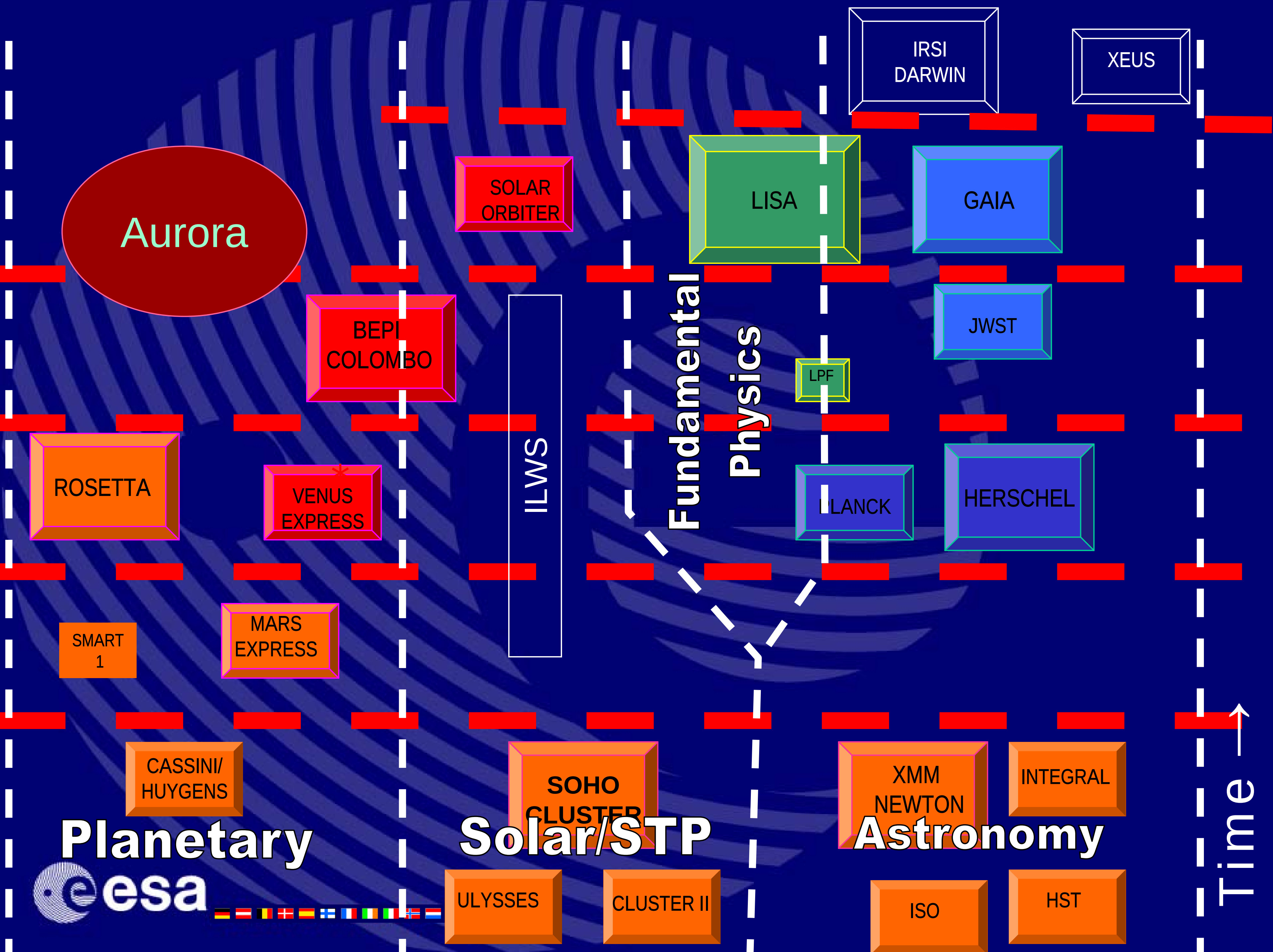
Cosmic Vision 2015 – 2025

ESA's new long term plan for space science


IRSI
DARWIN
XEUS
SOLAR
ORBITER
LISA
GAIA
Aurora
BEPI
COLOMBO
JWST
LPF
Fundamental
Physics
ILWS
ROSETTA
VENUS
EXPRESS
PLANCK
HERSCHEL
SMART
1
MARS
EXPRESS
CASSINI/
HUYGENS
SOHO
CLUSTER
XMM
NEWTON
INTEGRAL
Planetary
Solar/STP
Astronomy
esa
ULYSSES
CLUSTER II
ISO
HST
Time


