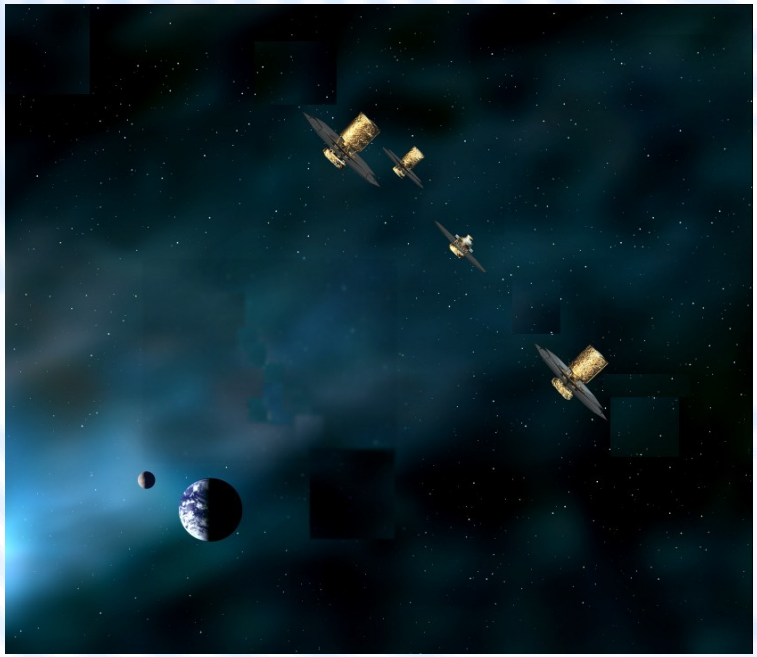
ESA's exoplanetary program
The Darwin Mission
Status & recent progress



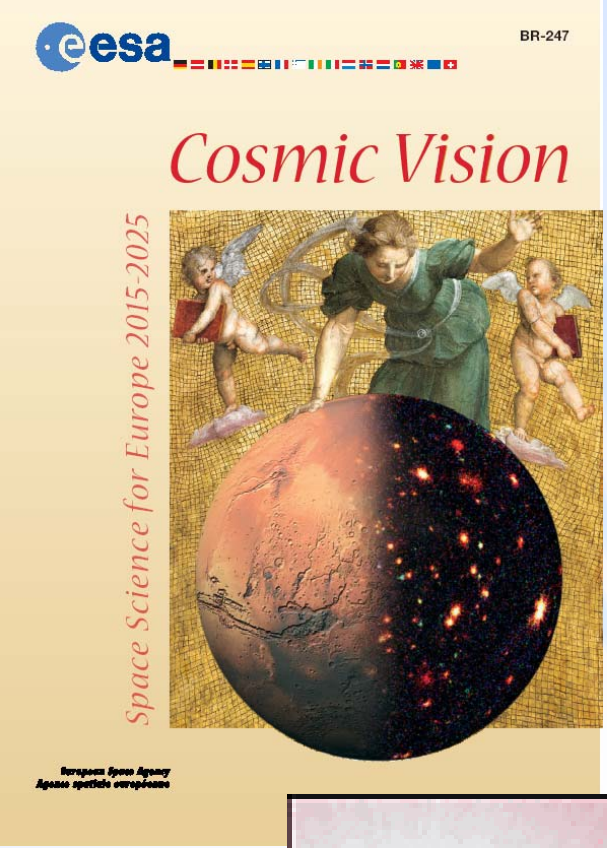
M. Fridlund

Outline:

1. **ESA Cosmic vision program**
2. **Scientific rationale**
3. **Status of the Darwin study**
4. **Current stepwise approach**
5. **Possible role for small missions**
6. **Where do we go from here?**

