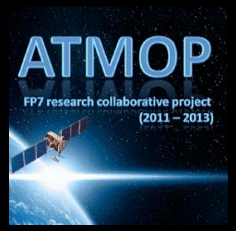
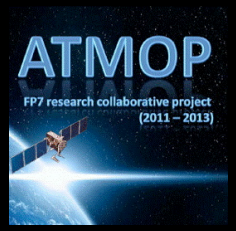


TunsBot Dumbers (TBD)

Thierry Dudok de Wit

University of Orléans

with thanks to M. Pick, S. Moussaoui, P.-O. Amblard, L. Vieira, and many more



Sunspot numbers: what their statistical properties tell us

Thierry Dudok de Wit

University of Orléans

with thanks to M. Pick, S. Moussaoui, P.-O. Amblard, L. Vieira, and many more

Outline

1. Separating Wolf sunspot numbers from Group sunspot numbers

2. What multi-wavelength radio observations tell us about the variability of the sunspot number

My favourite motto

We use fantastic telescopes, the best physical models and the best computers. The weak link in this chain is interpreting our data using 100-year-old mathematics.

Dana McKenzie, New Scientist, 2004.

Separating groups and spots

- We know that

Group Sunspot Number $GSN = N_{\text{groups}}$

Wolf Sunspot Number $ISN = \alpha N_{\text{groups}} + \beta N_{\text{spots}}$

- Does that mean that the number of spots can be estimated by taking the difference

$$N_{\text{spots}} = \gamma \cdot ISN - \delta \cdot GSN \quad ?$$

No !
because this may lead to irrealistic (negative) values

Our approach

- Use a **Bayesian** approach: a recent and highly productive field of research that is appropriate for **data with uncertainties**

- Instead of making (questionable) least squares fits, estimate the probability

$$\mathcal{P}(N_{\rm spots}|{\rm Obs}) = \frac{\mathcal{P}({\rm Obs}|N_{\rm spots}) \cdot \mathcal{P}(N_{\rm spots})}{\mathcal{P}({\rm Obs})}$$

Probability that the true number of spots is N_{spots} given a set of observations Obs

Obviously, one should have $P(N_{spots})=0$ if $N_{spots}<0$

Our approch

- We consider a **blind source separation** approach

- Each record is a linear combination of two unknown “sources” x and y

$$\mathrm{ISN} = \alpha x + \beta y$$

$$\mathrm{GSN} = \gamma x + \delta y$$

- We wish we could find x = *spots* and y = *groups*

- But this problem is hopeless : none of $\{x, y, \alpha, \beta, \gamma, \delta\}$ is known !

We need physical constraints to obtain a unique solution

Blind source separation

Basic idea : extract elementary building blocks from their mixtures

“Cocktail party problem”

“Cocktail party problem”

“Cocktail party problem”

Assumptions

- Our basic assumptions are
  - the combination of the sources x and y is **linear** and **instantaneous**
  - the sources are **positive** and so is their mixture
  - the sources are **different**

Our approach

- **Advantages**
  - a consistent method for extracting information from imperfect data
  - need to specify assumptions explicitly
- **Disadvantages**
  - can be computationally expensive
  - people tend to be scared by the word “Bayes”

Results

- With these constraints, we get a unique solution

$$\mathrm{GSN} = 1 \cdot x + 0 \cdot y$$

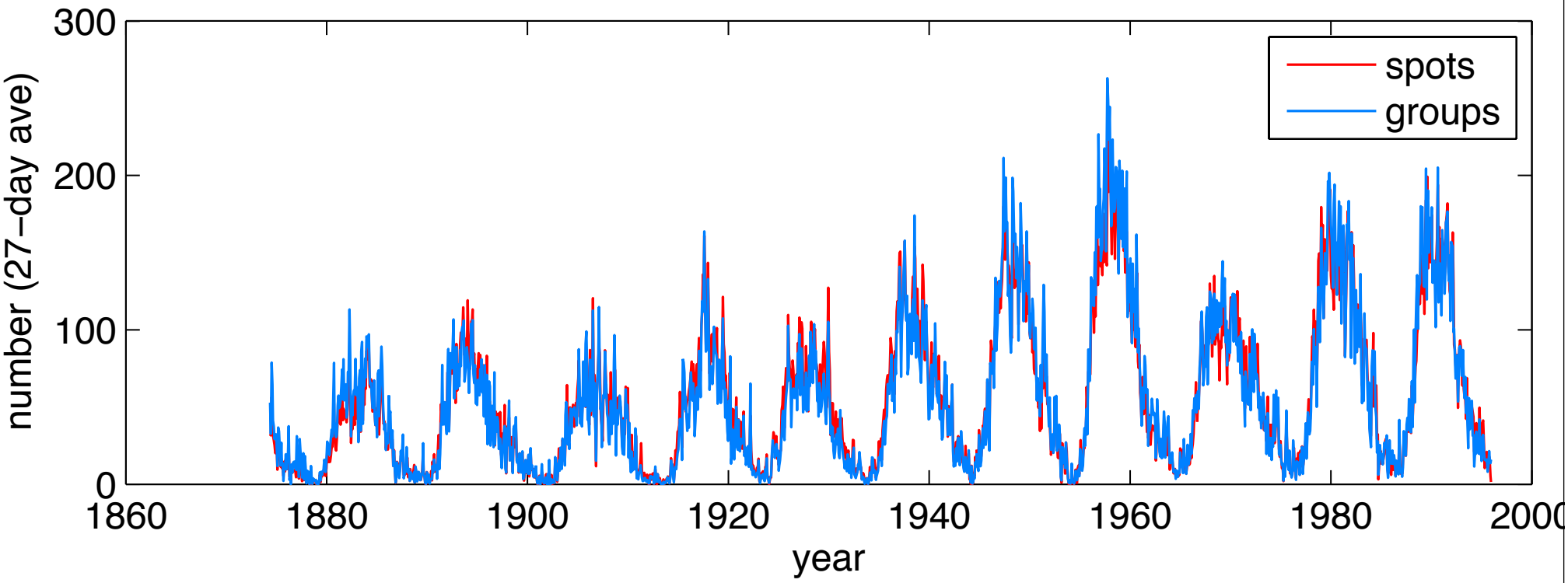
$$\mathrm{ISN} = 0.19 \cdot x + 0.81 \cdot y$$

