

Transits in the Solar System and the Composition of the Exoplanet Atmospheres

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Background

Our current knowledge about exoplanets depends on very limited measurements and resolution.

However, upcoming space missions will give us unprecedented access to even Earth-like exoplanet light curves.

Could we use our Solar System's terrestrial planets light curves for habitability modelling?

Same HZ, Very Different Worlds

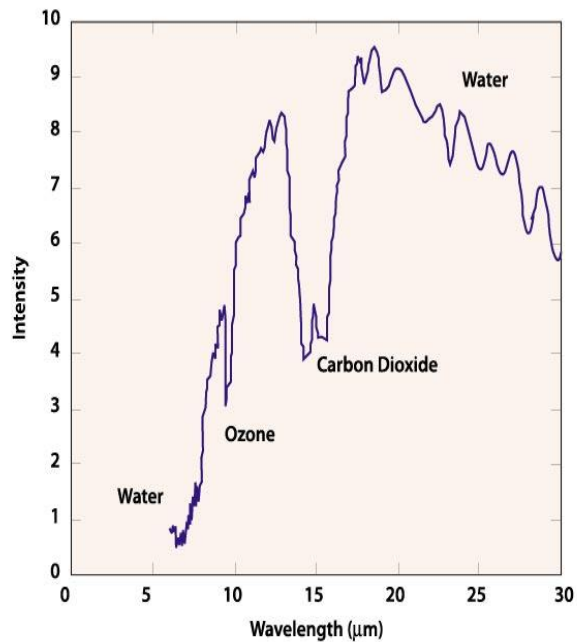
Habitable Zone of Earths Solar System



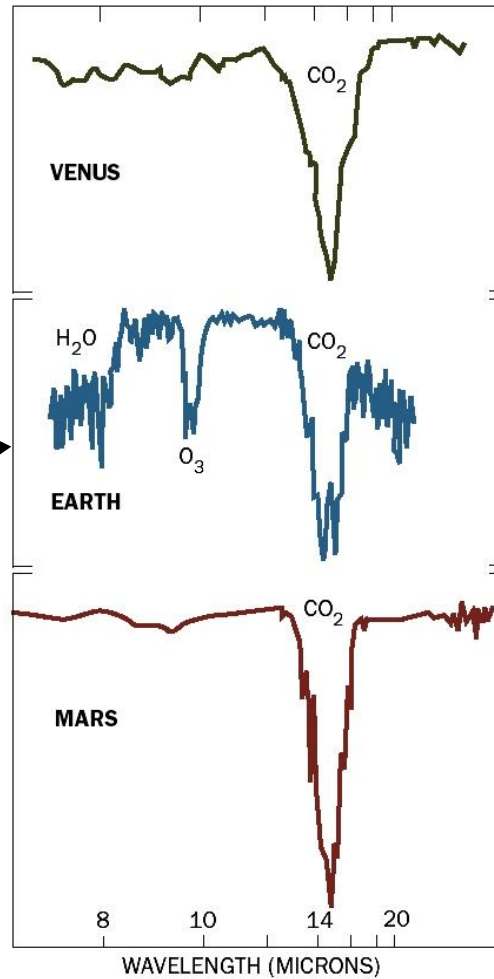
Planets and orbits to scale

Solar System

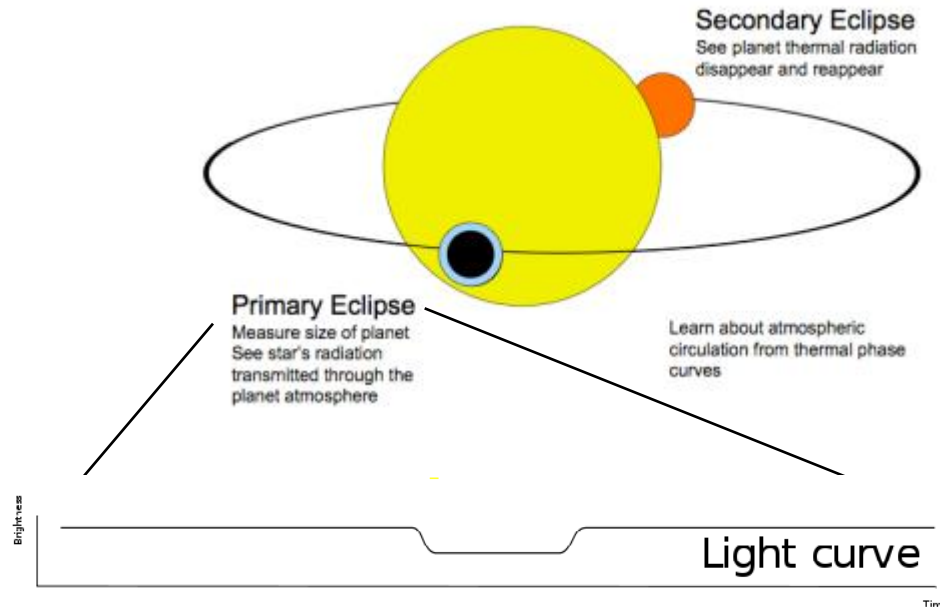
Background



?



