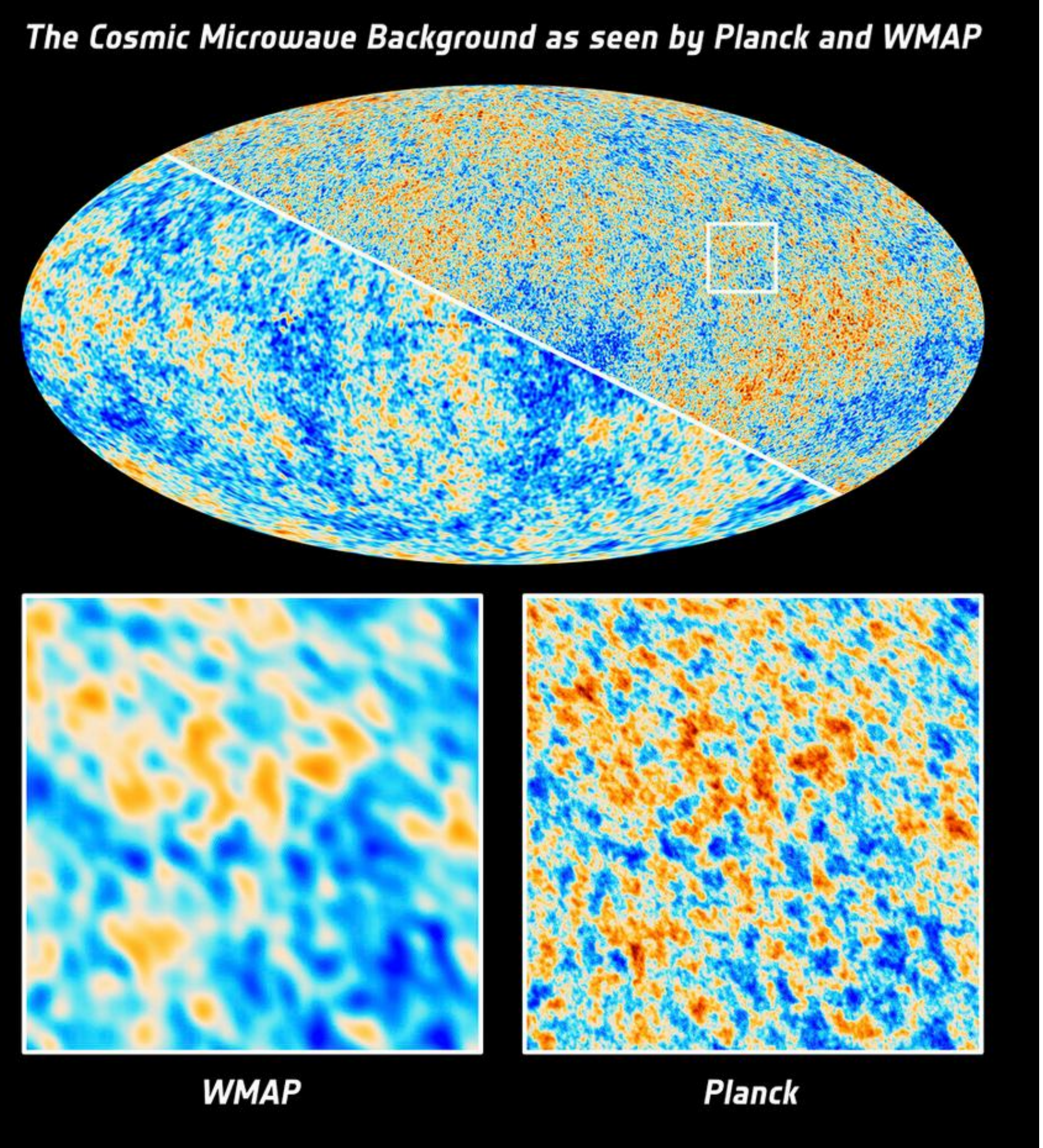


From small inhomogeneities of cosmic microwave background to ...

CREDIT: ESA and the Planck Collaboration; NASA / WMAP Science Team

… galaxies, stars

and planets

Ewa Szuszkiewicz,
CASA* and Institute of Physics,
University of Szczecin, POLAND

Credit: NASA's Earth Observatory

Main themes:

Connection between a planetary system and its galactic environment

From gas and dust to stars, planets and planetary systems

Detection and characterization of exoplanets

Geosciences for understanding habitability

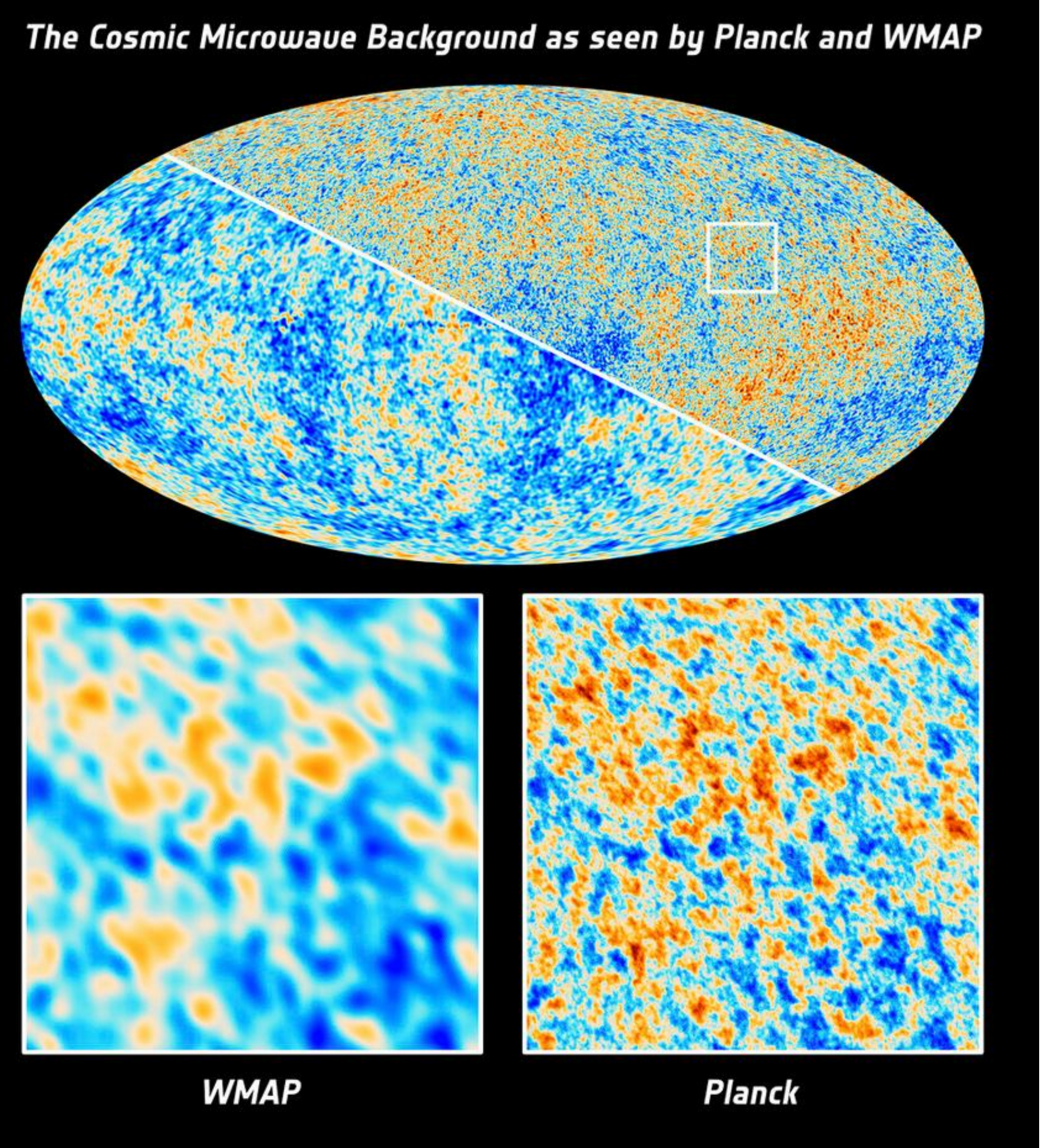
Planetary atmospheres and fundamental processes in climate dynamics

Life and habitability in the Solar System

Habitability in the planetary systems (case studies)

Connection between a planetary system

and its galactic environment



Local Group and its cosmic environment

The structures we observe evolve continuously.

