A new family of planets ?
“Ocean-planets”

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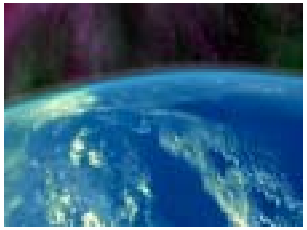
B. Chazelas, H. Lammer , D. Ehreinreich

San Diego 2004

Goals

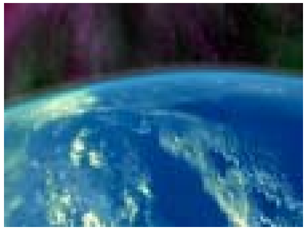


- Learn a lesson from **our lack of preparation** / 51 Peg
- A possible new family of planets: **Ocean-Planets**
- Considerations / biosignatures, valuable for Darwin/TPF

Outline

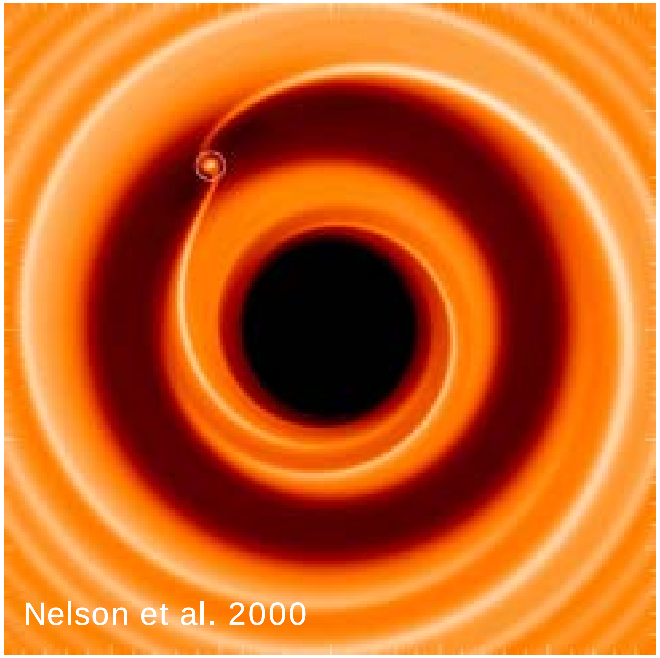
- Nature, formation
- Internal structure ➔ **R(M)**
- Ocean ➔ **h**
- Atmosphere ➔ **biosignature ?**
- Conclusion

(1) nature, formation



Proposed:

- at Darwin/TPF conf. (Heidelberg, 2003)
- Kuchner, ApJ, 2003
- Léger et al., Icarus 2004



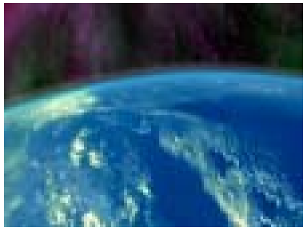
Nelson et al. 2000

Migration:

- needed to explain hot jupiters
- (too?) likely a phenomenon

➔ legitimises the idea of **"Ocean-Planets"**

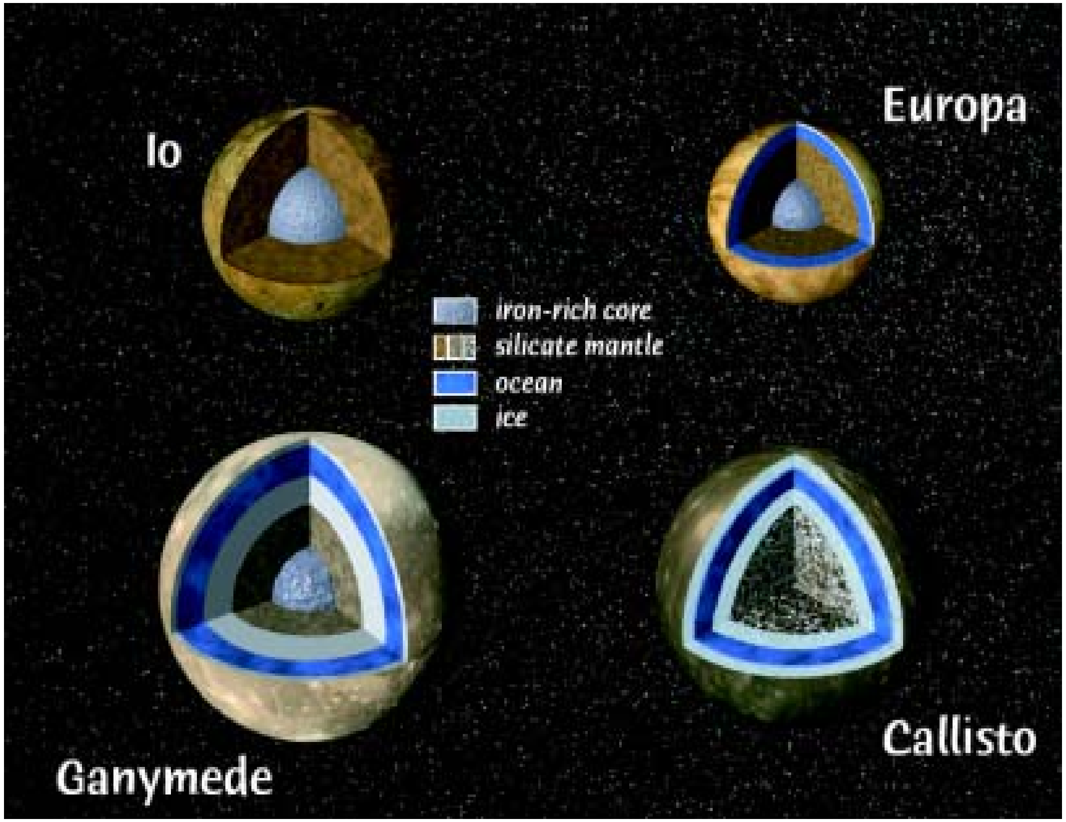
Formation



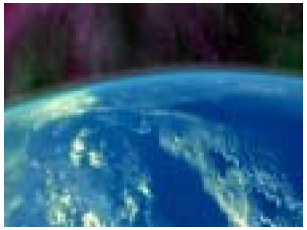
- accretion at **a > a** $_{\text{ice}}$

  ➔ rocks + ices (≈ **50%:50%**)

~ jovian satellites



Hypotheses



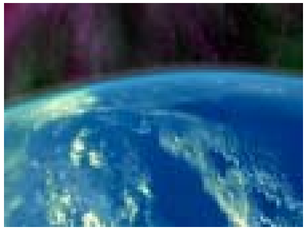
- consider: $1 < M/M_{earth} < 8$

- ice composition ~ comet (H_2O + 5% NH_3 + 5% CO_2)

- **migration to HZ**

  ➔ ice fusion ➔ **huge ocean ?**

New planetary family



- interests:
  - **planetology**
  - **exobiology**

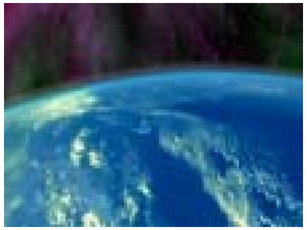
- special targets for Darwin / TPF

  (large R_{planet} ➔ **fair S/N**)

- **existence** to be suggested (confirmed) by

  COROT (Kepler/ Eddington)

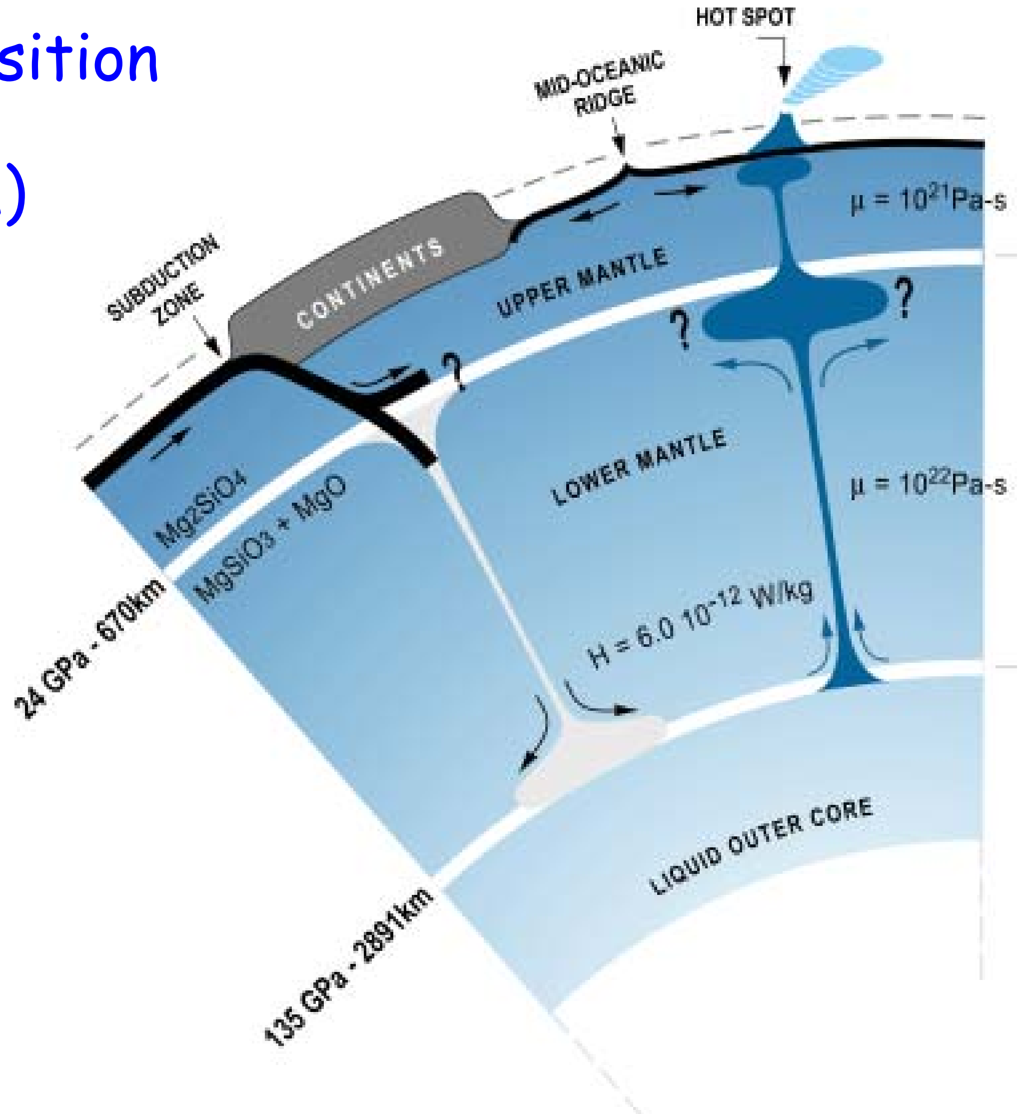
(2) Internal structure



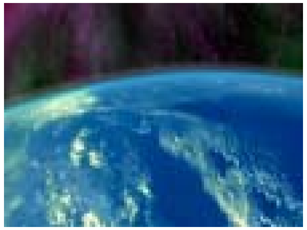
- input: M_{planet} , composition

  output: structure, R(M)

