Impact of activity on exoplanets detectability : from the Sun to other stars

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Outline of the talk

- Context of stellar activity
- Approach for the modeling of stellar activity
- The Sun as a case study
- Results for the observed Sun : time series, periodograms and detection limits
- Parametrization of solar / stellar activity for simulations : work in progress
- Conclusion and perspectives

Stellar activity

• Instruments (spectrographs / photometry / astrometry) with increased precision and stability

- search for very low mass planets allowed
- BUT: at low levels, stellar perturbations **impact exoplanet detectability**

• Stellar activity components

- short timescale (min/hour) : *stellar oscillations*

- longer timescales (day, month, year, decade...): ***'magnetic' activity***
> **impacts both astrometry, radial velocities (RV) and photometry (transits)**

• Two challenges

-to extract a planetary signal from stellar 'noise'

-to disentangle between exoplanet and stellar activity signals

> **need to study detectability**

Modeling the impact of activity

- Astrometry

  Simulations : - one-spot models : Hatzes 2002, Makarov et al 2009

  - complex activity pattern : Makarov et al 2010, **Lagrange et al 2011**, **this talk**

- Radial velocities (RV)

  Simulations : - one spot : Saar & Donahue 1997, **Desort et al 2007**

  - complex activity pattern : **Lagrange et al 2010**, **Meunier et al 2010a/b**, Dumusque et al 2011

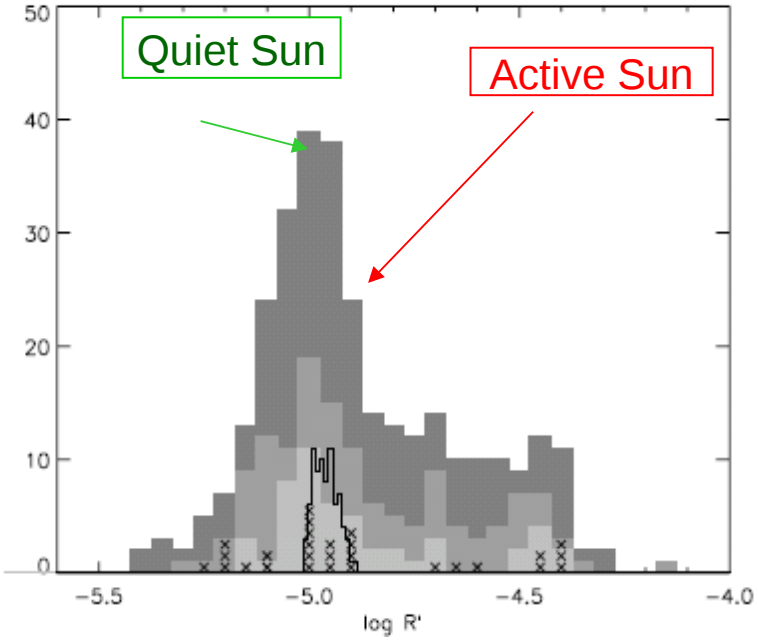
  RV observations and case studies : Boisse et al 2009, Dumusque et al 2010, etc