Eclipses & Light Curves



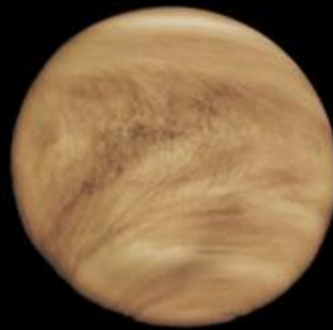
Photometry
Physical features

Transmission spectroscopy
Atmospheric composition

Past Experiments: Venus

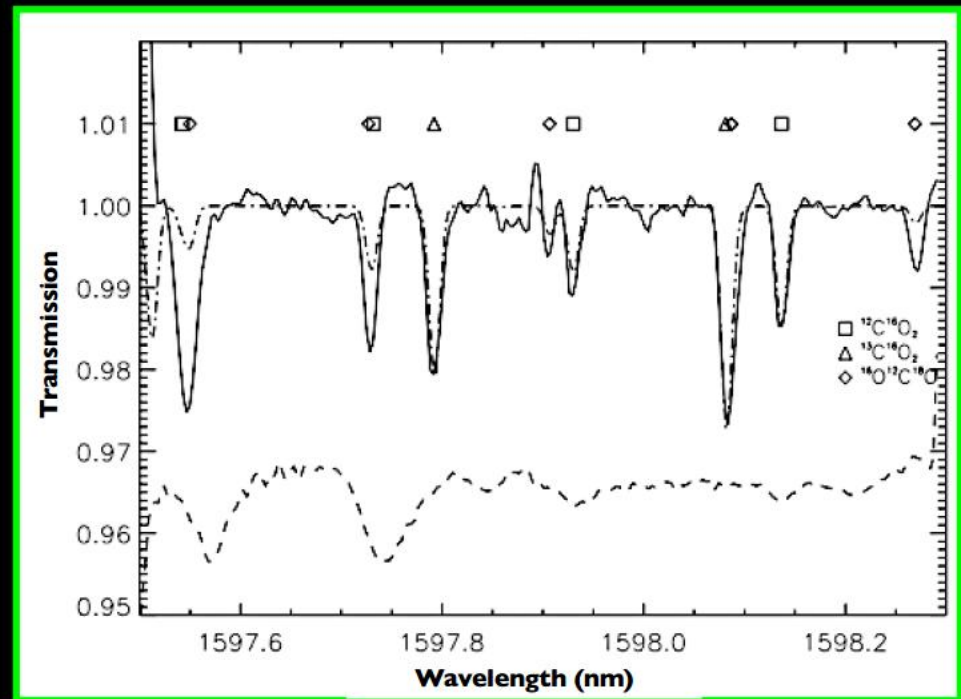
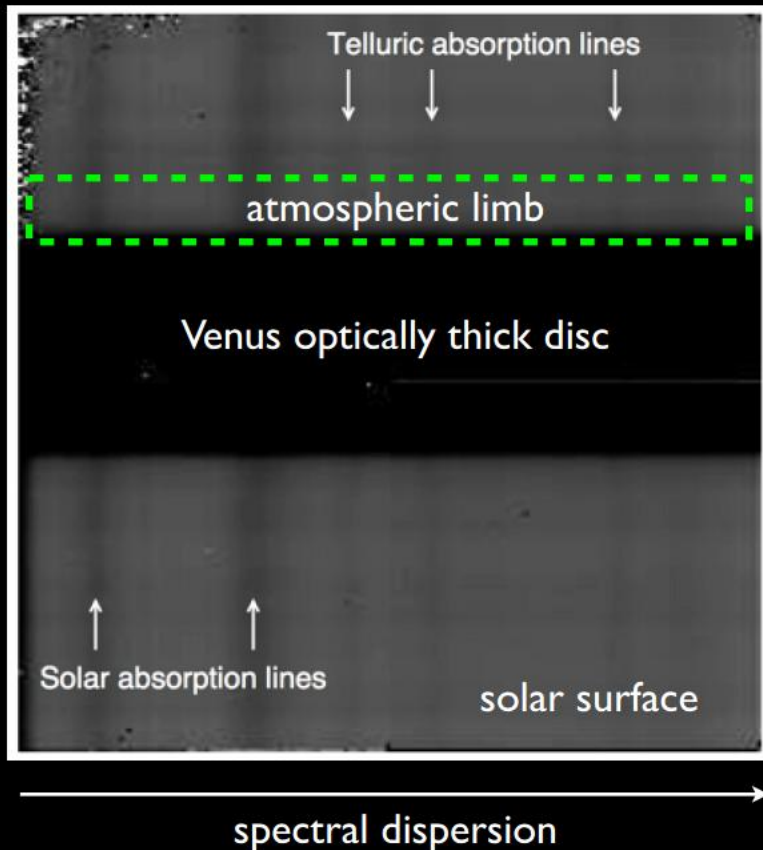
Venus transits in 2004 and 2012

