Search for Planets & Life in the Universe

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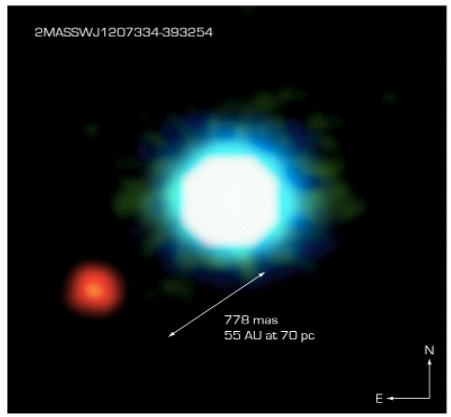
Cosmic Vision, Paris, sept 2004

A Great Adventure

1) **Giant** exoplanets do exist



NACO Image of the Brown Dwarf Object 2M1207 and GPCC

ESO, Sept. 2004

2) Are there **terrestrial** exoplanets?

3) - - **inhabited** - (primitive life) ?

4) Are **we alone** in the Universe ? (Fermi Paradox…)

Goal / Feasibility

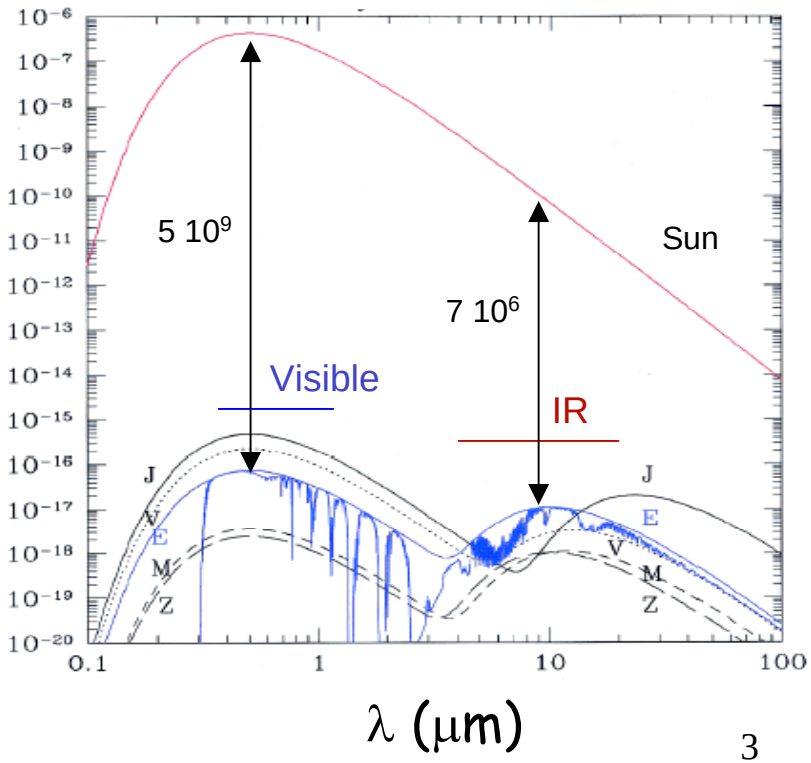
- **We want to:**
  - **detect** terrestrial planets
  - **characterize** - -
  - search for indication of **biological activity**

- **This is feasible by**
  direct detection of planets

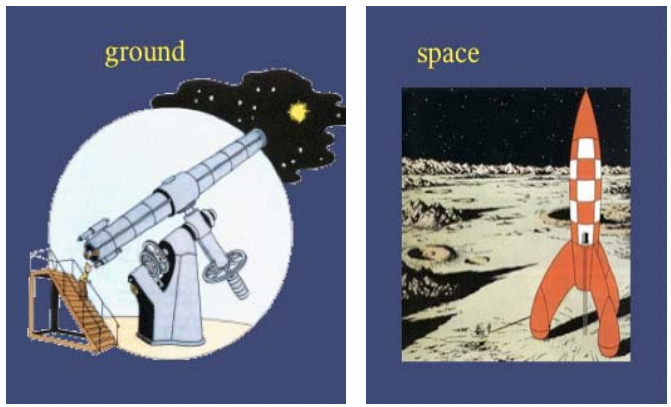
  - study of planetary light
    -> size
    -> orbit
    -> **atmospheric composition**
    (spectroscopy)

