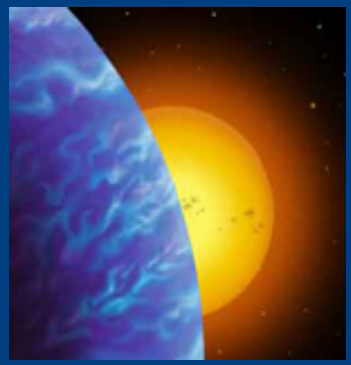
Cosmic Vision 2015-2025: The scientific priorities for astrophysics and fundamental physics

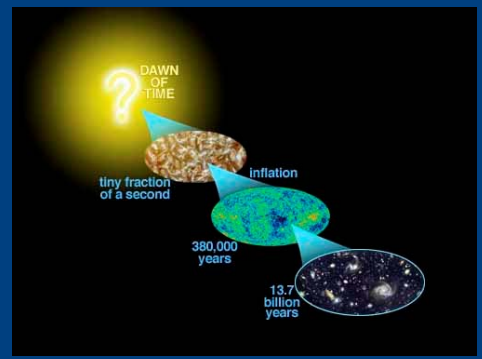
Fabio Favata

ESA, Astronomy & Fundamental Physics Mission Coordinator

Grand themes

1. What are the conditions for life and planetary formation?
2. How does the Solar System work?
3. What are the fundamental laws of the Universe?
4. How did the Universe originate and what is it made of?





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Previous studies: XEUS, Darwin

- Two large mission concepts have already been studied to significant detail using Science Program resources
  - XEUS [large aperture X-ray observatory]
  - Darwin [terrestrial planet finder]
- Neither has been up to now an element of the Program -> both have to compete for an L mission slot

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Previous studies: XEUS, Darwin

- A number of study activities concluded, some nearing conclusions
- Techno development plan for both missions already defined
- Implementation of techno plan contingent to proposal selection!

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Previous studies: XEUS, Darwin

- Extant scientific advisory groups no longer active
- If proposals are selected, new scientific advisory groups will be formed
- Definition phase studies will be conducted along the same lines as all other missions

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Previous studies: XEUS, Darwin

- Existing XEUS and Darwin concepts do not preempt the relative science in this call
- Other mission concepts addressing similar or related science, on L or M scale, are welcome

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Summary of LoIs: astrophysics

- L mission concepts
  - XEUS
  - FIR Interferometer
  - Darwin
  - Fresnel imager
- Exo-planet science (theme 1)
  - Pegase (interferometer)
  - Plato (high-accuracy photometry)
  - SEE-Coast (coronagraph)
  - CESO (2 S/C coronagraph)

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Summary of LoIs: astrophysics

- High-energy astrophysics (themes 3/4)
  - Gamma Ray Imager
  - GRIPS (GRBs via polarimetry and spectroscopy)
  - SAGE (FUV, soft X-rays)
  - Edge (broad band X-rays)
  - FUSO (far UV)
- Cosmology, using IR and (sub)mm (themes 3/4)
  - SPICA (FIR, submm)
  - Dune (NIR, Dark energy)
  - Space (NIR spectroscopic survey)
  - B-Pol (CMB polarization)
  - Millimetron (FIR, submm)
  - H2EX (H2 explorer)

Summary of LoIs: astrophysics

- Others (themes 3/4)
  - Luciola (interferometer)
  - UHEUniverse (high energy cosmic rays)
  - Sarim (interstellar matter sample return)
  - VLFA (very low frequency radio)

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Summary of LoIs: fundamental physics

- L class mission concepts
  - SAGAS (Search for Anomalous Gravitation using Atomic Sensors)
- Pioneer acceleration
  - DSGE
  - ODISSEY
  - ZACUTO

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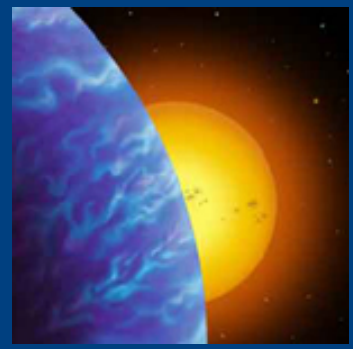
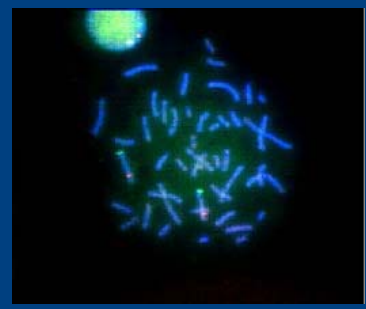
Summary of LoIs: fundamental physics

