

Discipline Working Groups 6+7

**Science Cases for Exoplanet
and Exo/Astrobiology Research**

H. Lammer → DWG 7 Exoplanets

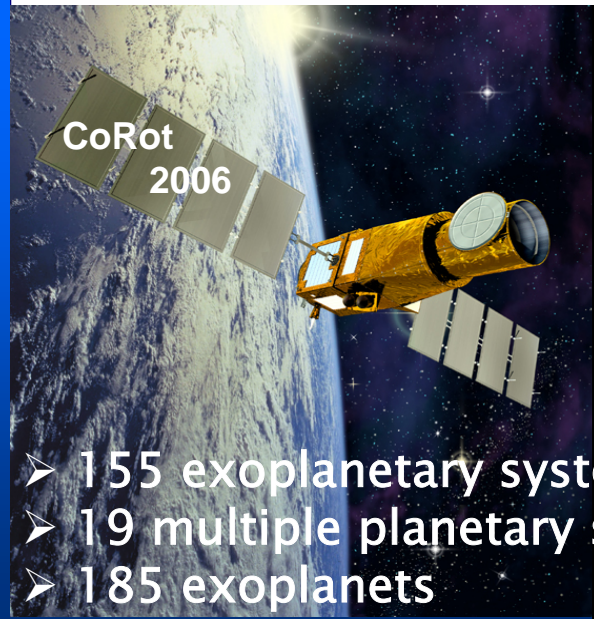
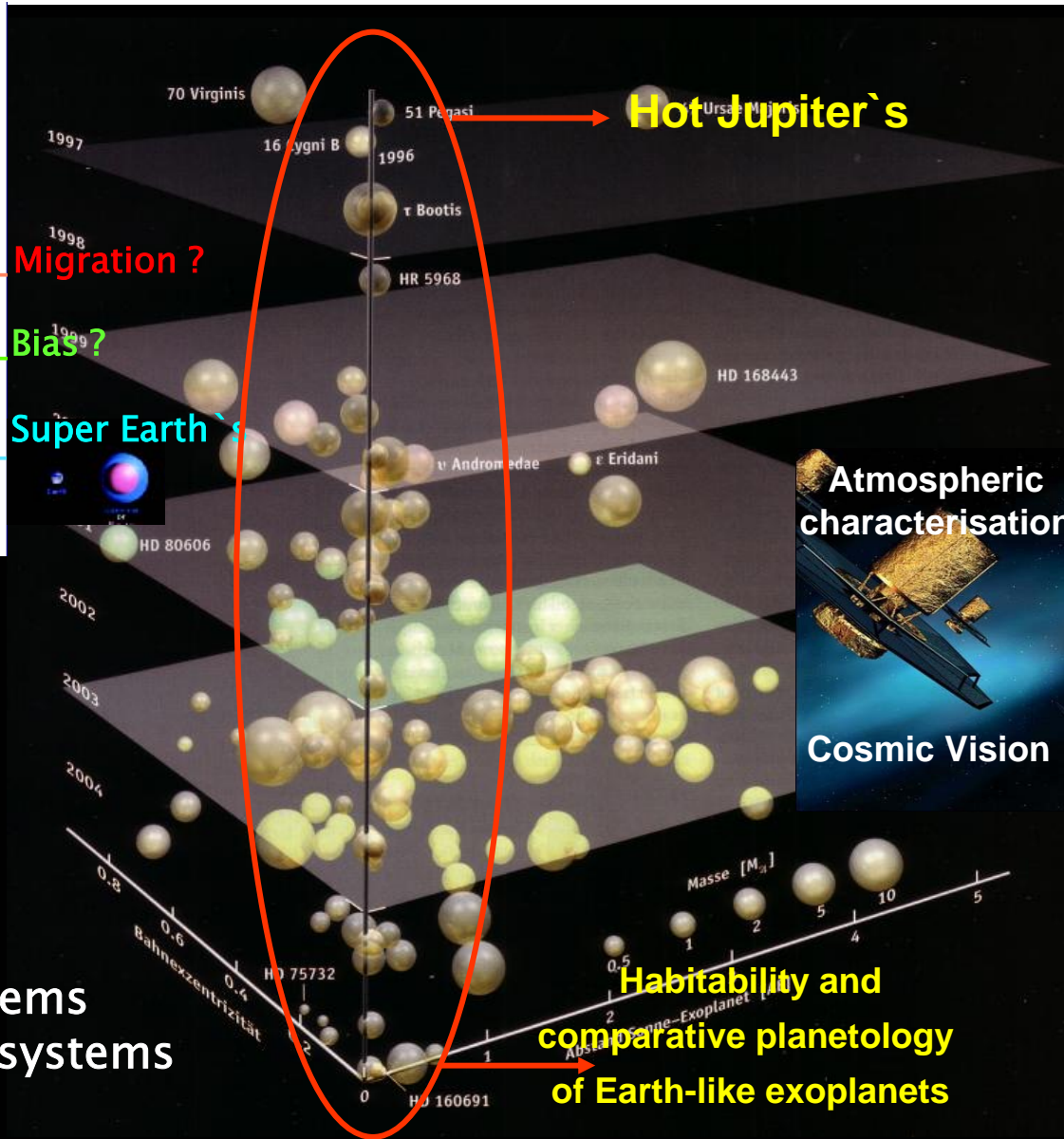
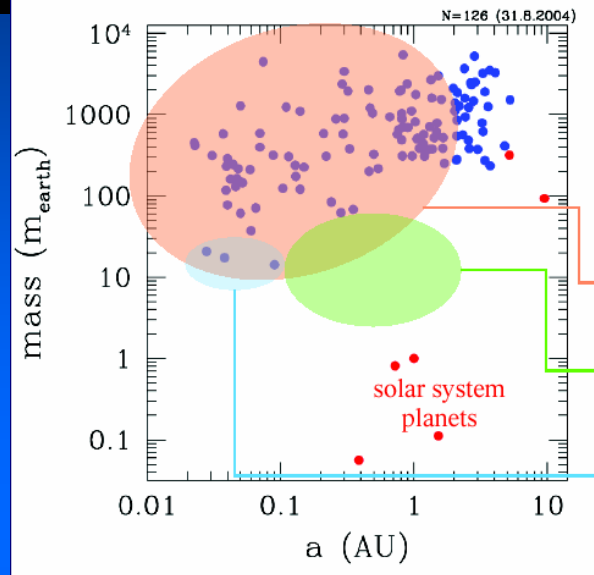
Space Research Institute, Austrian Academy of Sciences