  - there are reliable **biosignatures**

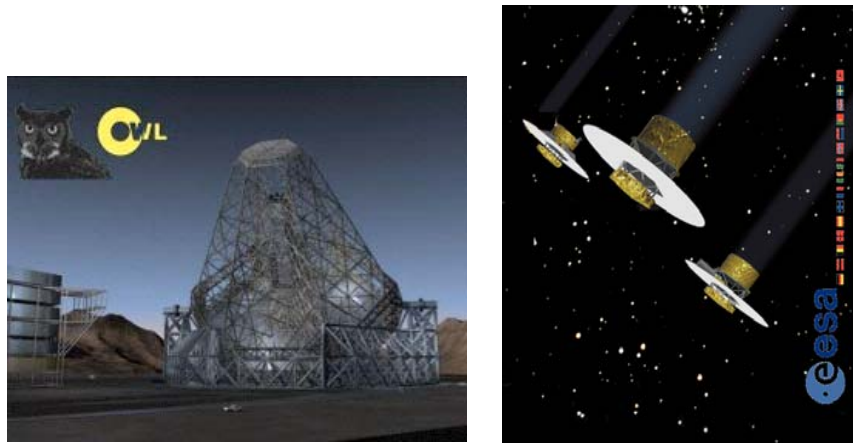
  - **but not so easy!**



Ground or Space ?



vision 1950



vision 2004

- Advantage of Space (***among others***):

full electromagnetic spectrum accessible
(e.g. **thermal IR**)

Spectral range ?

- **Visible** *(stellar reflected light)* ⇒ large telescope + coronograph + spectrometer

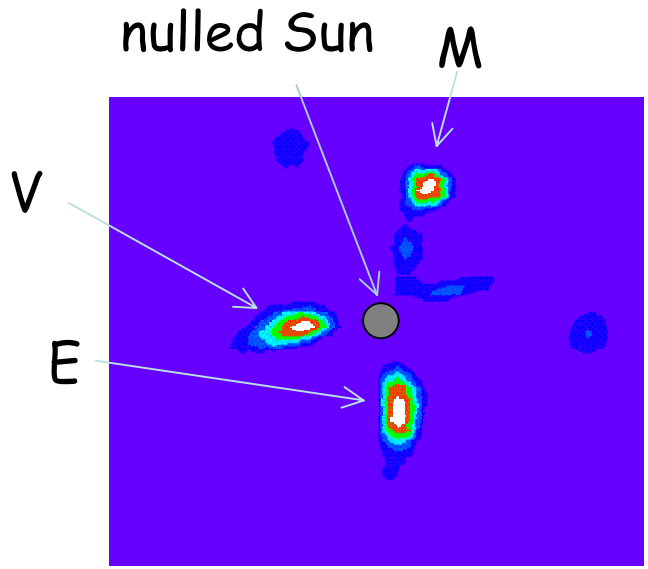
- **IR** *(planetary emission)* ⇒ interferometer nulling the star, + spectrometer

IR	Visible
R_{pl} , T_{eff} , albedo	
CO_2 , H_2O , **O_3** , CH_4 , NH_3, N_2O , SO_2 , **...**	~~CO_2~~ , H_2O , **O_2** , CH_4
3 x (3m tel.) , 300m base -> **200** solar type stars	6m tel. -> **30** solar type sters
European community's choice	

What can be learned ?

1) Detection/imaging planetary systems

- Several observations -> **a, e**
- Flux(t)
  - ✓ day/night variations
    -> **no atmosphere**
  - ✓ ~ no day/night variations
    -> **dense atmosphere**



