FRONTIERE DELL'ASTROFISICA ITALIANA:

come ottimizzare il ritorno scientifico dalle grandi infrastrutture internazionali

18 - 19 Marzo 2015

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

SISTEMA SOLARE, SISTEMI PLANETARI E ORIGINE DELLA VITA

Toward a global vision of the life cycle of planetary systems

Frontiere dell'astrofisica italiana

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Accademia dei Lincei
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SISTEMA SOLARE, SISTEMI PLANETARI E ORIGINE DELLA VITA
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ORIGIN OF LIFE

Interstellar Medium

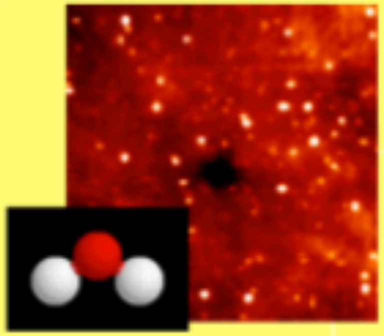
Disks (<10 Myr)

Planetary Systems

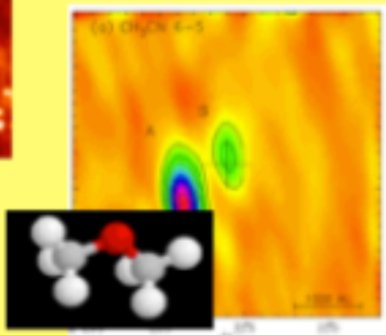
SOLAR SYSTEM ↔ EXOPLANETARY SYSTEMS

SOLAR SYSTEM	EXOPLANETARY SYSTEMS
The SUN	Architecture
Primitive Bodies: Building blocks of the Solar System	Atmosphere
Planets and their satellites	Host star role

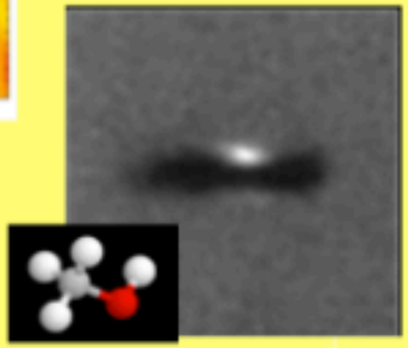
FROM A DIFFUSE CLOUD TO A SUN + PLANETARY SYSTEM
FROM ATOMS & SIMPLE MOLECULES TO LIFE



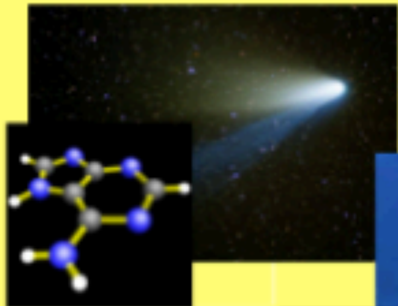
1- PRE-STELLAR PHASE: cold and dense gas
FORMATION OF SIMPLE MOLECULES

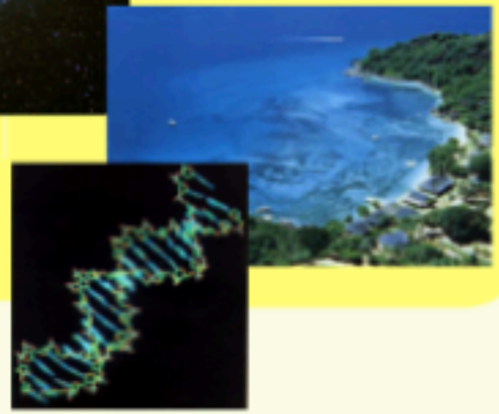


2- PROTOSTELLAR PHASE: collapsing, warm dense gas
FORMATION OF COMPLEX MOLECULES



3- PROTOPLANETARY DISK PHASE:
cold and warm dense gas
SIMPLE & COMPLEX MOLECULES



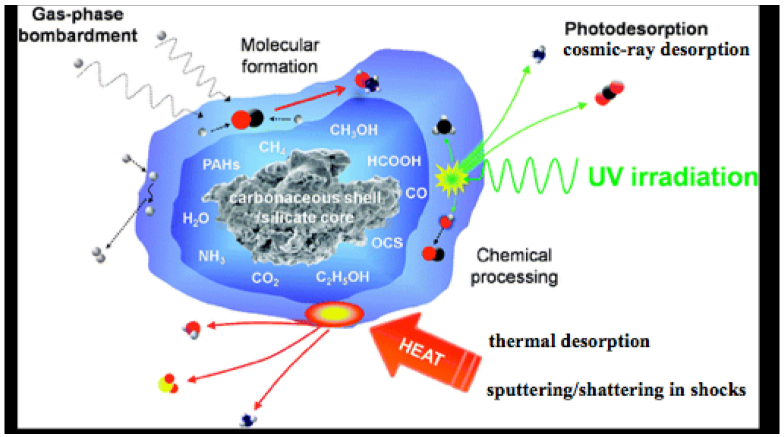


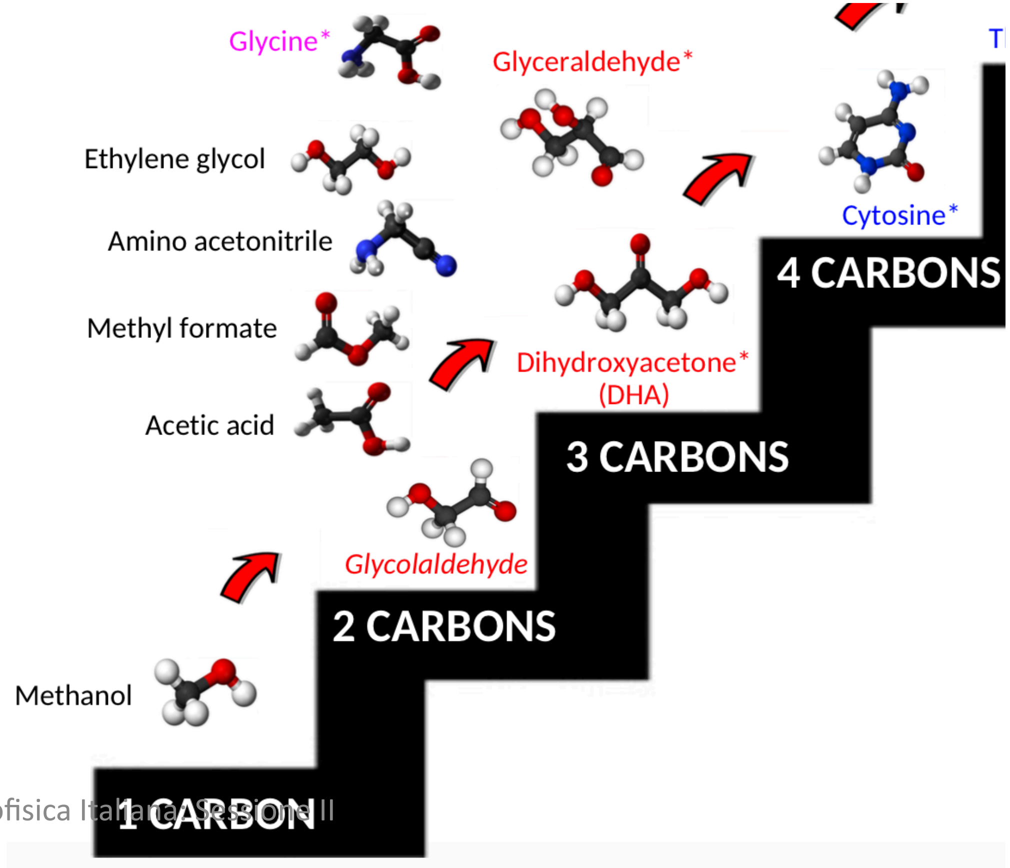
4- PLANETESIMAL FORMATION : grains agglomeration

5- PLANET FORMATION AND THE “COMET/ASTEROID RAIN”
CONSERVATION AND DELIVERY OF OLD MOLECULES + LIFE

Interstellar Medium: pre-planetary system chemistry

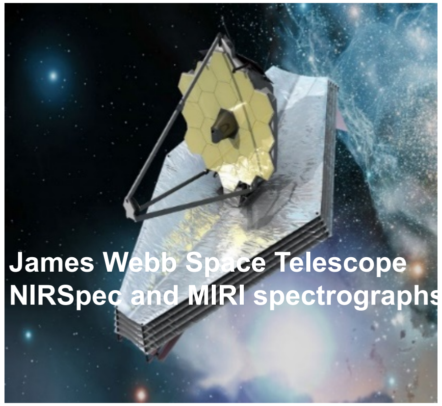
- *What is the role of the pre-solar chemistry in the Solar System chemical composition?*
- *Are complex organic molecules formed on Ice?*





Synergy between laboratory simulations and observations

STUDY OF ORGANIC SOLID MATTER FROM DENSE MOLECULAR CLOUDS TO THE SOLAR SYSTEM



WHAT IS THE EVOLUTION OF ORGANICS FROM THE INTERSTELLAR MEDIUM TO THE SOLAR SYSTEM?

COMPOSITION AND EVOLUTION OF PLANETARY SURFACES:
NATURE OF DUST CYCLE ON MARS
- ✓ Meteorological measurements;
- ✓ Hazard monitoring for equipment and human crew;
- ✓ Atmospheric electric phenomena

WHAT IS THE STRUCTURE AND POROSITY OF INTERSTELLAR ICE?
ARE COMPLEX MOLECULES TRAPPED IN THE CAGE OF POROUS ICES?

DO ORGANIC MATTER, AMINOACIDS AND BACTERIA SURVIVE IN HARSH ENVIRONMENTS (COSMIC RAYS, X-RAYS, UV PHOTONS)?

Synergy between laboratory simulations and observations

- *Laboratory results are triggering observational proposals and observational results are triggering new experiments (Labs :OAA, OACt, OANa, OAPa)*
- ***Molecular emission from several components of protostellar regions (cores, jets, disks, envelope, accretion shocks);***

  High Angular resolution → ESO-ALMA, IRAM-NOEMA, SKA

- ***ITALY has a longstanding tradition in observational and experimental astrochemistry;***

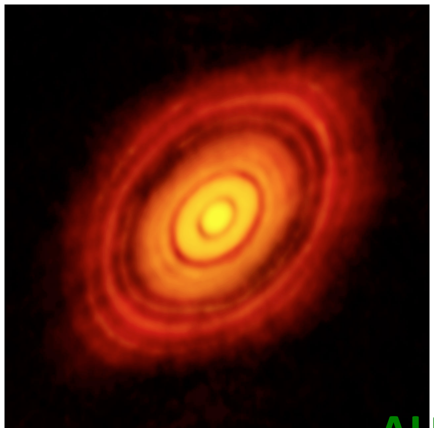
- **Synergies between INAF research units (observers, modelers and experimentalists).**
- **Effort started within the iALMA & WOW projects → to be pursued and increased**

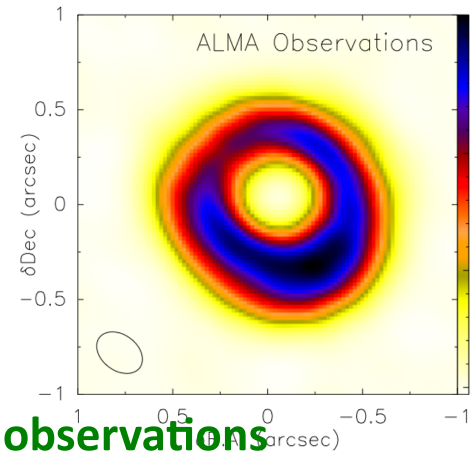
Circumstellar disks (< 10 Myr)

- Roles of gravitational instability and core accretion are still debated
  - Disk stability and dynamics: ALMA (gas mass profile and turbulence/kinematics, mass transport in disks)
  - Formation of rocky cores and solids evolution

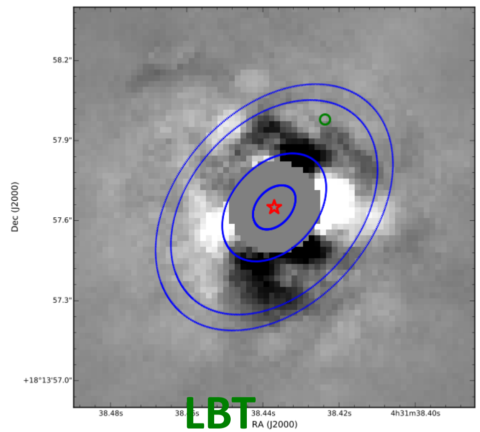
Breakthrough: epoch and location of planet formation, direct constraints of disk –planet interaction

Facilities: ALMA (gas/dust), SKA (dust), EELT (hot gas/planets)





ALMA observations



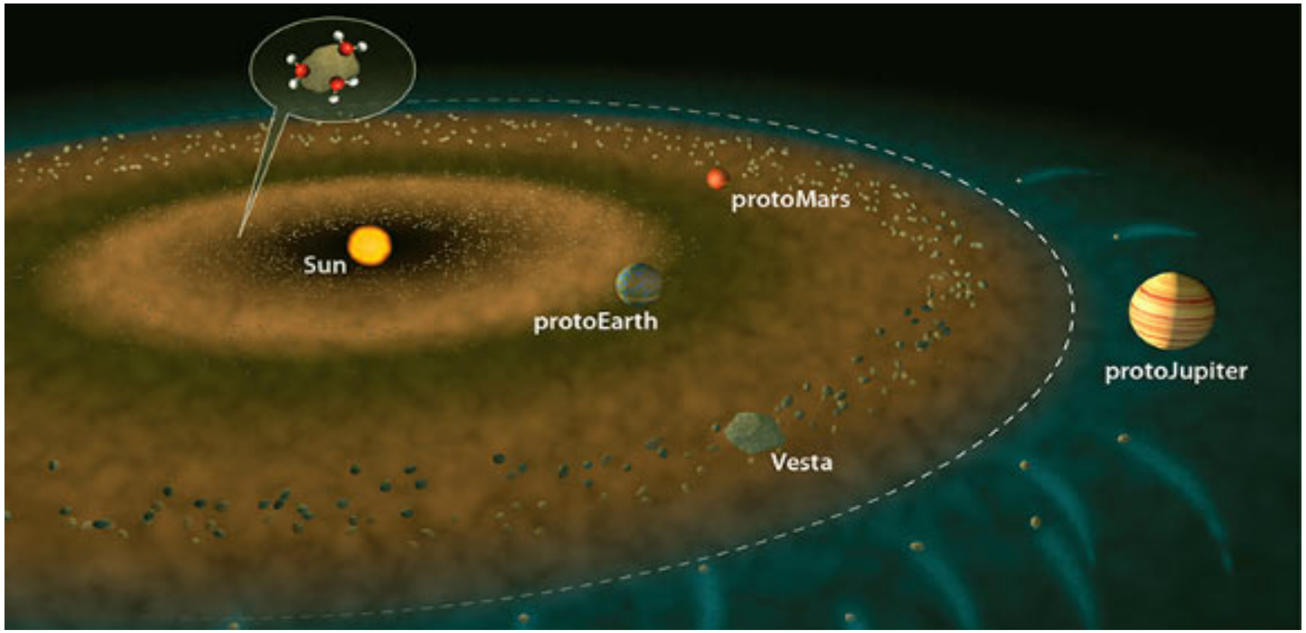
LBT

Circumstellar disks (< 10 Myr)

- Chemical evolution of protoplanetary disks
  - Snowlines and their impact on disc chemistry and structure
  - Advancing chemical complexity in disks and the delivery of volatiles on young protoplanets

Breakthrough: direct measurement of disk thermo-chemical structure (and its evolution)

Facilities: ALMA (cold gas), EELT (warm-hot gas)

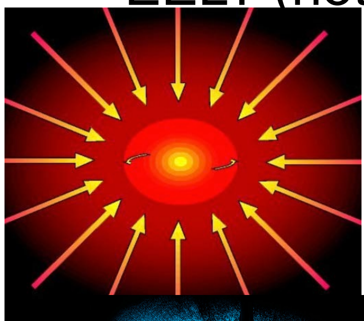


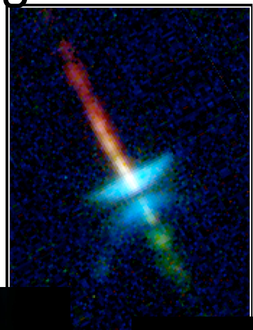
Circumstellar disks (< 10 Myr)

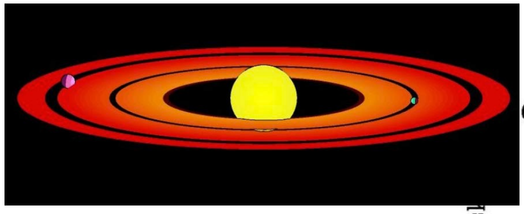
- Disk evolution timescales and processes
  - Disk evolution: role of wind in regulating transport of material in the disk and in disk clearing
  - Role of disk-planet interaction in self regulating planet formation
  - Role of giant planets

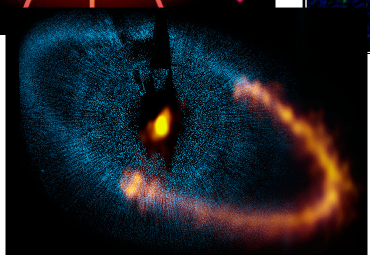
Breakthrough: direct detection of disk magnetic structure and disk wind connection

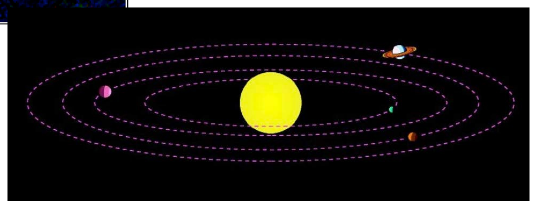
Facilities: ALMA (gas, polarization), SKA (ionised gas, polarization), EELT (hot gas in wind)

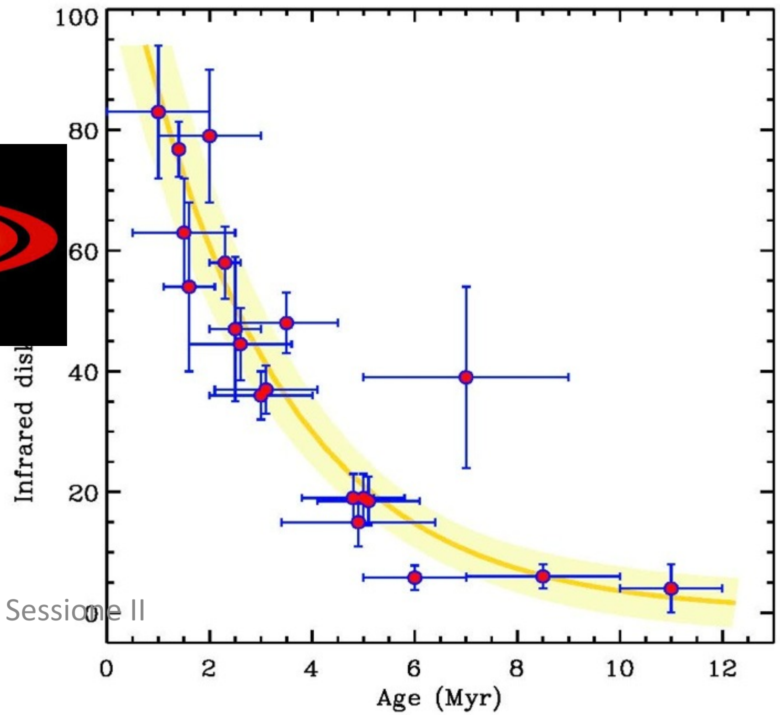












Early Planetary systems (0.01-1Gyr)

- Terrestrial planets and super-Earths complete their formation; they can incorporate water at this stage
- Planetary systems with multiple giant planets become unstable: orbital rearrangement and global bombardment

Early Planetary systems (0.01-1Gyr)

- Is water one of the "building materials" of terrestrial planets or is it brought to the formed planets later?
- Is this a by-product of the evolution of a planetary system or does it require a catastrophic event?
- All current models link the water of the terrestrial planets to the action of giant planets: what about planetary systems without giants?

Early Planetary systems(0.01-1Gyr)

APPROACH

- Study of minor bodies in SS (role of comets and asteroids in water delivery)
- Comparison of architectures and atmospheres of young planetary systems – *A challenge* -

NEEDS

- Modeling: high performance computing

Formation - dynamics + atmospheric abundance

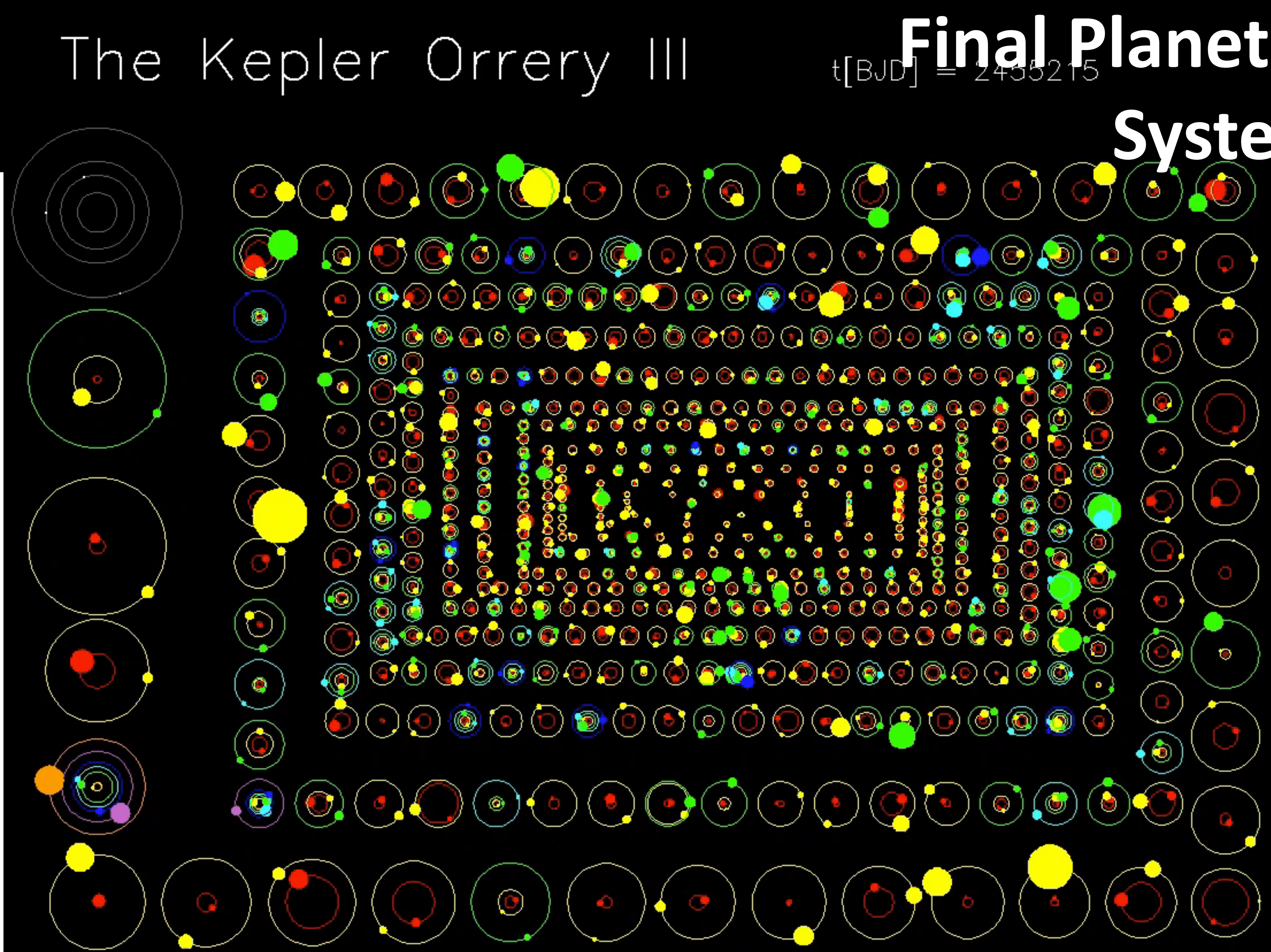
- Large sample of young planetary systems *(PLATO)*
- Atmosphere of young (rocky?) planets

Final Planetary systems (>1Gyr)

The Solar System is just one of the possible outcomes of planetary formation: it provides us with data that allow for a detailed testing of models and the reconstruction of the chronological sequence of events

Exoplanets provide us a view of all possible outcomes of planetary formation and evolution (although this view is still limited and biased

Final Planetary Systems



The Exoplanetary systems Architecture & dynamics

Which planetary systems architectures are possible (and with which frequency)?