Cosmic Vision 2015-2025
Current status

- Implementation of current H2000+ program in preparation:
  - GAIA: 2011/12
  - Bepi-Colombo: 2014
  - LISA/Pathfinder ?
  - Solar orbiter under review
- CV1525 addresses four grand themes
- Call for proposals 2006
- Call for one mission within small financial constraint for 2015-16
- + one larger mission without formal constraint
  flight in ~2020 (Darwin?)
- 3 candidates for either will be selected for (further) study
  and will receive funding for technology development



Cosmic Vision is centered around four Grand Themes:

1. **What are the conditions for planet formation and the emergence of life?**
   - **From gas and dust to stars and planets**
   - **From exo-planets to biomarkers**
   - **Life and habitability in the Solar System**
2. **How does the Solar system work?**
3. **What are the Fundamental Physical Laws of the Universe?**
4. **How did the Universe originate and what is it made of?**

Proposed strategy:

First:	In-depth analysis of terrestrial planets (Darwin / NIRI)
Next:	Understand the conditions for star, planet and life formation (Far IR observatory / Solar Polar Orbiter)
Later:	Census of Earth-sized planets & explore Europa (Terrestrial Planet Astrometric Surveyor / Europa orbiter / lander)
Finally:	Image terrestrial exo-planet (beyond 2025) (Large Optical Interferometer)

of Scientific Programmes

M. Fridlund, *August 2006*

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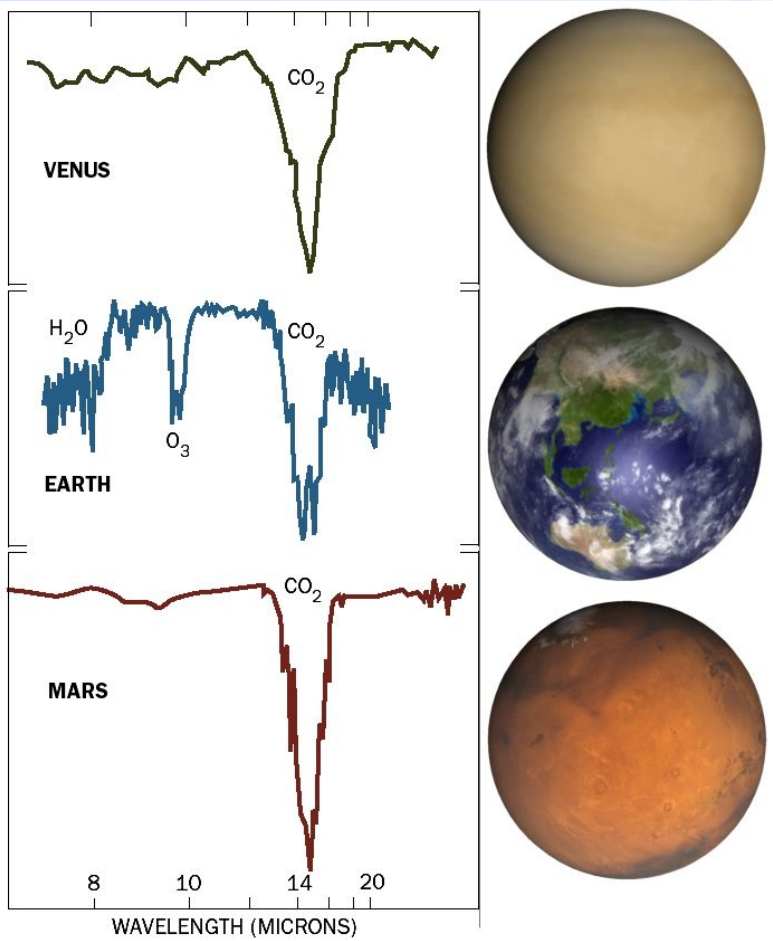
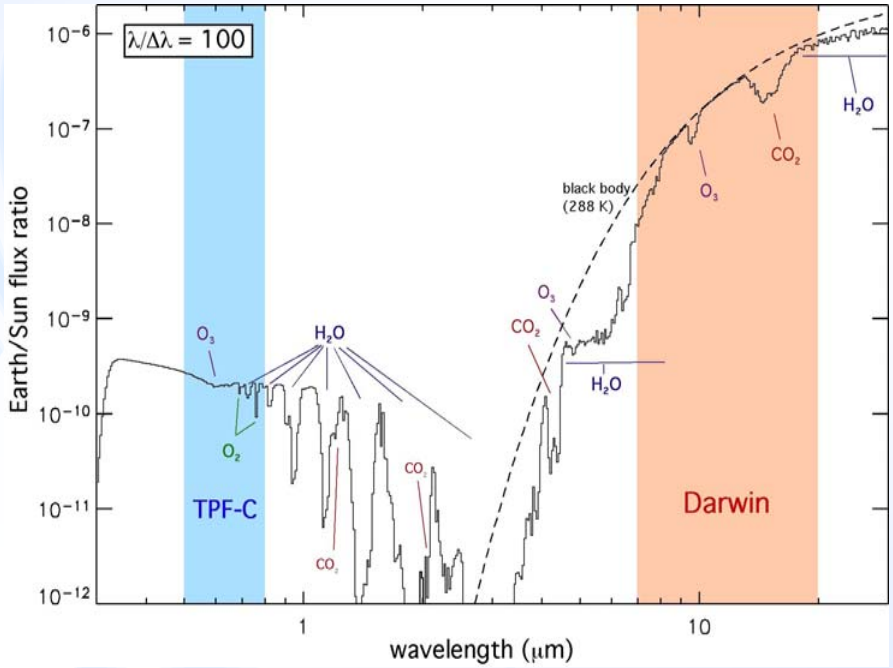
Bio markers