Atmospheric spectra were obtained using ground-based and space observations



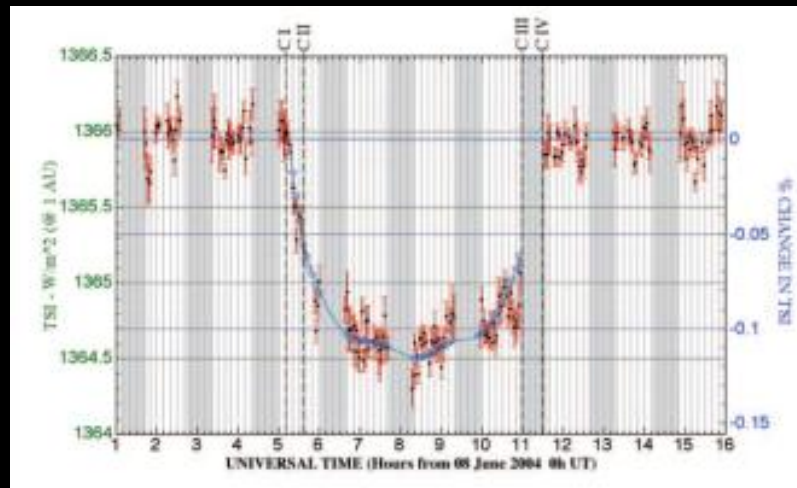
2004 Transit Spectrum of Venus

VTT observations during transit of Venus **2004**

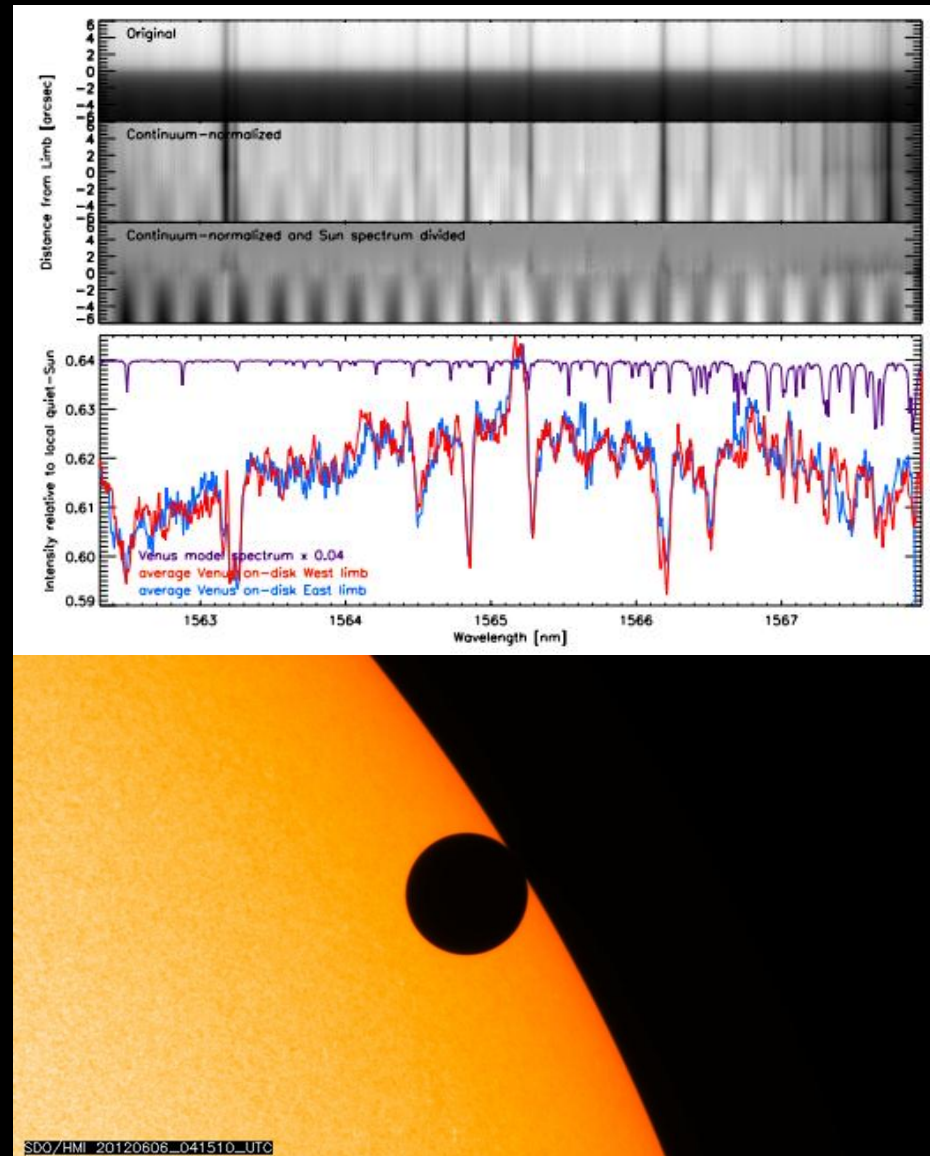


2004 Transit of Venus

Radiometric light curve



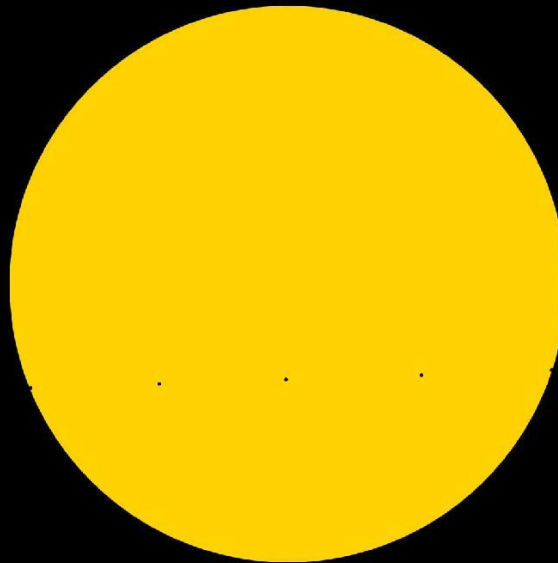