What is the role of the initial conditions?

Host star, disk properties, stellar crowding, metal abundance, nearby massive stars,…

How works the dynamical evolution?

How giants shape the entire planetary systems?

The Exoplanetary systems Architecture & dynamics

Our knowledge is still in a "pre-HR diagram" phase

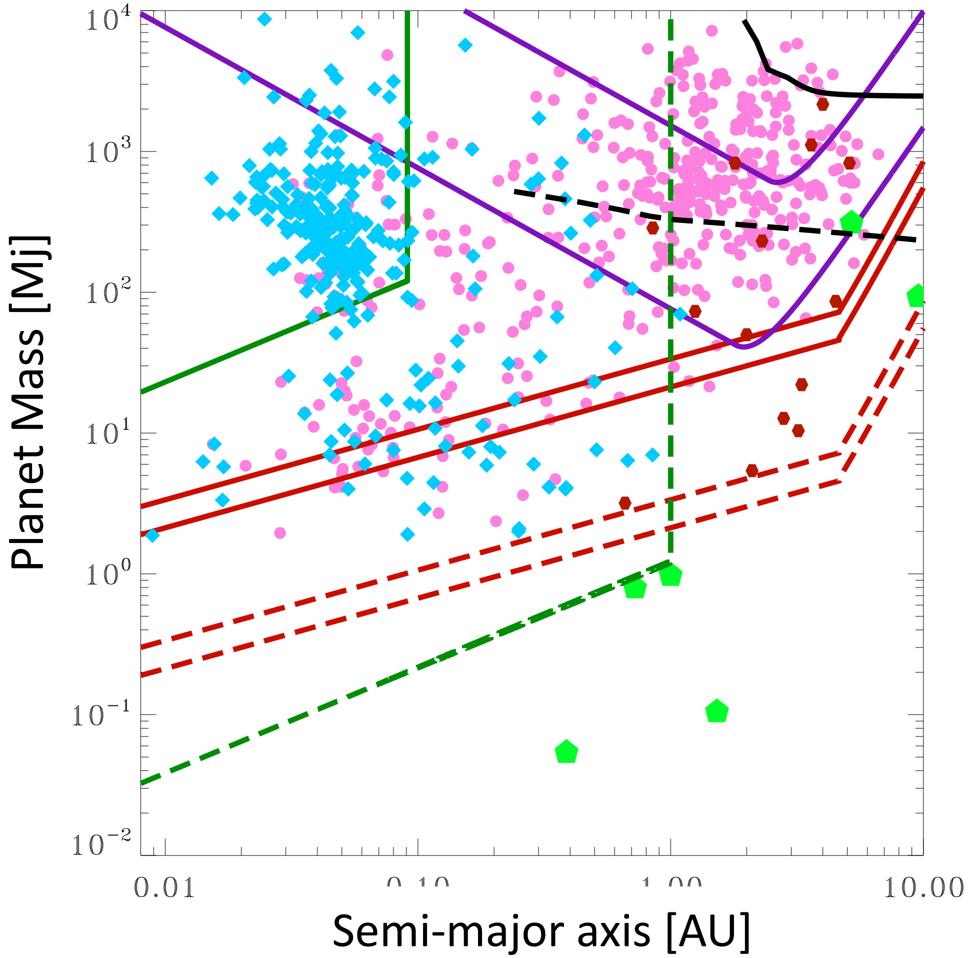
We need a population of planetary systems STATISTICALLY COMPLETE → small planets, large orbits, diversity of environments, different host,...

The Exoplanetary systems Architecture & Dynamics

Small planets, large orbital distance still missing

New facilities will fill a significant portion of the unexplored regime

HARPS-NwLaser-Comb, ESPRESSO, SPHERE, GAIA, CHEOPS,TESS **, PLATO, ELT-PCS**

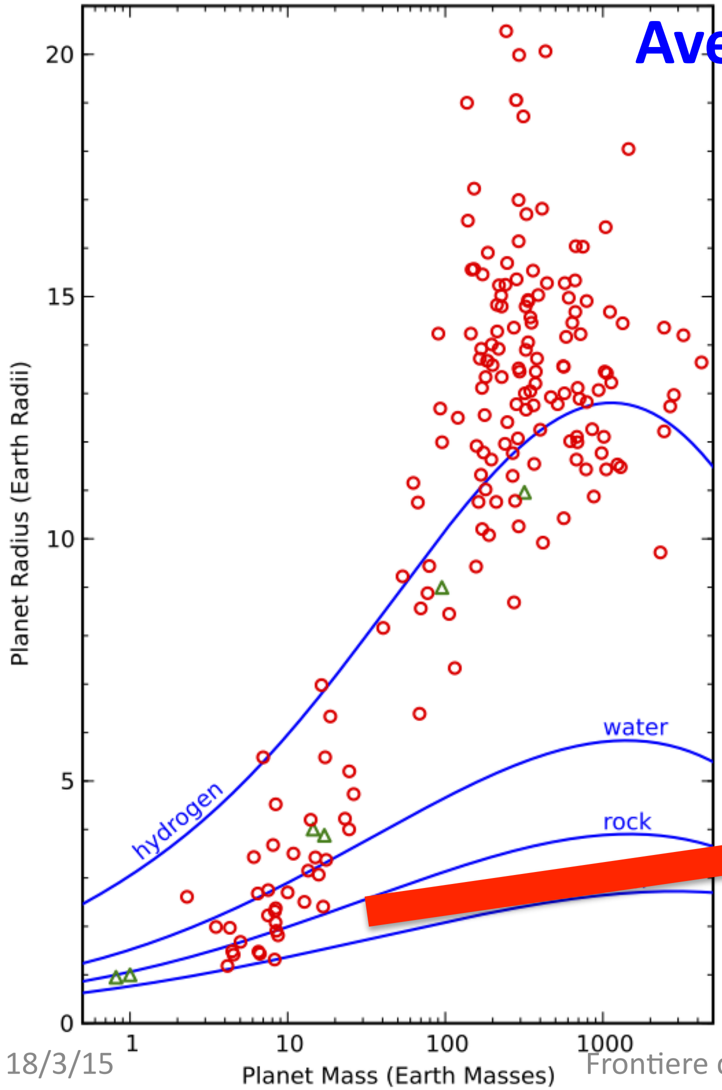


The Exoplanetary systems Architecture & Dynamics

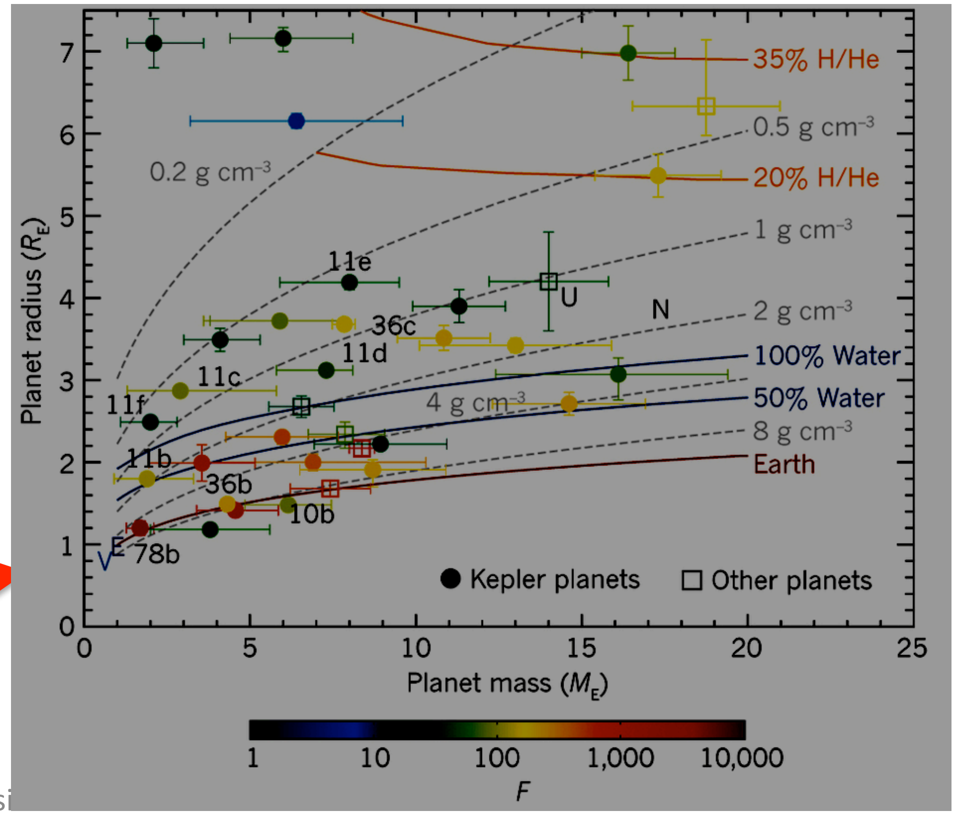
	Instrument	Method	When
(E)/SE -HZ bright G	HARPS-Laser Comb	vrad	2016
E/SE in HZ G/M	ESPRESSO	vrad	2016
J Young planets, large distance	SPHERE	imaging	today
J large distance F-M stars	Gaia	astrometry	2017-19
Young planets & multiplanet systems	LBT	Imaging	End 2017
E in bright G stars	CHEOPS	transits	2017-20
E in HZ M stars	*TESS*	transits	2017-21
E in HZ G stars	PLATO	transits	2023-26
N & J large distance	ELT_PCS	imaging	> 2023 -

The Exoplanetary systems Physics: internal structure

Average density → hint on internal structure



*Accurate planetary (and **stellar!!**!) radii are needed to discriminate among different compositions*

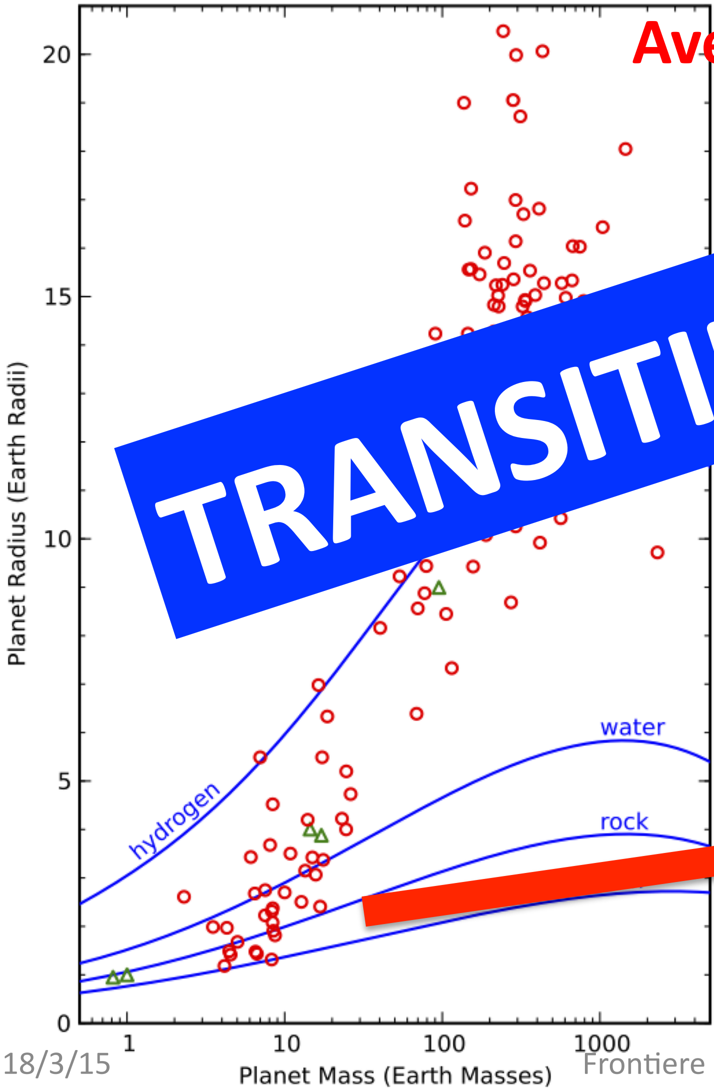


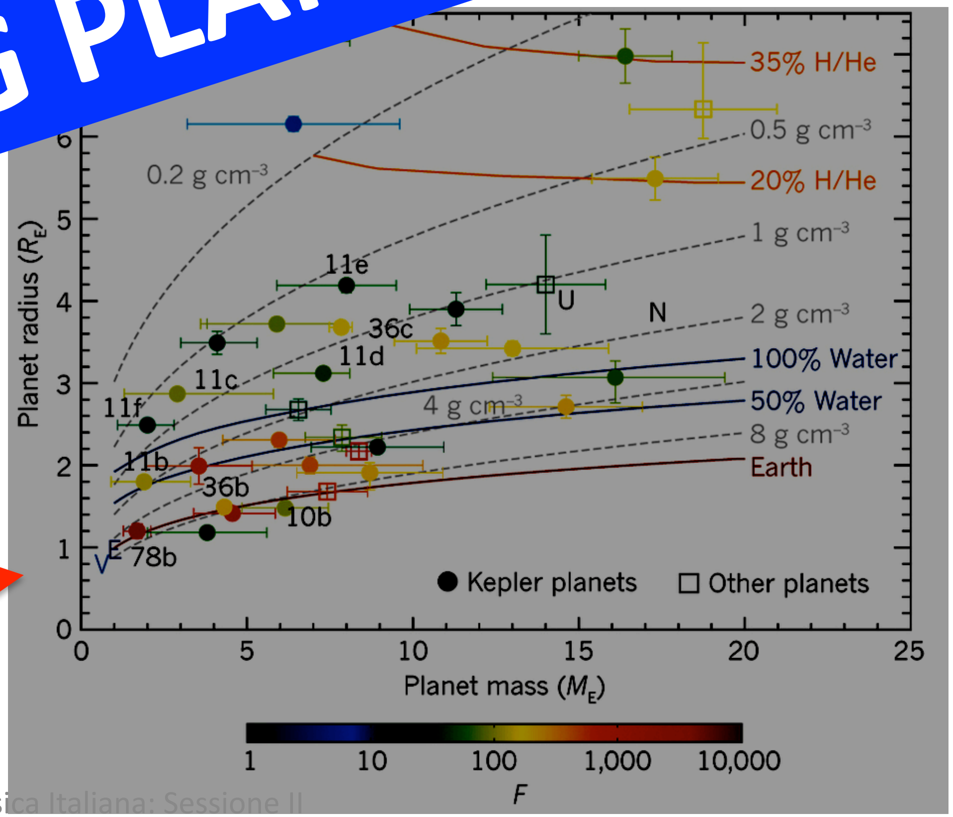
The Exoplanetary systems Physics: internal structure

Average density → hint on i... al structure

Accurate pl... re needed
to ... compositions

TRANSITING PLANETS!!





The Exoplanetary systems Physics: transiting planets

For planetary science transiting planets have the same role than eclipsing binaries have in stellar astronomy

- Determination of inclination → orbit, mass precise determination
- The only way to measure the radius –> average density –> planetary structure
- Atmospheric analysis (eclipse and occultation)

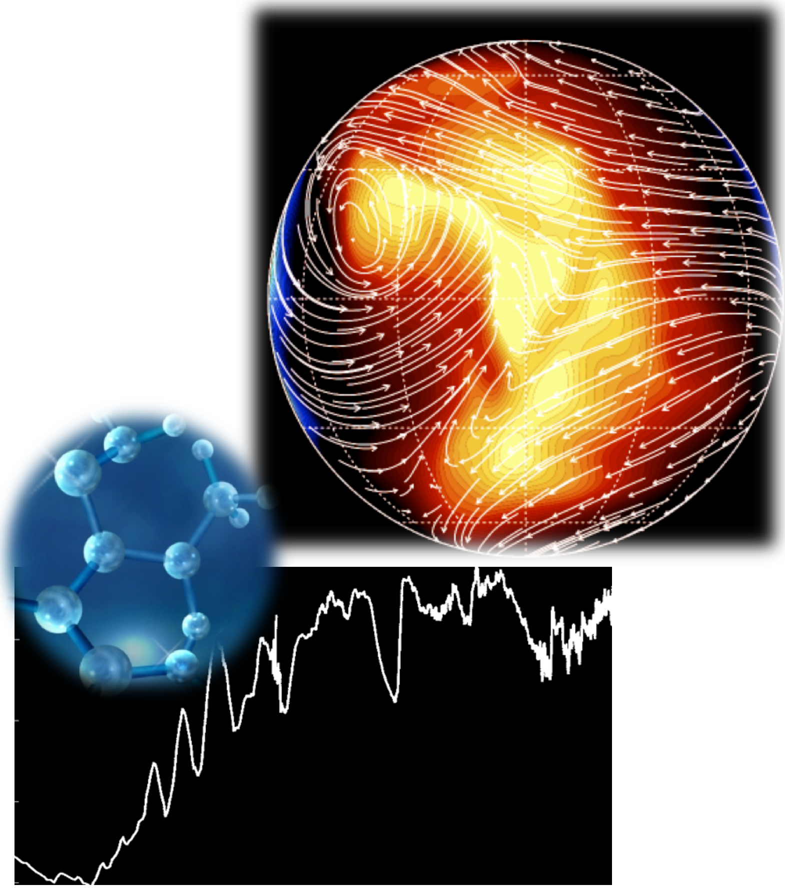
+ ....

A large number of dedicated ground and space projects

Conceptually simple: stability is the issue.

Large facilities from space: ***important italian involvement (ESA Cheops & PLATO)*** *both in instruments and science*

The Exoplanetary systems Physics: atmospheres

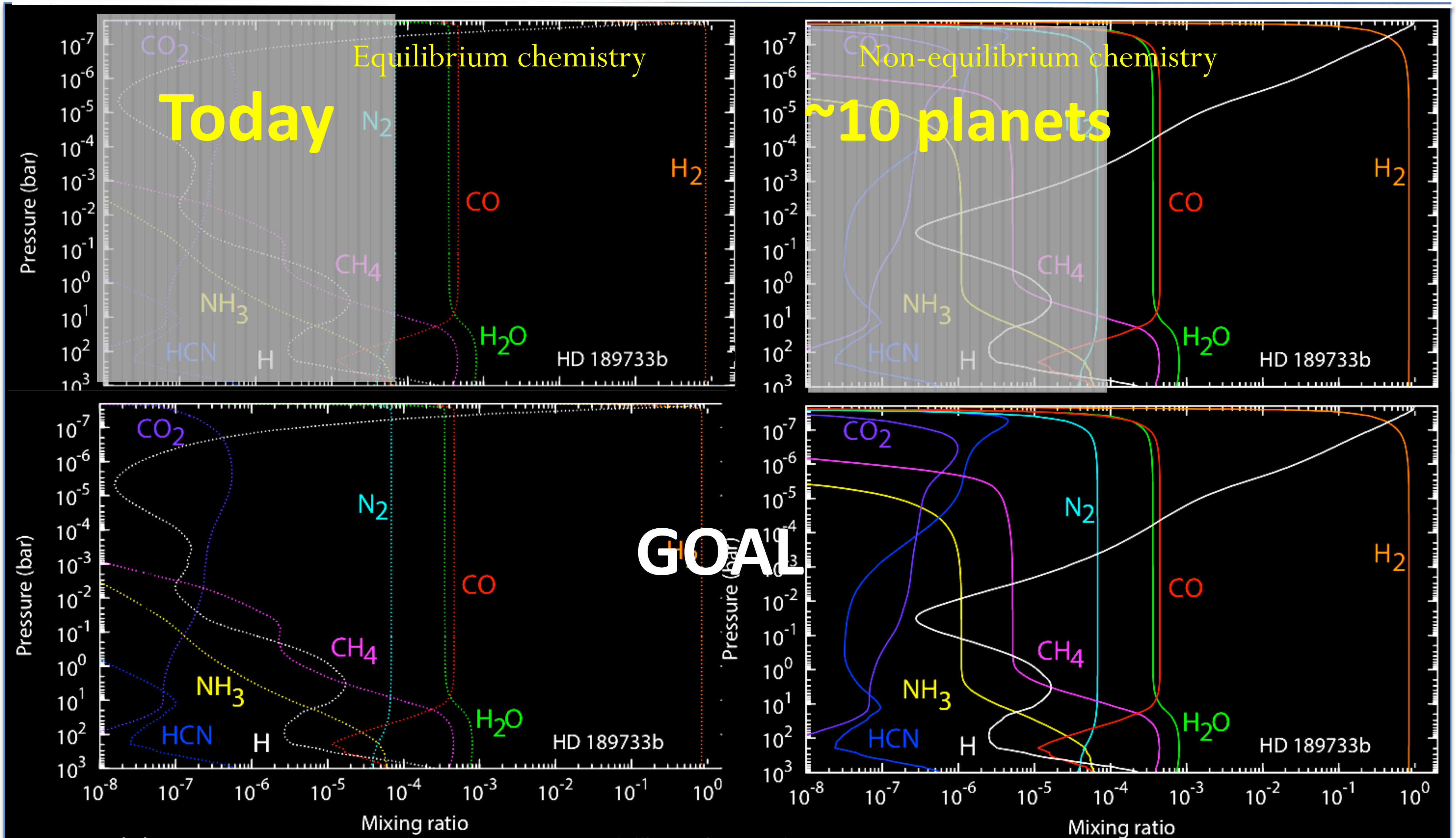


Which are the main properties that determine the characteristics of a planet and its following evolution?

- ***Planet mass***
- ***Orbital distance***
- ***Formation site***
- ***Stellar luminosity and color***
- ***temperature***
- ***Proto-planetary disk lifetime***
- ***.....***

Is it possible a "population" description for planets?

Exoplanetary systems
Physics: atmospheres



The Exoplanetary systems
Physics: atmospheres

Breakthrough for the next decade: **JWST**

	HOT	WARM	TEMP/ICE
Giants (up to ~150)	**Chemistry Vert. structure History Equilibrium vs. non-equiibrium Horizontal structure (few)**		
Mini-Nept (~50) (around dM)	**Chemistry Vert. structure History Equil. Vs. non-equil. Horizontal structure (few)**		
Super Earth (~1-2) (around dM)	**Main components**	**Main components**	**YES/NOT Main components**

A possible program of Giants+mini-Neptunes + Super Earths → 4800h

?

Instrumental issues still To be fixed: operations, stability, calibration

Beichman et al. 2014

No italian involvement

WG after JWST INAF day?

