ASTR/GEOL-2040: Search for life in the Universe: Lecture 34

- Biosignatures
- Generations of stars
- Current strategies

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)

Methane + Oxygen = ?

A. Water
B. Carbon dioxide
C. All of the above

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Lect. 3: Biosignatures from space

A search for life on Earth from the Galileo spacecraft

Carl Sagan*, **W. Reid Thompson***, **Robert Carlson†**, **Donald Gurnett‡** **& Charles Hord§**

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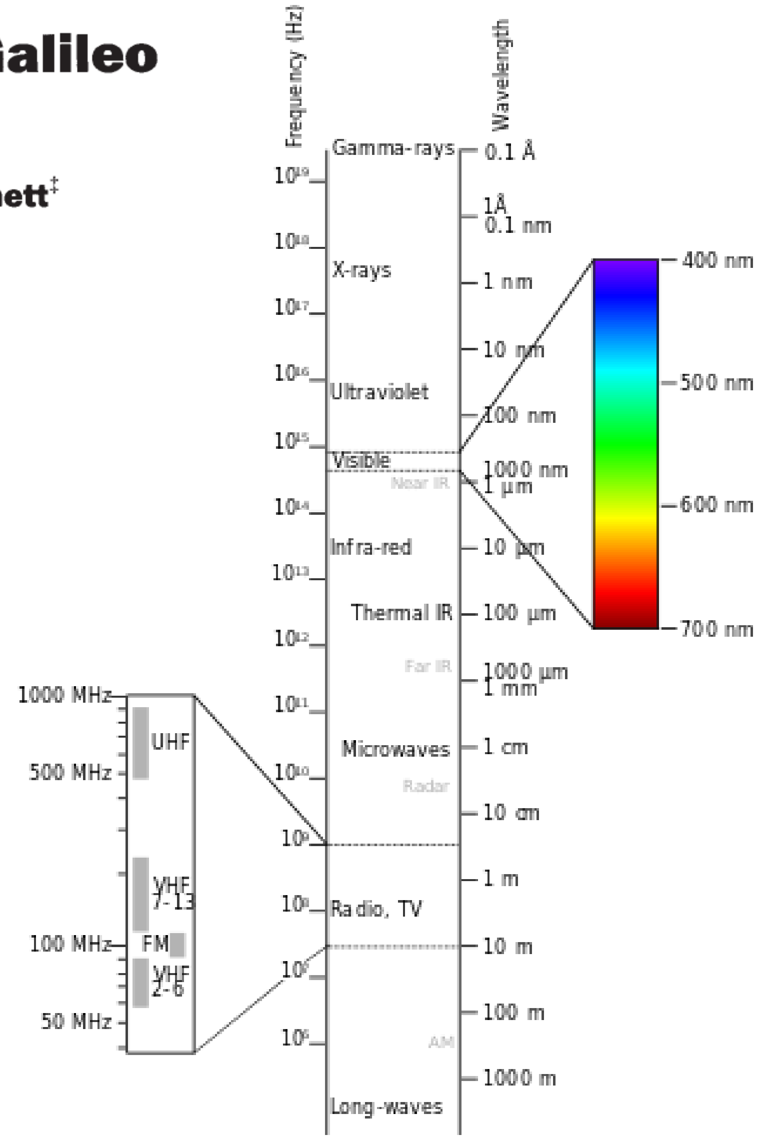

