g. Mars subsurface, icy moons or atmosphere of exoplanets)

How do we bring this all together?

Linking nuclear astrophysics,astrochemistry, cosmochemistry, and prebiotic chemistry

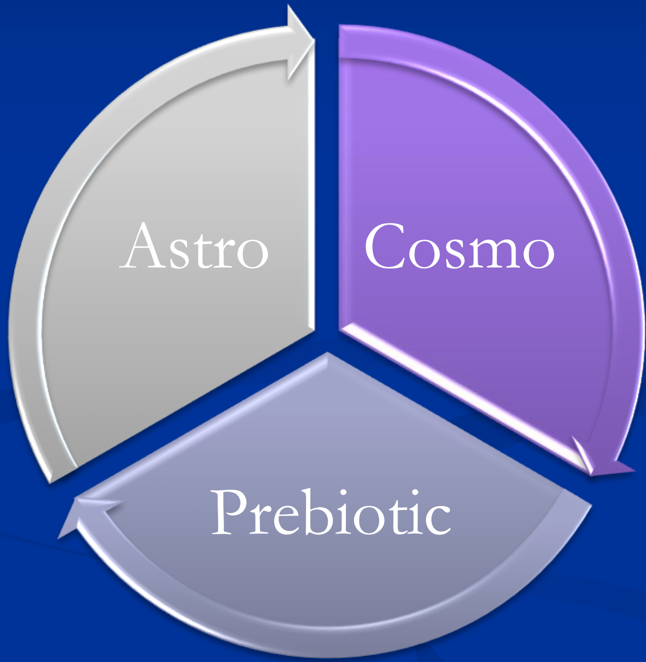
- *Nuclear Astrophysics*
  - Synthesis of the elements
  - Star formation and evolution
- *Astrochemistry*
  - Ice irradiation (ions, electrons, photons)
  - Ice processing (shocks, thermal processing)
  - Gas-phase experiments
- *Cosmochemistry*
  - Isotope studies of terrestrial geological analogues
  - Isotope studies of meteorites and processed ices
- *Prebiotic Chemistry*
  - Primordial Earth chemistry (formation of biomolecules)
  - The influence of mineral chemistry

  Origins of life

  Molecular assembly

  Biochemistry

  Evolution



Space Research in Europe
An Integrated model

• Star formation	Studies of ISM	Planetary formation	Evolution of life
• Nuclear synthesis	Molecular synthesis	Solar system studies	Terrestrial example
• Creation of elements	Complexity	Exoplanets & Habitability	
Nuclear astrophysics	Astrochemistry	Planetary Science	Origins of Life
ChETEC RI	JWST/ALMA ECLA	Europlanet	

European Astrobiology Institute

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- Bring these communities together to discuss challenges and how to collaborate.

- Review and discuss science and state of the art in each field.
- Review what facilities we have for conducting such research.
- Provide an opportunity for discussion and engagement – most of us have not met before.

Working groups for discussion

1. What are the major scientific questions and challenges that need to be addressed to understand the origins of the elemental and molecular constituents of the Universe and how did they evolve to their present form?
2. What are the ‘roadblocks’ to addressing 1? How may these be overcome?
3. How can we coordinate and ensure collaboration between the disparate communities of astrophysics, astrochemistry and astrobiology?
4. What facilities do we have to pursue these studies? Are there facilities and infrastructures that are currently lacking to support and deliver such research?
5. You may add other topics as you feel relevant.

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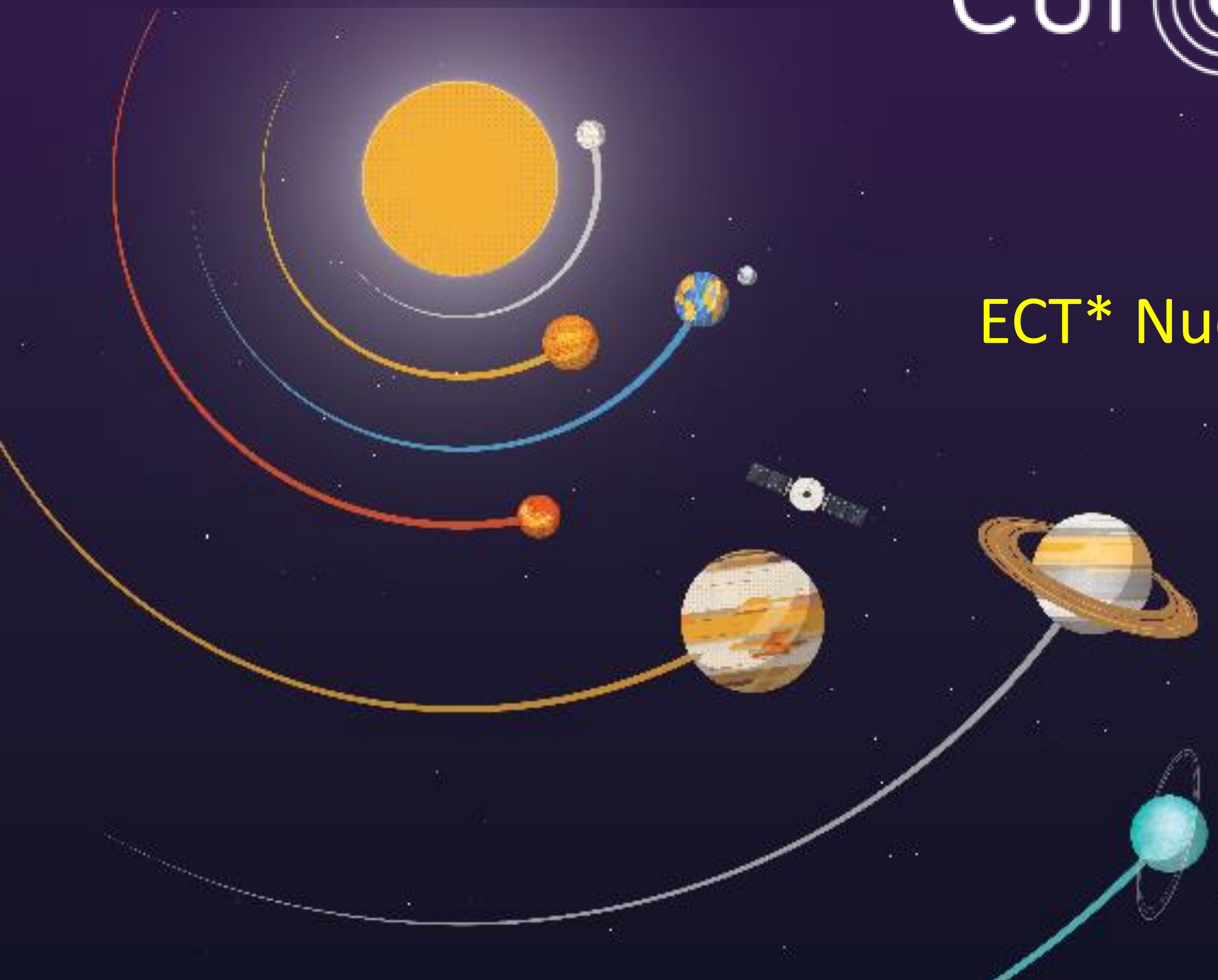

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