- comparison: / Earth



Internal structure



- example: $M_{pl} = 6\ M_E$

$$\begin{cases} M_{core} = 3\ M_E \\ M_{H2O} = 3\ M_E \end{cases}$$

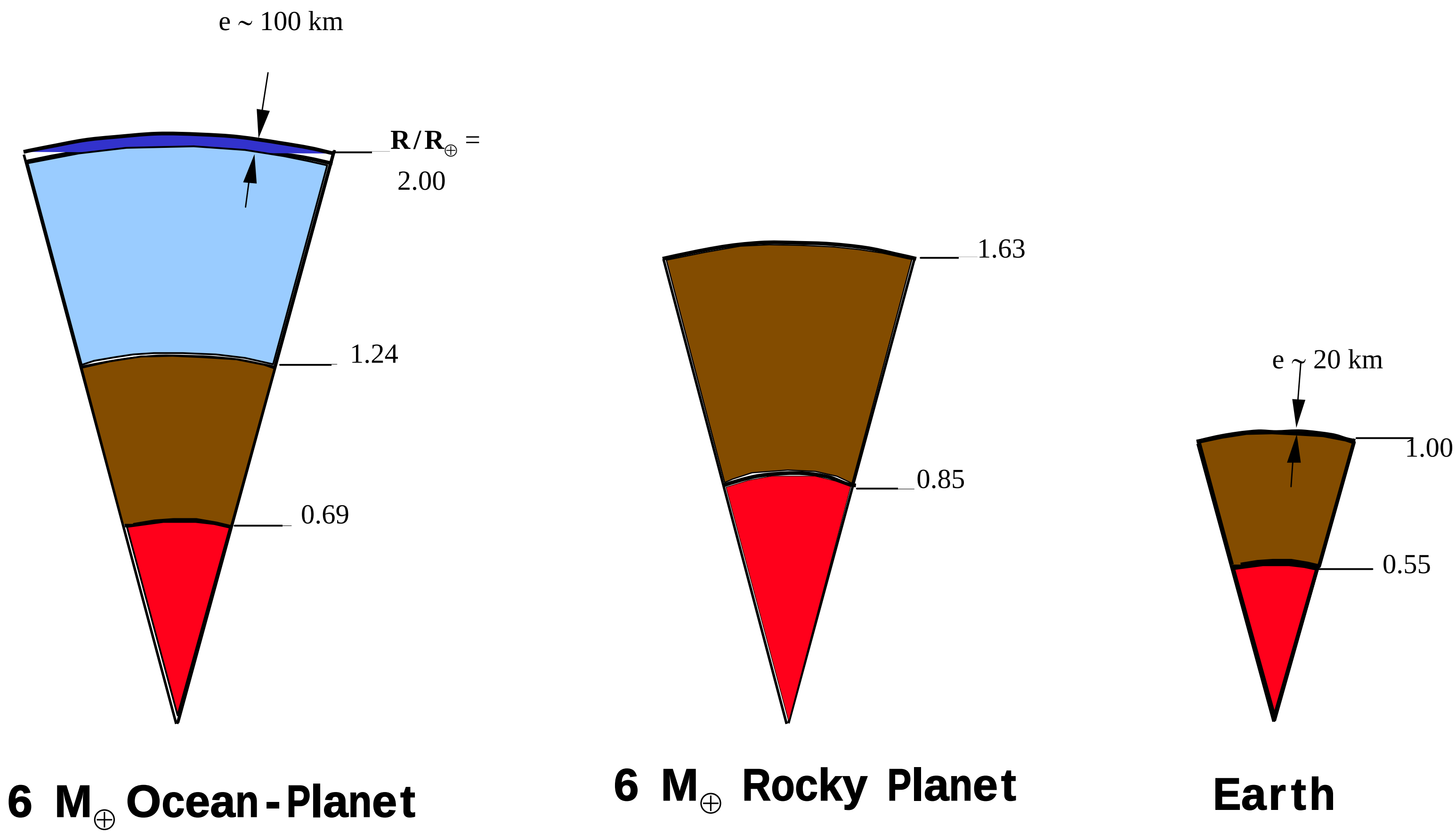
- physics:

$$M_i = 4\pi \int_0^{R_i} \rho_i^{(1)}(r)\, r^2\, dr$$

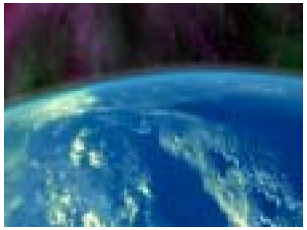
$$g(r) = G\, m(r) / r^2$$

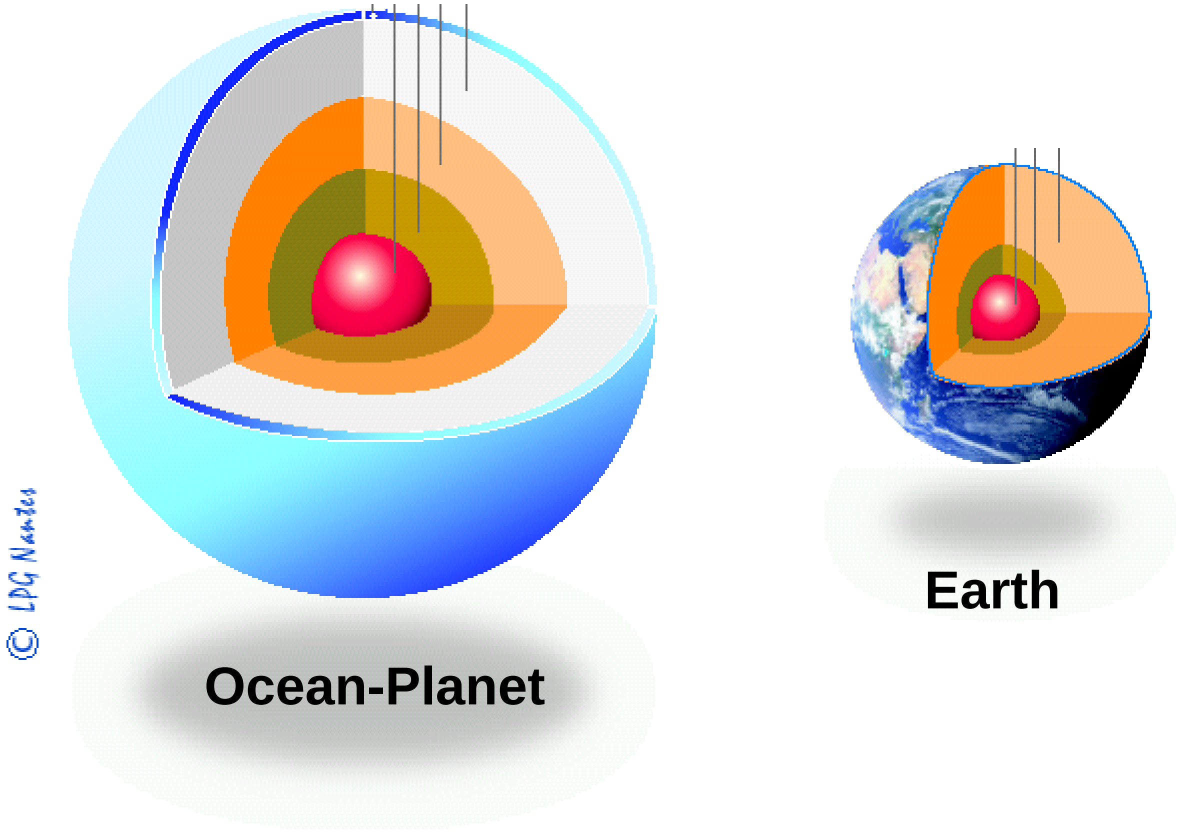
$$P(r) = \int_R^r -\rho^{(1)}(x)\, g(x)\, dx$$