$y = N_{spots}$

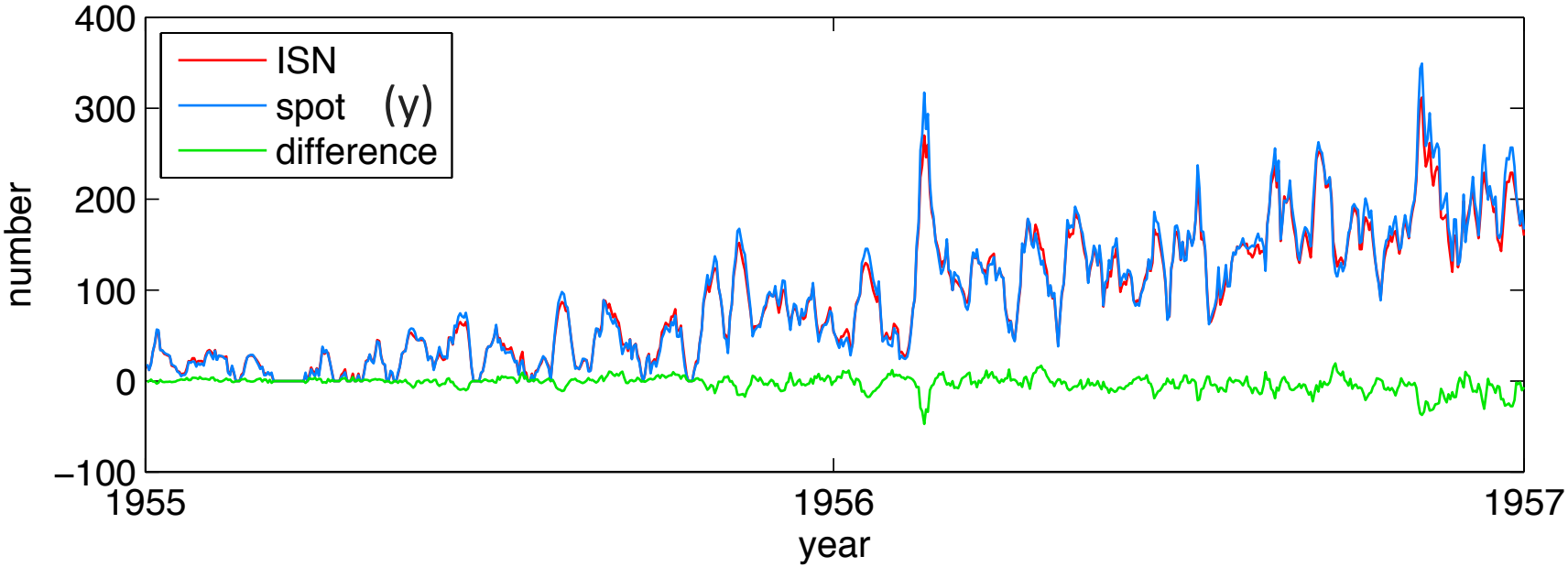
$x = N_{groups}$

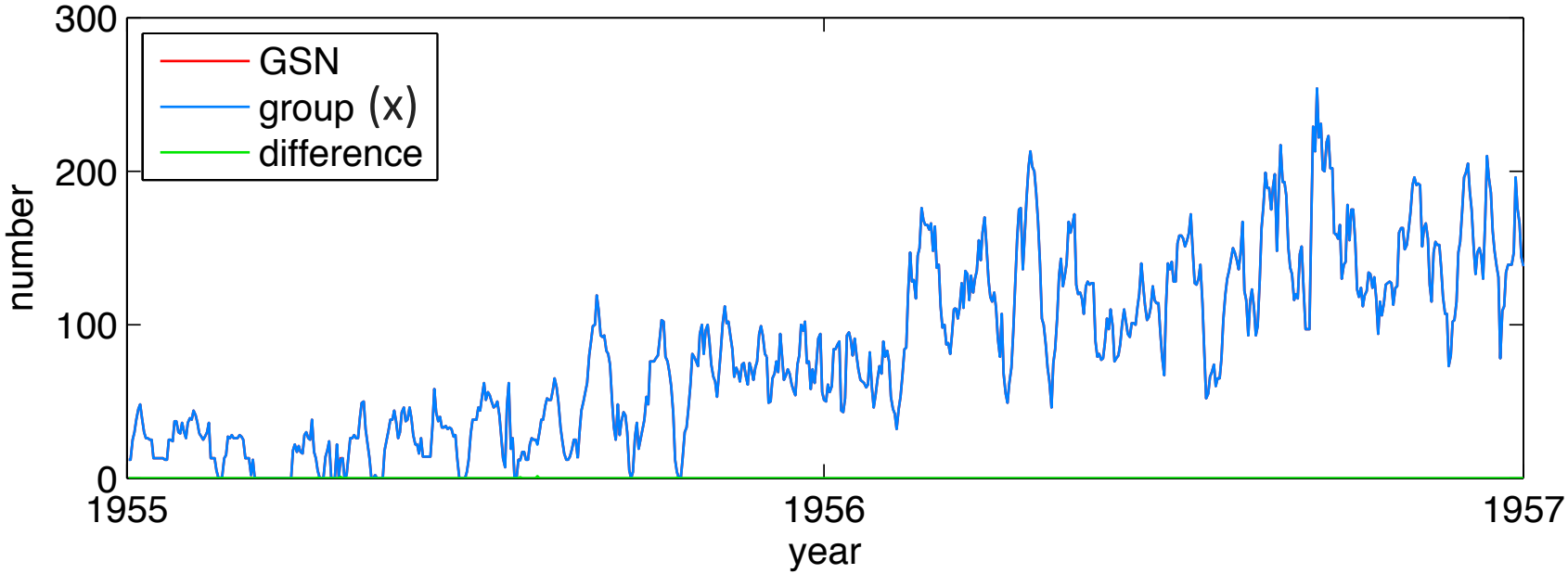
The first fully independent reconstruction of spots and groups !