The goal is to find rocky planets with an atmosphere out of photo-chemical balance.

(cf. Lederberg, 1965 and Lovelock, 1965)

Working definition:

Life ≡ O_3 + H_2O + CO_2

Ideally, detect reduced molecules (CH_4, N_2O) as well

The quest for Terrestrial exoplanets

Significantly smaller than currently detected planets but we are getting there

- No doubt that microlensing will start to pick up them

- RV requires 0.1 m/s (possible) over 3 years (1AU/G2V) with large telescope and no disturbing P-modes (6 month time scale 0.5-1 m/s) This is for the Habitable Zone. Real problem is stellar activity

Direct observation with next generation ELT's require:

- 100m class telescopes! Can only work on G-stars to 18pc! (35 targets)

If telescope surface Perfect!!

- Bright star ==> contrast ratios of 10^{10}-10^{11} at subarcsec separation!

- Diffraction control, wavefront quality (Strehl ratio), wavefront stability ➔ 2-3 orders of magnitude above today

If we need to observe directly: Go To Space!!

Two extreme cases are possible and need to be considered:

- **Earth-like planets are common**
- **Earth-like planets are extremely scarce**

This means any search need to be designed such that a negative result is also meaningful

Therefore, the DARWIN mission is designed to search and characterize Earth-like planets around at least 300 – 500 stars