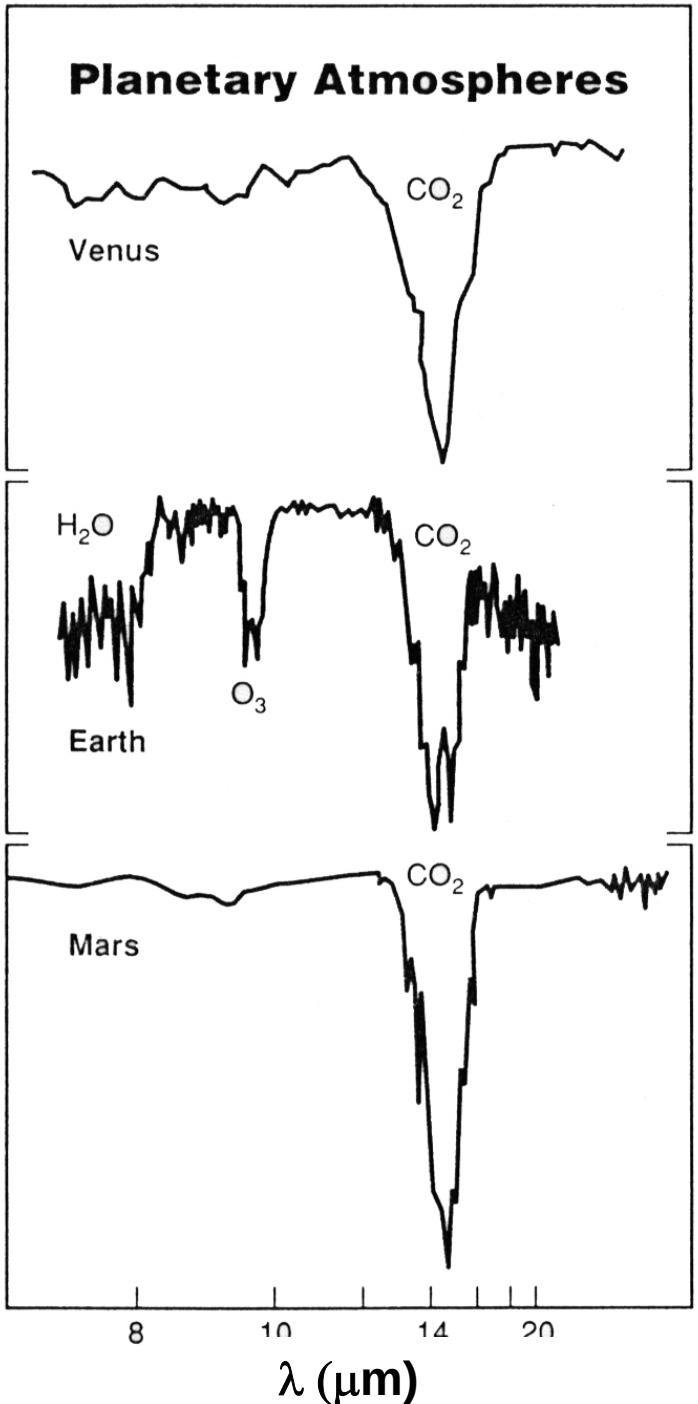
Solar System seen by a nulling IR interferometer

2) From spectroscopy (IR):