They started as density fluctuations of matter in the early Universe found by COBE, confirmed by WMAP and PLANCK.

The overdensity Δρ/ρ, where ρ is the mean density, determined from the Cosmic Microwave Background (CMB) was of the order of $\sim 10^{-6}$. To form a galaxy, we need the overdensity twelve orders of magnitude higher than that.

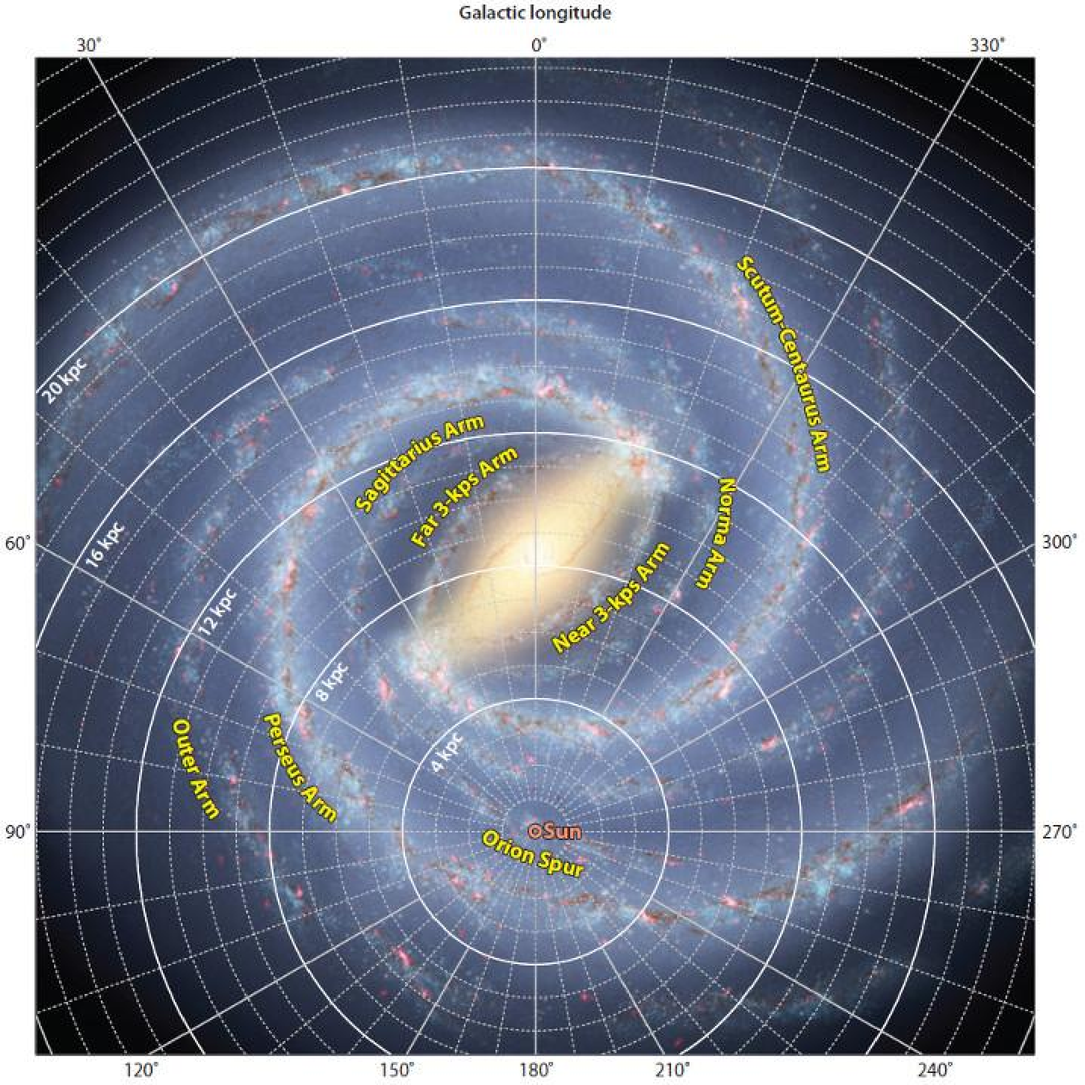
CREDIT: ESA and the Planck Collaboration; NASA / WMAP Science Team

The characteristic scales of:

a galaxy (our Galaxy) is 5×10^{4} light years (5×10^{17} km)

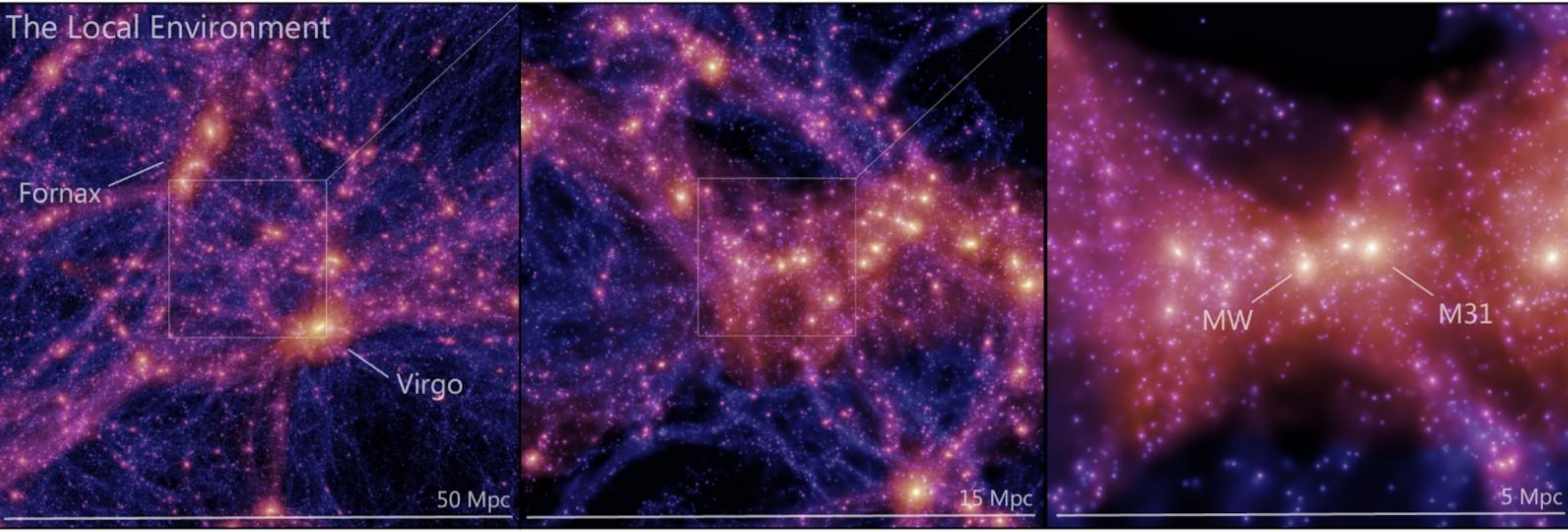
a planetary system is about 100 AU (1.6×10^{-3} light years, 1.5×10^{8} km), taking as an example our Solar System.

The supercluster's scale is much bigger, namely 5.5×10^{7} light years (5×10^{20} km), adopting the numbers for the Virgo Supercluster.