In-depth analysis of Earth-like planets

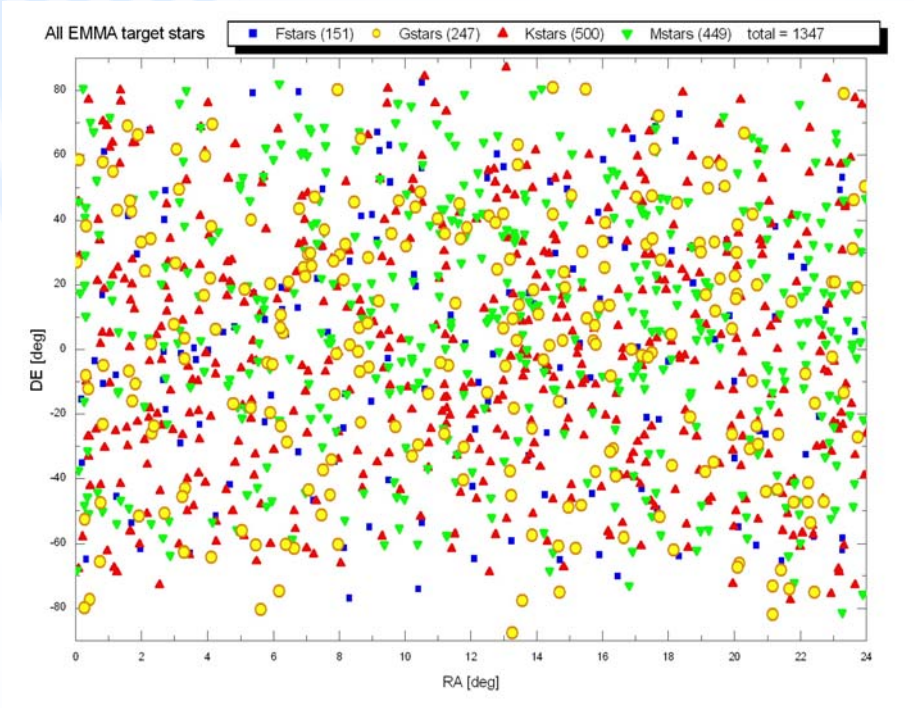
What strategy?

- Search for rocky planets and determine if they are common or rare
- Determine the physical conditions of and on these planets
- Determine whether these planets are in principle habitable
- Find out if these planets have life on them
- To place ourselves in context we need the science of Comparative Planetology

DARWIN Target catalogue

Single stars out to 25 pc:

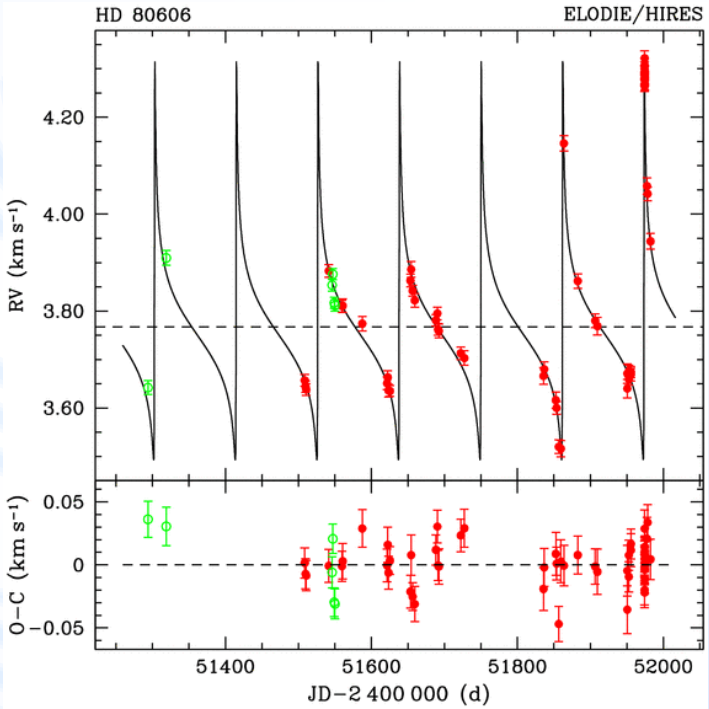
Spec. Type	Number
F	43
G	100
K	244 (incomplete)
M	241 (incomplete)
Total:	**608**



