Suzanne Aigrain
on behalf of the CoRoT exoplanet science team
Why space?

- Atmosphere limits precision photometry from the ground
  - Scintillation limit ~2 mmag
- Representative transit depths for Sun-like star
  - Jupiter: 10 mmag
  - Neptune: 1.3 mmag
  - Earth: 0.1 mmag
- Weather and daytime limit temporal coverage from the ground
- Many sources of noise transit timescales removed
  - colour dependent differential extinction, seeing, etc...
The satellite

- PI: Annie Baglin, LESIA, Meudon
- CNES PROTEUS bus
- 27cm aperture telescope
- Soyuz II-1b launcher from Baikonour
- Polar orbit
- 2.5 year minimum lifetime
Payload

27 cm focal box

focal box

DL: Dioptric Lens
MA: CCD Memory Area
IA: CCD Image Area
T: Temperature probe

Temperature Regulation

INSULATING
SHIELDING
Focal plane

- Sismo field
  - 5 windows / CCD
  - $5.7 < m_V < 9.5$
  - 32s sampling (1s on request)
  - frame transfer mode
  - used for astrometry

2.8°
Pointing stability

x-coord of stellar image barycenter

RMS stability:
0.12 pixel in x
0.15 pixel in y
~0.3 arcsec

vibrations due to Earth eclipse ingress and egress
• Exo field
  • up to 6000 LCs / CCD
  • $11.5 < m_V < 16$
  • 512s sampling (32s for 500 objects / CCD)
  • 3 colours for ~ 4500 objects / CCD with $m_V < 15$
  • some small background windows
  • up to 40 10x15 pixel windows
  • on-board aperture photometry using mask selected from 256 templates based on one initial long integration image
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Observing strategy

- **Sequence:**
  - ~1 month commissioning
  - 1 initial run (early science, ~50d)
  - then 5 x (150d long run + 21d short run)
  - rotate satellite every 6 months
  - 1st long run Galactic centre in March 2007

- **Visibility zone**
  - sun angle constraints imply 2 ‘CoRoT eyes’
  - 10° diameter, small drift over 2.5 yr lifetime
  - intersection of ecliptic & Galactic planes
  - field selection = compromise

<table>
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<th>Field</th>
<th>Dur. (d)</th>
<th>RA</th>
<th>Dec</th>
<th>Rot* (°)</th>
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*N-S direction: Rot = -5° in centre, +5° in anticentre
South Atlantic Anomaly

SAA shifted ~8° NW compared to previous AP8min model (L. Pinheiro)
Example charged particle deposit on Exo CCD

(F. Karioty)
Straylight background

Lower than expected
Implies baffle performance better than $10^{-12}$

Folded on orbital period

Earth eclipse ingress & egress
Duty cycle

Example background light curve

Source of gaps:
SAA (6%)
other random events (1-2%)
→ Duty cycle 92%

Hot pixels 10x more frequent than expected
Exoplanet noise budget

- Nominal noise budget
  - white noise
    - readout, background, jitter
  - see plot
  - orbital period (6174s)
    - jitter, temperature, residual straylight
    - 120 ppm
- Stellar variability
  - few tens of ppm over transit timescale
- Correlated noise?
  - Blind test light curves contain 0.5 mmag red noise after detrending
RAW performance in the exo field

Mv ~15.4
RMS = 1170 ppm
Photon noise = 1080 ppm

Mv ~12.3
RMS = 400 ppm
photon noise = 400 ppm

Already close to specification despite incomplete processing
Stellar micro-variability

- Rotational modulation & intrinsic evolution of surface structures (spots, faculae, granules)
- Roughly 1/f noise spectrum
- Very ill characterised in stars other than the Sun
- Attempts at predicting micro-variability for other stars (Aigrain, Favata & Gilmore 2004, Lanza et al. 2005)
- Could be a serious impediment to terrestrial transit detection from space
- Temporal signature different from transits
Example light curves from the seismo field
Blind test I - detection

- 999 simulated light curves
  - White light only
  - Diverse signals (rather than representative)
  - Pessimistic instrumental noise + variability
  - Content known only to “game master”
- 5 teams attempted detection
  - Fourier domain filtering successfully curbs most stellar variability
  - Best detection with BLS or similar
  - No ability to distinguish background EBs

Moutou et al. (2006)
Blind test 2 - characterisation

- 236 simulated light curves
  - 3 colours
  - Include contaminant info
  - All contain a signal
- 8 teams attempted detection & characterisation
  - Simplistic colour or transit duration tests dangerous
  - Checks for 2ary eclipses & ellipsoidal variation robust
  - Many BEBs can be identified from LC + contaminant information alone
  - Toughest type of contaminant to identify is low mass companion - easy RV

Best fit with EBAS (Tamuz et al 2006)
Planet on primary target

EB on contaminant
Follow-up

- Light curve filtering & transit detection
- Detailed LC analysis in conjunction with EXODAT database:
  - deep UVRIJHK catalog
  - SpT estimate of CoRoT targets
  - contamination estimate
- Photometric follow-up
  - which star in the PSF varies?
- RV follow-up (HARPS)
  - companion mass
- Spectroscopy of parent star
  - stellar parameters

Real time candidate prioritisation & coordination of follow-up effort

COROT is well matched to current RV facilities
Expected detections

- CoRoTLux simulator (Gillot, Fressin et al)
  - See talk by F. Fressin tomorrow for details
- Results over entire mission
  - 80 Hot Jupiters (15% P>10 days; nearly as many in short runs as long)
  - 15-30 Hot Neptunes (3-4 R\(\oplus\); almost all in short runs)
  - Possibly a few terrestrial planets (~2 R\(\oplus\))
  - About 100 candidates per run, 50 of which survive to follow-up stage
- But...
  - Assumes low-mass planets more abundant than giants
  - More astrophysical false alarms if shallower transits accepted
Initial run results

- Initial run: 60 days in Feb - March 2007
- Several transit/eclipse candidates identified by automatic ‘alarm mode’ software at LAM based on partial datasets from initial run and first long run
- Spectroscopic and photometric follow-up tests in April and July

CoRoT-exo-1b
1.5 d period
1.5-1.8 R\(_J\)
\~1.3M\(_J\)

Spectra from SOPHIE@OHP, ground-based photometric confirmation from WISE 1m and BEST
More & better spectra needed to improve stellar parameters and mass ratio estimate
more candidate images
Ultra precise Hot Jupiter light curves

HD209458b with HST (Brown et al. 2000)

- Ingress/egress shape: limits on planet oblateness and the presence of moons or rings
- Transit timing: limits on the presence of other planets in the system (Agol et al. 2005)
- Centre of transit shape: image strip of stellar surface (limb-darkening, spots)

Large ground-based telescopes would improve on CoRoT for fainter planets
Transit timing

CoRoT-exo-1b transits observed 40 times

Individual transits can be timed to ~ 30-40s

Would easily detect non-transiting Earth-mass planets in a variety of outer orbits

But... extremely sensitive to red noise - need fully processed data
The mass-radius relation

Legend:
- solar system
- discovered via RV
- bright (V<12) star
- faint (V~17) star

Data from obswww.unige.ch/~pont/TRANSITS.htm

CoRoT-exo-1b

GJ456b

gaseous-giant transition
Solid exoplanets

- Will we be able to differentiate between planet mostly made of
  - H/He
  - H$_2$O
  - MgSiO$_3$
  - Fe
  - a mixture?
- Simple calculation - hydrostatic equilibrium + EoS - gives mass-radius relation for hypothetical planets
Solid exoplanets

Seager, Kuchner, Hier-Majumder, Millitzer (in prep.)

7% error bars on mass and radius

Will be able to tell bulk composition but not much more
CoRoT is working extremely well
- all systems nominal, some significantly better
- should be sensitive to planets barely larger than the Earth

First science results - still under analysis
- a large transiting very hot jupiter, several candidates, many EBs
- clear detection of oscillations in Sun-like star, Scuti, etc...
- dozens of variables of all types

Timeline:
- First data release to co-Is later in 2007
- Data becomes public 1 year after release to Co-Is
- First long run started end may
- Follow-up in late summer for alarm mode candidates, spring / summer 2008 for the rest

More info:
http://corot.oamp.fr/

The CoRoT Book
ESA-SP 1306 (in press),
eds. M. Fridlund, A. Baglin,
L. Conroy and J. Lochard