- Photometry and transits

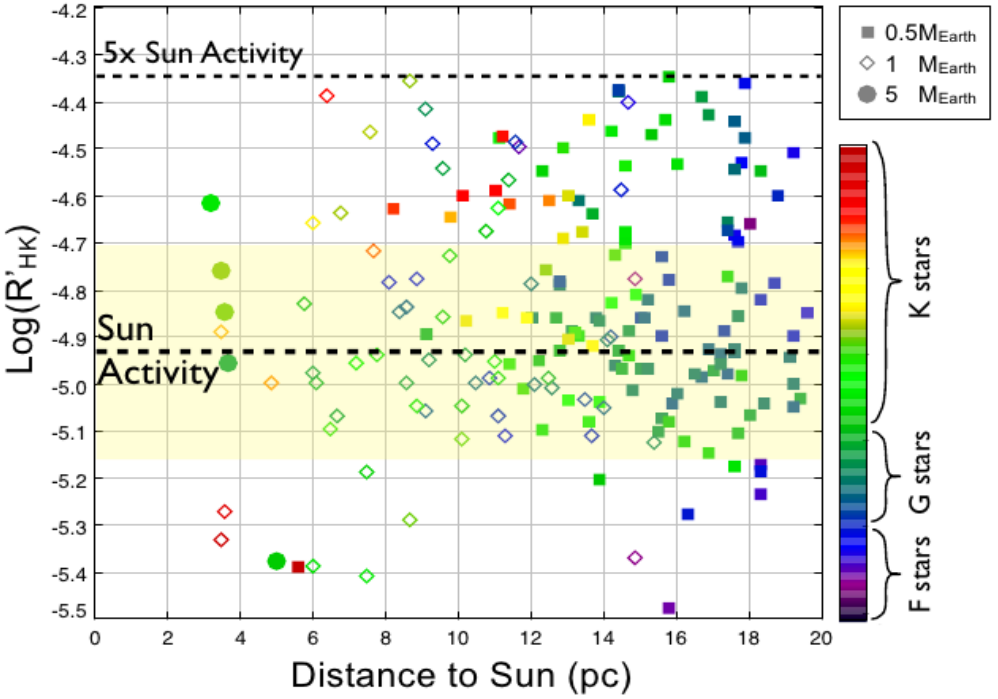
  Systematic approaches : Aigrain et al 2004, Aigrain & Irwin 2004, **[Lagrange et al 2010**, **Meunier et al 2010a : daily sampling]**

  Case studies : Lanza et al 2003, 2009, 2010, 2011..., Mosser & al 2009, etc

From the Sun to other stars



(Hall et al 2007)



Activity index of NEAT targets (taken from the NEAT proposal)

1.The Sun as a case study
Study of activity with:
- long-term timescale
- localisation of spots/plages

> If observing the Sun, would we be able to detect the Earth ?

2. The Sun as a moderately active star

> From what we learnt of the Sun -> extrapolation to other stars.

Methodology

Three main steps :

- 1. Building a **realistic** (= complex) **activity pattern** of the star.

  - dark spots + bright plages
  - size + position at each time step
  - daily sampling over a complete activity cycle

  -assuming a given convection level *(for RV)*

- 2. Deducing **time series** :

  -astrometry
  -photometry
  -RV *(computed from obtained spectra)*

- 3. **Analysis**

  - addition of noise, of a planetary signal, ...
  - tools : periodograms, detection limits

Stellar activity: three components

1) Attenuation of the convection blueshift (due to **B**) in active structures
> Found dominant in the case of the Sun
> Strongly correlated with log(R'hk)
BUT: specific to RV !!

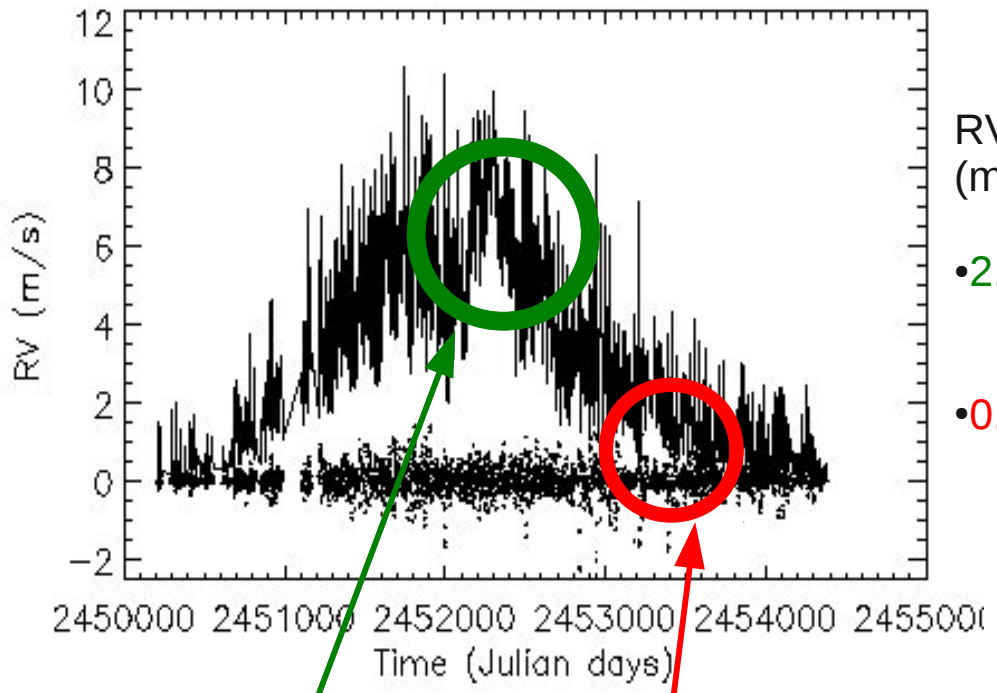
2) Photometric contribution of dark spots

