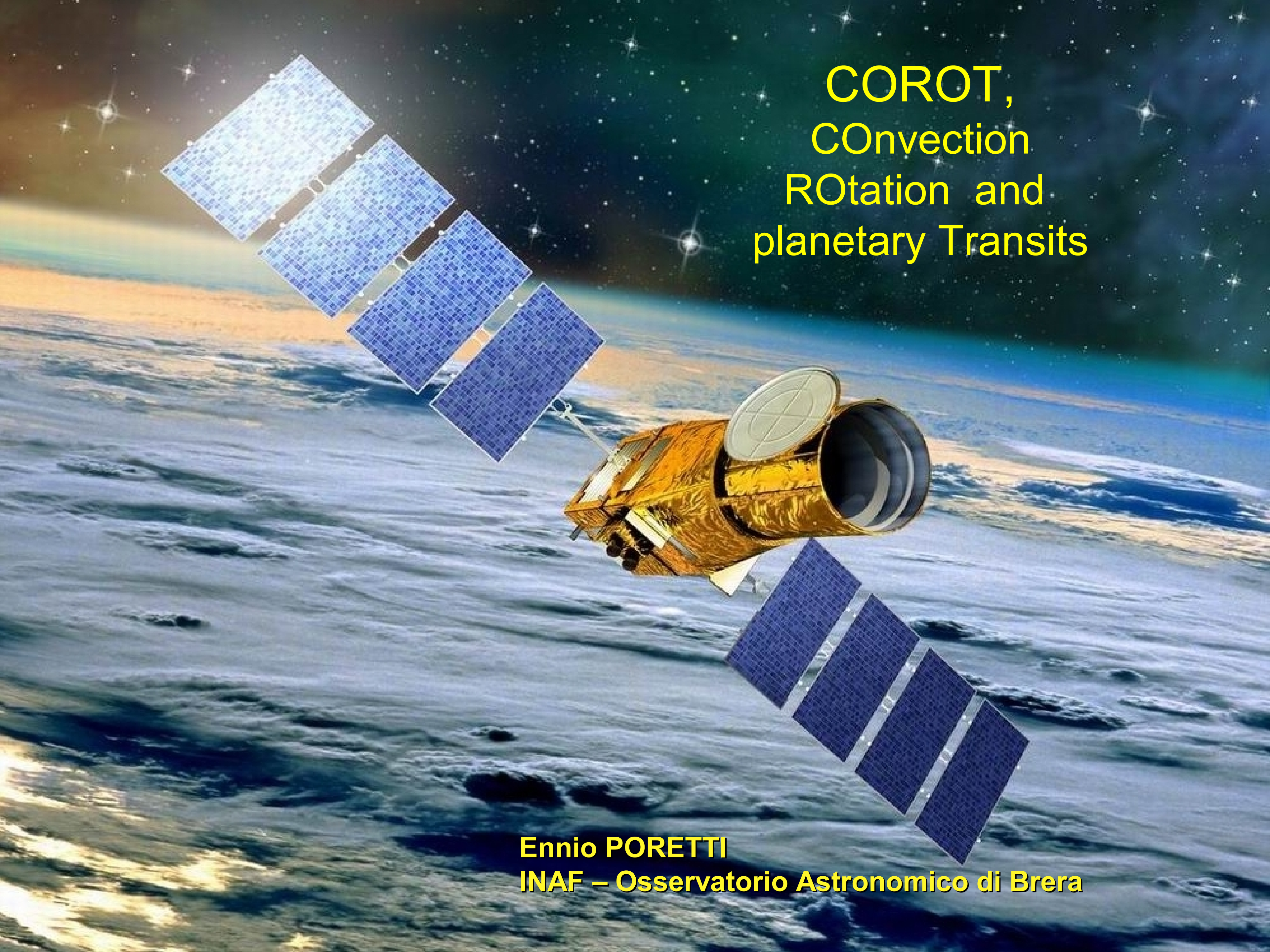
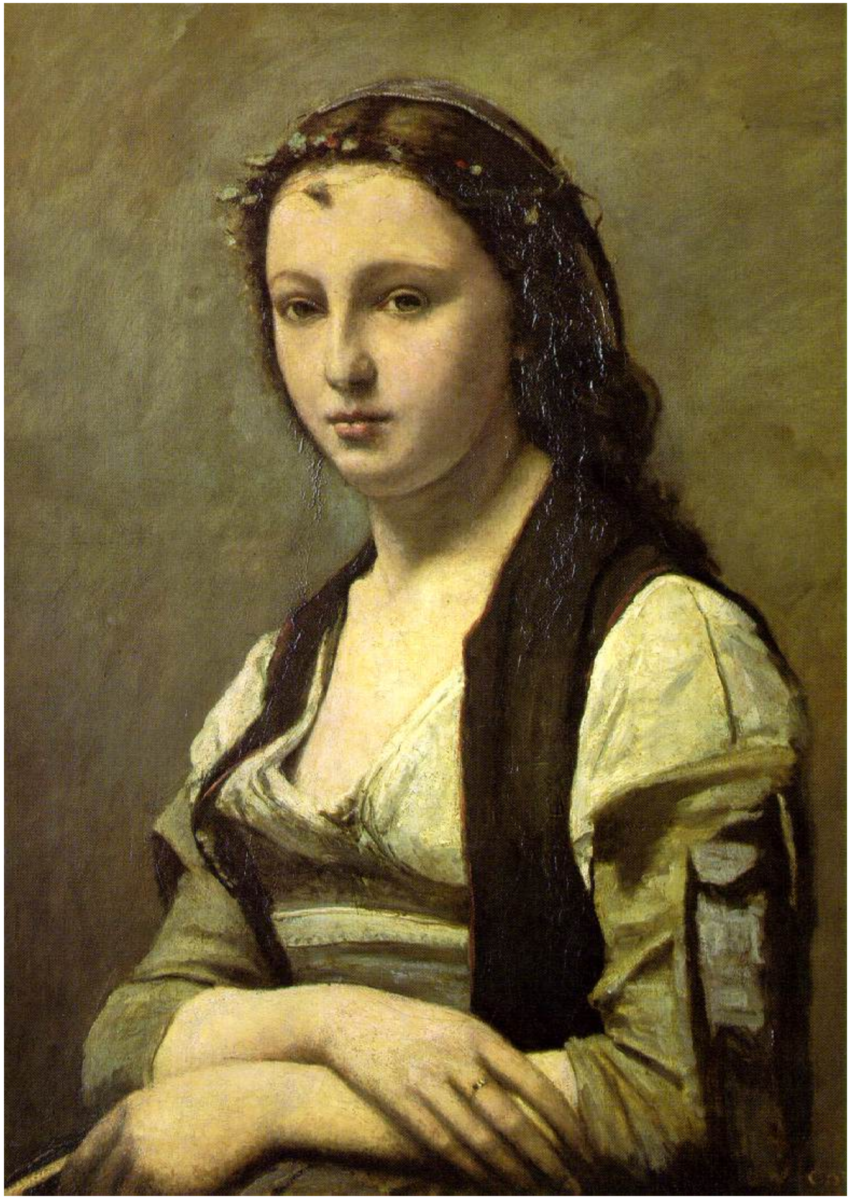


COROT, COnvection ROtation and planetary Transits

Ennio PORETTI
INAF – Osservatorio Astronomico di Brera



International Partners

7 countries or organizations are officially collaborating and supporting the mission

Instrument

ESA
Optics

SSD
Processors

Germany
On-fly software

Belgium
Case
and Baffle

Austria
Electronic parts

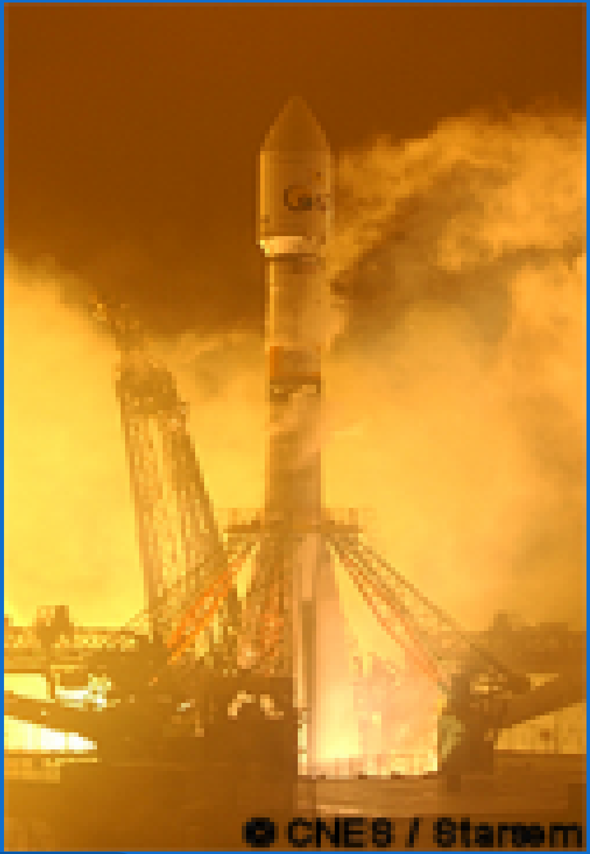
Ground segment

Brasil
Secondary antenna

Spain
Mission Center

Launched on December 27, 2006

⇨ **New SOYUZ rocket from Baïkonour**



A. Baglin	Principal Investigator
Th. Lam-Trong	Project Manager
M. Auvergne	Project Scientist
L. Boisnard	Mission Engineer

Documentation :

http://corot-mission.cnes.fr
http://www.obspm.fr/planets
http://www.astrsp-mrs/projets/corot

à Frédéric

Frédéric Bonneau, Chef de projet COROT au CNES,
disparu subitement le Samedi 19 Octobre sur un court de tennis

General characteristics

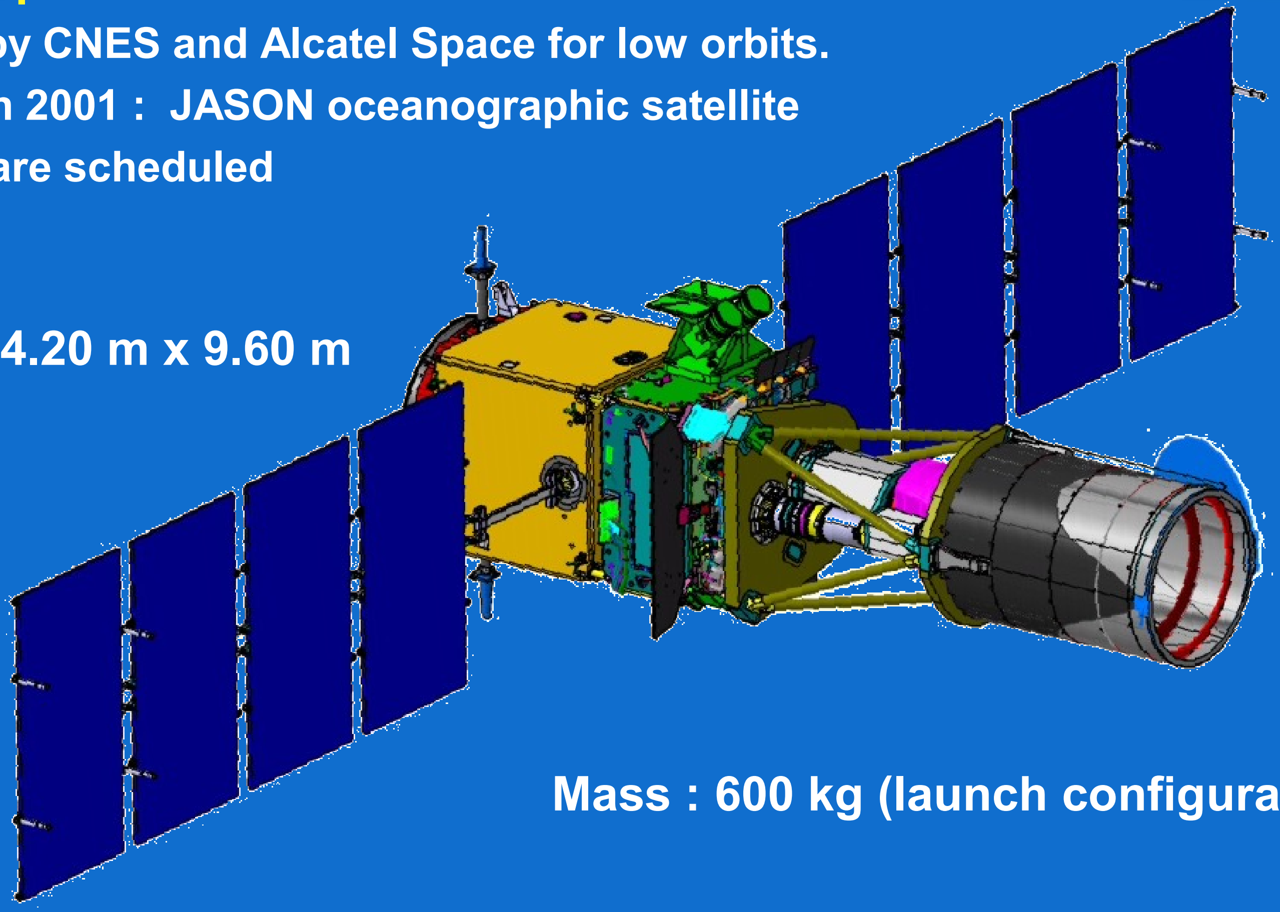
PROTEUS platform

Developed by CNES and Alcatel Space for low orbits.