The Exoplanetary systems Physics: atmospheres

Breakthrough for the next decade: **HIRES@ELT**

Individual lines (Area & Res)

→ *Avoid Earth atmosphere*

→ *Probe directly a range of altitude*

→ *Global circulation day side*

→ *Various phases of the orbit*

→ *Limit → O_2 in Earth around M3 → 30 transits (Snellen et al. 2013)*

NEEDS TO REINFORCE THE ITALIAN PRESENCE FOR EXOPLANETS IN HIRES

Preparation with simulations, CRIRES,

The Exoplanetary systems
Physics: atmospheres

Both JWST & ELT have issues with scheduling, calibrations, and stability.

Lack of a dedicated project optimized for atmospheres

Proposal in M4: ARIEL to study the hot and temperate population **(important italian role)**

The Exoplanetary systems
Physics: atmospheres

NEEDS:

- Development of **models** of atmospheres – from solar system to exoplanets – different planets, different host and environment
- Identification of **diagnostics**
- **Laboratory** activities

Good competence of Italian community

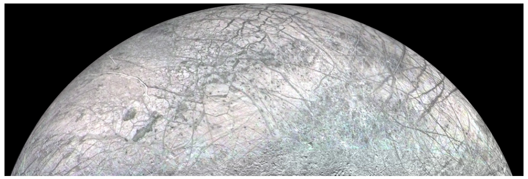
Synergy between Solar System and exoplanetary systems

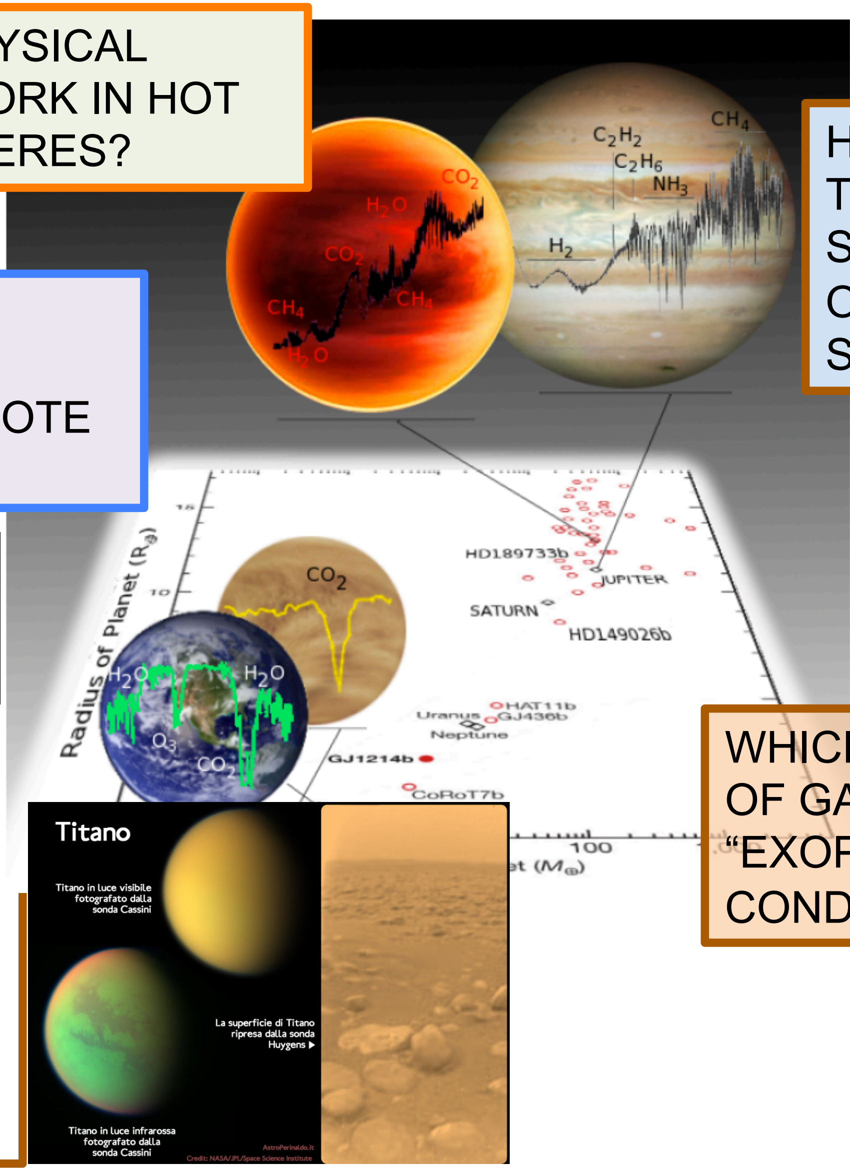
Laboratory Analogues of Solar System and Extra Solar Planet Atmospheres

WHAT ARE THE PHYSICAL PROCESSES AT WORK IN HOT PLANET ATMOSPHERES?

HOW LIFE COULD MODIFY THE ATMOSPHERE OF SUPER EARTHS ORBITING OTHER STARS THEN THE SUN?

WHAT ARE THE MAIN SIGNATURES OF LIFE RECOGNIZABLE BY REMOTE OBSERVATIONS?





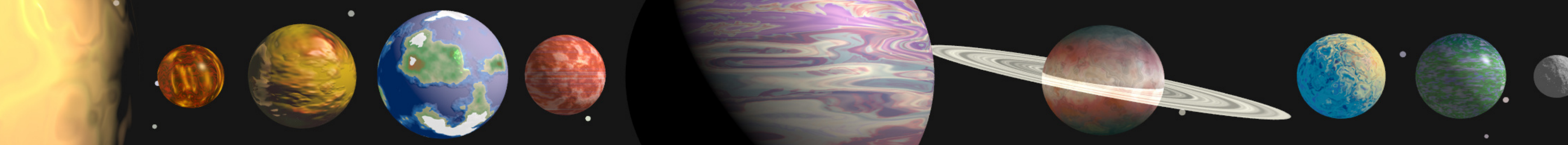
MAY EXPLORATION FINDS TRACES OF BIOLOGICAL ACTIVITIES OUT OF THE SOLAR HABITABLE ZONE (MARS, EUROPA, TITAN …)?

WHICH ARE THE PROPERTIES OF GAS MIXTURES IN "EXPLANETARY" CONDITIONS?

The Solar System
Normal or exceptio

Chemical peculiarities?

We have already detected organic molecules present in the comets. In the next year we expect further progresses:



Characterization of primordial bodies (Stardust, Rosetta, Dawn, Sample return missions)
Collection of ISM (sample return, stratospheric material)
Comparison SS and exosolar comets

See F. Capaccioni presentation

The Solar System
Normal or exception?

The interplanetary space: a lab for interactions of plasma with magnetic fields, magnetic reconnection, wave-particle interaction

- Life origin → origin of magnetic envelope protecting the solar system, dependence on solar activity and magnetic configuration, particle, X-rays, gamma rays

Interaction between Sun and planets

- *Origin and control of the heliosphere*
- *Solar activity and heliosphere variability*
- *Interaction between solar wind and planetary magnetosphere/ionospheres*
- *Which (and where) are the plasma heating and particle accelerating processes in the solar corona and heliosphere?*

Infrastructures:

Mainly focused on the base of heliosphere

Many in operation

Approved

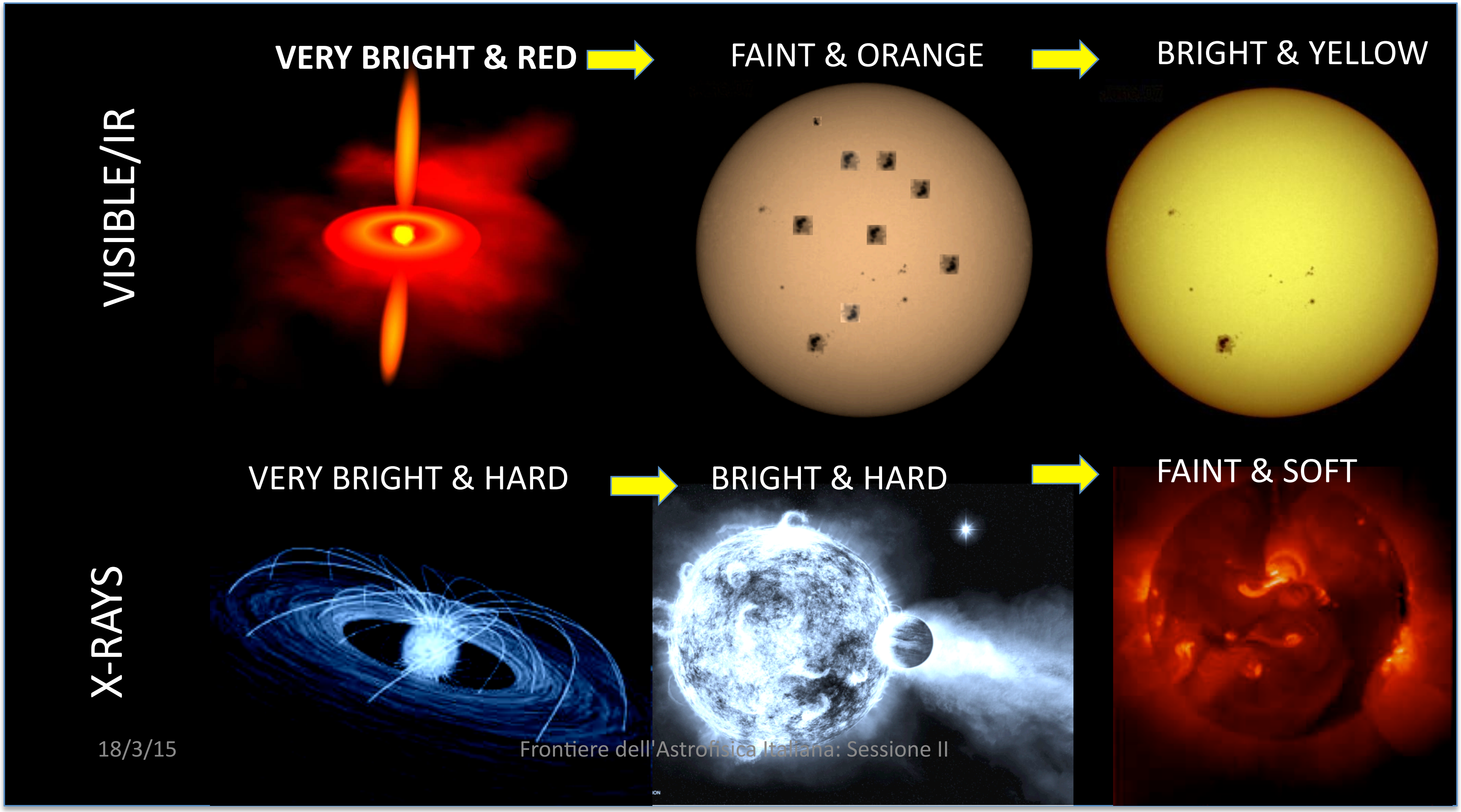
- **Solar Orbiter** (ESA, NASA) : will study the origin of heliosphere in situ and with remote sensing (particles, wave, radiation, magnetic fields) – Polar regions
- Solar Probe + (NASA) in situ
- SCORE(ASI)+HERSCHEL (NASA) – Helium
- ASPIICS (ESA, Proba3) coronograph (1.05 Rsun)

Proposed

- EPIC - Solar C – (ESA) Solar atmosphere
- MASC(ESA, China) Magnetograph, coronograph
- THOR (ESA) Plasma analyzer in situ

The Solar System: The early Sun

The "star" at the center of the early solar system was very different from today



The Solar System: The early Sun

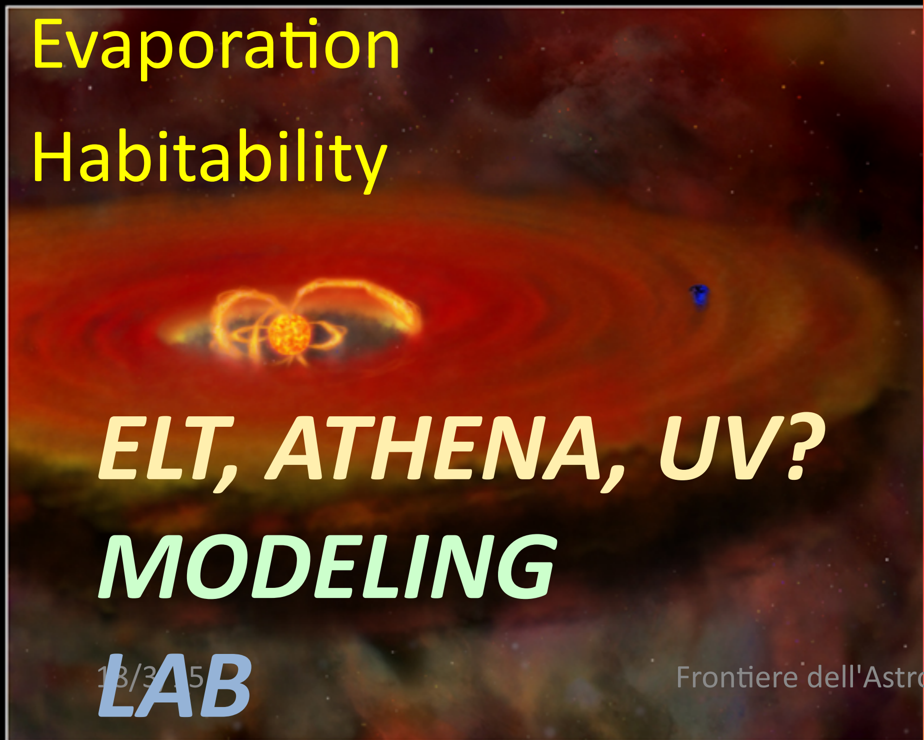
- How the stellar radiation incident on circumstellar disks and planets evolve?
- Which is the effect of stellar evolution on hot planets (and viceversa)?
- How change the habitable zone during the stellar evolution?

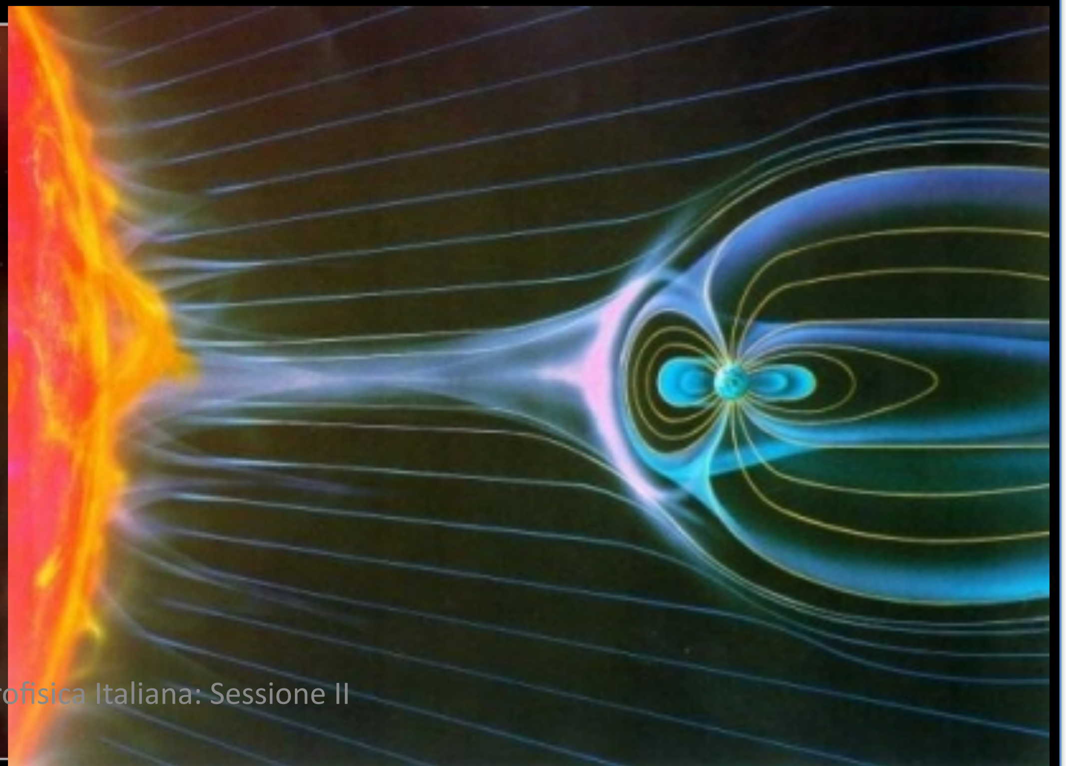
The Exoplanetary systems
Interaction star-planets

High stellar activity and close planets may enhance star-planet interaction

Magnetospheres interaction → flares

Tidal interaction





Evaporation

Habitability

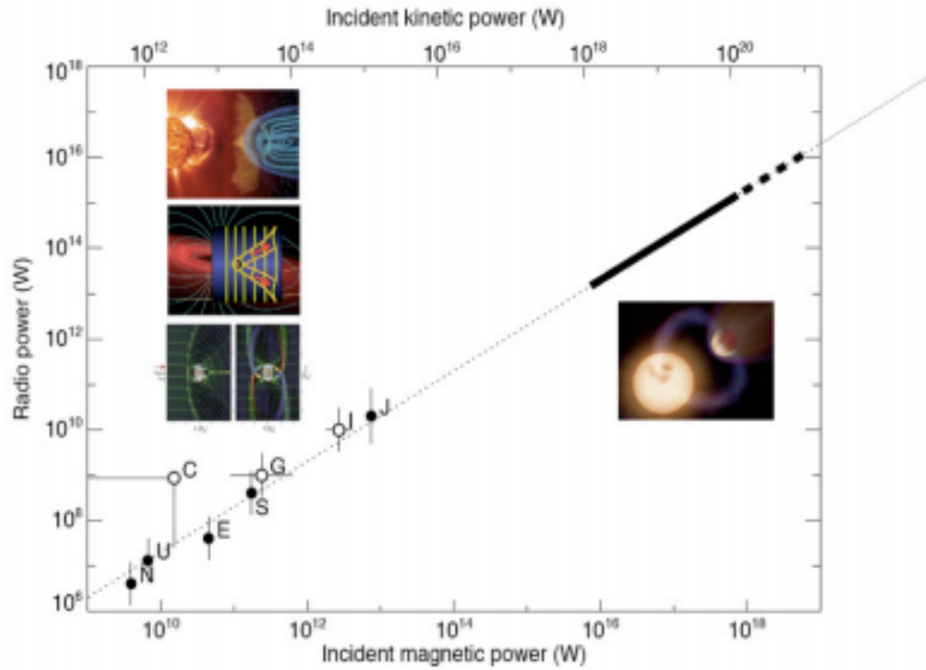
ELT, ATHENA, UV?

MODELING

LAB

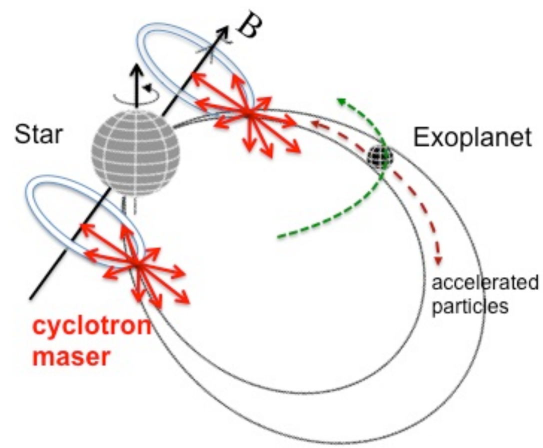
The Exoplanetary systems
Interaction star-planets

- **Stellar wind – planetary magnetosphere**



From kHz to MHz (close-in planet)
Power comparable with the stellar one

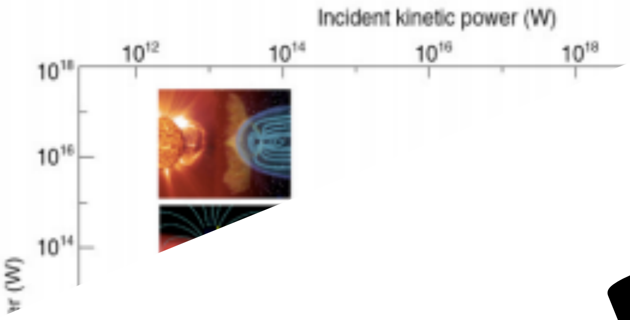
- **Planet crossing the stellar magnetosphere**



GHz Emission – It could be the reason of
High emission of a group of stars

The Exoplanetary systems
Interaction star-pl nets

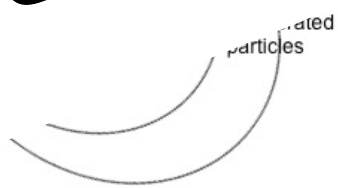
- **Stellar wind – planetary magnetosphere**



- **Plar**

SKA!

!



…ct)
…ne stellar one

GHz Emission – It could be the reason of High emission of a group of stars

Habitable environments: Identification, Exploration, Characterization

- The previous studies will contribute to determine the **likelihood** of an environment to **be able to generate and support life during stellar evolution**. Habitability indicators, including biosignatures, must be interpreted within a planetary and environmental **context both in Solar System and in exoplanetary environments**

Main future large infrastructures

	ISM	Discs	Exoplanets
ALMA	X	X	
IRAM	X	X	
SKA	X	X	X
ELT	X	X	X
ATHENA		X	X
JWST		X	X
CHEOPS			X
PLATO			X
ARIEL			X
LBT			X
GAIA			X

The SUN
Solar Orbiter
Bepi Colombo
ASPIICS
SCORE
HERSCHEL
EST
MASC

High level italian involvement (specially from space)

To be reinforced:

- **ELT (JWST) for Exoplanets**

(acceptable for ISM & Disks)

- **Investment on ALMA observation**
- **Preparation for SKA**

Solar System exploration rationale

Planetary sciences seek answers to basic questions such as

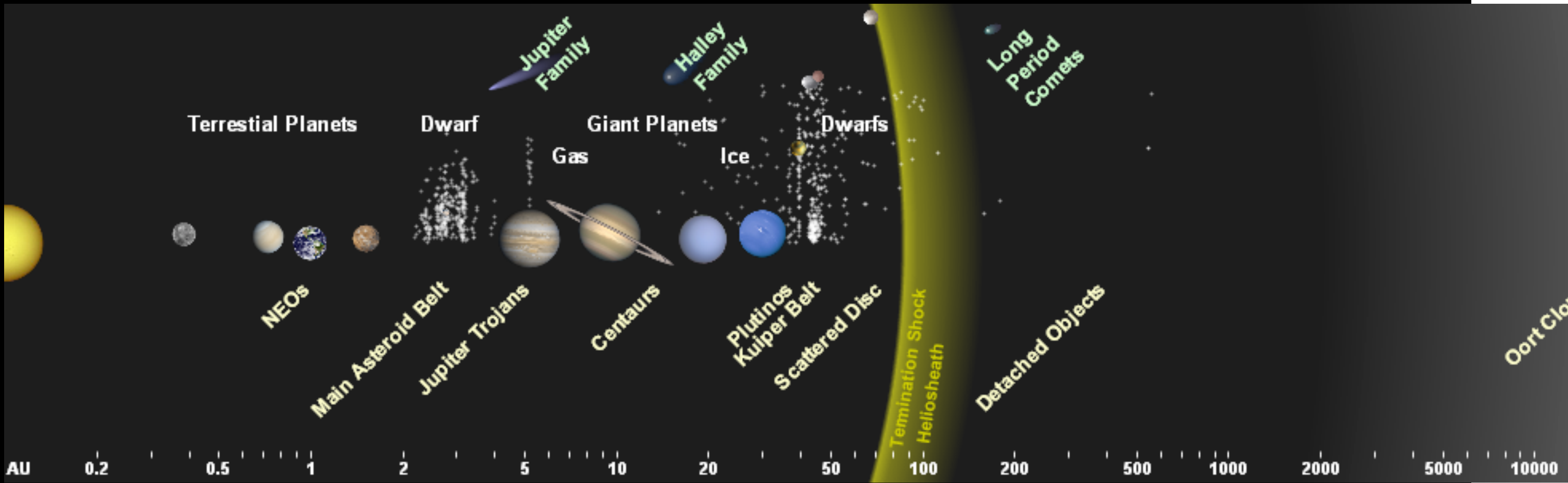
- how do planets form,
- how do they work, and
- why is at least one planet the abode of life.