3) Photometric contribution of bright plages

> Partially compensate

Impact on astrometry + photometry (+ RV)

Example from RV simulations (**Meunier et al 2010**).



RV rms (m/s) :

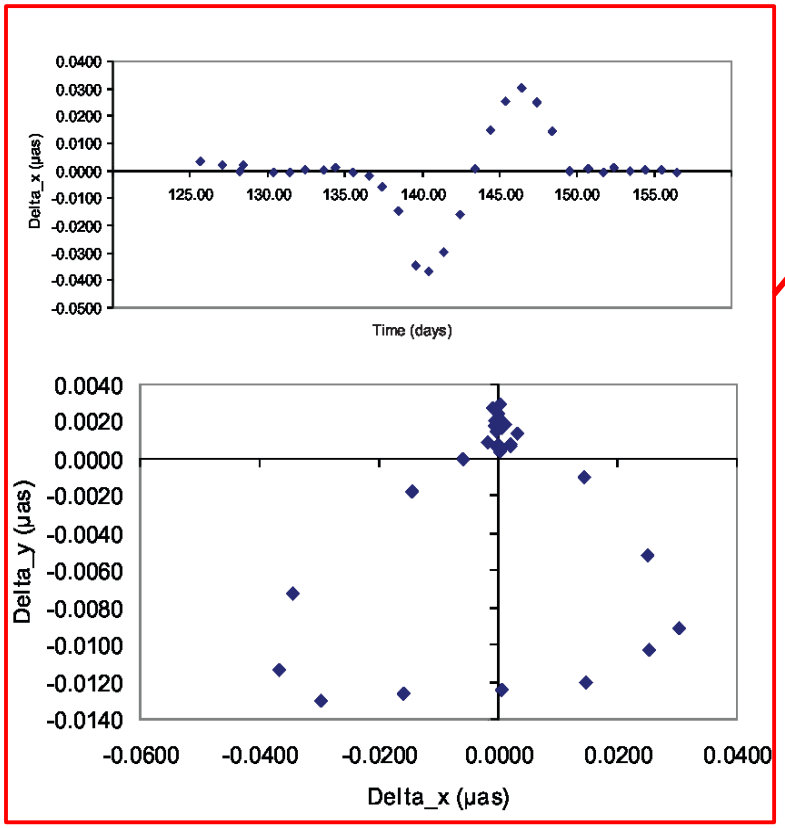
- 2.40
- 0.33

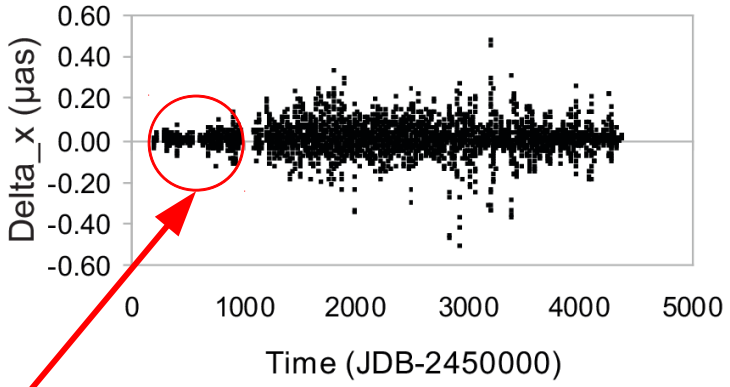
Total RV variations (considering spots, plages and convection)