Internal structure

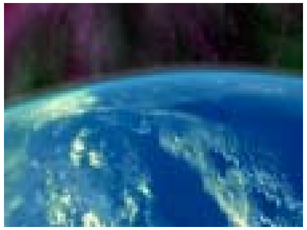


Internal structure

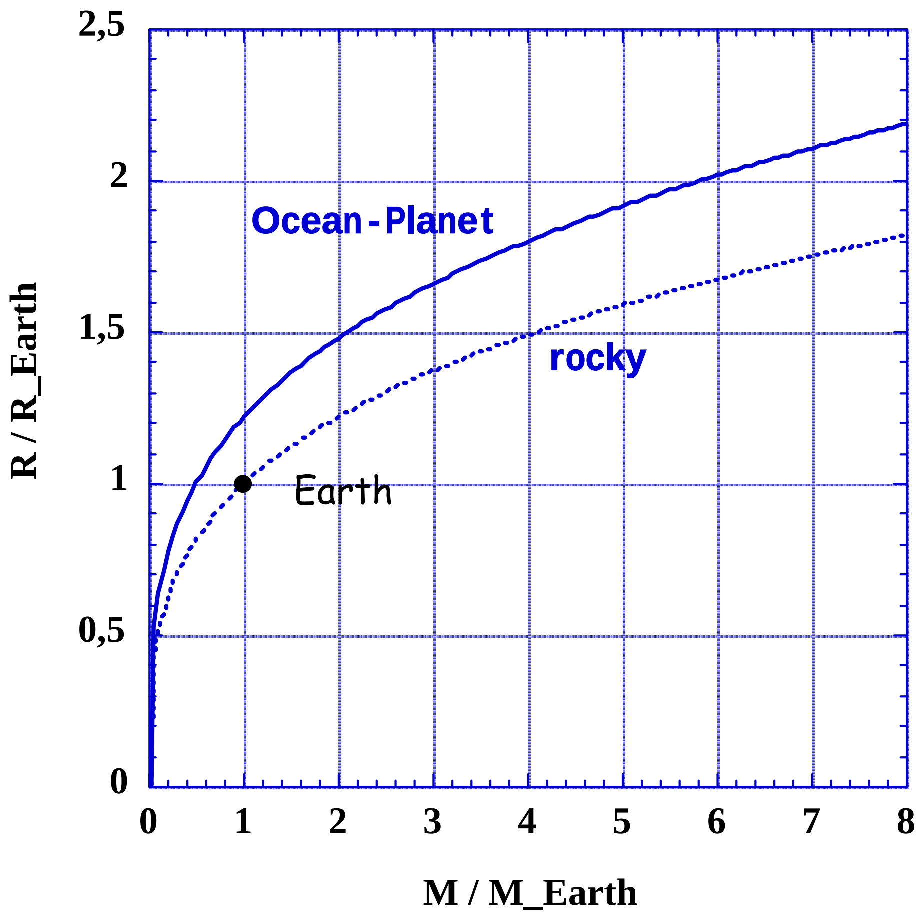




results

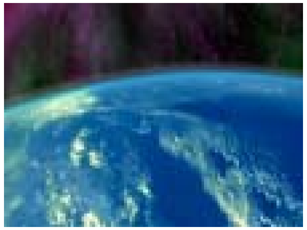


- **R(M)**



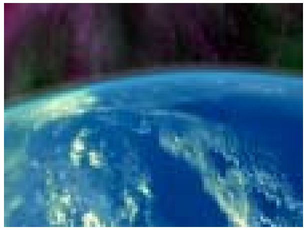
- **Ocean - Pl ➔ special targets for Darwin / TPF**

Ocean



- Question: how deep?
- T(P) in liquid: adiabat, or less (down to isotherm) ?
- crossing ➔ ocean bottom at: T_b , P_b , Z_b

Ocean (2)



Example:

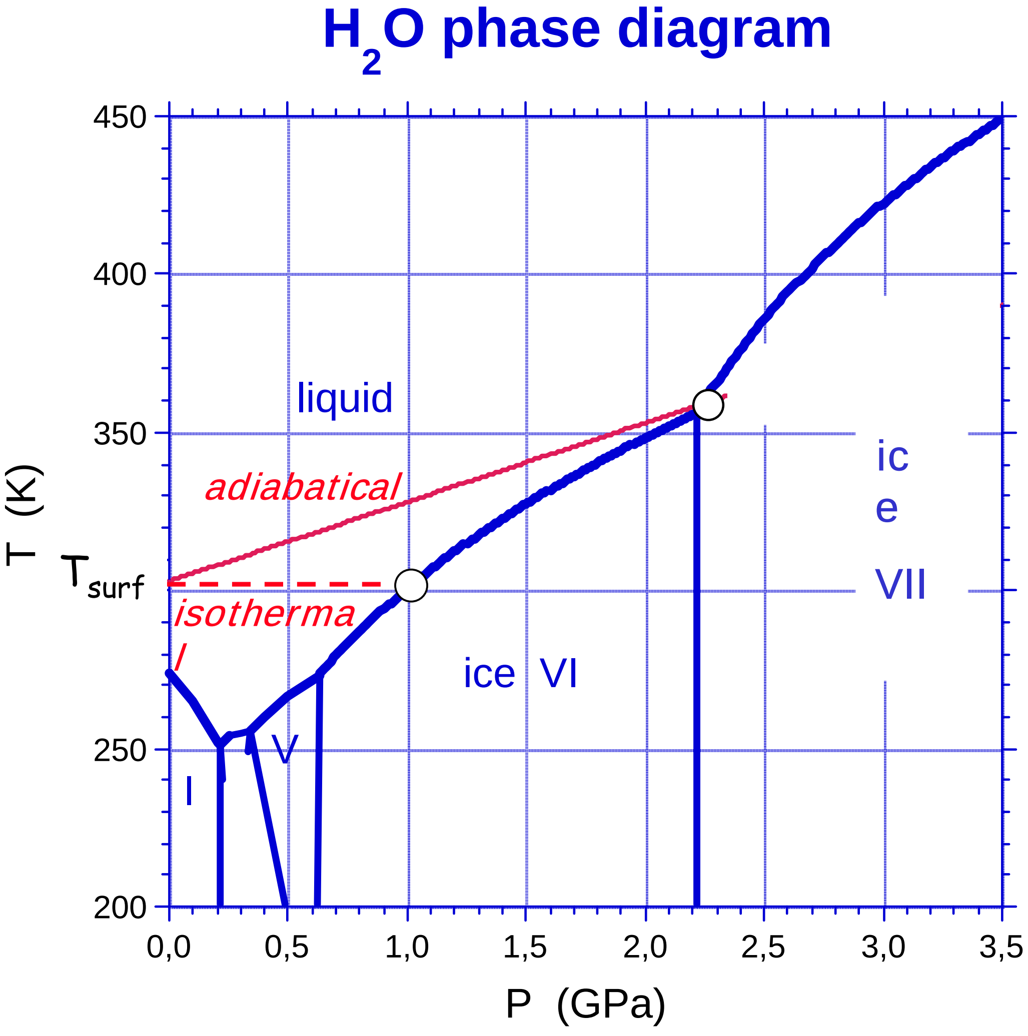
T_{surf} = 30 °C

➔ ocean bottom

T_{ad} = 87 °C

P_{ad} = 2.25 GPa

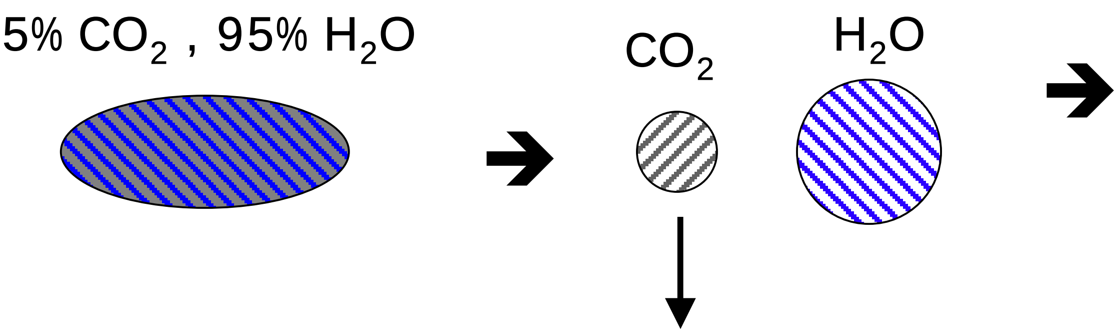
Z_{ad} = **130 km**

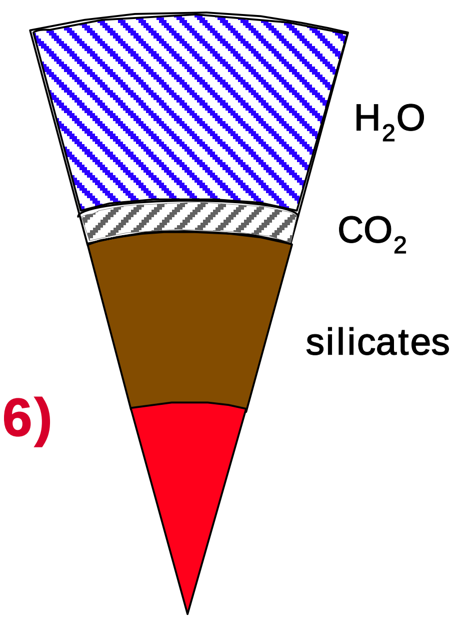


Atmosphere

- Composition: H_2O, NH_3 , CO_2

- **CO_2** amount : 5% (comets) x 3 M_{Earth}
  - ⇨ few 100 times Venus content! huge Greenhouse effect ?
  - ⇨ not obvious because ρ_{sol_CO2} **>** ρ_{sol_H2O} (x 1.30 @ 10 GPa)

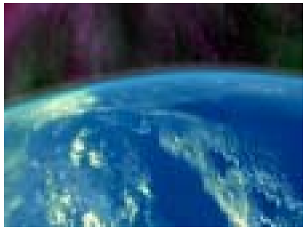




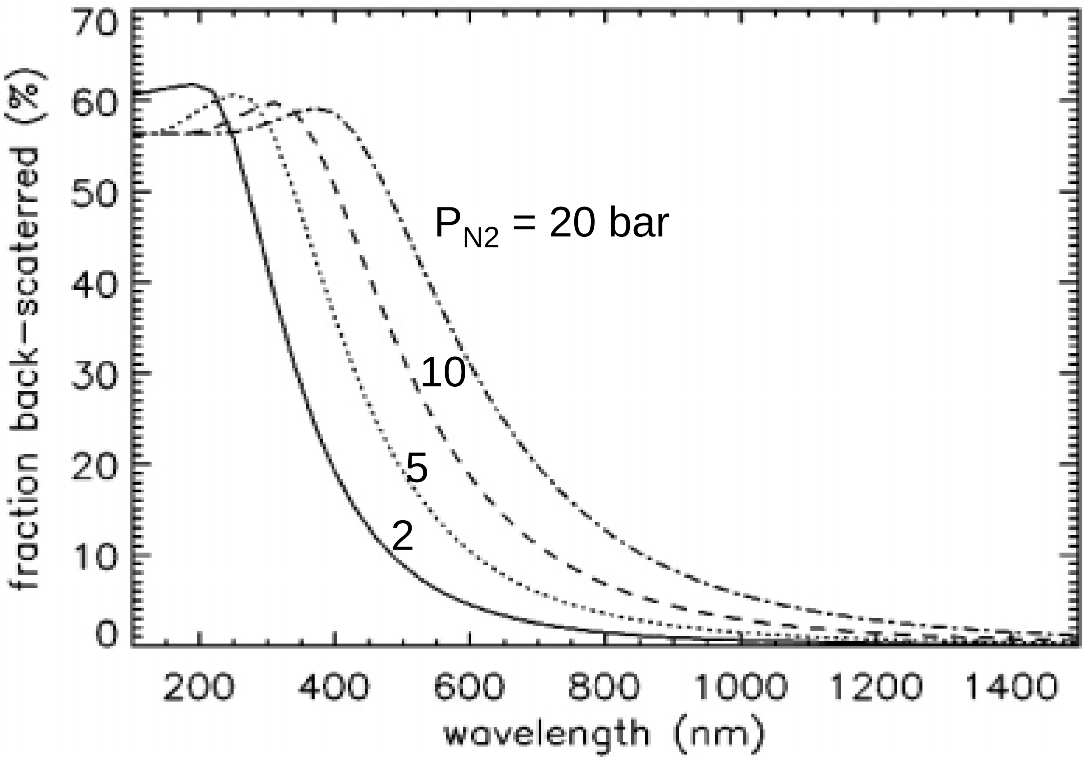
⇨ most CO_2 **sequestred** in mantle **(see poster # 56)**

- Question: how much left in atmosphere?