To do this we need exploratory missions by robotic spacecraft able to investigate every type of planetary body in the Solar System.

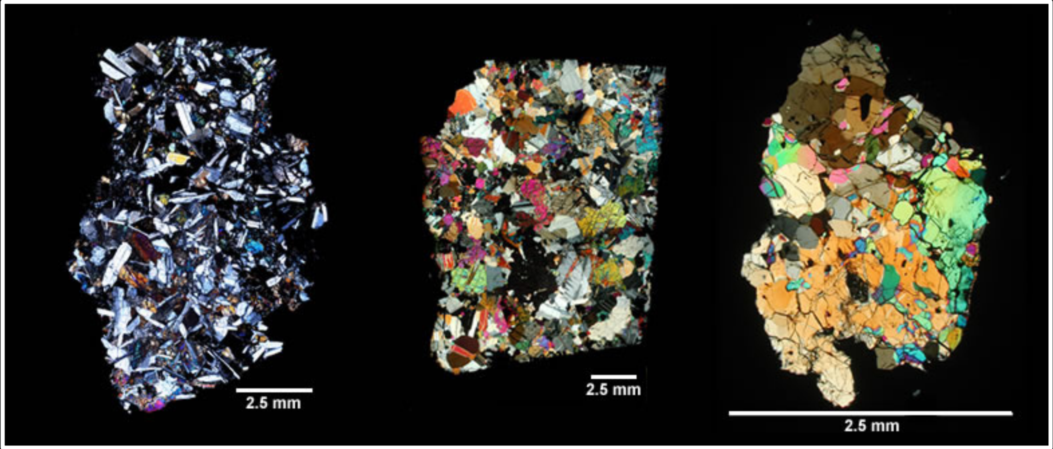
A most important task is the sample return for detailed study on ground

These robotic missions must be complemented by investigations with ground- and space-based telescopes, laboratory studies, theoretical studies, and modelling activities.

Primitive bodies: building blocks of the solar system



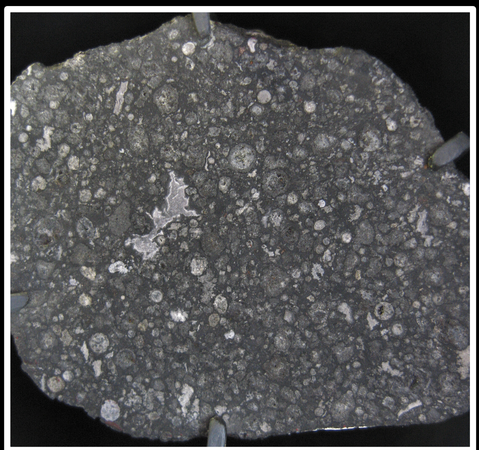
- Understand presolar processes and other formative processes in the solar nebula recorded in the materials of primitive bodies;
- Assess the nature and chronology of planetesimal differentiation
- Determine the composition, origin and primordial distribution of volatiles and organic matter in the Solar System;
- Understand how and when planetesimals were assembled to form planets;
- Constrain the dynamical evolution of planets by their effects on the distribution of primitive bodies.

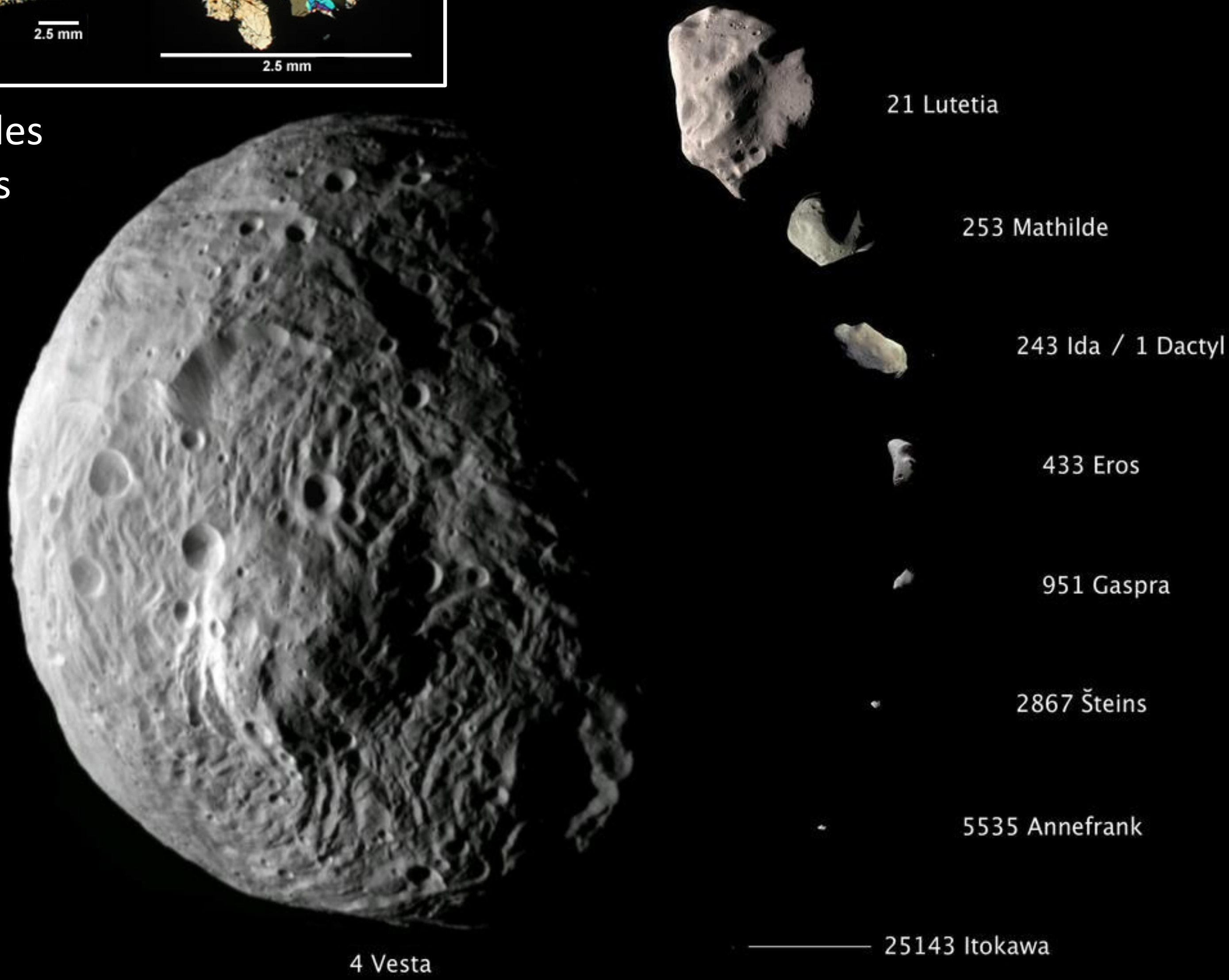


Primitive bodies: building blocks of the solar system

Basaltic achondrites, samples from evolved parent bodies

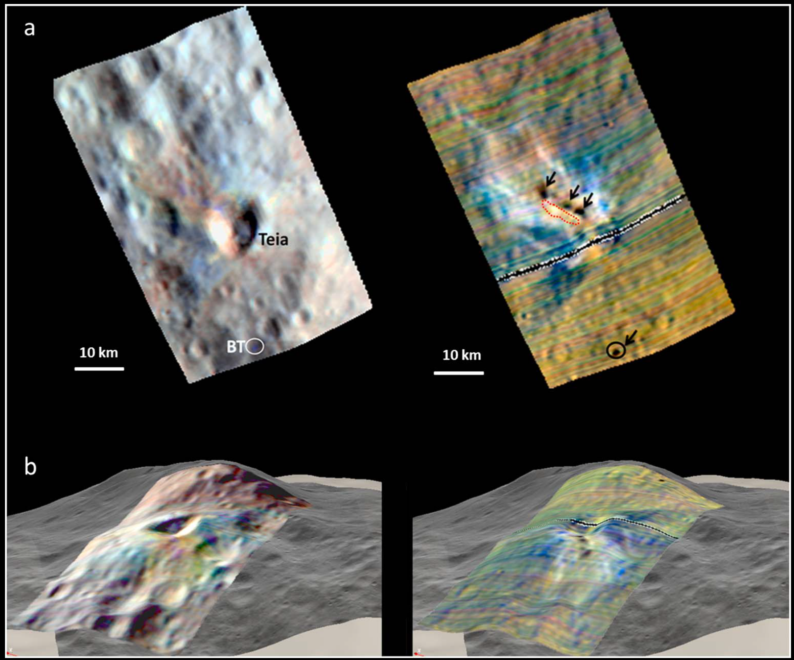
Carbonaceous Chondrites. Samples from primitive parent bodies



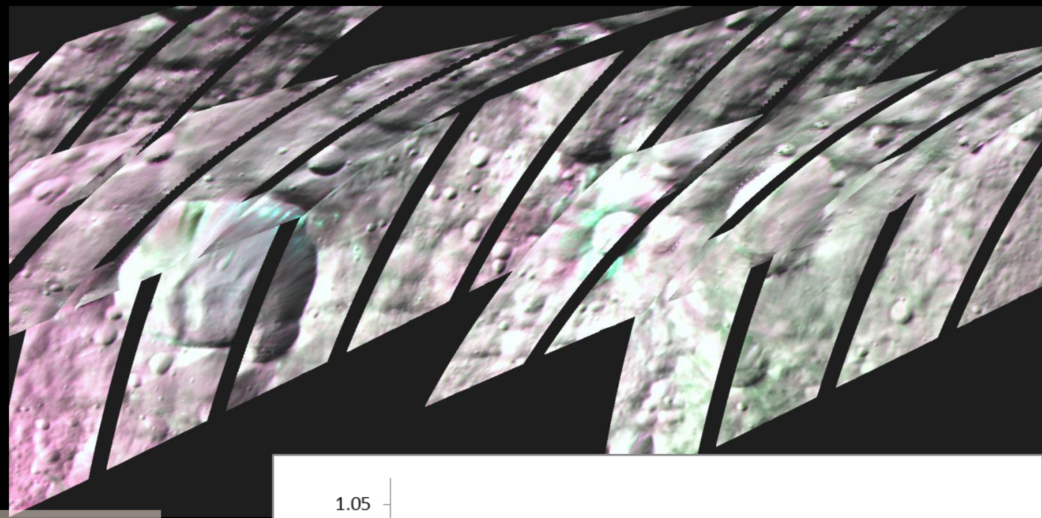


Primitive bodies: building blocks of the solar system

VIR at Vesta

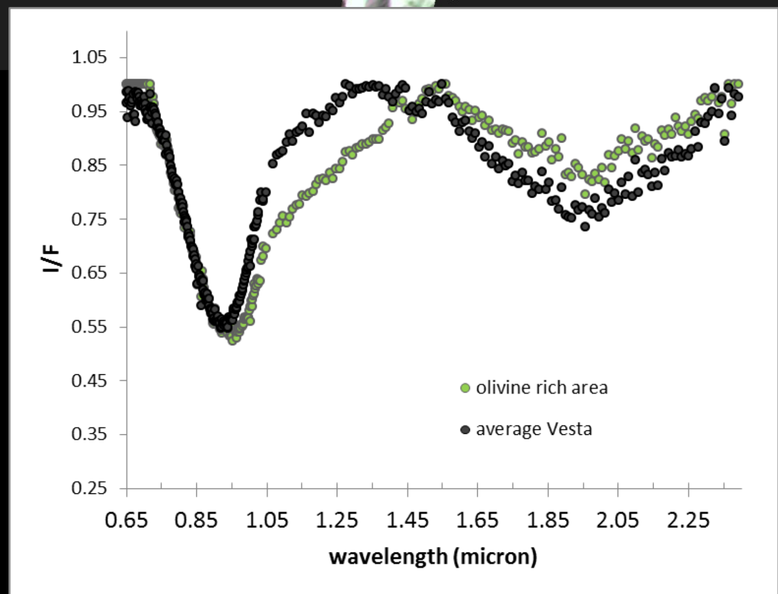


Evidence of volcanic activity
(De Sanctis et al, GeoRl2014)



Vesta is a differentiated body with evidence of resurfacing on its surface.

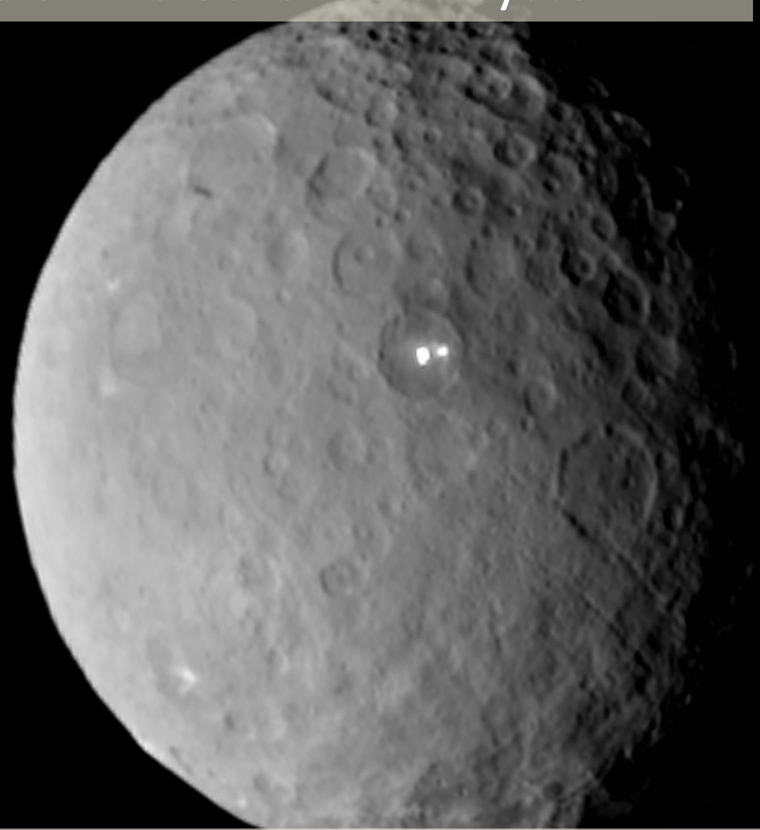
Vesta resembles the rocky bodies of the inner solar system, including the Earth.



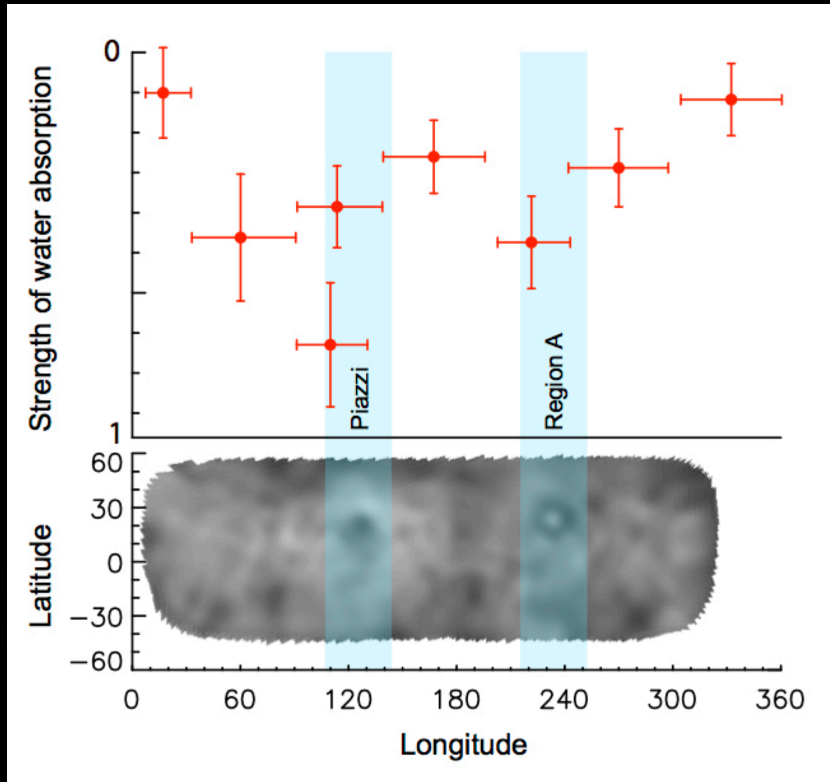
Olivine on the surface of Vesta
(Ammannito et al, Nature 2014)

Primitive bodies: building blocks of the solar system

Ceres, by contrast, has a primitive surface containing water-bearing minerals, and may possess a weak atmosphere. It appears to have many similarities to the large icy moons of the outer solar system.

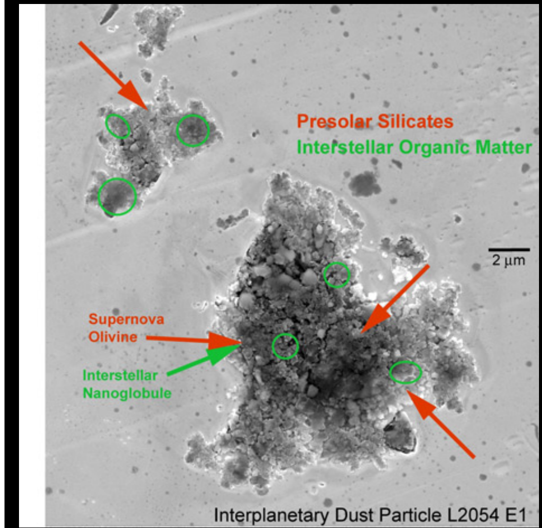


Dwarf Planet Ceres (D=1000km)as observed by the Dawn S/C

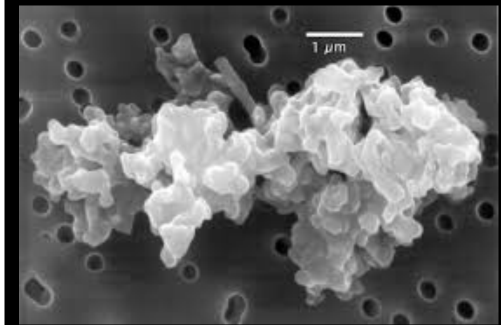


Water absorption variability detected at Ceres by Herschel on March 2013

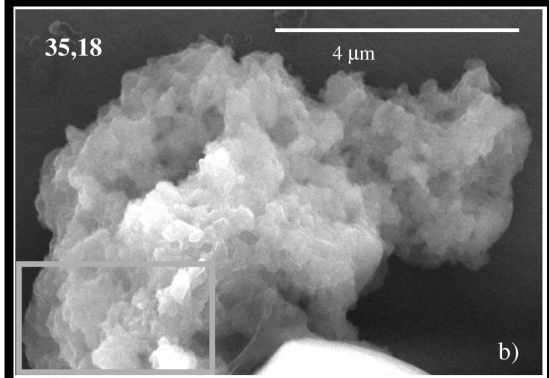
Primitive bodies: building blocks of the solar system

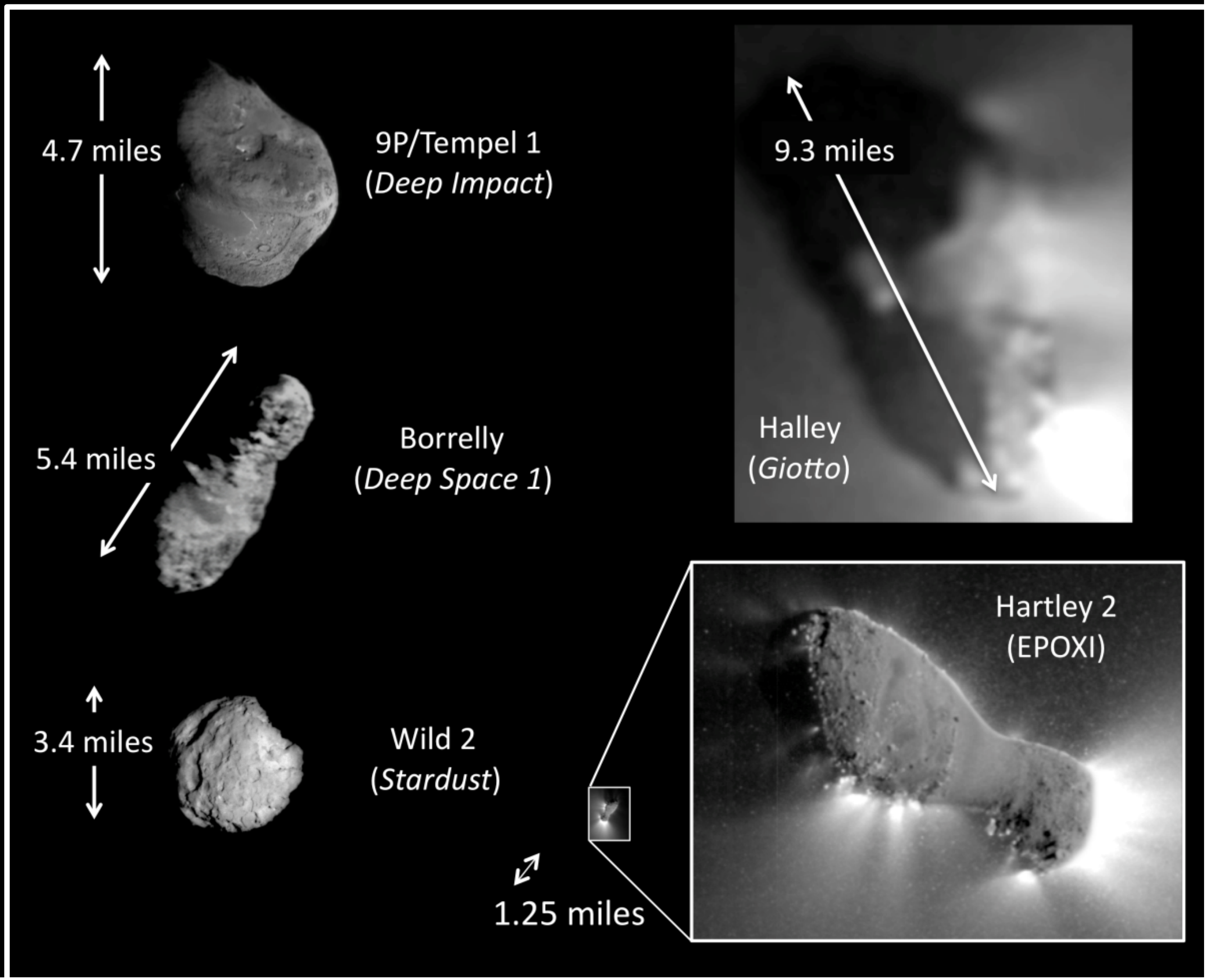


Interplanetary dust particles



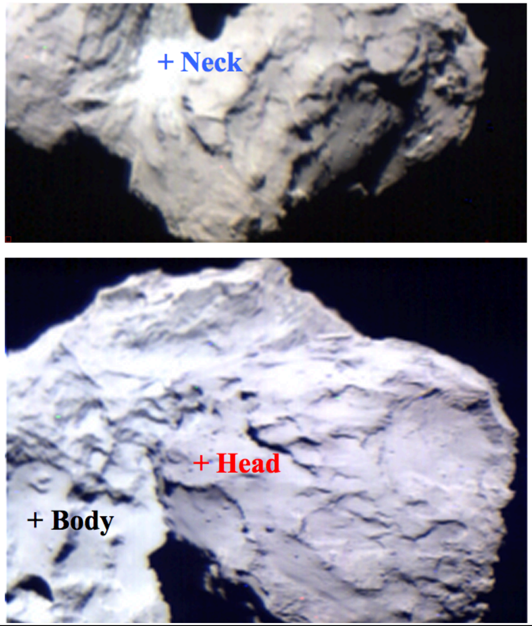
Stardust /Wild2 particle
(Rotundi et al, 2008)