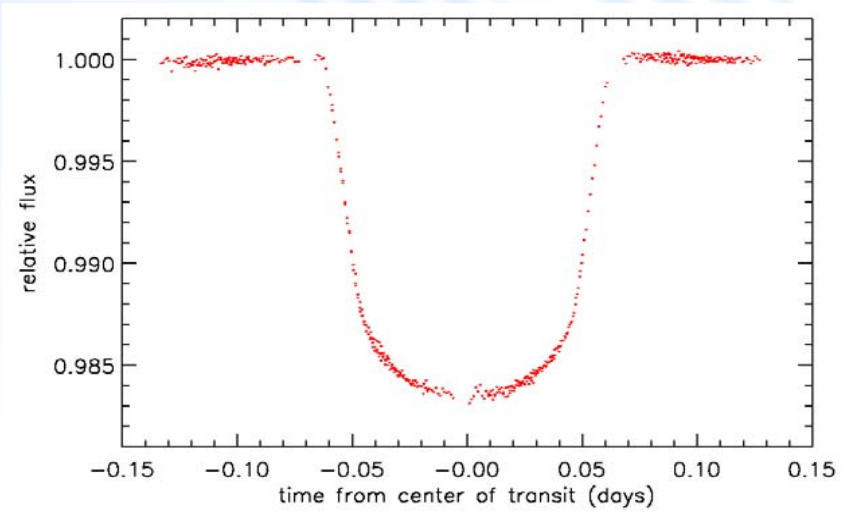
All missing late K and M stars within 25 pc will be found by GAIA in ~ 1.5 year of mission time because of large parallax and sensitivity (GAIA can observe down to R = 25 magnitude)

Exo-planets do exist in abundance...

- **>200 planets in > 140 systems since 1995**
- **But most detected so far are Jupiter-size planets in tight, eccentric orbits**
- **Some detected with 6 < M < 10 $M_\oplus$ but either in short period orbits or around M-stars!**



Naef, Latham et al., 2001
e = 0.927



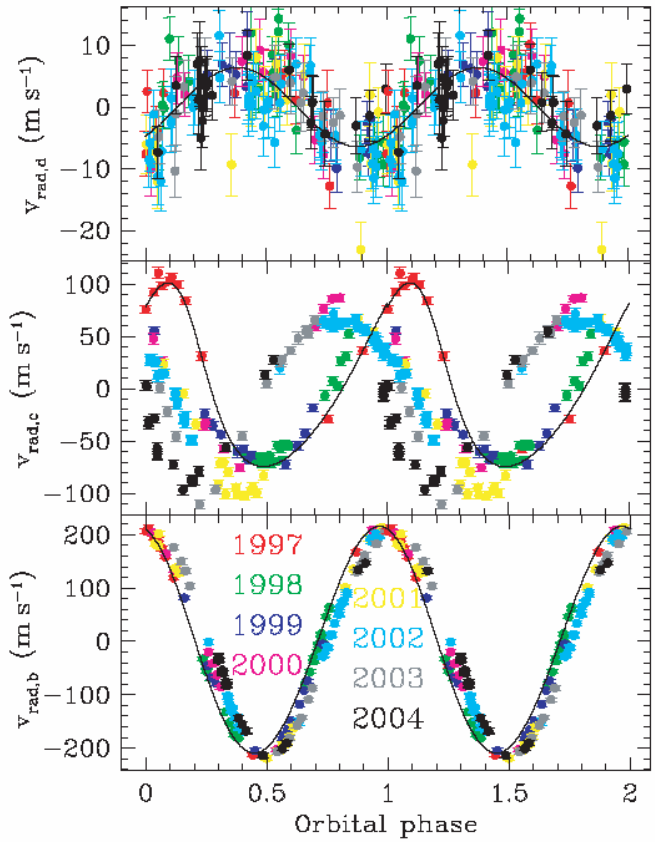
Charbonneau et al., 2000

probably down to Earth-like masses...

7.5 $M_\oplus$....