A search for life on Earth from the Galileo spacecraft

→ Lecture 3

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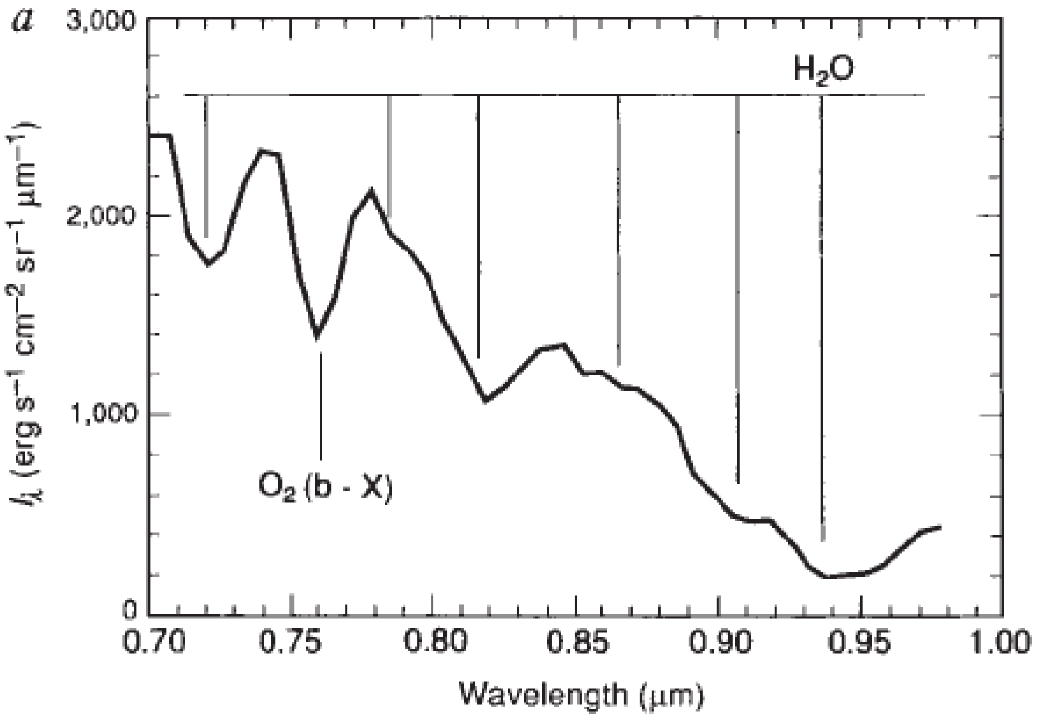
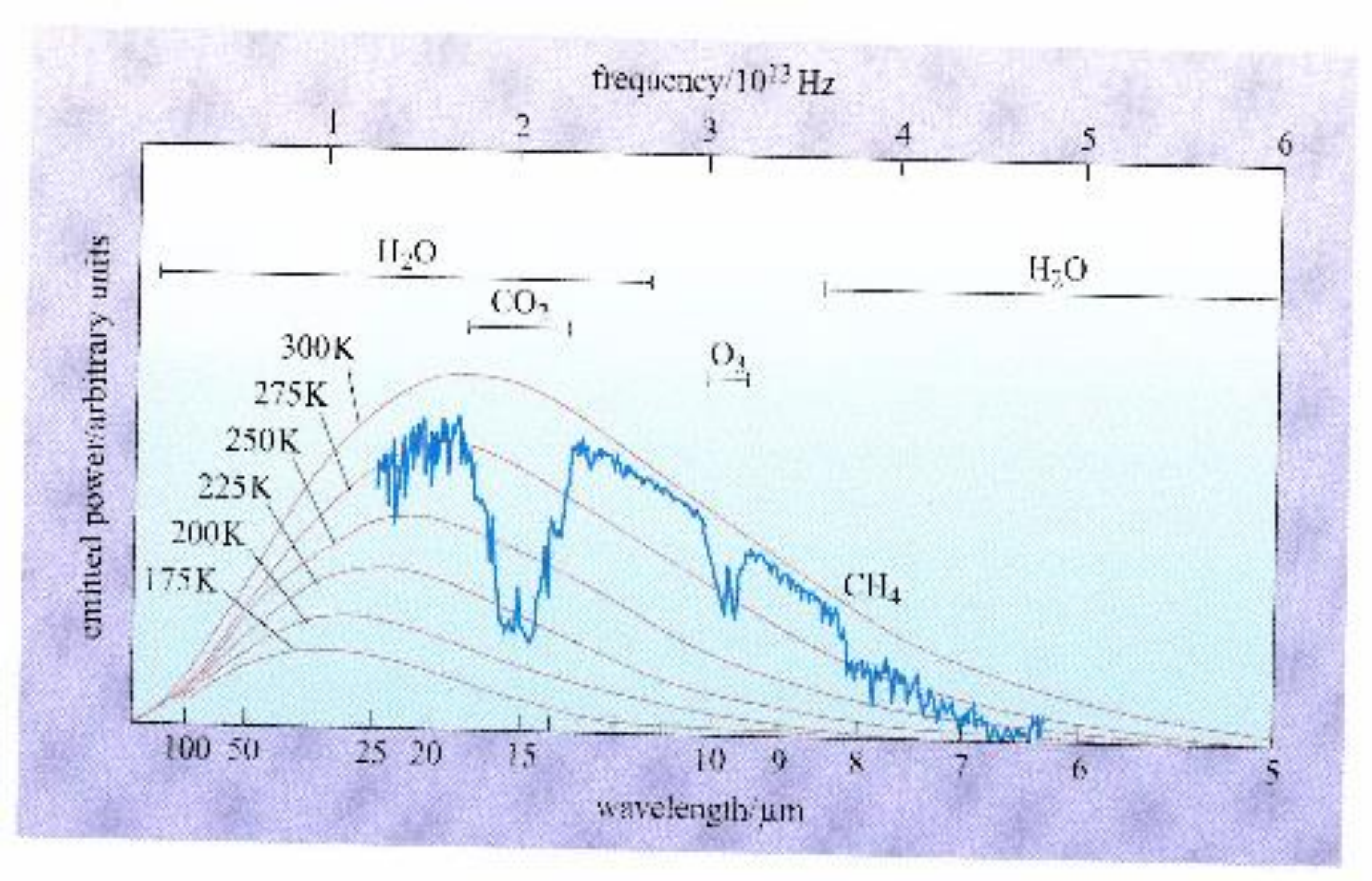