T_{eff} , Flux(λ) -> R_{pl} , albedo

Flux(λ) -> atmospheric components

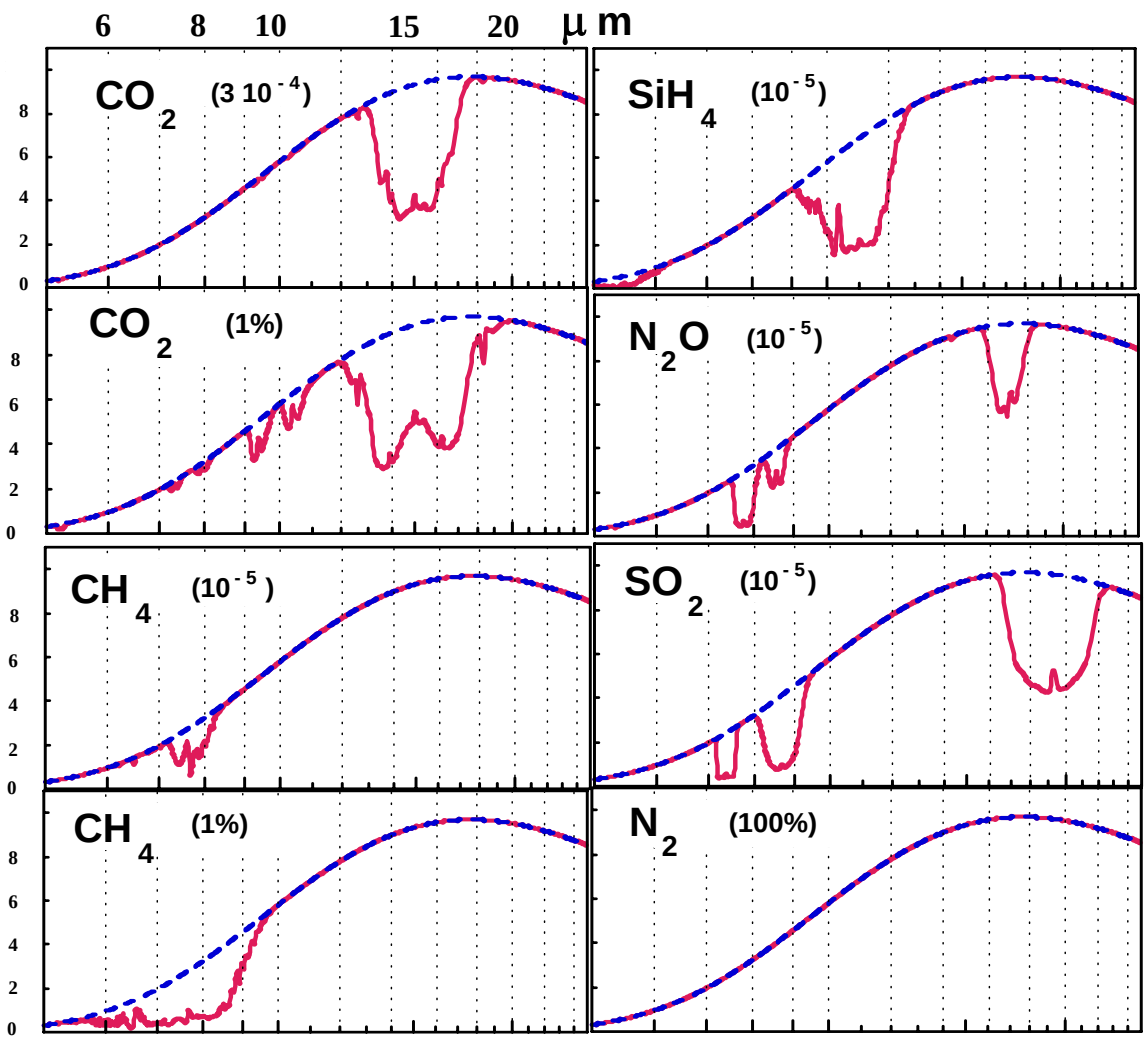
Atmospheric composition



--> allows identification of key gases

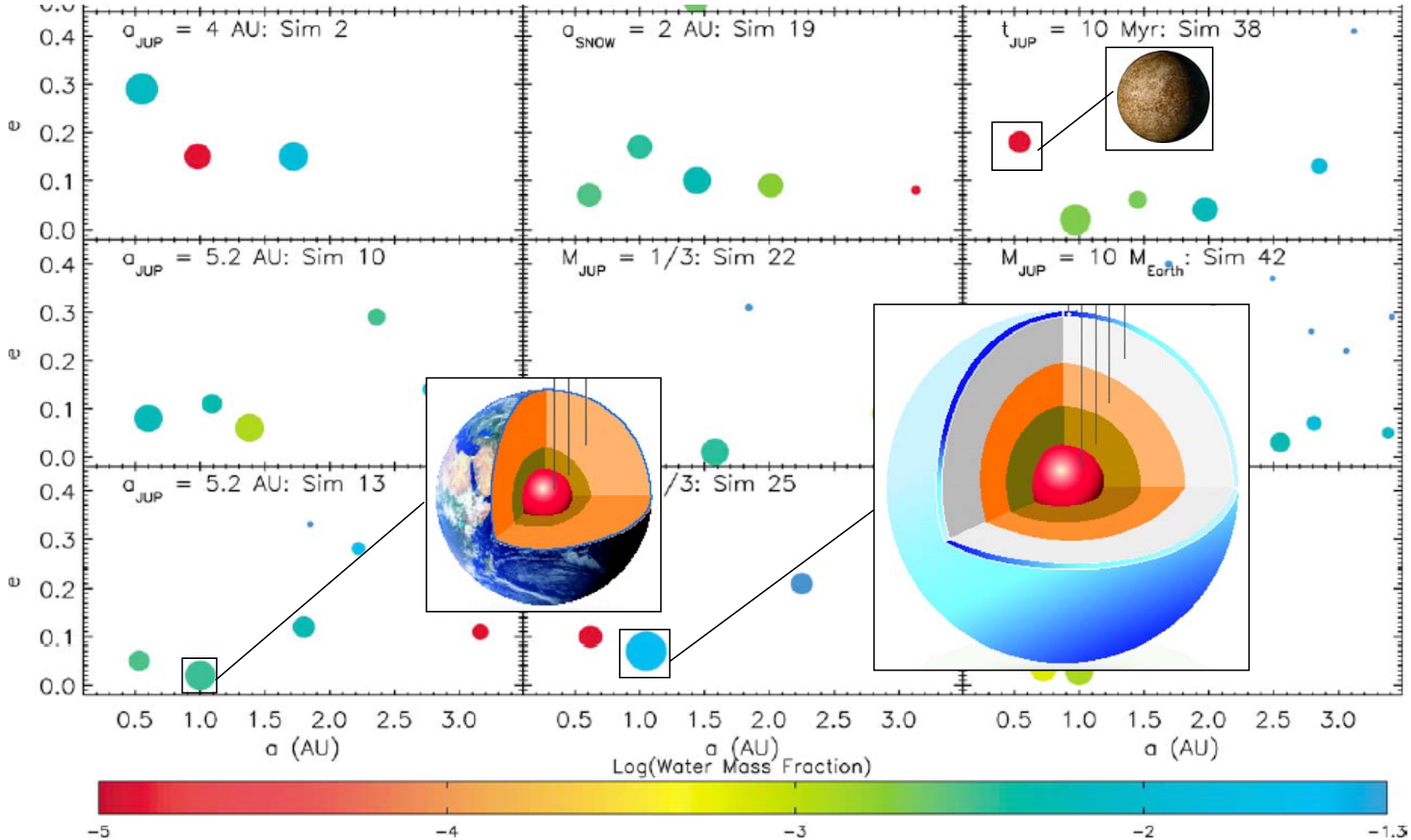
Atmospheric composition (2)