Credit: Robert C. Kennicutt, Jr. and Neal J. Evans II
Annu. Rev. Astron. Astrophys. 2012. 50:531-608

Simulations specially designed to reproduce directly the structure of our observed Universe.



The dark matter distribution in a region centred on the Milky Way, coloured by the projected density and velocity dispersion of the particles. Images are shown in y–z equatorial coordinates, projected down the x axis. Taken from McAlpine et al. (2022), 'Simulations Beyond The Local Universe' (SIBELIUS) project,

Our Galaxy and its cosmic environments

What can theoretical methods predict about the Galactic environment and its history?

To simulate the formation of a galaxy, it is minimally necessary to follow the evolution of a region of the universe comprising all the matter that ends up in the galaxy. For a typical Milky Way-like galaxy, such a region is of the order of $\sim$ 10 Mpc. The best computer facilities available cannot realistically perform hydrodynamical simulation of such a region with a resolution much better than $\sim$ 100 pc.

Necessity of the Semi-Analitical Models

The Galaxy: an environment populated by planetary systems

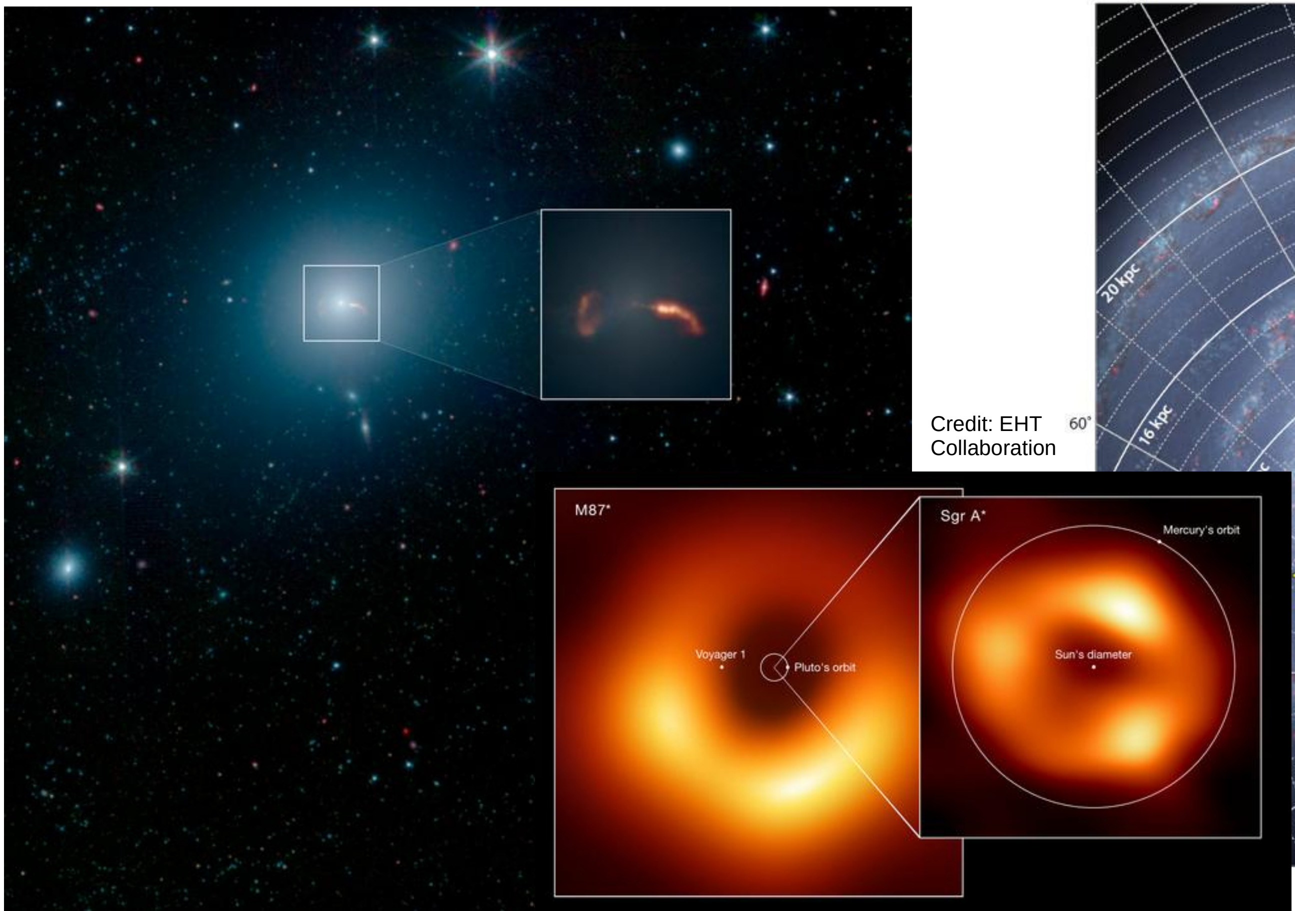
Complementary approach to investigate the history of formation and evolution of our Galaxy is to study its individual stars and stellar components, a method known as galactic archaeology. The observed properties found, using this approach, ideally should be consistent with the theoretical predictions.

Is there anything special about our Galaxy?

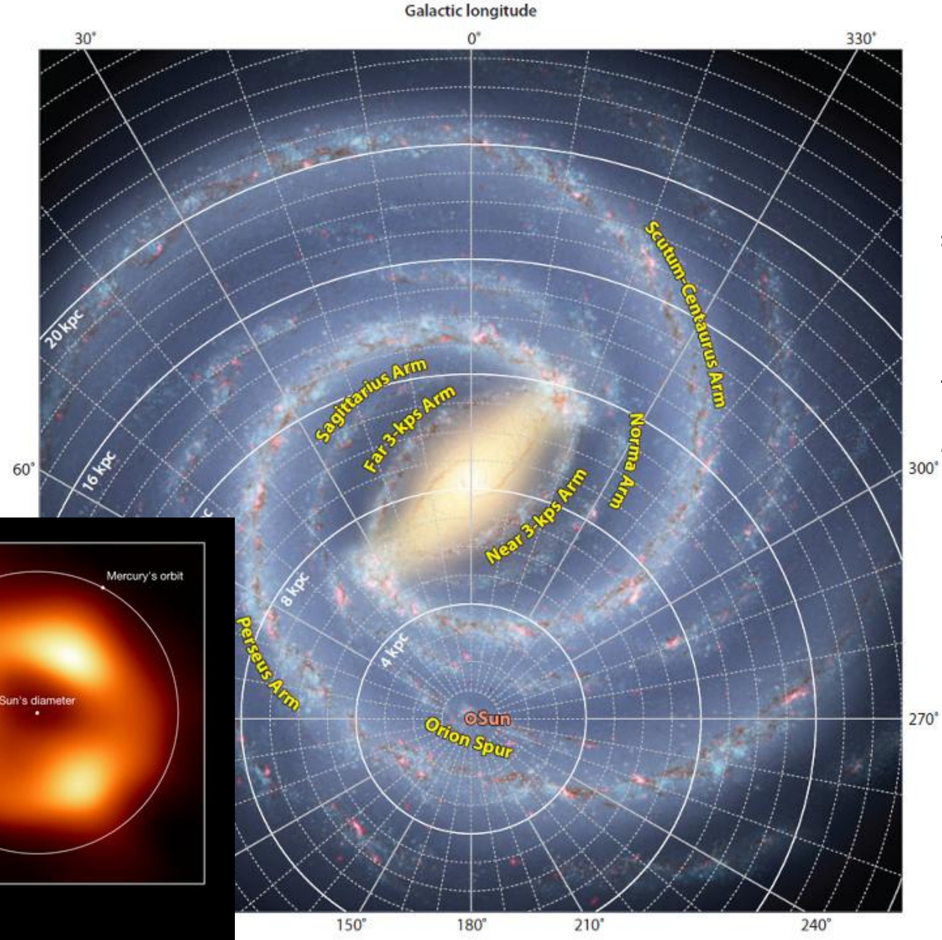
Active versus „normal” galaxy

What kind of large-scale, astrophysical processes can influence habitability in planetary systems?