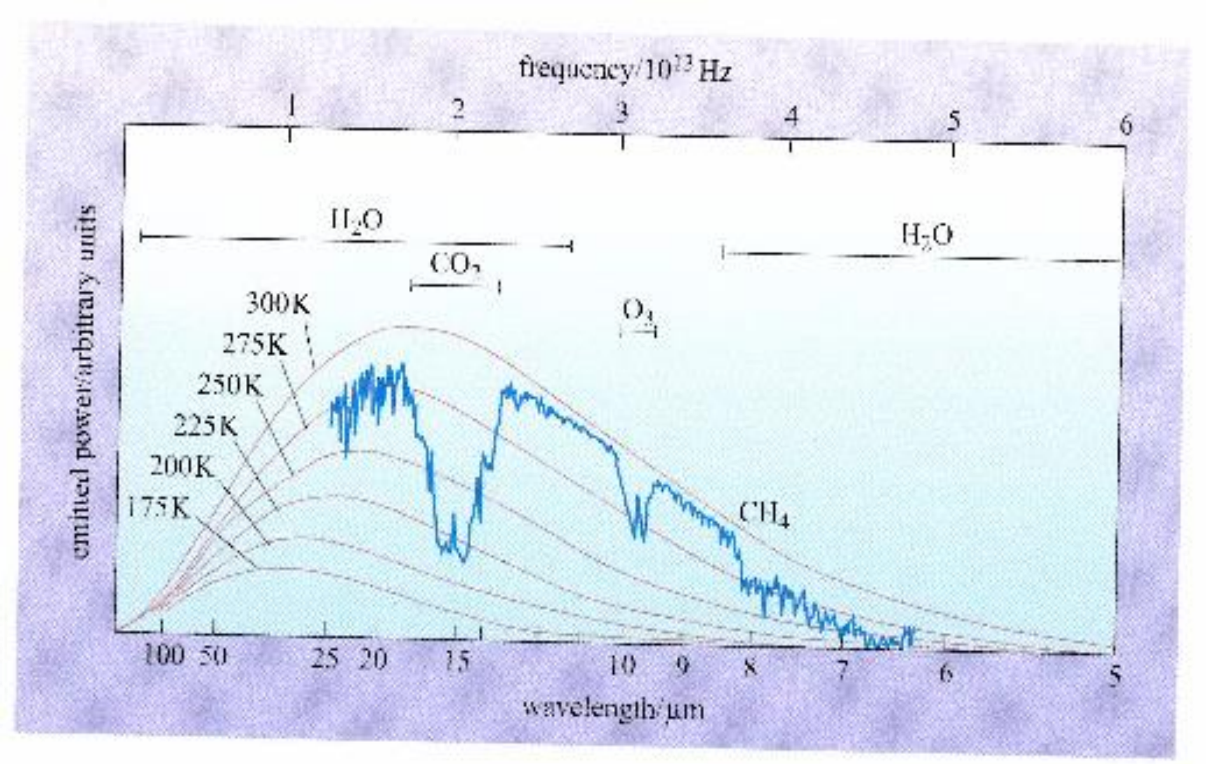
Near-infrared



RGS, p.268, Fig. 8.7

Both methane **and** ozone!

- Methane: absorption around 7 – 8 μm
- Carbondioxide: absorption around 15 μm
- Lots of water lines