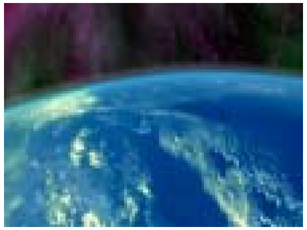
Atmosphere



1) Visible - NIR



Atmosphere

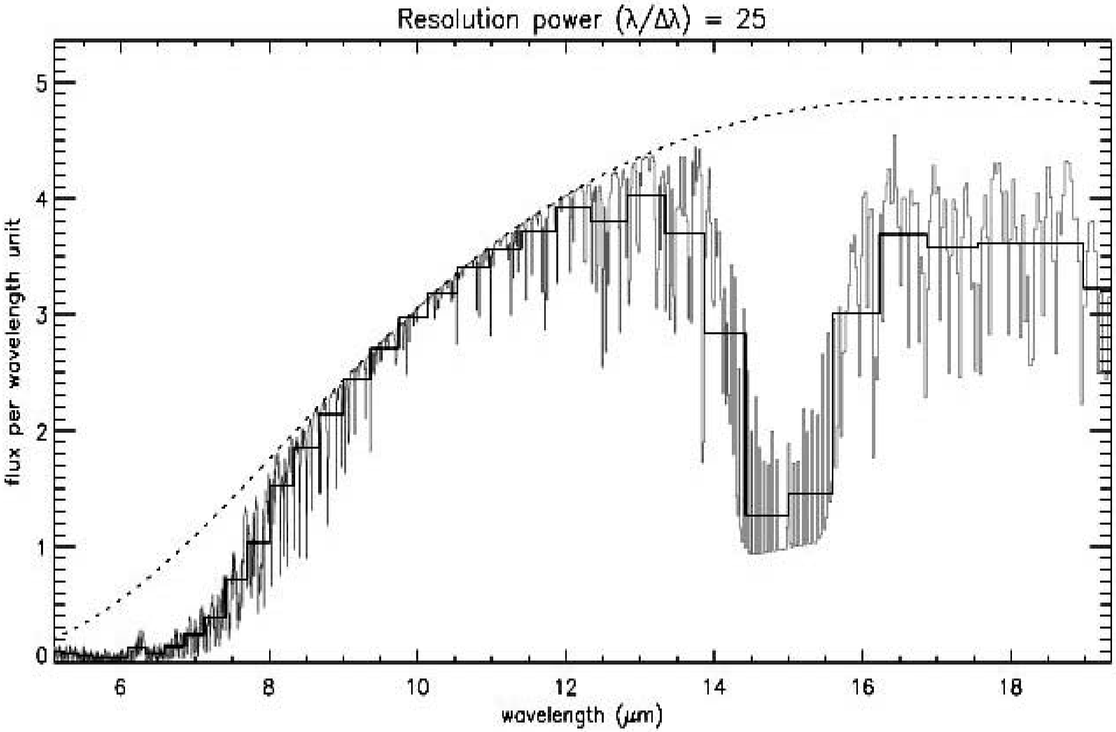


2) **Thermal IR**

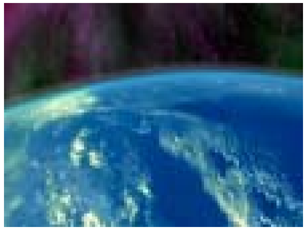
An example:

- $[CO_2]$ = Earth
- $[O_3] = 0$
- $[NH_3] = 0$
- $P_{H2O} = 0.5 \times P_{sat}(T)$, $T_{surf} = 320$ K (47 °C)
  ➔ very wet

➔ **strong H_2O bands**



Biosignatures



1) Oxygen

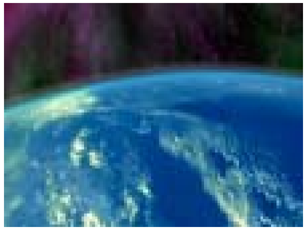
- if upper atmosph. wet, e.g. $T_{ground} \geq 50°C$, O_2 produced by H_2O photolysis

- weak O_2 sinks ⇨ **abiotic** O_2

- how long does this water-runaway can last?
  - Venus: ~ 200 Myr
  - Ocean-Planet ~ 10^3 Gyr !

⇨ O_2 is not a reliable biosignature

Biosignatures



2) **Ozone**

- if O_2 from H_2O photolysis,
  $OH^{\cdot}$ also present, that blocks O_3 production
  (Selsis et al. A&A 2002)

  ⇨ **no O_3**

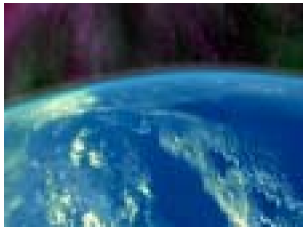
- if O_2 produced in low atmosphere (no $OH^{\cdot}$)
  e.g. **photosynthesis** in ocean,

  ⇨ **O_3** (Chapman cycle)