Credit: NASA/JPL-Caltech/IPAC



Credit: EHT Collaboration

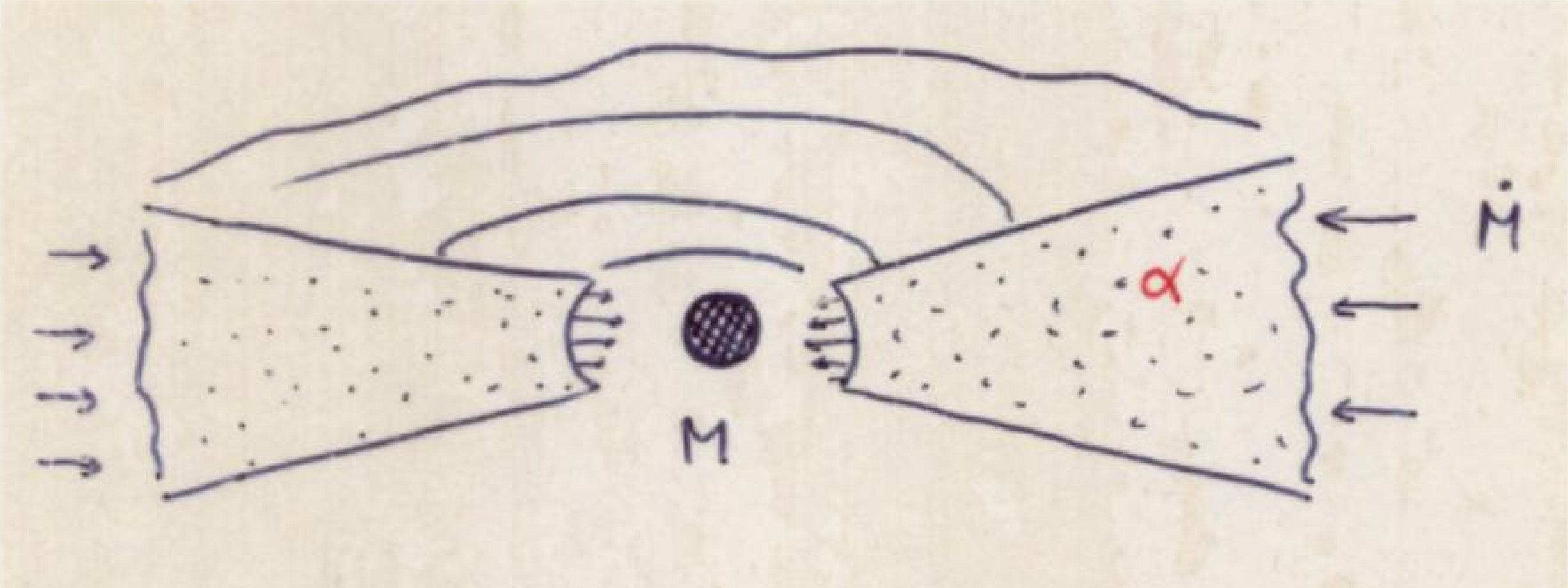


Credit: Robert C. Kennicutt, Jr. and Neal J. Evans II
Annu. Rev. Astron. Astrophys. 2012. 50:531-608

A new era for modelling of accretion processes

New life of the old accretion disk model

Stationary slim disk model



Abramowicz, Czerny, Lasota, Szuszkiewicz, 1988

What is it able to do, and what are its limitations?

Non-stationary accretion onto black holes - full limit cycle solution

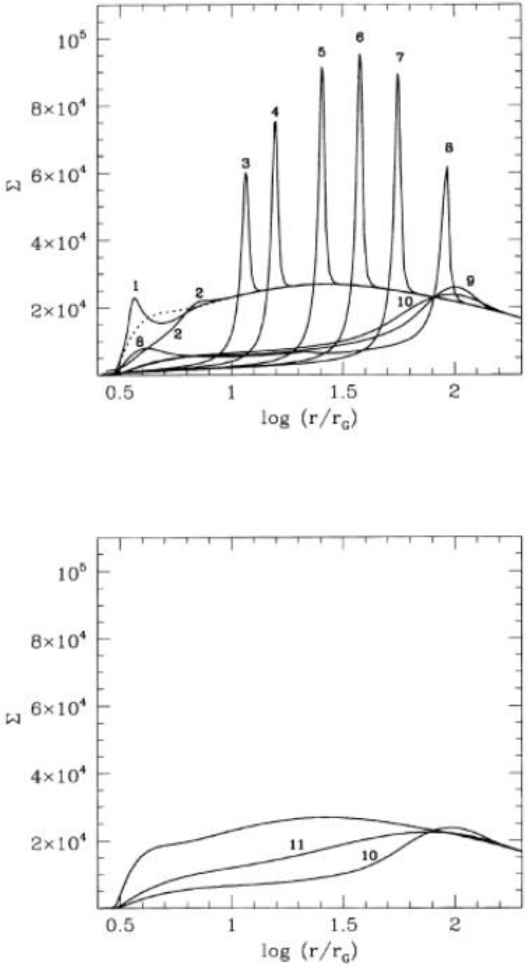
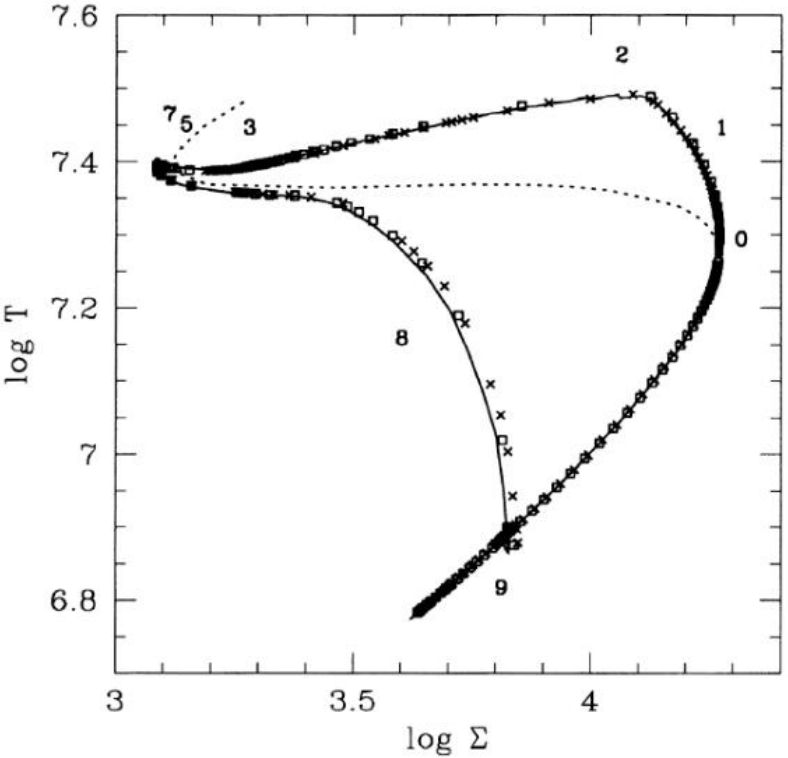


Figure 1. Changes in the radial distribution of the surface density Σ (measured in units of g cm^{-2}) during the second evolutionary cycle. The curves marked 1 to 11 show the situation after 876.41, 876.45, 876.79, 877.20, 878.36, 880.12, 883.42, 893.0, 925.0, 985.1 and 1209.0 s respectively. The dotted line corresponds to the beginning of the cycle, at around 876 s, and the unmarked solid line in the lower panel (which is essentially coincident with the dotted one) is for the end of the cycle at 1657 s.