F. Raulin → DWG 6 Exo/Astrobiology

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- 155 exoplanetary systems
- 19 multiple planetary systems
- 185 exoplanets

2006

LETTERS

Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing

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DWG 7 → Exoplanets → precursor planetary science for Darwin, etc.

Questions related to the evolution of habitable planets / atmospheres / water

1.) Stellar/solar (dense) plasma interaction of atmospheres of terrestrial (Earth-like) exoplanets with weak magnetic fields (Venus, Mars): many tidal-locked exoplanets are expected to have weak magnetic moments

- Stellar/solar wind plasma interaction with Earth/Venus-like planets in the early stage. Applications of hybrid models to heated (X-ray and EUV) extended/evaporating neutral atmospheres → **related to early Venus, Mars, Earth, Titan (DWG1, DWG2)**

2.) Tidal-locked exoplanets (related to Venus and Titan → terrestrial exoplanets)

- Generation of magnetic dynamos → what are the necessary conditions for the generation of magnetic dynamos on Earth-like planets (difference between Venus, Earth and Mars), water, plate tectonics, rotation, etc. → **expertise from DWG 8 is needed**
- Applications of GCMs to tidal-locked (Venus, Titan) exoplanets with CO₂ and N₂ atmospheres with different atmospheric densities → **expertise from DWG1 is needed**

3.) Dust in extrasolar systems and planet formation → exozodies, formation of terrestrial planets **DWG4+9 and link to N3**

DWG 7 → Exoplanets → CoRoT, ground-based observations (N3), etc.