2012 Transit Spectrum of Venus



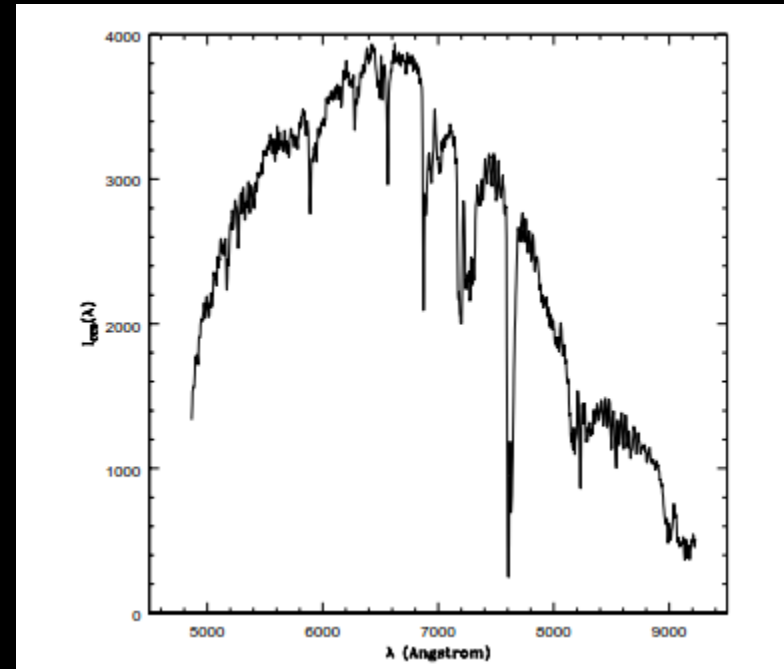
2012 Venus Transit

Experiment with Cassini's VIMS instrument
from Saturn (J. Pasachoff)

Transit of Venus as seen by Cassini



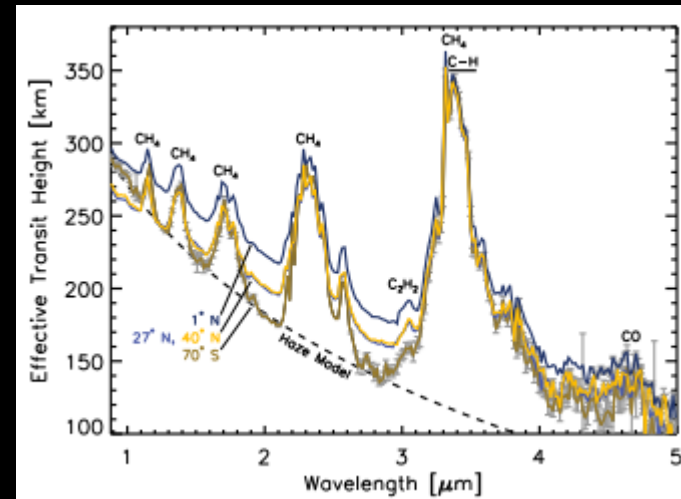
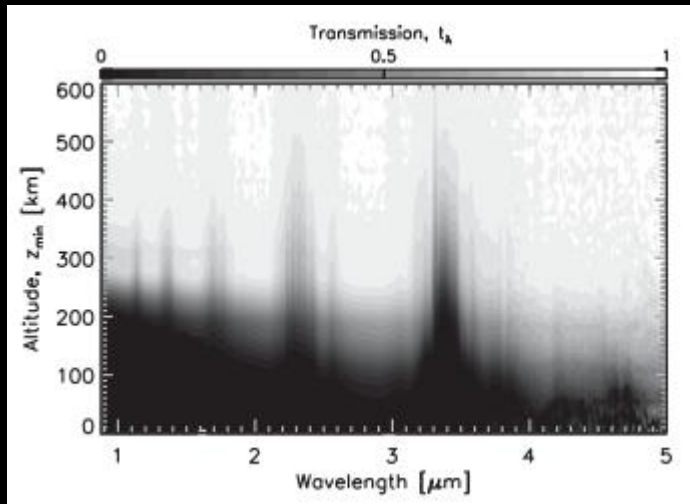
Past Experiments: Earthshine