$$\lambda = \frac{c}{\nu}$$

$$= \frac{3\times10^{8}\ \text{m/s}}{4\times10^{13}\ \text{s}^{-1}}$$

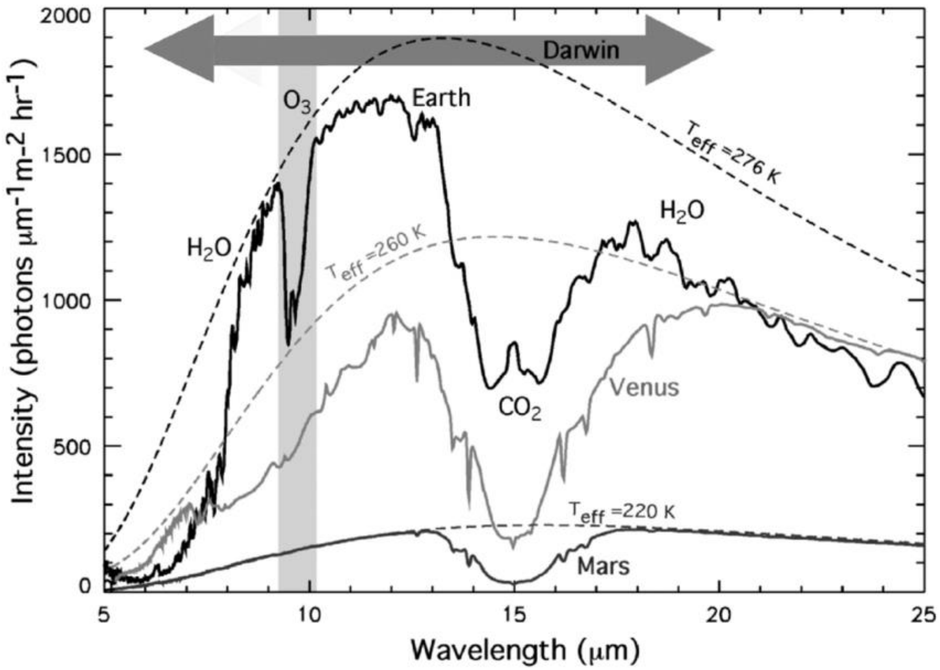
$$= 0.75\times10^{-5}\ \text{m}$$

$$= 7.5\times10^{-6}\ \text{m}$$

$$= 7.5\ \mu\text{m}$$

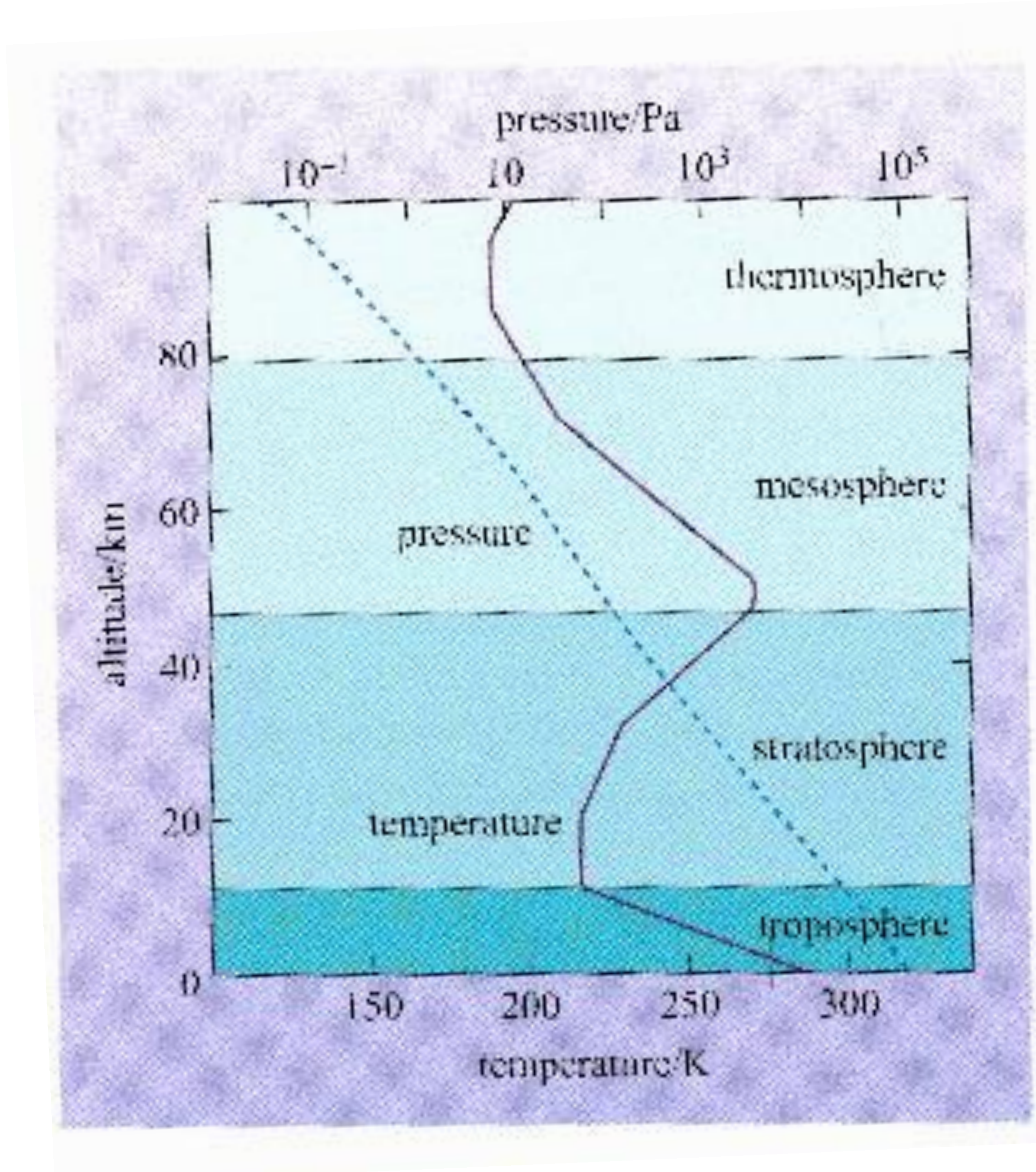
Why this 276 K for Earth?