Results


300
200
100
0
number (27–day ave)
1860
1880
1900
1920
1940
1960
1980
2000
year
spots
groups

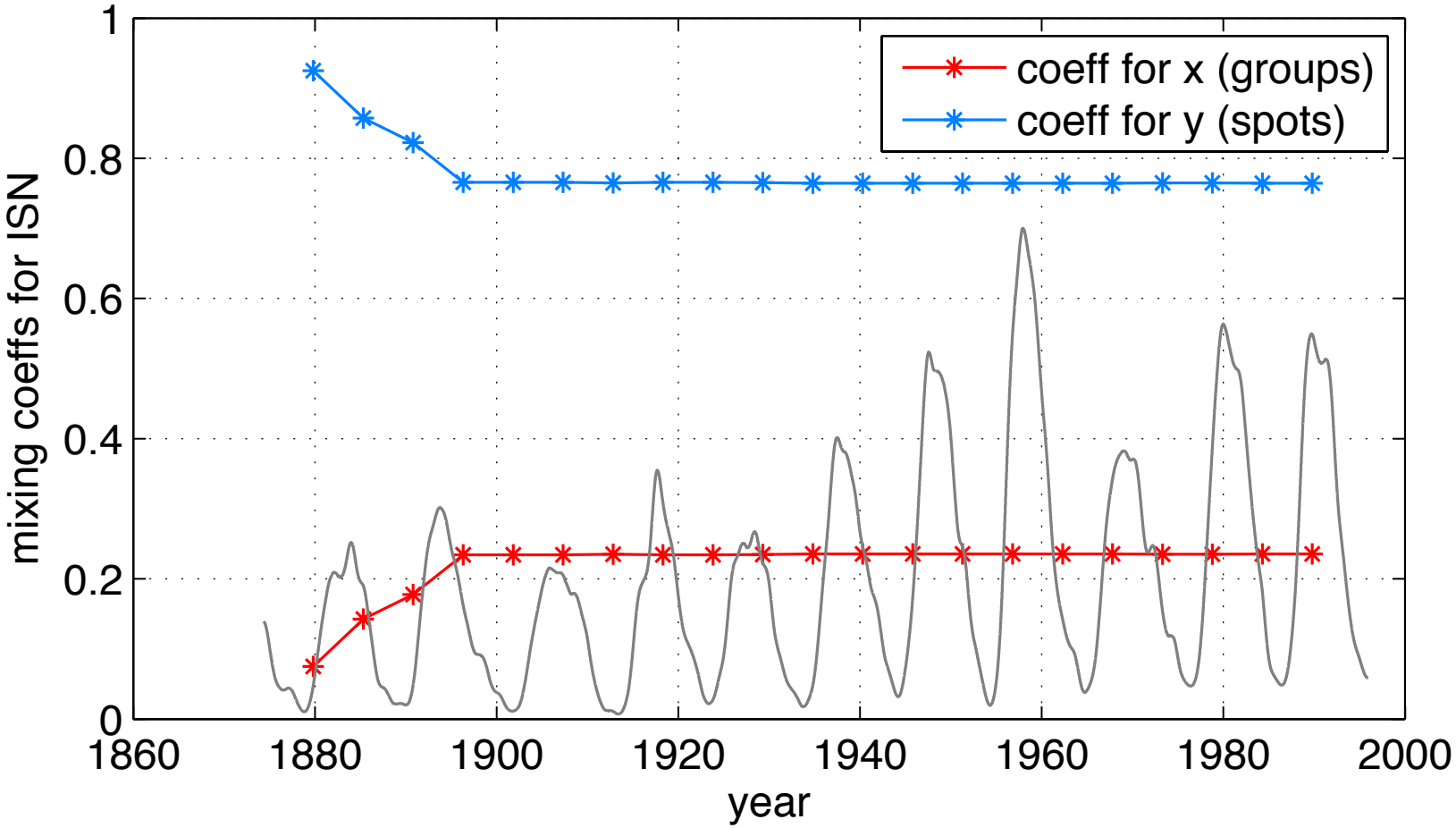