at 0.021 AU around an dM4 GJ 876

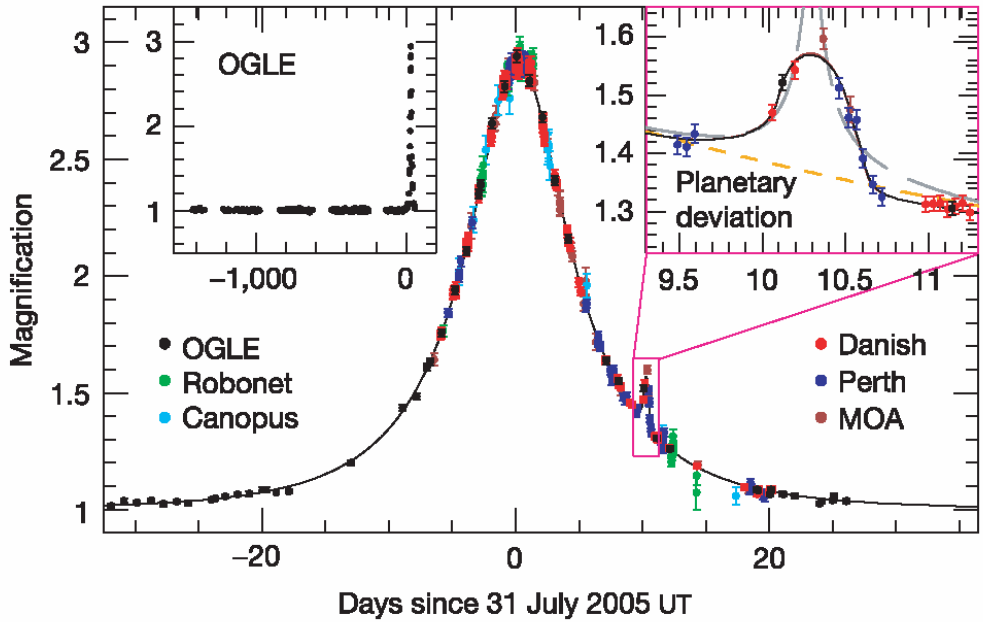
Rivera et al., ApJ 634, Nov. 2005



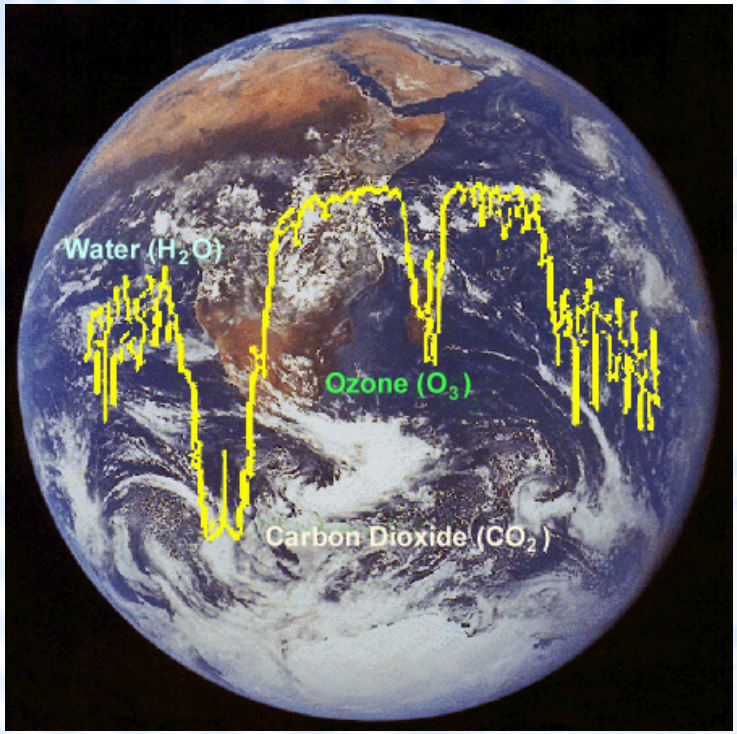
5.5 $M_\oplus$....