- Relativity
  - ASTROD
  - LATOR
- Equivalence principle
  - GAUGE
  - Galileo Galilei
- Nature of gravity
  - Gravity explorer
  - MWXG - Matter wave explorer of gravity
- Atomic interferometry
  - AIS
  - MWXG

1. What are the conditions for life and planetary formation?



Place the Solar System into the overall context of planetary formation, aiming at comparative planetology



1.1 From gas and dust to stars and planets.

1.2 From exo-planets to bio-markers.

1.3 Life and habitability in the Solar System.

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Strategy for Theme 1

Step 1: In-depth analysis of terrestrial planets

Direct detection and low resolution spectroscopy of exoplanets: NIR-MIR Space nulling interferometer

Mars exploration: in-situ measurements with rovers and sample return.

Step 2: Conditions for star, planet and life formation

Stars and exoplanets: Far Infrared observatory with high spatial and low to high spectral resolution.

Habitability in solar system : 3D solar magnetic field explorer (Solar Polar Orbiter)

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Strategy for Theme 1

Later steps:

Census of terrestrial planets orbiting stars < 100 pc: Terrestrial astrometric surveyor

In-situ Exploration of the surface of other solid bodies in the Solar System: Europa orbiter (lander) on Jupiter Explorer Probe (JEP)

Ultimate step:

Imaging of a terrestrial exo-planet: Large optical interferometer

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2. How does the Solar System work ?

2.1 From the Sun to the edge of the Solar System

2.2 Gaseous Giants and their Moons

2.3 The Building Blocks of the Solar System: Asteroids and Small Bodies

Strategy for Theme 2

From the Sun to the edge of the solar system:

Step 1: measure hierarchy of scales in the magnetosphere; Magnetosheric Swarm

Step 2: measure the 3D solar magnetic field; Solar Polar Orbiter

Step 3: measure the outer reaches of the heliosphere; Heliopause Probe

The Giant Planets and their environments:

Step 1: explore the Jovian environment including Europa; series of micro-spacecraft

Step 2: explore the Jovian atmosphere and Europa surface; in-situ probes

Asteroids and small bodies:

Step 1: study primitive Near-Earth objects; NEO sample return

Step 2: continued Mars studies; Mars Sample return

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3. What are the fundamental laws of the Universe?

3.1 Explore the limits of contemporary physics

3.2 The gravitational wave Universe

3.3 Matter under extreme conditions

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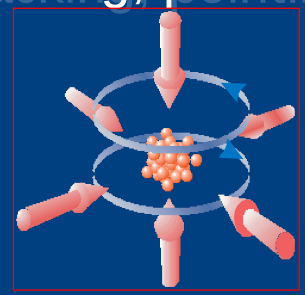
Strategy for Theme 3

To probe the limits of our current understanding:

Fundamental Physics Explorer Series (2015-2020)

- Sequence of inexpensive small missions using the same platform, designed for ultra-high-precision experiments, impossible on ground.
  - *An opportunity for Europe to take leadership in a new field of science*
- Going into space with completely new technologies, developed on the ground in Nobel-Prize winning experiments: cold atoms, Bose-Einstein condensates. Big increases in precision measurement, tracking, pointing.



- Many experiments already proposed by community:
  - *Test foundations of theoretical physics (nature of space and time)*
  - *Explore limits of quantum theory (entanglement, decoherence)*
  - *Look for signs of quantum gravity in high-precision experiments*

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Strategy for Theme 3

To explore the Gravitational Universe

- Probing black holes and high-energy physics (2015)
  - *Large-area X-ray telescope mission (XEUS)*
  - *Mission to detect anomalous ultra-high-energy cosmic rays*
- Explore solar-system gravity for hints of quantum effects (2020-2025)
  - *Large-scale violations of Einstein gravity*
  - *Resolve anomalies in tracking of Pioneer, other spacecraft*
  - *Speed of light tests, quantum measurements over large distances, ...*
- Gravitational Wave Explorer (2025)
  - *Build on LISA experience, but open up a new frequency window for gravitational waves: 0.1-1.0 Hz.*
  - *In this window it should be possible to see the Big Bang in gravitational waves, along with the earliest neutron stars and the first generation of black holes.*
  - *Technology development should start now: lasers, mirrors, controls*
  - *Partnerships with NASA ("Big Bang Observer"), other agencies desirable*

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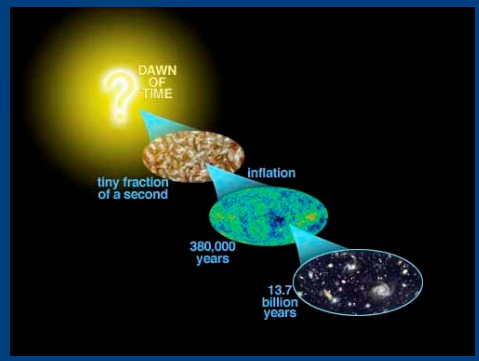
4. How did the Universe originate and what is it made of?