Other species (IR)



Planetology

Great diversity expected



Raymond et al., 2004, Léger et al., 2004

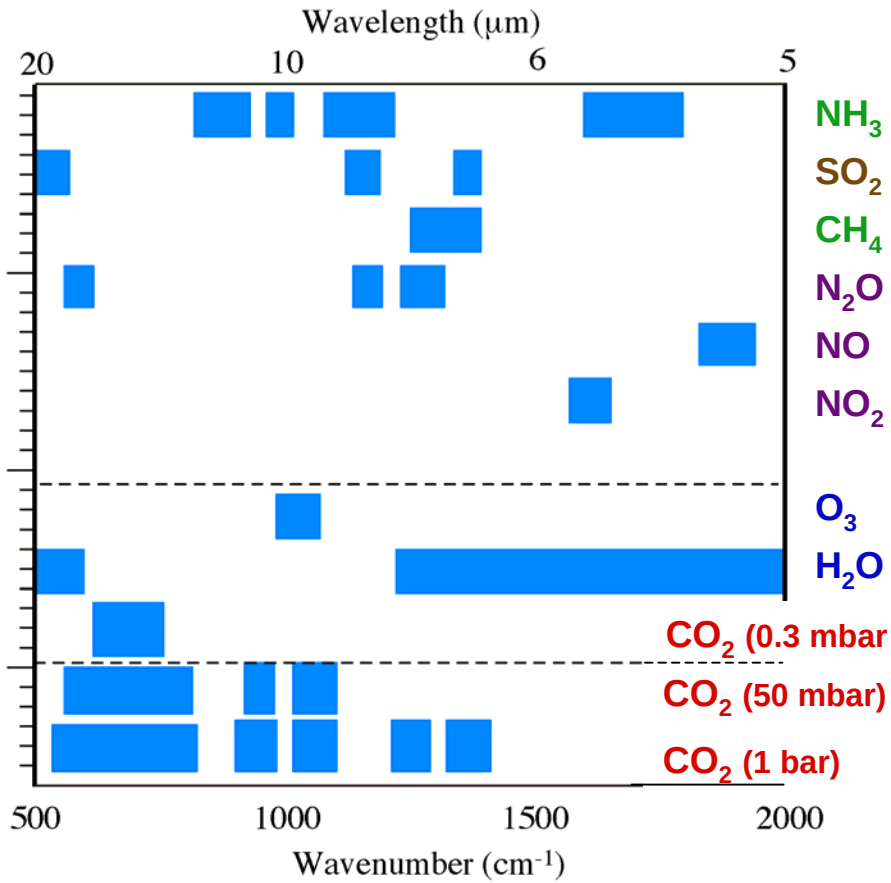
Planetology (2)

Composition of a young atmosphere?

- CO_2 level
  - <50 mbar
  - 50-500 mbar
  - >500 mbar

- CH_4, NH_3
  reducing atmospheres

- Volcanic SO_2
- NO, NO_2
  produced by lightning and impacts



Planetology (3)

- **There are young stars**
  in the 200 star sample, **22 stars** younger than **0.5 Gyr**
  e.g. k^1 Ori (1 M_{Sun}, 8.7 pc, ~300 Myrs old)

- At the same age,
  the **Earth had an ocean and an atmosphere**.