A. Surface temperature of the Earth
B. Temperature higher in the atmosphere
C. Contributions from oceans
D. Caused by chlorophyl



Match?

- Yes, a few km
- Think of IR telescopes



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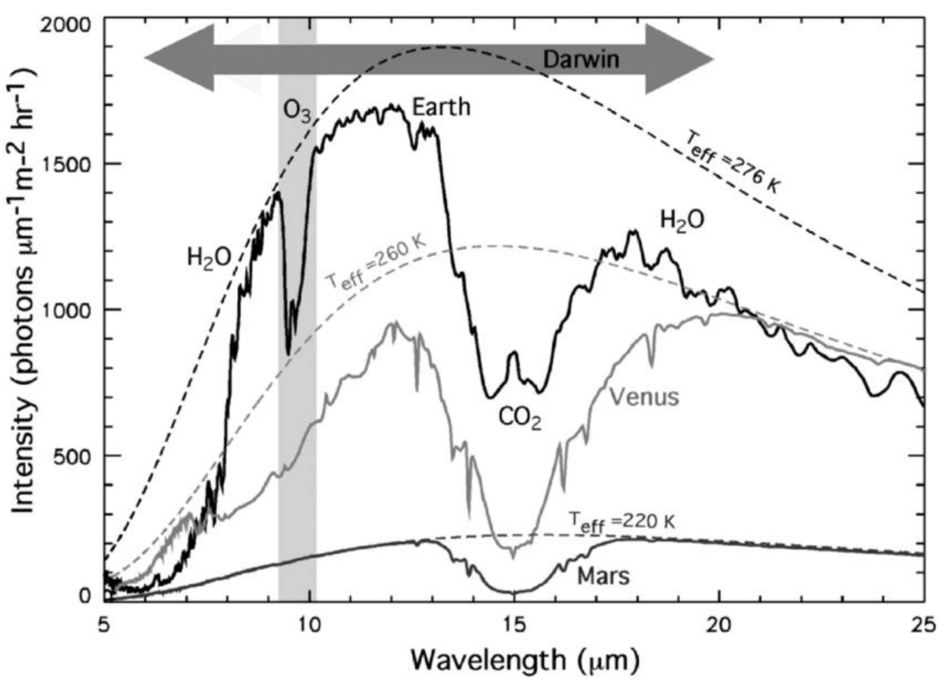
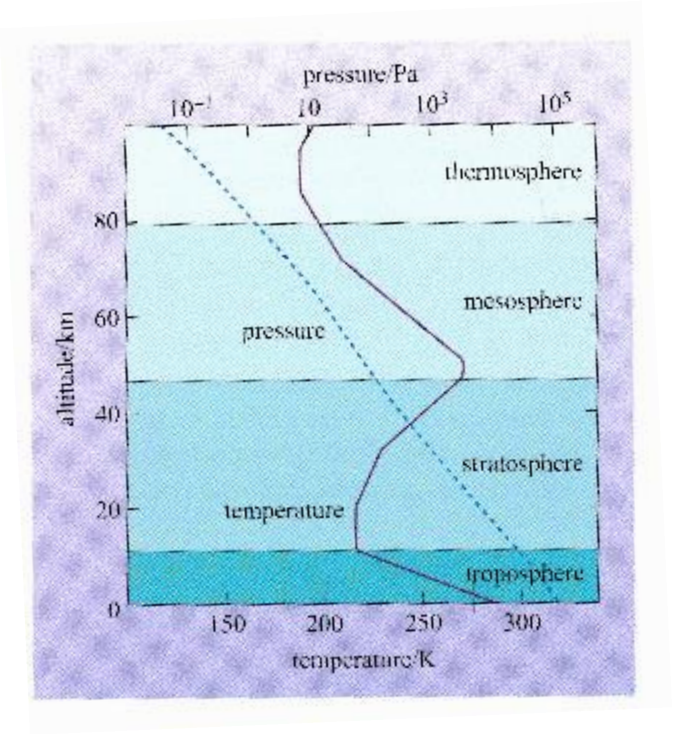
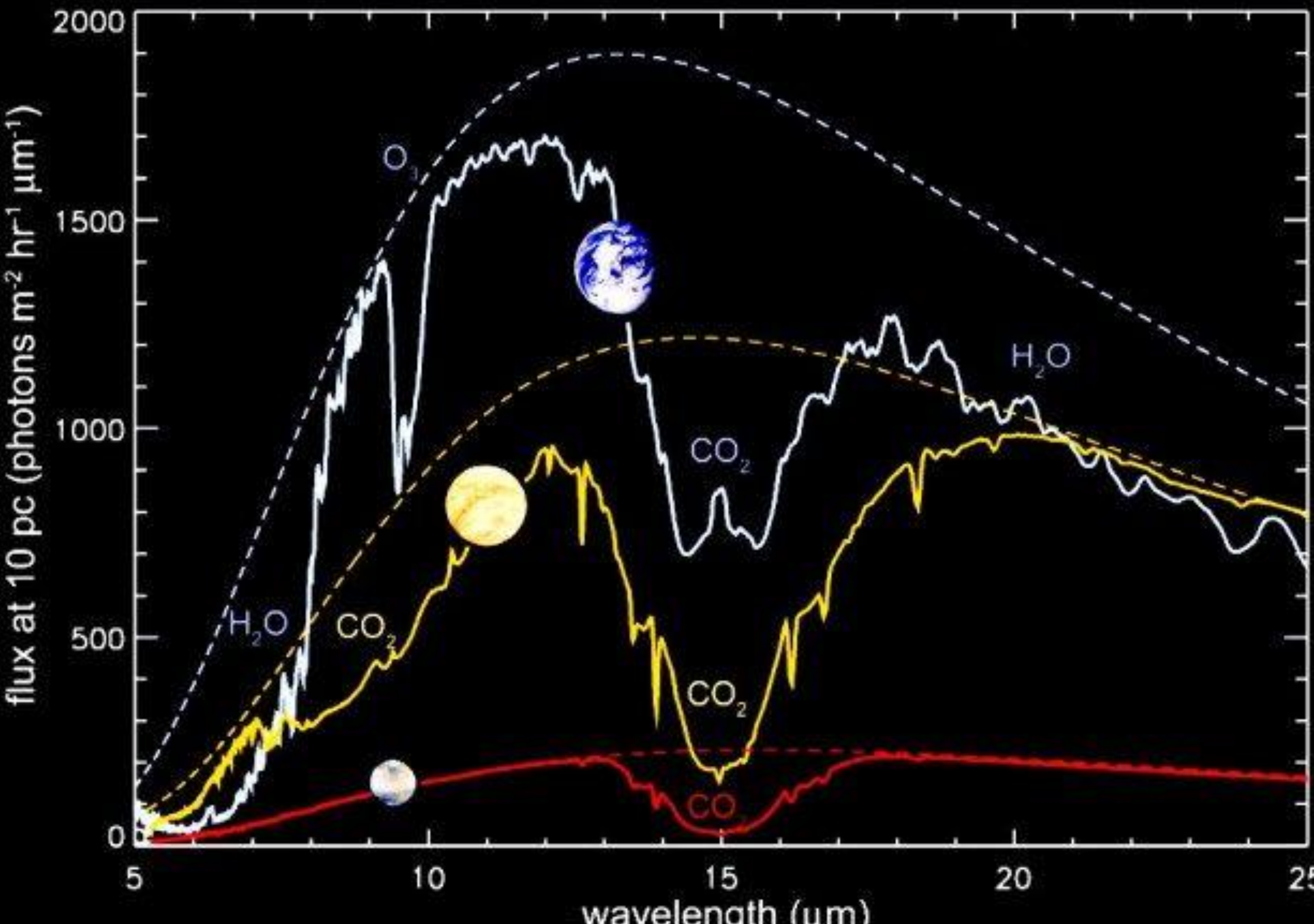