Missions in preparation
Corot
(CNES-ESA)
. 2006
Herschel-Planck
2007
JWST
(NASA-ESA)
2011
Bepi-Colombo
2012
Lisa
2014
Venus Express
. 2005
Astro-F
(Japan-ESA)
2006
Microscope
(CNES-ESA)
2008
Lisa-
Pathfinder 2009
Gaia
2011-12
Solar
Orbiter
2015
2005
2006
2007
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2013
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Cosmic Vision process

- ✓ Cosmic Vision 2015 –2025 process launched on 2 April 04 with call for Science themes
- ✓ 1June 04: deadline for proposal submission
- ✓ July 04: Analysis of responses by the ESA Science advisory bodies (AWG, SSWG, FPAG, SSAC)
- ✓ 15-16 September 04: Workshop in Paris (~400 participants)
- ✓ Nov 04: progress report to SPC
- ✓ Spring 05: presentation of Cosmic Vision 2015-2025 to community
- → May 05: Final Presentation of Cosmic Vision to SPC

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Response to Cosmic Vision call

- In excess of 150 responses received !

- Horizon 2000 + consultation received less than 100 responses

- Reveals today's strong expectations of the community from the ESA Science Programme

Cosmic Vision proposal evaluation

Proposals evaluated for prime scientific objectives by ESA’s working groups

- Astronomy/Astrophysics (AWG)
- Fundamental Physics (FPAG)
- Solar System Science (SSWG)

Space Science Advisory Committee (SSAC) merged working group objectives into 4 grand themes

- Building on scientific heritage from H2000 missions
- Capitalizing on synergies across disciplines
- Propose implementation strategy

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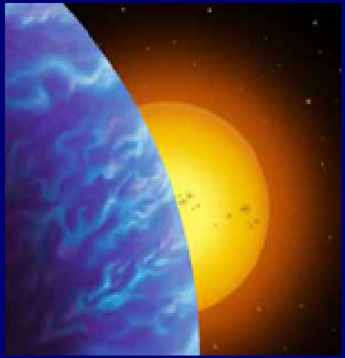
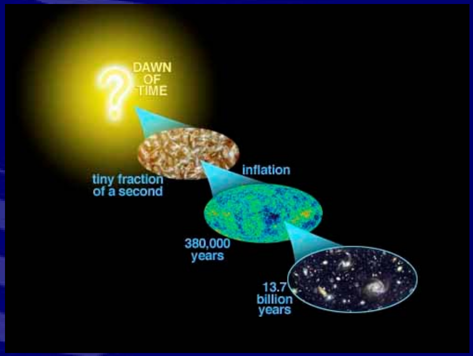
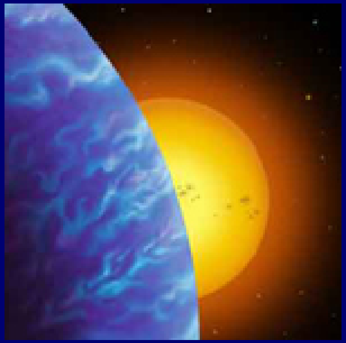
Grand themes

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?





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

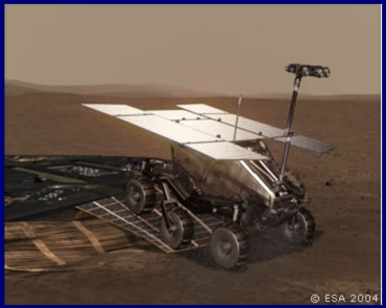


Place the Solar System into the overall context of planetary formation, aiming at comparative planetology

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.