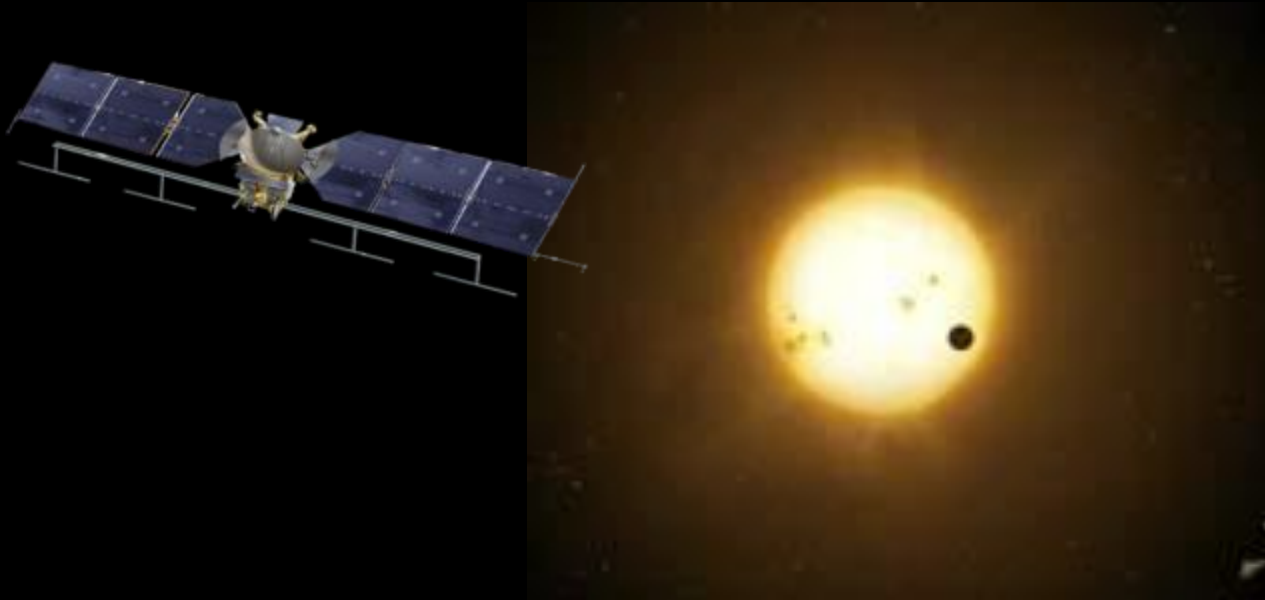
Limb absorption spectrum

Woolf *et al.* 2002

Past Experiments: Titan Solar Occultation



Future Transits



Transits in the Solar System

From the Planets/Orbit

- Earth transits
 - Jupiter
 - 2026
 - Saturn
 - 2020
- Venus transits
 - Mars
 - 2030, 2032
 - Jupiter
 - 2024, 2030
- Mars transit
 - Saturn
 - 2024

Transits in the Solar System

From the Planets/Orbit

- Earth transits
 - Jupiter
 - 2026: JUICE orbit insertion 2030
 - Saturn
 - 2020: Cassini End of Mission 2017
- Venus transits
 - Mars
 - 2030, 2032: ExoMars 2016, 2018, Mars 2020
 - Jupiter
 - 2024, 2030: Cassini End of Mission 2017
- Mars transits
 - Saturn
 - 2024: Cassini End of Mission 2017

Transits in the Solar System

From the Planets/Orbit

- Earth transits
 - Jupiter
 - 2026: JUICE orbit insertion 2030
 - Saturn
 - 2020: Cassini End of Mission 2017
- Venus transits
 - Mars
 - 2030, 2032: ExoMars 2016, 2018, Mars 2020, Future missions?
 - Jupiter
 - 2024, 2030: Cassini End of Mission 2017, JUICE?
- Mars transits
 - Saturn
 - 2024: Cassini End of Mission 2017