Examples: Infrared telescope: Sofia

- 4-12 km above the ground





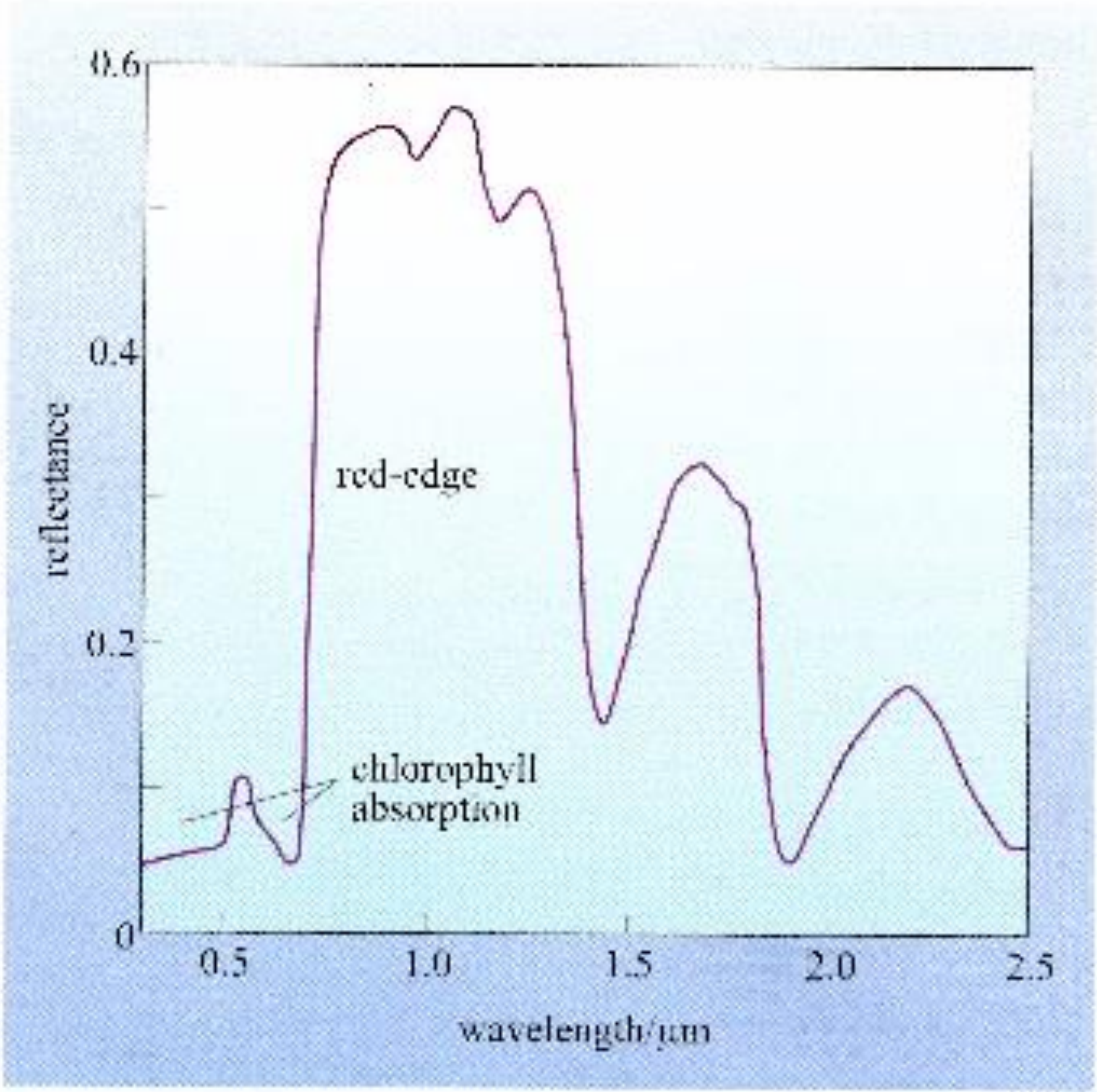
flux at 10 pc (photons m-2 hr-1 μm-1)
2000
1500
1000
500
0
5
10
15
20
25
wavelength (μm)
O3
H2O
CO2
H2O
CO2
CO2
CO2

How to find biospheres

- No CH_4 reservoir on warm Earth
- Only 1 molecule in ever 600,000
- Enough for case beyond reasonable doubt