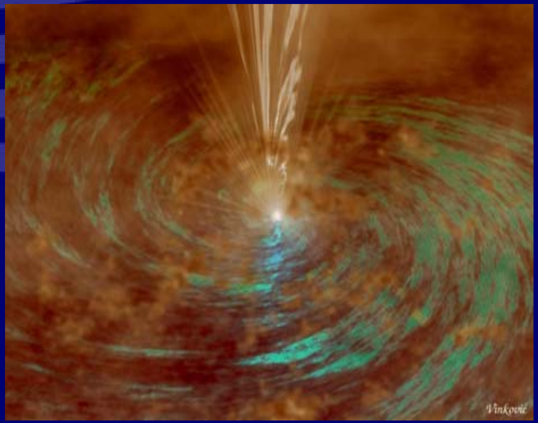


1.1 From gas and dust to stars and planets

Map the birth of stars and planets by peering into the highly obscured cocoons where they form.

Investigate star formation areas, protostars and protoplanetary disks

Investigate the conditions for star and planet formation and evolution

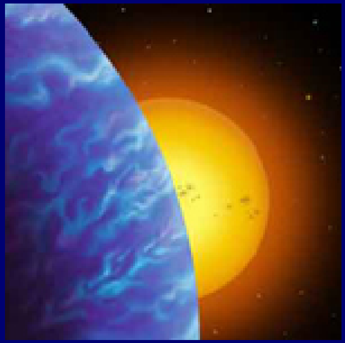


Investigate which properties of the host stars and which location in the Galaxy are more favourable to the formation of planets

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

1.2 From exo-planets to bio-markers

Search for and image planets around stars other than the Sun, looking for biomarkers in their atmospheres



Direct detection of Earth-like planets. Physical and chemical characterization of their atmospheres for the identification of unique biomarkers.

Systematic census of terrestrial planets

Ultimate goal: image terrestrial planets

Tool: Space nulling interferometer with near to mid-infrared low resolution spectroscopy capability.

Later: terrestrial astrometric surveyor

Much later: large optical interferometer

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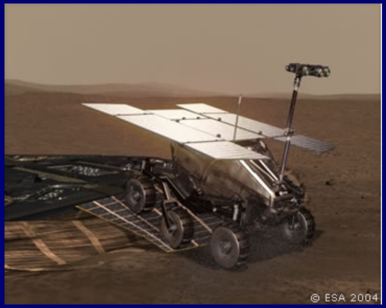
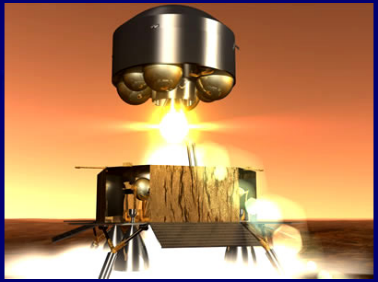
1.3 Life and habitability in the Solar System

Explore ‘in situ’ the surface and subsurface of the solid bodies in the Solar System more likely to host –or have hosted- life.



Appearance and evolution of life depends on environmental conditions (geological processes, water presence, climatic and atmospheric conditions, Solar magnetic and radiation environment)



Mars is ideally suited to address key scientific questions of habitability. Europa is the other priority for study of internal structure, composition of ocean and icy crust and radiation environment around Jupiter.

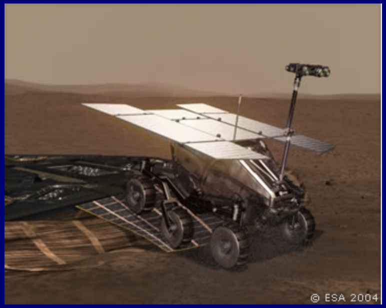
1.3 Life and habitability in the Solar System

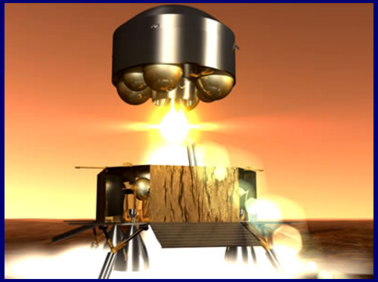
Tools:

•Mars exploration with in-situ measurements(rovers) and sample return.

•3D solar magnetic field explorer (Solar Polar Orbiter)

•Dedicated Europa orbiter (lander) on Jupiter Explorer Probe (JEP).