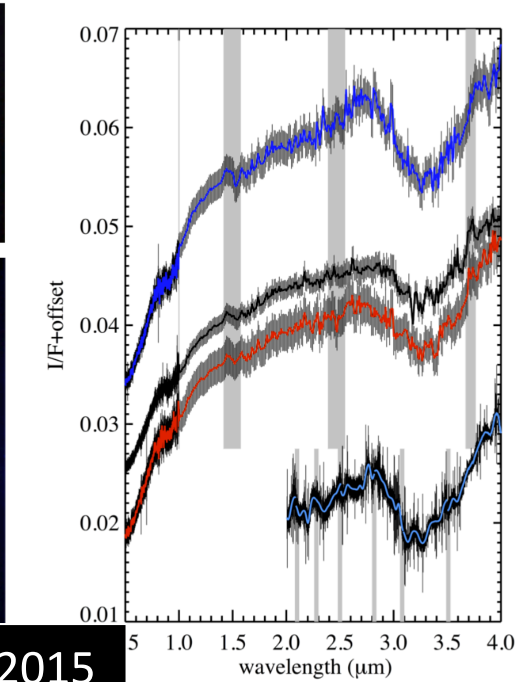




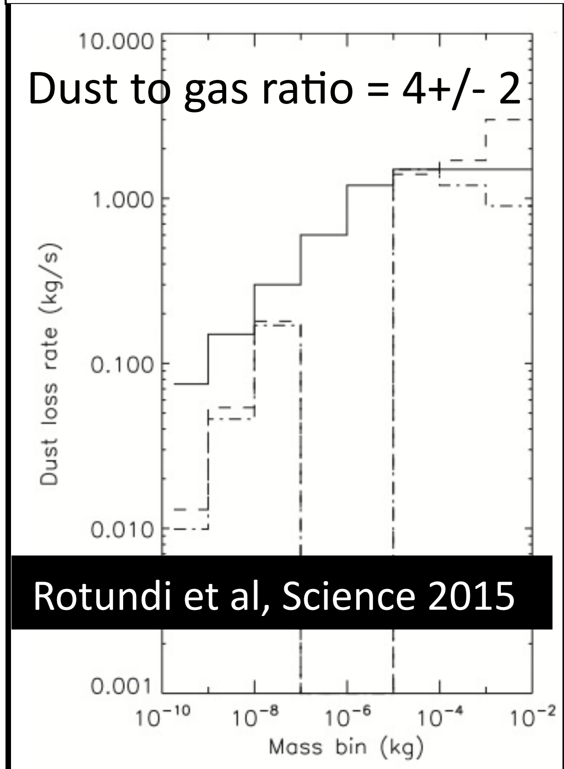
The Rosetta mission to comet 67P/Churyumov-Gerasimenko

A "genuine" primitive Kuiper Belt Object





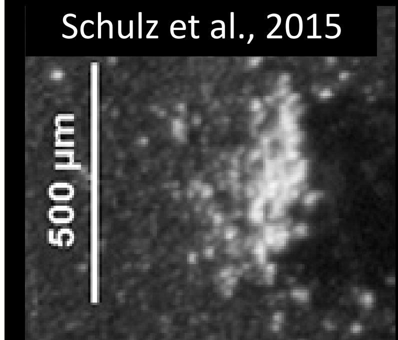
Capaccioni et al, Science 2015



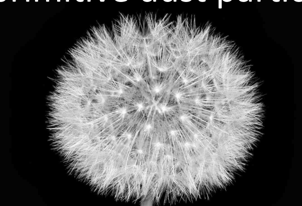
Dust to gas ratio = 4+/- 2

Rotundi et al, Science 2015

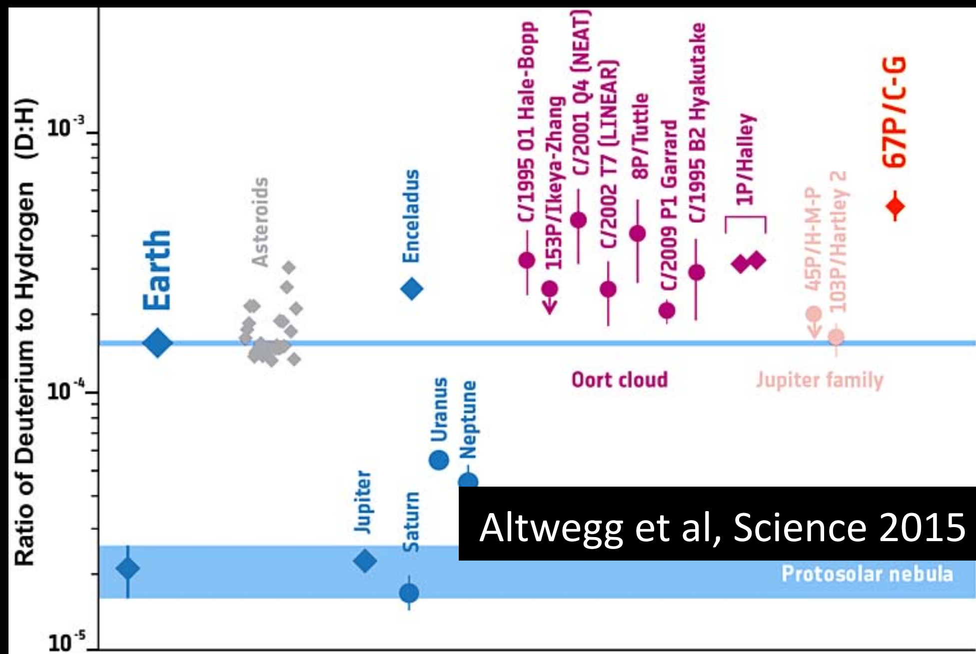
Schulz et al., 2015



Very Fluffy and primitive dust particles



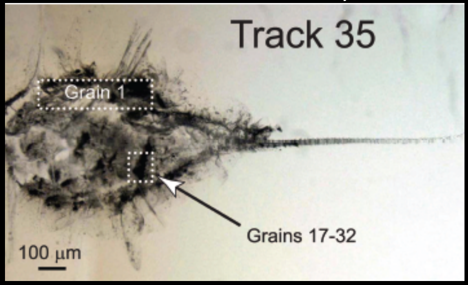
Fulle et al., 2015, ApJL



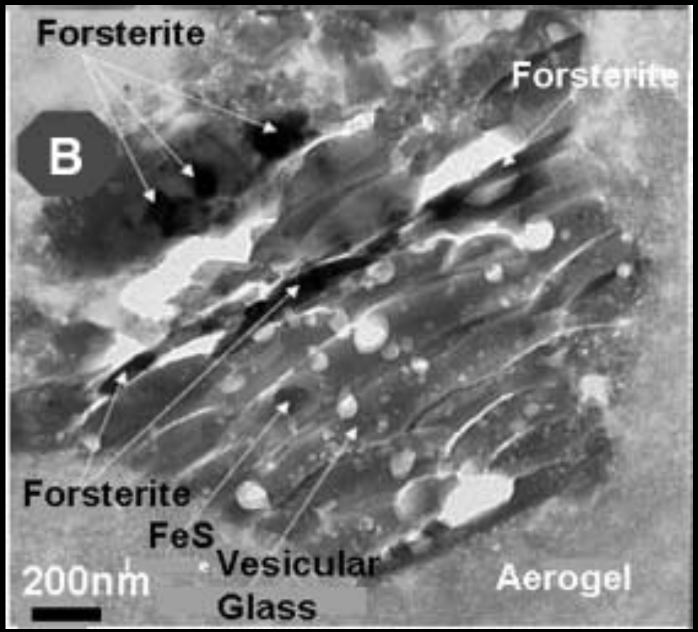
Altwegg et al, Science 2015

Stardust samples of Wild2 dust

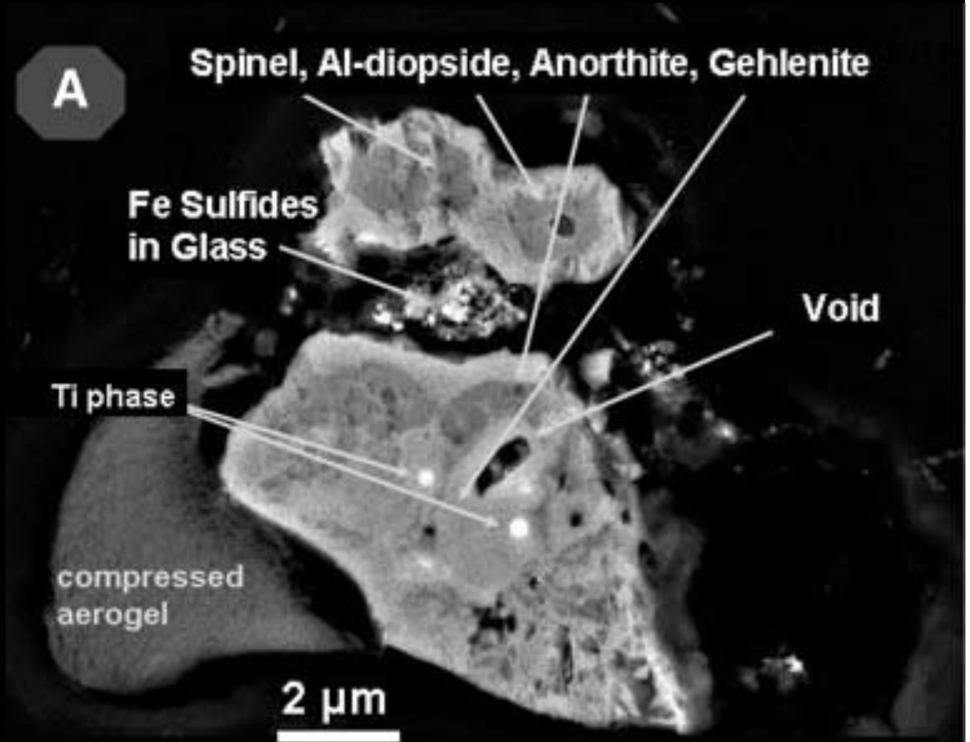
Rotundi et al, 2014



- Wide range of olivine and low-Ca pyroxene compositions
- Requires a wide range of formation conditions. Reflecting different formation locations in the protoplanetary disk
- Shows that extensive and earlier mixing of materials took place in early SS.
- Identification of amminoacids and prebiotic organic materials



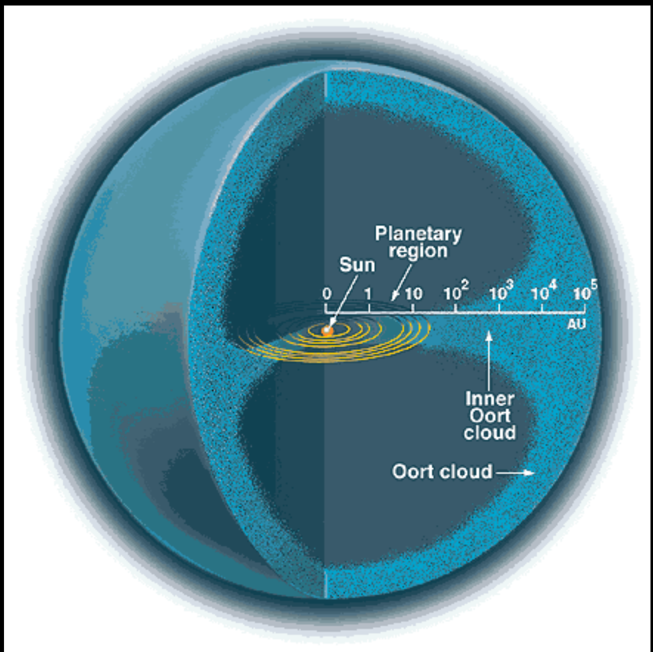
Zolensky et al, 2006

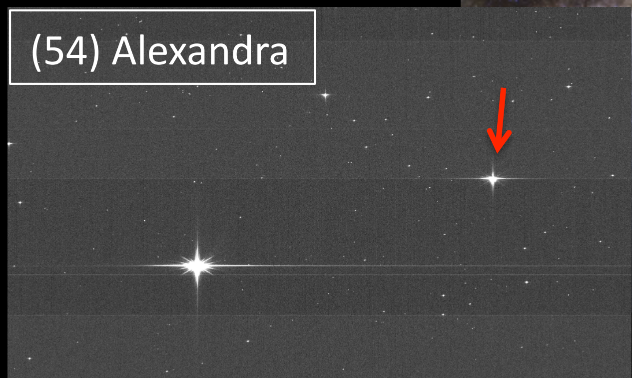


CAI-Like grain

Future Prospects 'Minor Bodies' (1)

- Space Research in this field supported by the active missions Dawn (at Ceres 2015-2016) , Rosetta (extended mission, if approved, will last throughout 2016).
- Major challenge: Sample Return from a primitive object >> Hayabusa-2 (Jaxa), Osiris-Rex (NASA) (2023)
- Gaia will bring a revolution in asteroid science:
  – Precise orbits for ALL (several hundred thousand) objects with V=20 and brighter
  – Asteroid masses from Gaia observations of asteroids mutual close encounters (20% error in mass for about 80 asteroids)





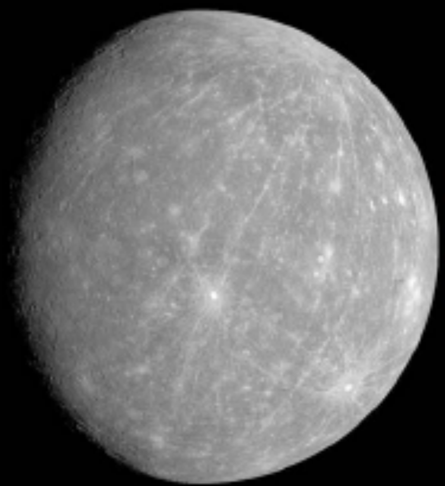
Future Prospects 'Minor Bodies' (2)

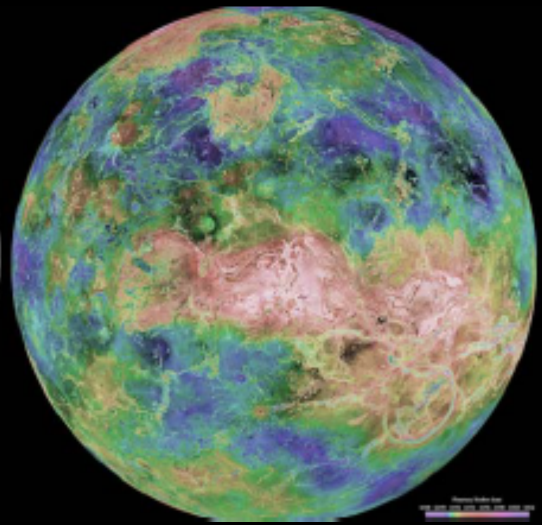
- Ground observations with large telescopes:
  - Pan-STARRS/Catalina/DECam – Main belt complete to V=21 (D~4km), TNOs 80% complete to V=21 (D~600km), NEOs 90% complete to D~0.8km
  - JWST - High-resolution opt/NIR studies of individual objects
  - Large Synoptic Survey Telescope - 3-day cadence to V~24, increasing all populations by ~10
  - E-ELT - High sensitivity, high spatial resolution in opt+NIR.
  - LBT/ELT-like occultation: discovery of very distant (beyond several 100 to 10000 AU) planetesimal-like objects
  - LBT/ELT-like AO exploration of population properties for NEOs, MBAs, MBCs, cometary nuclei and KBOs resolved in the medium-small size range (e.g. in the Main Belt < 14km)

<u>The italian minor bodies community, and INAF plays a major role, has a long standing tradition and is well recognised at the international level for achievements in space activities as well as in ground observations, modelling and dynamics, laboratory analysis of returned samples</u>

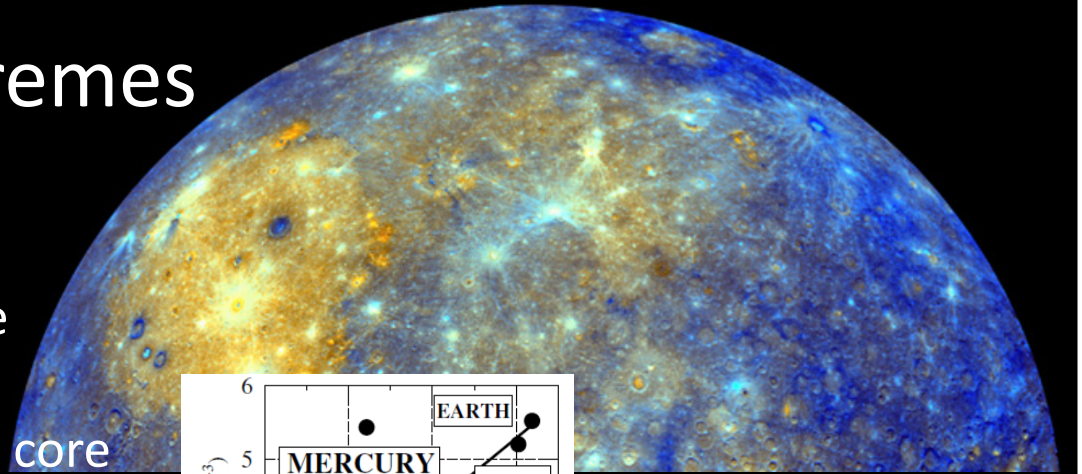
the inner planets: understanding Earth-like worlds

- Understand the origin and diversity of terrestrial planets.
- How are Earth and its sister terrestrial planets unique in the solar system and how common are Earth-like planets around other stars?
- Constrain the range of terrestrial planet characteristics, from their compositions to internal structure to atmospheres.
- How the evolution of terrestrial planets enables / limits origin and evolution of life
- What conditions enabled life to evolve and thrive on the early Earth? The Moon and Mercury may preserve early solar system history that is a prelude to life.
- Understand the processes that control climate on Earth-like planets.
- Study other climate systems (Venus, Mars and Titan), to isolate some climate processes and quantify their importance.



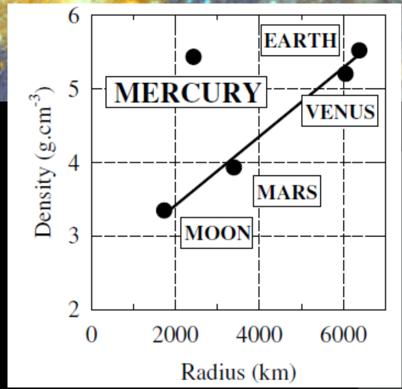


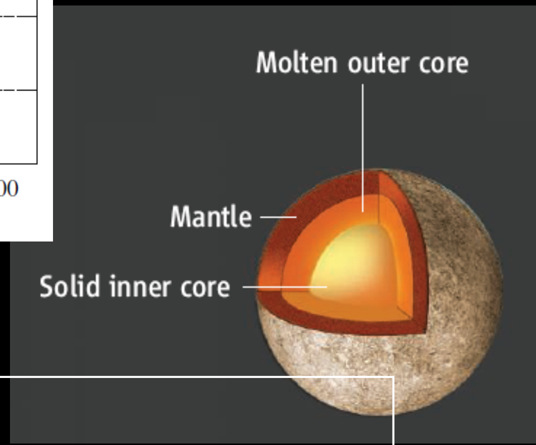
Mercury a Planet of Extremes

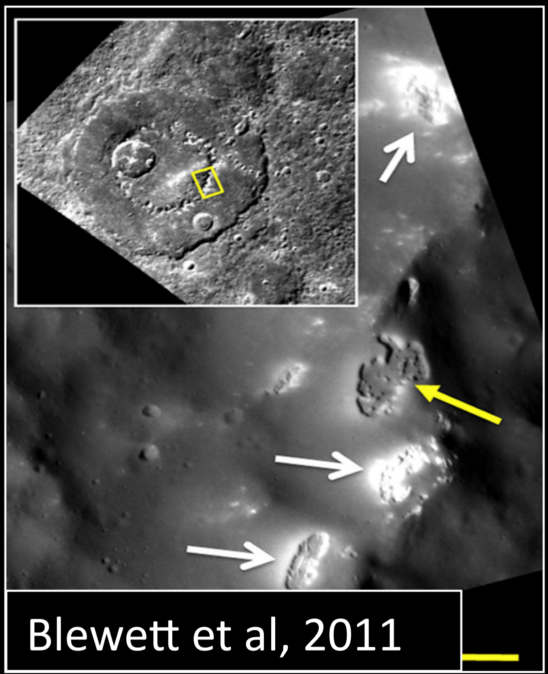


Mercury's liquid core.

Mercury appears to have a solid silicate crust and mantle overlying a solid, iron sulfide outer core layer, a deeper liquid core layer, and possibly a solid inner core.
This internal structure is possibly responsible for the Mercury's magnetic field







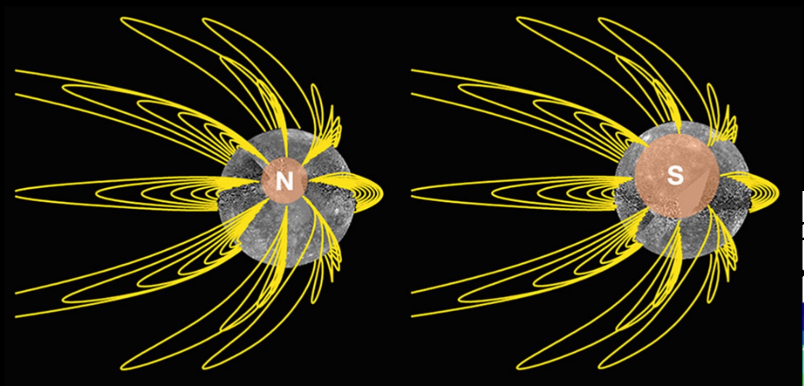
Blewett et al, 2011

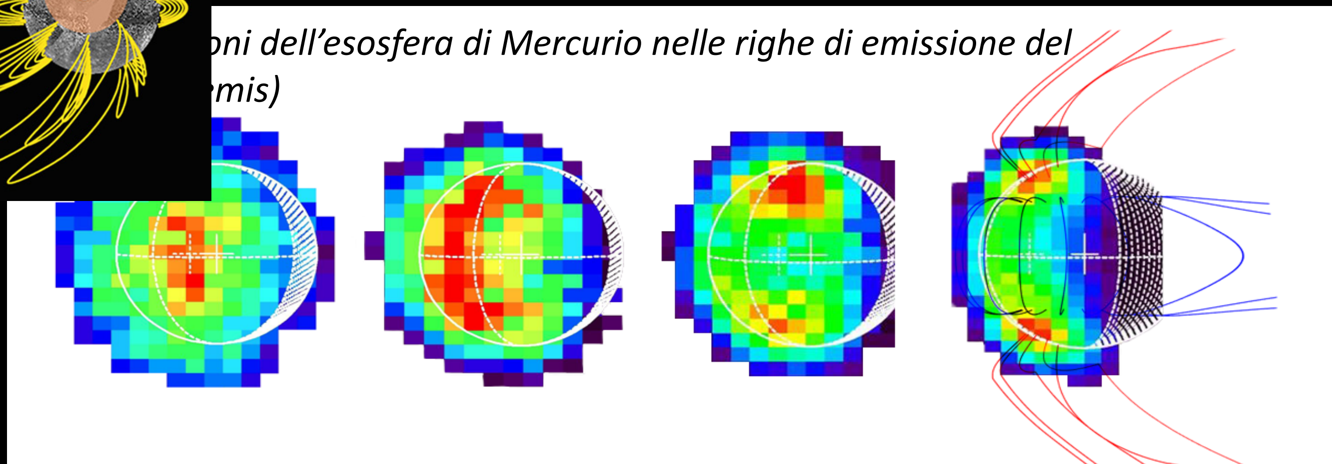
Hollows on Mercury

Irregular, shallow rimless depressions have bright interiors and bright halos generated by the sublimation or some other loss of volatile material from subsurface

Mercury Exosphere

- Solar wind, cosmic rays, dust particles permeate the interplanetary medium, interacting with surface, atmospheres or magnetosphere of the bodies of the Solar System
- Surface erosion due to various processes (ion-sputtering, impact vapourisation and photon desorption) generate exospheres. Studying the exospheres from space we derive information on the processes active on the surfaces.