at 2.6 AU around an 0.22 M_{sun} M-dwarf

Beaulieu et al., Nature, Jan. 2006



… but the ‘Holy Grail’ is still eluding us



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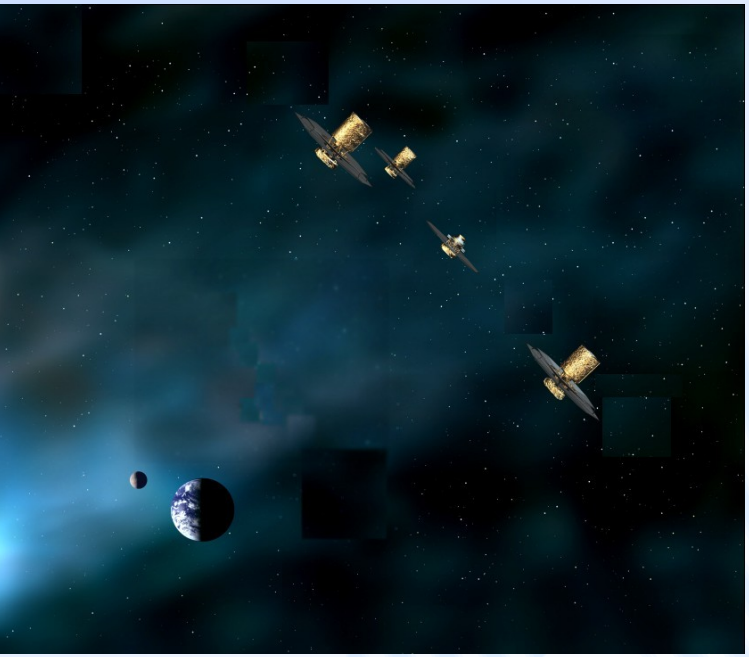

Darwin is a nulling interferometer connecting 3 - 4 telescopes, each on its own s/c with phase delays extinguishing the light on the optical axis, while enhancing the light a small distance (in the Habitable Zone for the star in question) away. Interferometry takes place in the beam combiner s/c for a total of 4-5 s/c. Mirrors in 4m class are required to reach all stars out to 25-30pc. Modulation (to alleviate noise factors) is introduced by using sub-interferometers (and 'chop' the signal) and by rotating the array, essentially producing a transmission pattern on the sky 'searching' the HZ.

Status of Darwin

- Data processing study by Alcatel Alenia (F) to finish October 2005
- End-to-end simulator development by EADS Astrium (D) + 18 months
- Two parallel system studies by Alcatel Alenia (F) and EADS Astrium (D) kicked-off in October 2005, finish in April 2007
  - Study Darwin in triangular or X-array formation (i.e. 3 or 4 tel.)
  - 3 – 4 m class telescopes
  - Spectral range: 6 – 20 μm
  - Spectral resolution 20 – 50 (120)
  - A5 launch to L2
  - 5 years nominal mission time + 5 years extended
- To be proposed by community for the Cosmic Vision as a major mission this Fall

Status of the field

GENIE:	**(ESA) ground-based nulling at VLTI:**	**on hold (polarisation, CV approval)**
COROT:	**(F) transition search, large rocky planets:**	**launch 2006**
PRISMA:	**(S, D, F) 2 Free Flying techno precursor s/c for 35 M€:**	**launch 2008**
KEPLER:	**(NASA) transition search, also for Earths:**	**launch 2008**
HERSCHEL:	**(ESA) dust levels in target systems:**	**launch 2008**
GAIA:	**(ESA) completion of star catalogue:**	**launch 2011 / 12**
SIM:	**(NASA) space interferometer:**	**launch, 201?**
TPF-C:	**(NASA) space coronograph:**	**on hold**
TPF-I:	**(NASA) nulling interferometer: Darwin partner/counterpart**	**on hold**

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Darwin preparatory work

- **Technology Research Program**
  - **5 Meuro in 2006, 4.5 Meuro in 2007**
  - **Expect similar funding during Cosmic Vision**
  - **Major goal: 'realistic' nulling breadboard**
  - **Bring enabling technology in place**