Szuszkiewicz, Miller (1998)

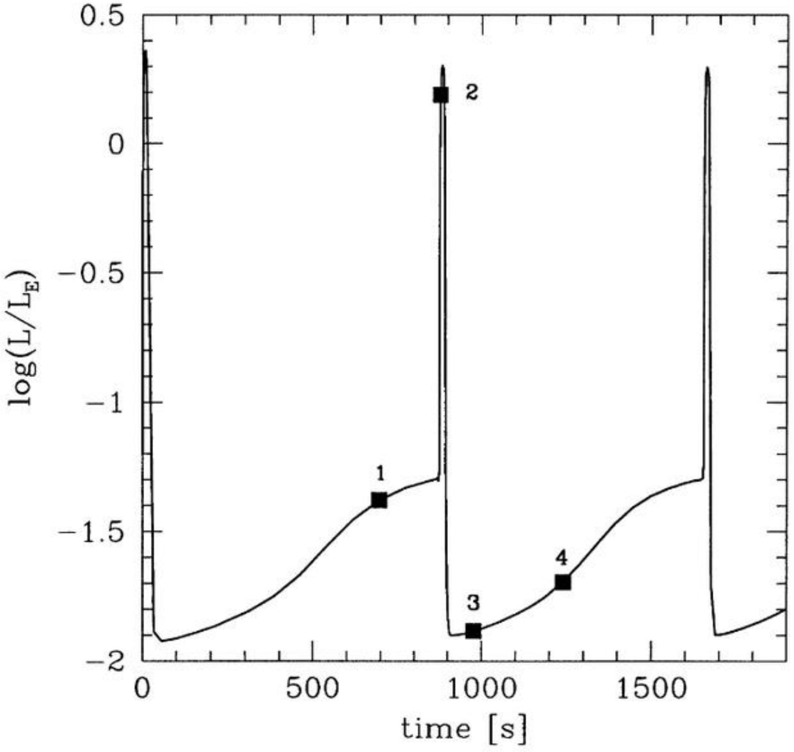


Figure 1. The bolometric light curve with the positions of four particular evolutionary stages described in the text.

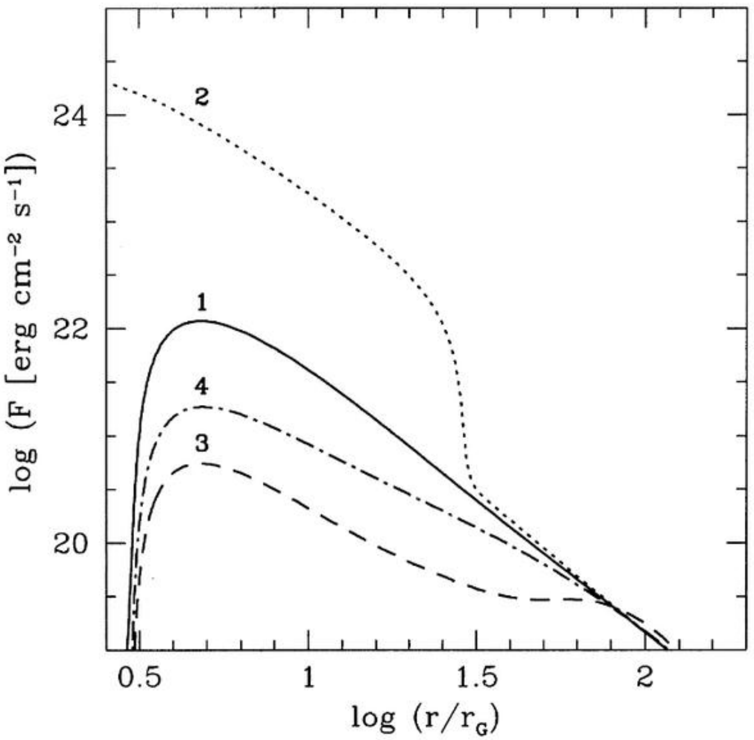


Figure 6. Same as in Fig. 2 for the emitted flux.

Zampieri, Turolla,Szuszkiewicz (2001)

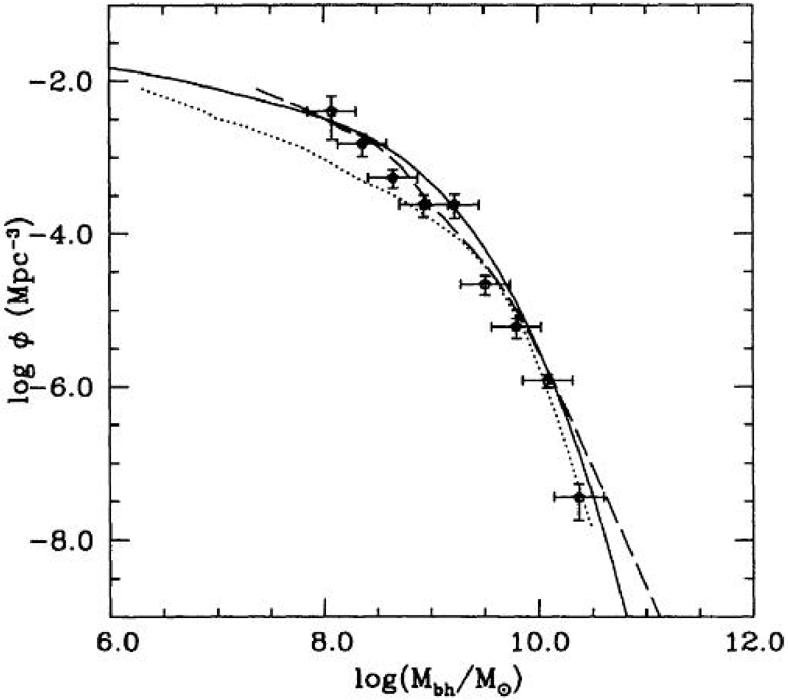


Figure 1. The mass function, $\phi_{OMF} d \log M_{BH}$, derived using a Gaussian in the logarithm distribution of the ratio M_{MDO}/M_{sph} (solid line) compared to the mass function, $\phi_{RMF} d \log M_{BH}$, derived from the radio luminosity function of of E/S0 cores (points with error bars). and to the MF of the relic BHs derived from the past activity of AGN under assumption: $\lambda = (L/L_E) = 10^{0.2(\log\ L-49)}$ (dashed line). The dotted line is the MF of the relic BHs as predicted by Cavaliere and Vittorini (1998).

Now, it is the right time to remove the main slim disk limitation.