Transits in the Solar System

From the Trajectories

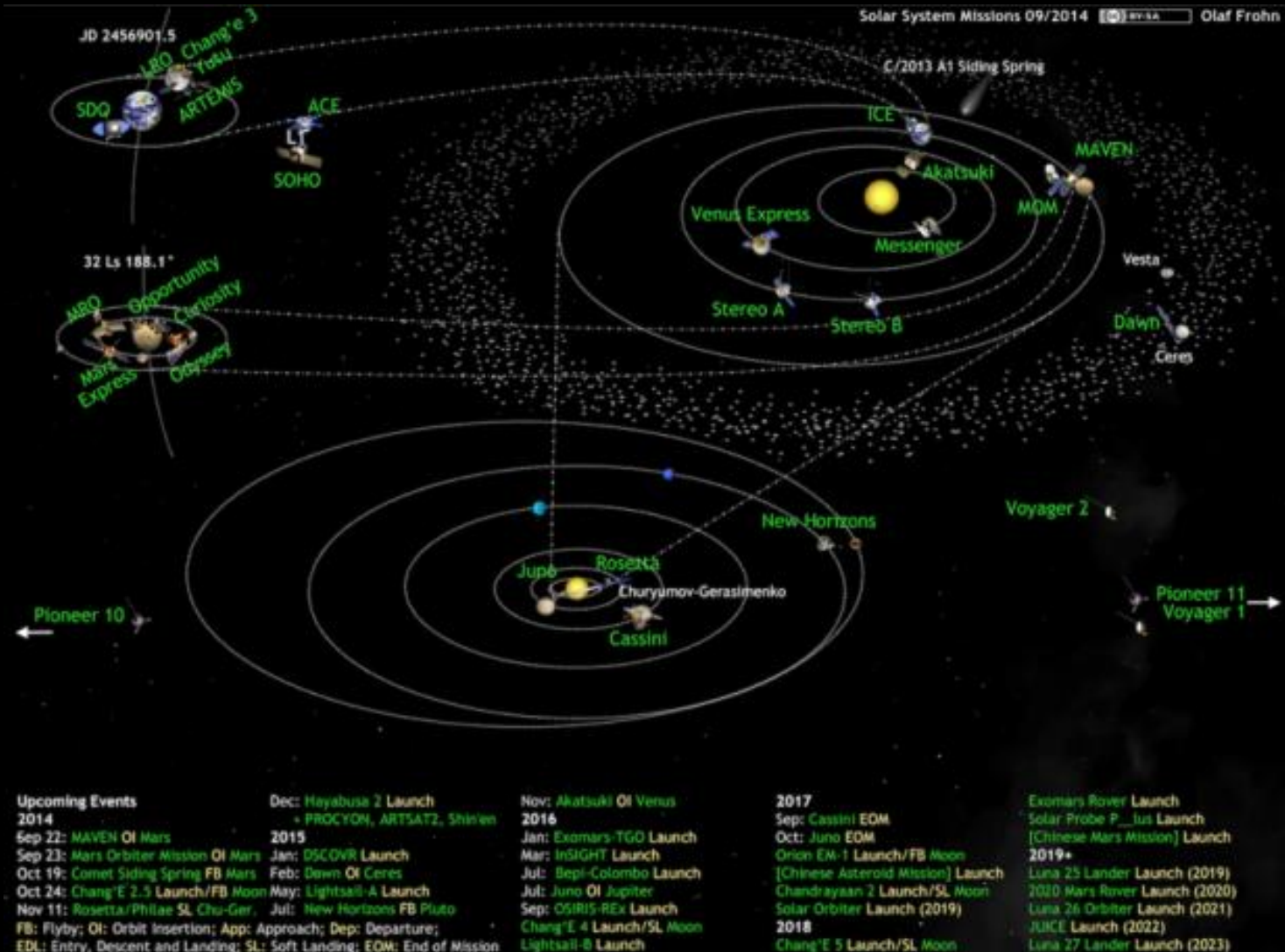
About 8 free-flying spacecrafts beyond Earth's orbit

Juno, Dawn, New Horizon, Rosetta, (Voyager 1 & 2, Pioneer 10 & 11)