- -> will help to understand:
  - the composition of **early Earth** atmosphere
  - its role in the **origins of life** on Earth

- **Stars** at different ages -> **Sun** evolution
- **Planets** - - -> **Earth** evolution

Direct detection of planets will provide
valuable information for **planetology**

Life ?

✓ What is a bio-marker ?

A mixture of gases that cannot be produced in atmospheres, without a local biological activity

✓ Good news: - some exist

- that can be remotely detected

(CO_2 + H_2O + O_3), or (CH_4 + O_3), or (N_2O)

Interdisciplinary, public outreach

Interdisciplinary

- Astronomy
- Planetary/Geo/Atmospheric sciences
- Chemistry
- Biology

Developed in tight synergy --> reliable evidence of life

Public outreach

- this vision well understood
- a contribution to stimulate interest of younger generations for sciences

Conclusion (1)

A program:

1) **Detecting** terrestrial planets:

COROT, 2006; (**Eddington**, 2009 ?);
Kepler, 2008 (NASA)

2) **Characterizing** planets, (**1st generation**)

ESA: - **IR** has been studied for **10 yr**
- major **simplifications** of the instrument & improved **capabilities**
-> **200 target stars**

good news: - **Darwin is technically feasible** and a **launch in 2015 is possible**

Conclusion (2)

3) **Characterizing** them (**2nd generation**)

- **in IR**
  - $\lambda/\Delta\lambda$: 20 --> ~ 200
  - 200 stars --> 2,000 stars ?
- **in Visible**: complementary information

4) **Next ?**

An **whole new domain** in Astronoy and Planetology:

Imaging (minimum 30x30 pixels)

or/and **high resolution, high S/N spectroscopy**

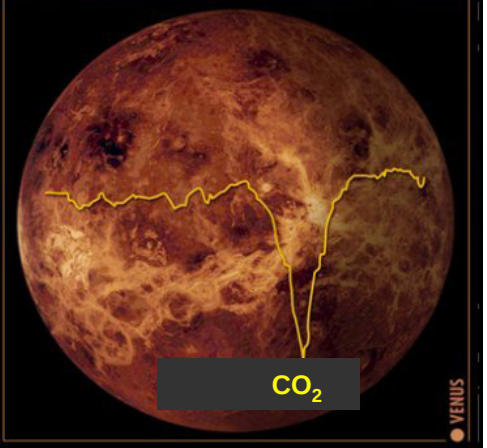
Europe has the elements to make a real breakthrough,

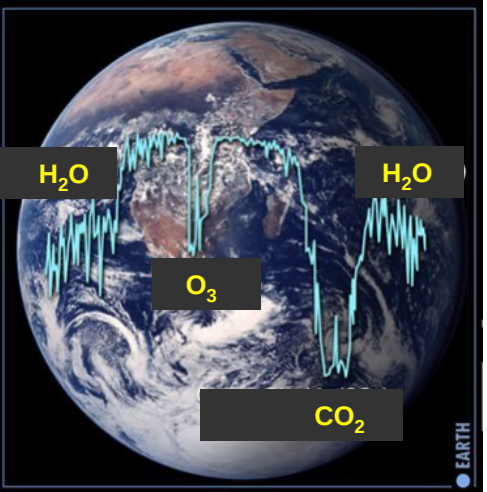
1st mission, for characterisation, can fly in 2015

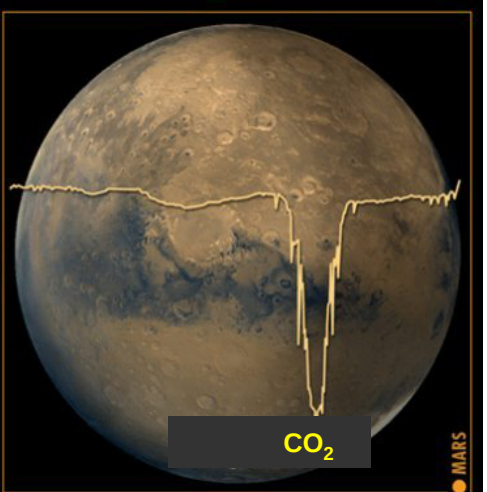
Thanks to:

- Jean-Marie Mariotti
- Robin Laurance
- Franck Selsis
- Malcolm Fridlund
- Anders Karlsson
- the ESA "Terrestrial Extrasolar Science Advisory Team"

- atmospheric composition -







<-- in T(λ)

in F (λ)

--> allows identification of key gases