Strategies for Theme 1

First: In-depth analysis of terrestrial planets

-**Exoplanets: a space nulling interferometer with near to mid-infrared** low resolution spectroscopy capability.

-**Mars exploration**: **in-situ measurements** (rovers) and sample return.

Later: Understand the conditions for star, planet and life formation

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

-**Solar system**: **3-D solar magnetic field explorer** (Solar Polar Orbiter)

Strategies for Theme 1

Still later:

-Make a census of terrestrial planets orbiting stars < 100 pc: **Terrestrial astrometric surveyor**

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

Much later:

-Image a terrestrial exo-planet: **Large optical interferometer**

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

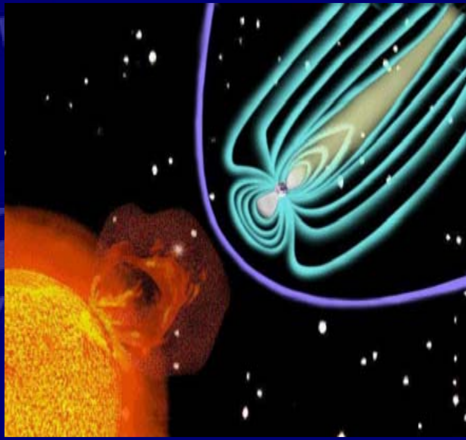
2.1 From the Sun to the edge of the Solar System

Study the plasma and magnetic field environment around the Earth, the Jovian system –as a mini Solar System-, the Solar poles and the heliopause where the Solar influence area meets the interstellar medium.

The structure of the magnetic field at the solar surface requires observations from above the poles to understand the field's origin.

The Solar System pervaded by the solar plasma and magnetic field provides a range of laboratories to study the interactions of planets (Jupiter) with the solar wind

In-situ observation of the heliopause would provide ground truth measurements of the interstellar medium .



Tools: Solar Polar Orbiter, Earth magnetospheric swarm, Jupiter Probe, Interstellar Helio-Pause Probe.

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2.2 Gaseous Giants and their Moons

Study Jupiter In-situ , its atmosphere and internal structure.

Giant planets with their rings,diverse satellites and complex environments, constitute systems which play a key role in the evolution of planetary systems.

Tools: Jupiter Explorer Probe/JEP

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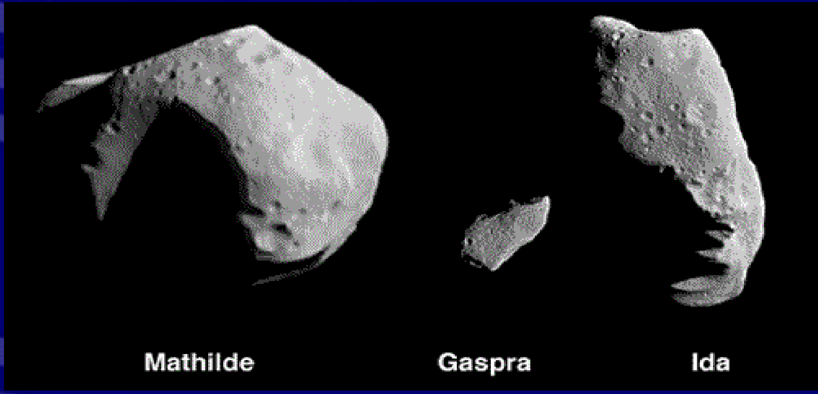
2.3 The Building Blocks of the Solar System

Obtain direct laboratory information of the building blocks of the Solar System by analysing samples from a Near-Earth Object (NEO).