RV variations considering spots and plages only

Impact of activity on astrometry : case of the observed Sun (*Lagrange et al 2011*)

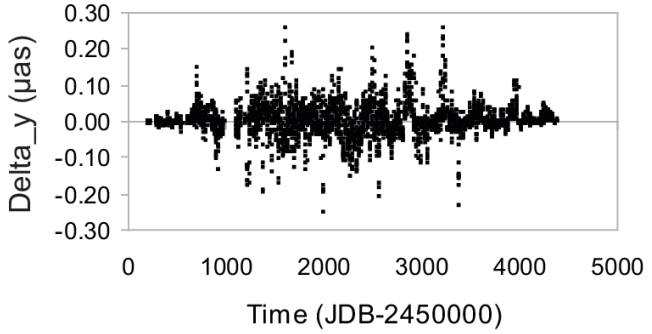
Steps : 1. solar activity pattern from catalogs + MDI-SOHO magnetograms
(> observed activity pattern for the Sun seen edge-on)
2. **time series**





RMS on Δx (spot + plage):

0.07 µas *(all cycle)*
0.02 <-> 0.09 µas



RMS on Δy (spot + plage):

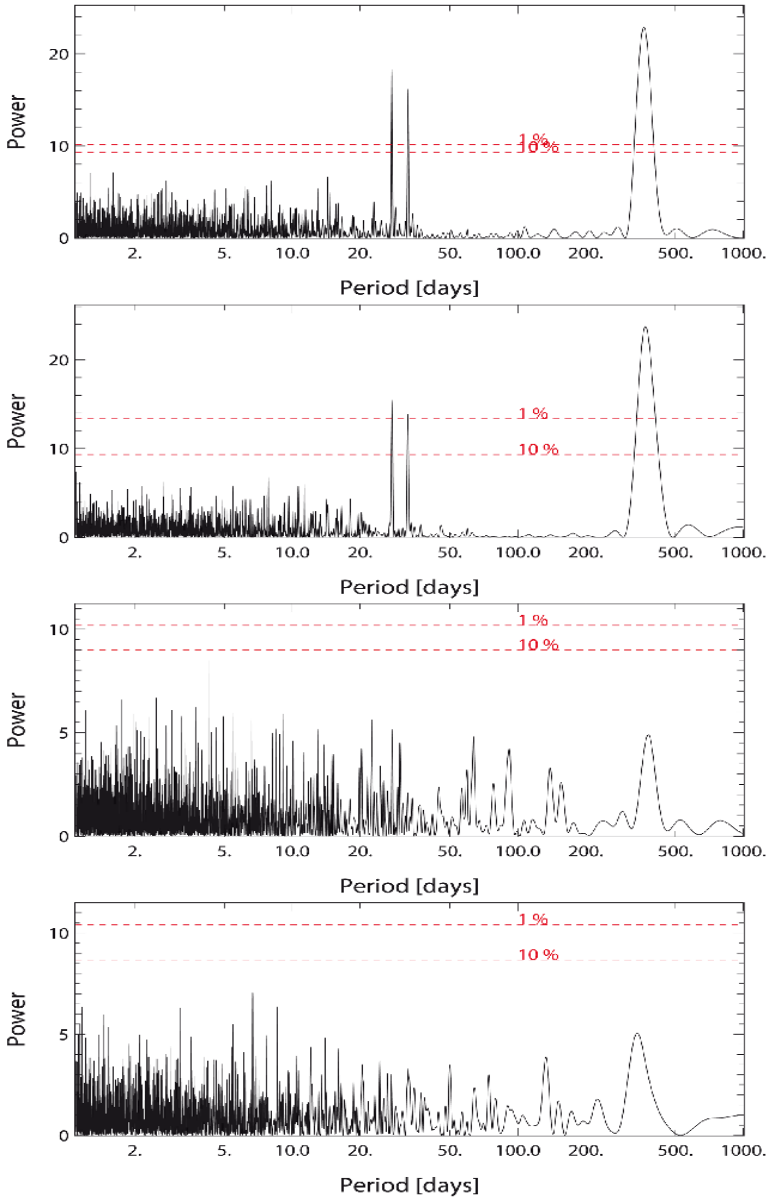
0.05 µas *(all cycle)*
0.01 <-> 0.06 µas