Results : excerpt





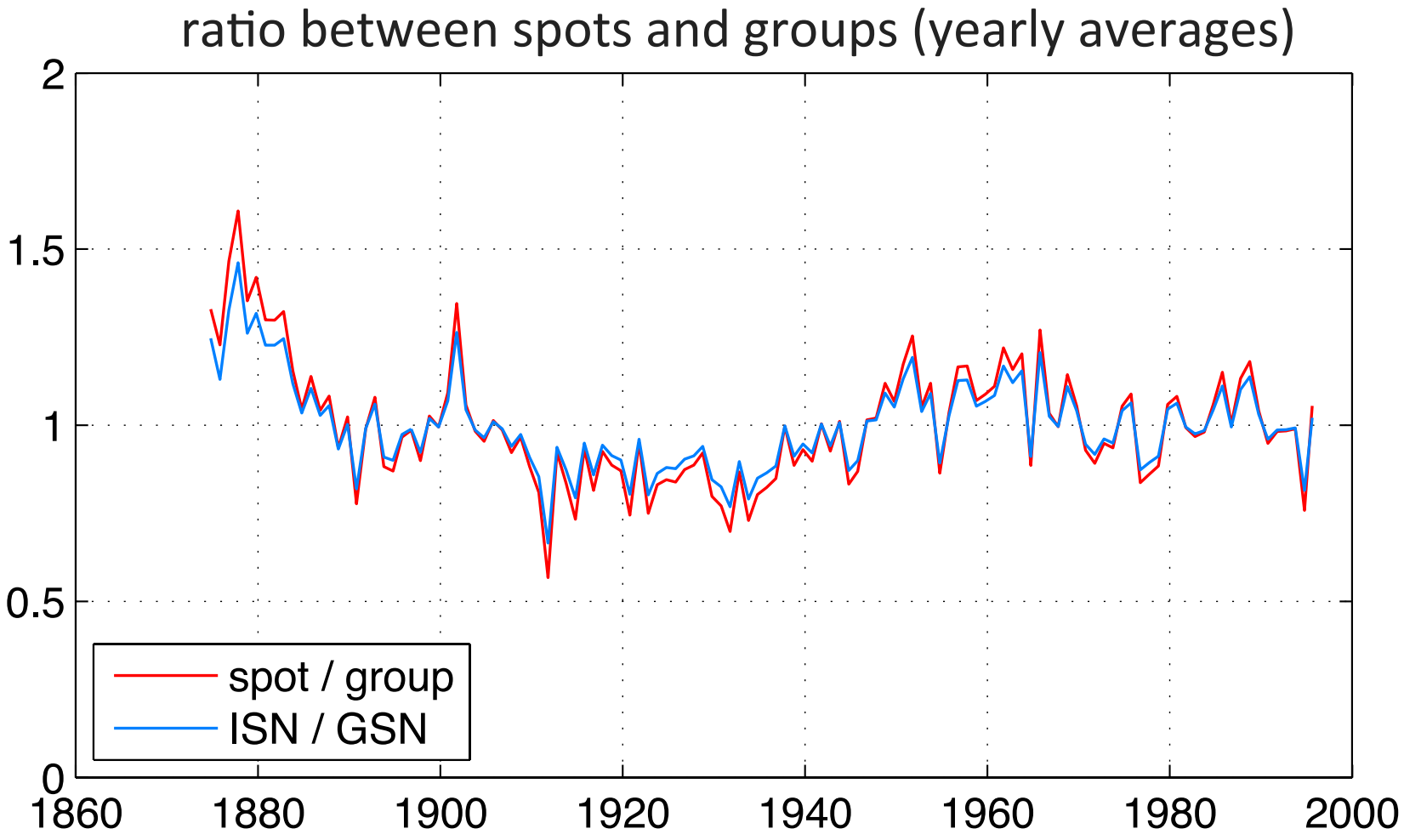
Results

- Do these coefficients change in time ?