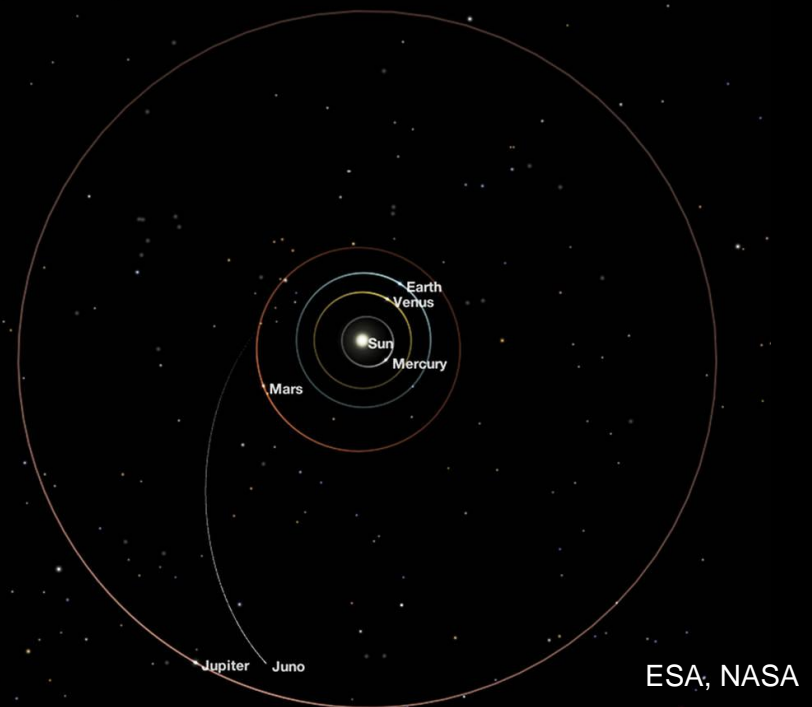
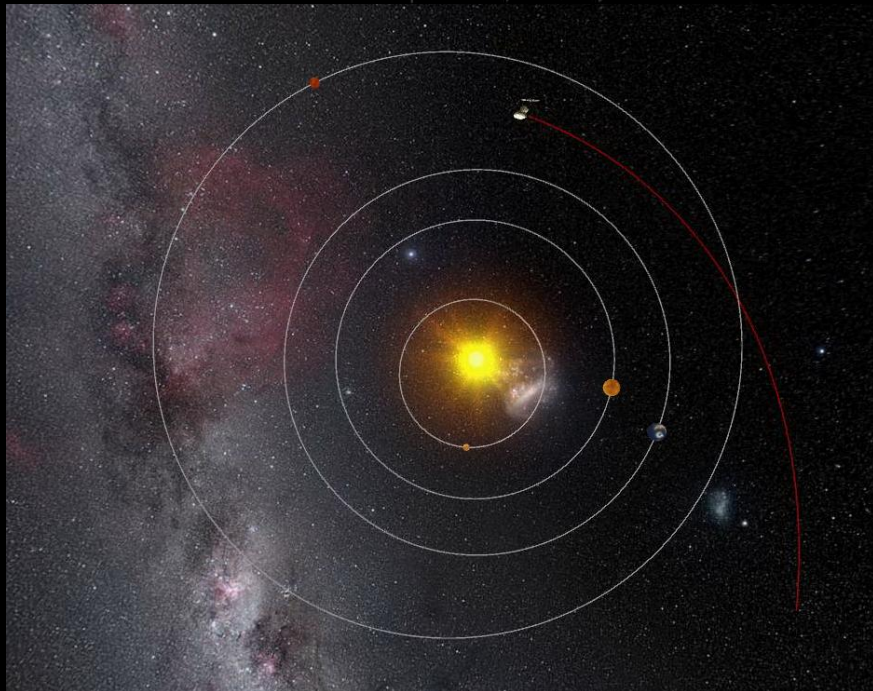
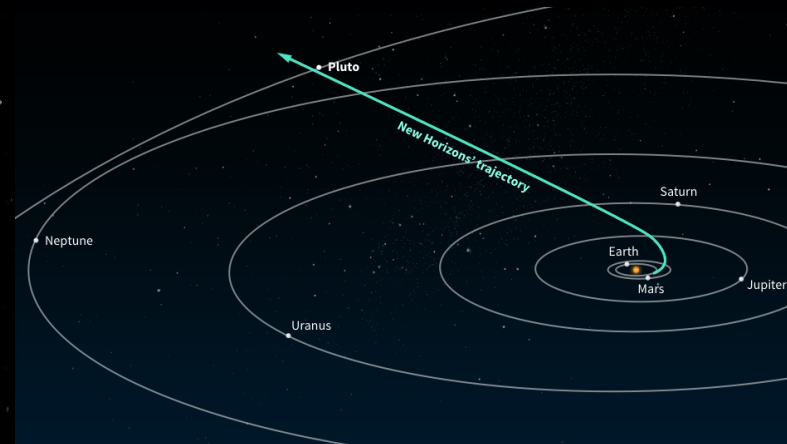
JUICE during the Earth transit in 2026 (EVEE)

Constraints: trajectory & instruments

Spacecrafts



Trajectory constraints



Instrument constraints

Sun is very bright within the Solar System =>

Problems when pointing camera to the Sun!