First flight in 2001 : JASON oceanographic satellite

5 missions are scheduled

Aperture : 4.20 m x 9.60 m

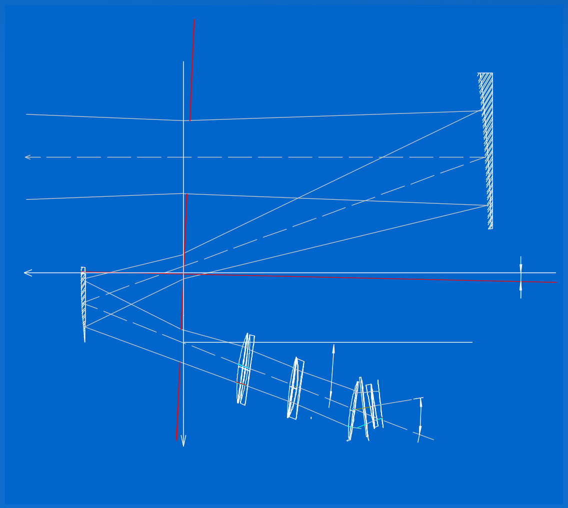


Mass : 600 kg (launch configuration)

Optical design

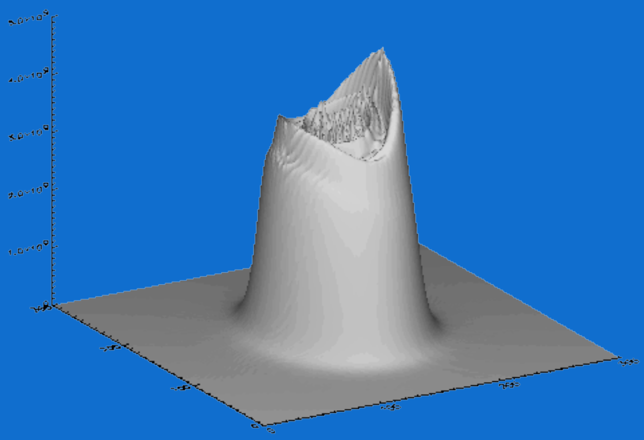
Telescope (COROTEL)

- entrance pupil 270 mm
- 2 parabolic mirrors
- cylindric external baffle
- cylindric internal baffle
- shutter



Instrument (COROTCAM)

- 6 lents
- Detectors: 4 CCD 2048 x 2048
- Radiation shielded
- 2 CCD seismology, 2 CCD exoplanets
- Field of view : 3.05° x 2.70°



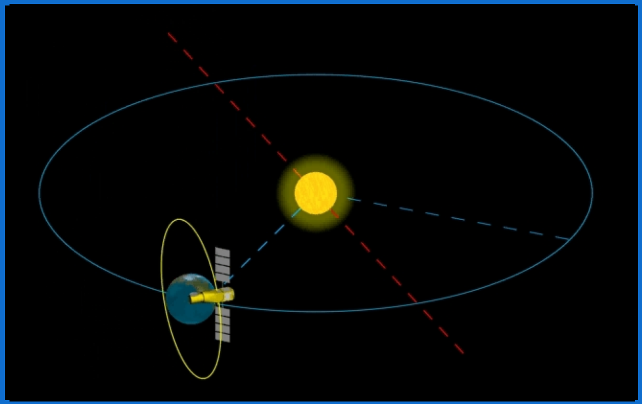
Orbit

Polar orbite, low altitude

It allows to maintain the same direction of observation for 6 months without be disturbed by sun light or undergo Earth eclipses

Orbital parameters

- a = 7274 km (altitude =896 km)
- e = $1.27.10^{-3}$
- i = 90°
- T_{orb} = 6174 sec (1 h 43 min)



Winter : line of sight at 6 h 50

Sun at 90° from COROT: rotation of the satellite

Summer: line of sight at 18 h 50

LAUNCH

Orbital parameters
Perfect
NO correction

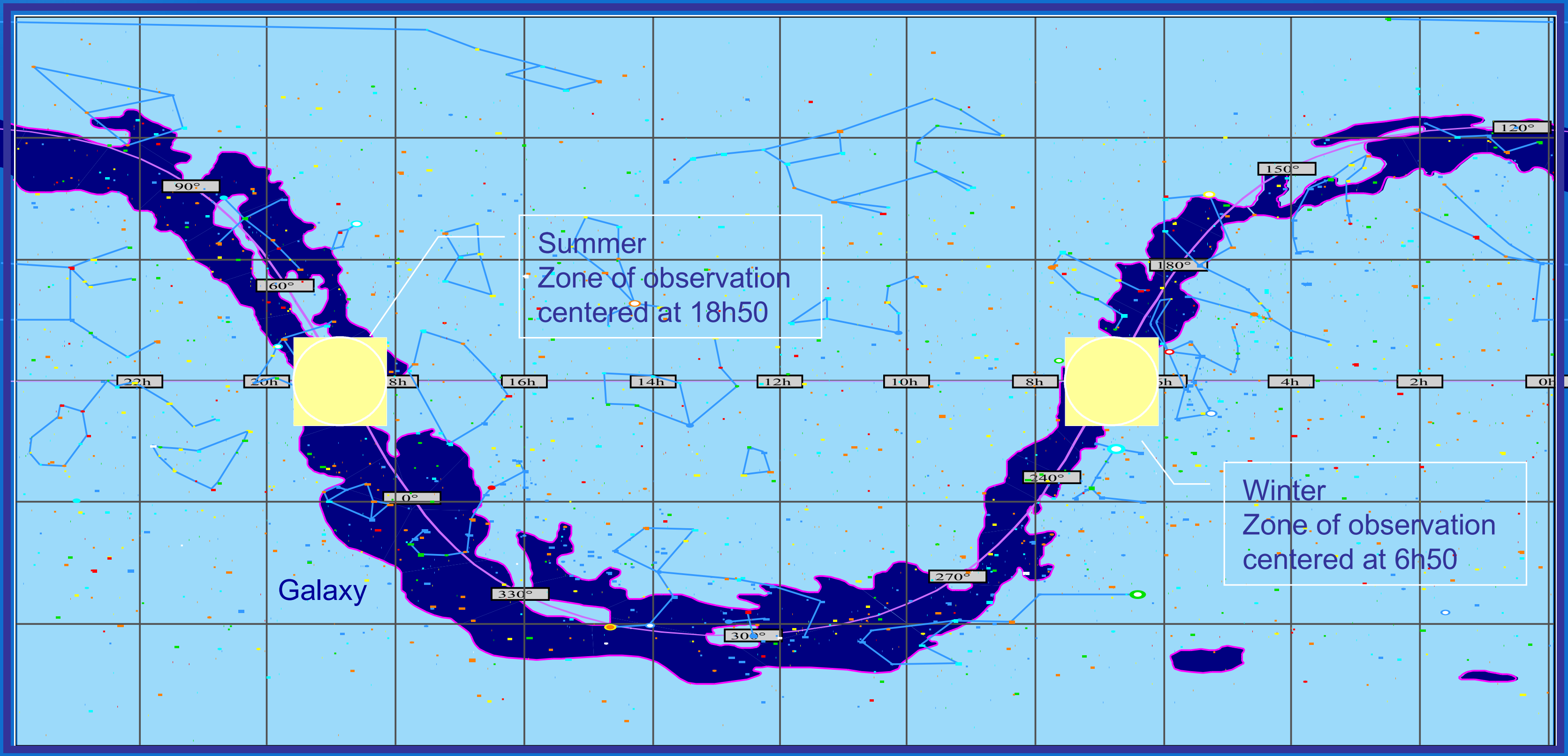
- Mean orbit radius 7275.7 km (~+20)
- Eccentricity 1.8 E-3 (0)
- Inclination 90.02 (90)

-> drift of the orbit of 1°/year toward the first center run.

- Omega: 14.54 (14.5)
- Orbital Period 6184 sec (6172) (In blue, expected values)

with a decrease of 5 to 6 seconds over three years

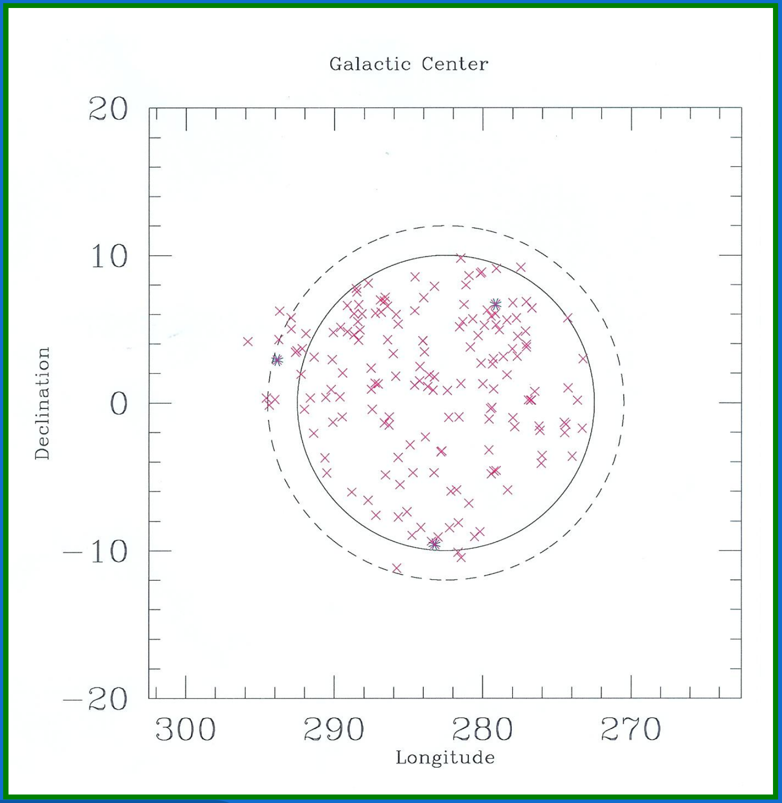
The two COROT eyes

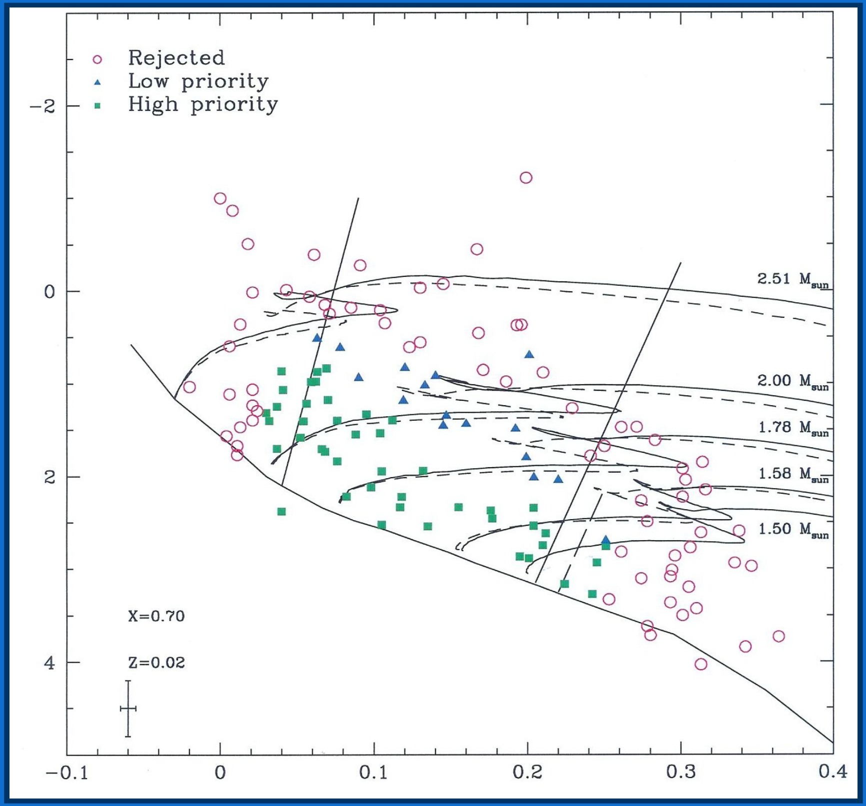


GALACTIC CENTER DIRECTION

The summer 2002 challenge : find new variables in the Lower Instability Strip for COROT

Too few primary targets. Necessity to enlarge the primary targets list.
Which stars are actually variable ones ?

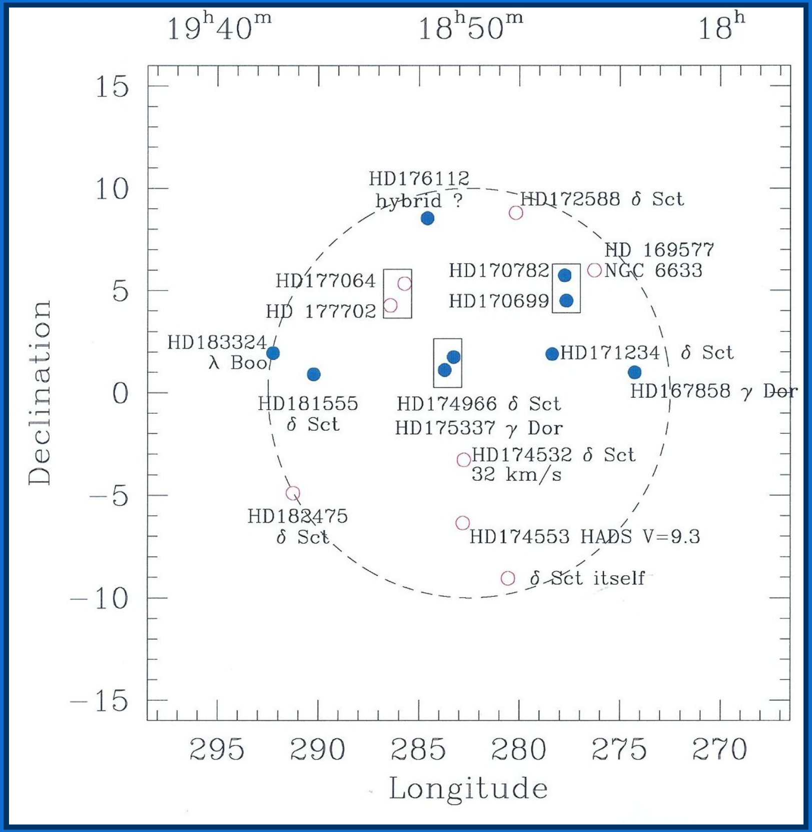


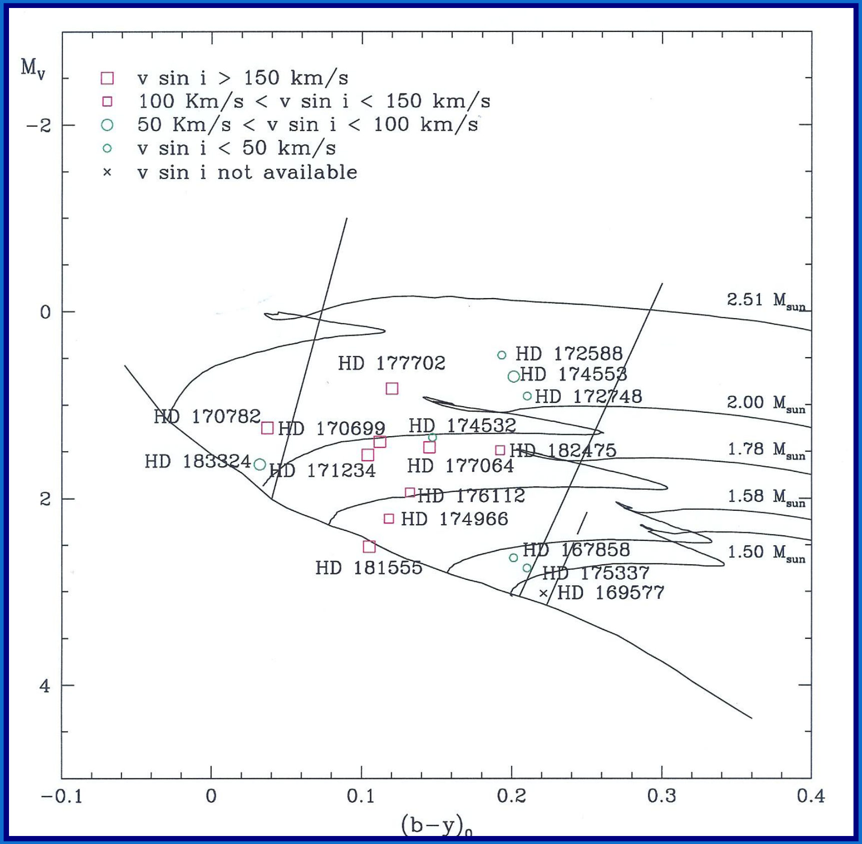


Challenge won !!!