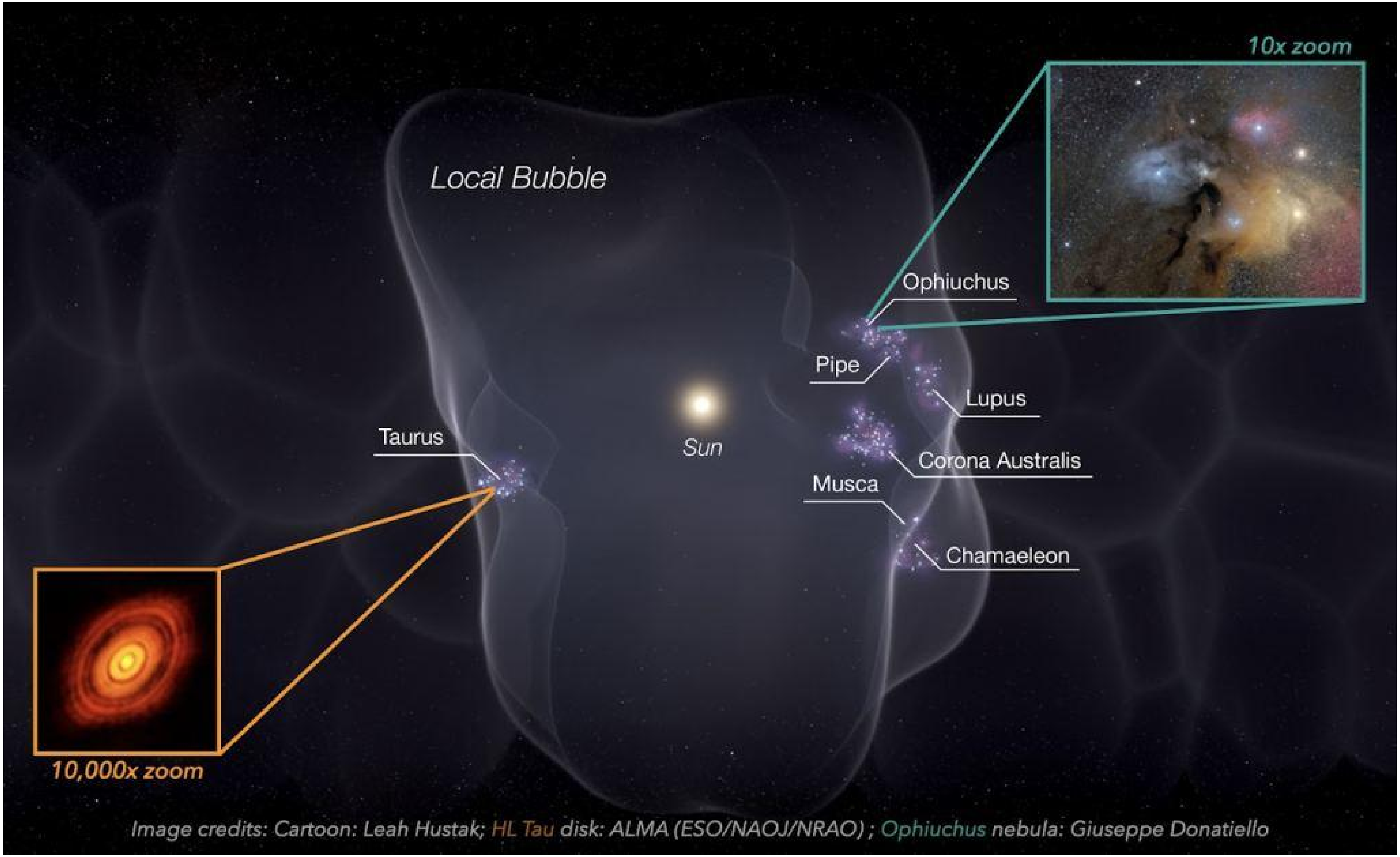
Stay tuned!

Salucci, Szuszkiewicz, Monaco, Danese (1998)

From gas and dust to stars, planets and planetary systems

(stars with planets, dwarf planets, asteroids ...)

From gas and dust to a star and its planetary system



Based on the results of Zucker et al. 2022

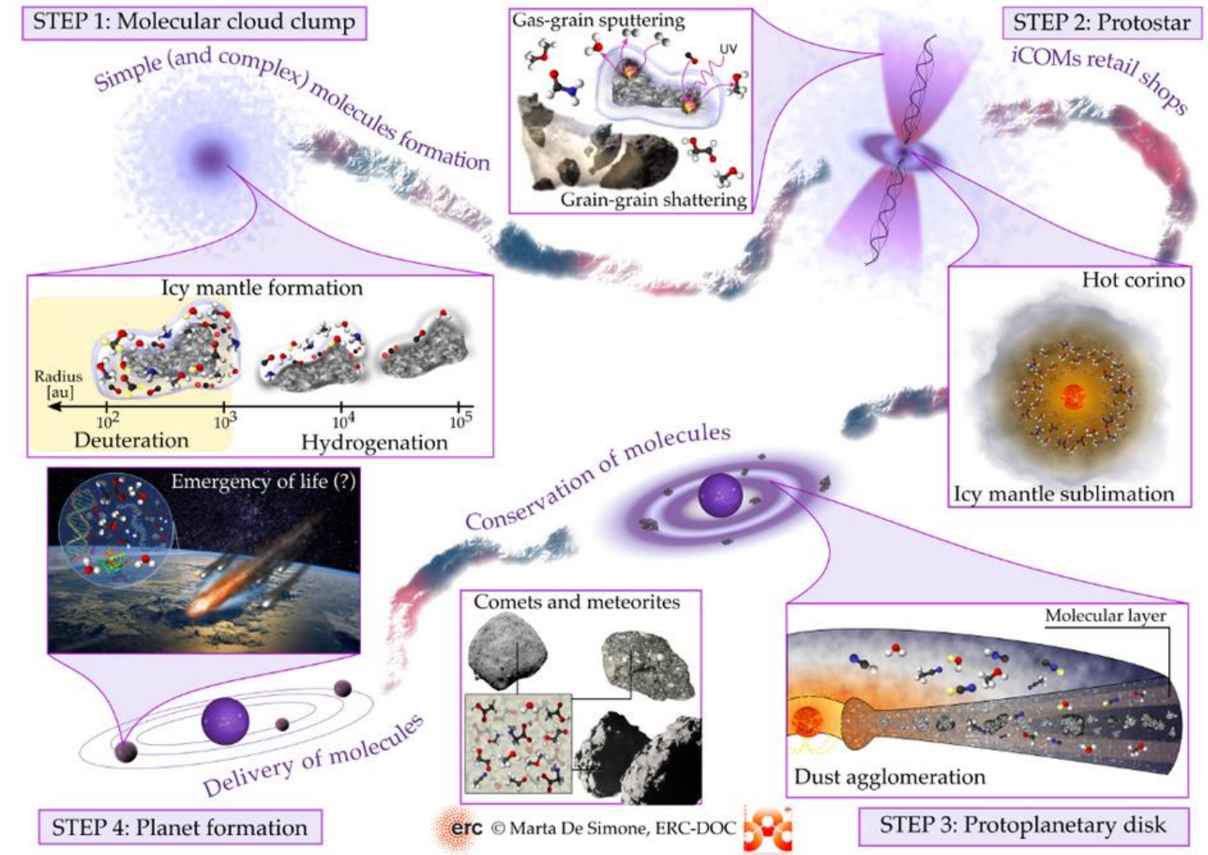


Fig. 1 A schematic sequence illustrating the formation of a Sun-like star and its disk. From a molecolar core inside a large-scale filament to the protostellar stage, and eventually to a planetary system around a Main Sequence star [from 12]. Simultaneously, complex molecular species are forming, through gas chemistry and/or gas-phase chemistry (see Sect. 1.1.1).