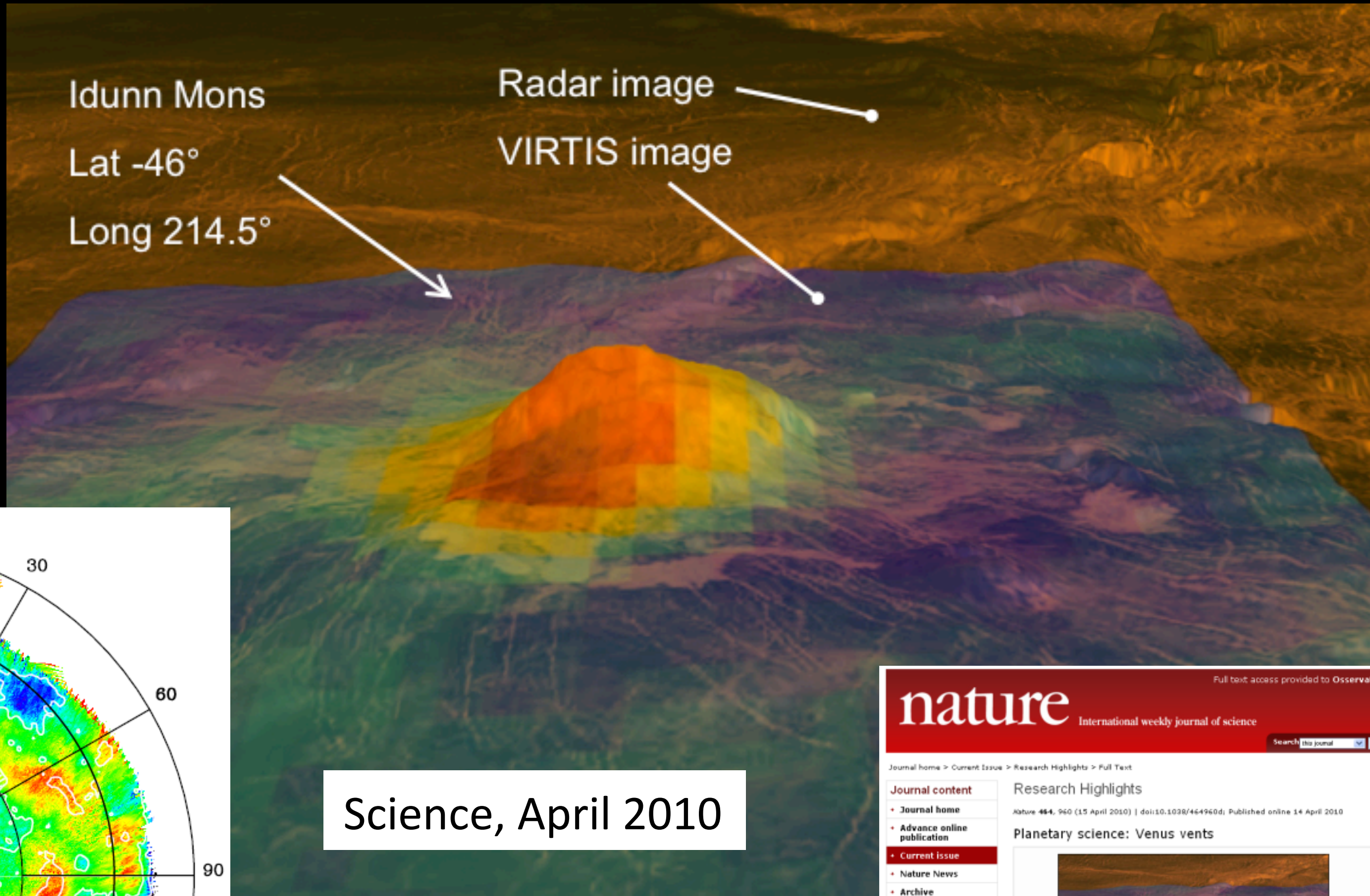




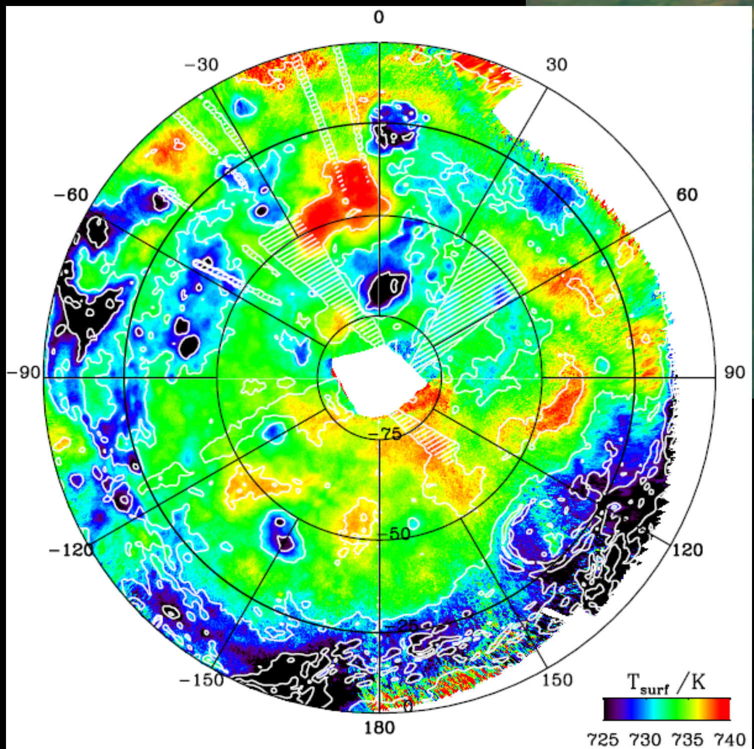
Massetti et al, PSS,2015

Recent volcanic activity on Venus

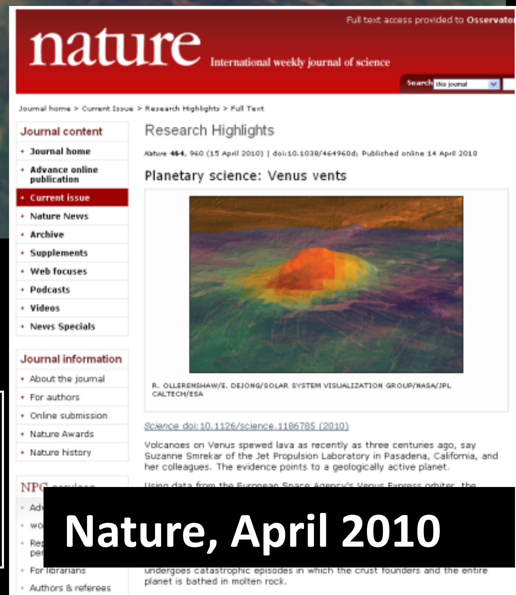
Volcanic activity supports models of ongoing volcanic emission of SO2 feeding the global H2SO4 clouds



Science, April 2010



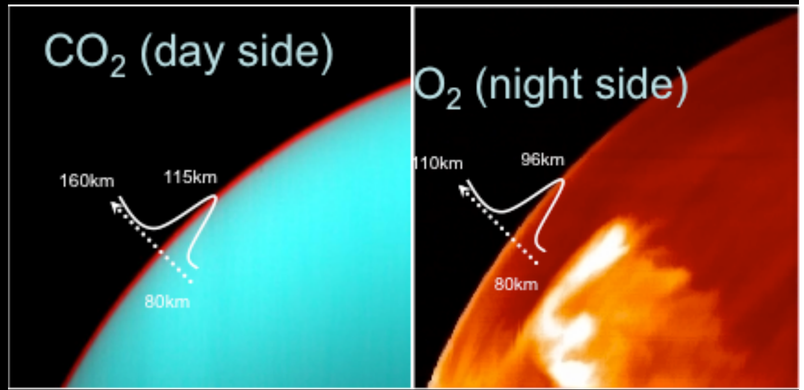
VIRTIS Detailed map of surface emissivity



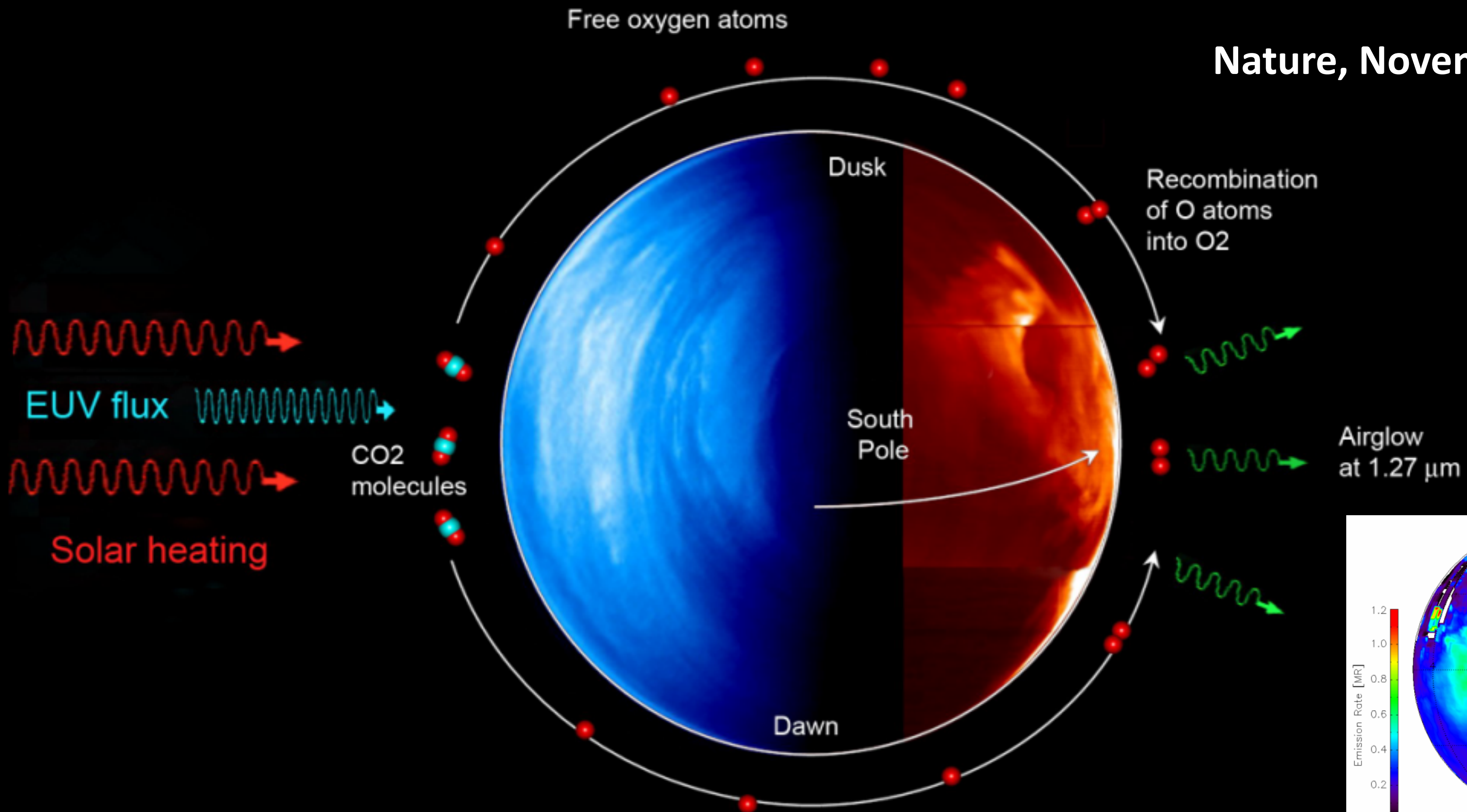
Nature, April 2010

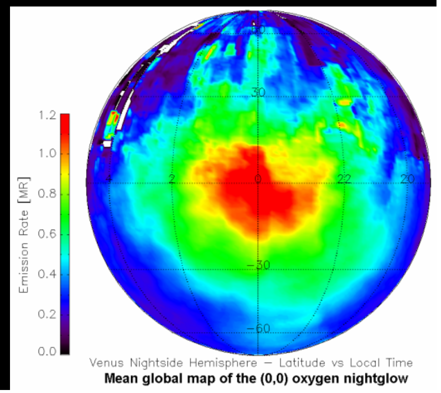
CO_2 photolysis and O_2 recombination

Photolysis of CO_2 molecules forms atomic oxygen O, which is transported to the night side by large scale circulation. The recombination occurs on the night side at the convergence point, around the local midnight.

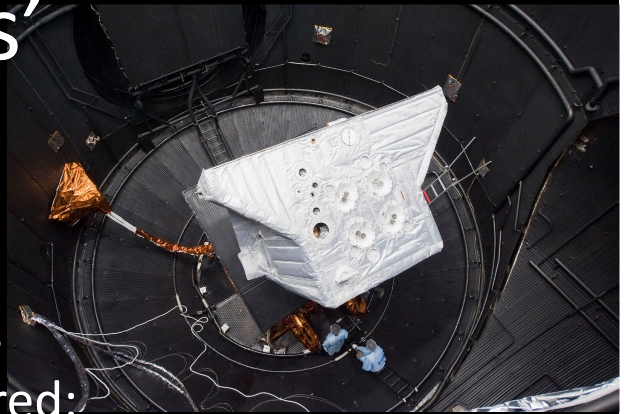


Nature, November 29 2007





Future Prospect 'Inner Planets'



The next scientific breakthrough from a space mission perspective is certainly the ESA's Cornerstone mission BepiColombo.

Messenger has been very productive, but by no means has completed the work, and some questions remain unanswered:

- What gave Mercury its large density? Several theories but no accepted explanation yet
- Is there really a liquid core? and which is the size of the core itself and the overall internal structure of Mercury?
- Which is the role of volatiles on the surface of Mercury (Hollows, potential presence of ice in the polar sun shielded craters)?

ESA's BepiColombo mission will be launched 2017, arrival 2024

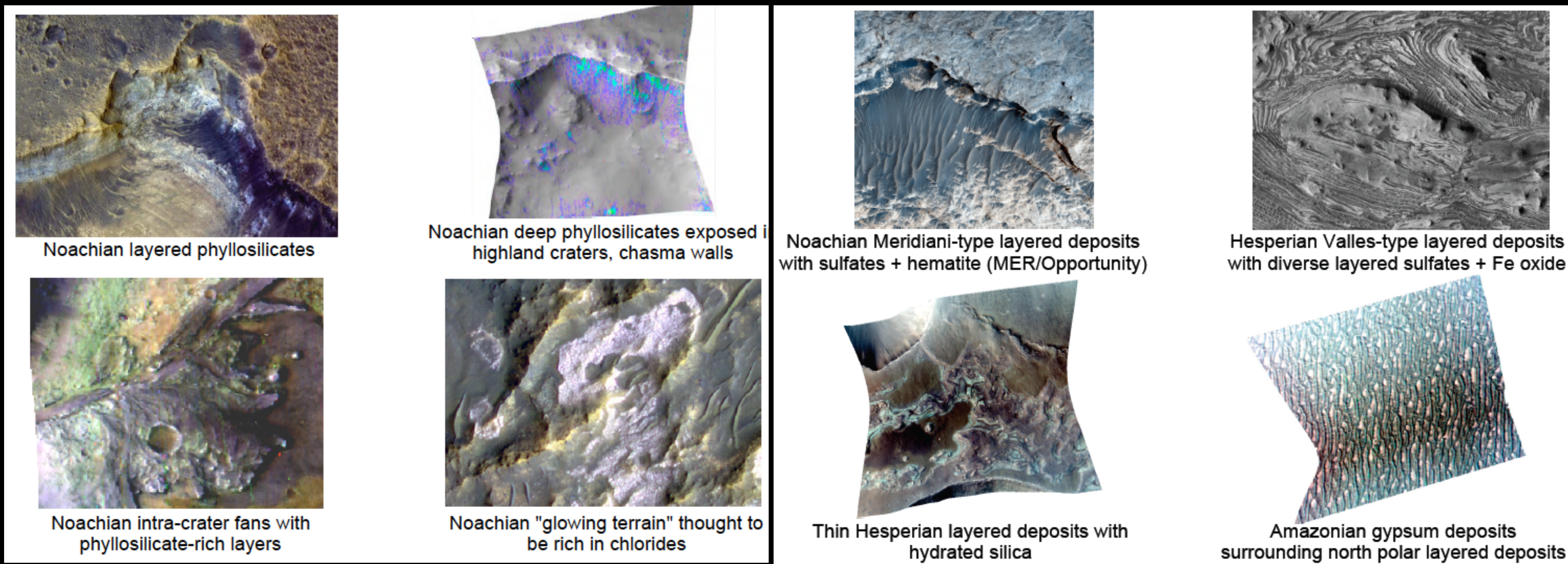
Relevant INAF contribution, 2PIs (SERENA, ISA) and 2CoPIs (SIMBIO-SYS)

Additional University PI (MORE) and Co-PI (SIMBIO-SYS)

A strong contribution to the mission of a mature community involving physicists and geologists

Follow the water

- *On Mars minerals must have formed in a diverse set of aqueous environments throughout the martian history*.
- Observations from multiple orbiters and rovers have identified a broad suite of water-related minerals including sulfates, phyllosilicates, iron oxides and oxyhydroxides, chlorides, iron and magnesium clays, carbonates, and hydrated amorphous silica.



Noachian layered phyllosilicates

Noachian deep phyllosilicates exposed i highland craters, chasma walls

Noachian Meridiani-type layered deposits with sulfates + hematite (MER/Opportunity)

Hesperian Valles-type layered deposits with diverse layered sulfates + Fe oxide

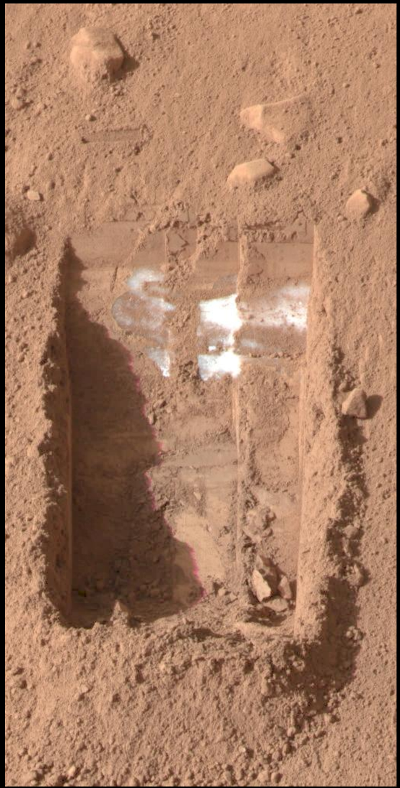
Noachian intra-crater fans with phyllosilicate-rich layers

Noachian "glowing terrain" thought to be rich in chlorides

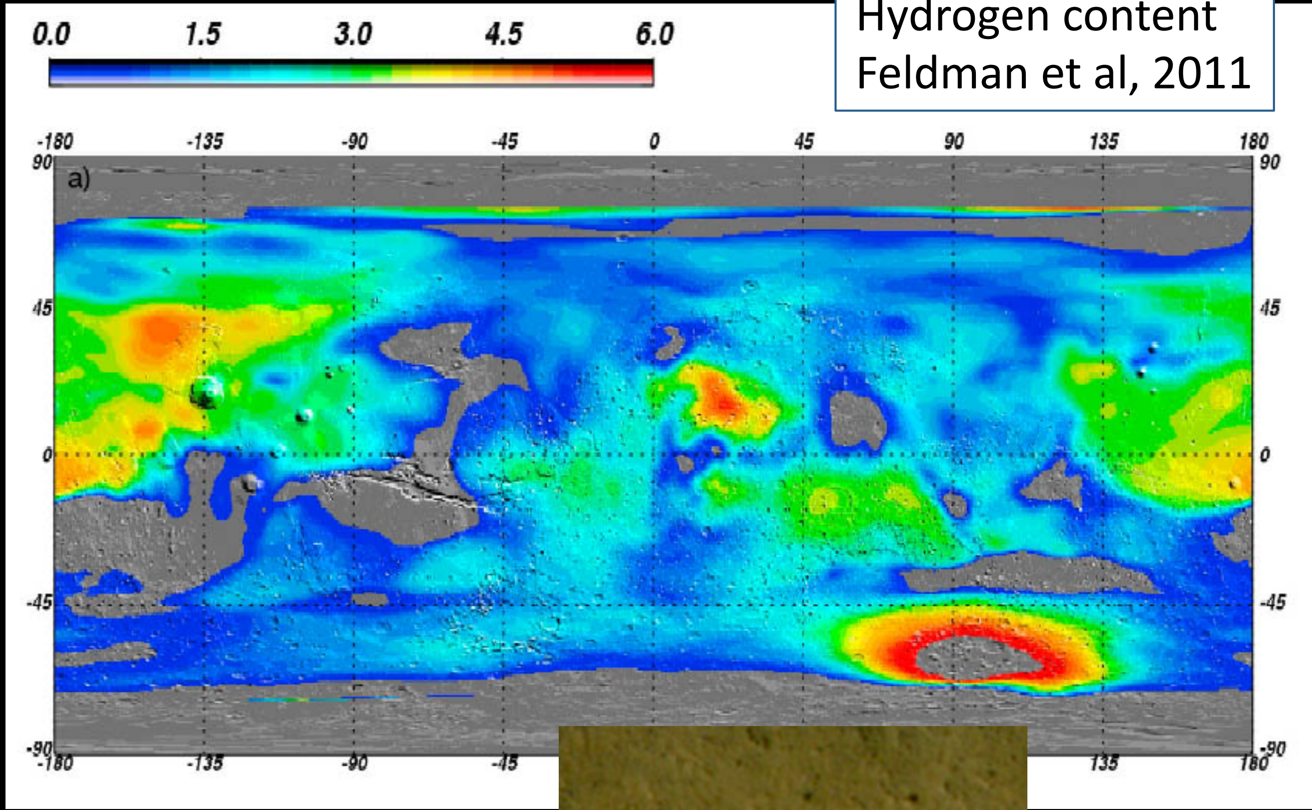
Thin Hesperian layered deposits with hydrated silica