Observations performed mainly at OSN and SPM

New targets proposed to the COROT Scientific Committee (December 2002, Corot Week 3)





SUMMARY OF THE PREPARATORY WORK

Ground-based observations: high-resolution spectroscopy using FEROS at ESO and SARG at TNG and detailed reductions

Solano et al., 2003 (GAUDI ARCHIVE)

Decisive, complementary observations at Serra La Nave observatory

P.I. G. Cutispoto

Identification of new primary targets in the Center direction

Poretti et al., 2003

Identification of secondary targets in the AntiCenter direction

Poretti et al., 2005

Preliminary asteroseismic characterisation of primary targets *(in progress)*

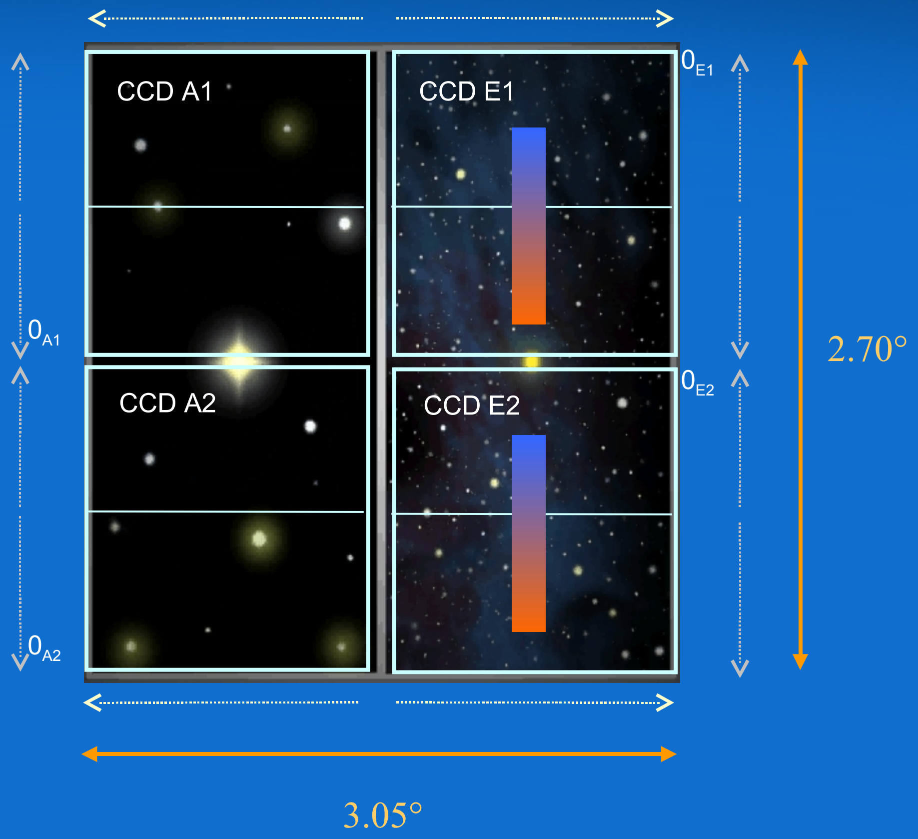
THE COROT MISSION: Pre-launch Status (ESA Book SP-1306)

The observing modes

Asteroseismology
Bright stars 5.5 < V < 9.5
10 ★ in each field

Exoplanetary search
Faint stars 11.0 < V < 16.5
12 000 ★ in each field

Mission life expected : 2.5 y
5 long runs (150 d each)
10 short runs (20 - 30 d)



V = 6 --> ~2.5 10^4 photons cm^{-2} s^{-1}
outside atmosphere , T ~ 6000°K
mv = 16 --> ~2.5 photons cm^{-2} s^{-1}

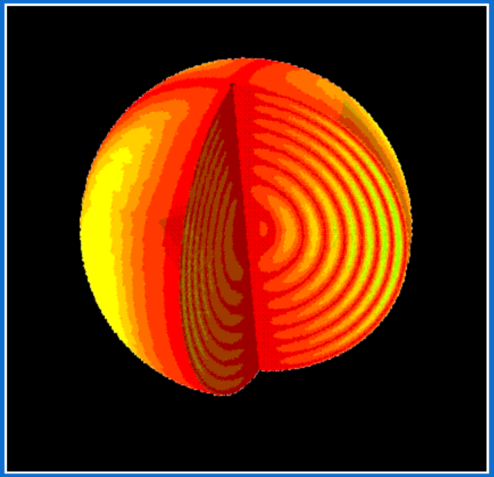
The communalities

Stellar photometry with a very high accuracy on a long time baseline

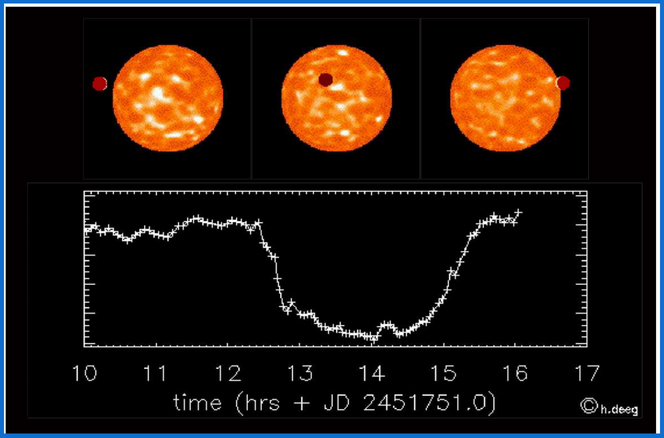
Seismology : 6 micromag, V=6.0 in 5 days
Planetary transits : 0.1 mmag on a V=15.5 star

Two scientific goals, simultaneously performed in two adjacent sky regions

Asteroseismology



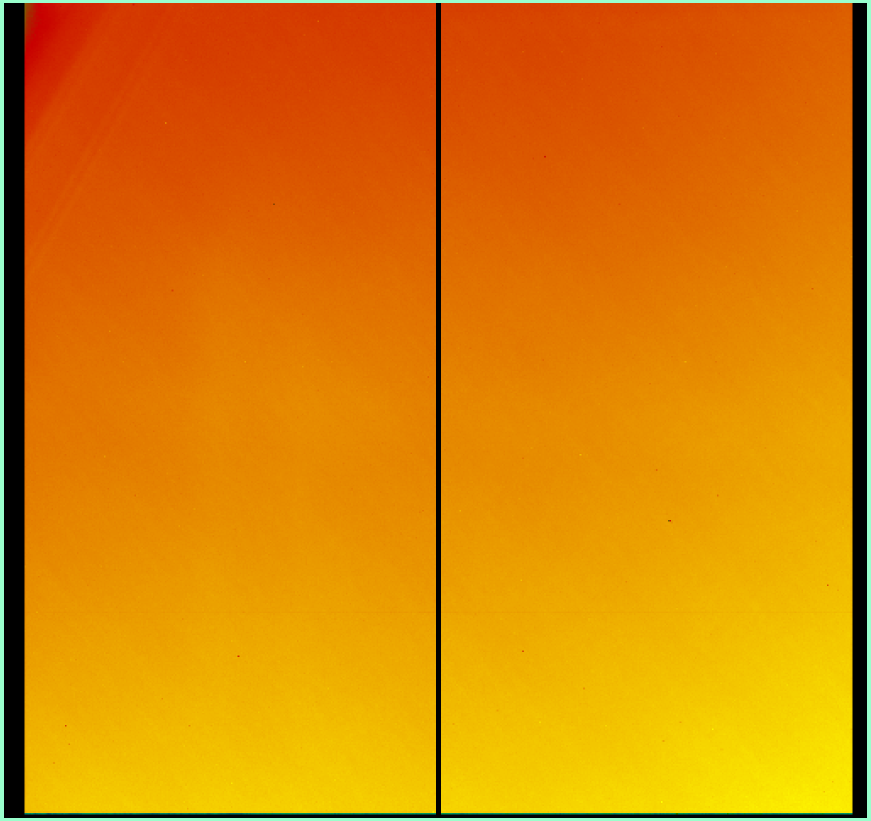
Exoplanet search



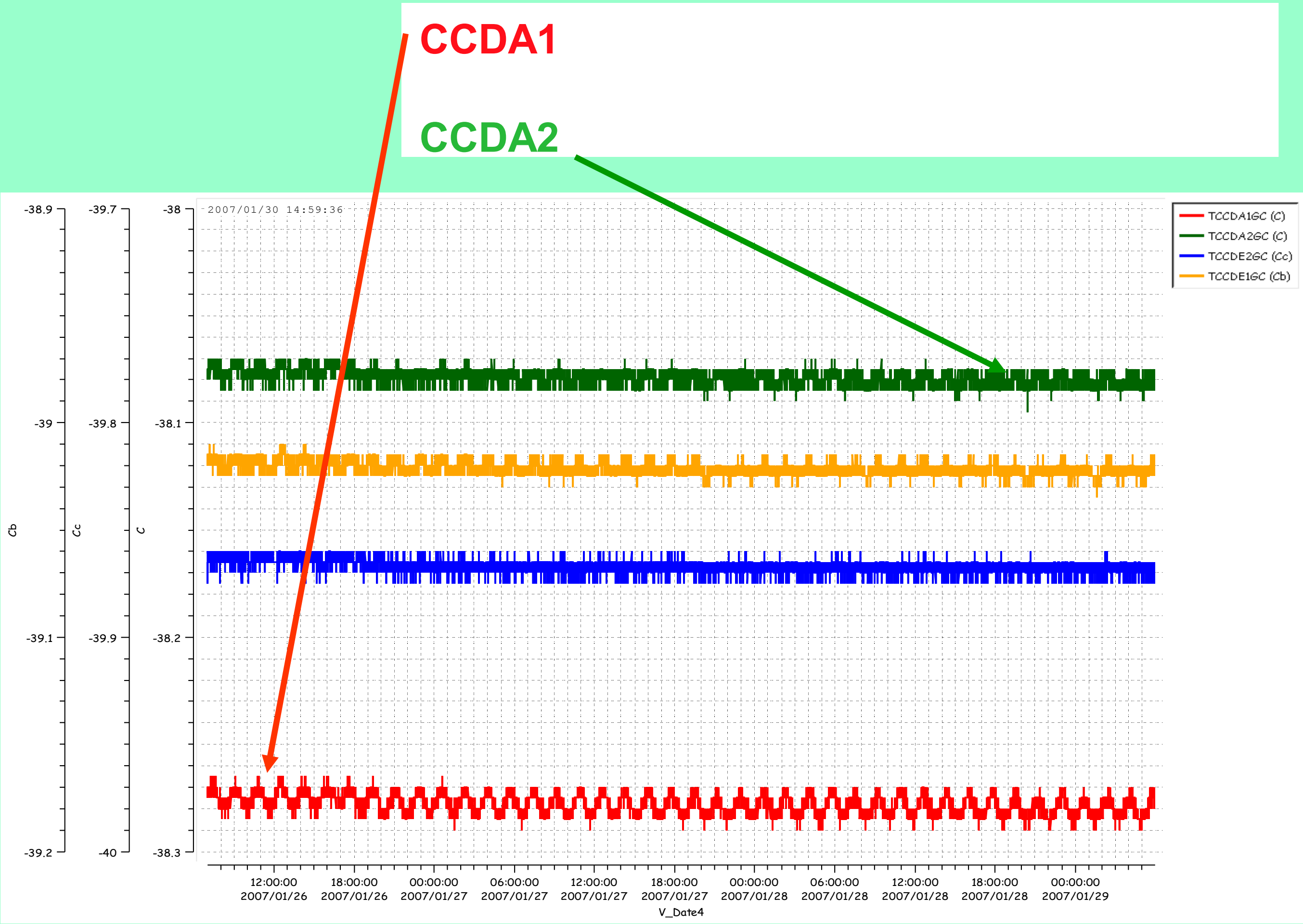
In orbit flat field

local PRNU about 0.6 % conform to ground based measurement

~10 black pixels / CCD + 2 columns on A2 (same as measured on ground)



Temperatures of the detectors



Amplitude regulation:
< 0.01 K peak to peak
Nominal

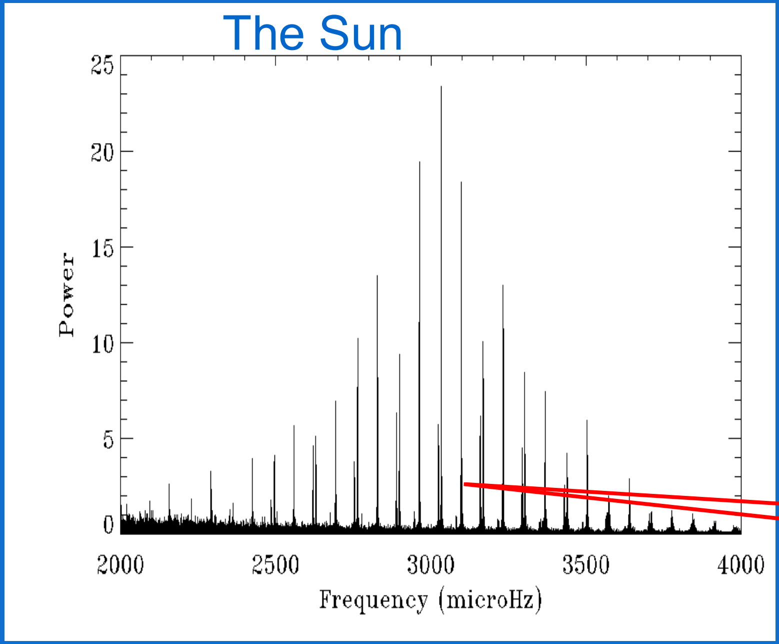
Absolute CCD temp
-38 C (A) and -39 (E)
Slightly too high

Temperature of video
Electronics OK

Asteroseismology

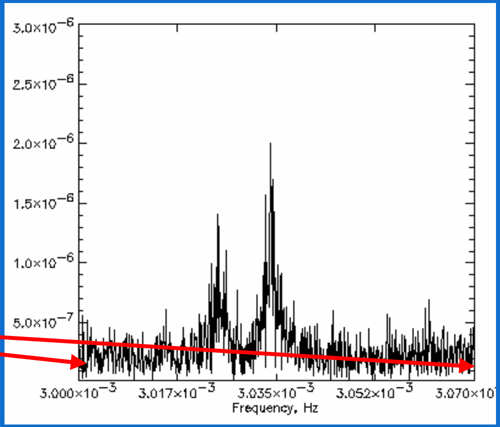
Sounding to stellar interiors and physical processes