As primitive building blocks in the solar system, small bodies give clues to the chemical mixture and initial conditions from which the planets formed in the early solar nebula

Tools: NEO sample return, Mars sample return



Strategies for Theme 2

From the Sun to the edge of the solar system **<u>measure</u> :**

- First., the hierarchy of scales in the magnetosphere (e.g. M^3, Magnetospheric SWARM)
- Next, the 3-D solar magnetic field: (e.g. Solar Polar Orbiter)
- Finally, the outer reaches of the heliosphere (e.g. Heliopause probe)

The Giant Planets and their environments **<u>explore</u> :**

- First, the Jovian environment, including Europa, using a series of multiple micro-spacecraft
- Then the Jovian atmosphere and Europan surface with in-situ probes

Asteroids and small bodies **<u>return samples from</u> :**

- First, primitive Near-Earth objects (e.g. NEO sample return)
- Then Mars (e.g. Mars Sample return)

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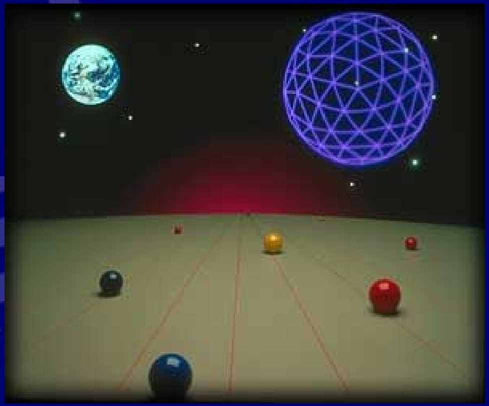
3. What are the fundamental laws of the Universe?

3.1 Explore the limits of contemporary physics

3.2 The gravitational wave Universe

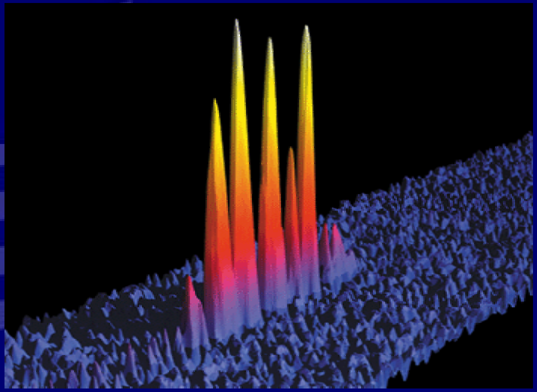


3.3 Matter under extreme conditions

3.1 Explore the limits of contemporary physics

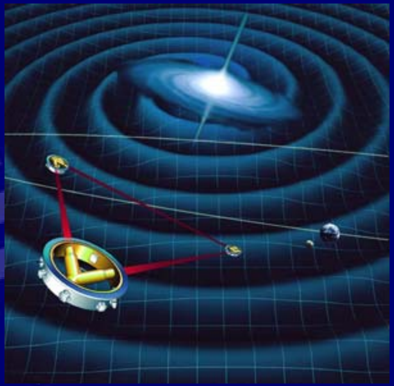
Probe the limits of GR, symmetry violations, fundamental constants, Short Range Forces, Quantum Physics of Bose-Einstein Condensates, Cosmic rays, to look for clues to Unified Theories.

Use the stable and gravity-free environment of space to implement high precision experiments to search for tiny deviations from the standard model of fundamental interactions.



Tool: Fundamental Physics Exlorer programme

3.2 The gravitational wave Universe



Detect and study the gravitational radiation background generated at the Big Bang. Probe the universe at high red shift and explore the dark universe.

Primordial gravitational waves, unaffected by matter, are ideal probes of the laws of physics at the primordial energies and temperatures.

They open an ideal window to probe the very early Universe and dark energy at very early times.

Tool: Gravitational Wave Cosmic Surveyor

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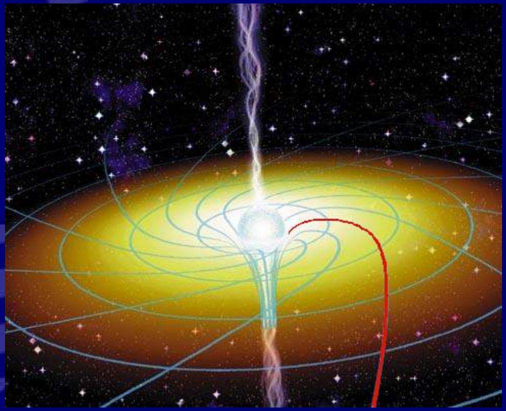
3.3 Matter under extreme conditions

Probe General Relativity in the environment of Black Holes and compact objects, as well as the equation of state of matter in Neutron Stars.

The study of the spectrum and time variability of radiation from matter near BHs carry the imprint of the curvature of space-time as predicted by general relativity. This has strong implications for astrophysics and cosmology in general.