Amazonian gypsum deposits surrounding north polar layered deposits

Water ice on Mars



Phoenix Probe



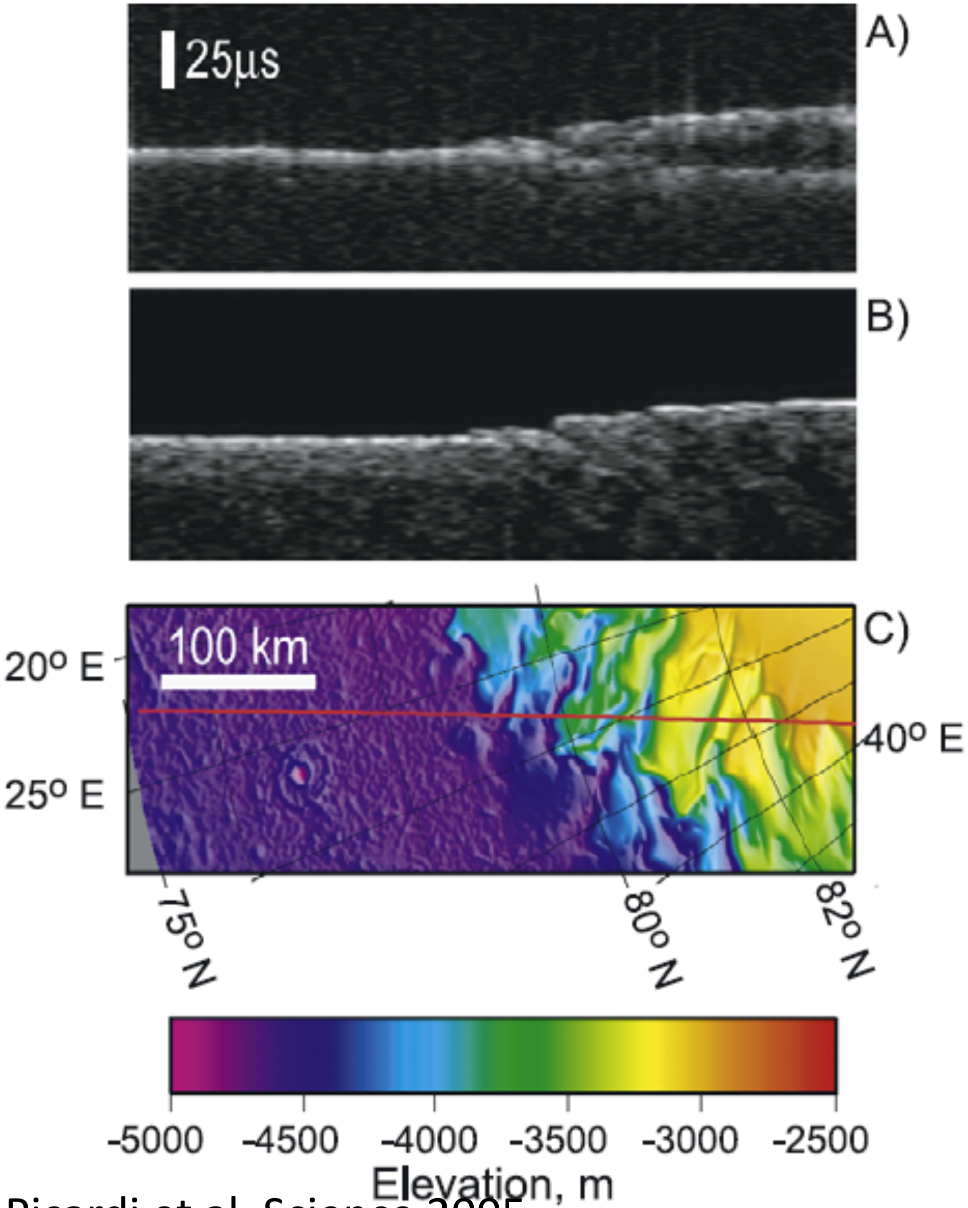
Water equivalent
Hydrogen content
Feldman et al, 2011

Extensive deposits of near-surface ice on Mars

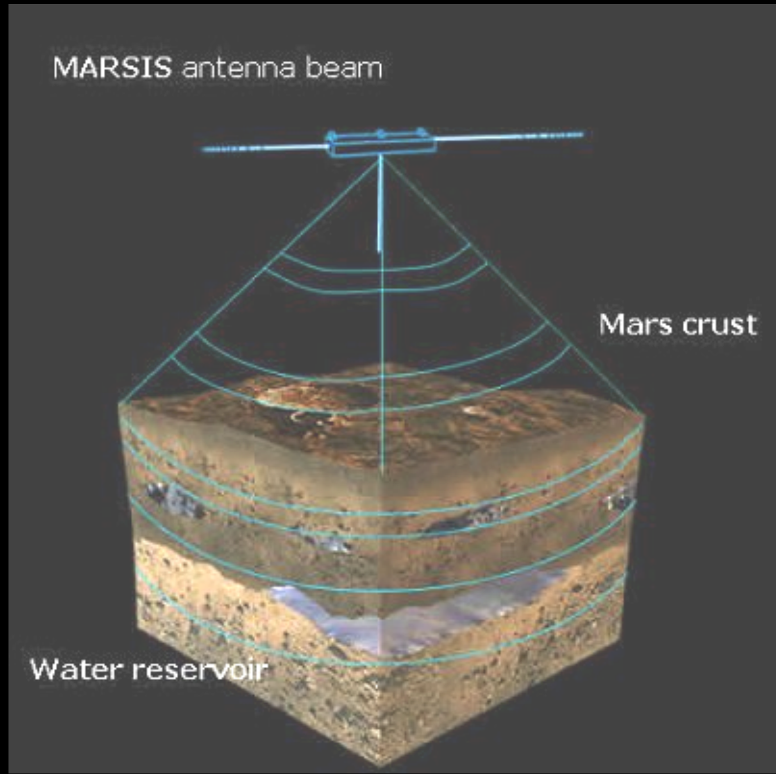
These deposits are a major reservoir of martian water, and because of oscillating climate conditions, potentially lead to geologically brief periods of locally available liquid water.

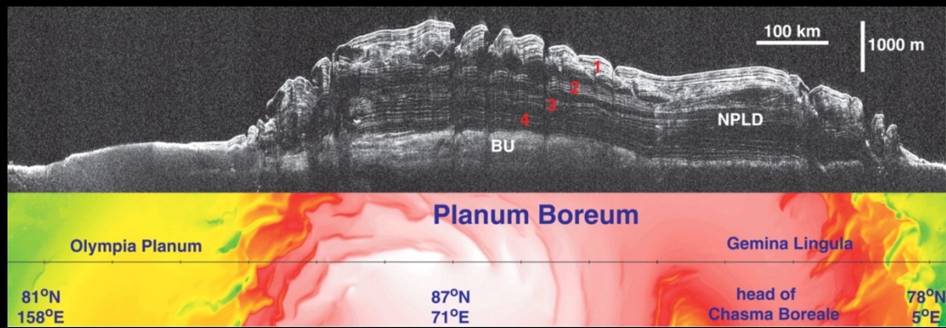
8 meters crater formed in 2008.

Radar Sounders



Picardi et al, Science 2005





North Polar Deposit Layering as seen by MARSIS

North Polar Deposit Layering as seen by SHARAD

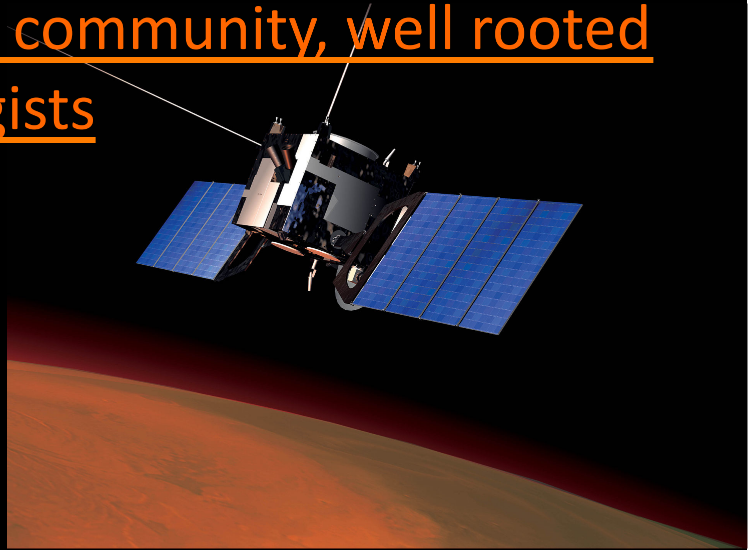
Future Prospect 'Mars exploration'

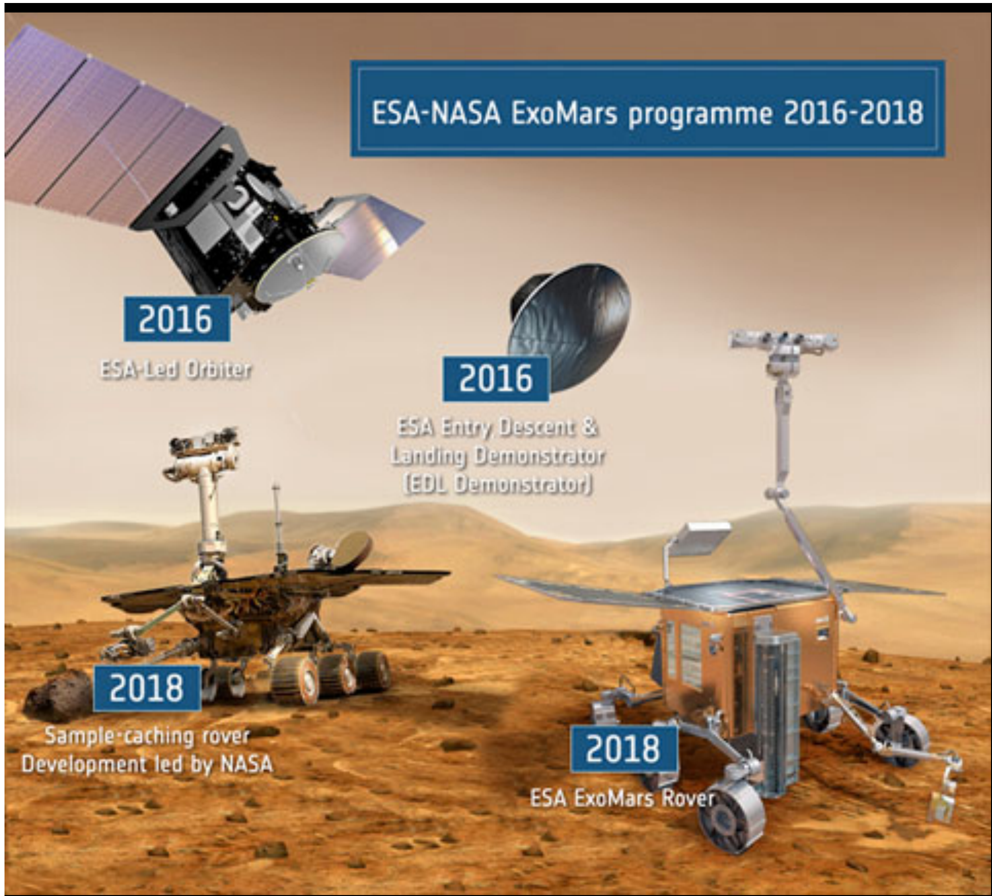
Relevant INAF contribution to Mars Express: participation in OMEGA (the imaging spectrometer in the VIS and NearIR) and HRSC (High Resolution Stereo Camera), PIship of PFS (Planetary Fourier Spectrometer)

University of Rome PIship of Subsurface sounders MARSIS (Mars Express) and SHARAD onboard NASA's Mars Reconnaissance Orbiter (MRO).

Medium Term involvement: Exomars 2016 and 2018 (next slides)

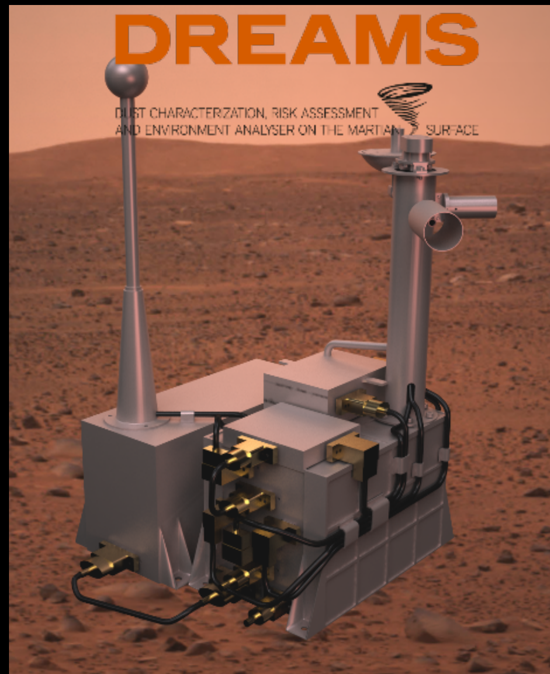
Relevant scientific contribution of a mature community, well rooted in INAF, and involving physicists and geologists





Exomars - 2016

- Trace Gas Orbiter - Searching for signature of minor gases in the Martian atmosphere
- Entry, Descent and Landing Demonstrator Module – Testing critical technology for future missions



INAF Contribution:

PI of DREAMS a laboratory for wind speed and direction, humidity, pressure, surface, the transparency of the atmosphere and atmospheric electrification

Co-PIship in Nomad (TGO atmospheric spectrometer) and CASSIS (TGO high resolution Camera)

Exomars - 2018

To search for signs of past and present life on Mars;

To characterise the water/geochemical environment as a function of depth in the shallow subsurface;

To study the surface environment and identify hazards to future human missions;

To investigate the planet's subsurface and deep interior to better understand the evolution and habitability of Mars

Mission elements

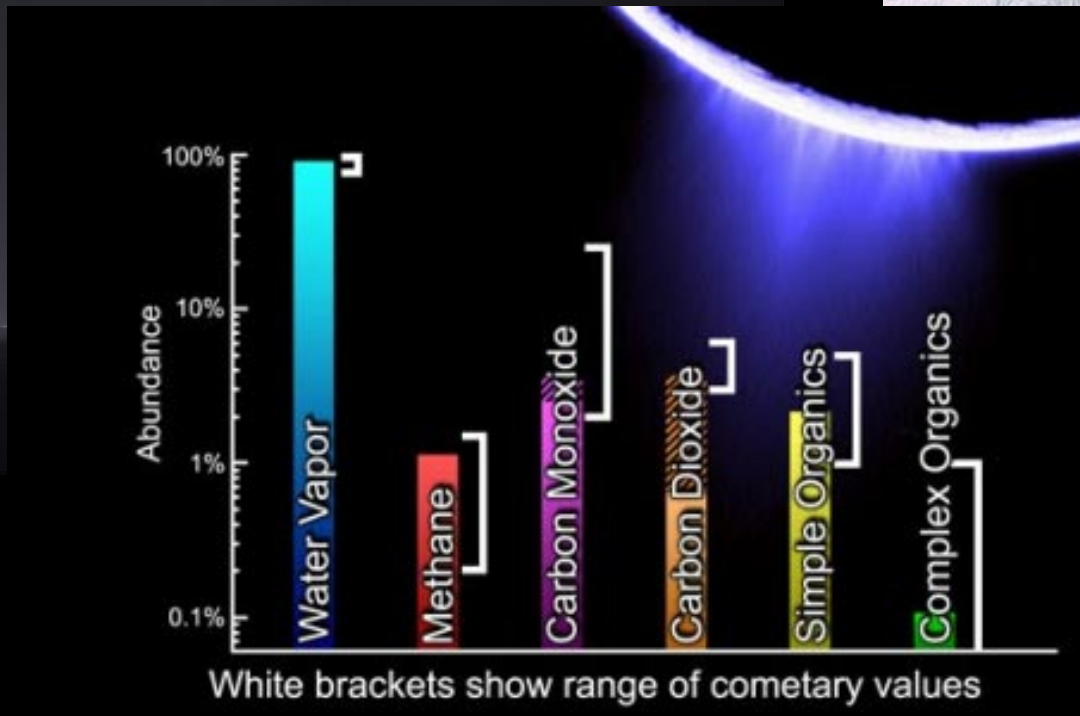
- Russian Lander
- ESA led Exomars Rover

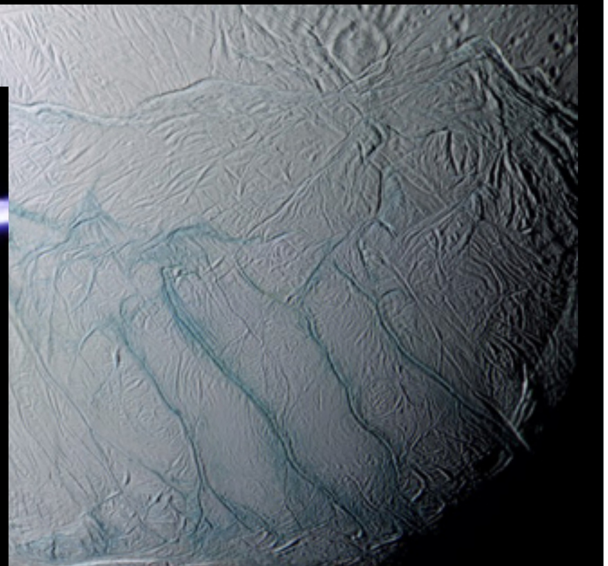
INAF Contribution: PI Ma_Miss Subsurface imaging spectrometer Vis-NearIR

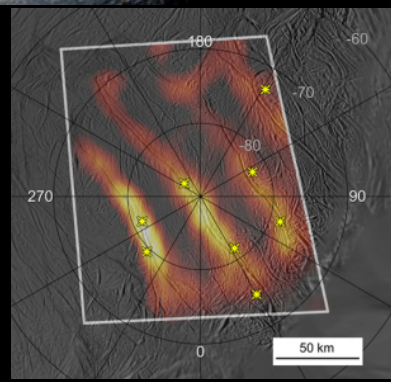
Exomars drill 2m into the surface

Follow the water

- *Geothermal and plume activity at the south pole of Enceladus.*
  Observations by the Cassini spacecraft have revealed anomalous sources of geothermal energy coincident with rifts in the south polar region of Enceladus. The energy source is responsible for plumes of ice particles and organic materials that emanate from discrete locations along the rifts.

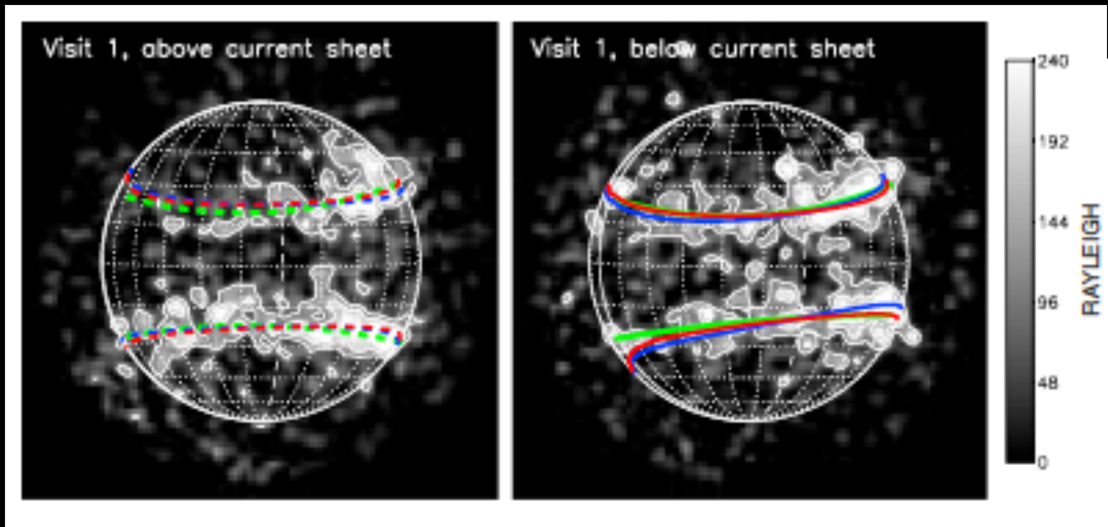


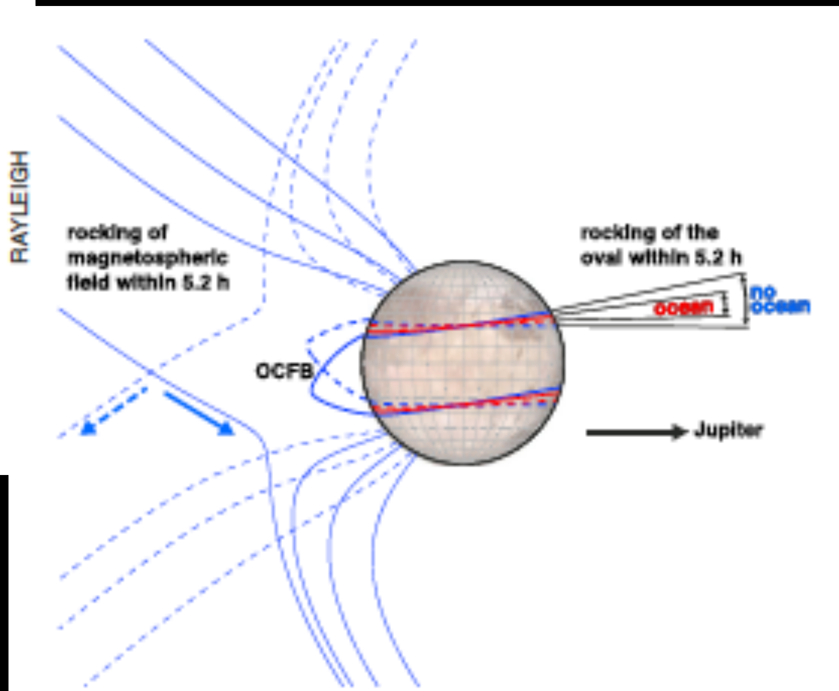




Follow the water

- *Ganymede subsurface ocean.* Probing the interior of a planetary body by telescopic observations. Hubble telescope has been used to study the latitudinal wobbling of the aurorae induced by Ganymede on Jupiter. The magnitude of the wobbling can be correlated with conductive layers like a saline underground ocean.
- Present estimate is an ocean 100 km thick buried under 150 km crust of mostly ice.