- Frequencies of the oscillation modes (both pression and gravity) on a a wide range of values
- photometric precision of 6 ppm (white noise) on a V=6 star in 5 days of continuous monitoring



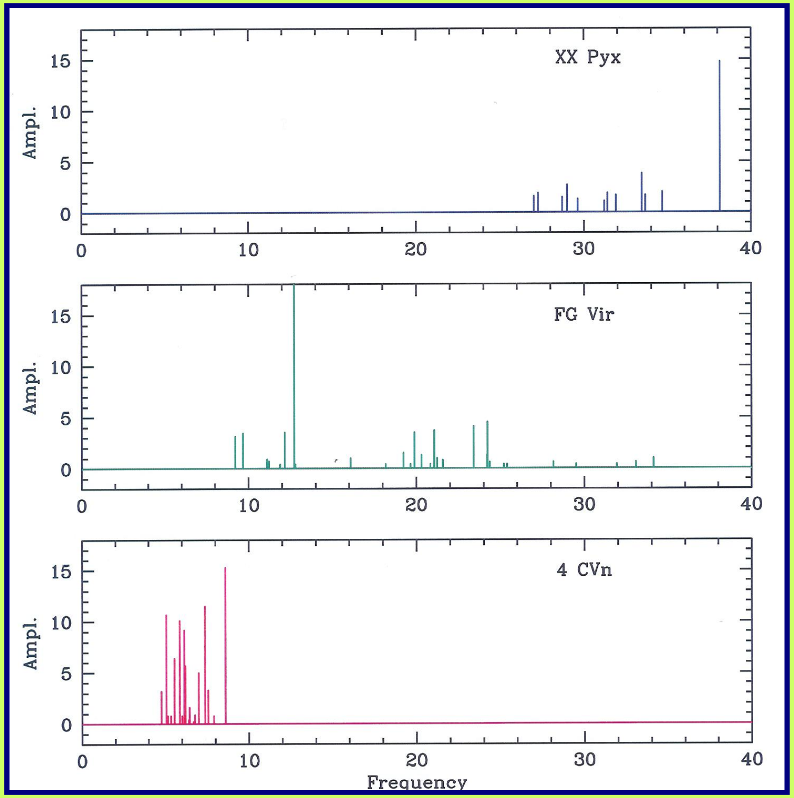
Parameters

Helium content and core radius, depth of convection zones, internal rotation profile…

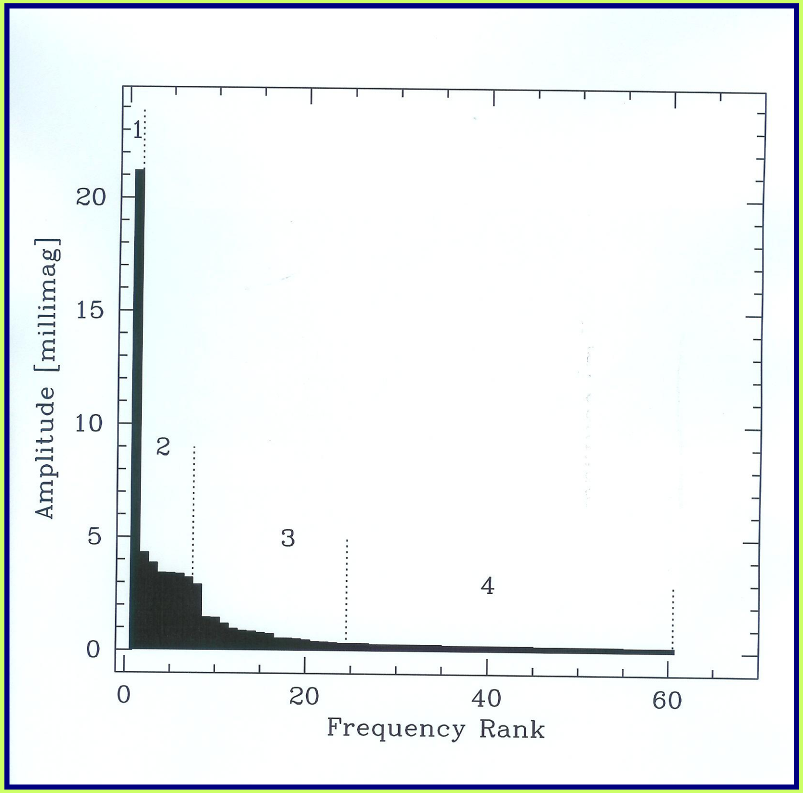


Target selection in the instability strip is based on the matching between theory and observation. Large experience from ground-based campaigns

The frequency detection depend on the S/N.



(Poretti, 2000)

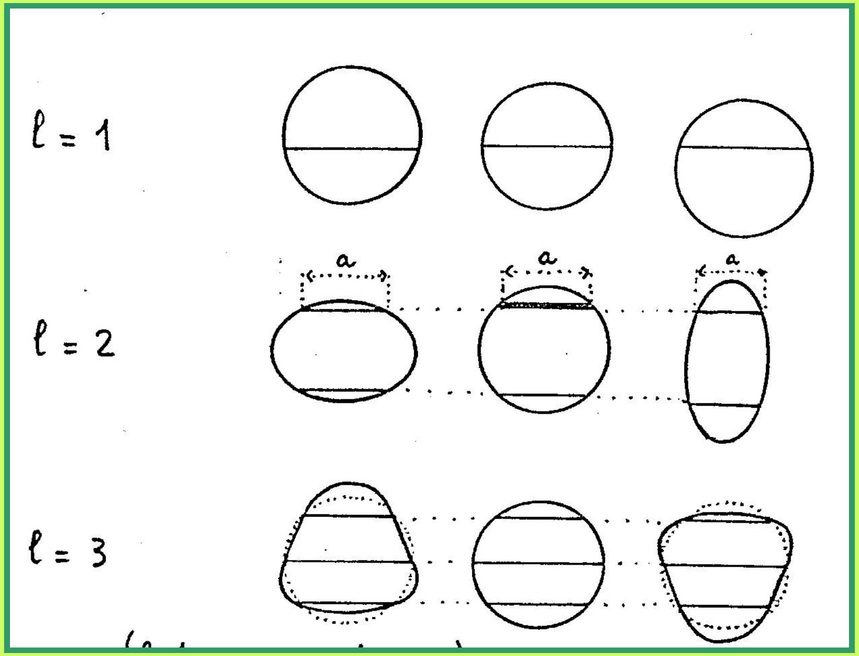


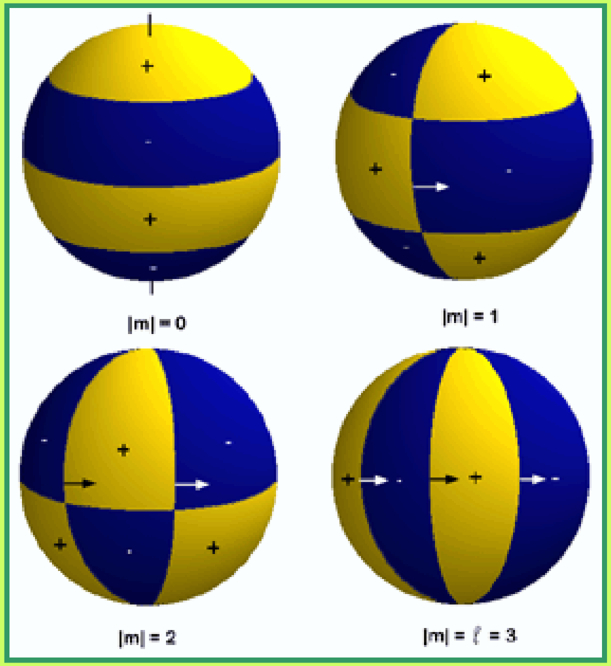
(Garrido and Poretti 2004)

Nonradial modes

Each pulsational mode is defined by three numbers n, l, m

n : radial number
l : nodes on the surface
m : how many nodes from the poles

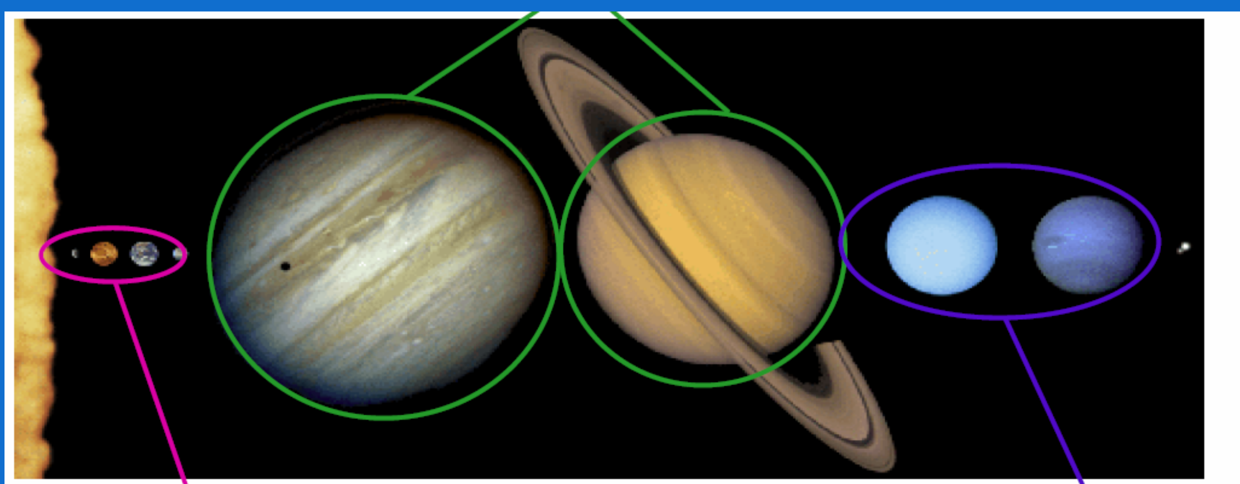


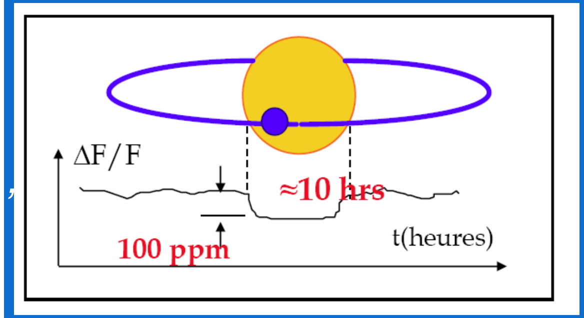


Exoplanet Search

Search for Earth-like planets

- detection by means of transits across the disk of parent star
- photometric precision around 10^{-4} down to V=15.5
- Detection criterium : repetitivity (150 d runs)
- colour information (3 'filters' available) to disentangle between stellar activity and transits





Planets searched by COROT (transits)

THE FUTURE OF THE EXOPLANETARY SEARCH

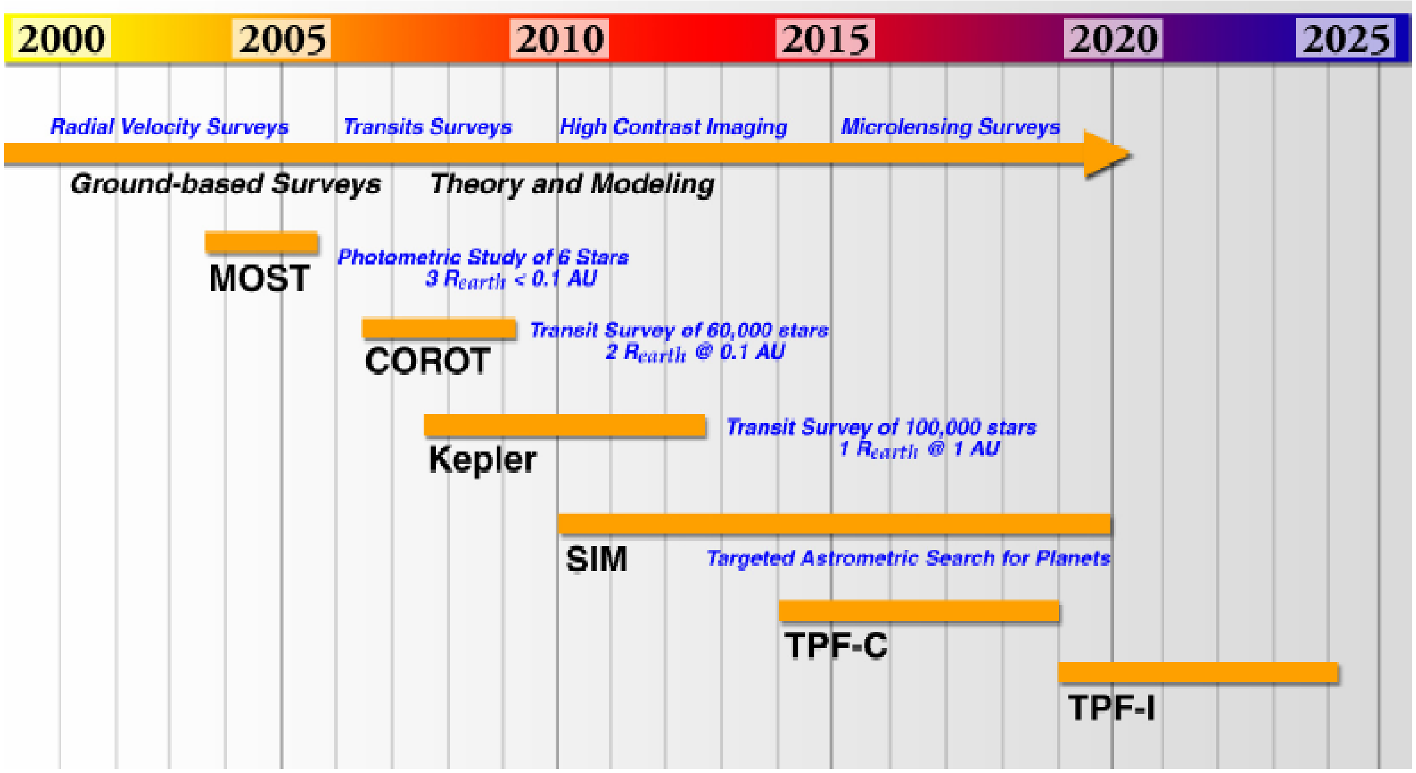


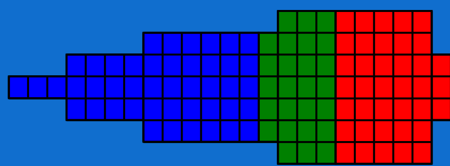
Figure 11. Timeline for ground and space observations contributing to our understanding of the characteristics of extrasolar planetary systems. By 2010, results from the COROT and Kepler missions will have refined our knowledge of the frequency of Earth-like planets and thereby assist in defining the scope of TPF-C prior to its Phase B.