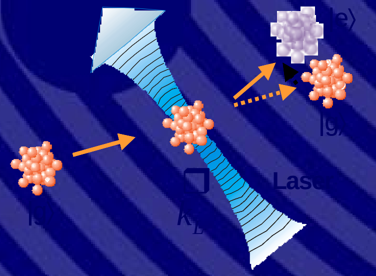
Tools: Large aperture X-ray observatory, gamma-ray observatory.

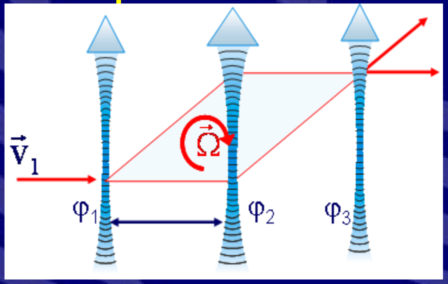
Strategies for Theme 3

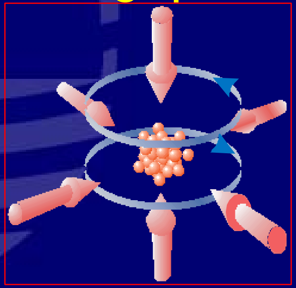
To probe the limits of our current understanding:

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*

Strategies for Theme 3

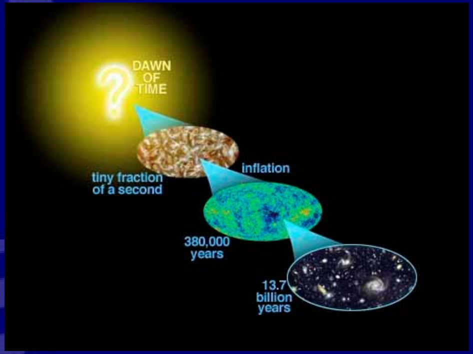
To explore the Gravitational Universe

- **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*

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

4.1 The early Universe

Investigate the physical processes that lead to the inflationary phase in the early Universe during which a drastic expansion took place. Investigate the nature and origin of the Dark Energy that currently drives our Universe apart.

Imprints of inflation are related to the polarization parameters of anisotropies of the Cosmic Microwave Background (CMB) due to primordial gravitational waves from Big Bang.

Dark energy can be studied in the gravitational lensing from cosmic large scale structures and the measurement of the luminosity-redshift relation of distant Supernovae (SN) Ia.

Tools: All-sky CMB polarisation mapper, Wide-field optical-near IR imager.

Later: Gravitational Wave Cosmic Surveyor

4.2 The Universe taking shape

Find the very first gravitationally bound structures assembled in the Universe (precursors to today's galaxies and clusters of galaxies) and trace their evolution to today.

The very first clusters of galaxies back to their formation epoch are keys to study their relation to AGN activity and the chemical enrichment of the Inter Galactic Medium.

Also important are the studies of the joint galaxy and super-massive BH evolution, the resolution of the far IR background into discrete sources and the star-formation activity hidden by dust absorption.

Tools: Large aperture X-ray observatory, far-infrared imaging observatory

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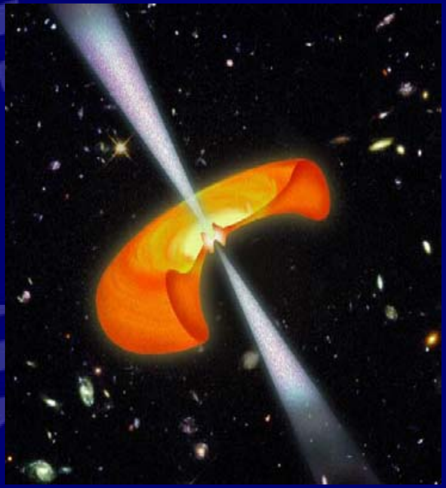
4.3 The evolving violent Universe

Formation and evolution of the super-massive black holes at galaxy centres –in relation to galaxy and star formation. Life cycles of matter in the Universe along its cosmic history.

Observing Black Holes in the centre of most galaxies allows the study of the interplay between their formation and evolution and that of their host galaxies.



