Suzanne Aigrain
on behalf of the CoRoT exoplanet science team

Why space?

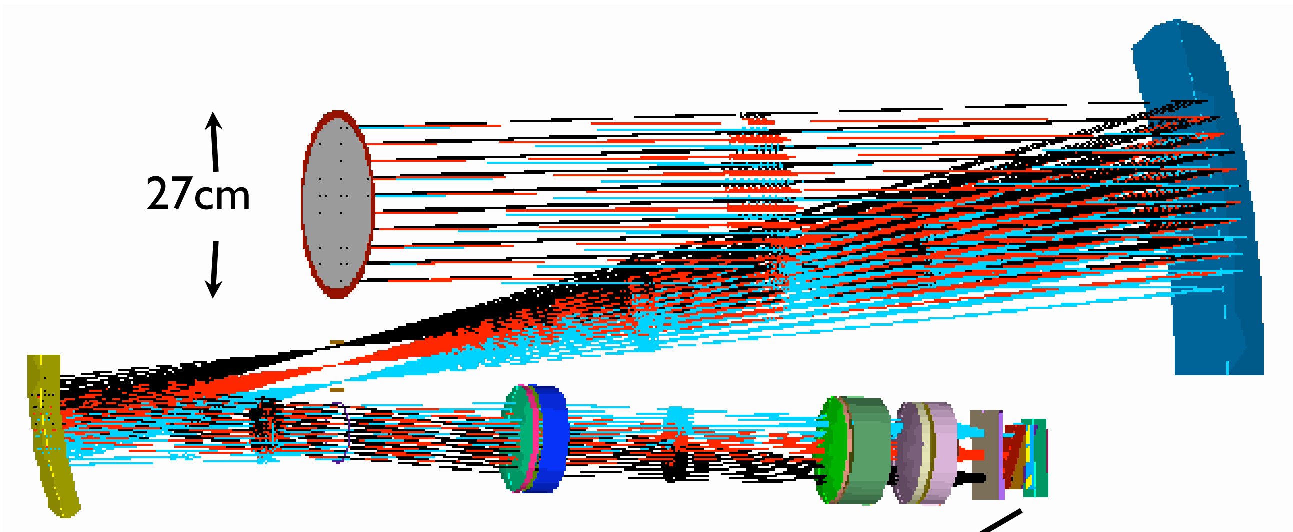
- Atmosphere limits precision photometry from the ground
  - Scintillation limit ~2 mmag
- Representative transit depths for Sun-like star
  - Jupiter: 10 mmag
  - Neptune: 1.3 mmag
  - Earth: 0.1 mmag
- Weather and daytime limit temporal coverage from the ground
- Many sources of noise transit timescales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

27 December 2006

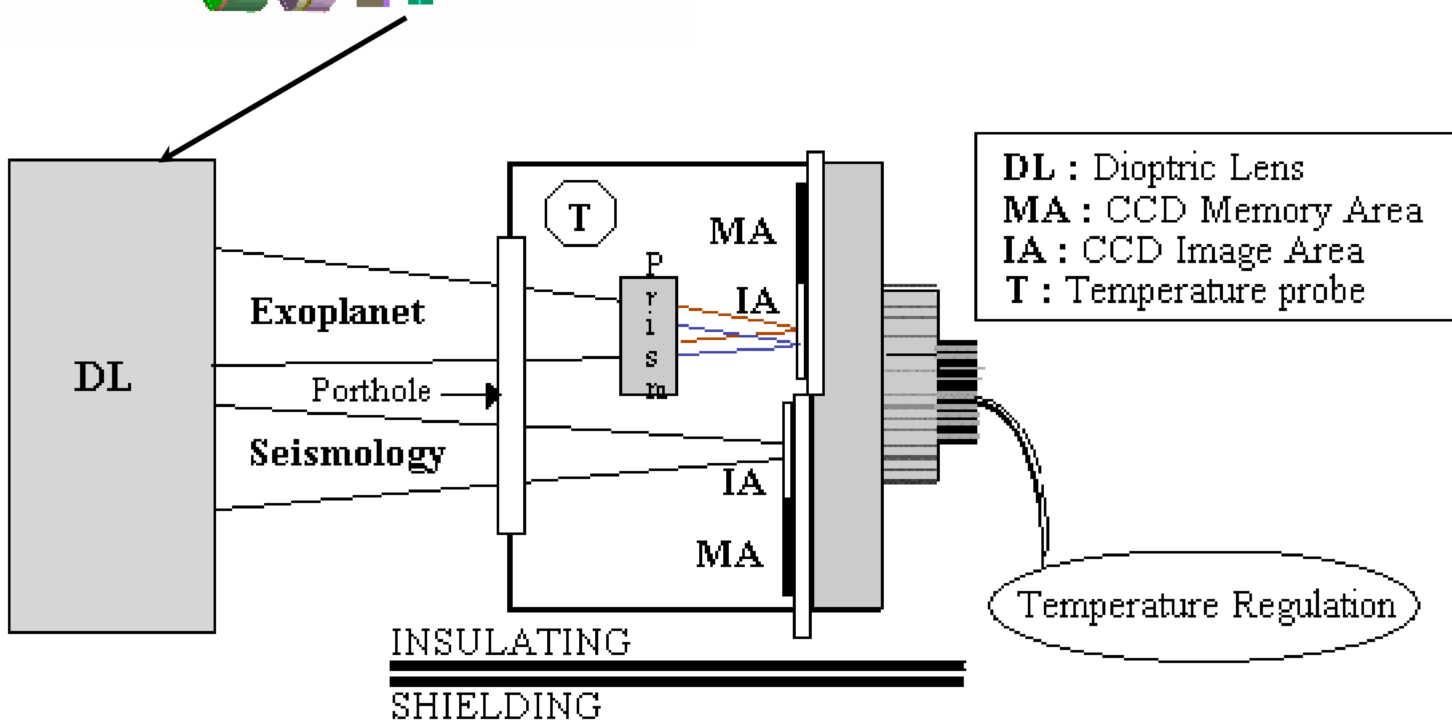
The satellite

- 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



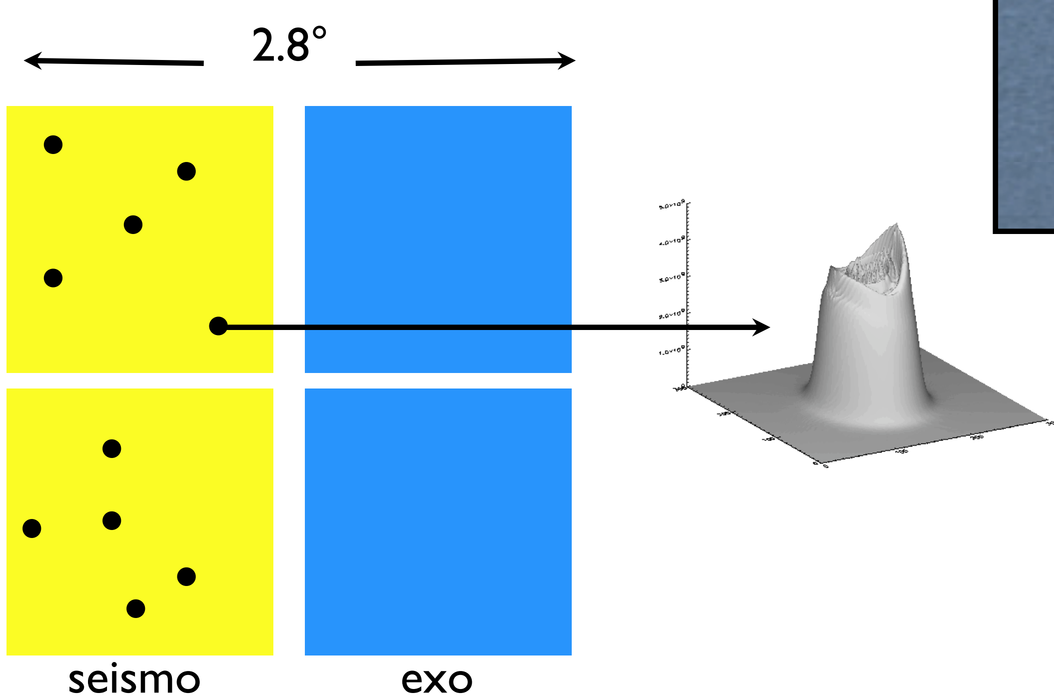
telescope layout



focal box

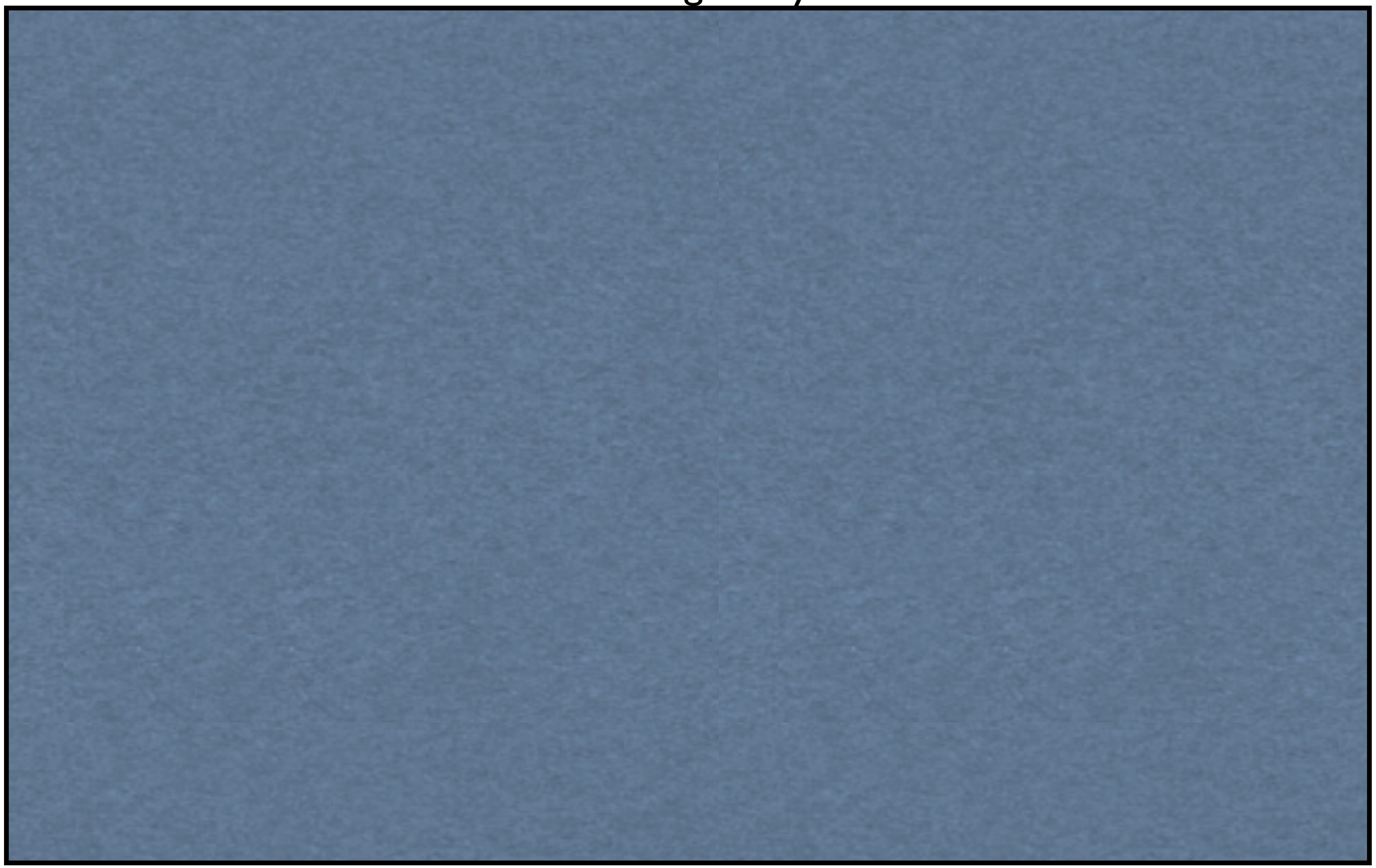
Focal plane

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



Pointing stability

x-coord of stellar image barycenter

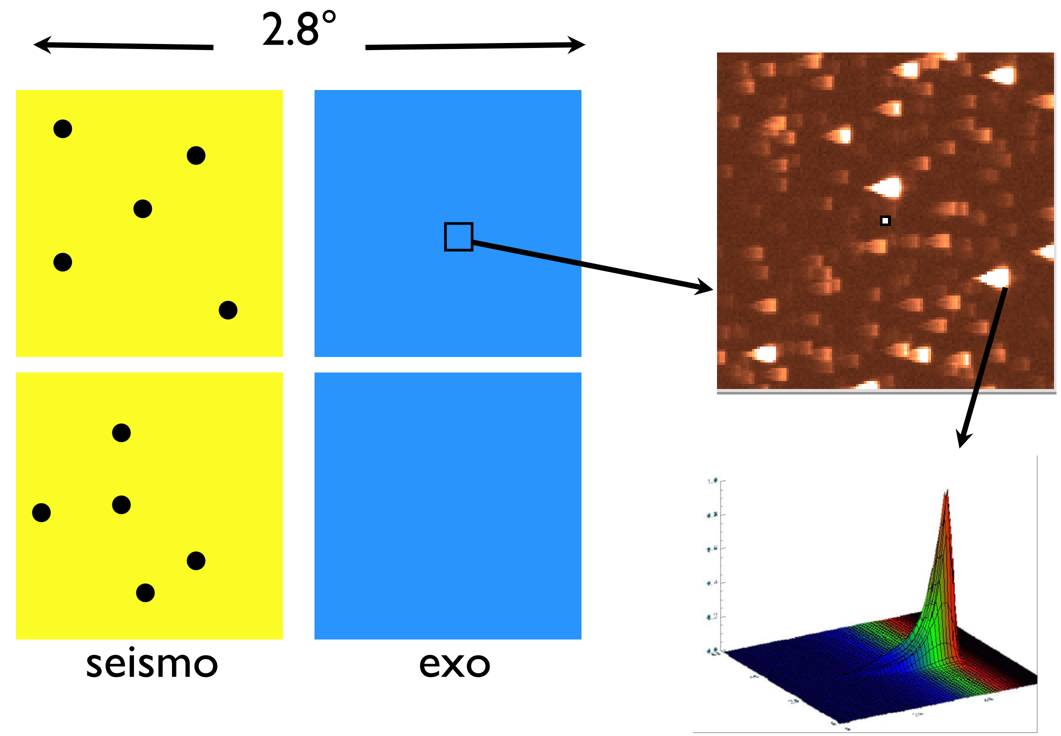


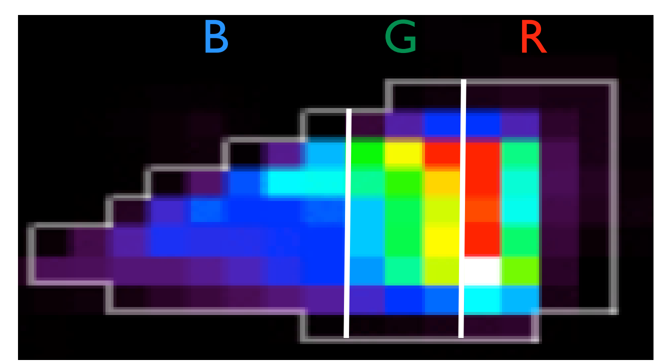
vibrations due to Earth eclipse ingress and egress

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

Exo field

- 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 form 256 templates based on one initial long integration image





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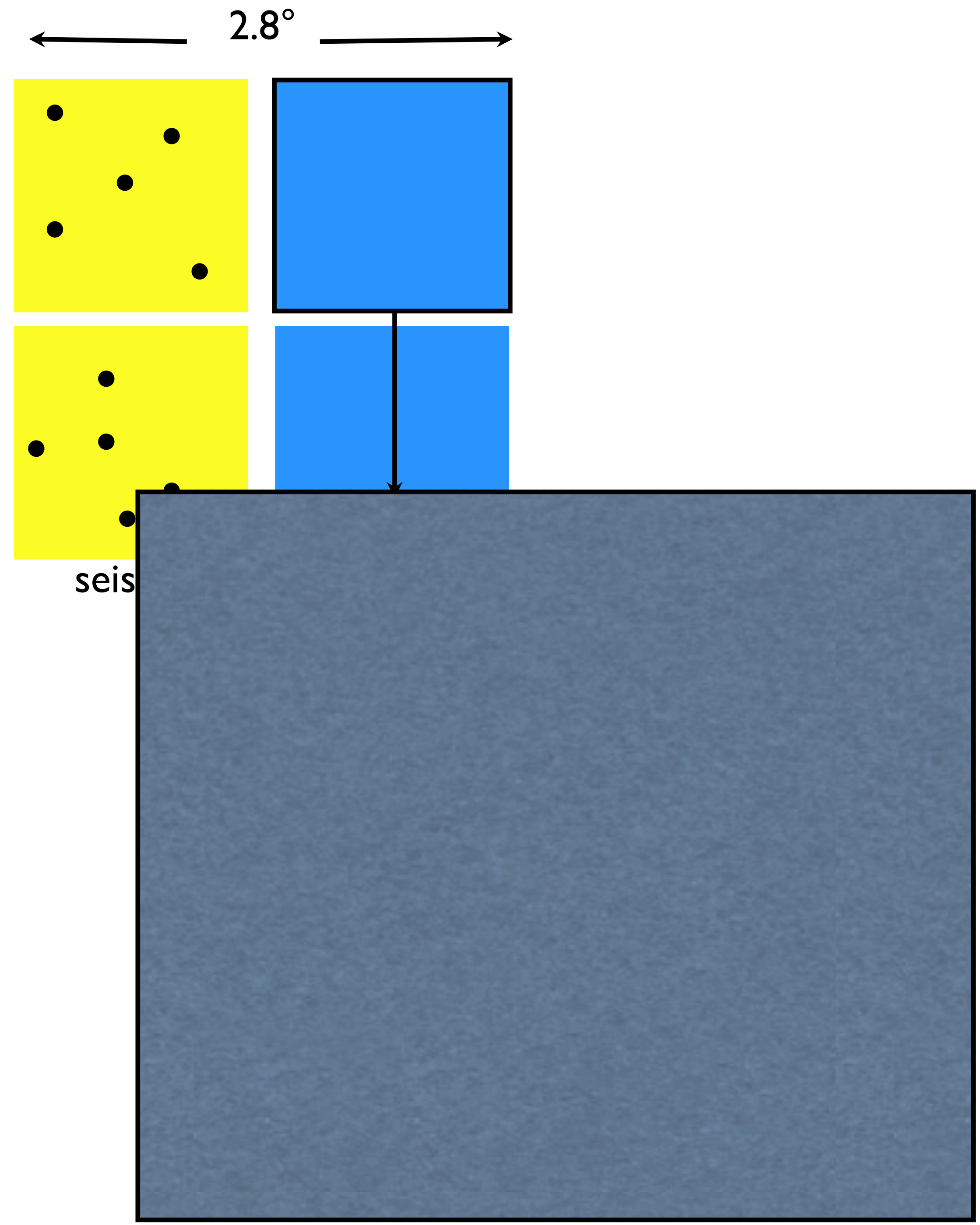
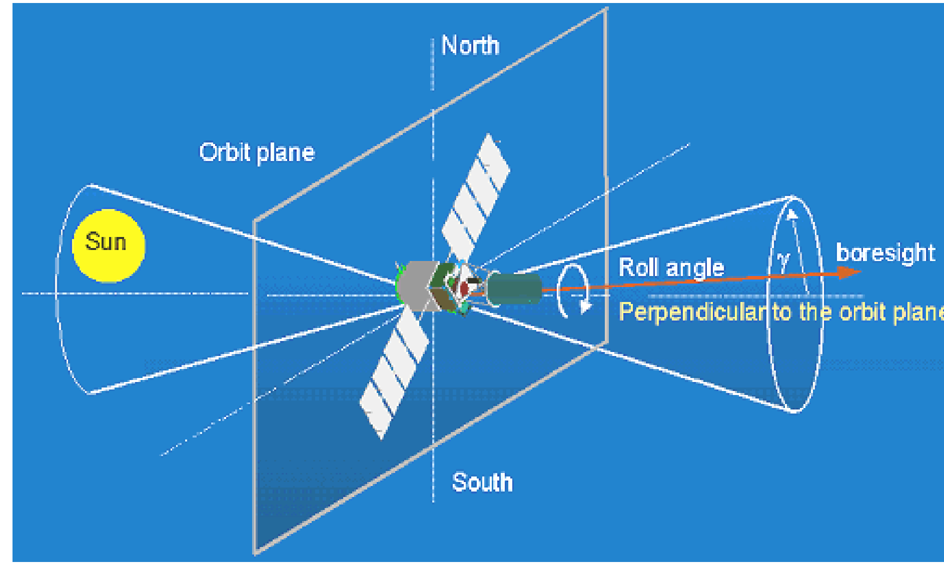


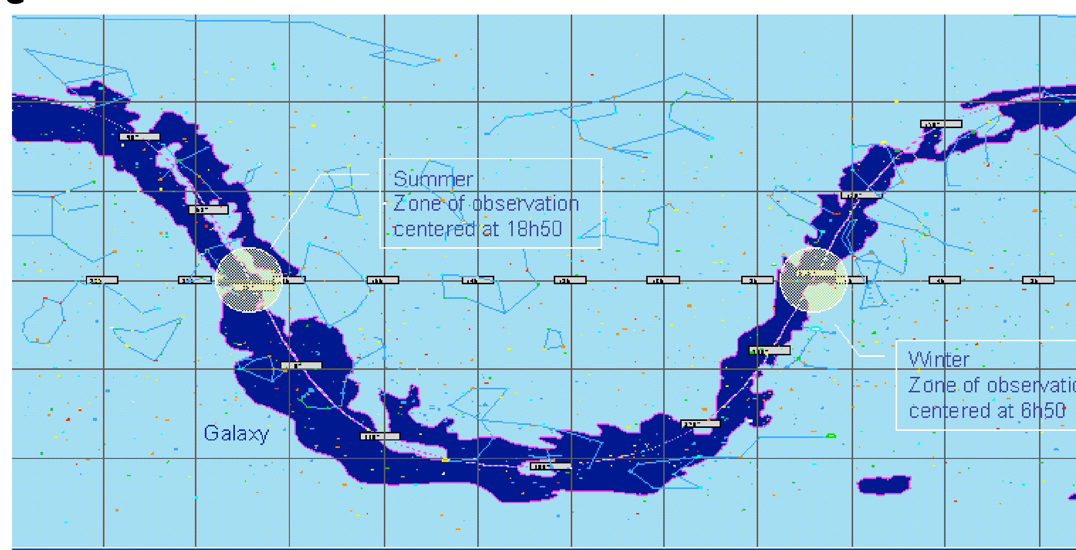
Observing strategy

- 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

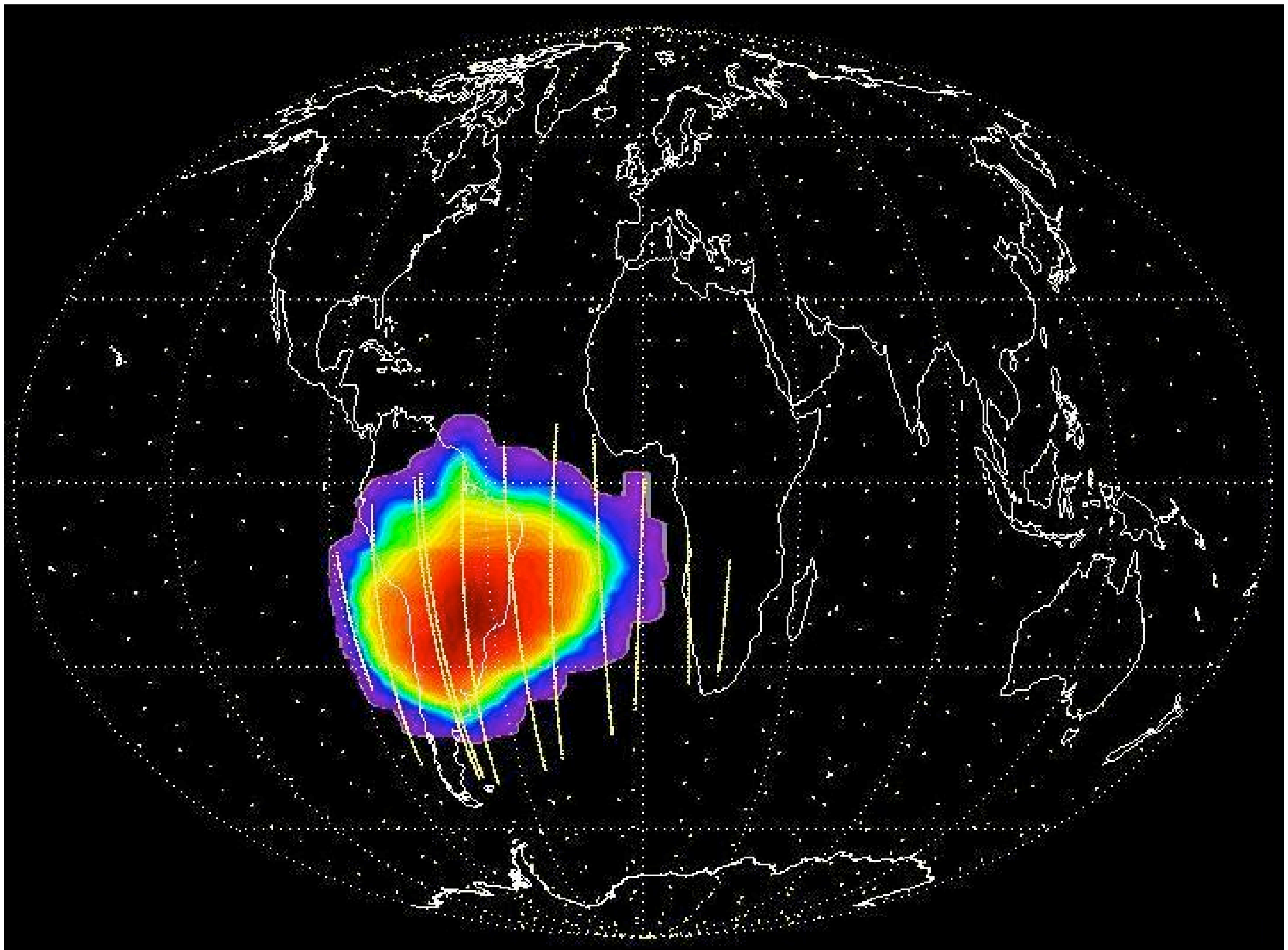


Field	Dur. (d)	RA	Dec	Rot* (°)
IR1	~60	06:50:25	-01:42:00	+14.96
LRc1	150	19:23:28.8	+00:28:48	+19.0
LRa1	150	06:46:48.0	-00:11:24	+7.3

*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

Earth eclipse ingress & egress

Folded on orbital period

Lower than expected

Implies baffle performance better than 10^{-12}

Duty cycle

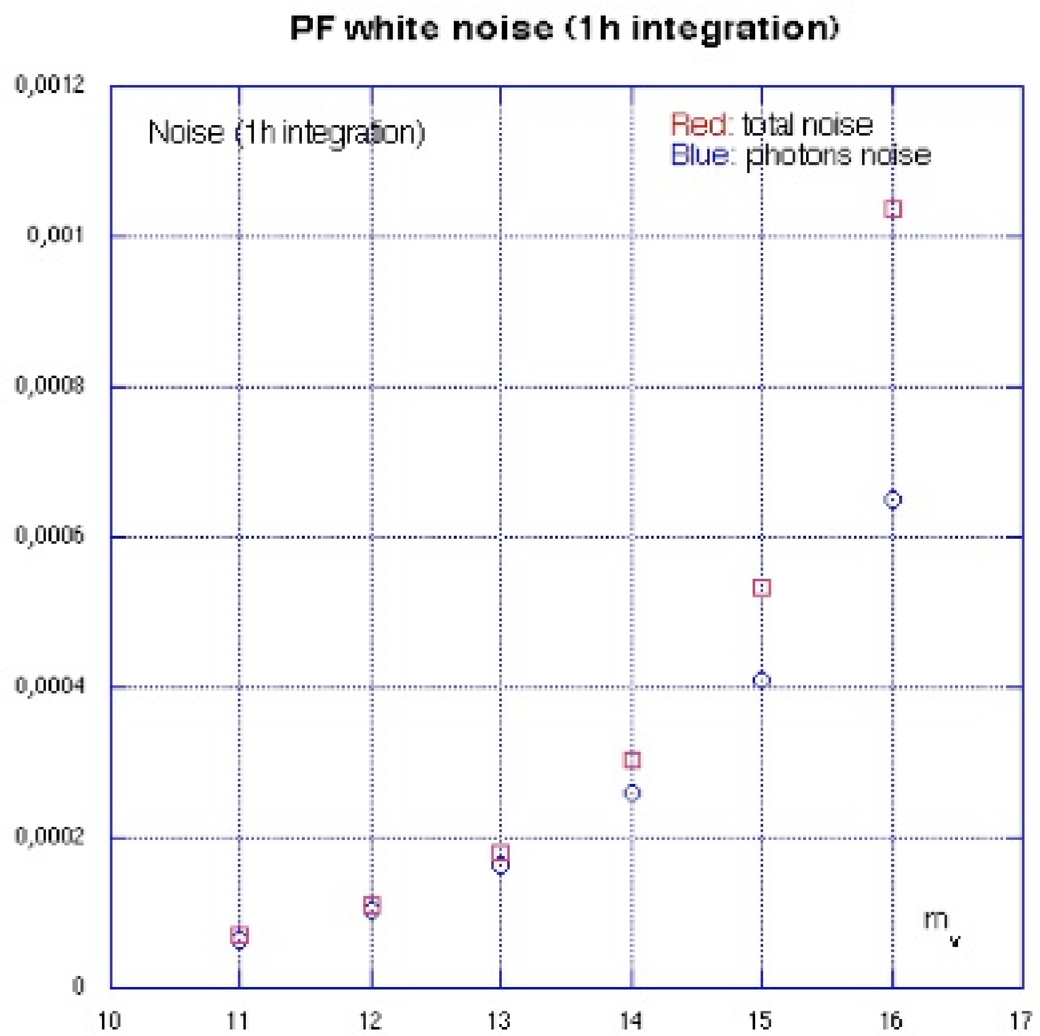
Example background light curve

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

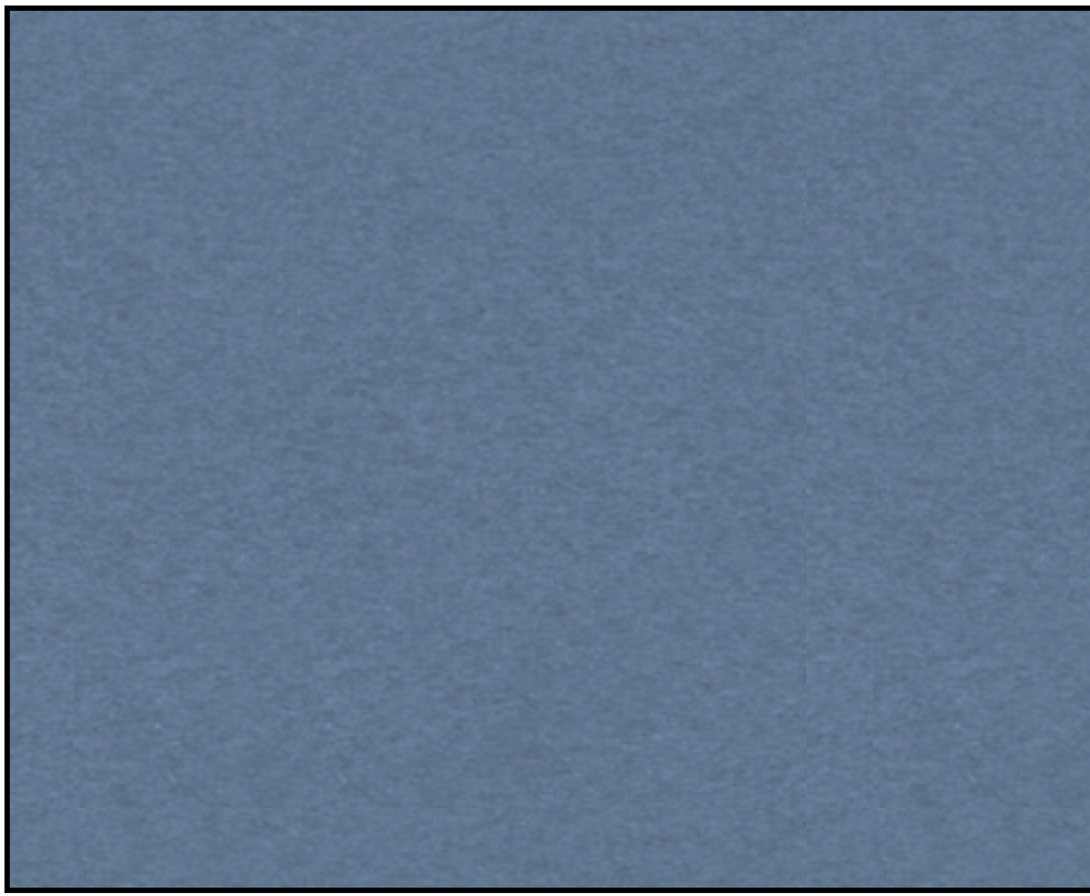
Hot pixels 10x more frequent than expected

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



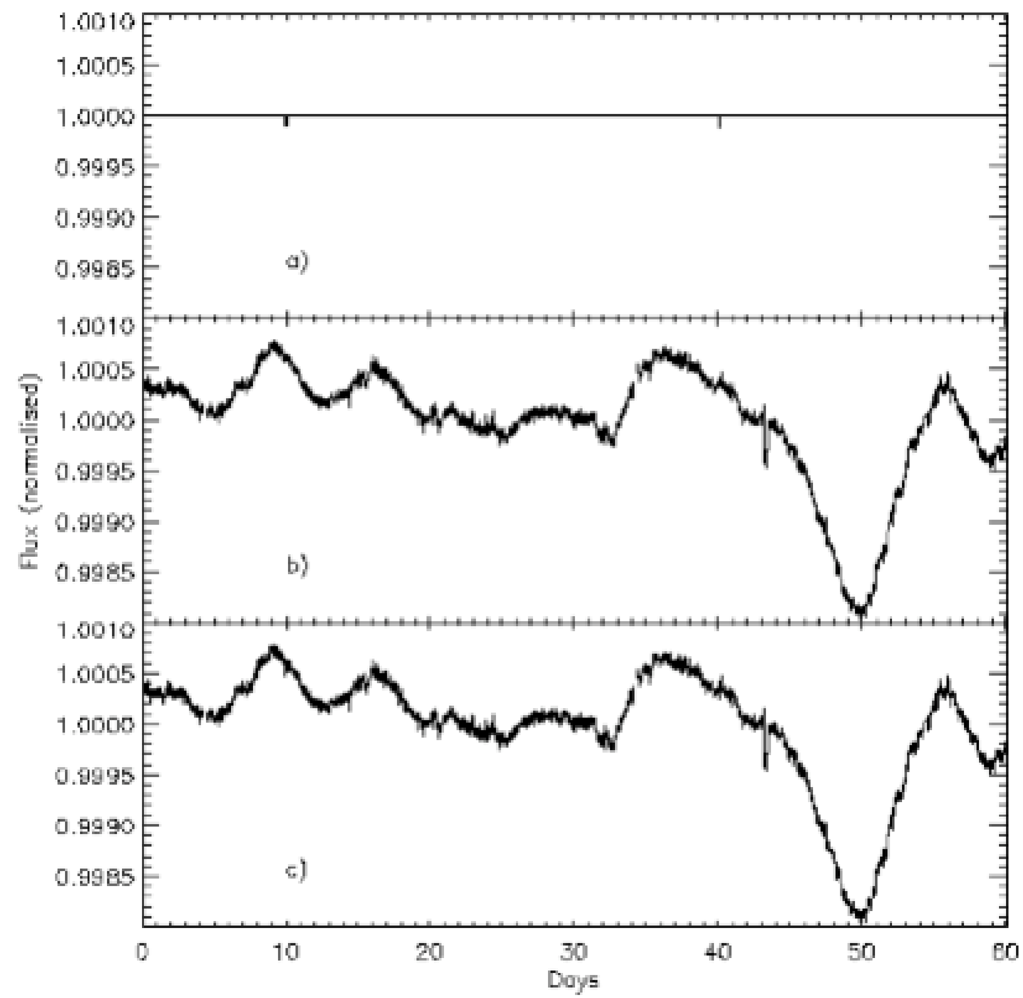
Mv ~15.4
RMS = 1170 ppm
Photon noise = 1080 ppm

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

Already close to specification despite incomplete processing

Stellar micro-variability

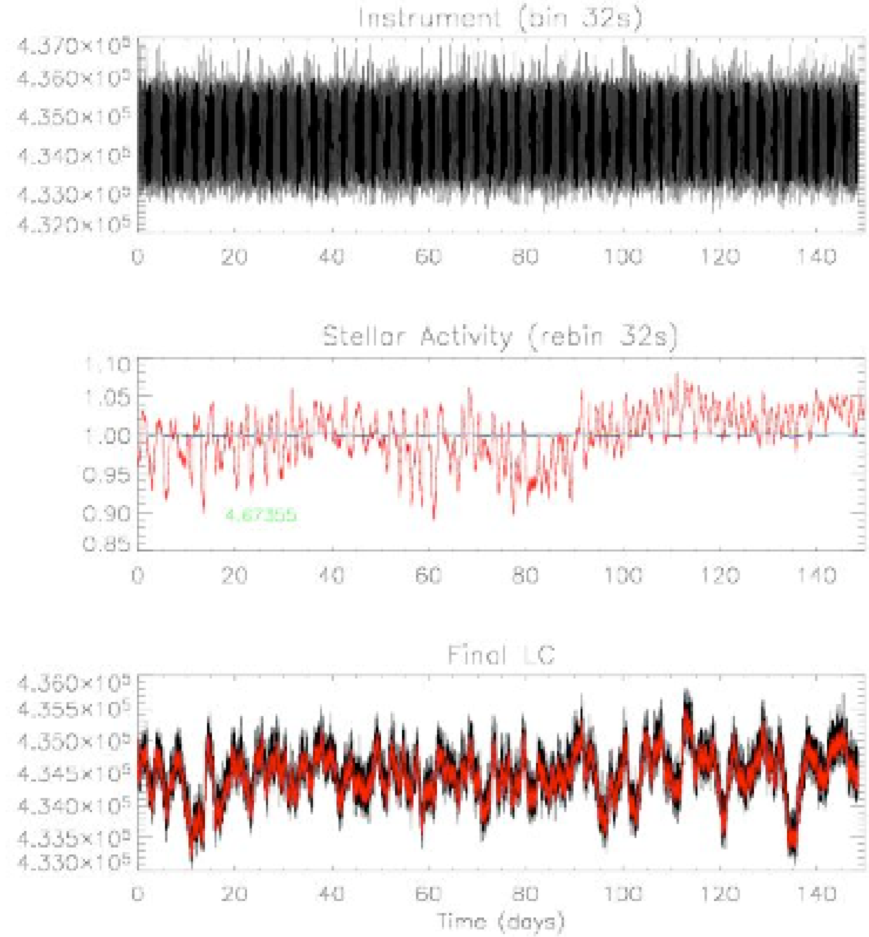
- Rotational modulation & intrinsic evolution of surface structures (spots, faculae, granules)
- Roughly 1/f noise spectrum
- Very ill characterised in stars other than the Sun
- Attempts at predicting micro-variability for other stars (Aigrain, Favata & Gilmore 2004, Lanza et al. 2005)
- Could be a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

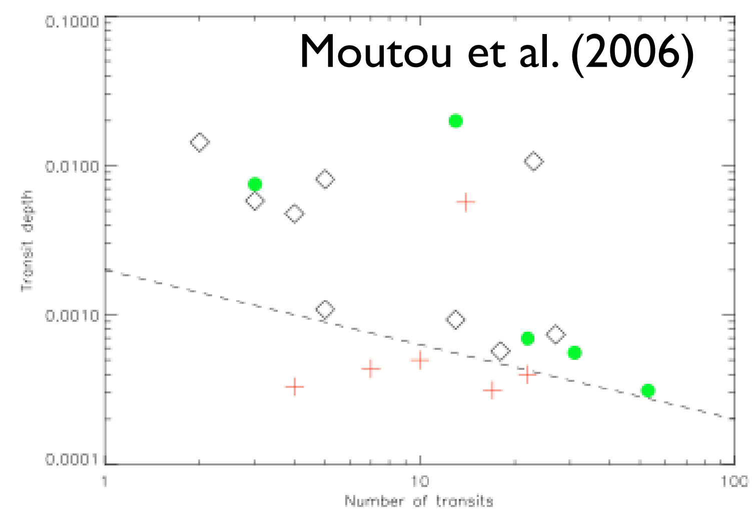


Example light curves from the seismo field

Blind test 1 - 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

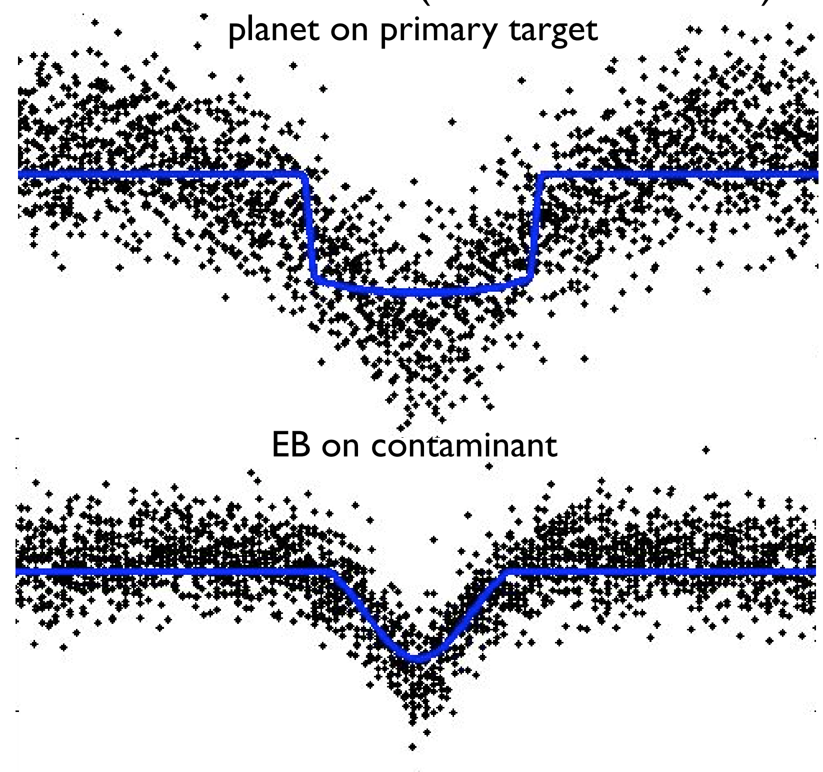




Blind test 2 - characterisation

- 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
  - Thoughest type of contaminant to identify is low mass companion - easy RV

best fit with EBAS (Tamuz et al 2006)

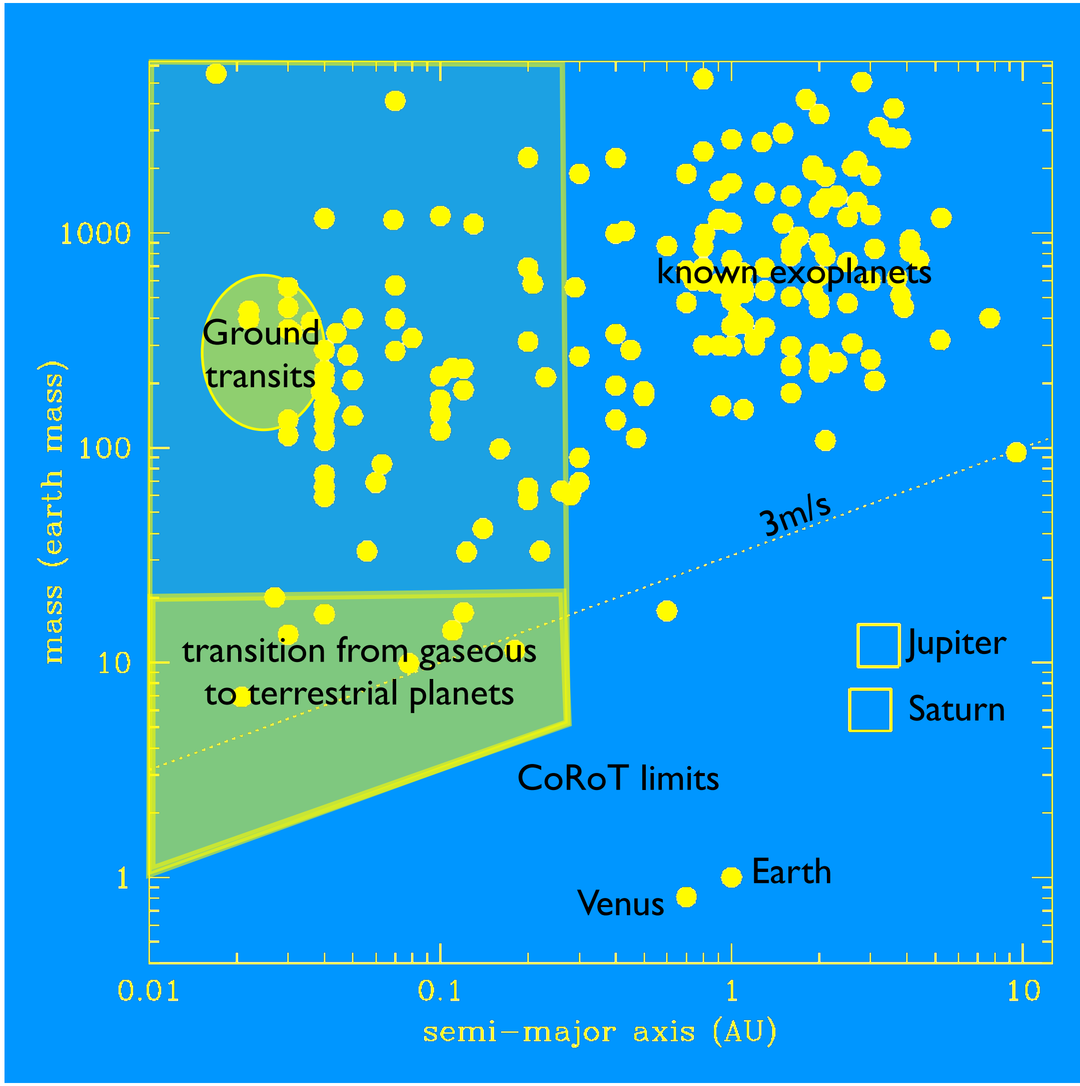


Follow-up

- 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

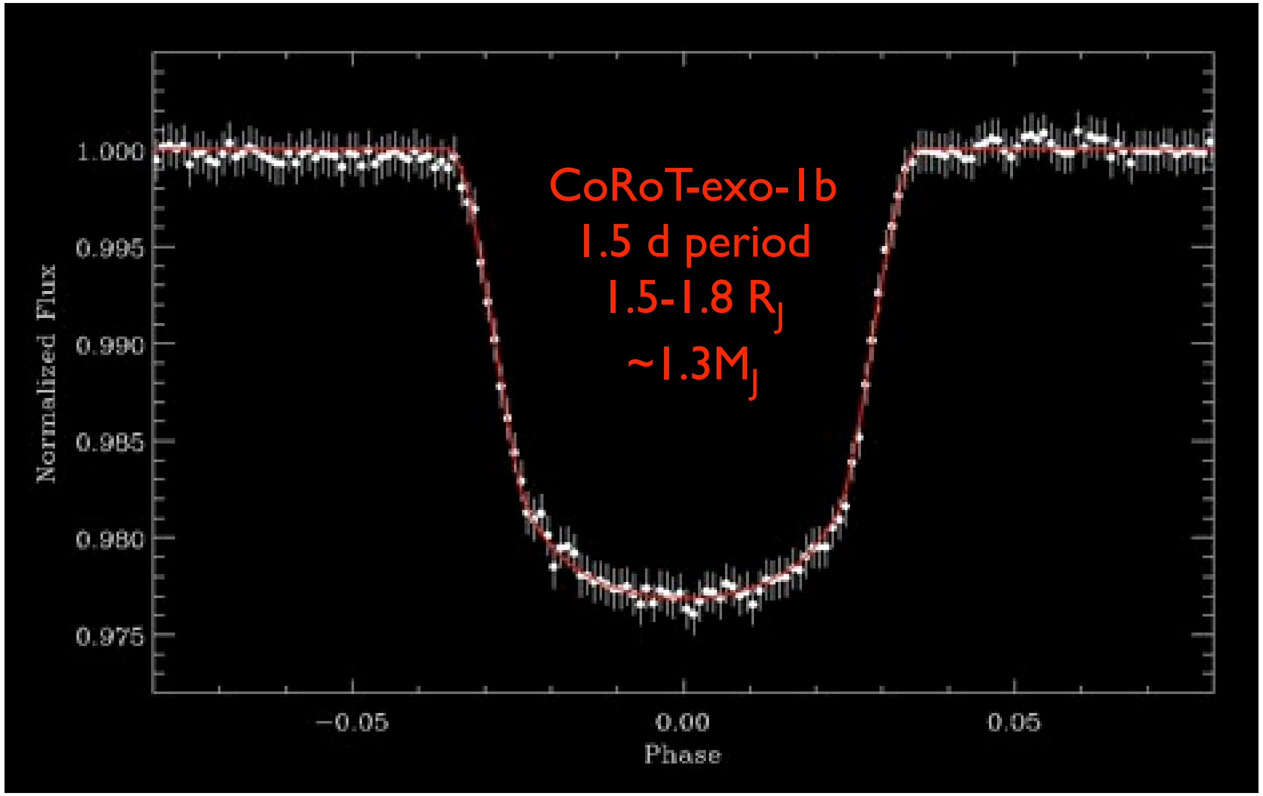


Expected detections

- 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 $R_{\oplus}$)
  - Bbout 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

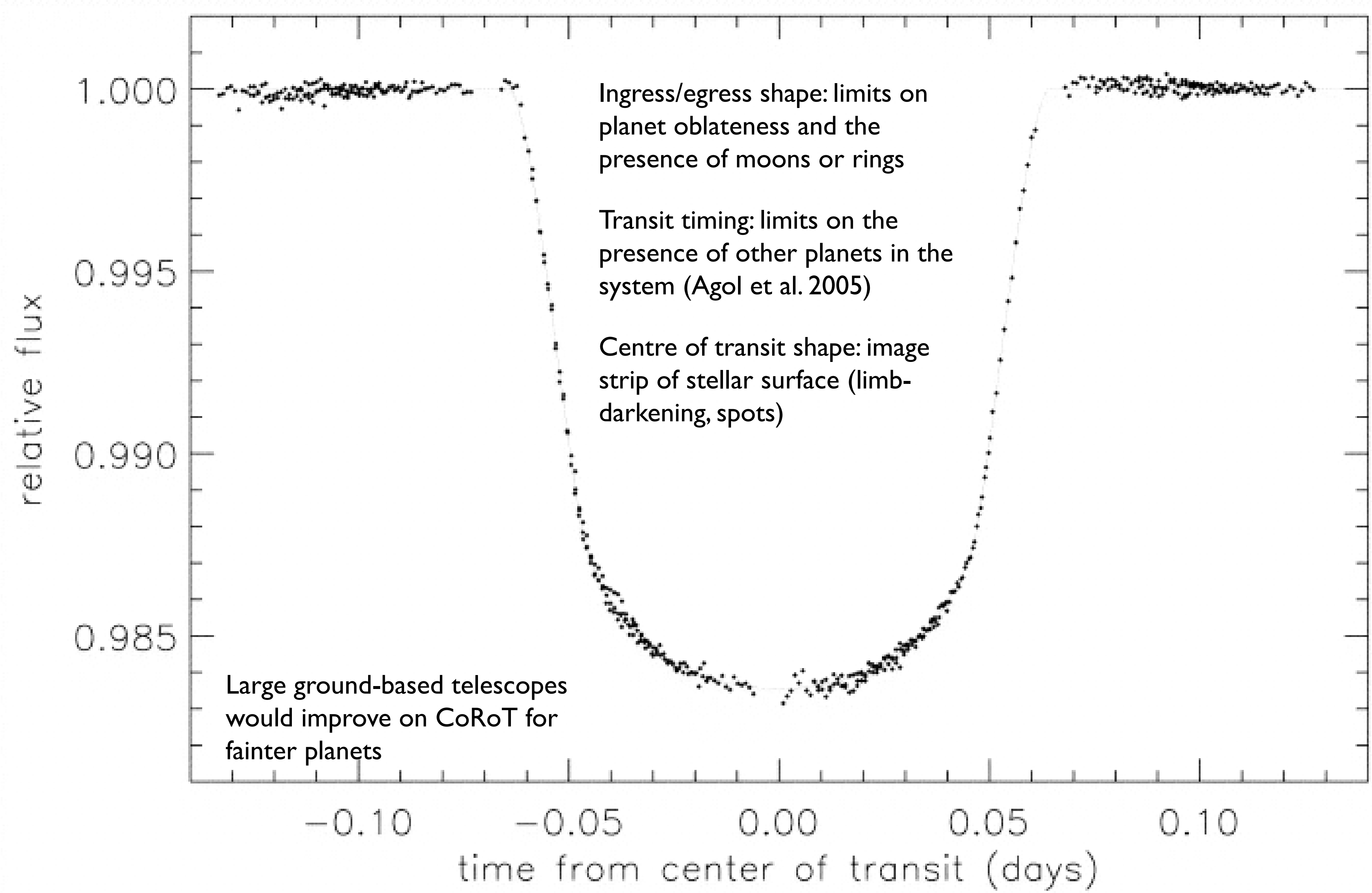


Spectra from SOPHIE@OHP, ground-based photometric confirmation from WISE 1m and BEST
More & better spectra needed to improve stellar parameters and mass ratio estimate

more candidate images

Ultraprecise Hot Jupiter light curves

HD209458b with HST (Brown et al. 2000)



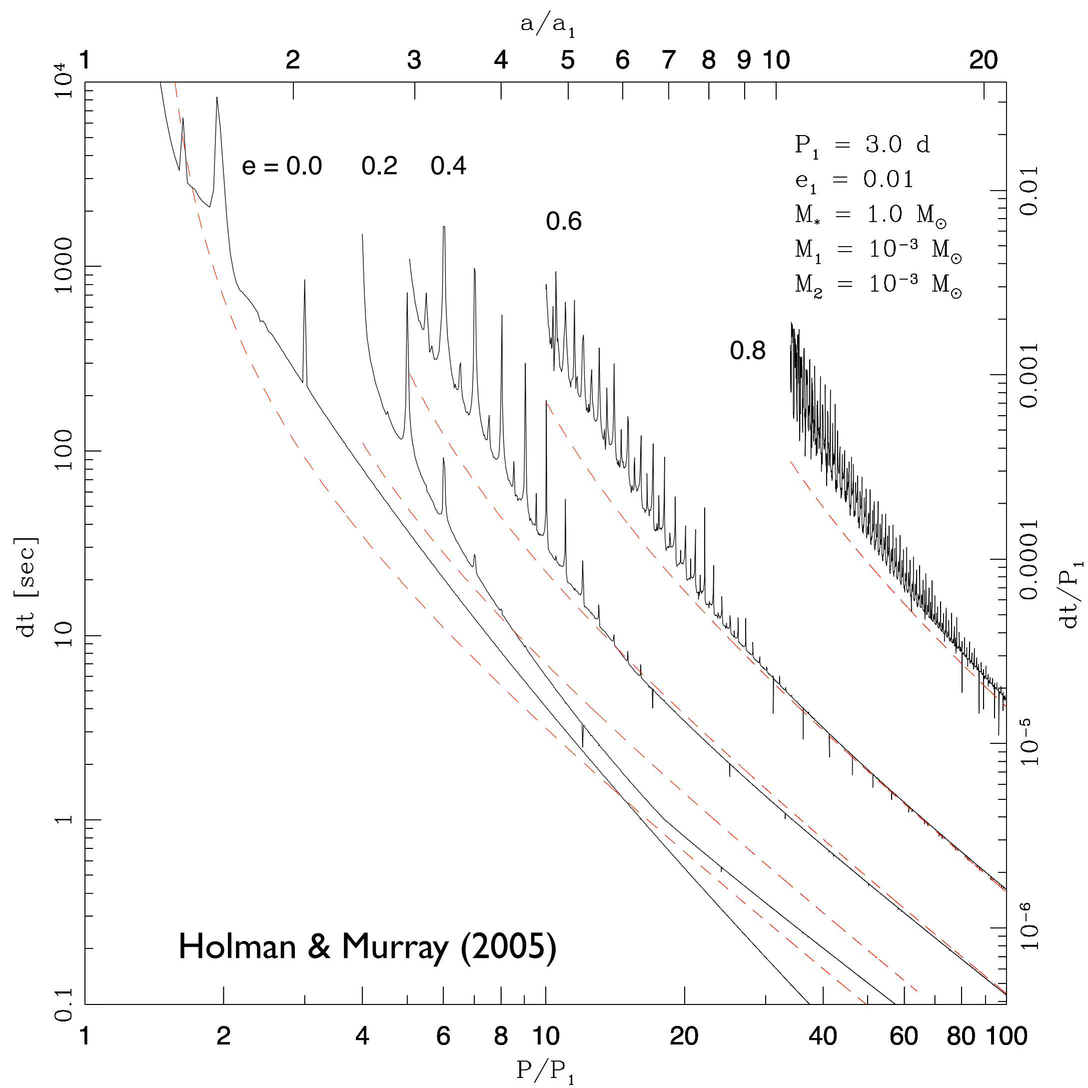
Transit timing

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

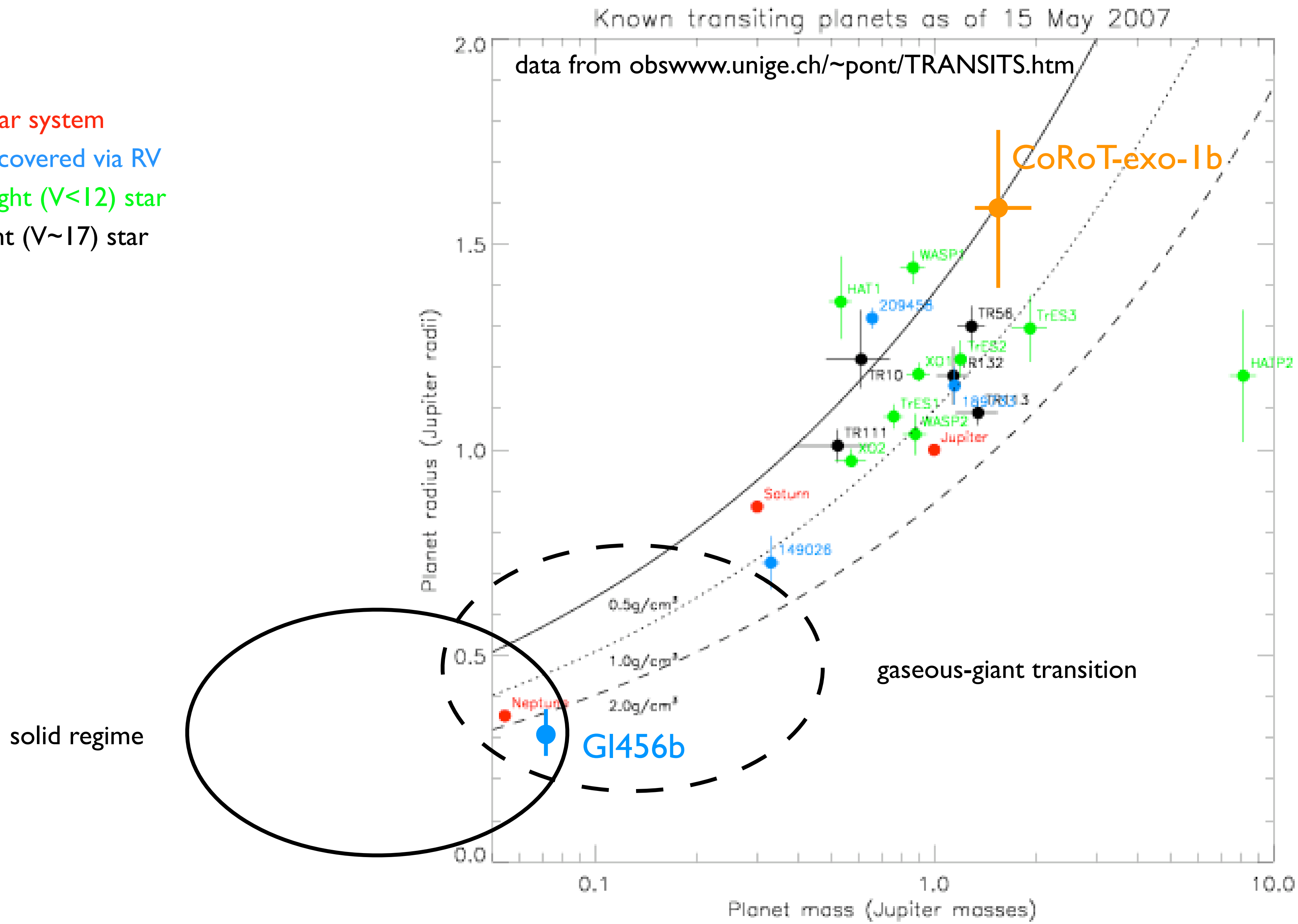
But... extremely sensitive to red noise - need fully processed data



The mass-radius relation

Legend:

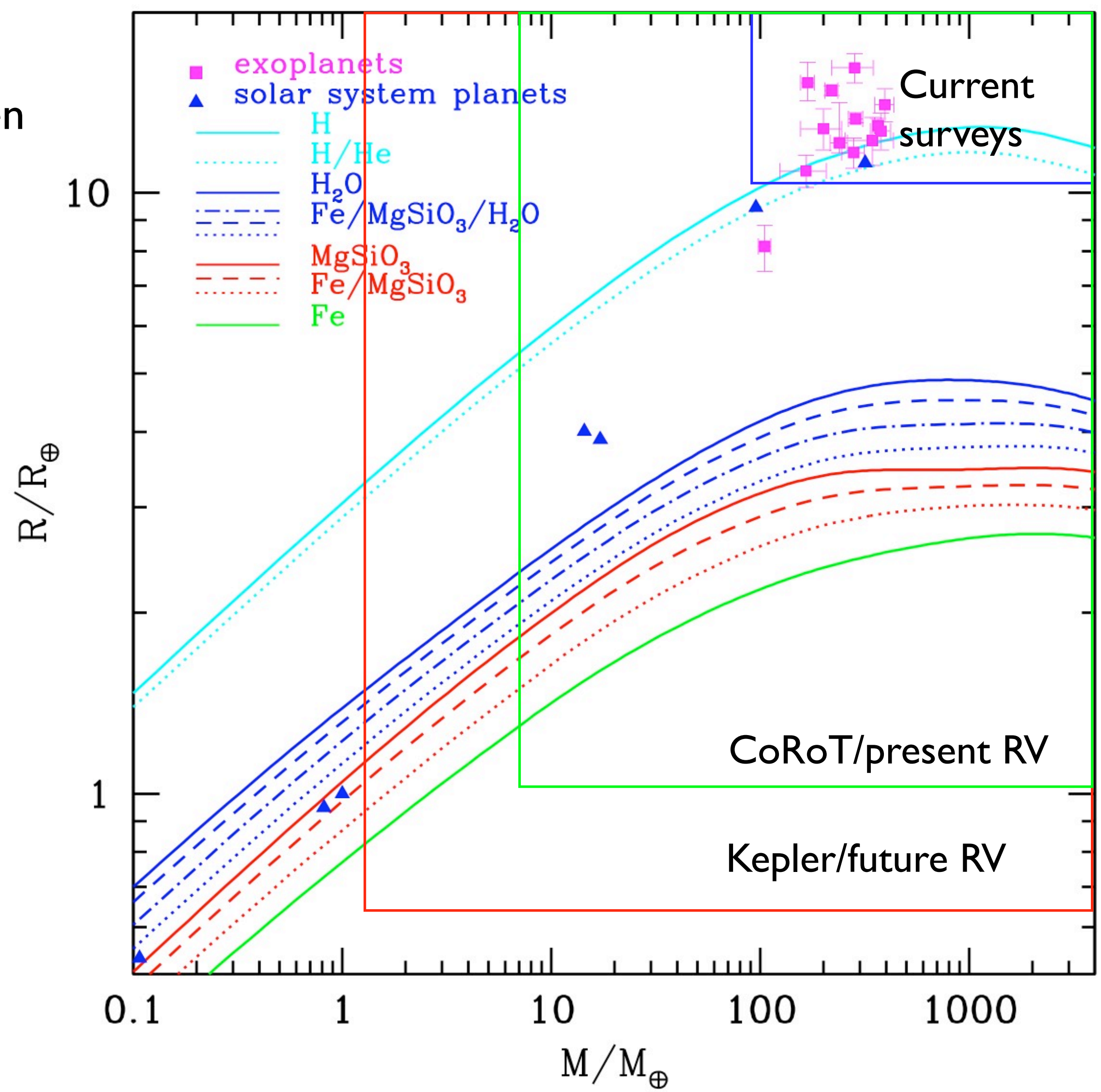
- solar system
- discovered via RV
- bright (V<12) star
- faint (V~17) star



Solid exoplanets

- Will we be able to differentiate between planet mostly made of
  - H/He
  - H_2O
  - $MgSiO_3$
  - Fe
  - a mixture?
- Simple calculation - hydrostatic equilibrium + EoS - gives mass-radius relation for hypothetical planets

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



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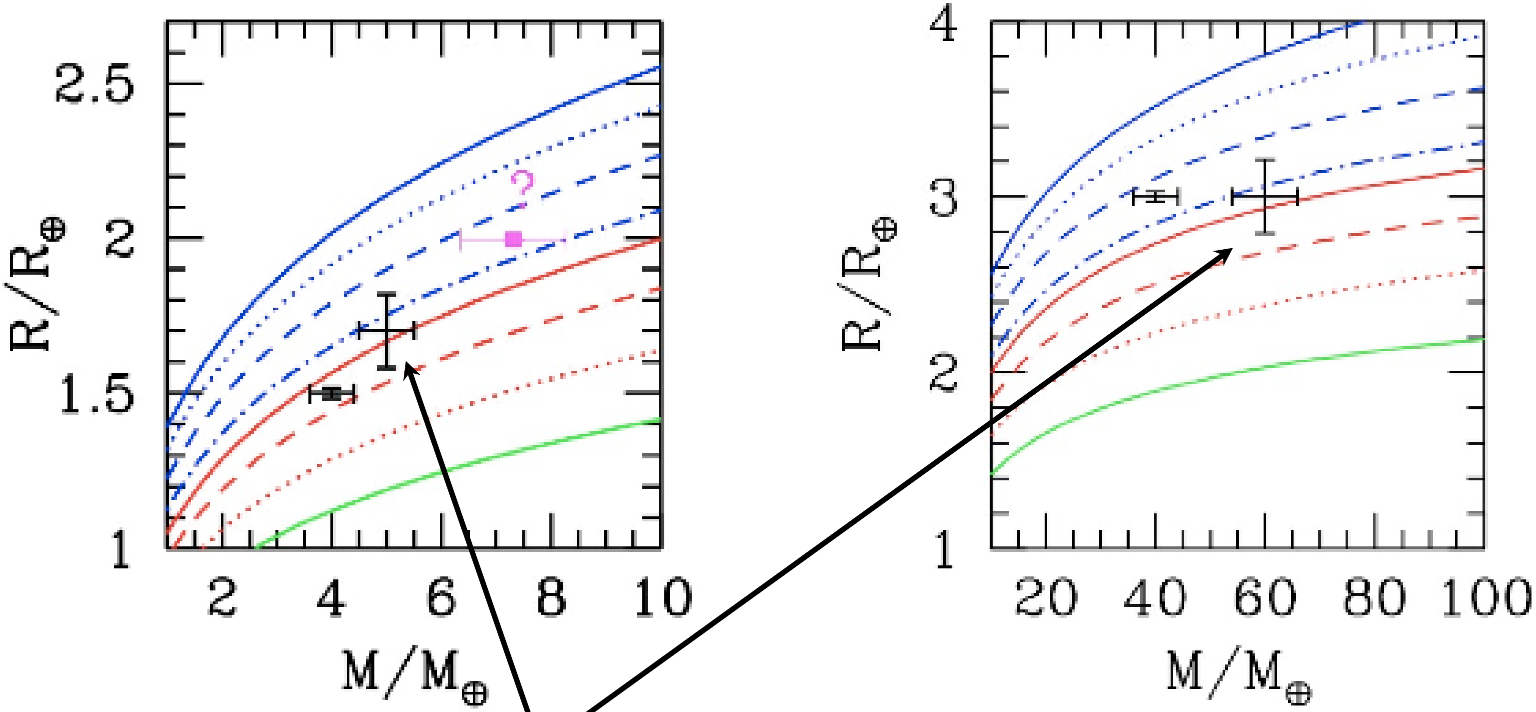

7% error bars on mass and radius

Will be able to tell bulk composition but not much more

Summary

- 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 candiates, 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