Exoplanet search

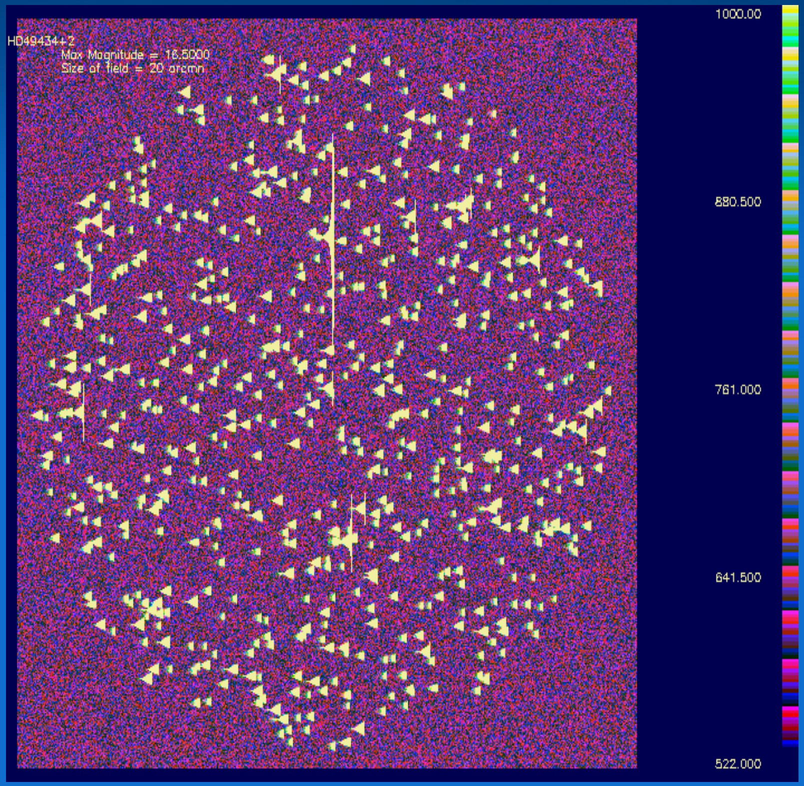
Exoplanetary CCDs

Acquisition

- 5 000 x 2 windows in 3 colours



- 40% in red, 30% in blue for a K0 star
- 1 000 x 2 windows monocromatic
- 20 imagettes (10x15 pixels)
- 512 sec integration time, oversampling on request



ADDITIONAL PROGRAMS

Studies on particular classes of variable stars located in the EXO fields.
Several Italian Guest Investigators have observing programmes already accepted (AO1):

Carla Maceroni, Nuccio Lanza, Giusi Micela, Isabella Pagano, Ennio Poretti,
Vincenzo Ripepi, Roberto Silvotti,

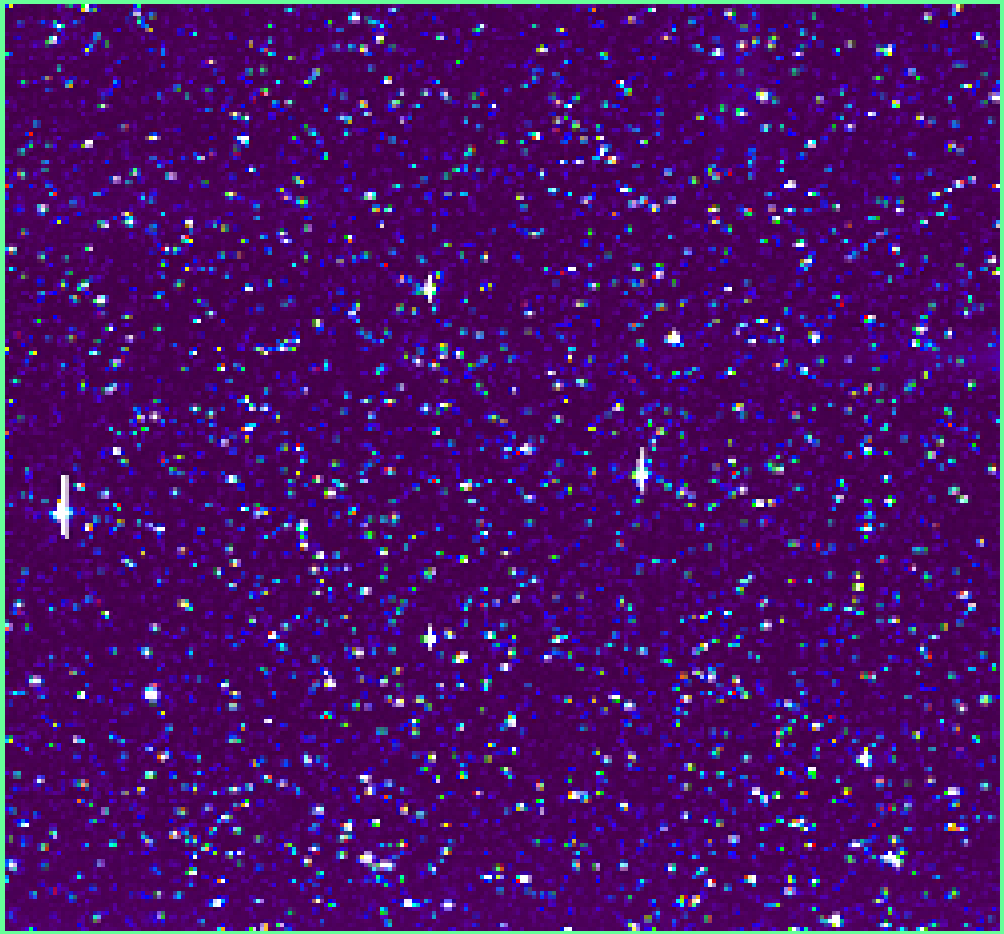
COROT FIRST LIGHT

Initial run from February to early April

Main targets : HD 49933 (solar-like) and HD 50844 (Delta Sct)

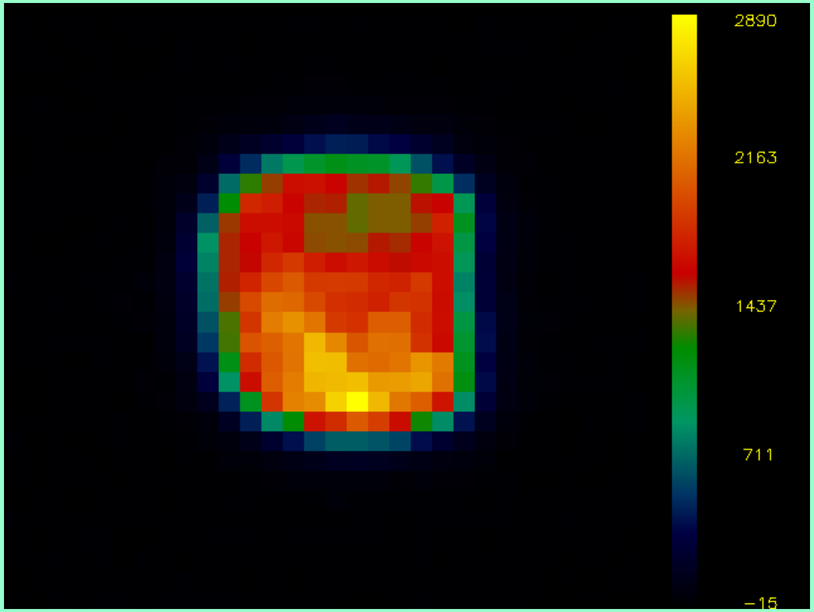
Simultaneous HR spectroscopy from ground (Large Programme ESO, FEROS at 2.2m, P.I. E. Poretti)

EMBARGO on the light curves Removed only by a cripted CNES-ESA press release May 3, 2007

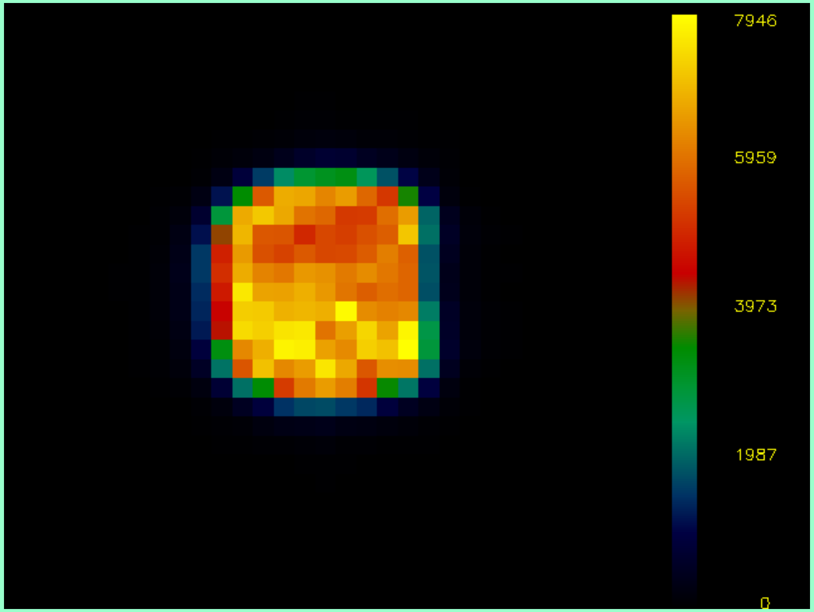


A beautiful starry sky in the Seismology channel

Seismology images



PSF measured



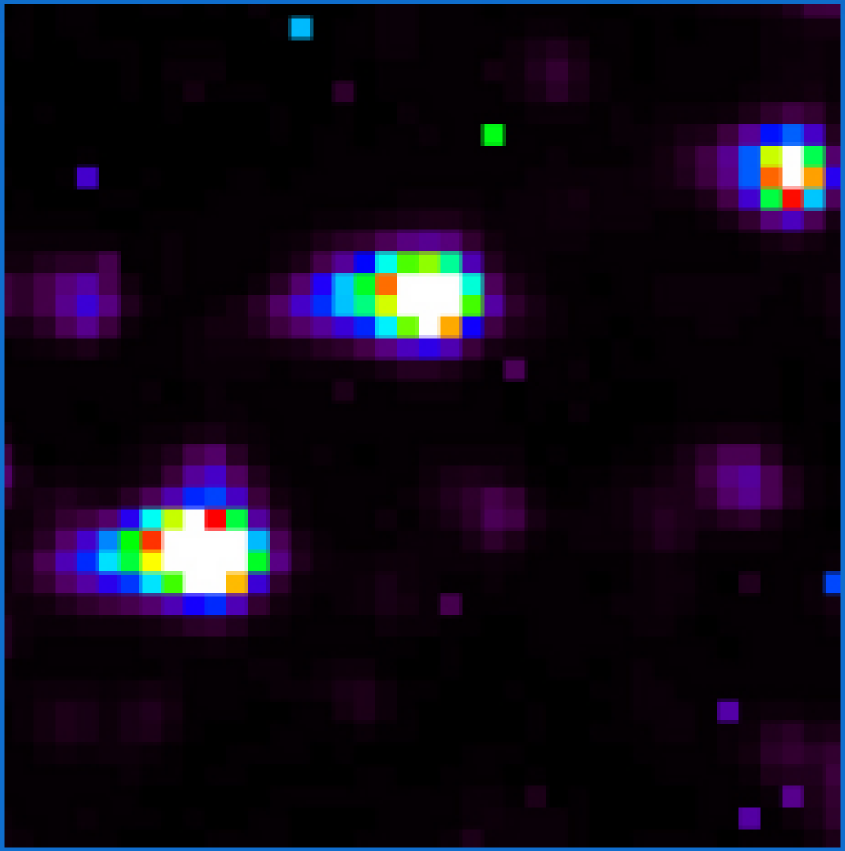
ZEMAX computation

Comparison between measurements and simulations for 10 stars

HD 49933 : brightest pixel at 55000 e^- (V=5.77)