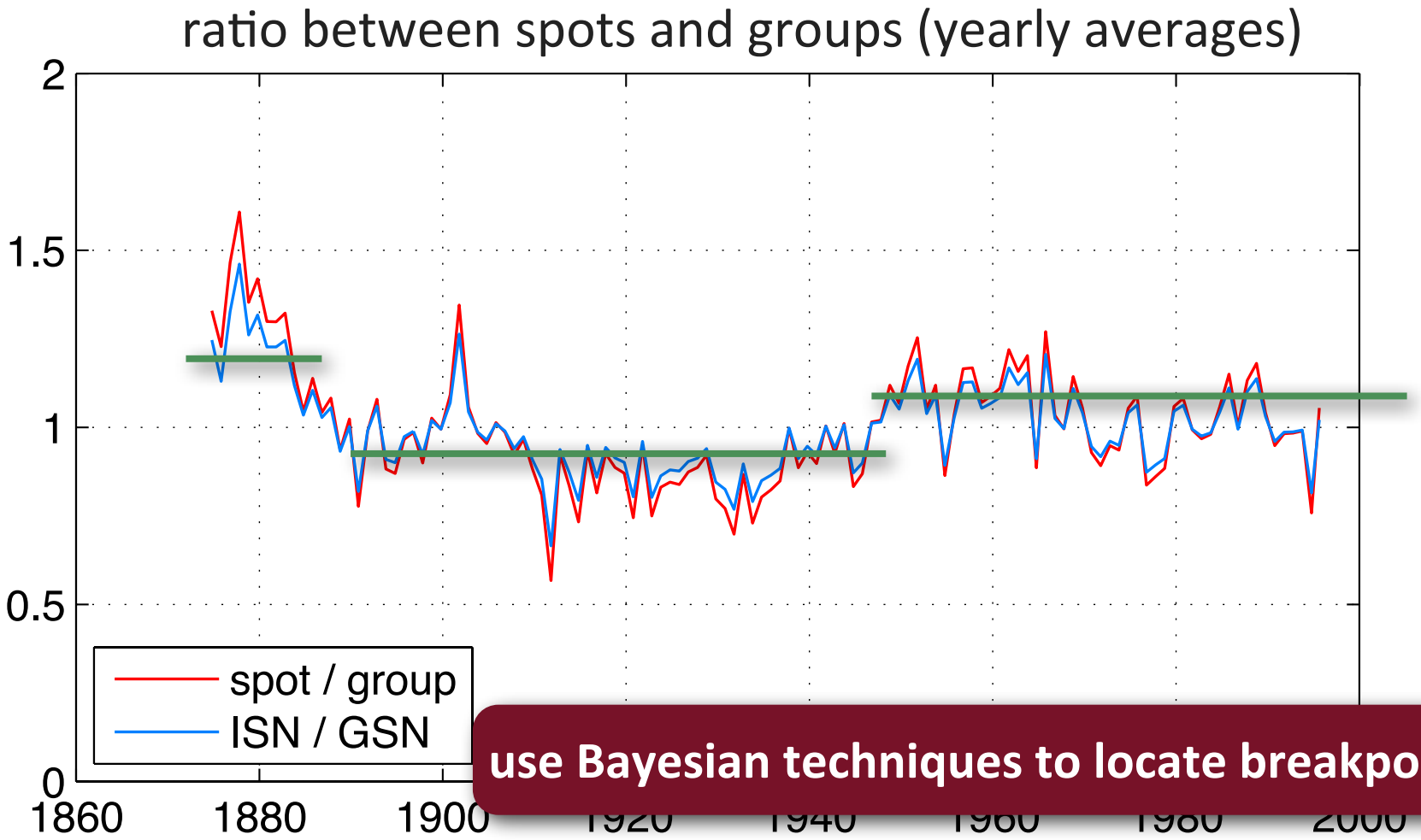
Results

- Does this tell us anything about calibration errors ?

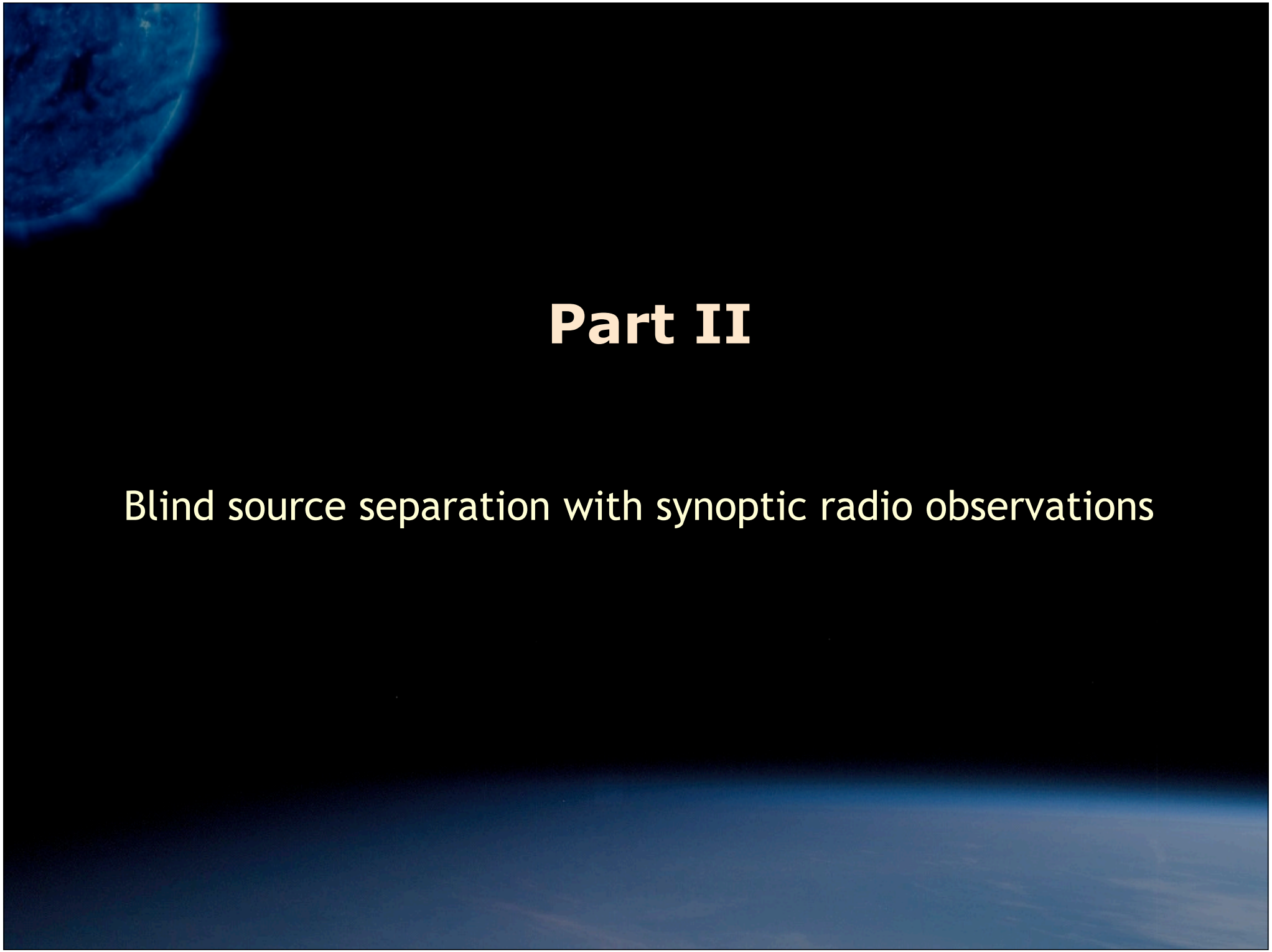


Results : breakpoint detection

- Does this tell us anything about calibration errors ?