1.) Stellar magnetospheric-atmospheric interaction of “hot Jupiter’s”

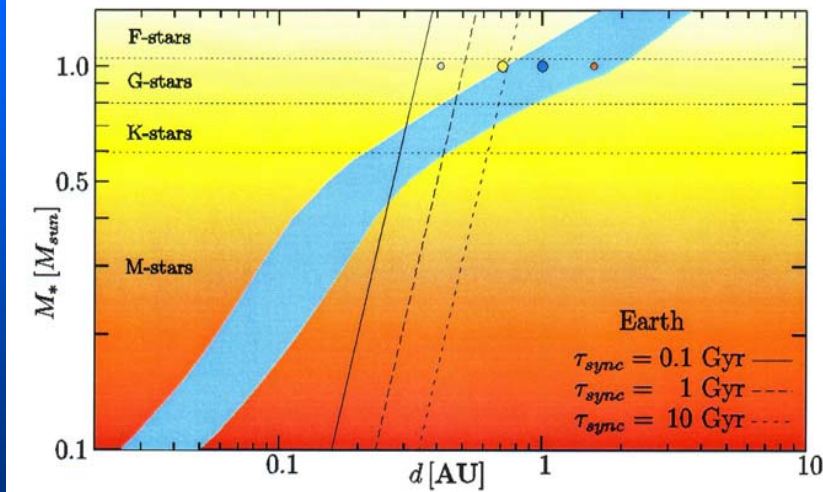
- Study of radio emission mechanism depending of the stellar and planetary parameters → **related to research on Jupiter (DWG2)**
- Modelling of mass-loss evolutionary scenarios, for determining mass-radius relations as a function of orbital distance → **related to blow-off phases of young Venus, Earth, Titan, etc. (DWG1)**

1 – Science goals

- Mass radius relation of Hot Jupiter's as a function of orbital location and evolutionary time-scales
- Stability of atmospheres, water inventories and biomarkers on Earth-like planets within F, G, K, and M star habitable zones

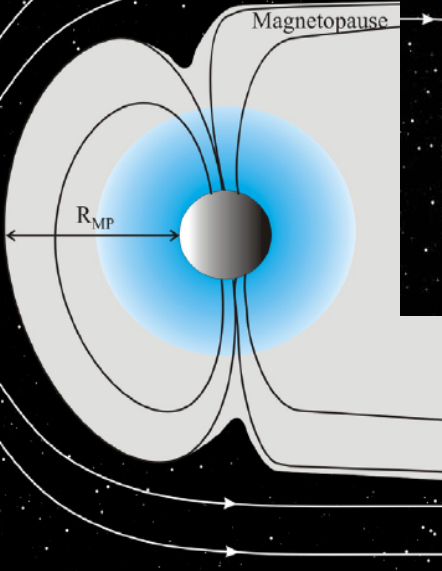
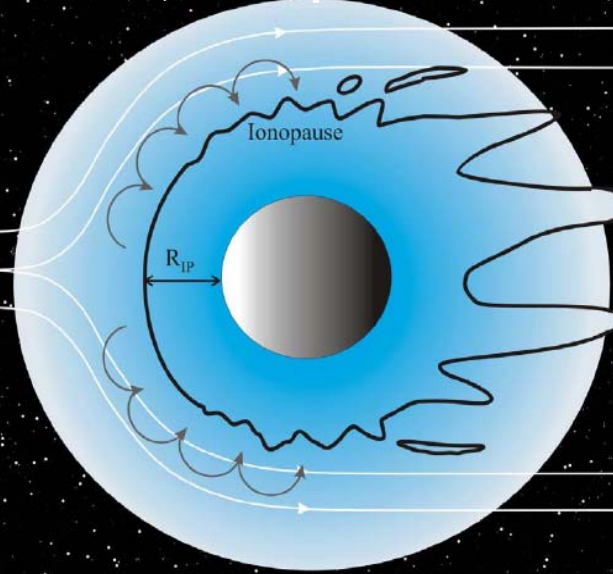
Open questions

- Extreme plasma and radiation interaction with atmospheres
- Are there cores of evaporated gas giants close to their stars ?
- Hot Neptune's or evaporated Jupiter's?
- Close-in "Super Earth's" or remaining cores of evaporated Jupiter's?
- Migration or in-situ formation?
- Role of magnetosphere protection?
- Connection of water, tidal locking, plate tectonics, slow rotation and magnetic dynamos?
- GCMs on slow rotating planets
- Effects on biomarkers

