Ancillary science from transit searches

A non exhaustive picture!

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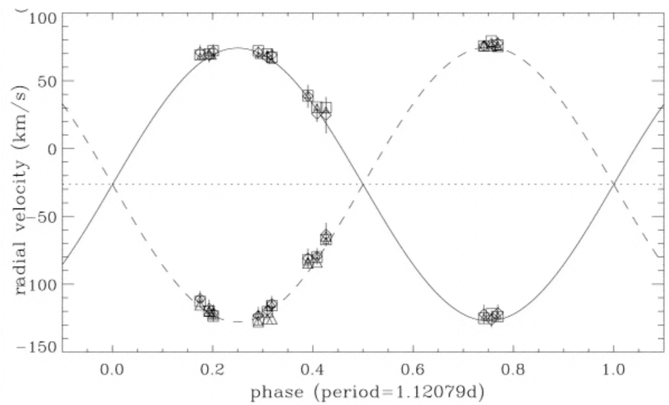
The time-domain bonanza

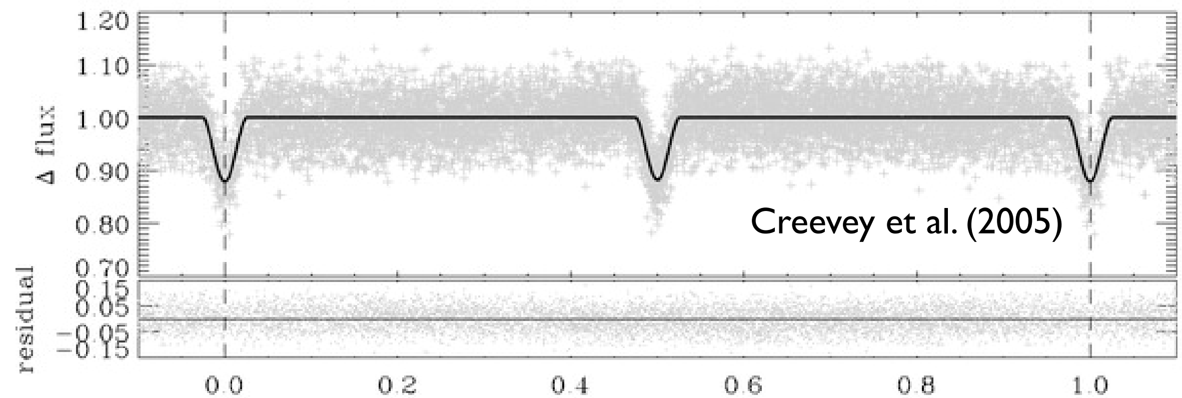
- Transit survey requirements are extremely stringent
  - Sub-percent precision, tight time sampling, long baseline
- Opens vast array of possibilities
  - Transit mimics (EBs)
  - Intrinsic stellar variability
    - Pulsating stars: δ Scuti, RR Lyrae, Cepheids, Sun-like, PMS, brown dwarfs
    - Rotation, flaring and convection in active and normal stars
  - Transients & moving objects
    - asteroids, KBOs
    - supernovae, GRB afterglows

Ancillary science publications from ground-based transit search projects - I

- EBs discovered as part of transit candidate follow-up
  - OGLE: Bouchy et al. (2005, A&A, 431, 1105); Pont et al. (2005a, A&A, 433, 21L; 2005b, A&A, 438, 1123; 2006, A&A, 447, 1035)
  - Tres: Mandushev et al. (2005, ApJ, 621, 1061); Creevey et al. (2005, ApJ, 625, 127L); O'Donovan et al. (2006, ApJ, 644, 1237)
  - APT: Young et al. (2006, MNRAS, 370, 1529)
  - probably many more... but not all get fully solved or published

Detached eclipsing binaries: anchoring stellar evolution





- Light curve + double lined spectroscopic orbit gives
  - inclination, masses, radii, temperature ratio, luminosities
  - all model-independent
  - to a precision of a few % (Andersen 1991, A&ARv, 3, 91)
  - Single lined: have to put in mass and radius for primary
- Applications:
  - Tight constraints on evolutionary models
    - Stellar parameters dominate uncertainties on transiting planet parameters!
  - Distance / age estimation for individual stars, star clusters...

The pre-transit survey era

Lastennet & Valls-Gabaud (2002, A&A, 396, 551)

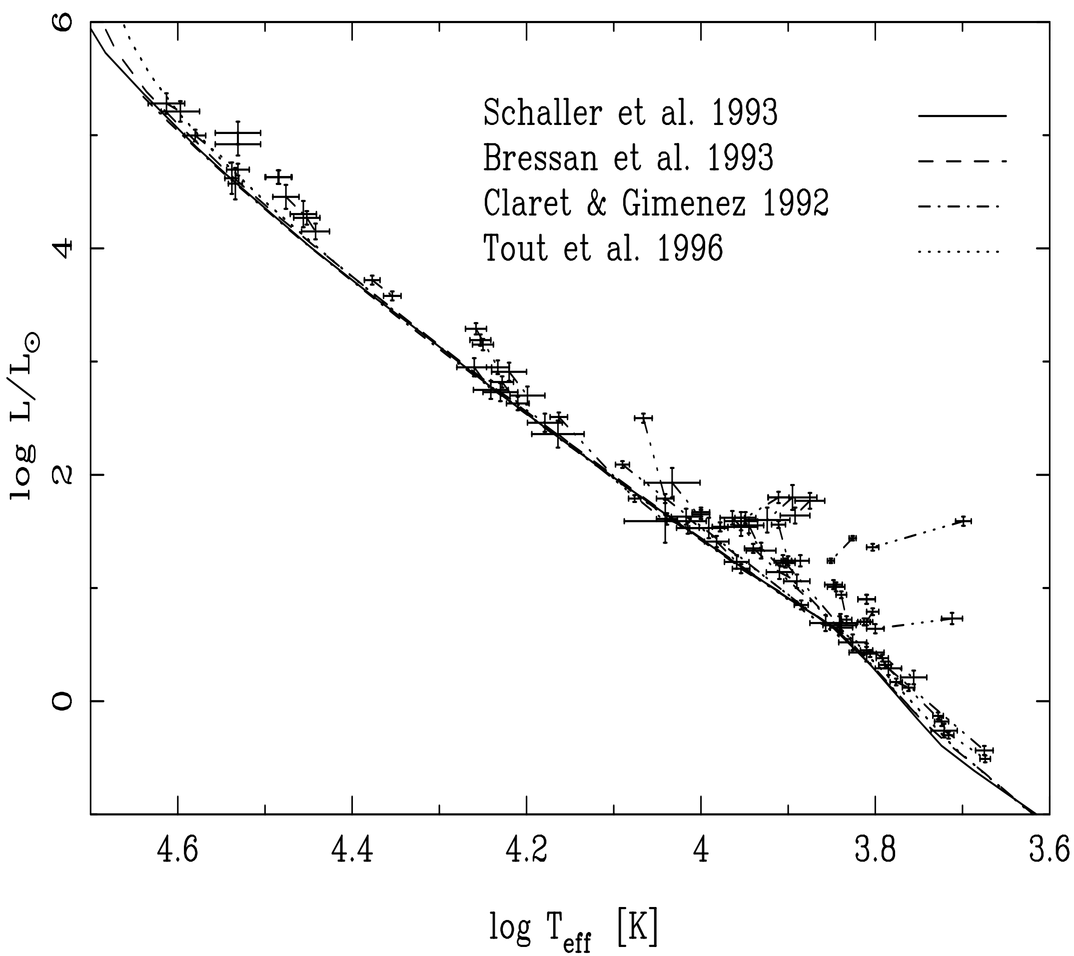


Fig. 1. HR diagram for the sample of 58 binary systems with components more massive than 0.6 $M_\odot$. ZAMS sequences computed by different authors for $Z = 0.02$ are also indicated for comparison.

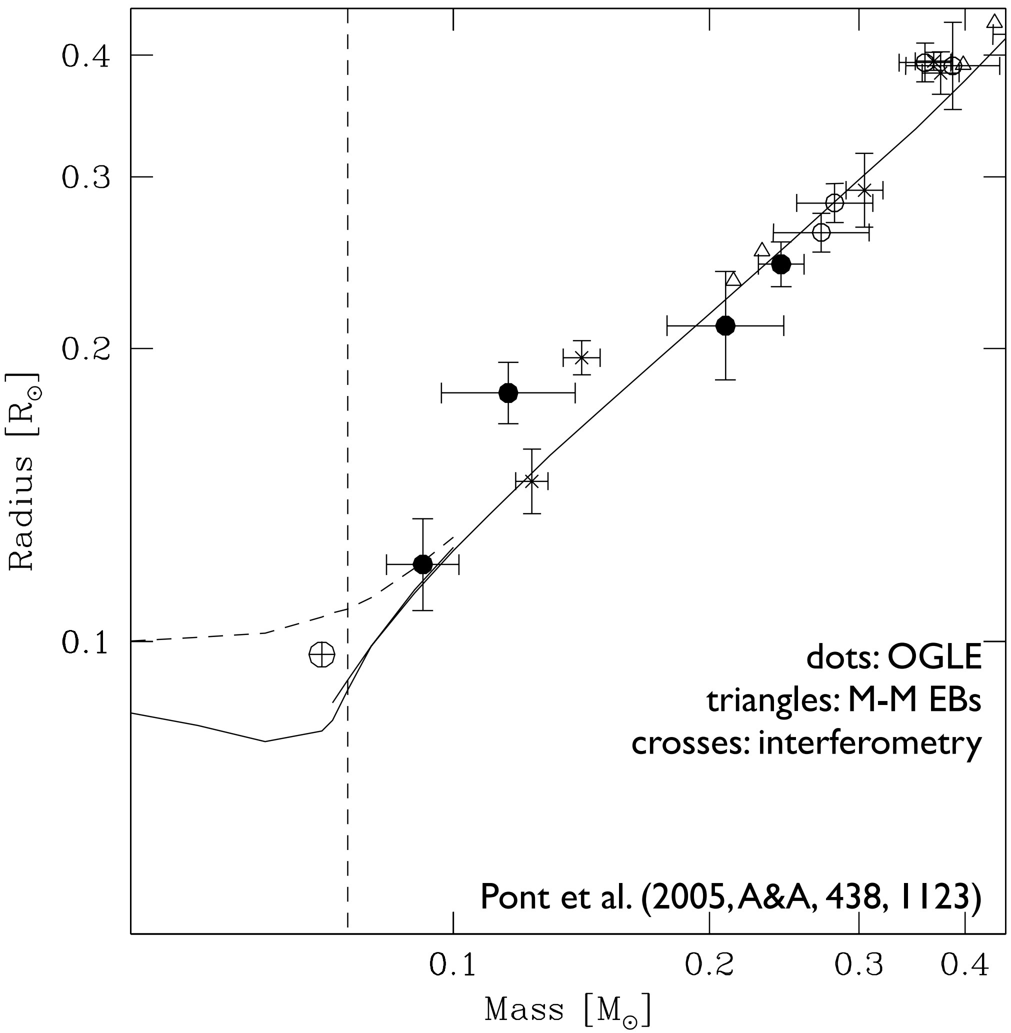
Above 0.6 $M_\odot$, given L and T_{eff}, all 3 sets of models tested predict M and R to 2-4%.

Systematics due to use of one set of tracks or other estimated at ~1σ.

Further tests of the models limited by precision of metallicities and ages.

Paucity of systems above 1.4 $M_\odot$ and below 0.6 $M_\odot$.

Low mass EBs from transit surveys



Follow-up of transit candidates from large surveys yields about as many low-mass EBs with full solutions as planets.

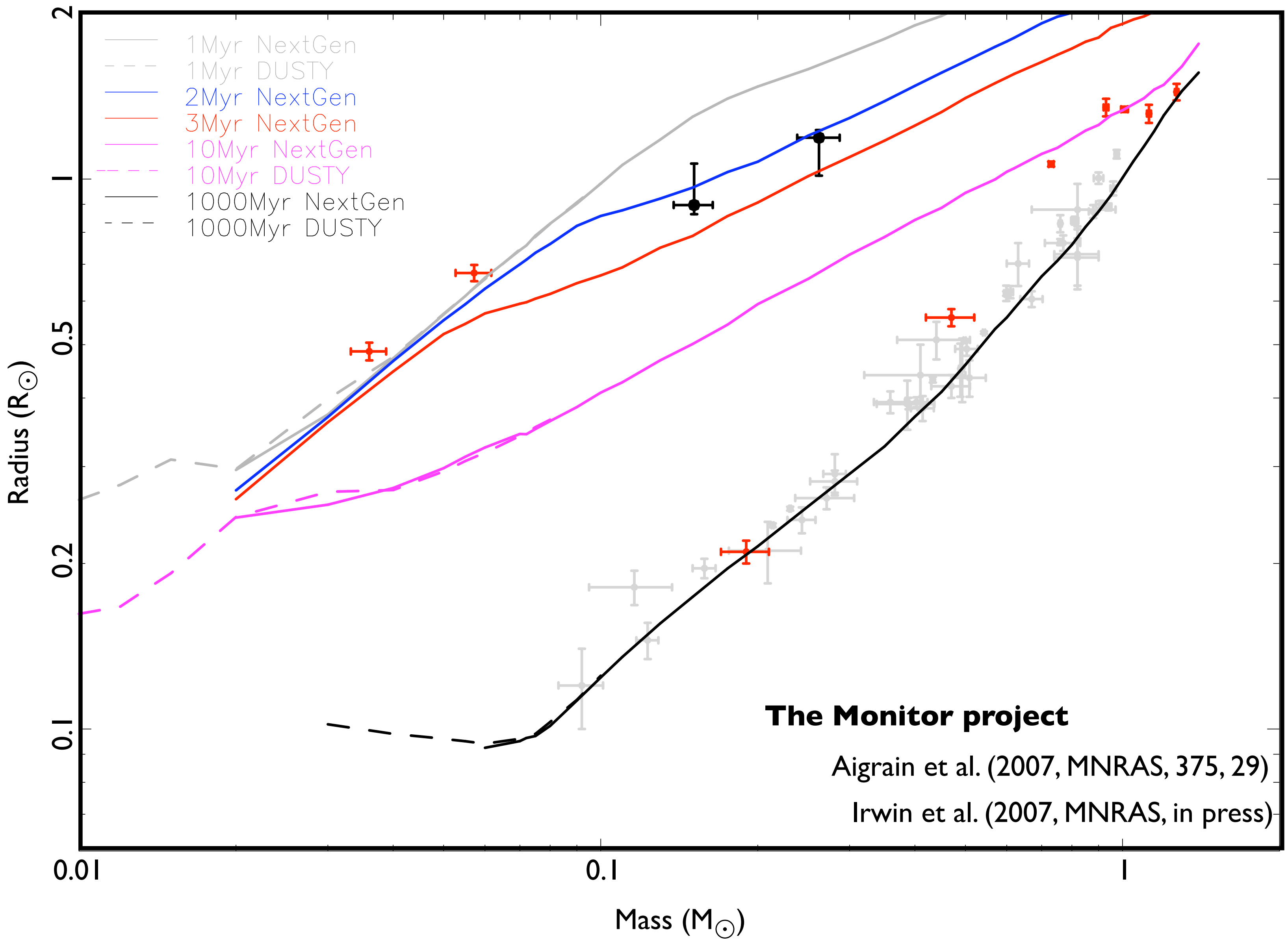
OGLE: extended calibration right to BD limit.

Significant discrepancies between data and models around 0.1-0.2 $M_\odot$.

Other surveys since added more systems, but many of the EBs are never fully solved.

Future effort likely to focus on worst constrained mass ranges. To improve statistics overall, would need order of magnitude increase in numbers - expensive!

PMS EBs

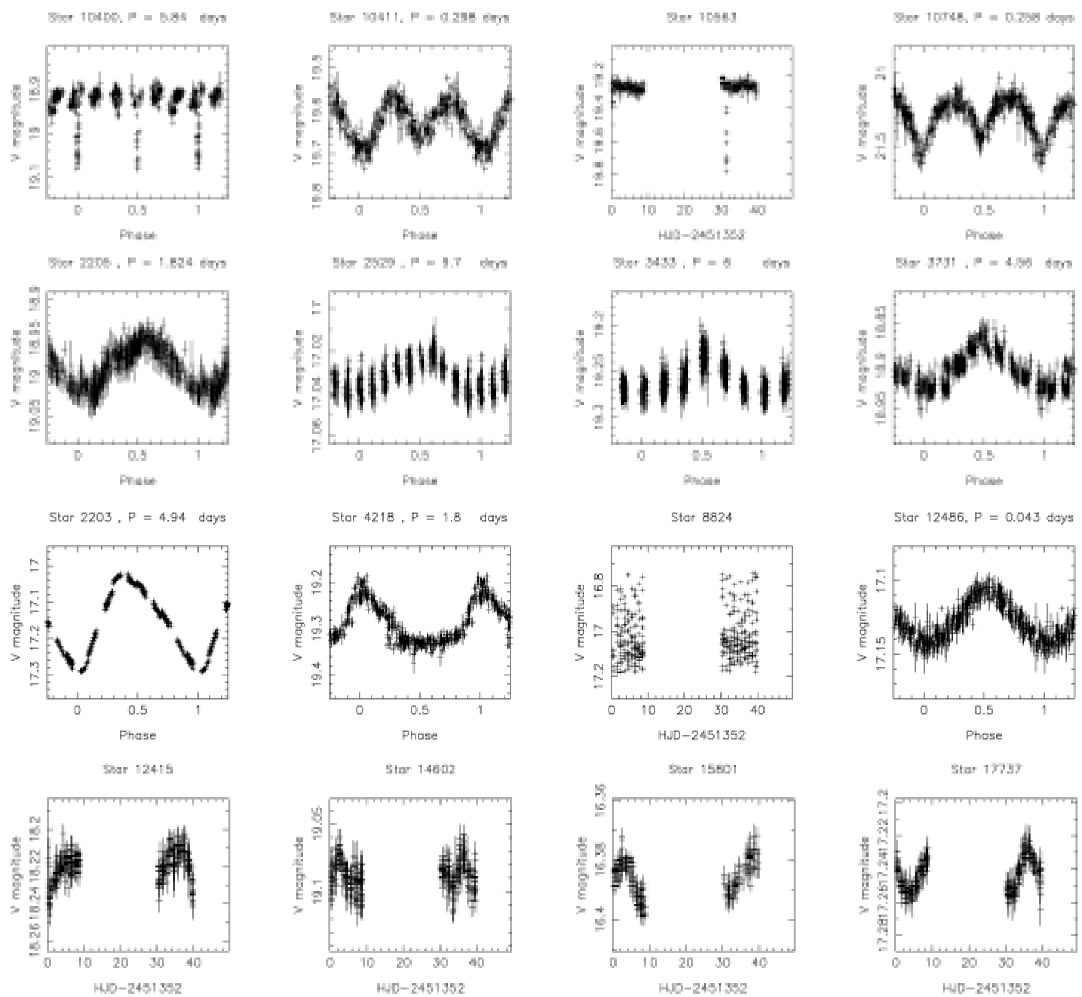


1Myr NextGen
1Myr DUSTY
2Myr NextGen
3Myr NextGen
10Myr NextGen
10Myr DUSTY
1000Myr NextGen
1000Myr DUSTY
The Monitor project
Aigrain et al. (2007, MNRAS, 375, 29)
Irwin et al. (2007, MNRAS, in press)
Radius ($R_\odot$)
Mass ($M_\odot$)
2
1
0.5
0.2
0.1
0.01
0.1
1

Ancillary science publications from ground-based transit search projects - II

- Generic variable star searches in transit search datasets
  - UStAPS: Street et al. (2002, MNRAS, 330, 737; 2005, MNRAS, 358, 795)
  - PISCES: Mochejska et al. (2002, AJ, 123, 3460; 2004, AJ, 128, 212)
  - APT: Hidas et al. (2005, MNRAS, 360, 703)
  - WASP0: Kane et al. (2005, MNRAS, 362, 117)
  - HATnet: Hartmann et al. (2004, AJ, 128, 1761)
  - (no publications on variability in OGLE transit survey fields?)

Variable stars in the field of Open Cluster NGC 6819 (Street et al. 2005)



eclipsing binaries

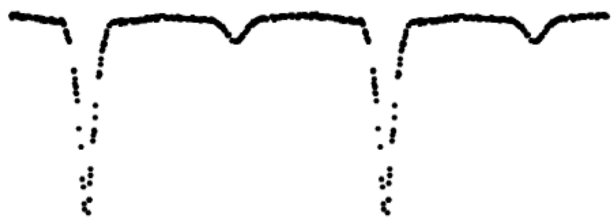
BY Dra (rotation)

other (mainly pulsating)

long period (baseline too short to classify)

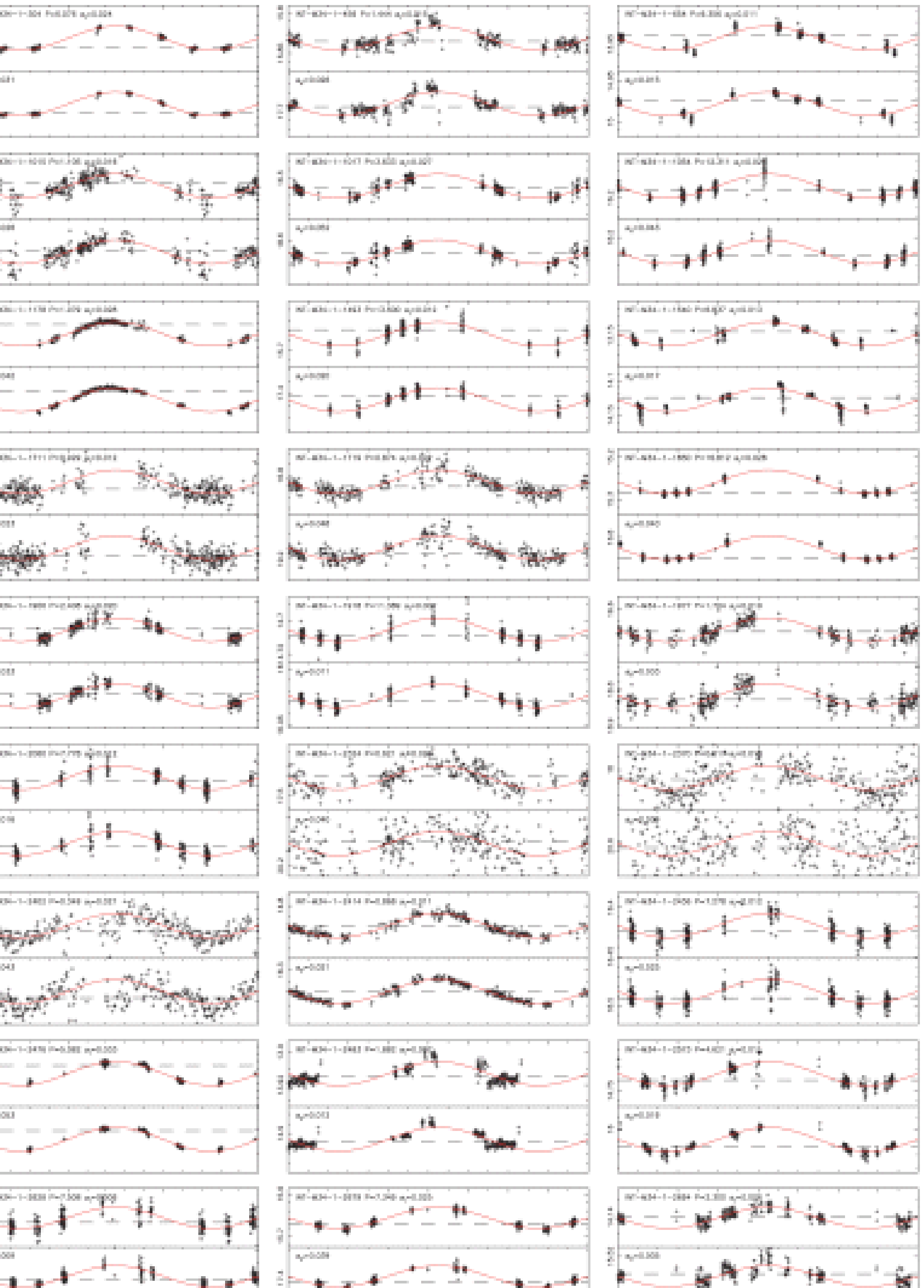
Under-exploited... variables are listed and classified, but usually that's it. Perhaps samples aren't large enough?

Large samples of eclipsing binaries



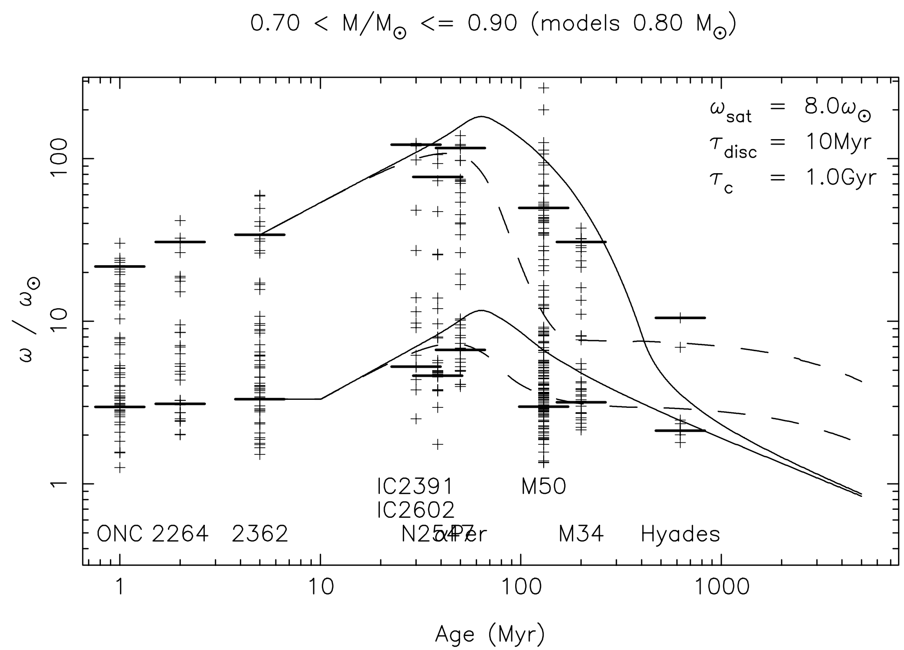
- The OGLE example
  - 1000's of new EBs in LMC & SMC from OGLE (Wyrzykowski et al. 2003, AcA, 53, 1; 2004, AcA, 54, 1)
  - Estimate of cloud distance from subset with spectroscopic solution (Harries et al. 2003, MNRAS, 339, 157); Hilditch et al. 2005, MNRAS, 357, 304)
  - Period distribution: test of formation and dynamical evolution models (Mazeh et al. 2006, Ap&SS, 304, 343)
- Huge potential in large area transit surveys
  - Constrain multiplicity properties of low-mass stars (Pinfield 2005, PASP, 117, 173)
  - Use relative numbers of different types of EBs for Galactic population studies and to constrain formation models (Willem et al. 2006, MNRAS, 367, 1103)
  - But requires dedicated EB searches

Large samples of rotation periods



e.g. Monitor

(Irwin et al. 2006, MNRAS, 370, 954; 2007, MNRAS, 377, 741)

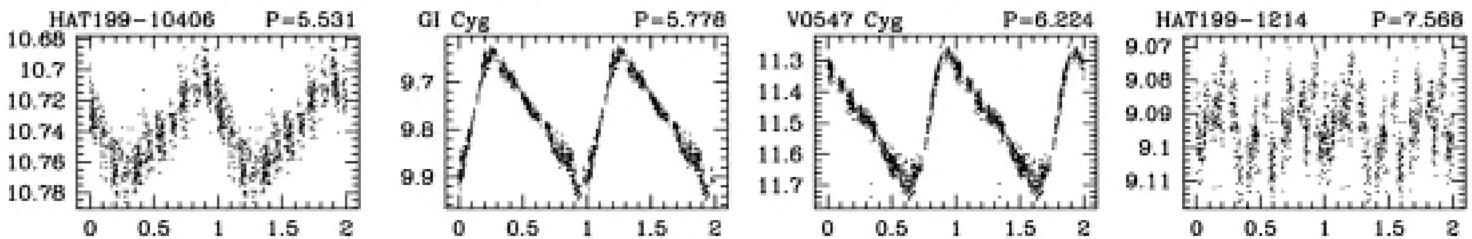


Both solid body and differentially rotating models are needed to explain evolution across full range of rotation rates in a given mass range.

Models now need constraining at older ages (those targeted by most cluster transit surveys) as well as the very earliest phases of evolution.

Pulsating stars

Pulsating variables in the Kepler field (Hartman et al. 2005)



- Standard candles (RR Lyrae, Cepheids)
  - Lead impact for Galactic structure studies
- Tests of stellar evolution across the HR diagram
- Very much under-exploited in ground-based surveys
- Significant increase in potential from space
  - lower amplitude, chart long term evolution (e.g. mode stability/period drifts)
  - new / emerging classes of pulsators (white & brown dwarfs, PMS pulsators)

Ancillary science publications from ground-based transit search projects - III

- Moving objects and transients
    - SuperWASP: Parley et al. (2006, EM&P, 97, 261)
- Exploiting exisiting catalogs
    - SuperWASP + ROSAT: Norton et al. (2007, A&A, 467, 785)

Transients and moving objects

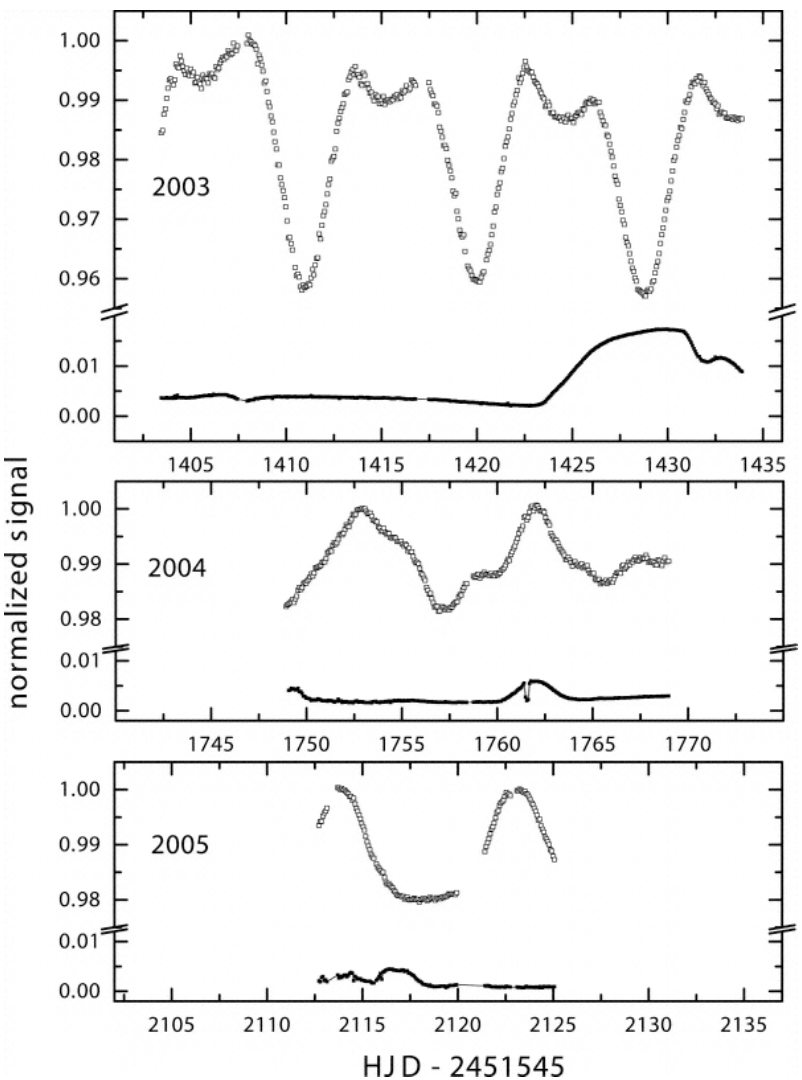
- Detected on some images and not on others
  - Pipeline and archive must be designed with these in mind
- Degree of interest correlated with degree of difficulty
  - previously known transits (e.g. supernovae) or moving objects (e.g. asteroids: Parley et al. 2006)
  - unambiguous new transients (e.g dwarf novae)
  - fast transients (e.g. GRBs) or new moving objects (e.g. asteroids & KBOs)

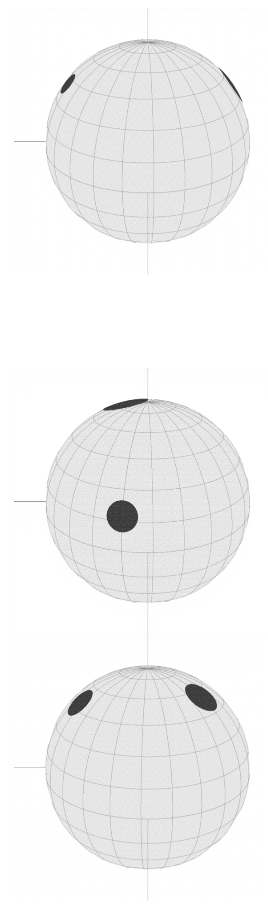
From space

- Bigger and Better
  - Much higher precision
  - More continuous time sampling
  - Longer baselines
- New types of variability
  - Many new types of pulsators
  - Micro-variability in normal stars
- More precise characterisation of "normal" variables
- Large samples with uniform photometric properties
  - Need large effort to parametrise the stars systematically
- Precursor missions like MOST and WIRE are showing now on a few stars some of what will soon be possible on 1000s

Differential rotation with MOST

G5V star κ^1 Ceti (Rucinski et al. 2004, PASP, 116, 1093; Walker et al. 2007, ApJ, 659, 1611)



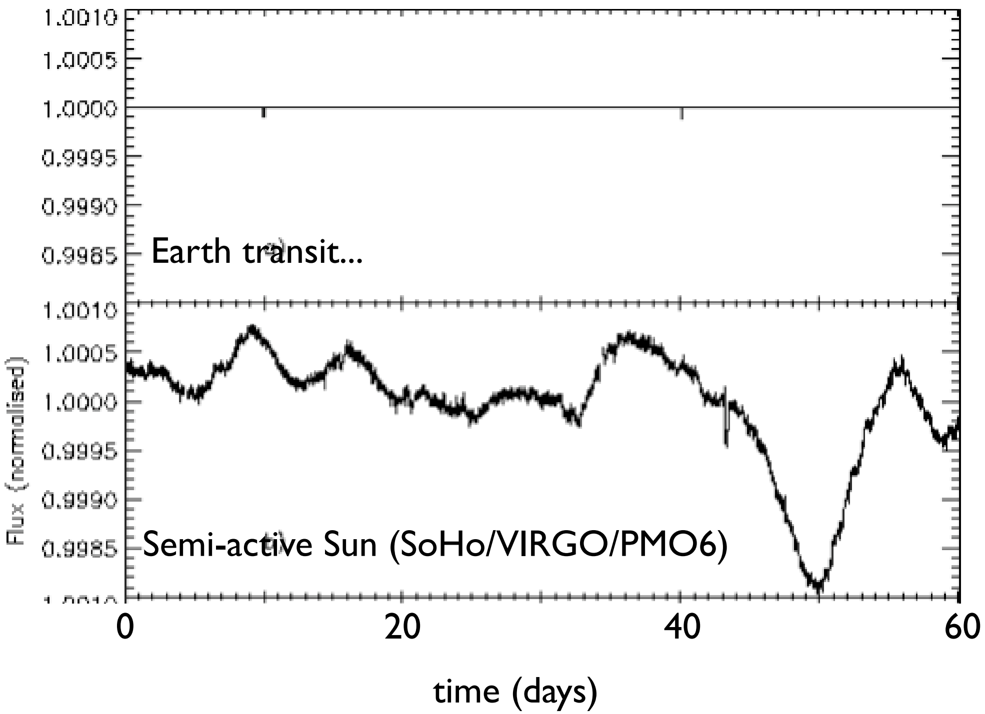


Pattern of differential rotation is close to solar.

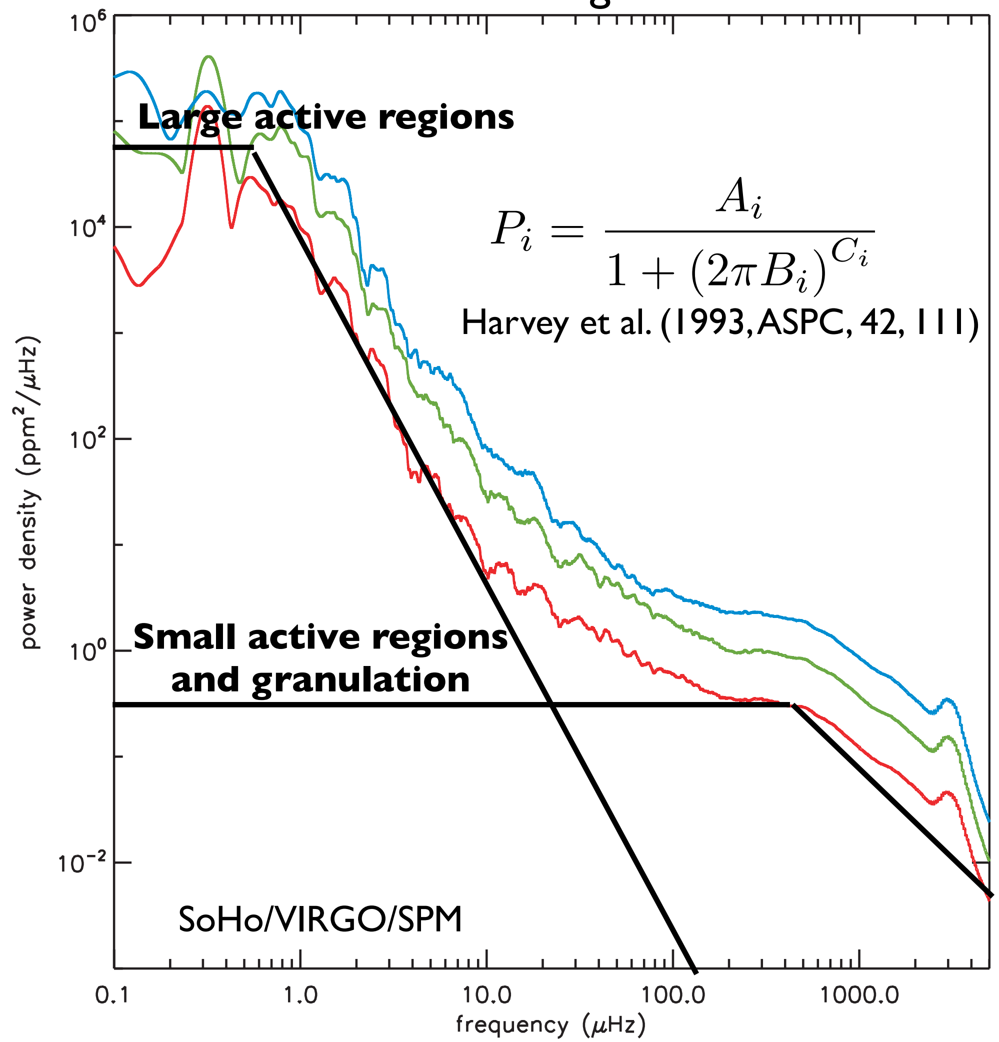
See also ϵ Eri (Croll et al. 2006, ApJ, 648, 607)

Light curve modelling yields accurate differential rotation pattern and spot properties (Lanza et al. 2007, A&A, 464, 741L: modelling of solar TSI and comparison to magnetograms)

Stellar micro-variability



The "solar background"



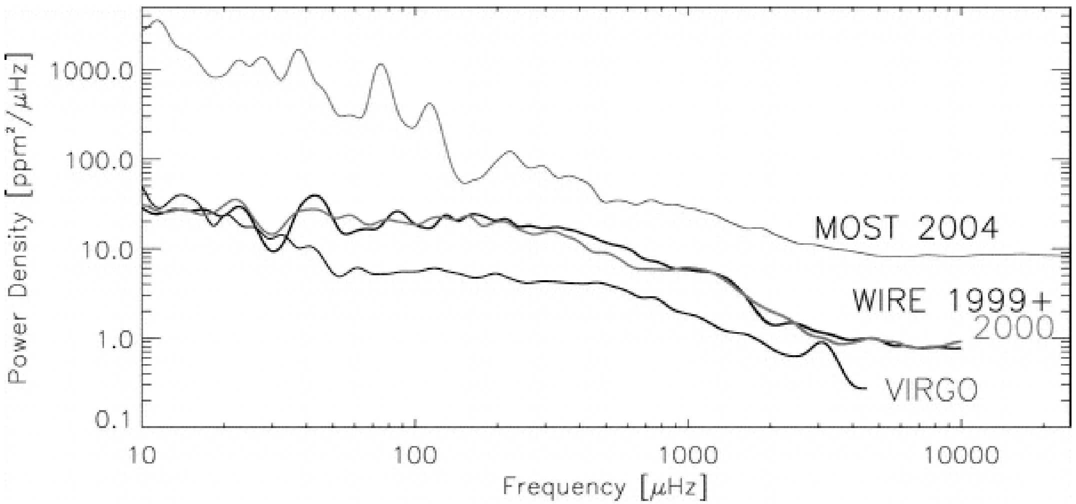
Low-amplitude variations due to intrinsic evolution and rotational modulation of magnetic and convective surface structures.

Major noise source - and scientific bonus - for space-based transit surveys

Use activity proxies to scale to other stars

(Aigrain et al. 2004, A&A, 414, 1139; Lanza et al. 2006, AN, 327, 21L)

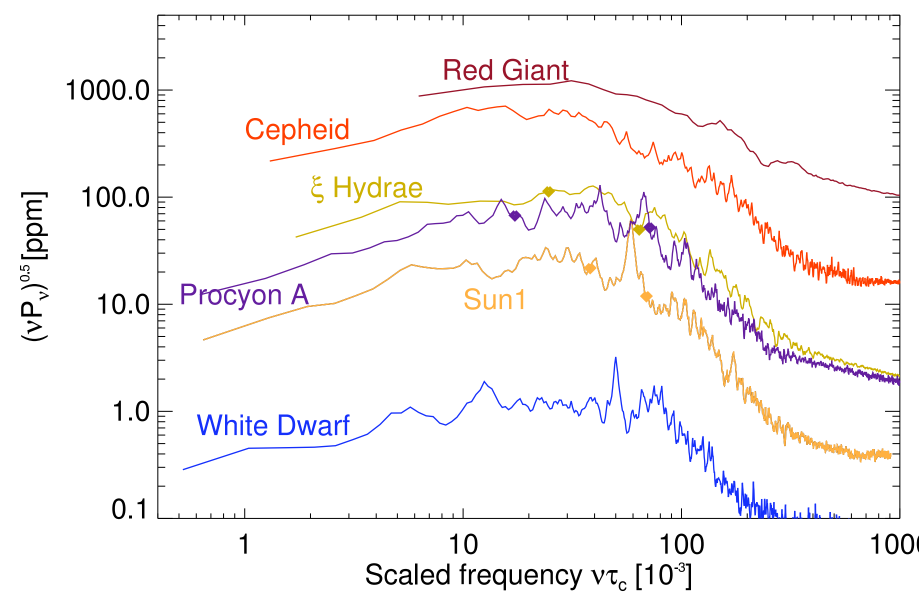
Granulation with WIRE



Granulation power in Procyon is ~3x that in Sun (Bruntt et al. 2005, ApJ, 633, 440)

Controversy over detection of oscillations (cf. MOST, Matthews et al. 2004, Nature, 430, 51L) highlights the analysis is delicate.

3-D simulations (Freitag et al. 2001 ASPC, 223, 785; Svensson et al. 2005, ESA SP-560, 979) are starting to predict dependence of granulation power and time-scale on stellar parameters, in particular log g, T_{eff}, [Fe/H]



The CoRoT Additional Program

- The additional program means
  - Any science except transiting planets in the exoplanet fields or seismology in the seismology fields
  - Use core program data or request specific targets (easy) / runs (hard)
- Yearly AO
  - open to anyone from countries contributing to CoRoT or ESA member states
  - next AO for 2nd year of operations in Autumn 2007
- Examples from 1st AO include
  - EBs and cataclysmic variables
  - Pulsating stars to rare or faint for seismology core program
  - Micro-variability and rotation
  - Search for reflected light by non-transiting planets
  - Dedicate run on star-forming region
  - ...

Sneak preview from first CoRoT data...

Images to be inserted later