use Bayesian techniques to locate breakpoints

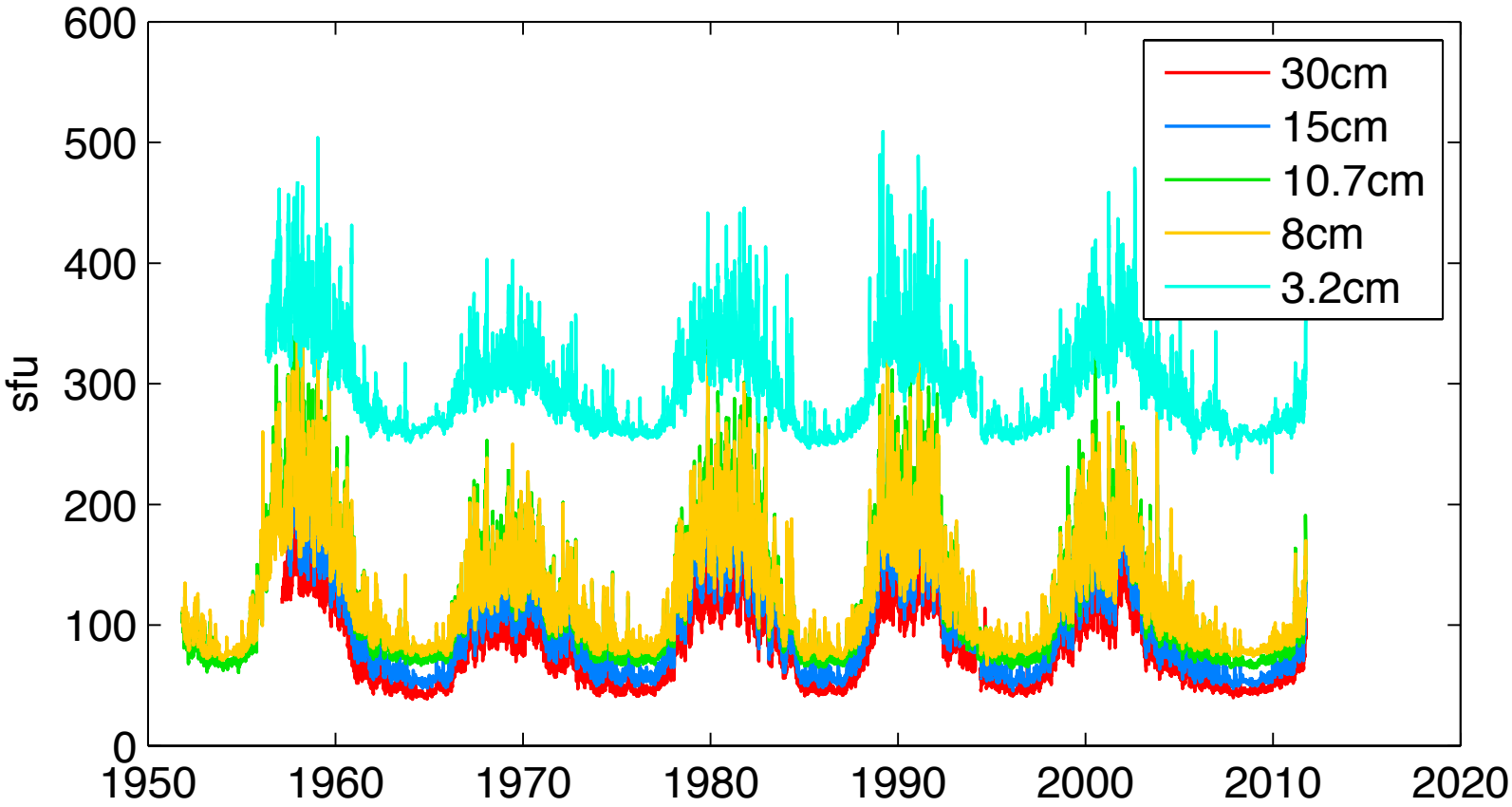


Part II

Blind source separation with synoptic radio observations

Radio observations

- The radio flux from 3-30 cm is a mix of free-free emission (plages) and gyroemission (sunspots)
- 60 years of daily observations from Toyokawa & Nobeyama