4.1 The early Universe

4.2 The Universe taking shape



4.3 The evolving violent Universe

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Strategy for Theme 4

Step 1:

Trace the evolution of galaxies back to their formation epoch and the life cycle of matter in the Universe:

Large aperture X-ray observatory

Investigate the inflationary phases in the evolution of the Universe:

All-sky CMB polarisation mapper,

Probe dark energy from high Z SNIa and weak lensing:

Wide-field optical-near IR imager.

Strategy for Theme 4

Step 2:

Resolve the sky background into discrete sources and the star formation activity hidden by dust absorption:

Far-infrared imaging observatory

Understand in detail the supernova history in our Galaxy and in the Local Group:

Gamma-ray observatory

Directly detect the primordial gravitational waves issued from the Big Bang:

Gravitational Wave Cosmic Surveyor

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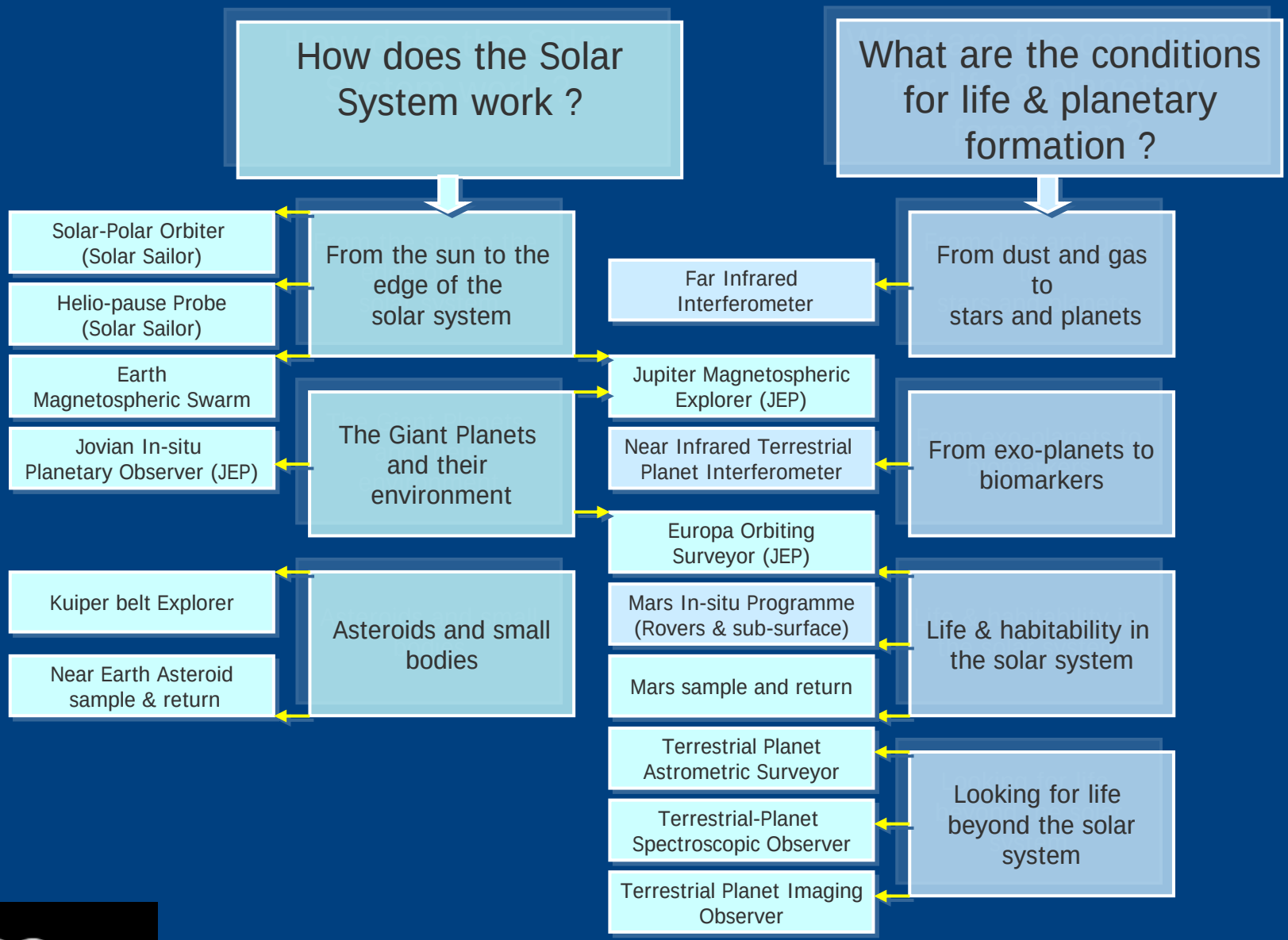
From themes to proto-missions