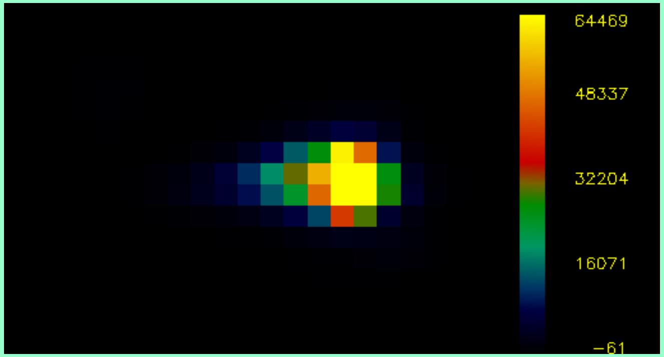
COROT FIRST LIGHT

The exoplanetary mask

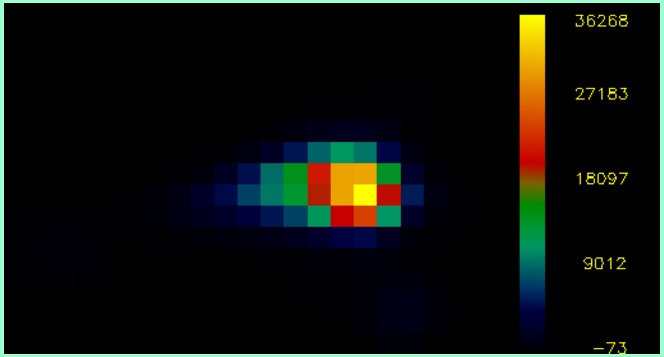


Exoplanet images

CCD E1

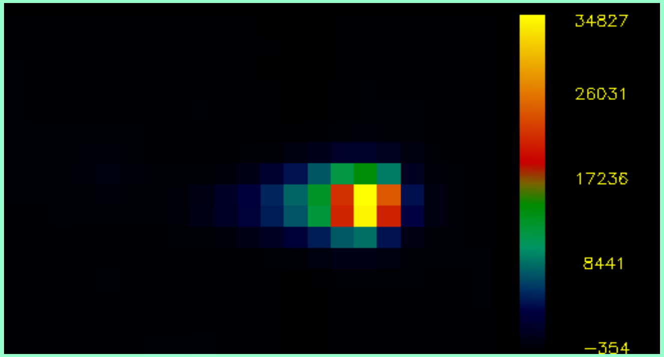


X=662, y=995

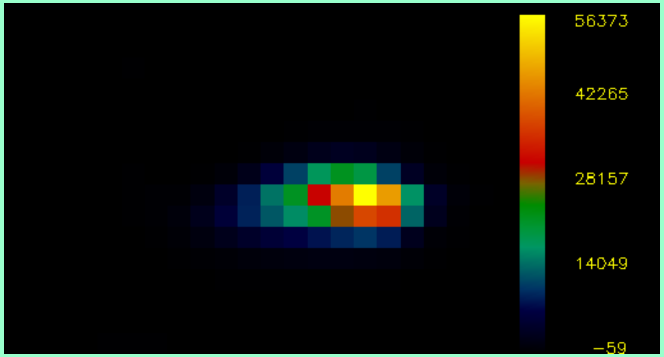


X=1537, y=100

CCD E2



X=171, y=1779

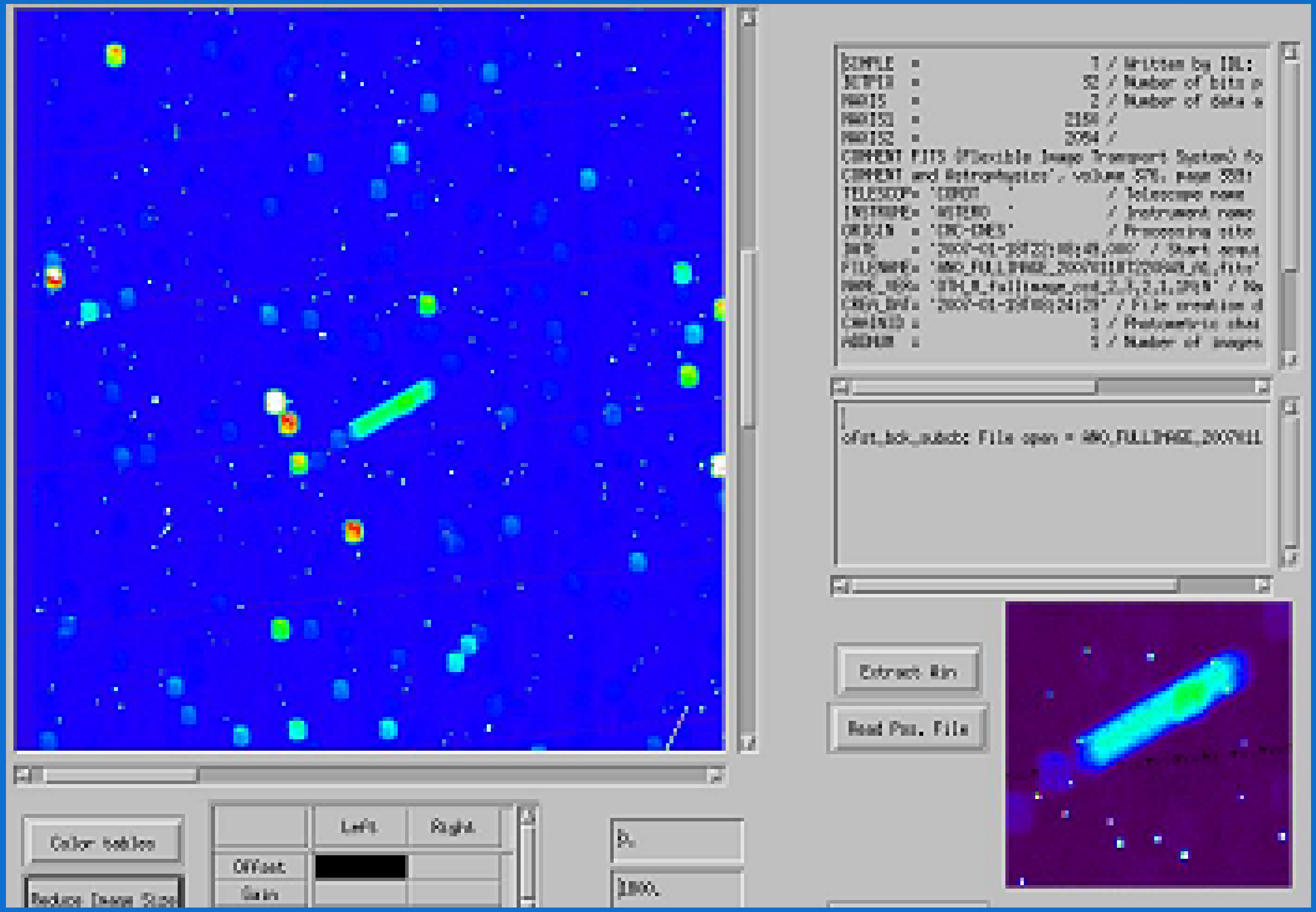


X=1632, y=260

The red color is more focused than expected ⇒ compatible with the -20µm of defocus seen in the AS channel

COROT FIRST LIGHT

What’s that ????



EXOPLANETARY CAMERA
Target V=13.0, Amplitude 20%=0.24 mag
Accuracy on a single point (RAW DATA): better than 0.001 mag
8 out of 60 days of continuous monitoring

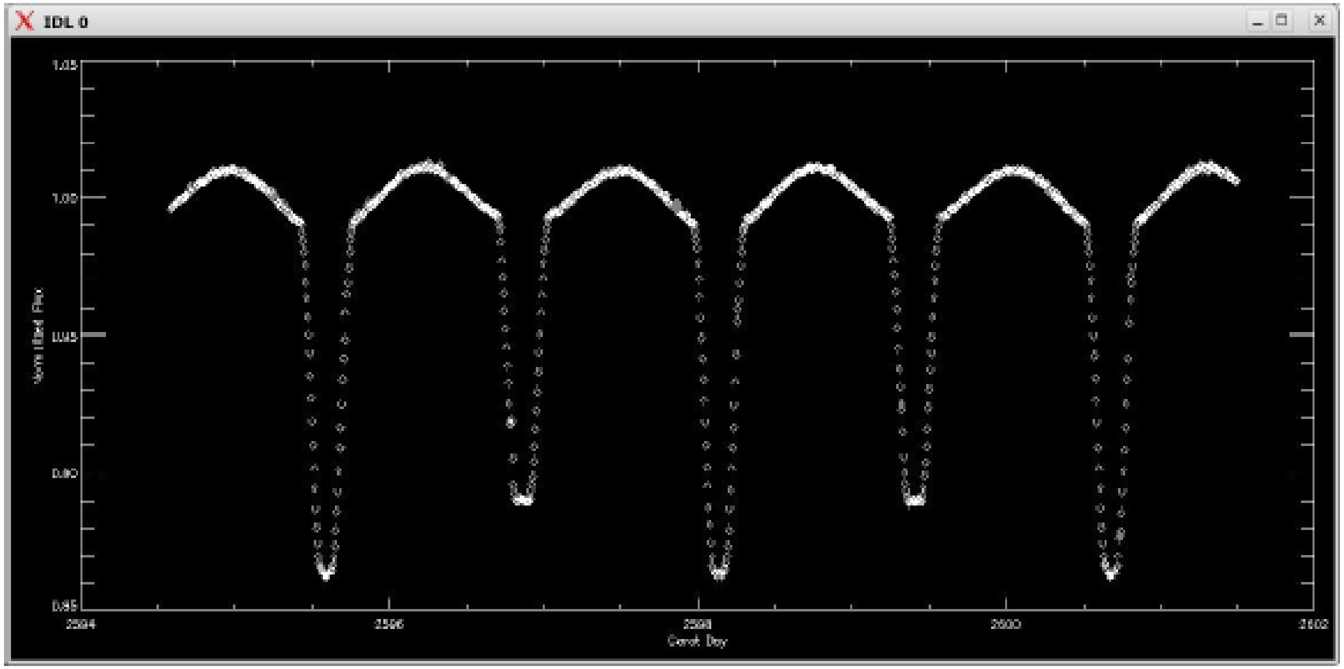
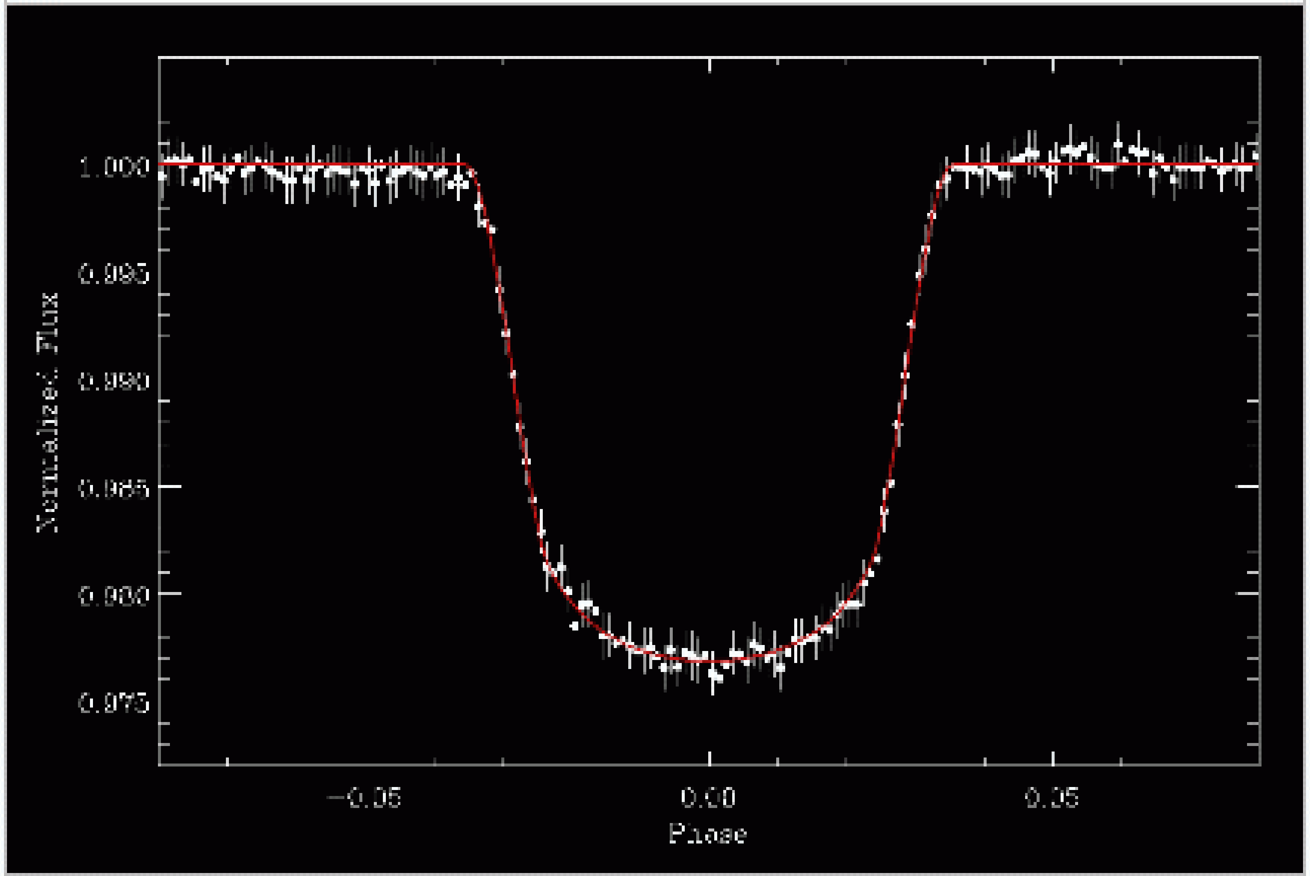
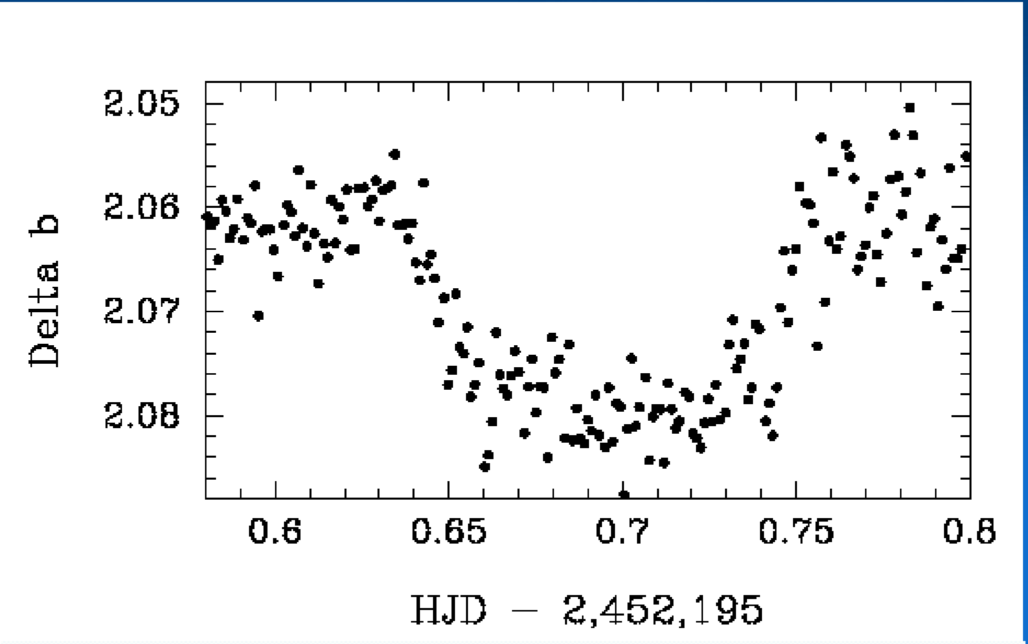


Figure 2 : Light curve of an eclipsing binary of magnitude 13, showing the reflected light between the two components. This figure illustrates both the continuity of the observations and the accuracy, better than 0.001 in 8 minutes.