Questions

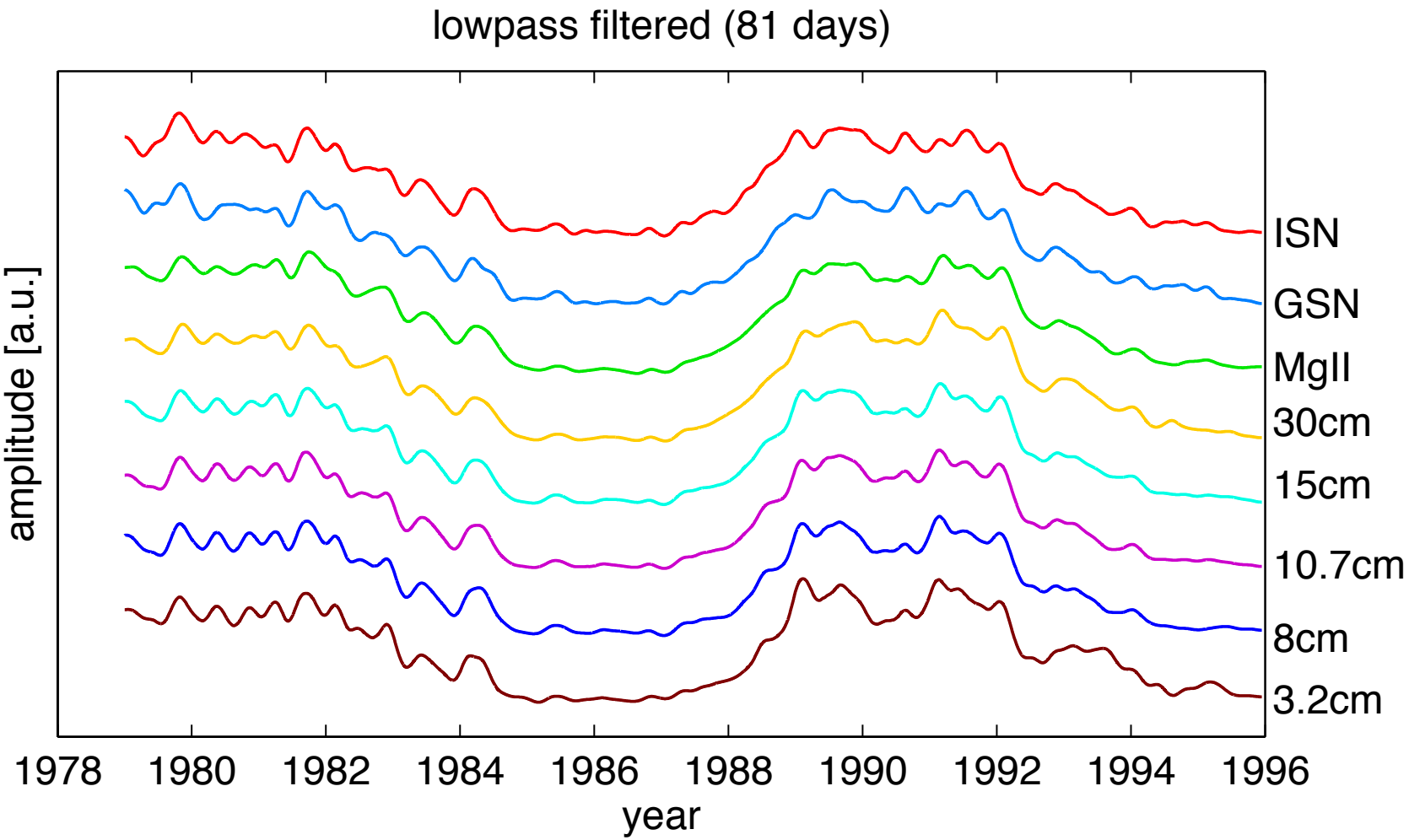
- **Question 1** : can we separate the Bremsstrahlung and the gyroresonance emissions ? Two different “sources” ?

- **Question 2** : How do they relate to the sunspot numbers ?

beware : long term calibration is a problem, so we focus on solar rotation scales (<< 100 days)