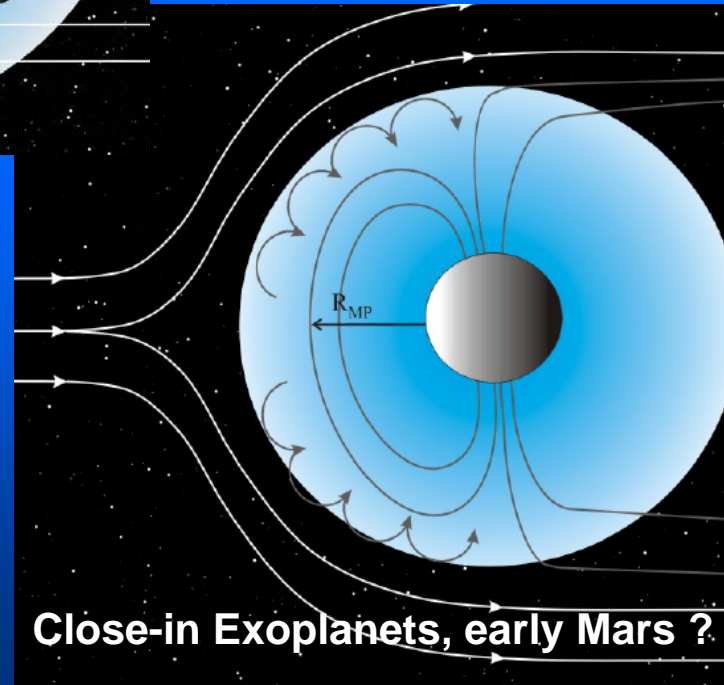


Science Case DWG 7: Planets under extreme stellar conditions

Venus, Titan, present Mars



Earth

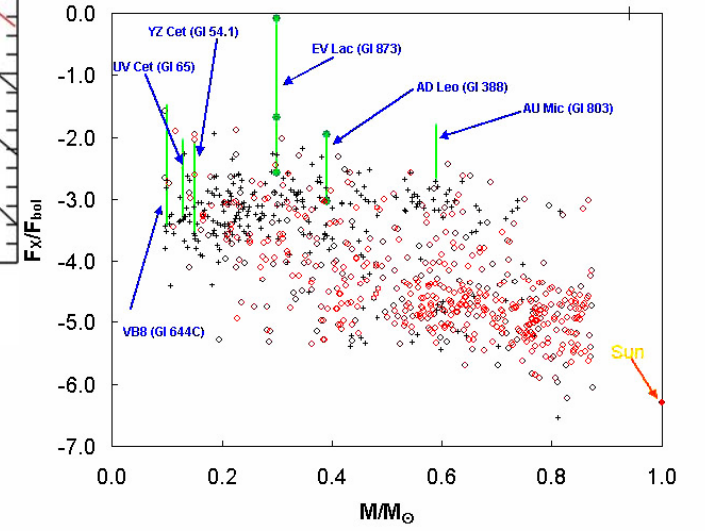
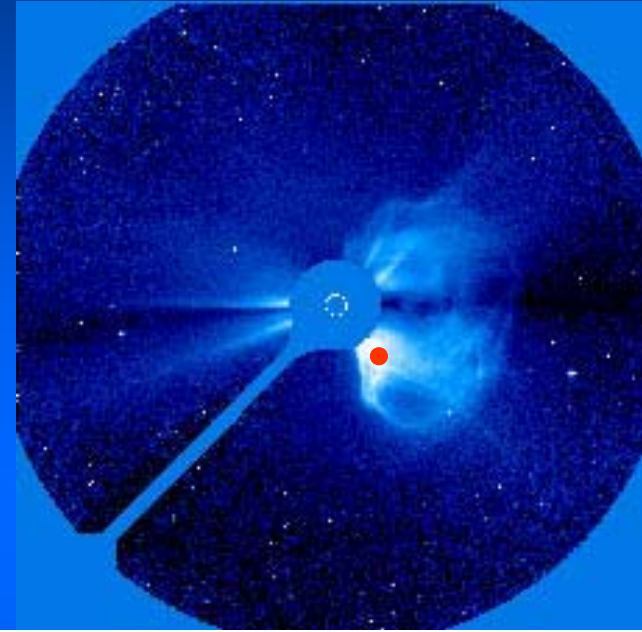
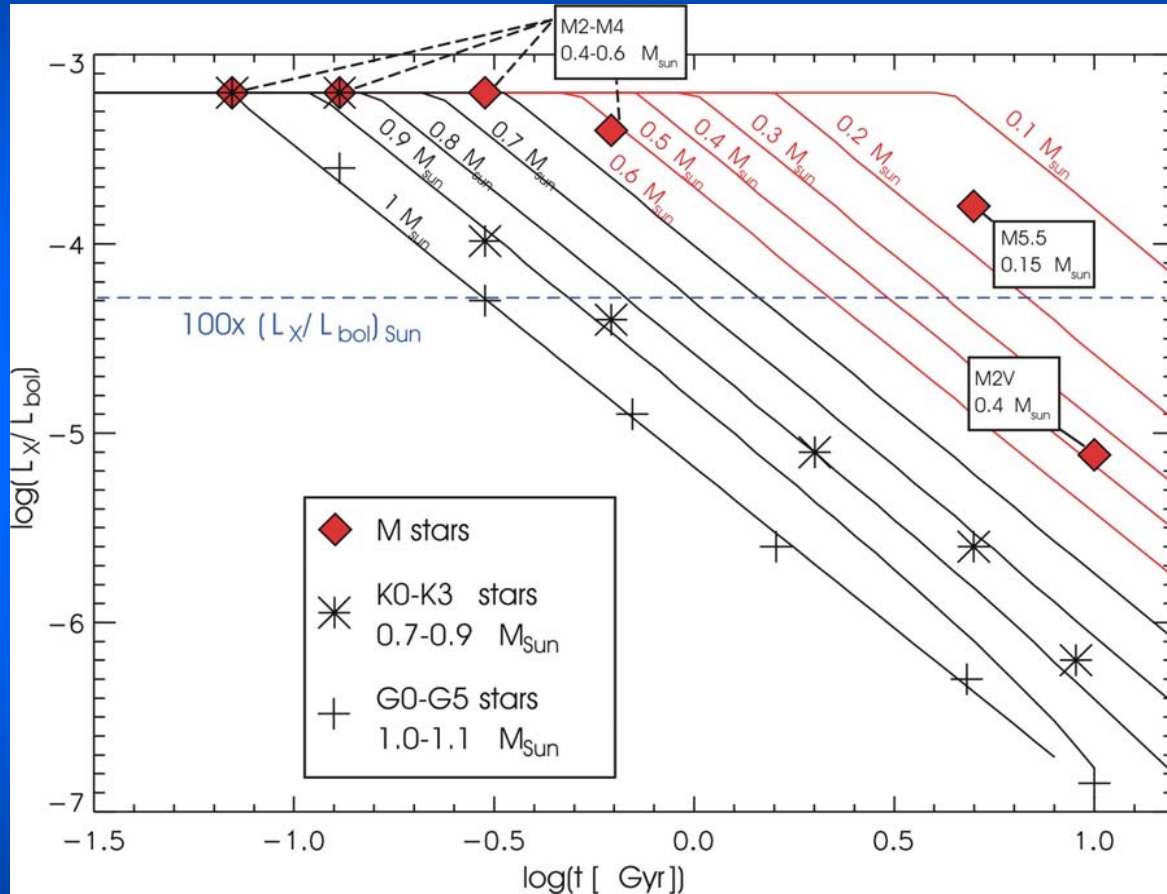


Close-in Exoplanets, early Mars ?

2 – Needed data sets:

- Space based → MEX, VEX, Cassini/Huygens, SoHO, CoRoT, etc.:
transits (planetary size), stellar/solar observations - future → astrometry (Gaia),
spectroscopic atmosphere characterization → Darwin-type, etc.
- Ground based (follow up) observations for mass determination and
characterisation of the host stars. Various programs inside and outside the
CoRoT EPWG are going on in Europe (CORALIE, SOPHIE, TLS, BEST, HARPS,
UVES+FLAMES, BEST, HARPS, etc.).
- Host stars: Analogies with solar activity, observations/data → solar proxies (age)
- Atomic and molecular parameters (collision cross sections, production and
dissociation rates, ionization rates, etc.) → extreme and hot conditions !
- Application of theoretical models
 - Modelling of Jupiter-type thermospheres under
extreme conditions → Energy balance
 - Hydrodynamic modelling → Cooling by planetary winds, loss
 - Numerical test particle codes, hybrid codes,
sputter codes, GCMs slow rotating planets
 - Biomarker and spectra simulations (IR and vis)
 - Dynamo generation – magnetosphere protection