⇨ fortunately enough, **(H_2O + CO_2 + O_3)**

remains a biomarker

Implications for Darwin/TPF



Visible-NIR and **thermal IR** are **not on equal footing** / searching for life

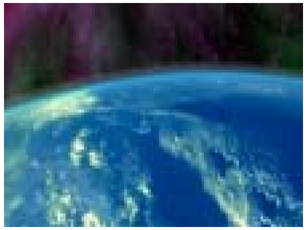
1) **thermal IR**

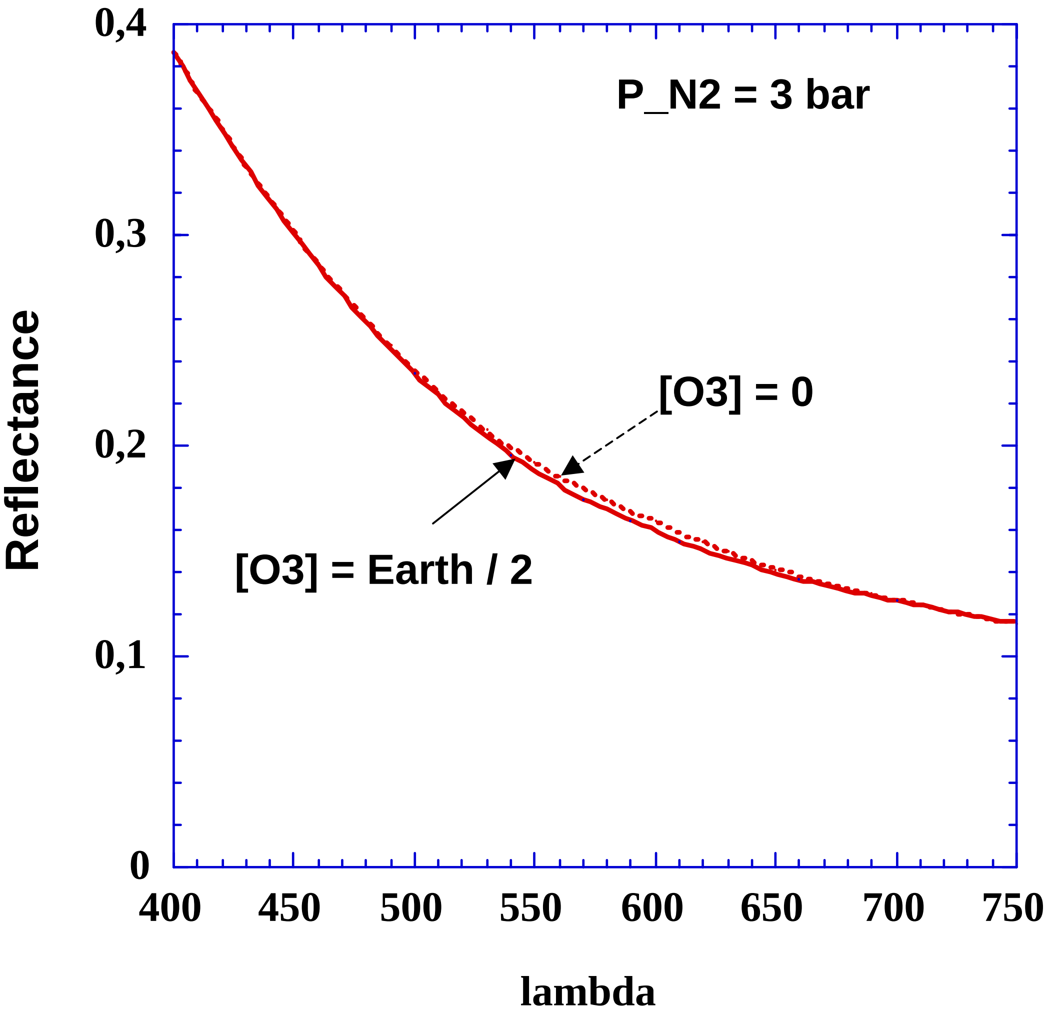
(H_2O + CO_2 + O_3) can be detected ⇨ biosignature is OK

2) **Visible-NIR**

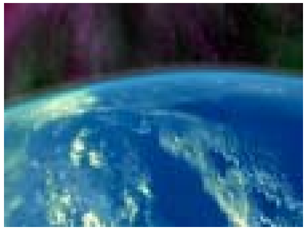
- H_2O : OK
- CO_2 : **no** if **0.5-1.05** μm only, **0.5-1.15** μm required
- O_3 : questionnable (broad band, + Rayleigh structure at same λ)
- (O_2 not relevant as a biosignature)

O_3 band in visible





CO_2 problem

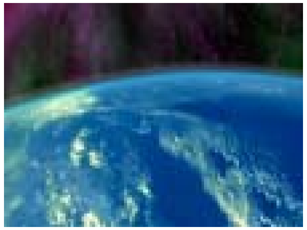


- in **dense CO_2** atmosphere, e.g. 1 bar,
  photolysis ➢ O_2 (and O_3)

⇨ you have to estimate the amount of CO_2

- **thermal IR** : CO_2 bands OK
- **visible - IR** : spectra must go up 1.15 μm ⇨ 1st CO_2 band
  if not, **search for life would not be possible**
  (∃ false positives)

Conclusion



- **unknown:** are they common?

- **for sure:** (1) interest for planetology, exo-biology

  (2) **serious warning** / biosignatures

  (3) thinking / them **is a lot of fun**