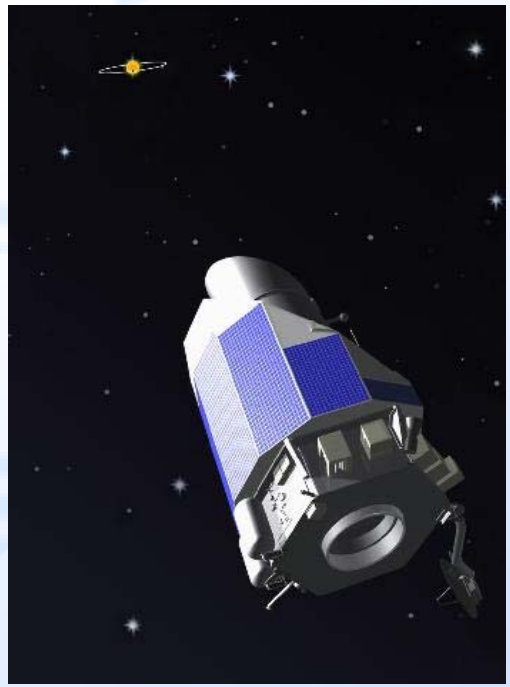
- **HERSCHEL program**
  - **Building on Spitzer legacy**
  - **Unbiased search for Kuiper belts / exo-zodi in GT program of closest 80 FGK stars.**
  - **Sensitivity is 1 Kuiper-belt around G2V at 10pc with S/N of 5 in ~30 min.**

COROT:

- Launch in fall of 2006 (Soyuz from Bajkonur) into LEO
- Capacity to detect 2 Earth-radii planets in short period orbits
- Field of view 2 deg^2; 1 field every 150 days for 2.5 years
- Two tasks: astroseismology and planet finding
- ~50 astroseismology targets and 60000 planet-finding targets

KEPLER:

- **Launch 2009, results in 1-3 years, total mission time 4 years**
- **Scans 100,000 stars in a 150 sq. deg. field in Cygnus-Lyra**
- **Expected to find ~50 'real Earths'**
  = 1 $R_\oplus$ in HZ = 1 AU around G2V)



Astrometry in space & on ground

Goals:

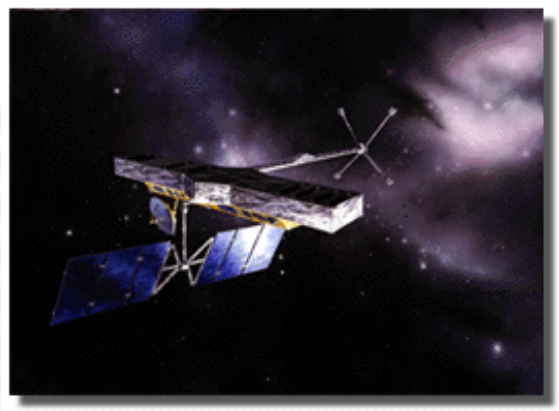
- **complete census of giant planets to 200 – 500 pc**
- **orbital characteristics of several thousand systems**

Present: **Using FGS on HST** **(GL876b mass determination)**

Soon: **VLTI-PRIMA**

2011/12: **GAIA**

201?: **SIM-PlanetQuest**



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DARWIN-Lite or Super-PEGASE

- First mission in CV1525 is too small an envelope for DARWIN proper (300 Meuro)
- CV plan allows for several (sub-)missions or experiments to answer a Theme

➔ Investigate Darwin-lite:

- Cheaper mission with less encompassing science case
- Smaller DARWIN or larger PEGASE: “Where shall the twain meet?”

➔ Outcome of initial study by Univ. of Liège:

- Science case not compelling
- Cost & complexity NOT significantly reduced!
- TE-SAT recommends NO Darwin-lite!

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Where do we go from here?

0. **Get DARWIN into Cosmic Vision program**

   - **Role of Europlanet = ? But must be significant**

1. **Continue development of enabling technology**
2. **Broaden interest base:** **Again a role for Europlanet**
   - **Solar system community**
   - **Biology**
   - **Paleontology**
   - **Geophysics**
3. **Work on preparation**
   - **Study of target systems: Kuiper-Edgeworth belts, exo-zodiacal dust, inclination, etc…**
   - **Models of planetary evolution**