Matter falling onto Black Holes produces X and γ –rays. Their spectral and time variability trace the accretion process, and are clues to understand the processes at work in SN and Hypernova explosions connected to Gamma Ray Bursts

Tools: Large aperture X-ray observatory, gamma-ray observatory.

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Strategies for Theme 4

First

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

Investigate the inflationary phases in the evolution of the Universe.

-Observatory-type mission: **Large aperture X-ray observatory**

-Focused missions: **All-sky CMB polarisation mapper, Wide-field optical-near IR imager.**

Strategies for Theme 4

Later

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

From themes to proto-missions

How does the Solar System work ?

From the sun to the edge of the solar system

- Solar-Polar Orbiter (Solar Sailor)
- Helio-pause Probe (Solar Sailor)
- Earth Magnetospheric Swarm
- Jupiter Magnetospheric Explorer (JEP)

The Giant Planets and their environment

- Jovian In-situ Planetary Observer (JEP)
- Jupiter Magnetospheric Explorer (JEP)
- Europa Orbiting Surveyor (JEP)

Asteroids and small bodies

- Kuiper belt Explorer
- Near Earth Asteroid sample & return

What are the conditions for life & planetary formation ?

From dust and gas to stars and planets

- Far Infrared Interferometer

From exo-planets to biomarkers

- Near Infrared Terrestrial Planet Interferometer

Life & habitability in the solar system

- Europa Orbiting Surveyor (JEP)
- Mars In-situ Programme (Rovers & sub-surface)
- Mars sample and return

Looking for life beyond the solar system

- Terrestrial Planet Astrometric Surveyor
- Terrestrial-Planet Spectroscopic Observer
- Terrestrial Planet Imaging Observer

From themes to proto-missions

What are the fundamental laws of the Universe ?

How did the Universe originate and what is the Universe made of?

Fundamental Physics Explorer Programme

General Relativity Probes

Binary source Gravitational Surveyor

Big Bang Cosmic Gravitational Surveyor

Exploring the limits of contemporary physics

The gravitational wave Universe

Matter under extreme conditions

Wide Field NIR Dark Energy Observer

CMB Polarization Surveyor

Far Infrared Observatory

Next Generation X-ray Observatory

Gamma-ray Observatory

The early Universe

The Universe taking shape

The evolving violent Universe

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COSMIC VISION 2015 – 2025

Potential implementation

Proposal for increased Level of Resources (LoR)

In preparation of next ESA Council meeting at Ministerial level in December 2005 and after concurrence by ESA DG, it is proposed to:

- Maintain the present Science Programme LoR with inflation correction to 2006
- From 2007, seek a 5 year annual increase of 2.4% over the current LoR

General assumptions

- Loan reimbursement extended to 2009
- Continuation of current charging policy
- Present envelopes for BC, GAIA, LISA and SO
- Launcher for JWST

Uncertainties

- The income level and the loan reimbursement.
- The envelopes of GAIA, BepiColombo and LISA and their impact on the future programme.
- The launcher for JWST.

Programme Slices

- To implement the major objectives of Cosmic Vision 2015-2025 while keeping flexibility of planning, slices of 1 to 1.5 B€ each can be identified for missions to be launched in 2015-2025.

- Flexibility within each slice will depend on size, number and order of missions and inclusion of international cooperation.

- Flexibility within each slice allows to maintain a good balance of scientific disciplines

- The first Call for Mission Proposals to cover first slice (2015 – 2018). Next slices to be implemented through subsequent Calls.