3 – Problem description:



**Connection to early atmospheres of
Venus, Earth, Mars, Titan, Jovian
satellites?**

4 – Current solution:

- Identification of the problems during the past three years (ESA TE-Sat, etc.)
- Developments/applications of numerical hydrodynamic models
→ combined with stellar radiation (X-ray and EUV) evolution are currently applied for studying thermal evaporation over Gyr-time scales
- Recent application of a numerical test particle model to ion pick up due to a weakly magnetized Hot Jupiter indicate that CMEs occurring at the present solar rate may destroy (erode) the planet due to large loss rates

Problems:

- The application of thermospheric modelling (chemistry under extreme conditions) is needed → Expertise from scientists working on the thermospheres of Solar System gas and ice giants is needed!
- Problems with test particle models (plasma penetration depth, planetary obstacles) → Hybrid codes, contribution of sputtering, magnetic protection, ionized exospheres, etc.

5 – What services users expect from IDIS to work efficiently:

- Information and easy access to laboratory measurements/data related to atmospheric/thermospheric chemistry (collision cross sections, reaction rates, etc.), spectroscopic data (absorption spectra, emission spectra) observed in planetary atmospheres, etc.
- Applications of Hybrid codes and sputter codes available in Europe to extreme plasma flow conditions and their interactions with expanded atmospheres of X-ray and EUV (XUV) heated close-in exoplanets (Venus-type, Earth-type, Jupiter-type)
- **The DWG 7 science case has a strong synergy for atmospheric studies of early Venus, Earth, Mars, Titan → Evolution of their atmospheres and water inventories**

Exobiology (~ Astrobiology, Bioastronomy)

Study of Life in the universe

- ⇒ origins, distribution and evolution of life
- ⇒ & structures and processes related to life
- ⇒ destiny of life (Astrobiology)

Very multidisciplinary field (from Life sciences to chemistry, geology, physics and astrophysics)

Many planetary targets in the solar solar system and beyond:
Mars, more generally telluric planets for understanding the Earth,
Europa, carbonaceous chondrites and related asteroids, comets,
Titan, exoplanets: Earth-like and ocean-planets

DWG 6 → Astrobiology

1.) Carbon cycle on Titan → **Cassini/Huygens**

- a.) Origin and release processes of methane in Titan's atmosphere
- b.) Mechanisms of formation and properties of Titan's organic aerosols

2.) Martian surface, near-subsurface environment → **ExoMars, etc.**

- a.) Source, nature and evolution of organics on the surface and near subsurface
- b.) Environmental conditions: UV, energetic particles, oxidants
- c.) Selection of landing sites of great astrobiological interest
- d.) Evolution of the Martian water inventory

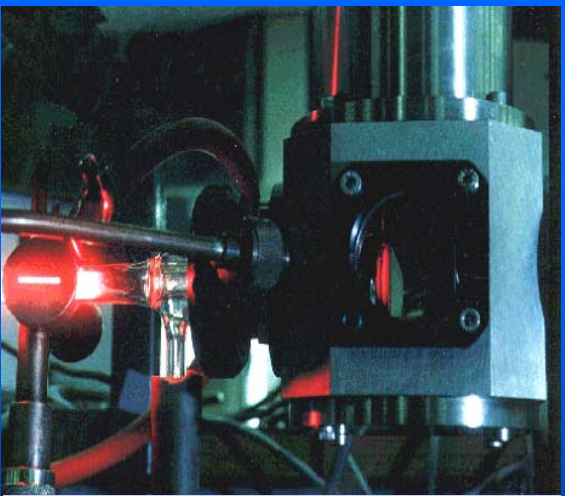
3.) Astrobiology on Europa → **future Europa mission**

- a.) Were the initial conditions on Europa favourable for the emergence of life (energy sources, liquid water and prebiotic matter)
- b.) How can we detect bio-markers related to Europa's life if it exists?