1.1.1 Chemical complexity around protostars

1.1.2 Protoplanetary disks: hosts for the planet formation process

1.1.3 Forming planets

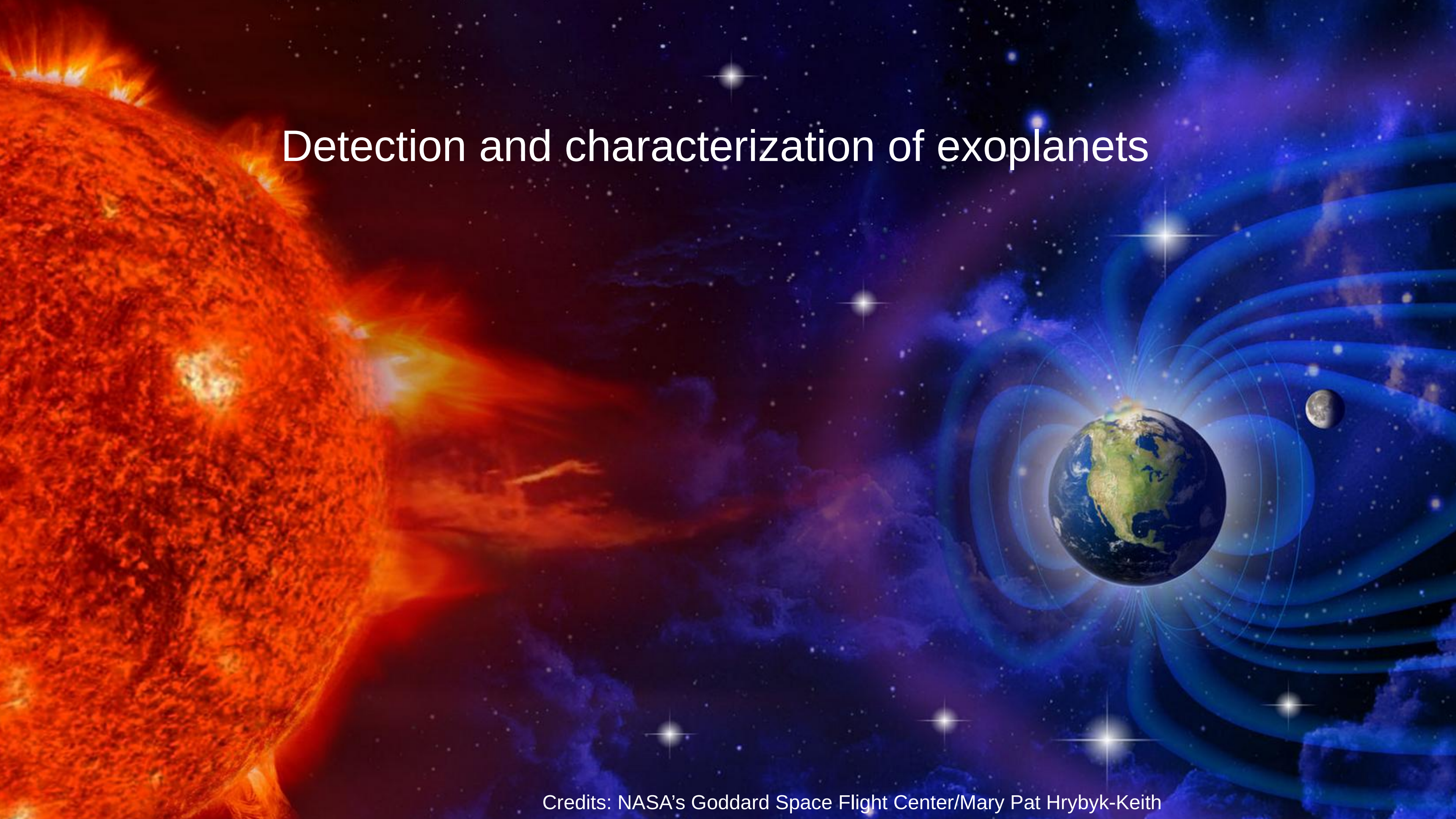
1.1.4 The challenge of detecting young planets

Where should we look for the planetary systems?

[12] De Simone, M.: Hot corinos: the early organic molecular enrichment of the planet formation zones. PhD thesis (2022)

Detection and characterization of exoplanets

Detection and characterization of exoplanets



Credits: NASA’s Goddard Space Flight Center/Mary Pat Hrybyk-Keith

3.1 Rocky planet detection: towards other Earth

3.1.1 What can be done today and some good examples: transits, RVs, direct imaging? (a few words on microlensing and astrometry)

3.1.2 What to expect with future instruments? (PLATO… prospects for rocky planets in HZ)

3.1.3 Challenges: exomoons, stellar noise, the connection between interior and atmosphere

3.2 Rocky planet characterization

3.2.1 What can be done today: mass, radius, composition, atmospheres?

3.2.2 What to expect from future instruments?

3.3 Detecting biosignatures: prospects and open questions

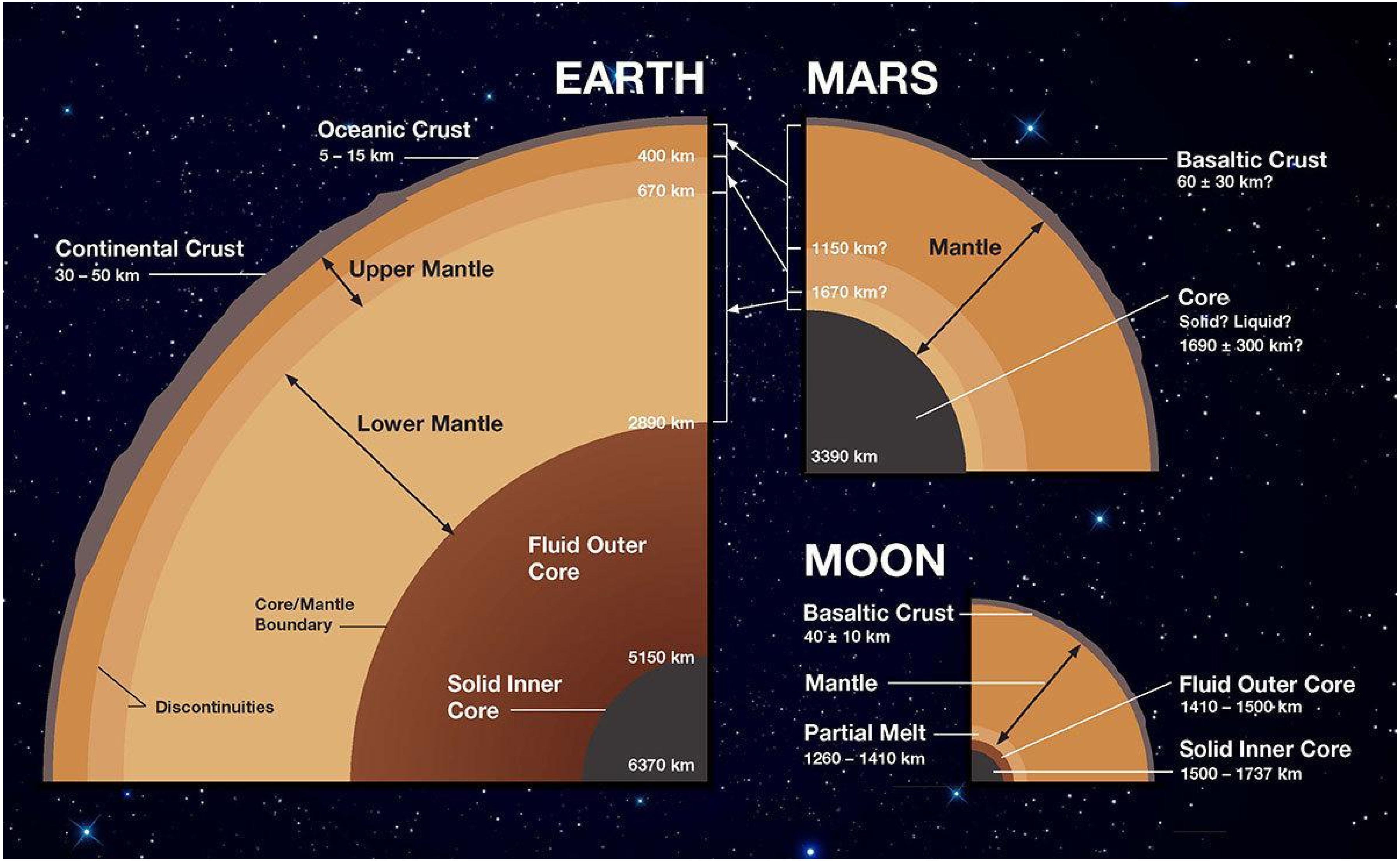
3.3.1 What to expect from future instruments concerning the detection of life

