



MAIN RESEARCH QUESTIONS

- How does stellar/solar plasma and short wavelength radiation (X-rays, XUV, EUV) impact planetary environments (i.e., exo-/thermospheres, surfaces), and what kinds of physics govern the evolution of planetary water inventories and atmospheres?
- How does comparative planetology lead to better understand the evolution of planets towards Earth-like habitats?
- How do electromagnetic emissions from an underground seismic source penetrate and disturb atmosphere/ionosphere?
- How can we characterize physical processes on icy surfaces?
- What properties of porous material on comet/asteroid surfaces are most significant for gas flow, and how do they generate the mass transport and thermal balance on the surface?

WHAT IS COMPARATIVE PLANETOLOGY?

Comparative planetology studies the joint evolution of terrestrial planets within a planetary system by explaining their diverging paths as influenced by the same host star. A main goal is to explain why the Earth evolved towards a habitat while the other planets did not.

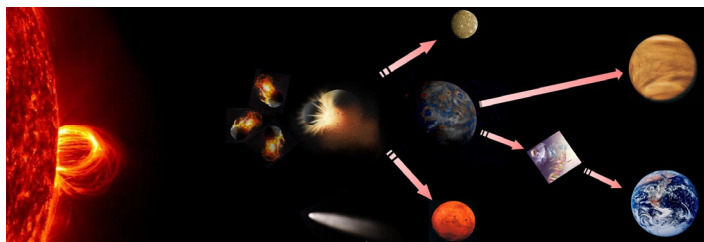
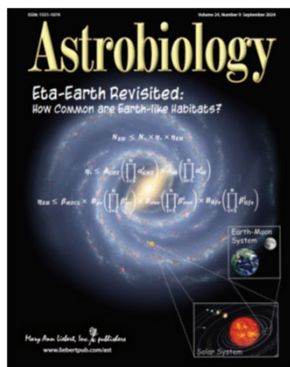
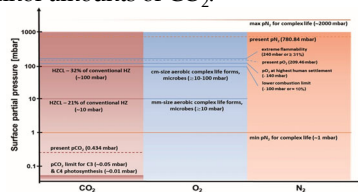


Illustration of the diverging paths of Mercury, Venus, Earth, and Mars.

HOW COMMON ARE EARTH-LIKE HABITATS?

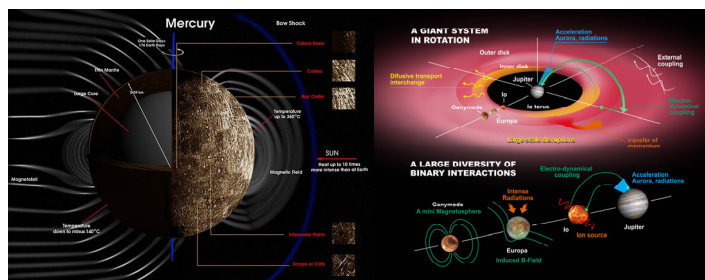


For the PLATO mission, we study Earth-like habitats, which are necessary for aerobic complex lifeforms and are defined as rocky planets that orbit within the HZ of complex life and host an N_2 - O_2 -dominated atmosphere with minor amounts of CO_2 .



Aerobic lifeforms are most likely rare because they can originate only at very finely tuned astrophysical and geophysical planetary environments, the complexity of which depends on the developed lifeforms.

FROM MERCURY TO ICY SATELLITES

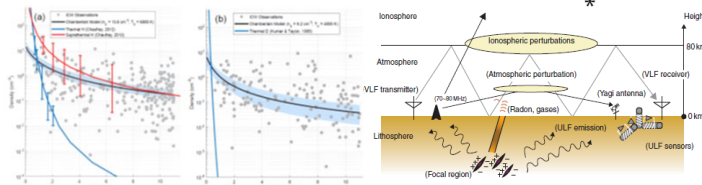


Plasma and radiative interaction with hot and icy surfaces. © ESA

With the particle detectors aboard ESA's **BepiColombo**, **JUICE** and **Comet Interceptor** missions (e.g., **PICAM** ion camera), we study the formation of Mercury's silicate exosphere and investigate similar surface release processes at icy satellites and cometary material.

ATMOSPHERE EVOLUTION AND LITHO-IONOSPHERE COUPLING

We further study the evolution of the atmospheres and water inventories of Venus, Earth, and Mars.



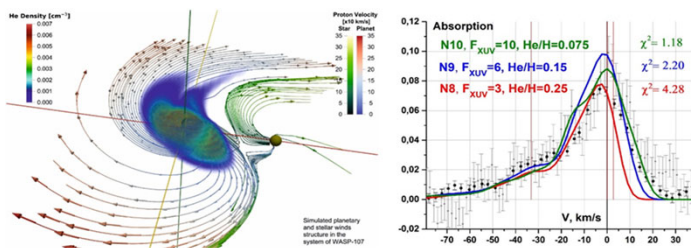
Left: Exospheric suprathermal H atom (a) and D isotope (b) neutral densities that originated from water molecules in Venus' thermosphere, derived from Venus Express/MAG and Ion Cyclotron Wave data analysis over the mission lifetime. Right: Radio techniques developed to investigate physical processes from lithosphere-ionosphere coupling (e.g., seismo-electromagnetic waves from earthquakes).

Knowing the D/H ratio of the escaping hydrogen particles, it is possible to shed light on the evolution of the planet's water balance over geological timescales. In Venus' case, the planet had no liquid water ocean for the past billion years after its origin.

On Earth, earthquakes generate electrical charges that create seismo-electromagnetic waves, which can be detected by satellites like China's **CSES-1** and **CSES-2** missions, as well as ground-based antennas such as the **INFREP** network.

STAR/SUN-PLANET MAGNETO-ATMOSPHERE INTERACTIONS

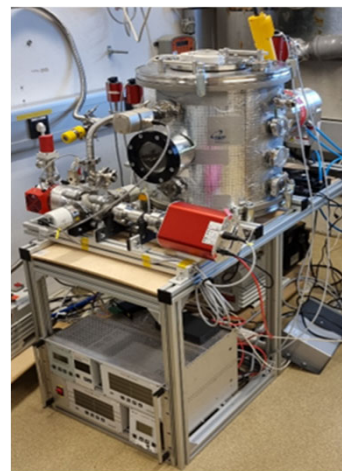
We employ a multidisciplinary approach to characterize and understand the physical processes in the dynamical (magnetic) environments of (exo)planets, driven by complex interactions between stars and planets, such as stellar and solar activity, plasma flows, and radiation. We use synergies between observations, laboratory experiments, and theoretical models.



Left: Modelled 3D distribution of He, of the escaping planetary wind from WASP-107b. The planetary and solar wind flows are shown with colored streamlines. The planet is at the center of the coordinate and moves counterclockwise relative to the star (green sphere). Right: He (10830 Å) absorption profiles, simulated for different He abundances and stellar radiation fluxes, versus observations.

ASTROLAB

The Astrolab studies the principal properties of porous surface materials on planets, asteroids, and comets. Thermal conductivity and the gas permeability of near-surface materials are decisive for the thermal budget as well as for the surface-atmosphere interaction. These parameters are investigated in suitable vacuum chambers under well-controlled conditions. Comparison with observations leads to a better understanding of ongoing processes, improving our physical models in support of upcoming space missions like **Comet Interceptor** and **JUICE**.



Example of an experimental setup. Experiments in the Astrolab are carried out so that we can support theoretical studies and simulations.