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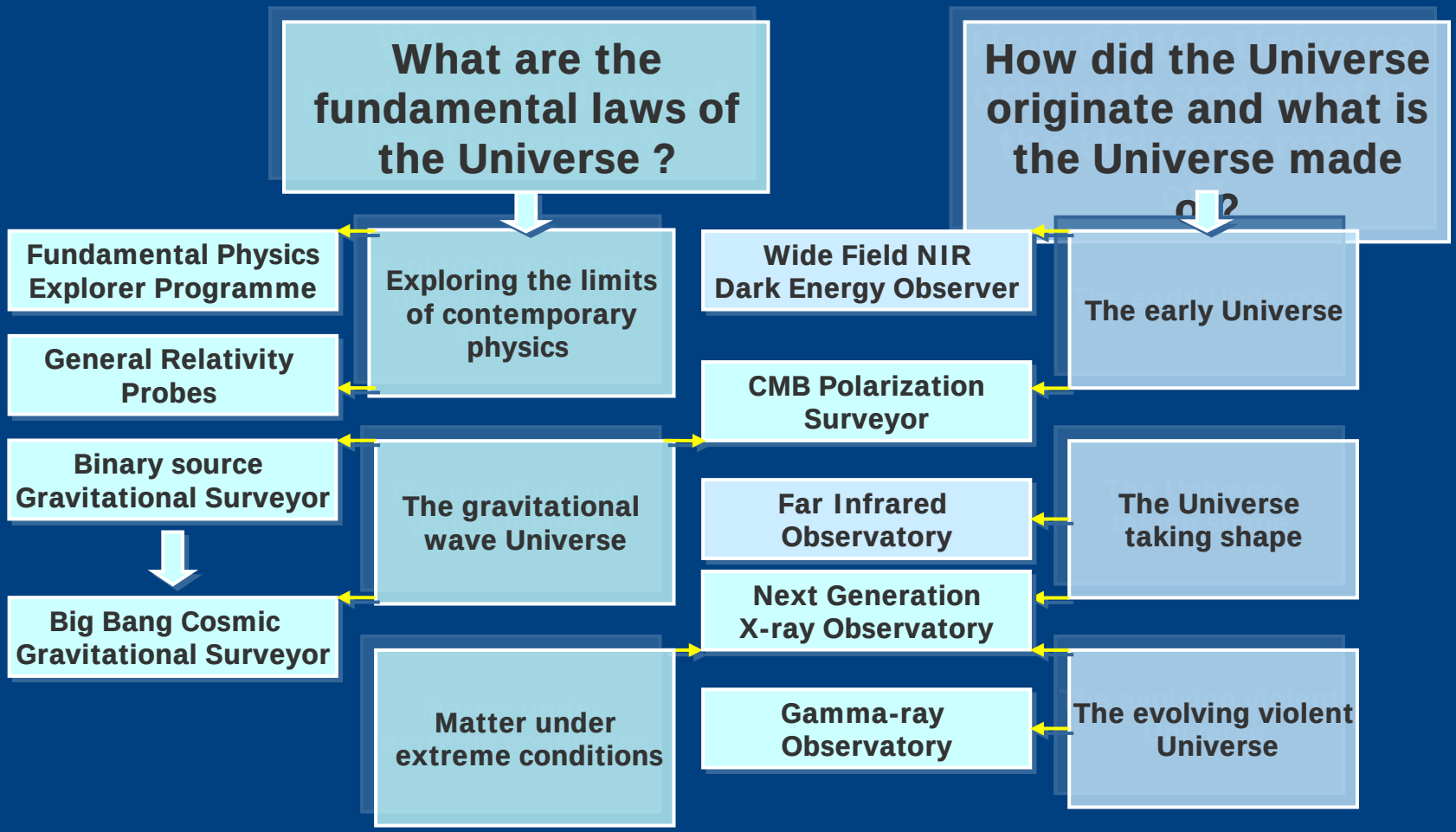
From themes to proto-missions



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The end