- 4.) Delivery and survival of organics
 - a.) Studies on micrometeoroids → early Earth early Mars, Europa, Titan, etc.
 - b.) Simulations on ices and dust under simulated interstellar conditions → **Comets**
 - c.) Space and ground-based exposure experiments



The analysis of 50-100µm micrometeorites collected at Cap-Prudhomme, Antarctica, indicates that a huge amount of extraterrestrial organic matter has been delivered to the primitive oceans.



Sixteen amino acids have been obtained when irradiating ices of CO, CO₂, CH₃OH, NH₃ and H₂O, under simulated interstellar conditions.



Amino acids survive in Earth orbit when they are embedded in few µm of meteorite powder

Exposure facility BIOPAN onboard unmanned Russian satellite FOTON

1.) Carbon cycle on Titan

a.) Experimental determination of constants in Titan-like environmental conditions → input for theoretical models

PALMS, Rennes, France → determination of rate constants related to photochemical modelling

IPC-PAS Warsaw, Poland; LISA, Paris, France; LPPM, Orsay, France; Bessy Synchrotron, Berlin, Germany → spectroscopic data related to photochemistry

→ DWG3+5: DWG 1: LPG, Nantes, France

b.) Experimental determination of physical and chemical properties of Titan's aerosol analogues

SA, Paris; LISA, Paris; ENSCP, Paris; LPG, Grenoble; LPG, Nantes; CETP, Paris; France; Open University, UK; IWF, Graz, Austria; Italian team related to radar spectroscopy

Note: SA & LISA can provide analogues for experimental determination

2.) Martian surface and subsurface environment

a.) Experimental determination of the evolution of organics under Martian environmental conditions

LISA, SA, Paris, France; Leiden University; The Netherlands, DLR,
Cologne, Germany; CAB, Madrid, Spain; IWF, Graz, Austria

b.) Experiments related to the diffusion of oxidants into the Martian soil and resistance of biological matter to Martian conditions

CBM, Orleans, INRA, Paris, IJM, Paris, France; DLR, Cologne;
HAS, Budapest, Hungary; IWF, Graz, Austria; Salzburg,
University, Salzburg, Austria; Aarhus, University, Danmark;
Leiden University, The Netherlands; CAB, Spain; Open University,
UK

3.) Astrobiology on Europa

a.) Hydrothermal vents in situ and in the lab as possible experimental model for Europa's oceans

CBM, Orléans; Univ. Brest ; LISA, Paris; LPG, Nantes; SRSN, Poitiers, France ; Stockholm University, Sweden

b.) Search for bio-markers, from terrestrial analogues

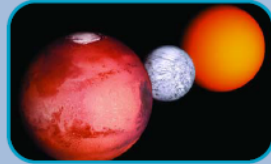
Open University, UK; IWF, Graz; Univ. Salzburg, Austria; CAB, Madrid, Spain; CBM, Orléans; Univ. Orsay, France

c.) Spectroscopic and particle detection of bio-markers from orbiters [particles] Univ. Bern, Switzerland; [modelling] IWF, Graz, Austria; other institutions ? → **DWG 3**

What services users expect from IDIS to work efficiently:

- Information and easy access to laboratory measurements/data related to the experiments described before
- Delivery of data obtained in Astrobiology labs and experiments to N7
- Astrobiology relevant data base

Search for habitats and signatures of life beyond the Earth



Exploration of our Solar System

- Mars likely had conditions for life, and might harbour life today, at depth, in hydrothermal or ice-rich regions.
- On Europa, recent studies indicate the presence of large quantities of liquid water – an ocean – below the thick ice crust.
- Titan, while too cold for life, exhibits planetary-scale organic chemistry in its dense atmosphere.

The search for extrasolar planetary systems

- Among the most remarkable discoveries of the last decade is the detection of numerous extrasolar planetary systems.
- Detection, analysis, and understanding of extrasolar systems provides essential information about the possibility of life elsewhere.

The development of ground and space-based telescopes, space missions, laboratory simulations, and the design of dedicated instrumentation and robotic tools, is necessary to understand life's position in the Universe.



Only interdisciplinary and international collaboration can lead to progress in these fundamental fields of research....

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<http://www.spaceflight.esa.int/exobio>

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European Astrobiology Network Association



Website → links to relevant sites related to astrobiology (DWG6) and exoplanet research (DWG7) in Europe, like exoplanets encyclopaedia – statistics, new discoveries (J. Schneider), - relevant papers, . . .