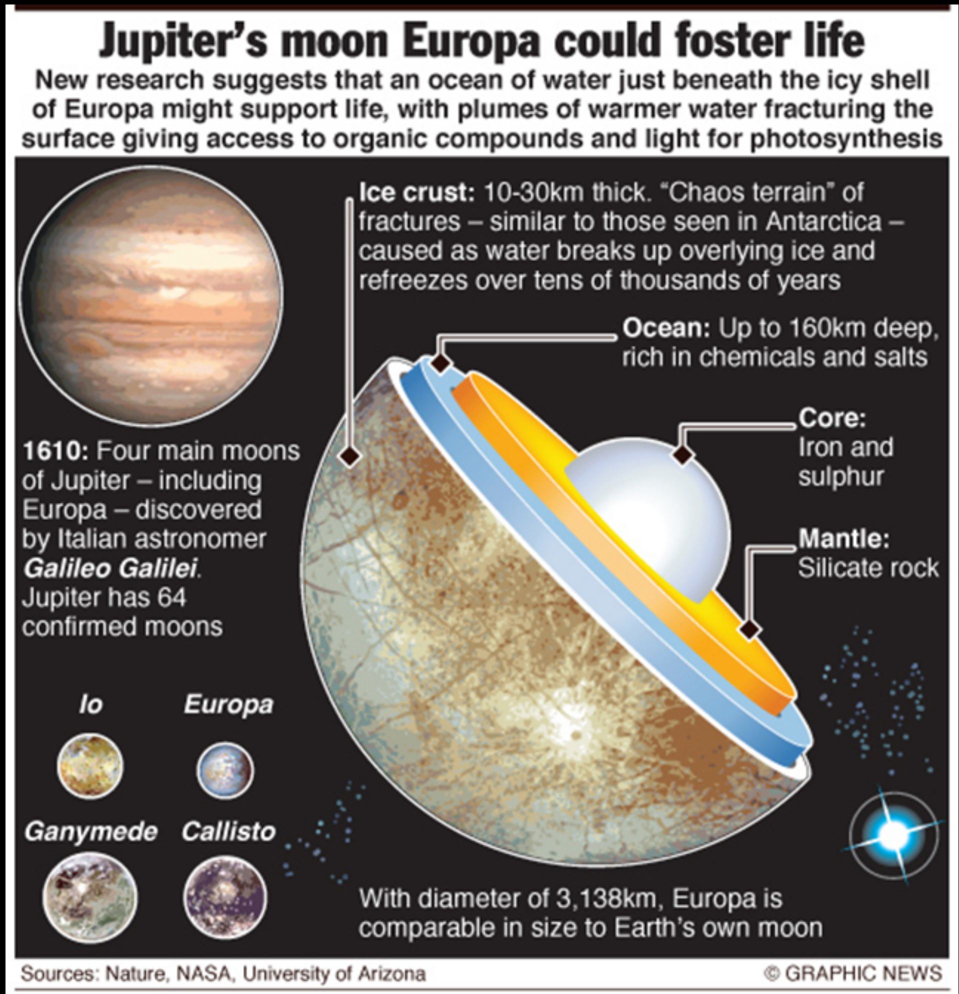


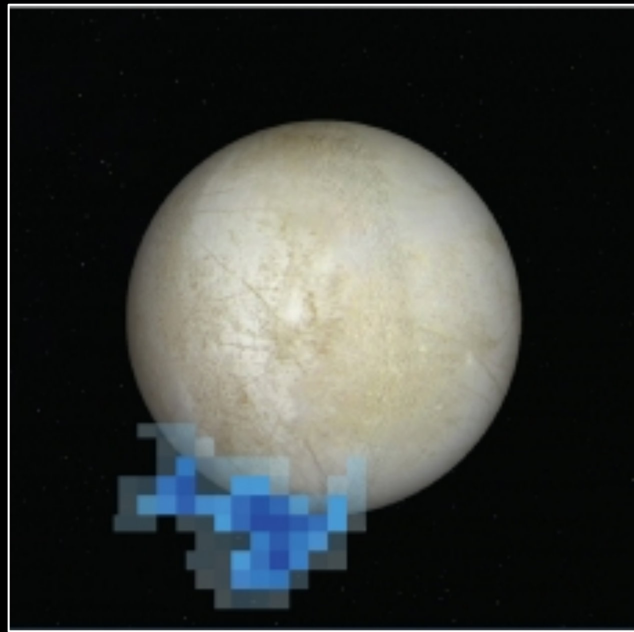


Saur et al, Science, 2015

Follow the water

Europa Subsurface Ocean





The water vapour plume observation by HST (2012) in the UV could be an evidence of cryovolcanism or eruption from linear fractures (as for Enceladus)

Organic chemistry?

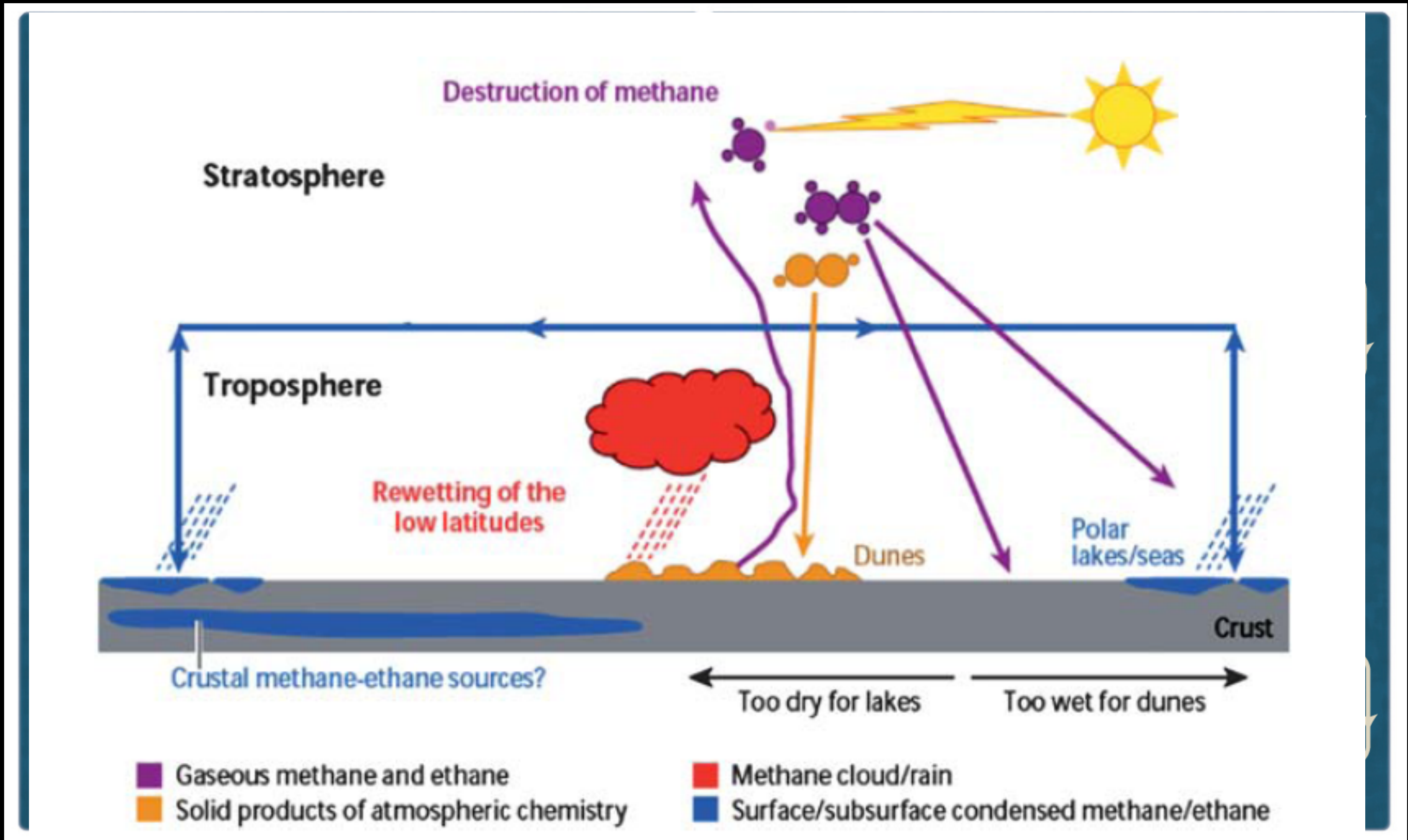
- Icy satellites display abundant evidence for organic chemistry. At Saturn, Iapetus and Phoebe are largely covered by complex dark organics. Ganymede and Callisto and all five uranian satellites exhibit numerous dark organic-rich geologic units.

- Europa probably harbors a subsurface ocean at a shallow depth giving it high potential as a habitat for life. Satellite plumes have been observed on Europa (HST) and on several geologically active bodies (Io, Enceladus, and Triton).

- High scientific goals that emerge from this key question are to identify organic molecules and characterize processes of organic synthesis in the interiors and at the surfaces of Europa and Enceladus as well as Titan.

Follow the Methane: Titan Circulation

- *An active meteorological cycle involving liquid methane on Titan and supporting complex organic chemistry*
- During southern summer, Warm air rises in Titan's southern hemisphere and sinks in the northern hemisphere, resulting in high-altitude air flow from south to north and low-altitude airflow from north to south.



the gas giant and icy giant planets
local laboratories and ground truth for exoplanets

- Giant Planets as ground truth for exoplanets
- Giant Planet's roles in promoting a habitable planetary system
- Giant Planets as laboratories for properties and processes on Earth

Future prospect ‘Outer Planets’

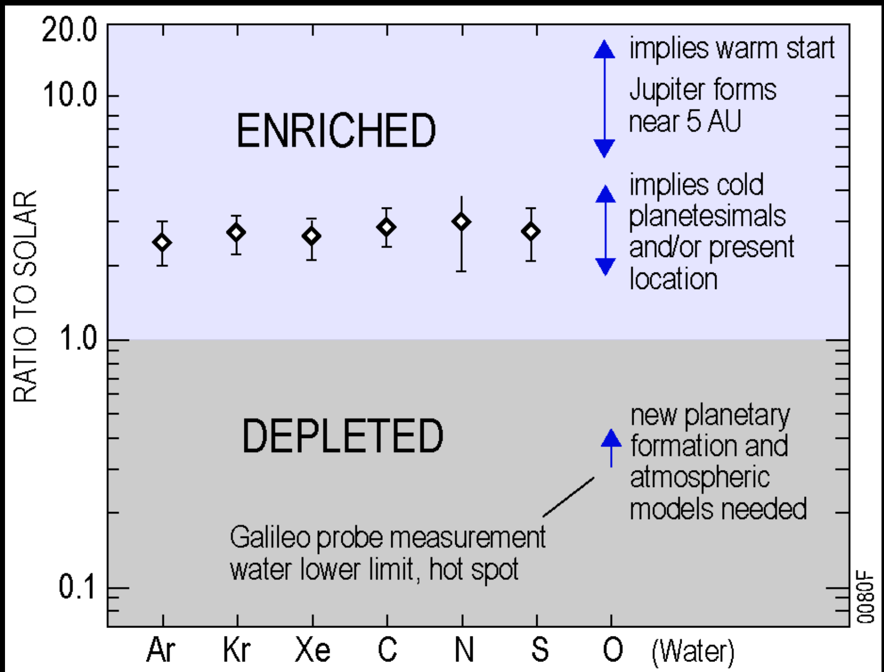
- Cassini will be active until 2017; Italian contribution to VIMS, RADAR and Radio Science.
- 4 participating scientists role have been awarded to INAF researchers in the last few years.
- Major future missions and breakthrough are expected from NASA’s New Frontier JUNO arrival 2016 (INAF direct responsibility of JIRAM) and ESA’s Large Mission JUICE (Three University PIs and one INAF Co-PI roles – out of 11 instruments)

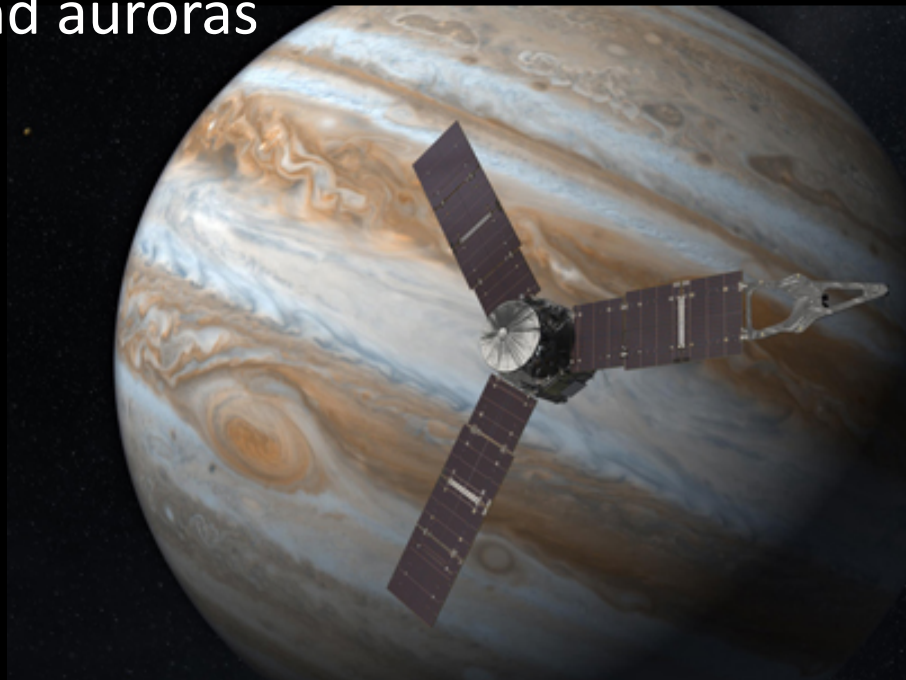
Relevant scientific contribution of a mature community, well rooted in INAF, and involving physicists and geologists.

On the other hand, we need to identify opportunities and seek involvement of the italian community in future telescopic observations either from ground or from space.

The Juno Mission Science and breakthroughs

1. Oxygen/Hydrogen Ratio and abundance of water
2. Improve estimate of core mass
3. Map gravity and magnetic field
4. Map atmosphere composition and physical properties up to 100bar
5. Characterise magnetosphere and auroras





Exploration of the habitable zone

JUICE

Three large icy moons to explore

Ganymede

- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies

- Archetype of waterworlds
- Best example of liquid environment trapped between icy layers

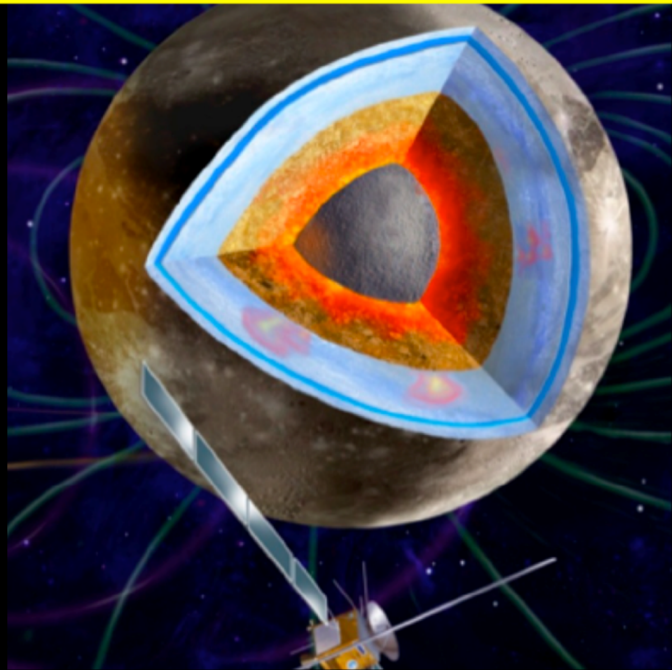
Callisto

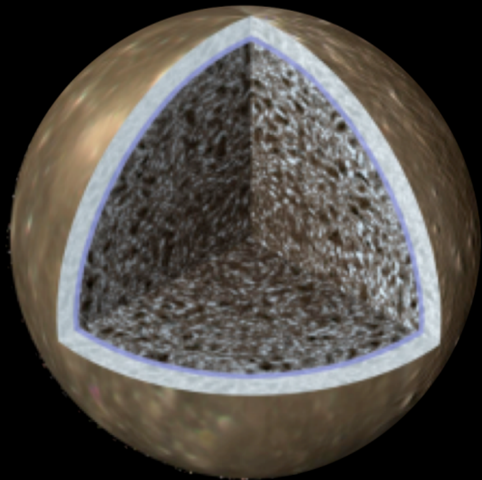
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages

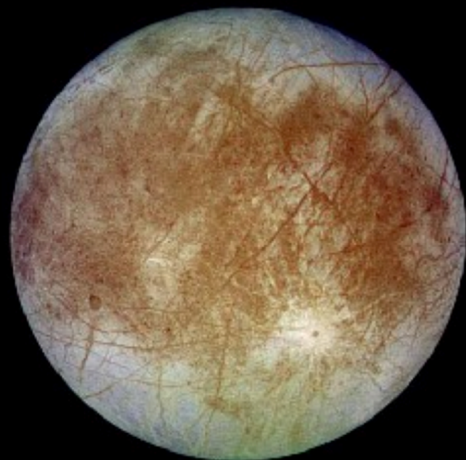
Europa

- A deep ocean
- An active world?

- Best example of liquid environment in contact with silicates







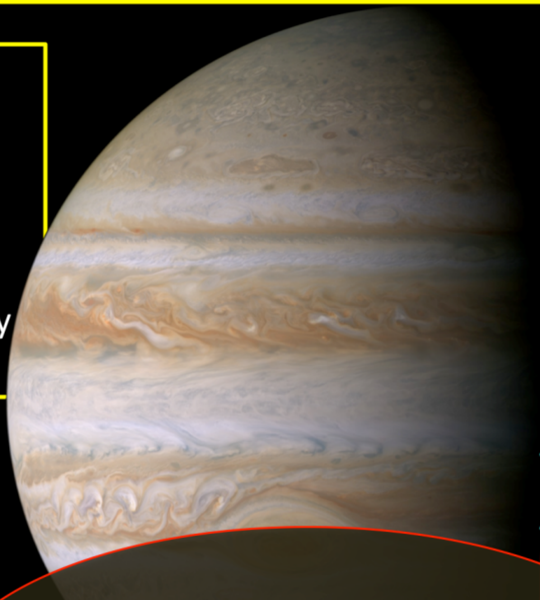
Exploration of the Jupiter system

JUICE

The biggest planet, the biggest magnetosphere, and a mini solar system

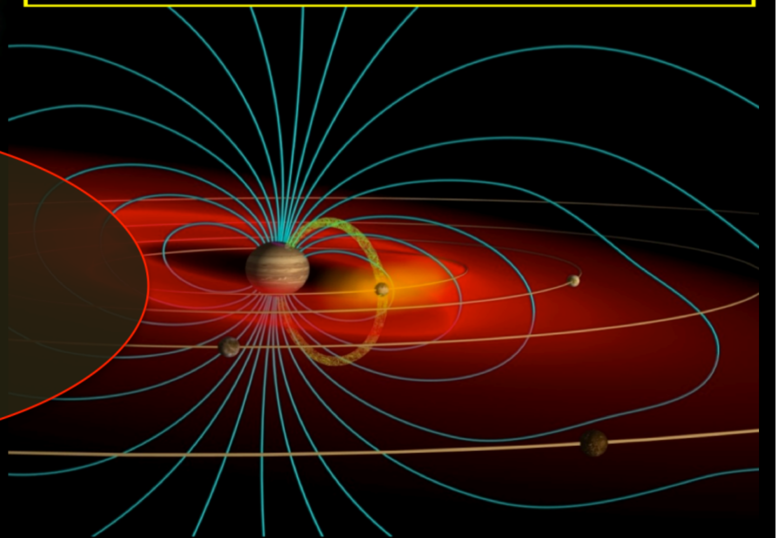
Jupiter

- Archetype for giant planets
- Natural planetary-scale laboratory for fundamental fluid dynamics, chemistry, meteorology,...
- Window into the formational history of our planetary system



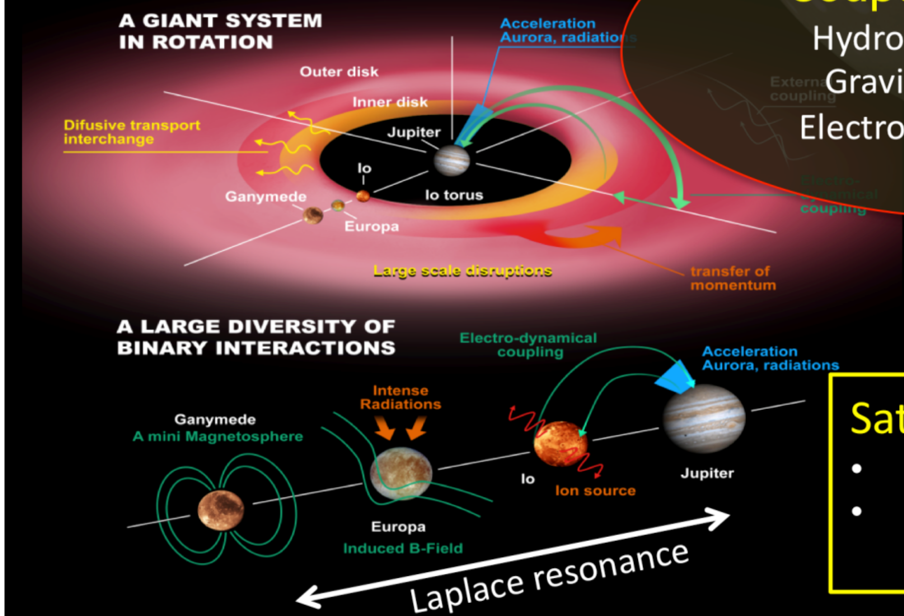
Magnetosphere

- Largest object in our Solar System
- Biggest particle accelerator in the Solar System
- Unveil global dynamics of an astrophysical object



Coupling processes

Hydrodynamic coupling
Gravitational coupling
Electromagnetic coupling



Satellite system

- Tidal forces: Laplace resonance
- Electromagnetic interactions to magnetosphere and upper atmosphere of Jupiter

SUN-Planet interaction

- Staff INAF : 35
- Non-staff INAF : 15
- Università : 25
  (20 associati INAF)
- Tecnologi (CNR) : 6

- **Solar Orbiter** (1PI + 1 CoPI)
- **Bepi Colombo**: (1PI)
- **2FP7 + 1 H2020 projects**

People
ISM & Discs

ISM

- Staff :~30
- Non-staff :~15

Lab

- staff :~15
- non staff :~15
- PhD :~5

Disk

- Staff :~30
- non-staff :~15

People
Exo-planets

- Scienza /tecn: ~70 staff + 40 non-staff
- Tecnologia: ~15 staff + 10 non staff
- **GAIA** (1 resp WP)
- **ALMA** (1 PS)
- **SKA** (2-3 WG astrob)
- **ELT**
- **ATHENA** (3 nel WG esopianeti)
- **ESPRESSO** (2 SAT)
- **LBT** (1 SAC Shark, 3 col Ilocater)
- **PLATO** (2ST, 2 Board)
- **CHEOPS** (3 ST, 2 Board)
- **ARIEL** (1coPI, 3 resp di sistemi, 3 resp di WG)
- FP7 Space (1PI)

People
Solar System

Space projects:

- Staff INAF: 40
- Non staff INAF: **60**
- Staff Uni: 20
- Non staff Uni:10

Analysis extraterrestrial material

- Staff INAF: 10
- Non staff INAF: 15
- Staff Uni: 20
- Non staff Uni:10

- PI (Giada, VIRTIS, VIR, Duster, SD2)
- dep. PI (VIRTIS, Giada,)
- Co-PI (Osiris)
- Dawn (3 Co-I)

At least 8 people available to take responsability

Intermediate steps:

- Formation – PhD: crucial points: dedicated schools – post doc –recruitment
- Data exploitation - archives
- Network on specific items *(see GAPS experience)* – **observations** - **lab** - **modeling**
- Integration of different aspects – multidisciplinary field (**solar, stellar, planets, discs, ISM, exoplanets, multiwavelength, geology, chemistry, biology**) –

  Examples: WOW & iALMA projects

Possible actions

- Support data analysis including archival data, also as preparatory phase for future instruments
- Ensure priority access to high performance computing facilities
- Support laboratory activities
- Find a balance between low-risk and high-risk projects

Possible actions

- Promote and support coordination of laboratory activities and modeling or other specific projects *(in line with GAPS and WOW experience)*
- Support interdisciplinary projects both within INAF and with non-INAF groups

Possible actions

- Open the new positions on INAF priority research lines
- Activate Tenure Tracks and ensure adequate careers to researchers
- Give the possibility to non staff (post-doc, TD) to manage own projects and funds

Possible actions

- Encourage the formation of young researchers in this field with specific PhD grants

- **Collaborate with the Universities to support training related to INAF Strategic priorities**

  Essential to exploit the INAF investment on given projects (e.g. ALMA, SKA, ELT or space missions)

FRONTIERE DELL'ASTROFISICA ITALIANA:

come ottimizzare il ritorno scientifico dalle grandi infrastrutture internazionali

18 - 19 Marzo 2015

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS