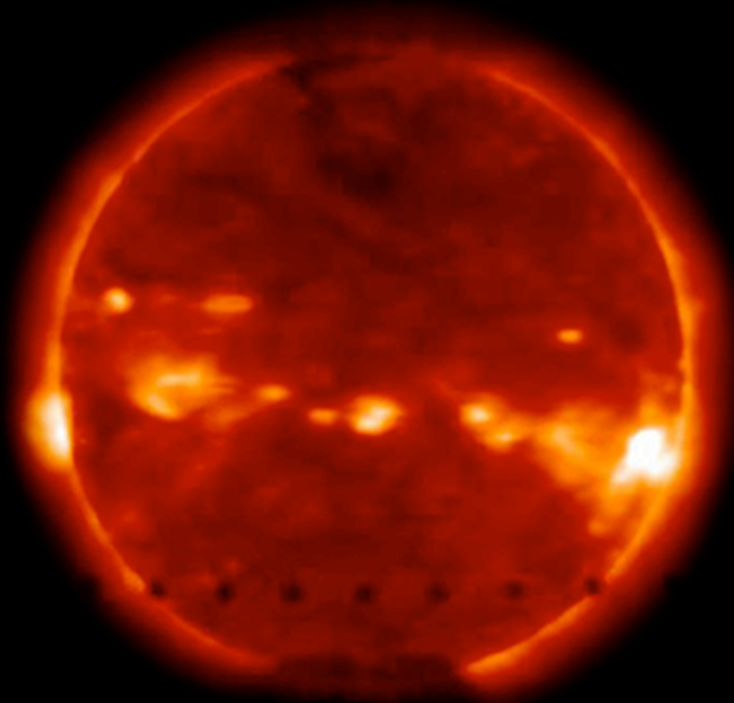
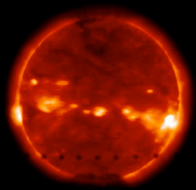
Modelling stellar micro-variability



S. Aigrain (IoA, Cambridge)
F. Favata (ESA/ESTEC), G. Gilmore (IoA, Cambridge)

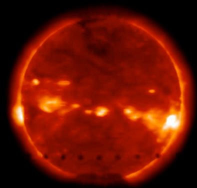
2nd CoRoT Brasil Meeting, Ubatuba, 11/05

Image: GOES-12 / SXI composite of Venus 2004 transit

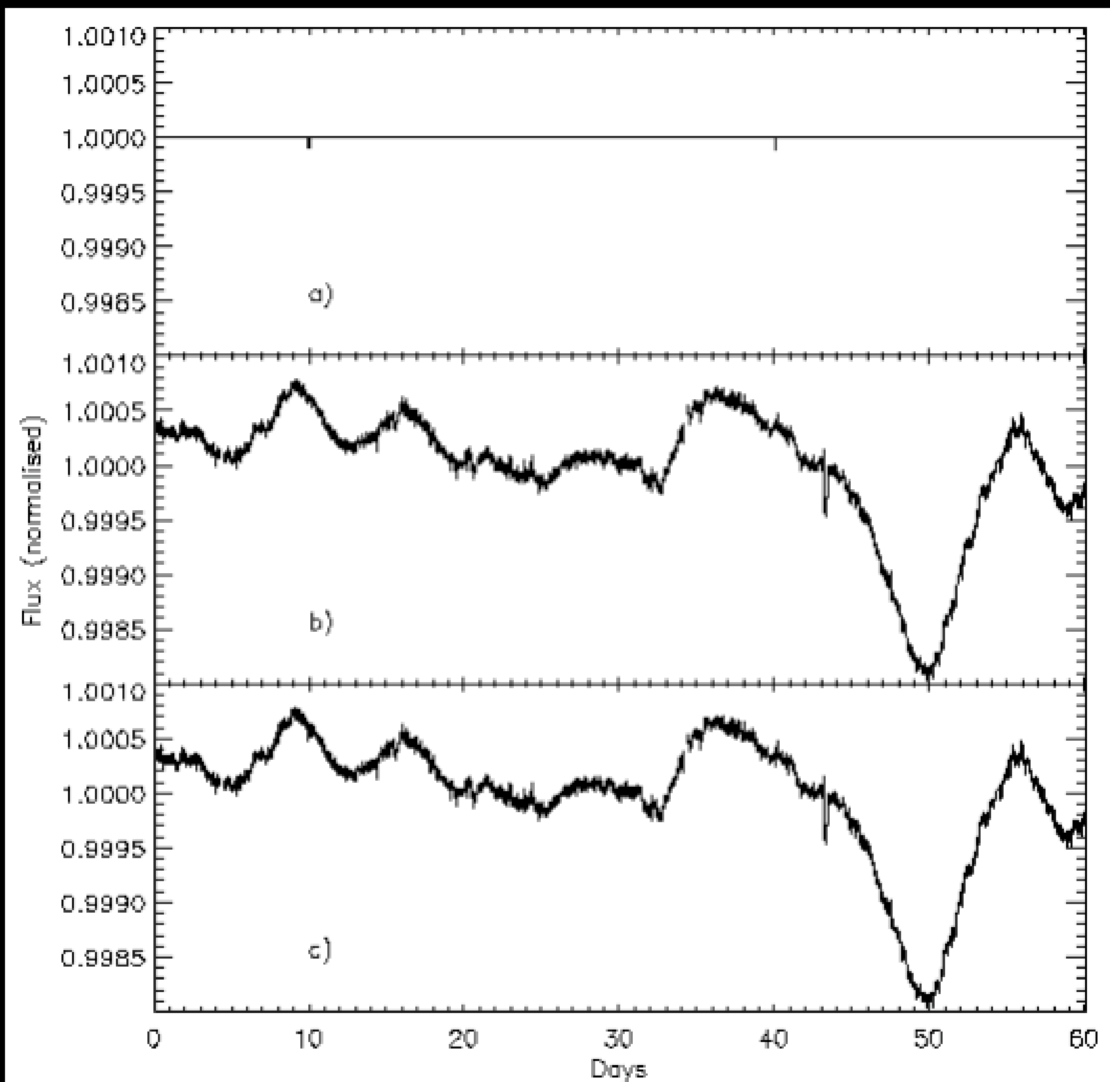


Outline

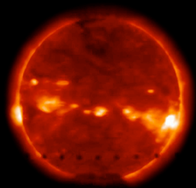
- Motivation in the context of CoRoT
- Modelling the solar background
- Rotational modulation model of Lanza et al.
- SIMLC: stochastic micro-variability model
- Understanding the chromaticity of Sun-like variations
- Summary



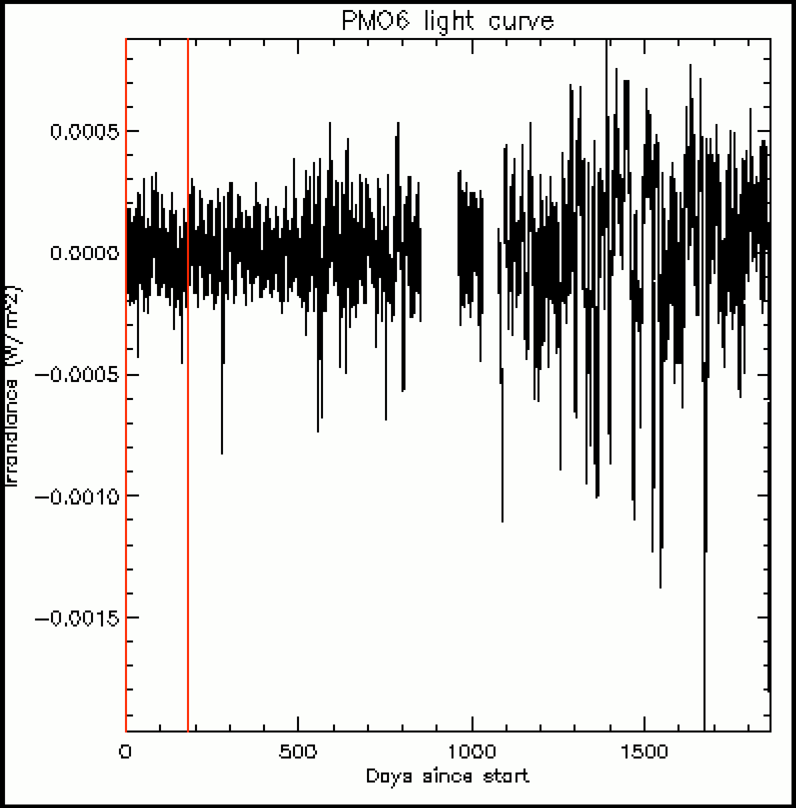
Motivation



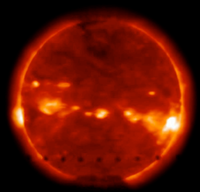
- need to find transits in the presence of variability
- one man's noise is another's signal - understand variability
- want tool to simulate light curves for stars of various temperatures and activity levels



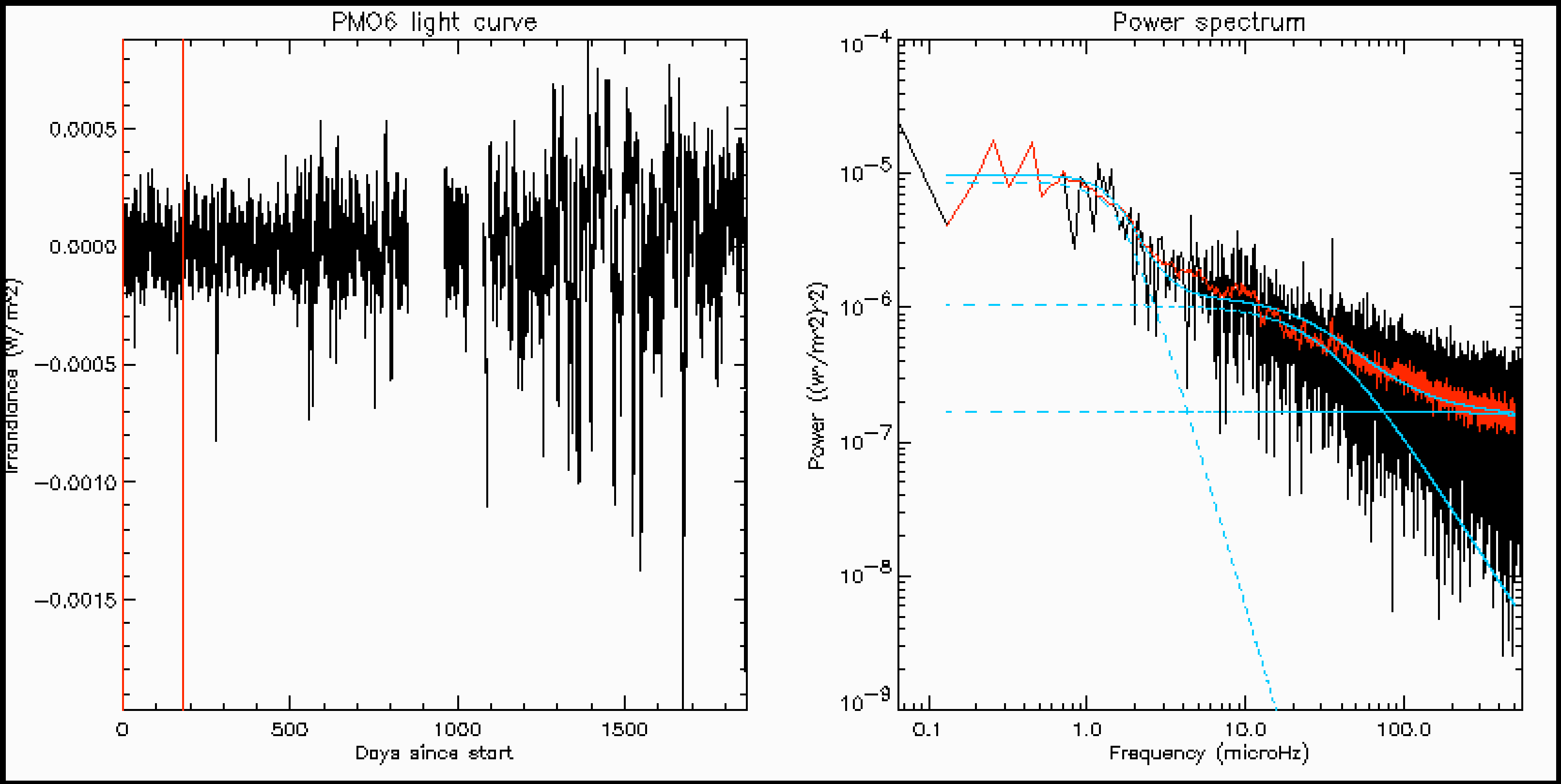
Solar irradiance variations



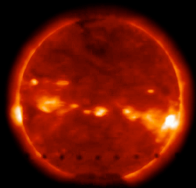
- VIRGO onboard SoHO:
  - PMO6 / DIARAD: total irradiance;
  - SPM: three narrow channels;
  - from activity minimum to maximum.
- No other star to date has been observed so regularly, for so long and to such a high degree of precision.



Solar irradiance variations

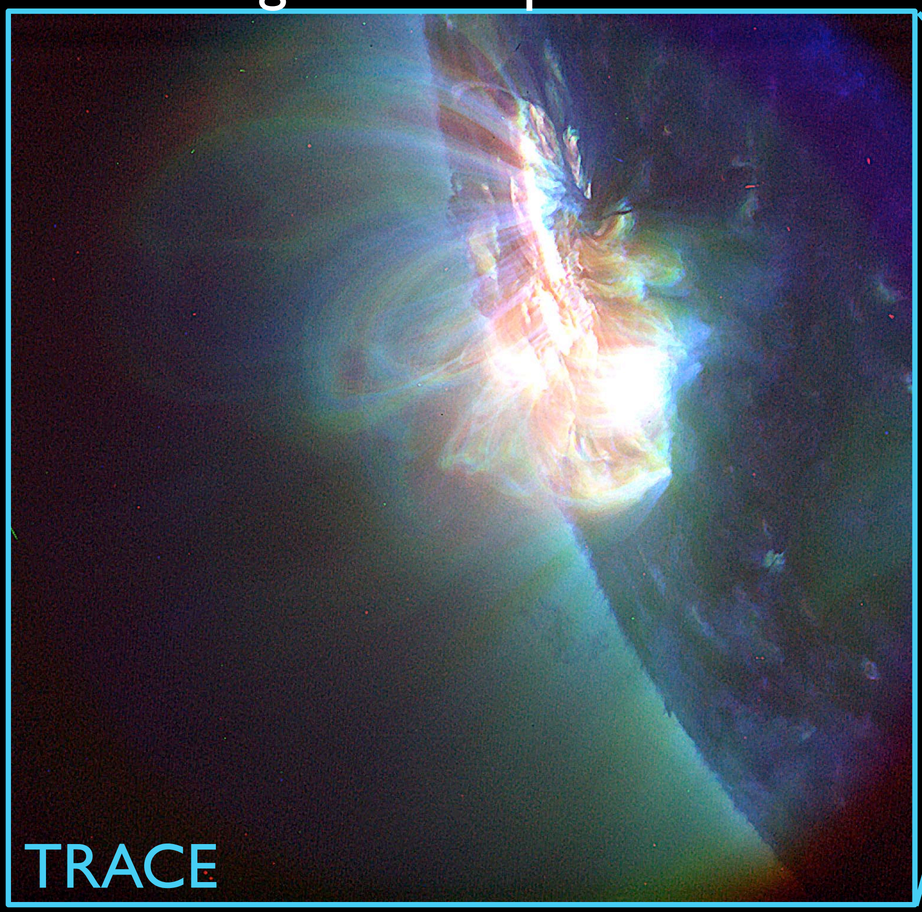


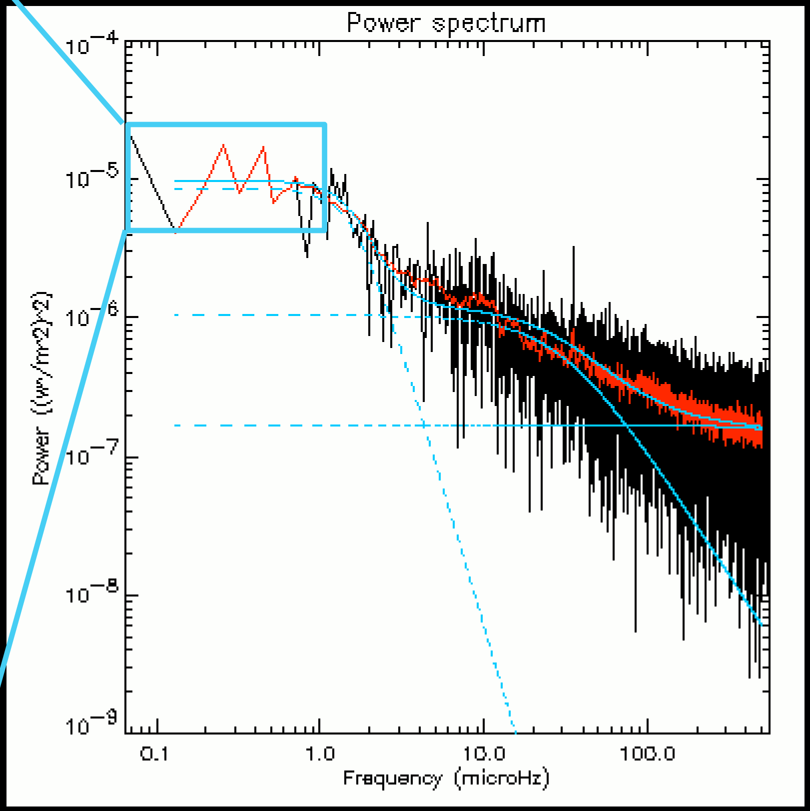
model power spectrum as: $$P(\nu) = \sum_i \frac{A_i}{1 + (2\pi B_i)^{C_i}}$$ (Harvey 1985, Harvey et al. 1993)

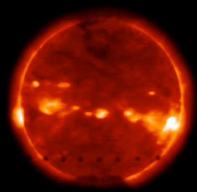


Solar irradiance variations

active regions component







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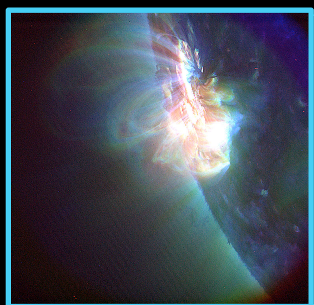
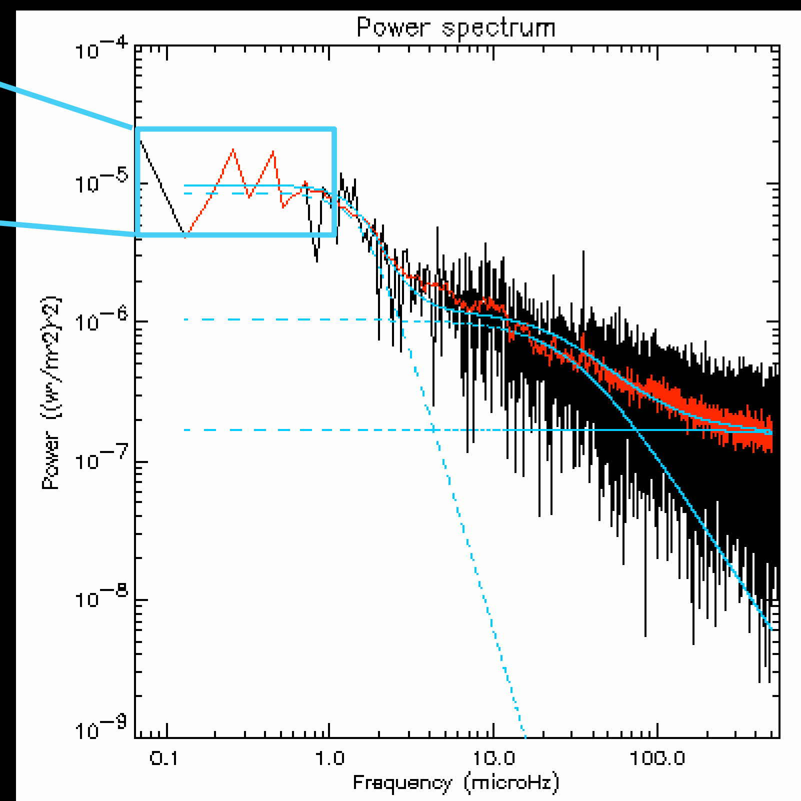
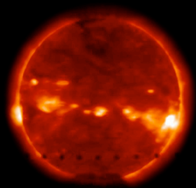




- active regions:
  - timescales > few days;
  - amplitudes ~ 0.0005 mag;
  - combined effect of (bright) faculae and (dark) spots;
  - due to rotational modulation and intrinsic variations.



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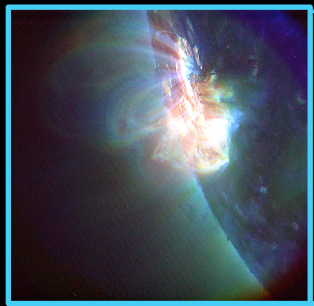
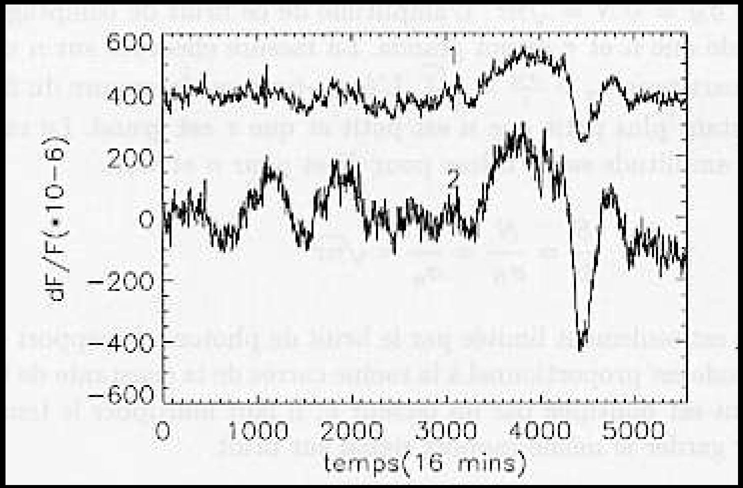
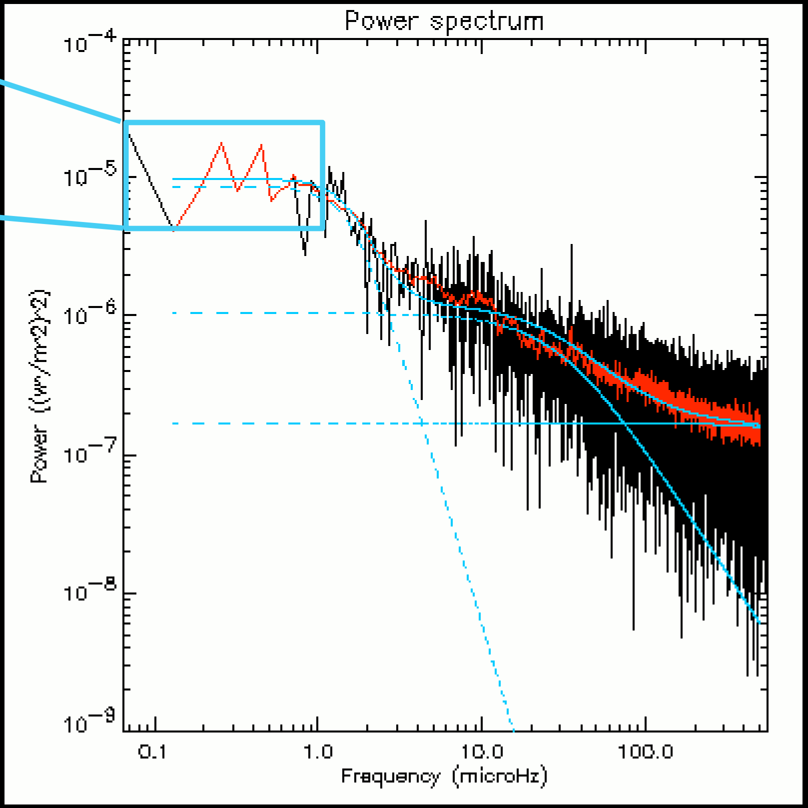
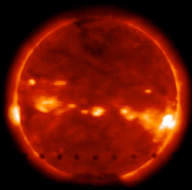


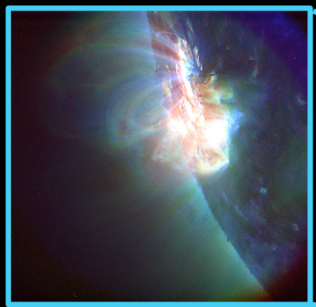
- active regions:
  - stronger effect at blue wavelengths



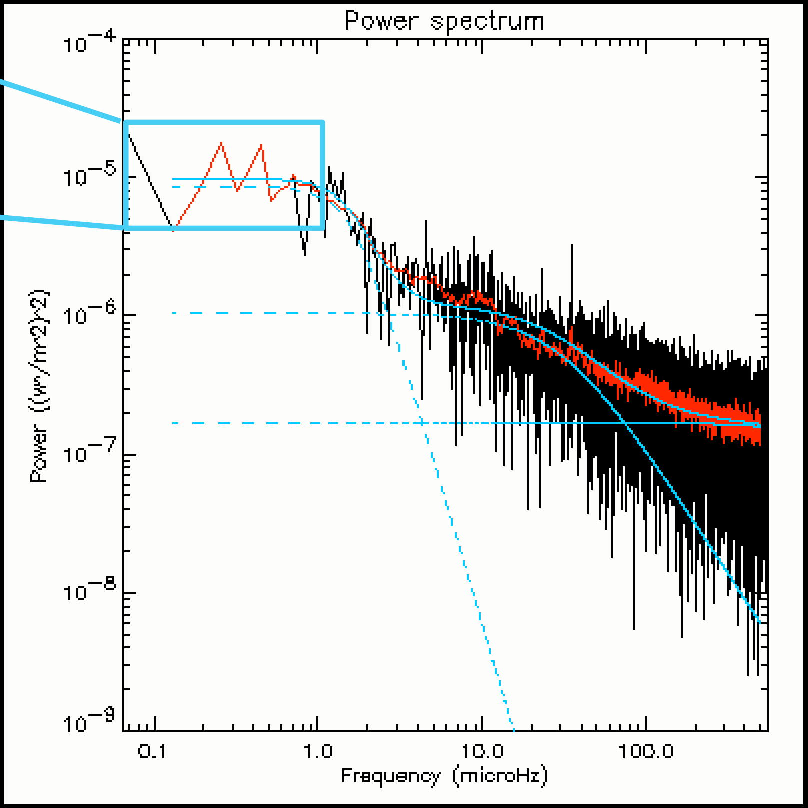


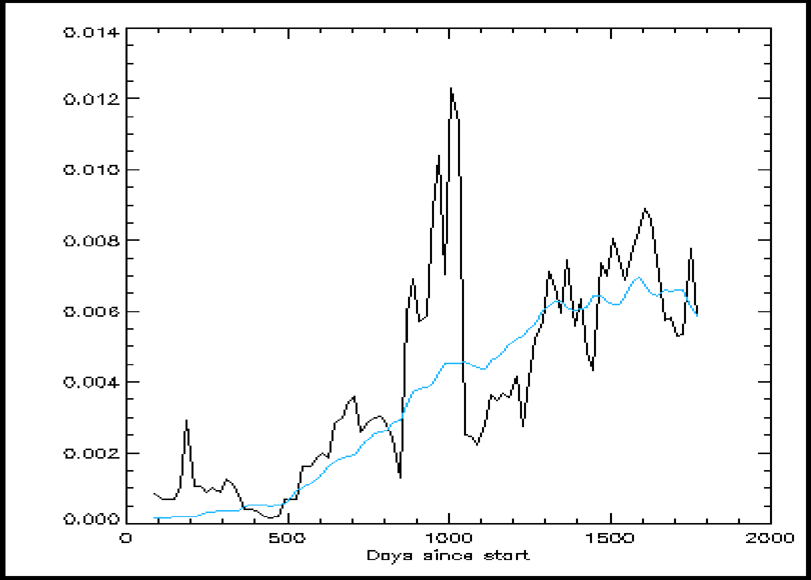


Solar irradiance variations



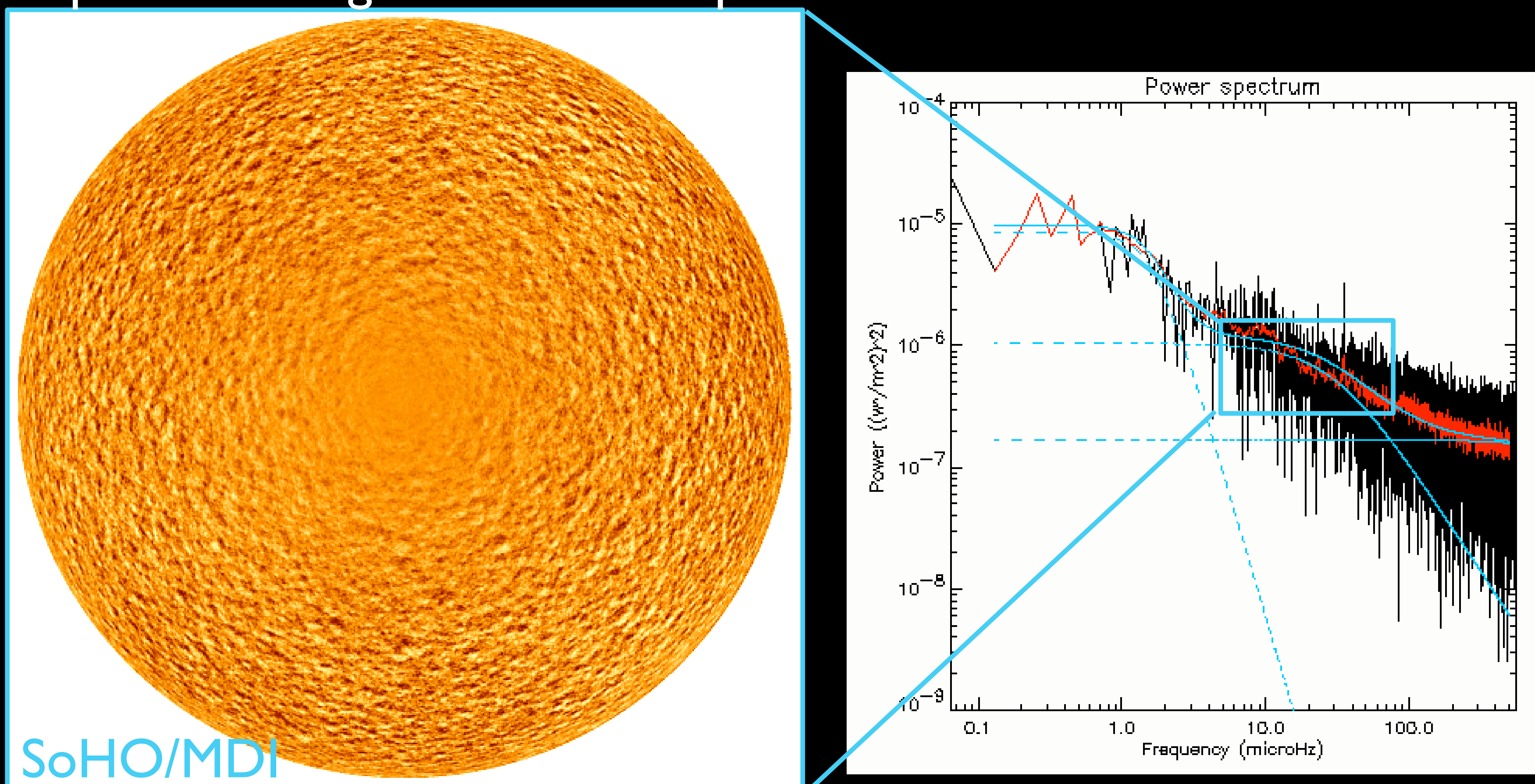
- active regions:
  - amplitude correlated with activity

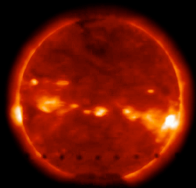




Solar irradiance variations

super- / meso-granulation component





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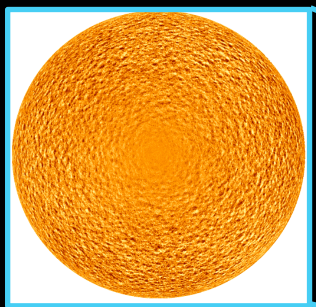
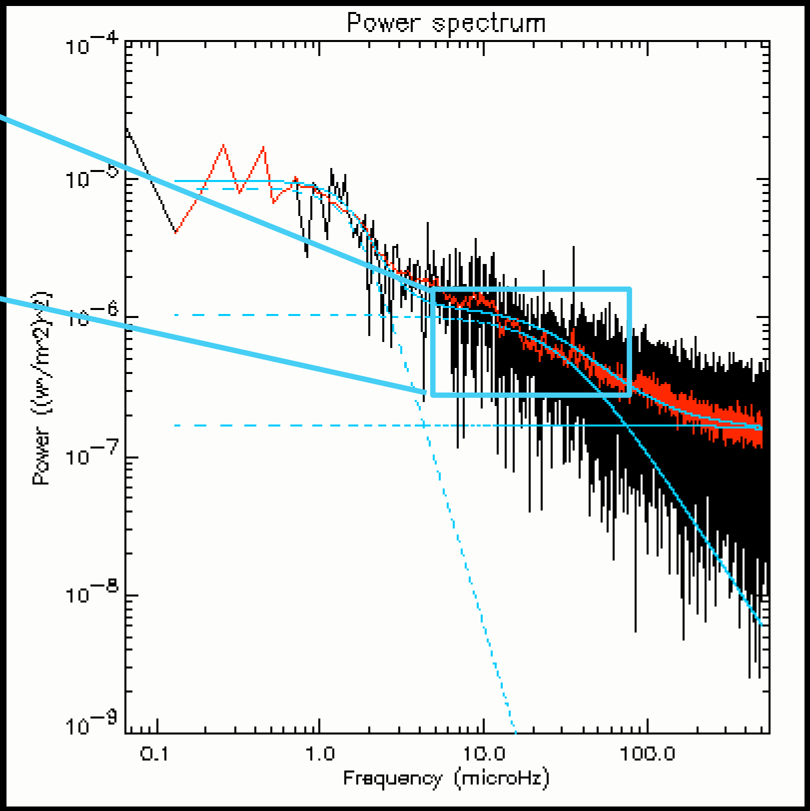
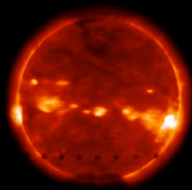
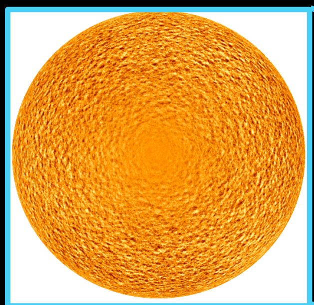


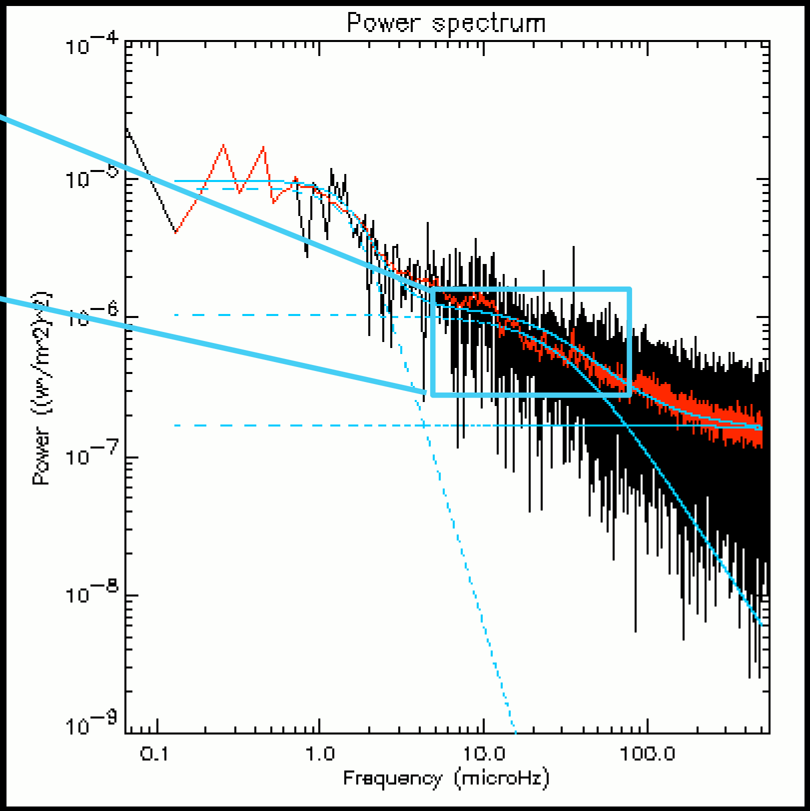
- super- / meso-granulation:
  - timescales of hours
  - close to transit duration
  - cause?





Solar irradiance variations





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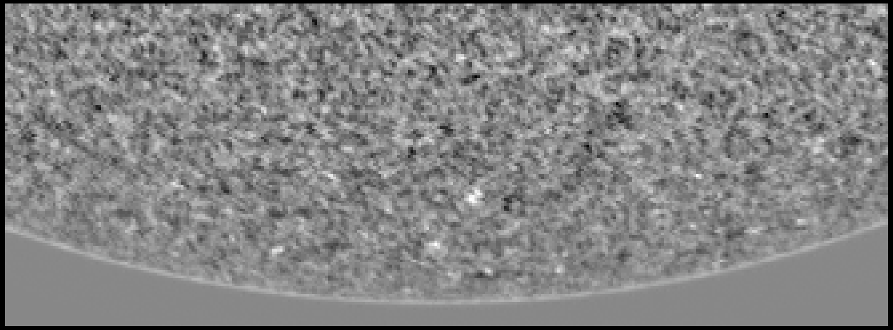
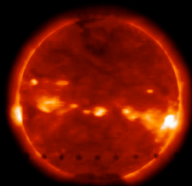
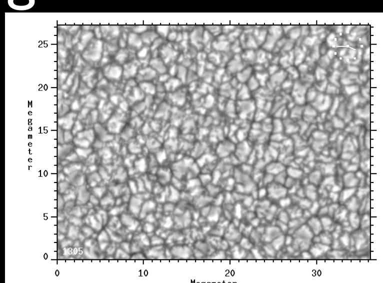


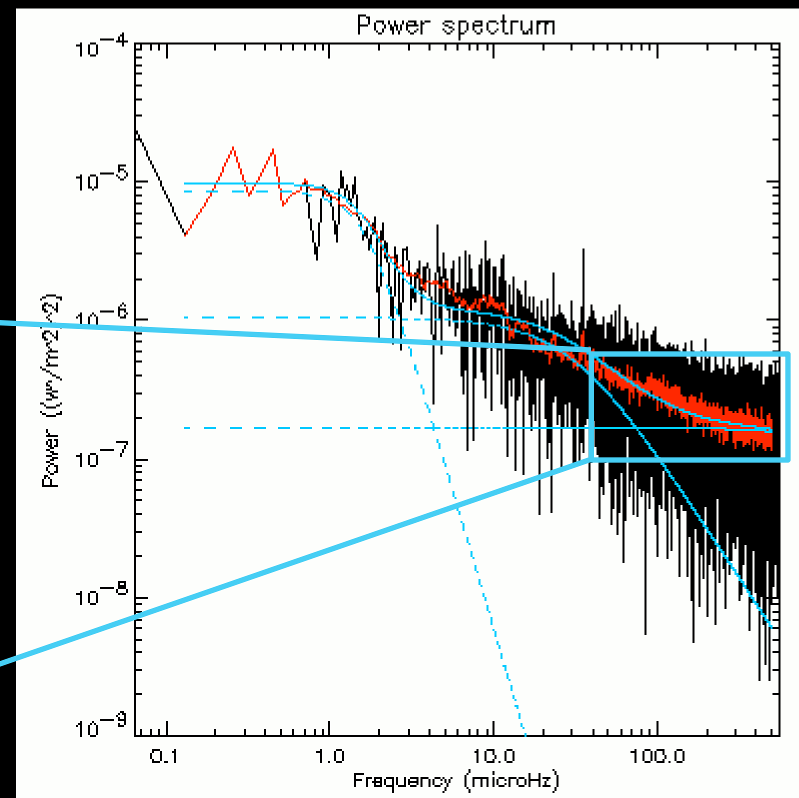


Solar irradiance variations

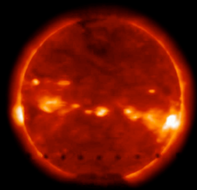
granulation

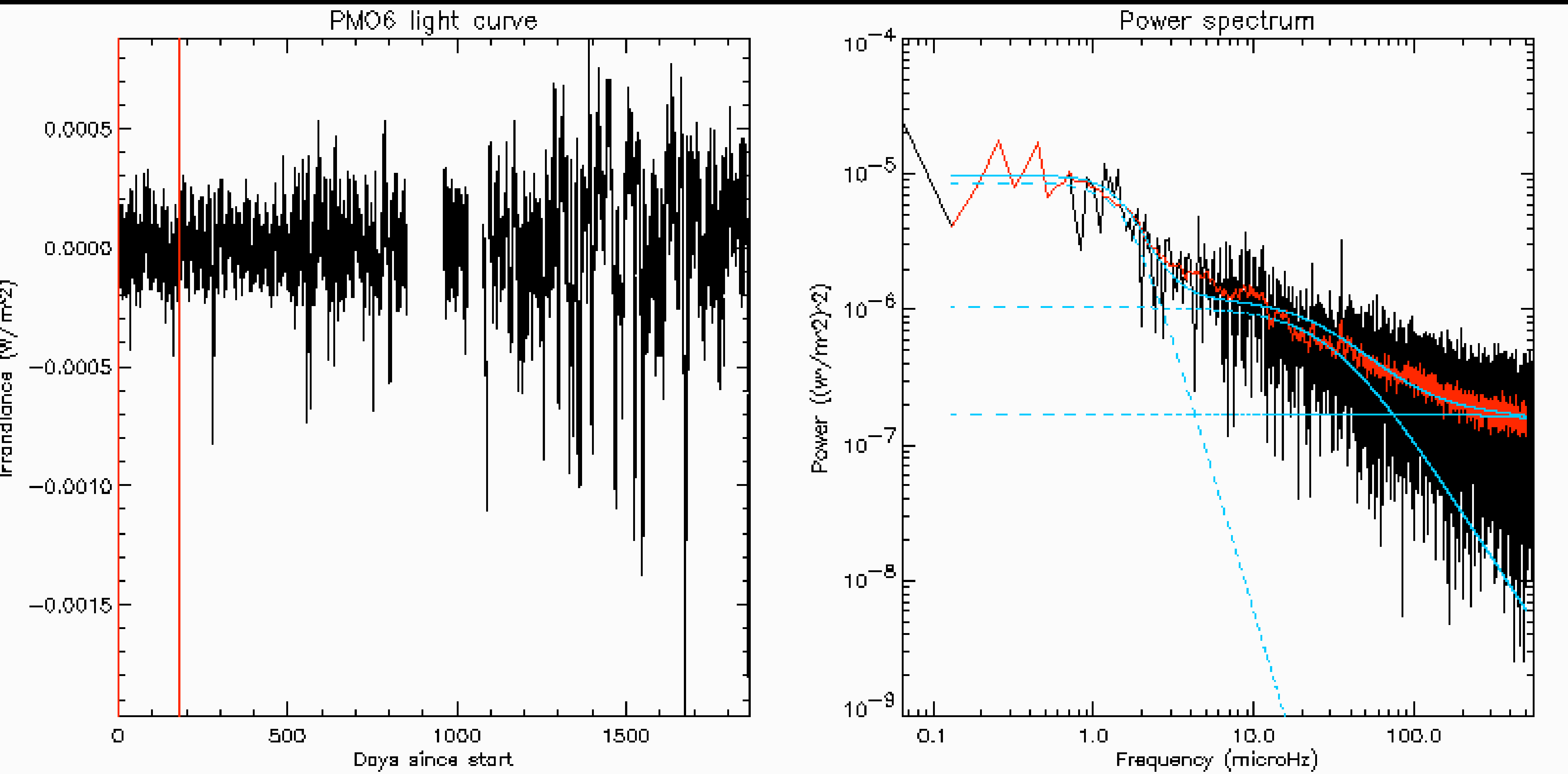


plus:
oscillations,
photon noise...



Evolution with activity





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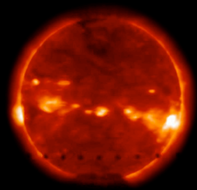
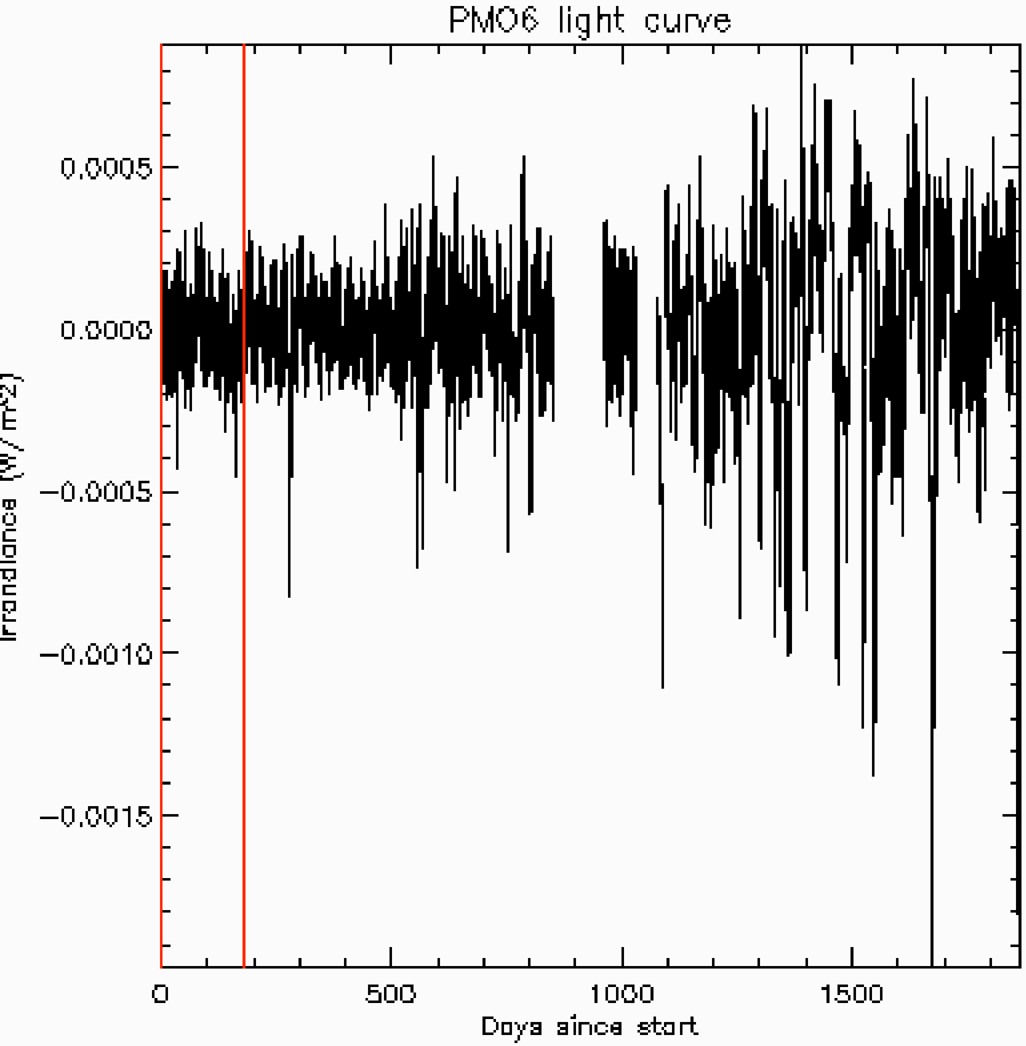
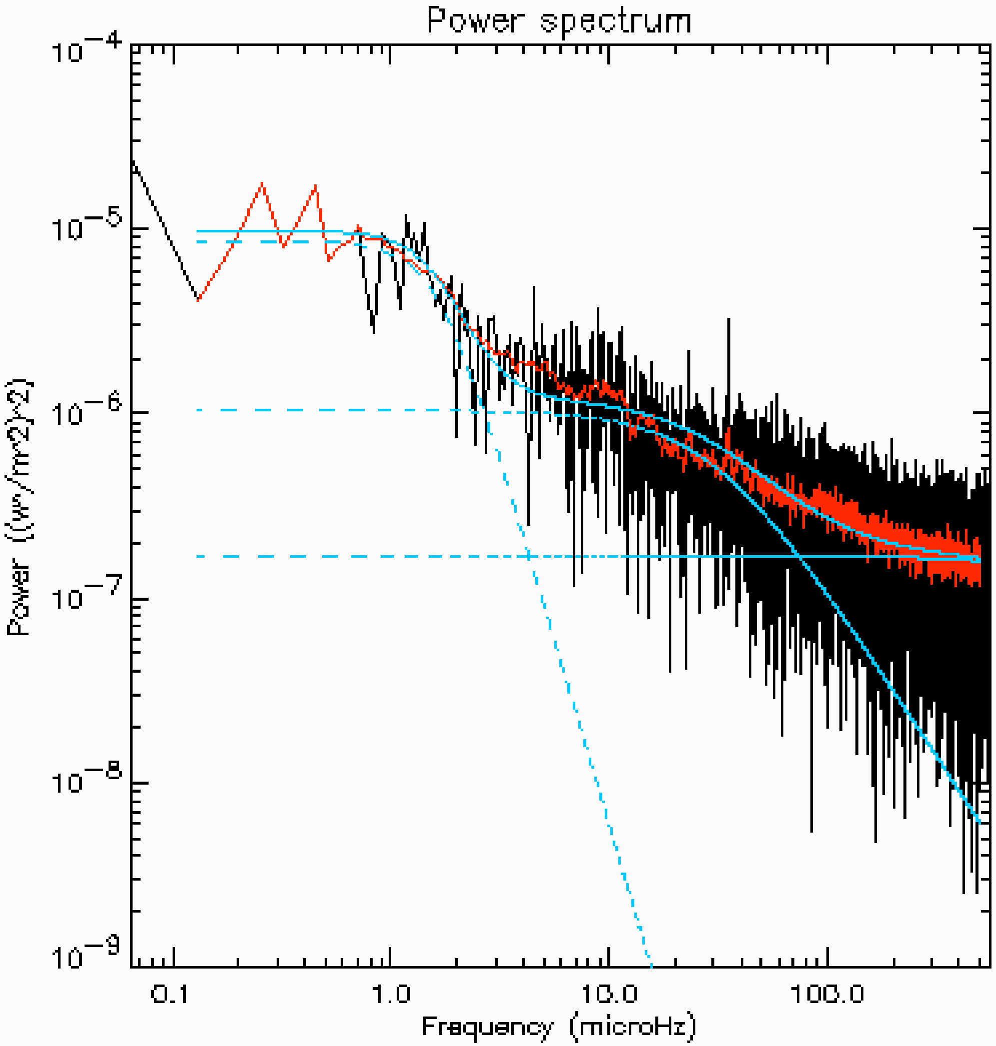
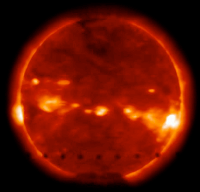




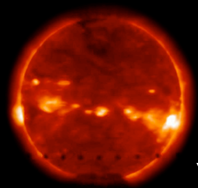




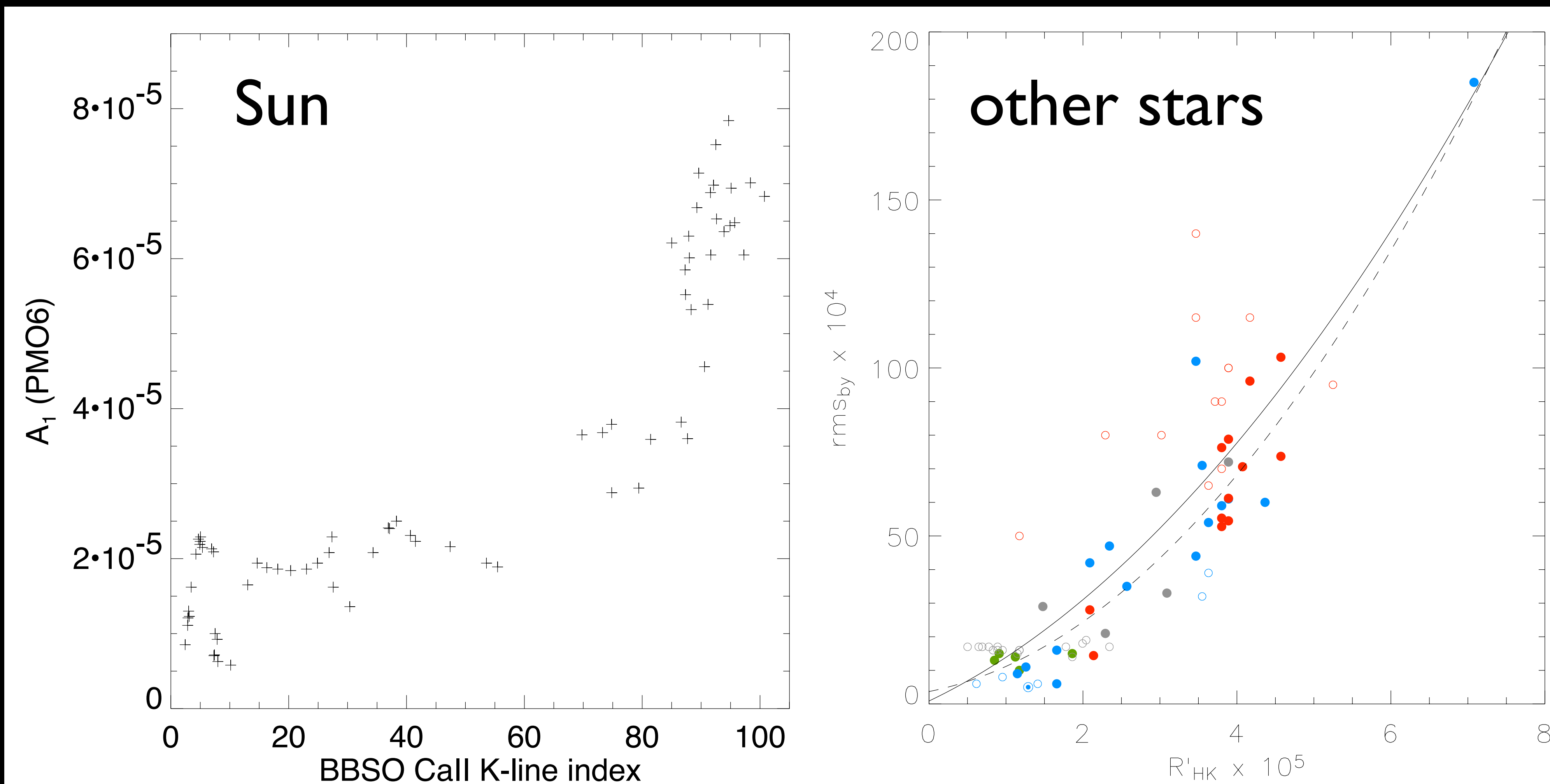
SIMLC: a stochastic micro-variability simulator

(Aigrain, Favata & Gilmore 2004 A&A 414 1139, updated version in prep.)

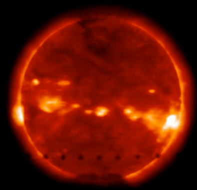
- start from the Sun:
  - model power spectrum of total irradiance variations;
  - follow changes with activity level.
- scale amplitude spectrum model to other star by using:
  - activity / variability correlation from Sun + some other stars;
  - existing scaling laws relating rotation period, colour and activity (Noyes et al. 1984);
  - initial colour / rotation period calibration in Hyades;
  - spin-down law to relate rotation period to age.
- convert back to time domain, applying required sampling.



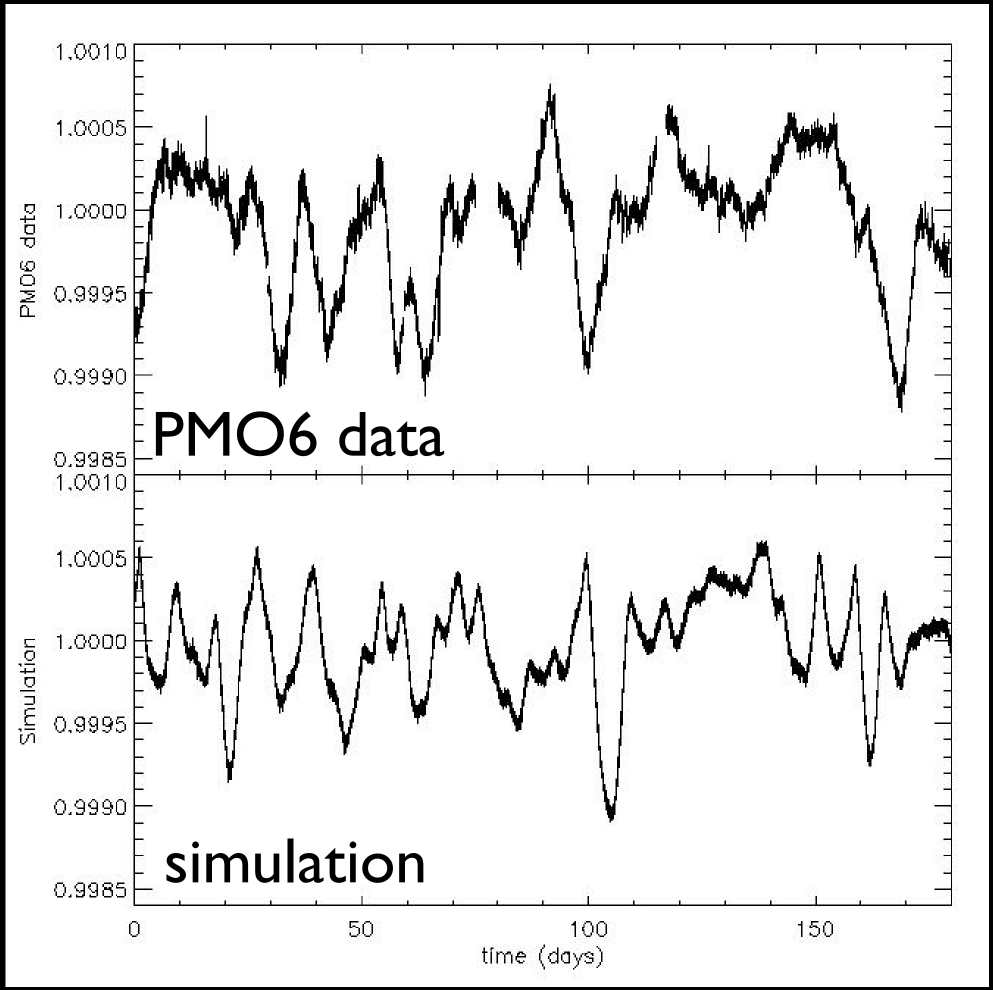
Active regions variability versus chromospheric activity

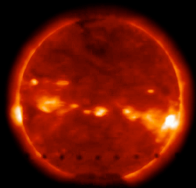


characteristic timescale scales as $B_i \sim P_{\rm rot}/3$

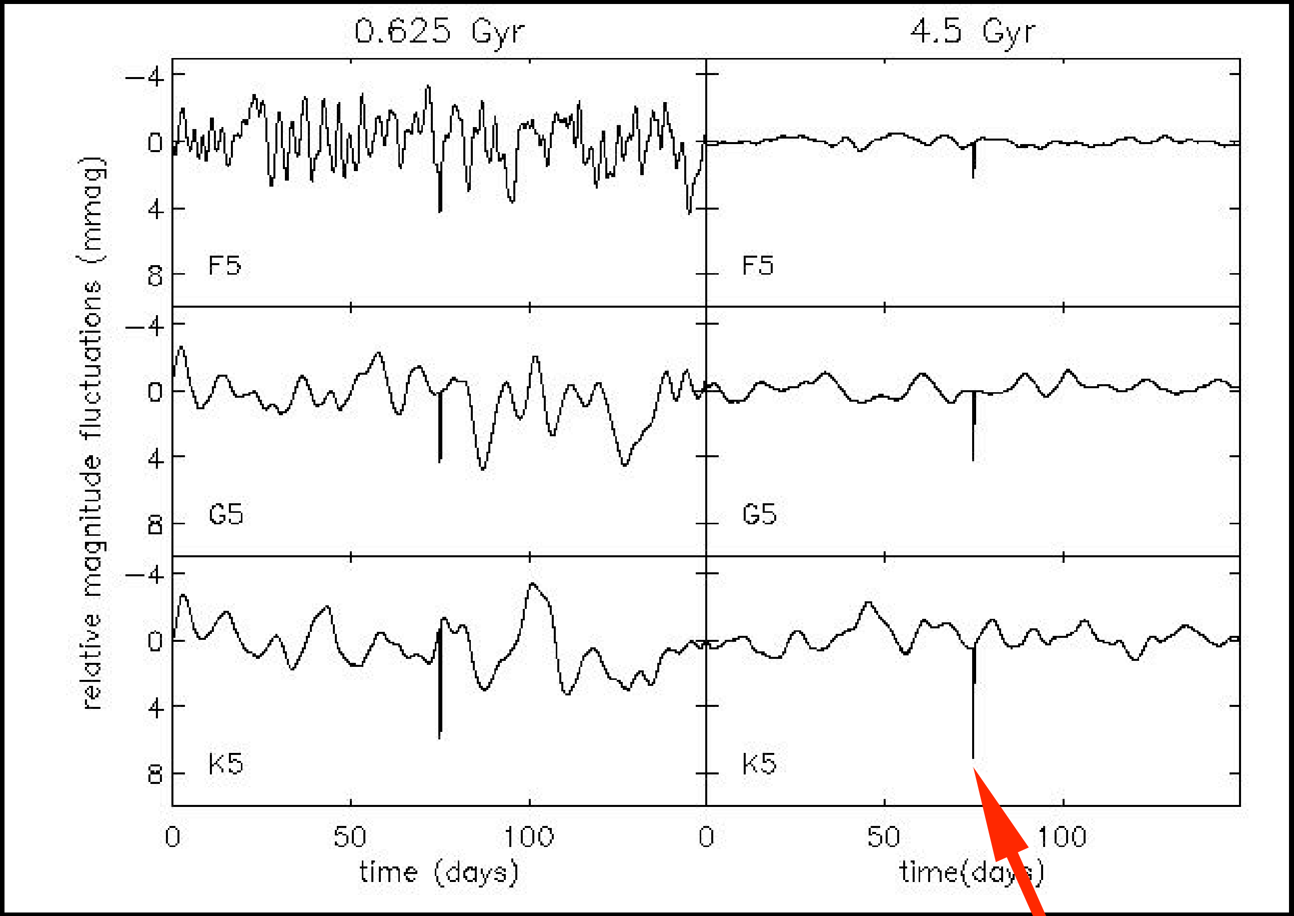


SIMLC examples: the Sun

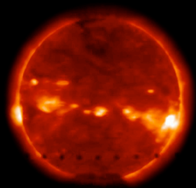




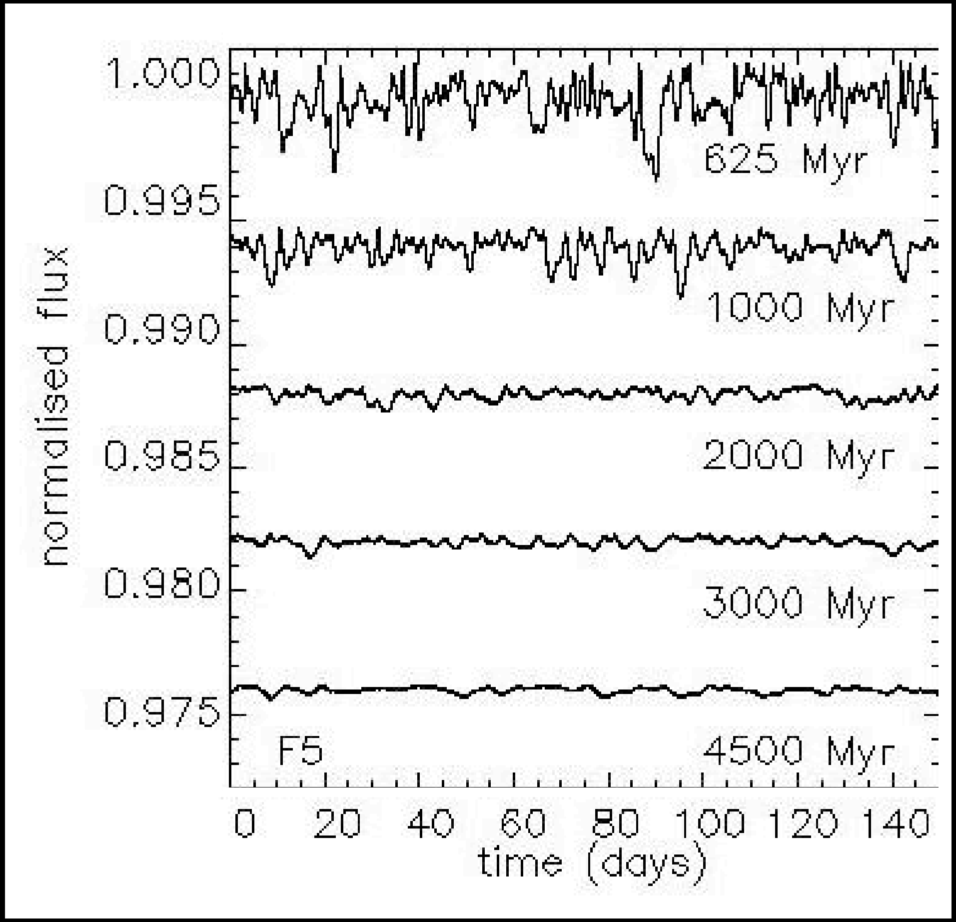
SIMLC examples: behaviour with age and spectral type

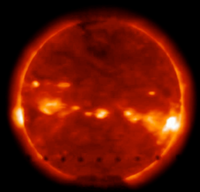


$0.5\ R_{\mathrm{Jup}}$ planet transiting across the Sun



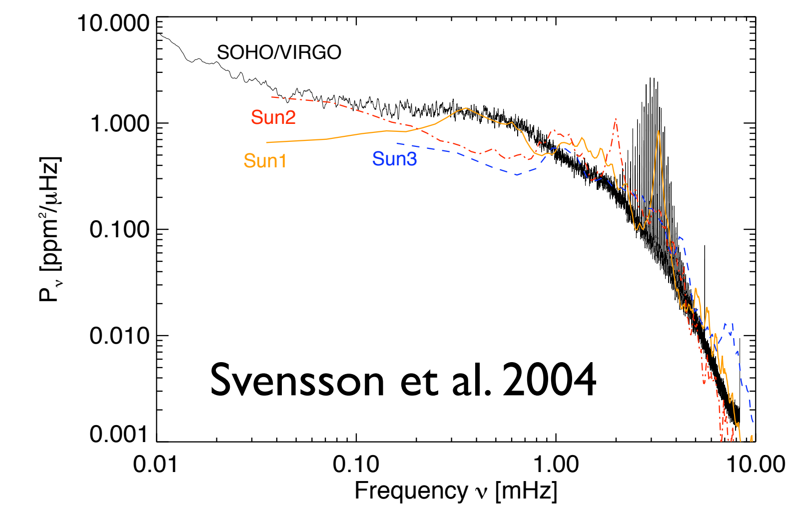
SIMLC examples: behaviour with age and spectral type

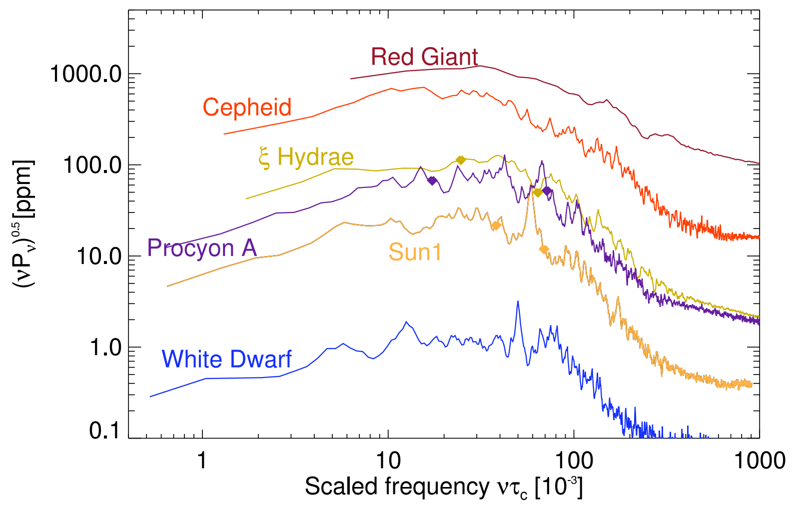




constraints on granulation

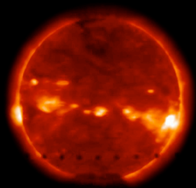
- recent modelling (Freytag et al. 2001, Seleznyov et al. at CW6, Svensson et al. 2004)
  - strong gravity dependence: log $P_{gr} \propto$ - ½ log g
  - temperature dependence
  - metallicity dependence
- observational constraints
  - RV: Kjeldsen et al. (1999): P_{gr}(αCen, G2V) ≈ P_{gr}(Sun)
  - WIRE: Bruntt et al. (2005): P_{gr}(Procyon, F5IV) ≈ 1.8 ± 0.3 × P_{gr}(Sun)
  - MOST: constraints so far elusive



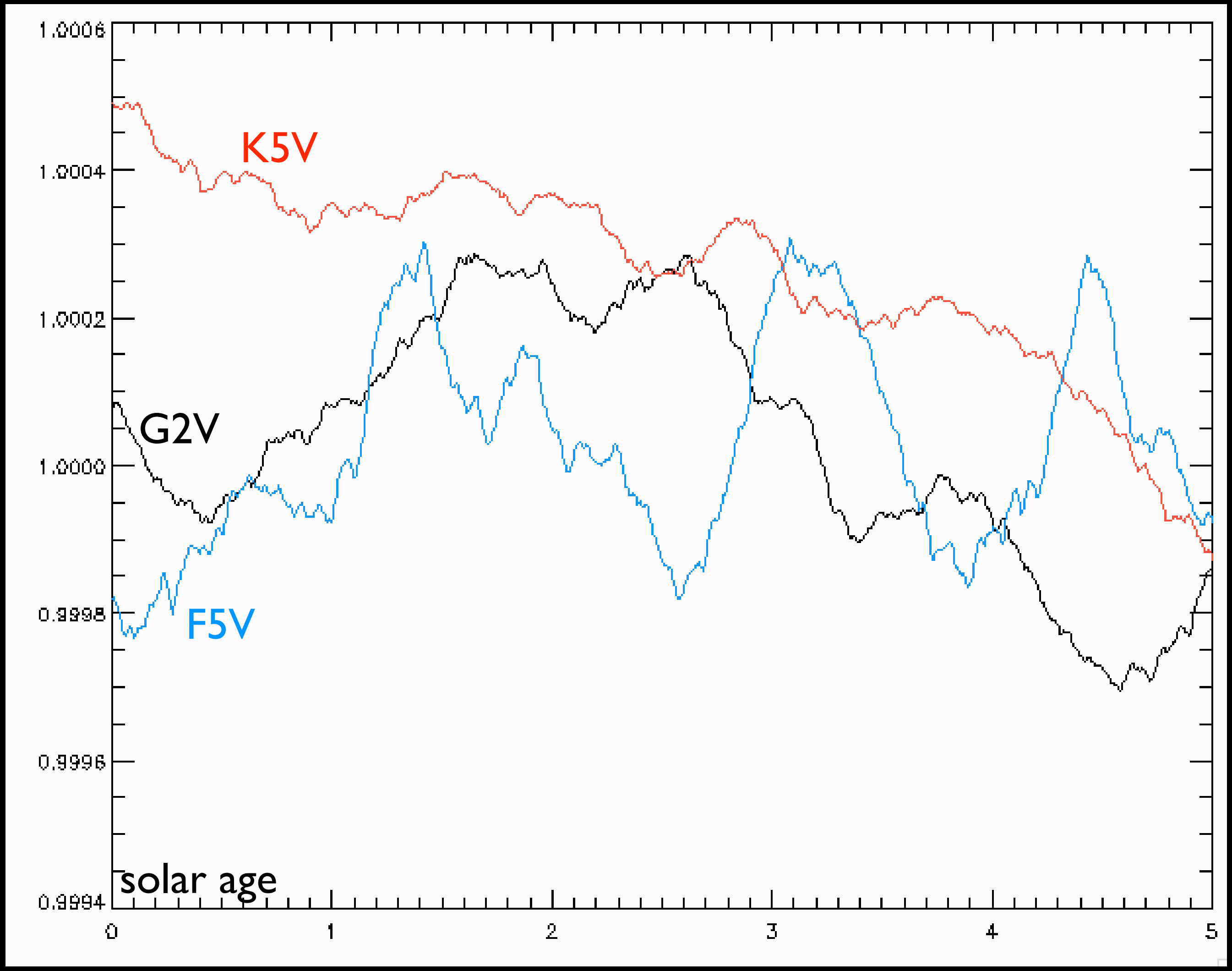


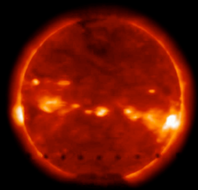
all constraints so far consistent with

$$P_{\rm gr}^2 \propto -\log g + 3\log T_{\rm eff}$$



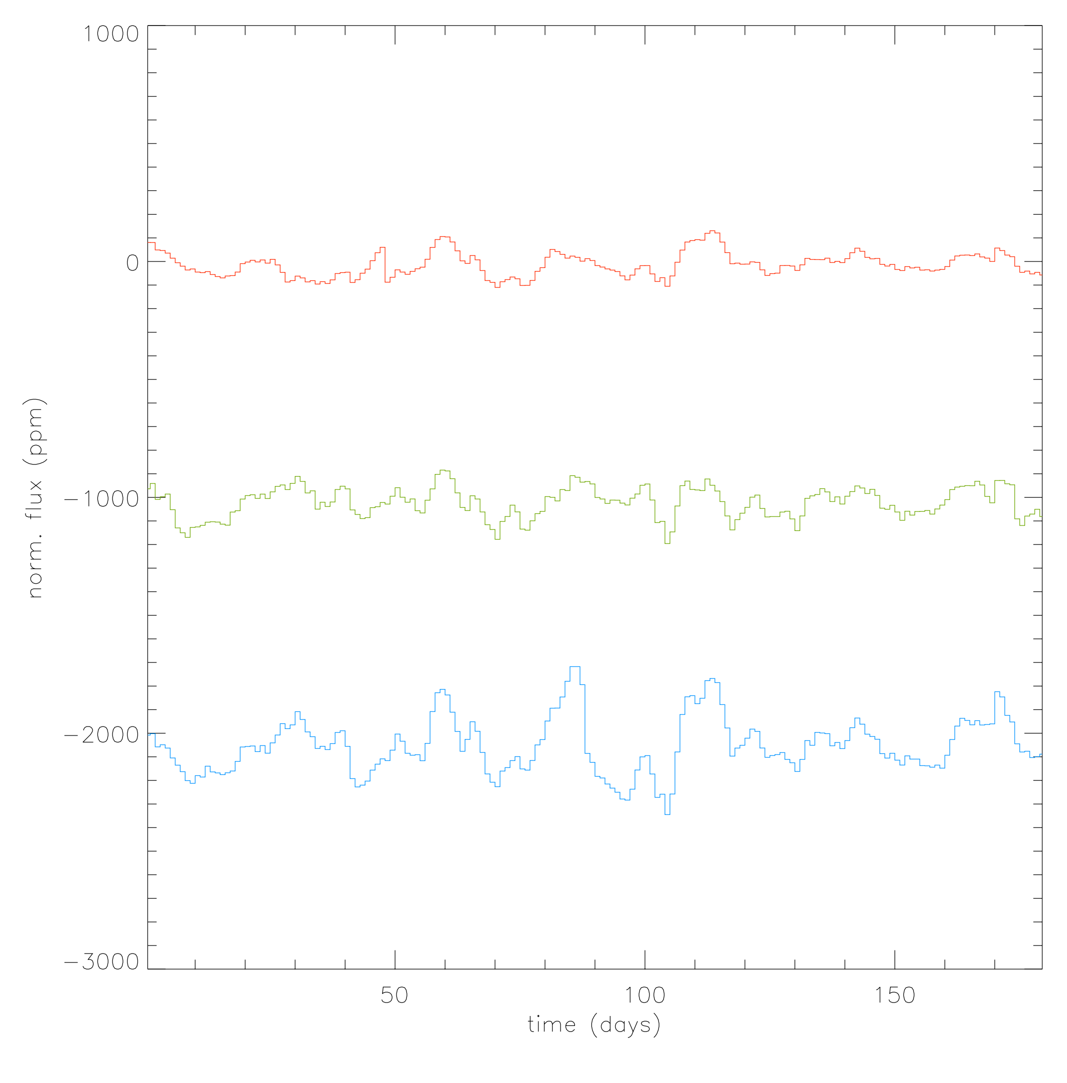
granulation - examples

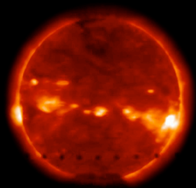




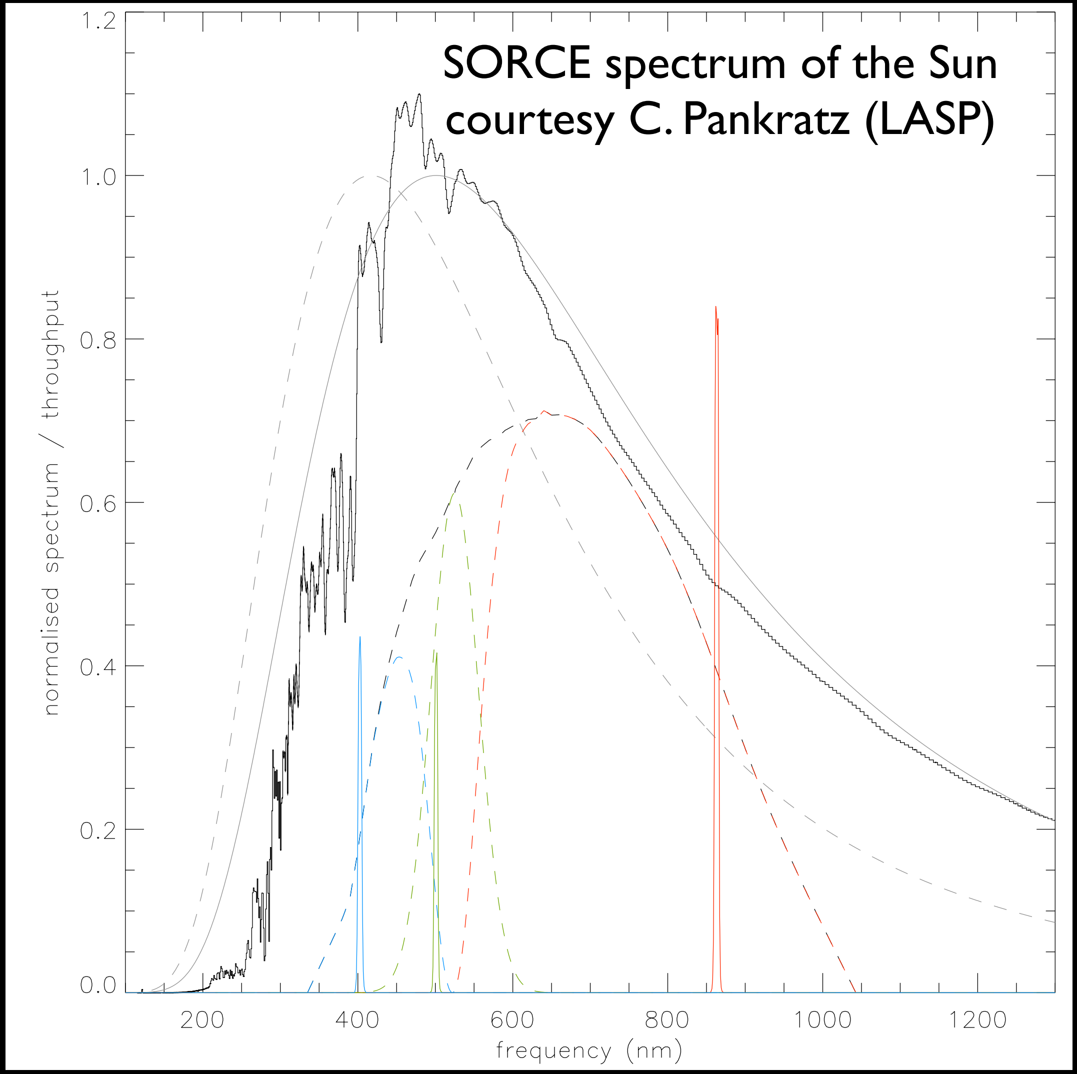
Colour-dependence

SPM data of the Sun (rebinned to 1-day sampling)

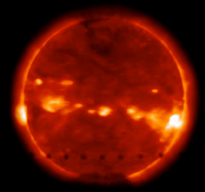




Colour-dependence

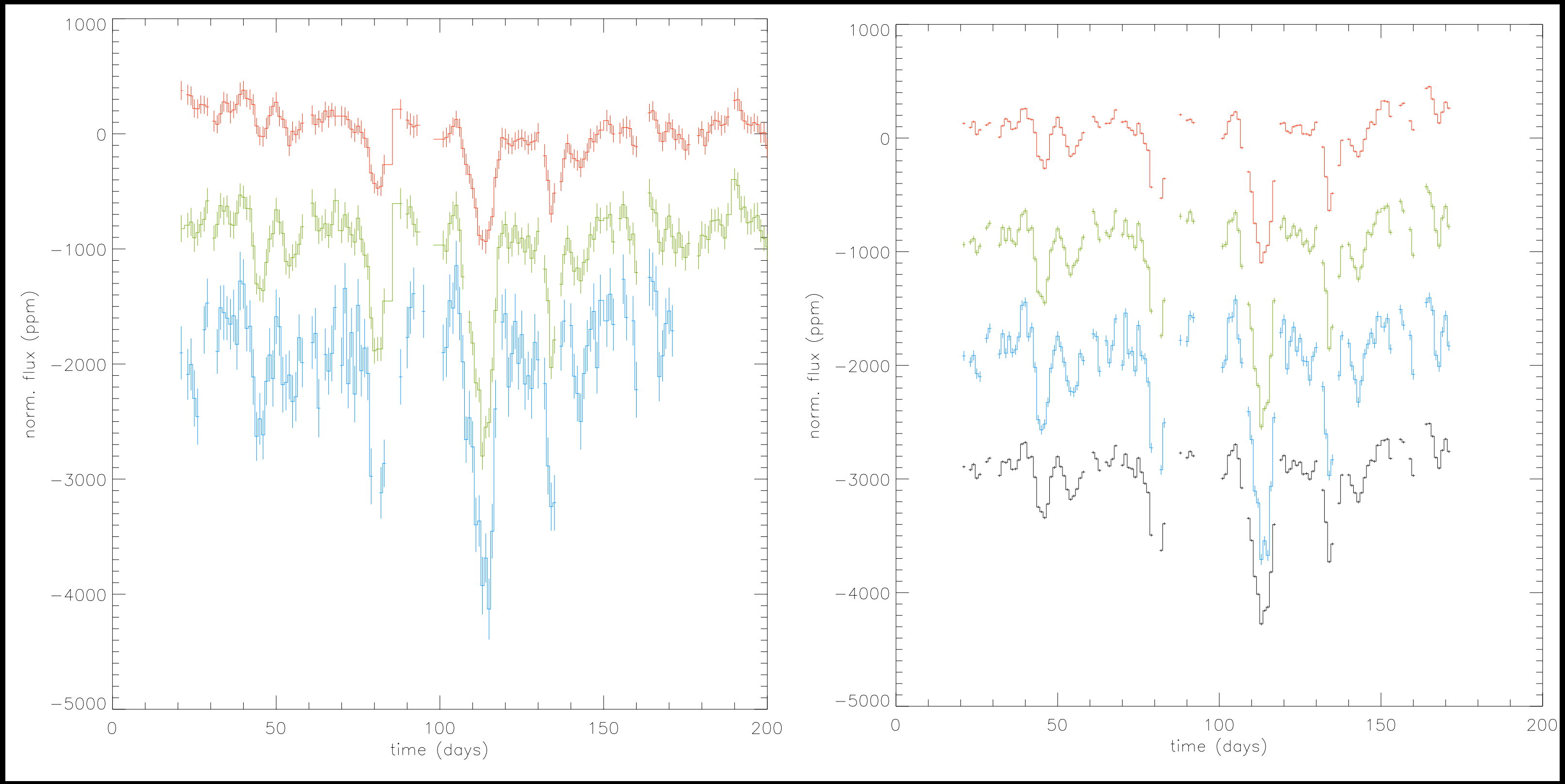


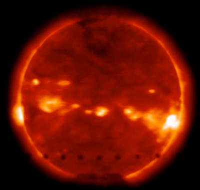
Sun-like variability in CoRoT light curves will show less colour dependence than in SPM data



Colour-dependence

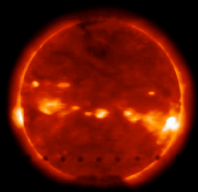
Light curves synthesized from SORCE spectra for SPM (left) & CoRoT (right) passbands





Summary

- Micro-variability is understood as the result of the rotational modulation and intrinsic evolution of structures on the surfaces of stars that have a different effective temperature from the undisturbed photosphere
- Structures of different sizes and lifetimes give rise to variability on different timescales
- Activity-related phenomena dominate on long timescales
- Convection-related phenomena dominate on short timescales
- Tools now exist to simulate micro-variability for a wide range of stars in the CoRoT passbands, though they are constantly being improved
    - see also rotational modulation model of Lanza et al. (G. Cutispoto's talk)



Micro-variability in the CoRoT era

- Unprecedented sample (10,000's stars across the HR diagram)
- Unprecedented data (photometric precision, baseline, time sampling, colour information)
- Many accepted additional programs in first AO...
- The role of the type of models described in this talk is to provide a link between the physical phenomena responsible and fundamental stellar parameters