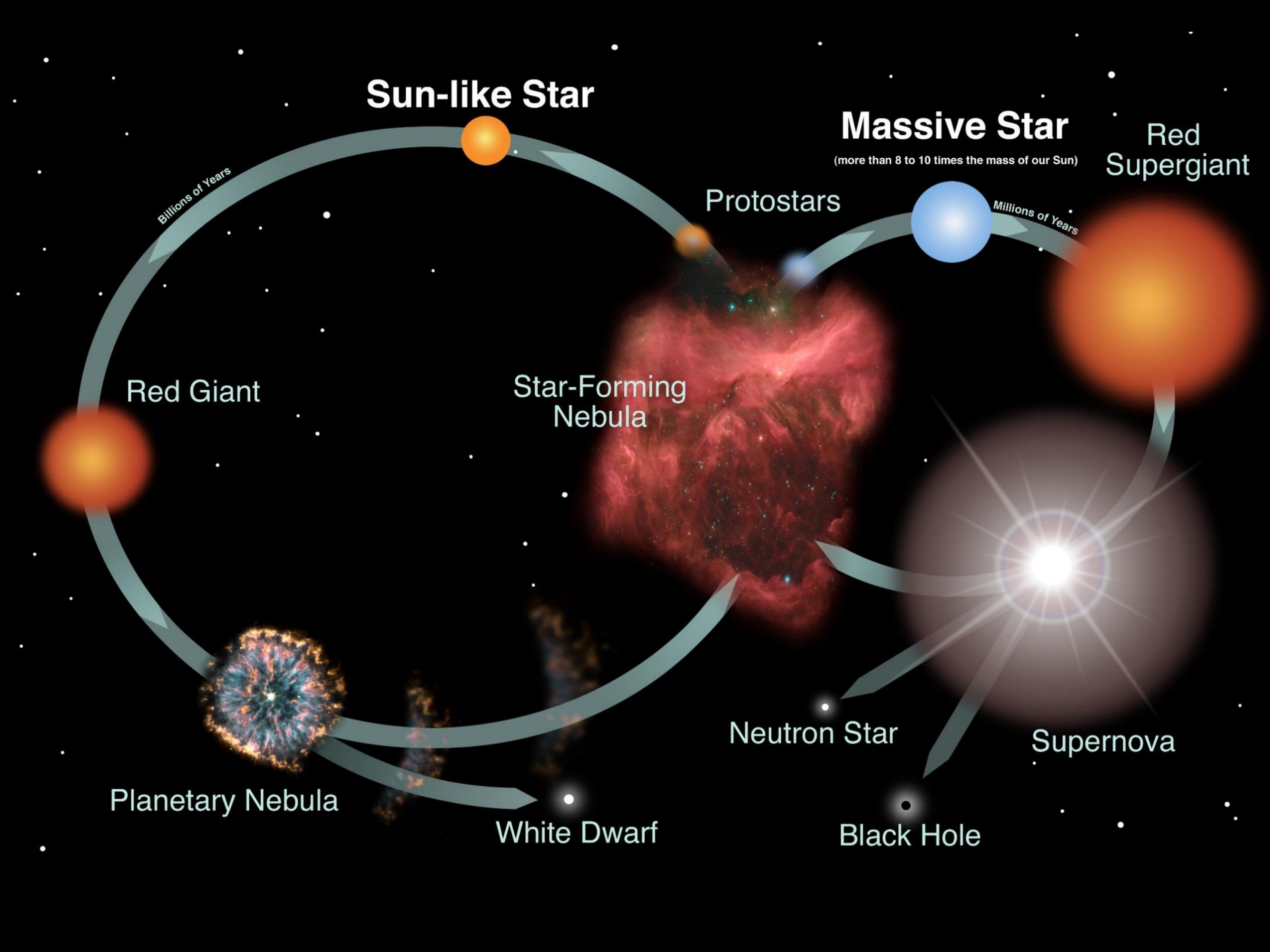
Reflectance spectrum

- Sharp rise in reflectance
- Red-edge
- Chlorophyll
- Figs 8.7, 8, 9, 12
- Also from Galileo: radio signals


0.6
0.4
0.2
0
reflectance
red-edge
chlorophyll
absorption
0.5
1.0
1.5
2.0
2.5
wavelength/μm

Potential habitats

- Focus on carbon-based life & water
  - Complex compounds, diverse, versatile
- Habitable zones (HZ)
  - If ok for 3% of planets: next one 20 ly
  - one planet every 6 ly, $(33*6^3)^{1/3}=20$
- HZ excludes icy worlds, but water worlds?
- Also: atmosphere, not too many impacts
  - Jupiter shields us from many impacts


Sun-like Star
Massive Star
(more than 8 to 10 times the mass of our Sun)
Red Supergiant
Billions of Years
Protostars
Millions of Years
Red Giant
Star-Forming Nebula
Neutron Star
Supernova
Planetary Nebula
White Dwarf
Black Hole

Older stars: iron fraction?

A. More Fe than younger stars
B. The same
C. Less

Example of Kepler 444: born when 20% age of the Universe

- Fewer stellar generations
- But only of massive stars
- Interstellar medium has less Fe
- Resulting stars have less Fe

Older stars: iron fraction?

A. More than younger stars
B. The same
C. Less

Older stars: iron fraction?

of its planetary and orbital parameters based on an analysis of the transit photometry. Kepler-444 is the densest star with detected solar-like oscillations. We use asteroseismology to directly measure a precise age of 11.2 ± 1.0 Gyr for the host star, indicating that Kepler-444 formed when the universe was less than 20% of its current age and making it the oldest known system of terrestrial-size planets. We thus show that Earth-size planets have formed throughout most of the universe's 13.8 billion year history, leaving open the possibility for the existence of ancient life in the Galaxy. The age of Kepler-444 not only suggests that thick-disk stars were among the hosts to the first Galactic planets, but may also help to pinpoint the beginning of the era of planet formation.

Details	
Mass	0.758 (± 0.043) $M_\odot$
Radius	0.752 (± 0.014) $R_\odot$
Temperature	5040 (± 74.0) K
Metallicity [Fe/H]	-0.55 (± 0.07) dex
Age	11.23 (± 0.99) Gyr

Other aspects

- Kepler-444?
- Ancient life?

$10^{-0.55}$ = 0.28 times solar = 28% solar Fe abundance

But [Fe/H] perhaps not important

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Metallicity, planetary formation and migration

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ABSTRACT

Recent observations show a clear correlation between the probability of hosting a planet and the metallicity of the parent star. As radial velocity surveys are biased, however, towards detecting planets with short orbital periods, the probability–metallicity correlation could merely reflect a dependence of migration rates on metallicity. We investigated the possibility, but find no basis to suggest that the migration process is sensitive to the metallicity. The indication is, therefore, that a higher metallicity results in a higher probability for planet *formation*.

→ [Fe/H] matters for making Jovian planets, not for terrestrial ones

Next time

- Finding more planets (& in future)
- Other methods
- Planets around binaries
- Tidally locked planets

- BS: 370 – 414
- RGS: 235 – 260
- Lon: 339 – 342