Astrometric shifts along (Δx) and ⊥ to (Δy) the equator.

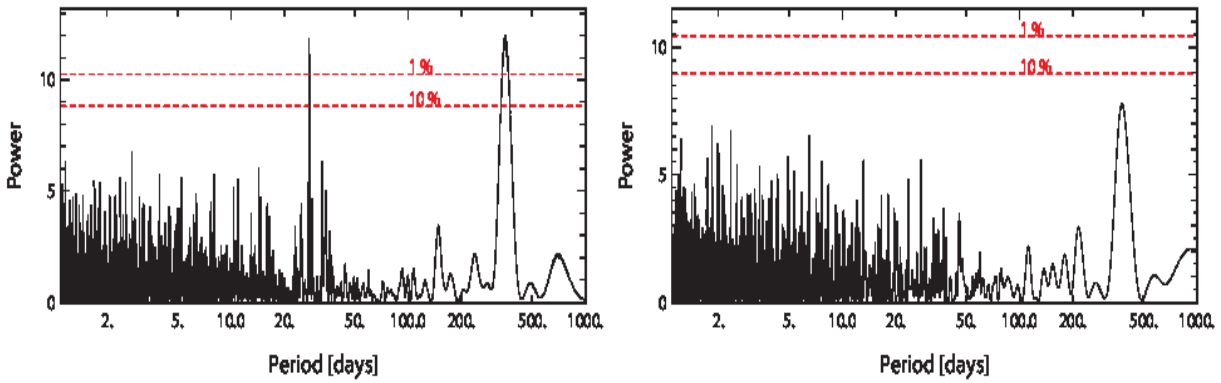
Impact of activity on astrometry : case of the observed Sun (*Lagrange et al 2011*)

Steps : 3. **Analysis**
(adding noise, + Earth-like signal -> periodograms)

Periodogram of Δx :
-with an Earth-like signal,
-with or without added noise (0.8 μas)
-low / high activity period



Same periodogram of Δx for a 5 times more active star



Impact of activity on astrometry : case of a simulated Sun-like star (***work in progress***)

Steps : 1. **Build a parametrized (and realistic) solar activity pattern**
(from various distribution laws)

2. **Time series**
(Comparison with previous results “from observations” (edge-on))

3. **Analysis**
-> Study the impact of **stellar inclination** along the line of sight
-> Study the impact of different levels of activity
-> Adding noise + Earth-like signal

Conclusion and perspectives

• All the tools to build time series and perform analysis are available

• Preliminary results for a simulated activity pattern : impact of stellar inclination on the shape of astrometric shifts ; deducing stellar rotation from excursion of photocenter

• Extrapolation to other types of stars and levels of activity :
 > to test the impact of the ≠ input parameters
 > to fix input parameters (from literature) for ≠ activity levels

• Perspectives for blind-tests :

 > ability to generate astrometric time series from simulated activity patterns
 > ability to add ≠ temporal samplings, levels of noise, planetary signals provided by the consortium
 > Stellar characterization (level of activity, stellar orientation)
 > Detection limits -> analysis by other groups