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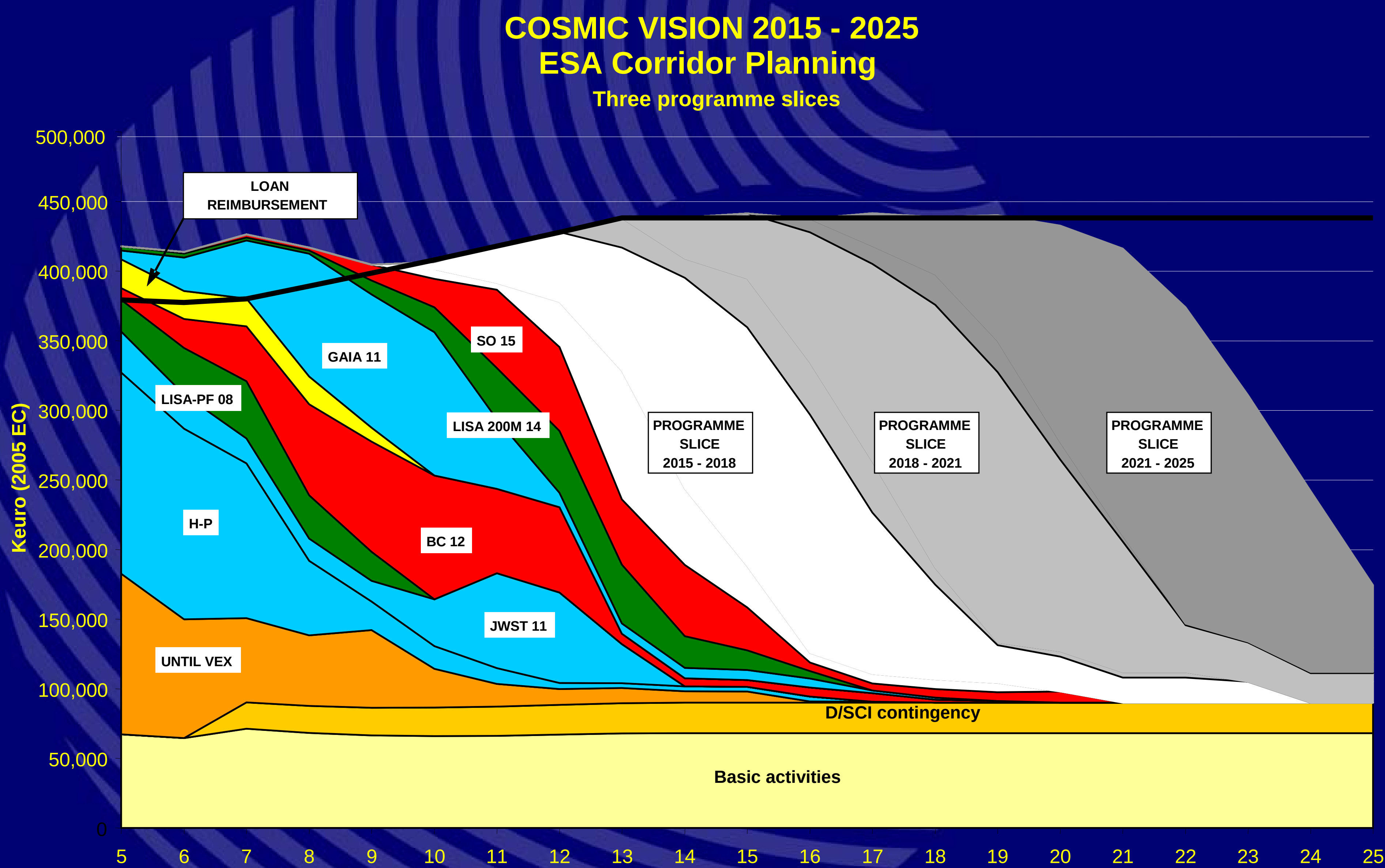
COSMIC VISION 2015 - 2025
ESA Corridor Planning
Three programme slices
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Keuro (2005 EC)
LOAN REIMBURSEMENT
GAIA 11
SO 15
LISA-PF 08
LISA 200M 14
H-P
BC 12
JWST 11
UNTIL VEX
PROGRAMME SLICE 2015 - 2018
PROGRAMME SLICE 2018 - 2021
PROGRAMME SLICE 2021 - 2025
D/SCI contingency
Basic activities
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Importance of proposed LoR increase

- Enables early support of Aurora programme by Science Directorate in areas of scientific payloads and science operations.

- Opens a programme wedge in 2010 to start industrial development for timely implementation (2015 launch) of initial mission of first Cosmic Vision slice.

Conclusions

let’s start soon dishing out the first slice !

a launch in 2015 requires a phase B start at the beginning of ’08

Phase A in ’07

Call for mission proposals early ‘06

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