Instrument constraints

Cassini VIMS-IR: 850-5100 nm, pixel scale 0.5 mrad/pixel ($\sim 1.7'$)

JUICE JANUS: 350-1050 nm, pixel scale 15 μ rad/pixel ($\sim 0.05'$)

Potential Transits

Earth transit from Jupiter 2026

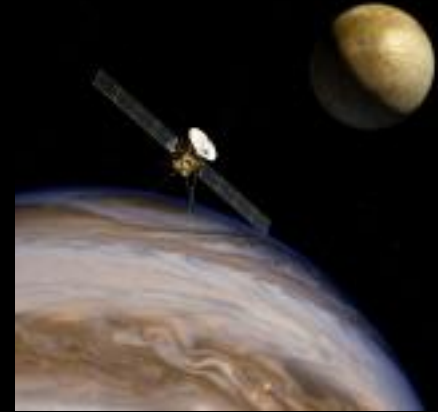
JUICE, but still on trajectory to Jupiter

Venus transit from Jupiter 2030

JUICE, Europa Mission

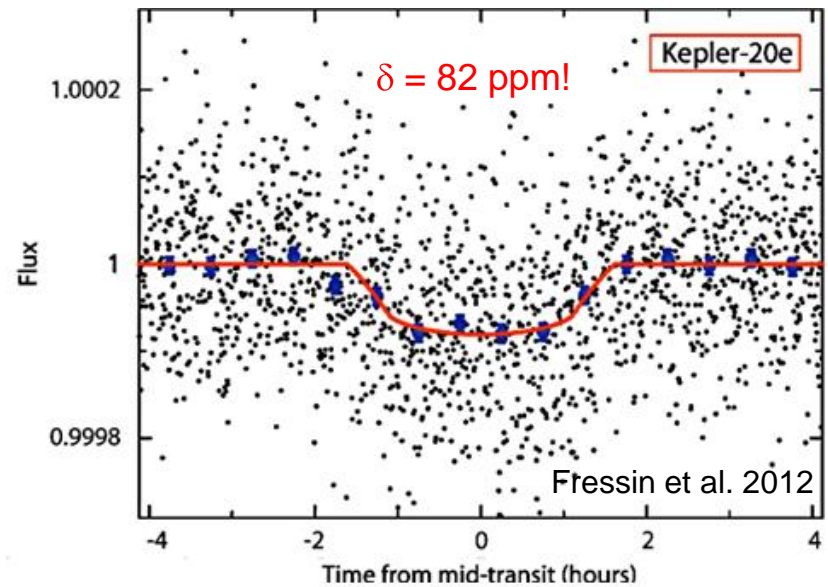
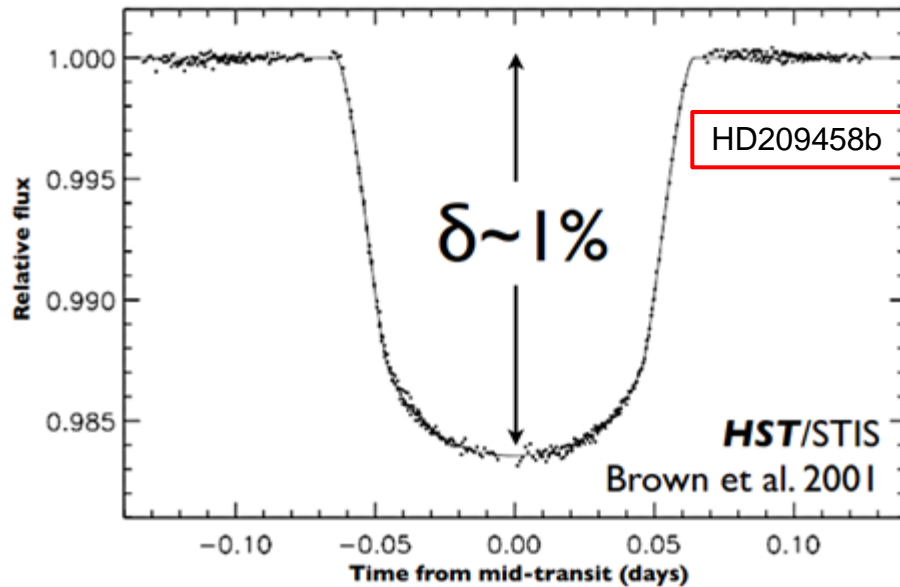
Venus transit from Mars 2030 and 2032

Future missions



Implications to Exoplanets

Earth-size planet has a very weak transit depth



Implications to Exoplanets

Atmospheric signal is even weaker

$$\Delta\delta = \underline{0.1 - 1 \text{ ppm}}$$

$$\Delta\delta \sim 2\delta \times (\text{Scale height}/R_p)$$

Terrestrial planet transits in the Solar System:

$$\Delta\delta \sim \underline{1 - 10 \text{ ppm}}$$

Scale heights (approx.)

Venus 16 km

Earth 8.5 km

Mars 11 km

Implications to Exoplanets

Transits of Venus, Earth and Mars can:

- Mimic Earth-like exoplanet atmosphere detection

- Serve as technique validation

- Help habitability assessment

Conclusions

Transits of the terrestrial planets in the Solar System can help us to identify habitable Earth-like exoplanets in the future.

Transit spectrum of Venus has already been obtained.

Earthshine and eclipses have been used to get Earth transit spectrum.

Next potential transits are: Earth 2026 (Jupiter), Venus 2030 (Jupiter), Venus 2030 & 2032 (Mars).



Thank You!

View from Saturn (Cassini)
900 million miles away

NASA