3.4 The need to characterize the full system

3.4.1 The star-planet connection (insolation, tidal effects, composition, magnetic fields

Geosciences for understanding habitability

Geosciences for understanding habitability



credit: NASA/JPL-Caltech

Planetary atmospheres and fundamental processes in climate dynamics

1.3 Atmospheric chemistry

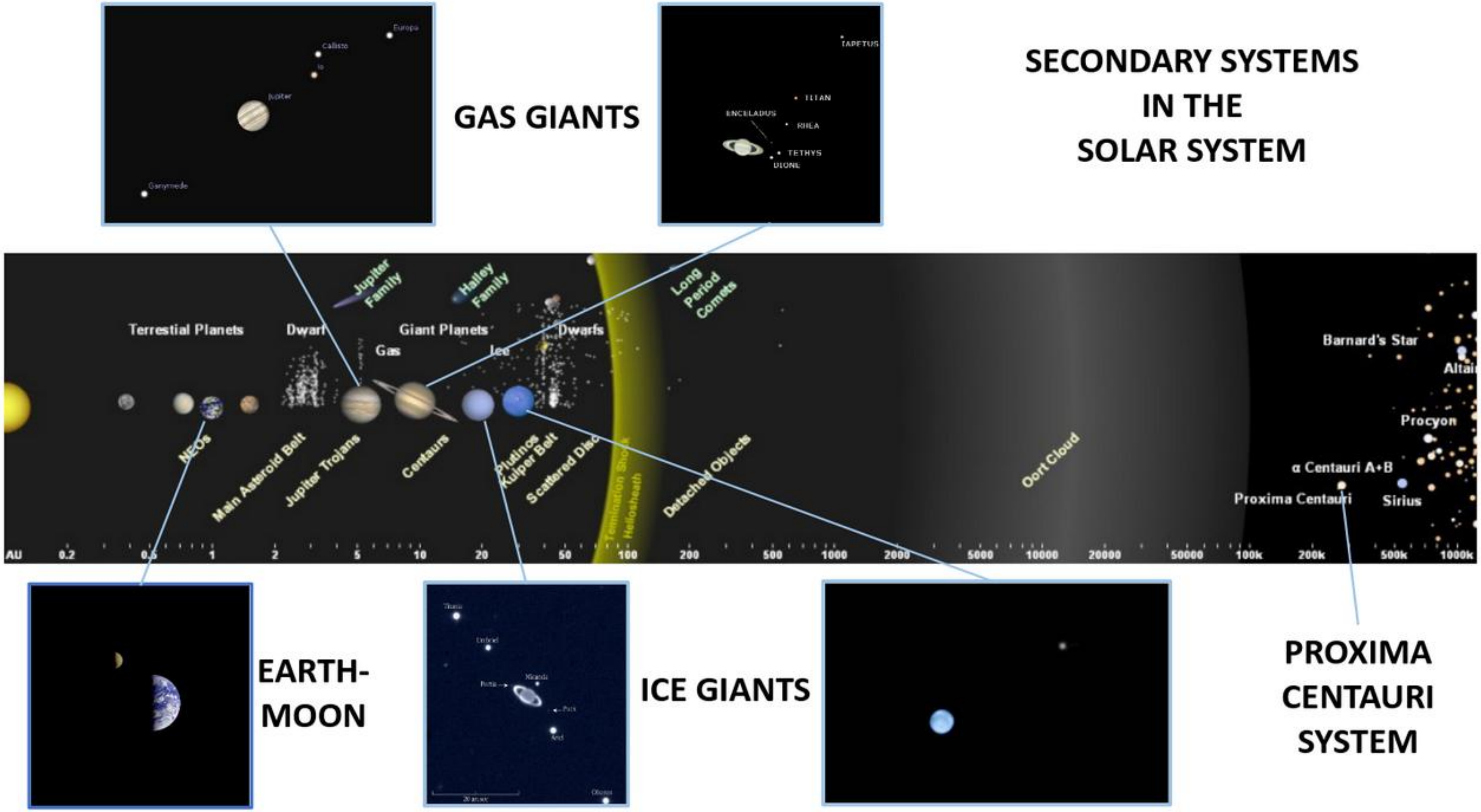
1.3.1 Habitability and atmospheric chemistry

1.3.2 Complexity and size of the chemical networks

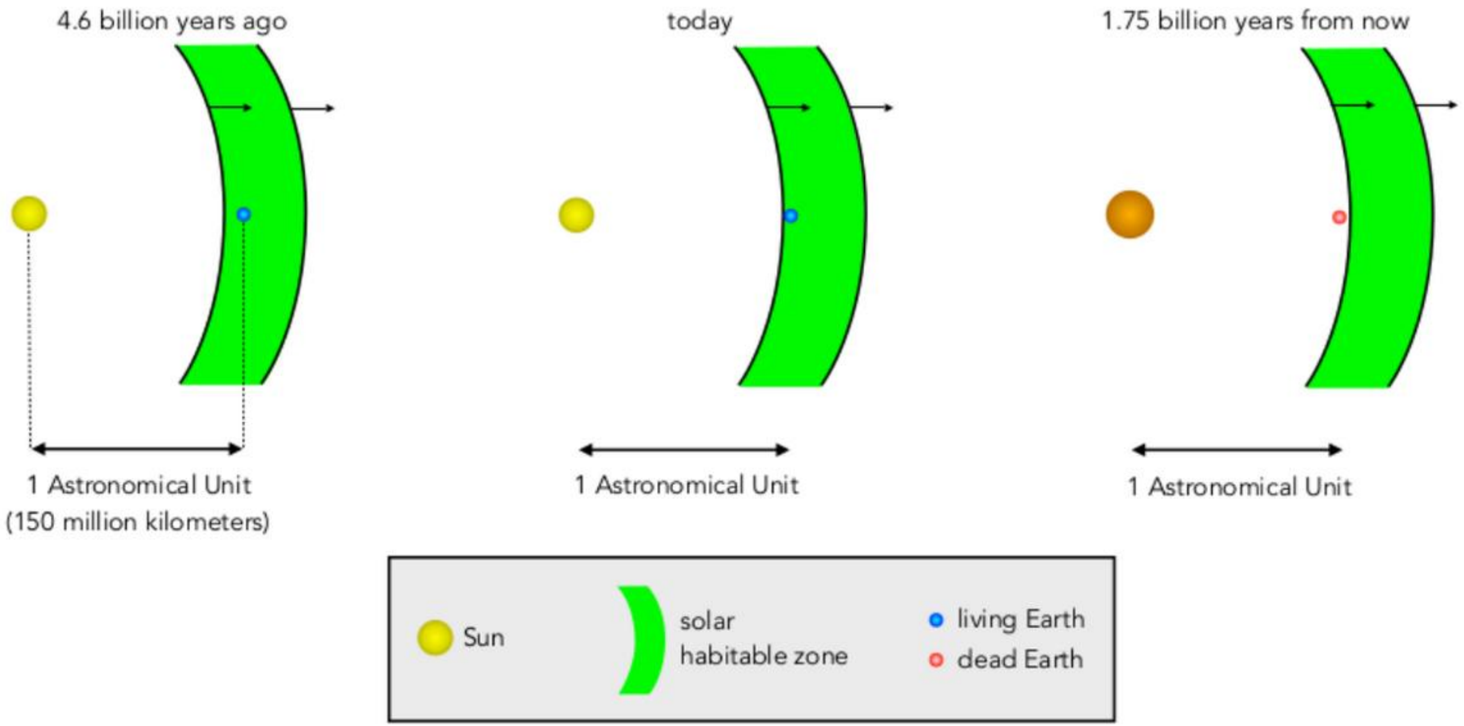
1.3.3 Limitations : uncertainties and missing chemistry

Life and habitability in the Solar System

Life and habitability in the Solar System



The Evolution of the Solar Habitable Zone



Habitability in planetary systems

1. **Solar System** (again but differently)
2. **alpha Centauri system:** Habitable worlds in the closest star system to our own.
3. **τ Ceti system:** Planets around the closest single Sun-like star to the solar system.
4. **TRAPPIST-1 system:** Seven Earth-size planets orbiting the nearby red dwarf.
5. **Kepler-452 system:** a super-Earth orbiting at the distance of one astronomical unit around a solar twin star.
6. …

Investigation of habitable worlds in one big laboratory – called Universe

If you are interested in, please join us.