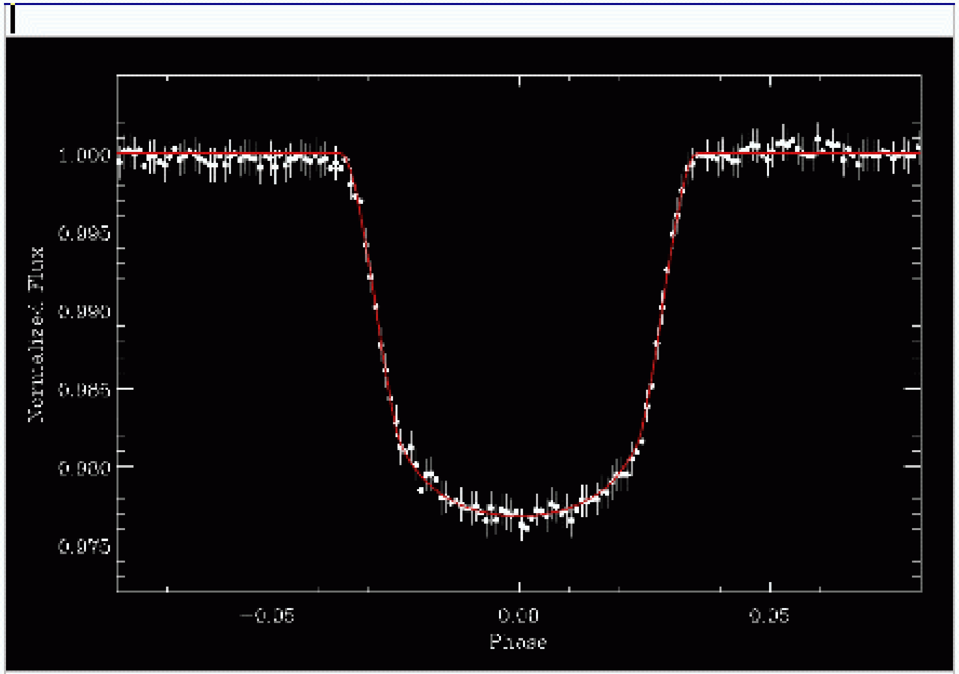
EXOPLANETARY CAMERA – COROT EXO-1b
Amplitude 2.3% in flux, 0.025 mag. Accuracy 0.001 mag
Hot giant planet, 1.5-1.8 Jupiter radius
1.3 Jupiter mass, period 1.5 d



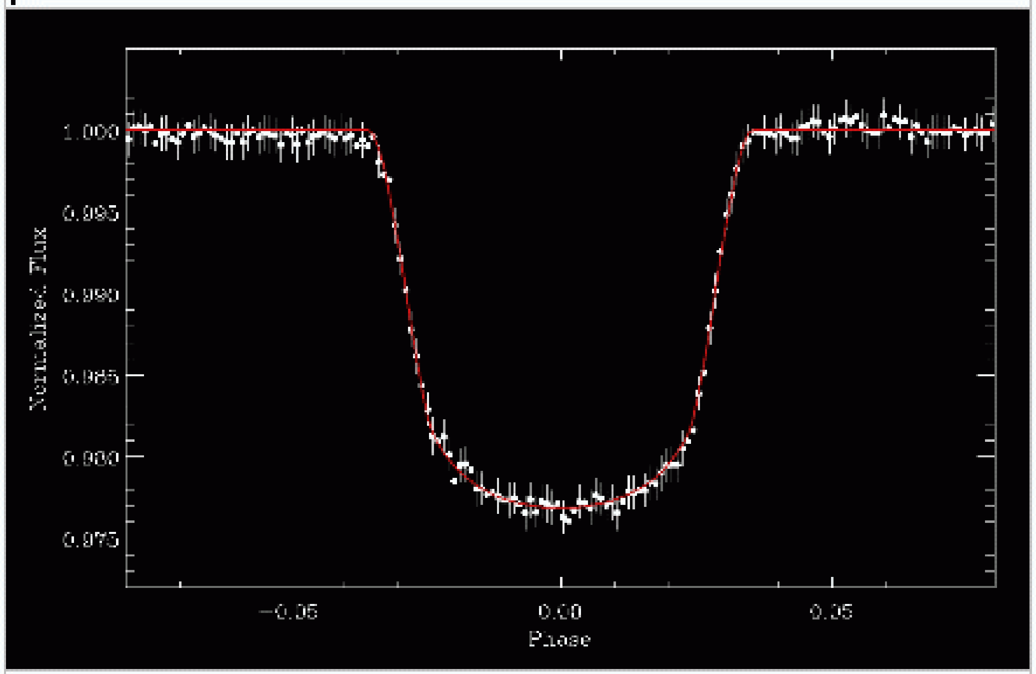
HD209458b
from ground



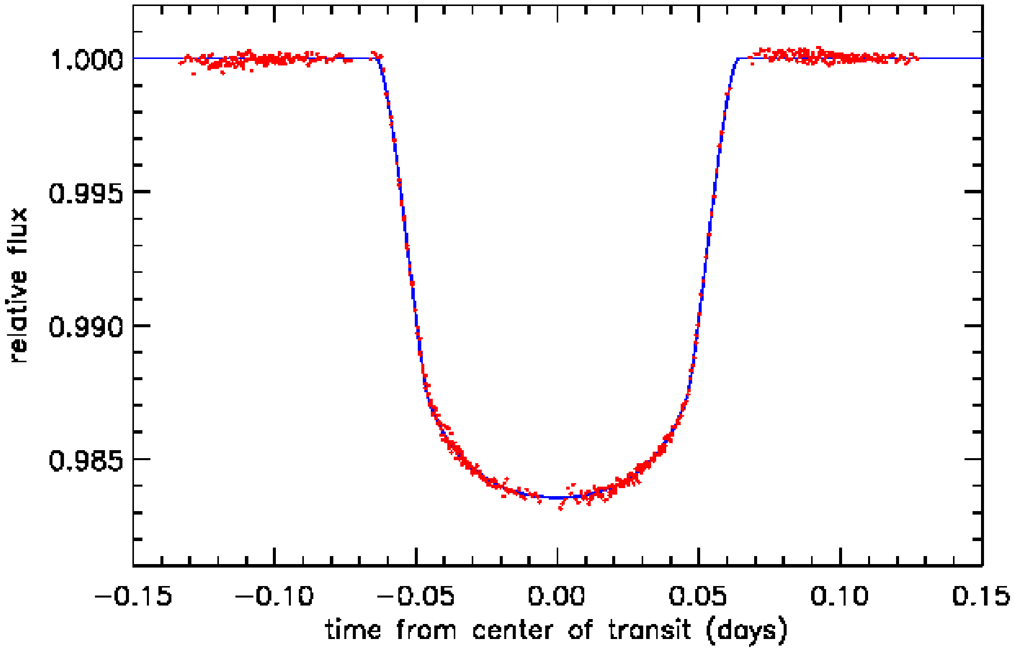
COROT-Exo-1b
from space



COROT, 30 cm mirror
V> 12 , raw data



HUBBLE, 2.5m mirror,
V=7.8, published curve

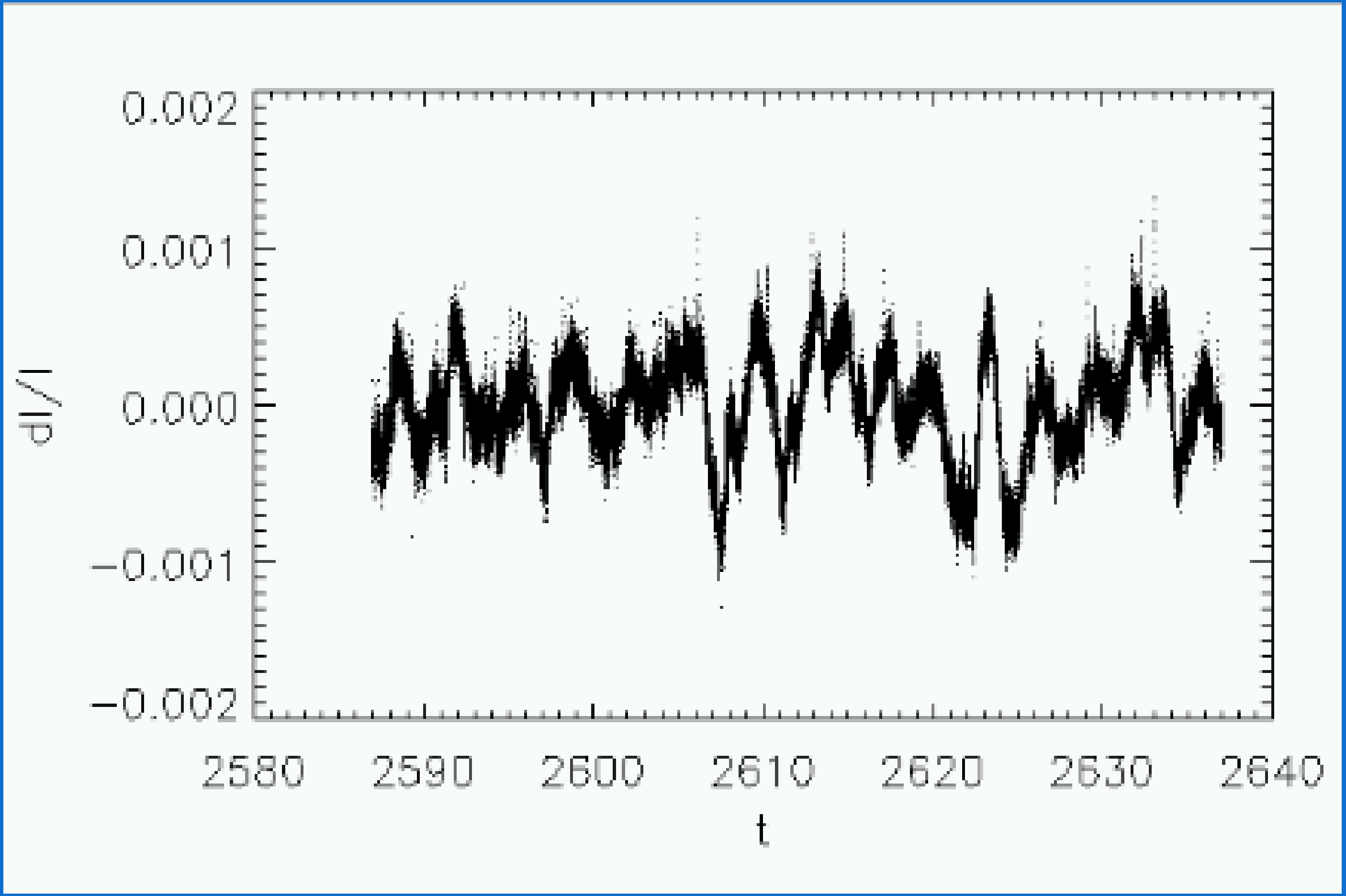


ASTEROSEISMOLOGY CAMERA

Target V=5.8, Amplitude 0.002 mag (peak-to-peak)

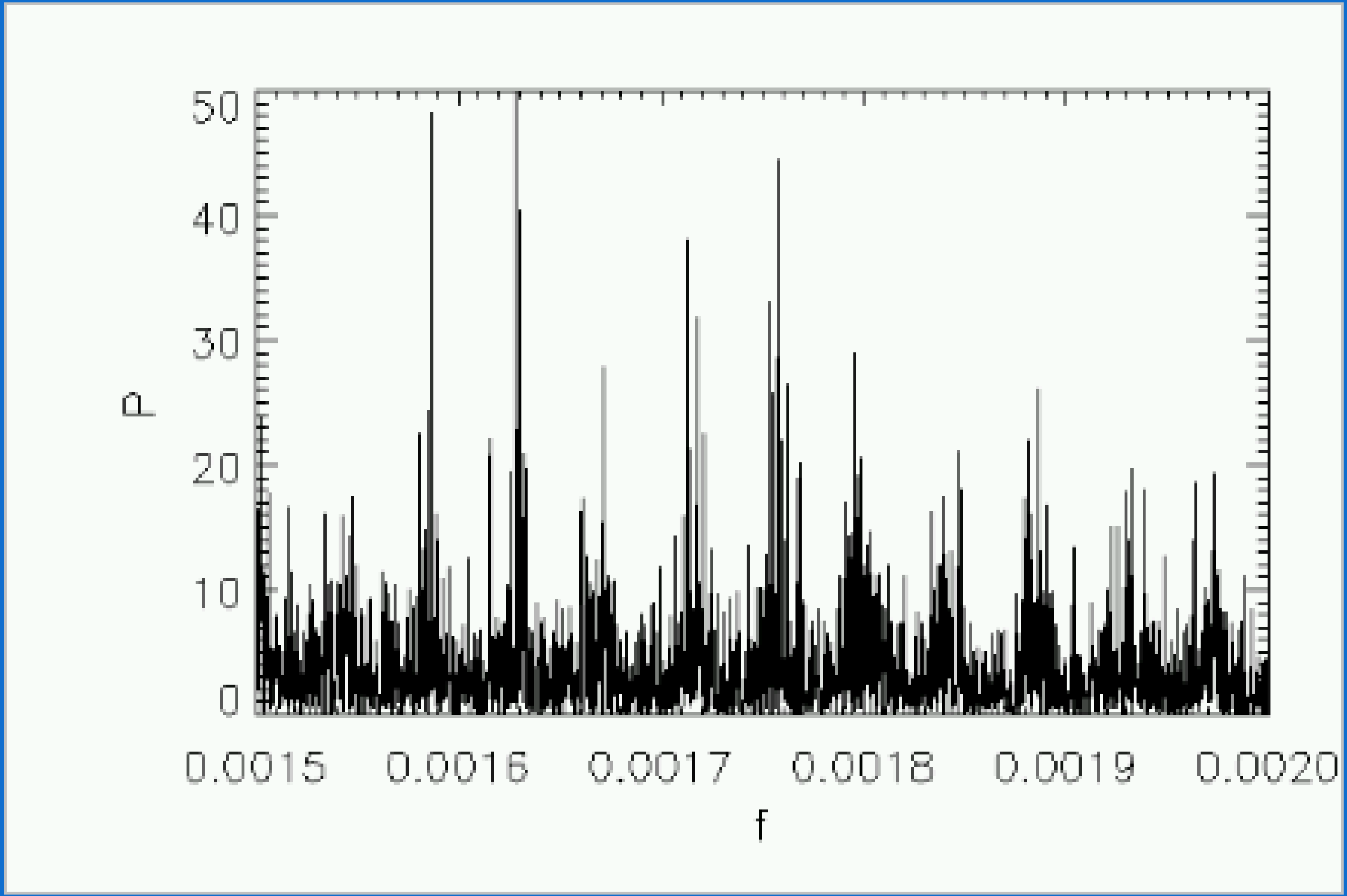
Accuracy 0.05 millimag on a 1-min integration (RAW DATA)

Note the continuous monitoring lasting 55 days



POWER SPECTRUM OF THE PREVIOUS LIGHT CURVE
Frequency range from 1.5 to 2.0 mHz
Declared level of the noise : 10^{-6} mag (RAW DATA …)

REGULAR SPACING=ASTEROSEISMIC SIGNATURE



Future activities supporting COROT observations

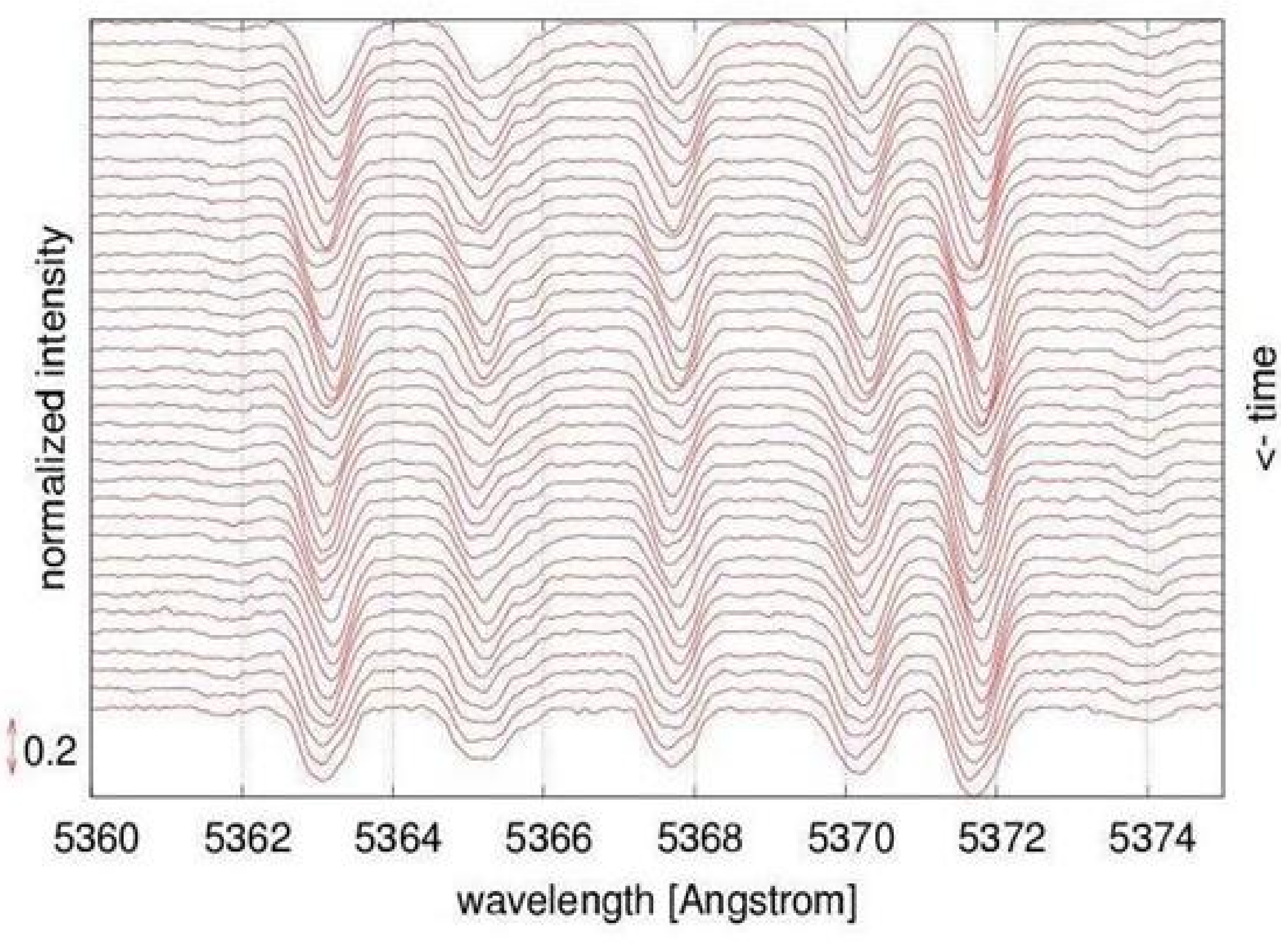
Multicolour photometry : OSN, SPM

detection of predominant modes and frequency ranges
identification of low-degree modes by phase shifts & amplitude ratios

High resolution spectroscopy : ESO, OHP, SLN

radial velocity curves
characterization of GDOR variables
Line Profile Variations for BCEP and DSCT stars

LARGE PROGRAMME (15 nights x 4 periods) with FEROS@2.2m


normalized intensity
<- time
0.2
5360
5362
5364
5366
5368
5370
5372
5374
wavelength [Angstrom]

THE LOWER PART OF THE INSTABILITY STRIP :
the DSCT bookmarks
Stars in different physical conditions

ZAMS :

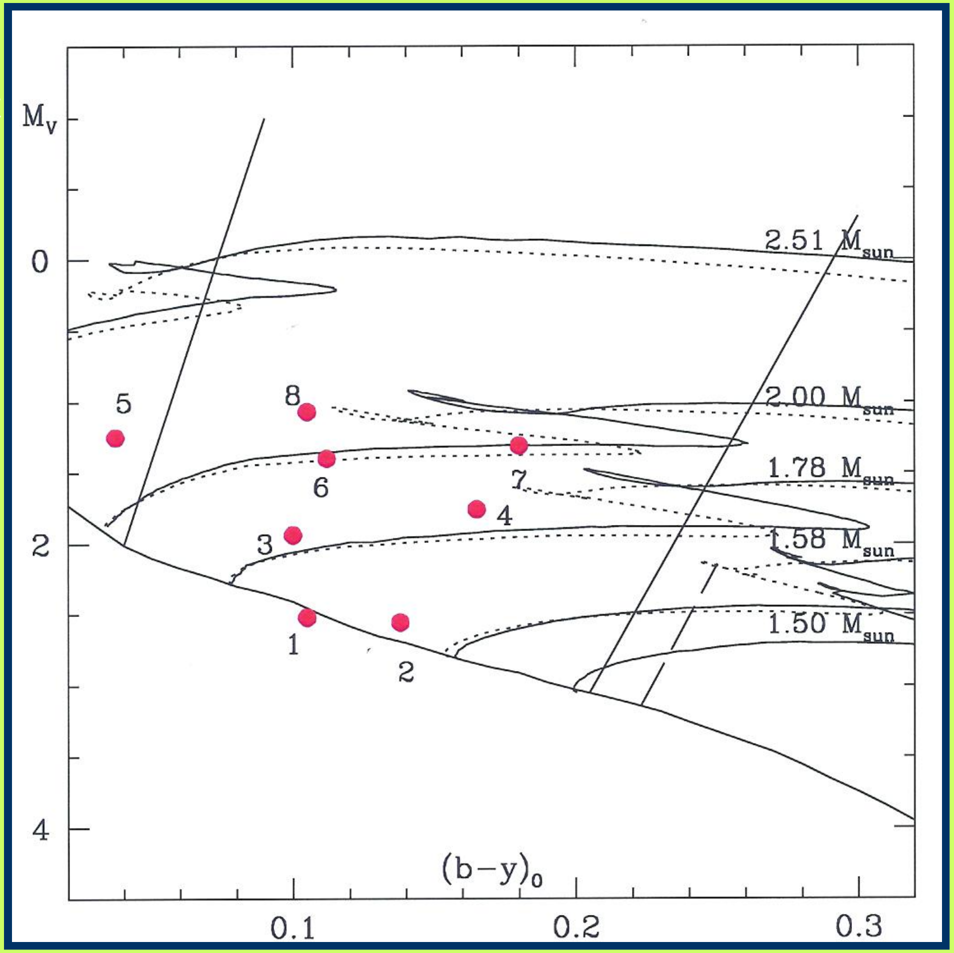
1 HD 181555 7.98 170 primary target
2 HD 44195 7.57 58 HD43587

UNEVOLVED :

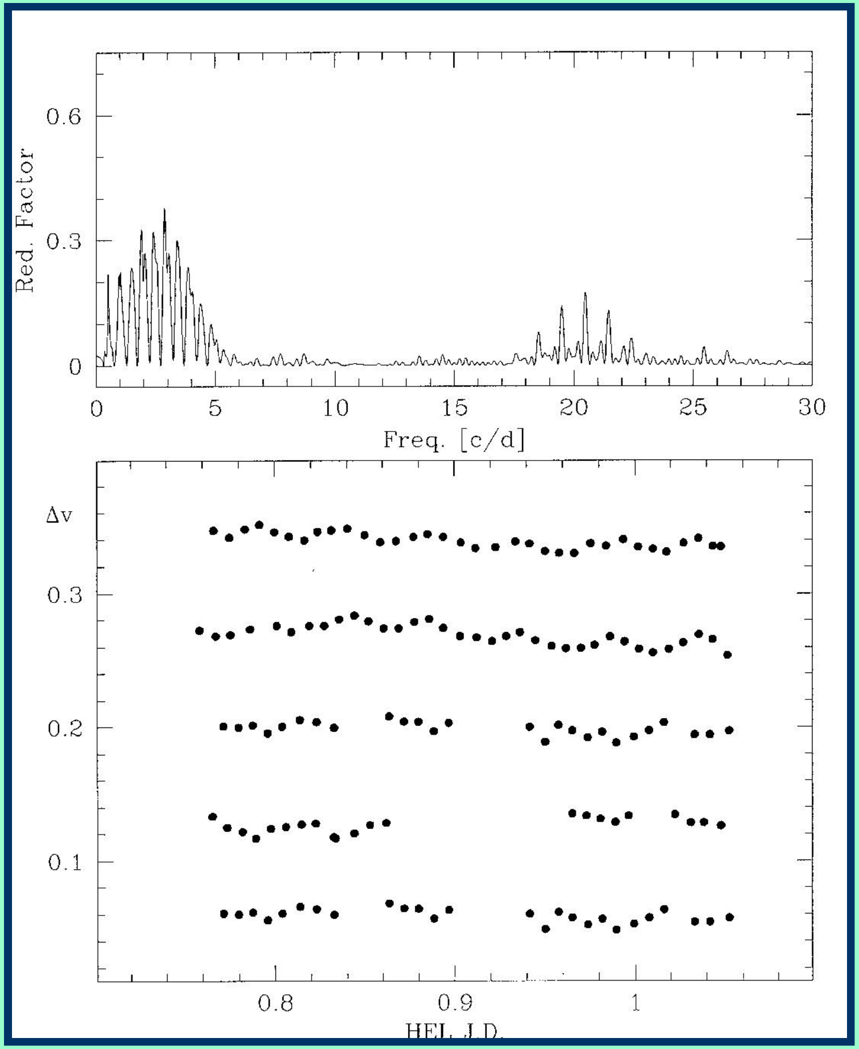
3 HD 181147 8.74 --- HD181555
4 HD 50870 8.86 17 HD52265
5 HD 170782 7.81 197 HD170580
6 HD 170699 6.95 >200 HD170580

ZIGZAGS (TAMS)

7 HD 44283 9.29 19 HD43587
8 HD 172189 8.85 EA HD171834



HD 44195, new DSCT star in the HD 43587 field



Power spectrum showing variability at low frequencies (f<5 c/d; GDOR regime ?) and at high frequencies (f>20 c/d; DSCT regime).

Unevolved object.

Slow rotator : v sin i = 58 km/s

PERFECT Delta Sct FOUND

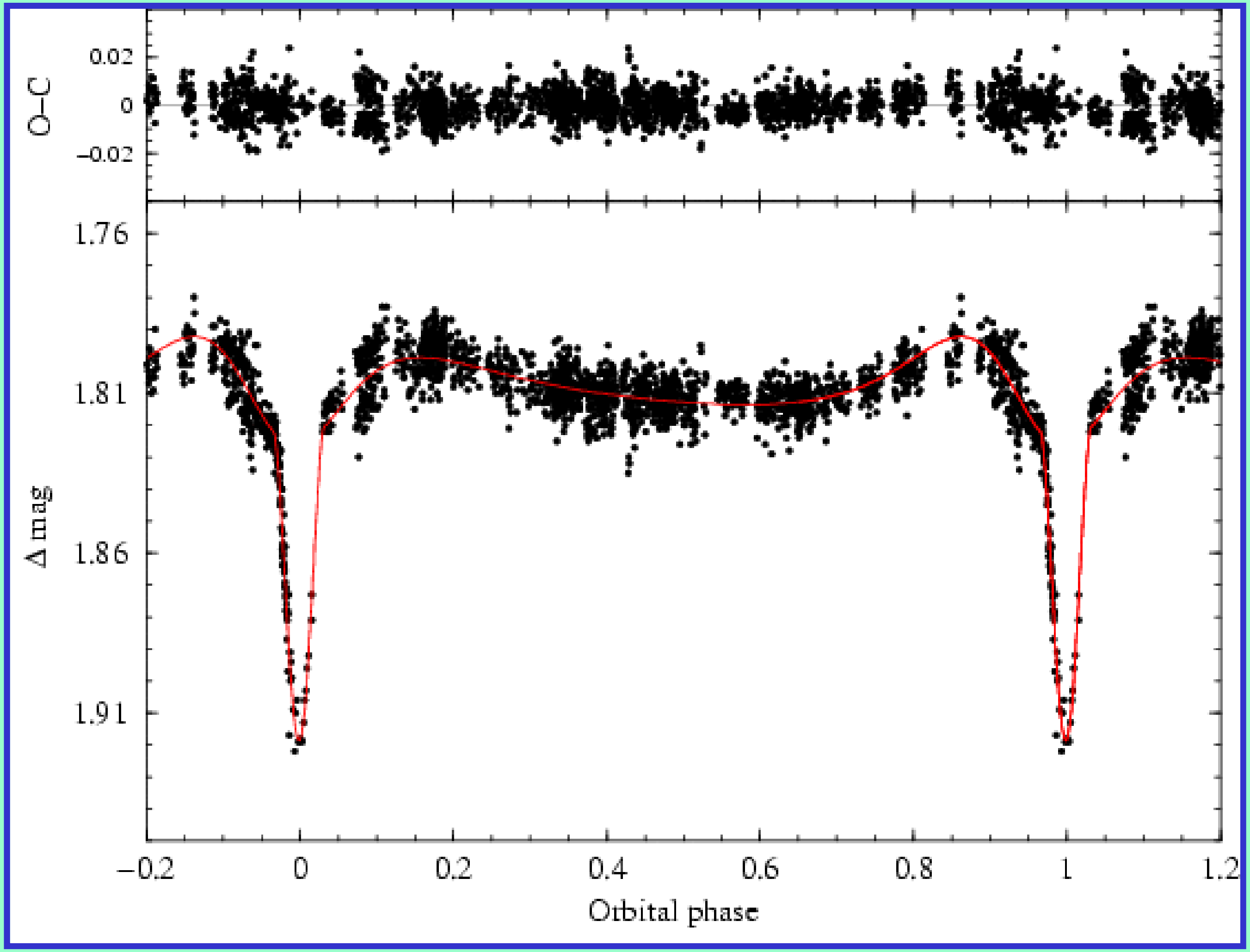
Unevolved : no dense frequency spectrum, no mixed modes

Slow rotator : a relief for theoreticians, though progresses have been made in the treatment of fast rotators.

HD 172189, orbital period has been detected: 5.702 d.
Eccentric orbit with only one minimum.
DSCT pulsation: frequencies in the 18-20 c/d interval.
(Martin et al., 2005, A&A 440, 711)

The RV curve has been the goal of successful **spectroscopic** observations in past summer (OHP, SLN, ESO).

The system is also a spectroscopic binary with two spectra



Summary

In the past decades we performed a huge observational effort to progress in asteroseismology

All the know-how is now at the service of COROT

In turn COROT is offering us the possibility to improve rapidly our knowledge of stellar interiors

We have the possibility to consign a more mature science to young researchers (HELAS)

At the moment all instrument and satellite performances are **slightly better or equal** to the expected values.

Some calibrations remain to be done to optimize several on-board software parameters. Correction pipe-lines are in progress.