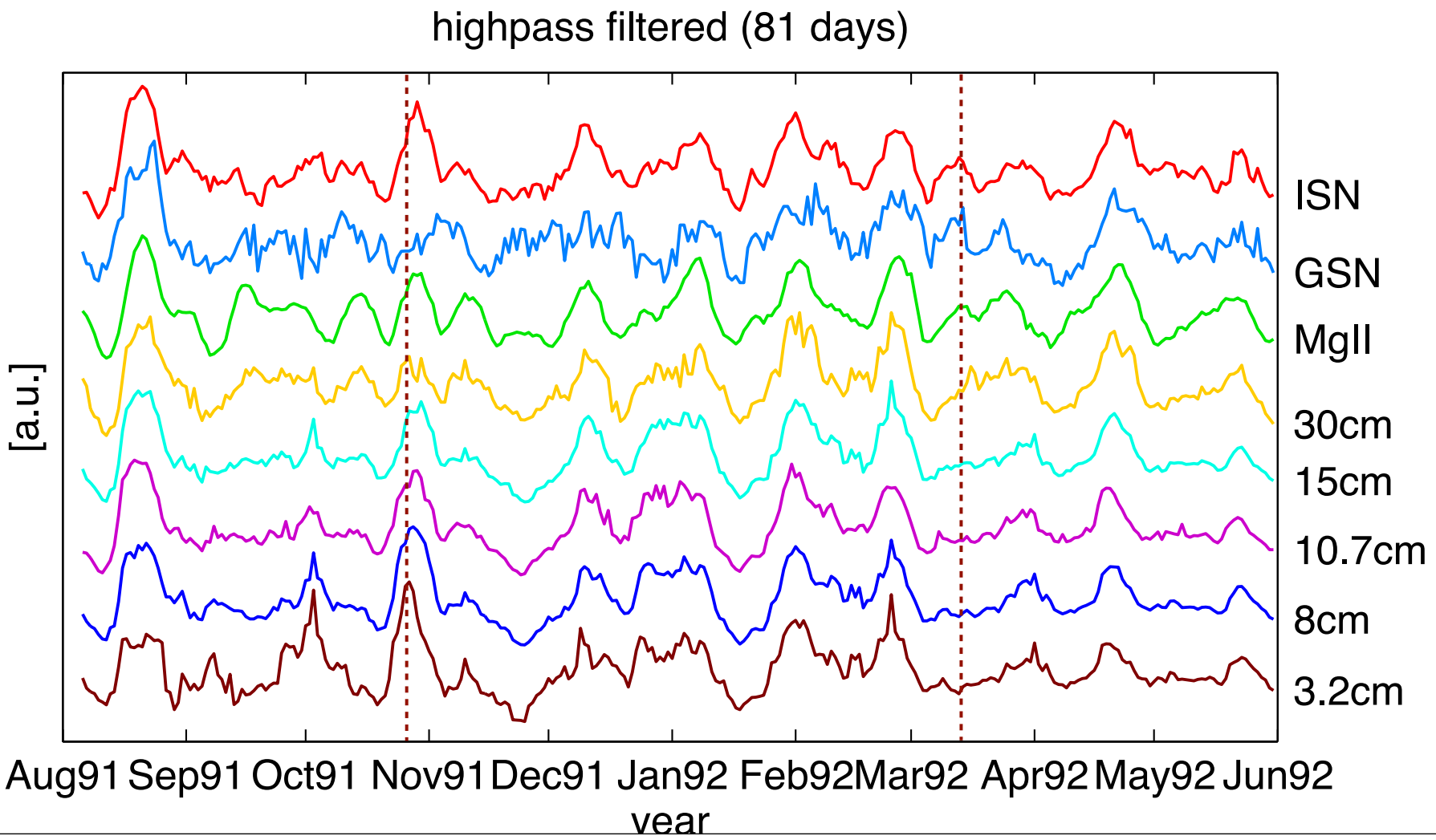
The observations

Long-term component only



The observations

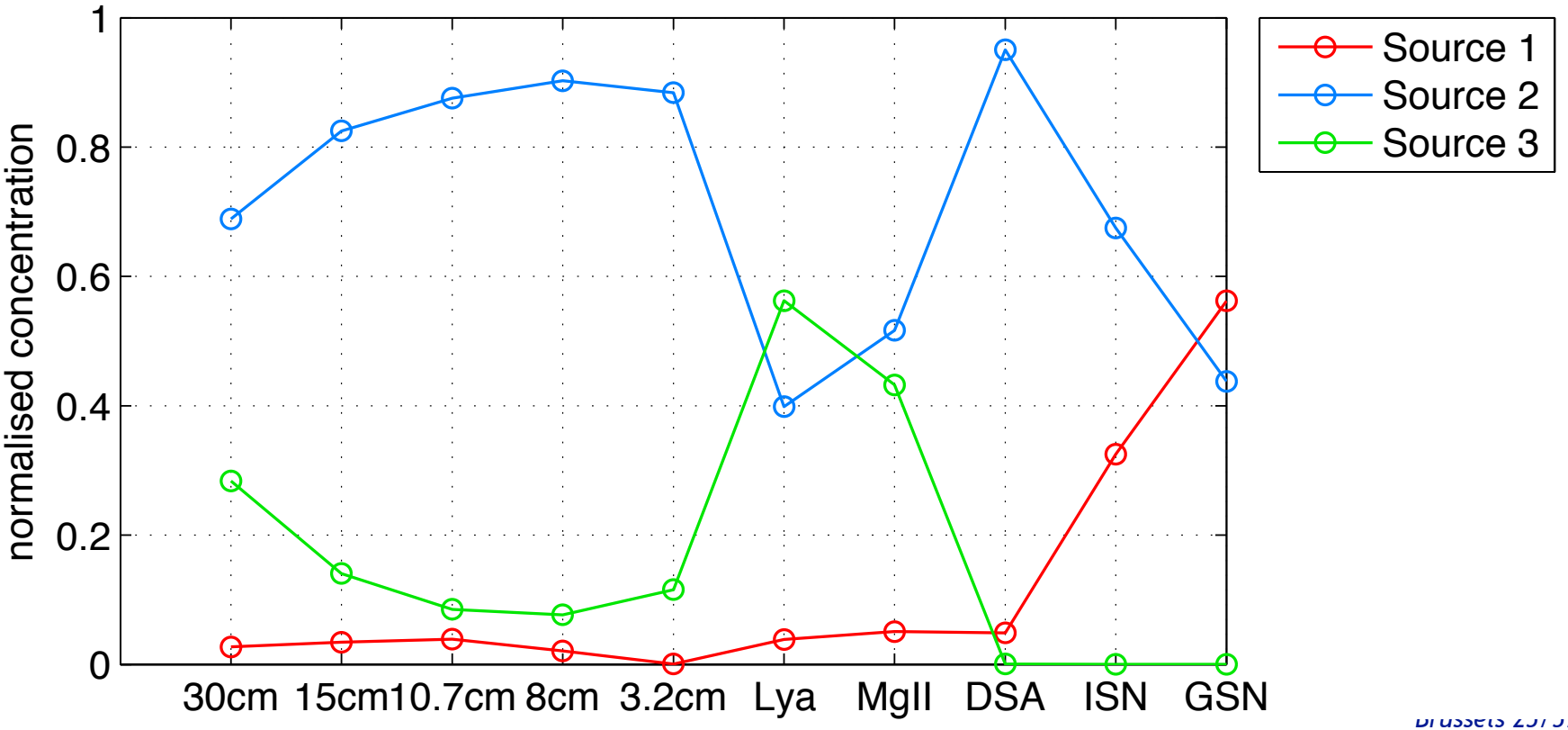
Short-term component only



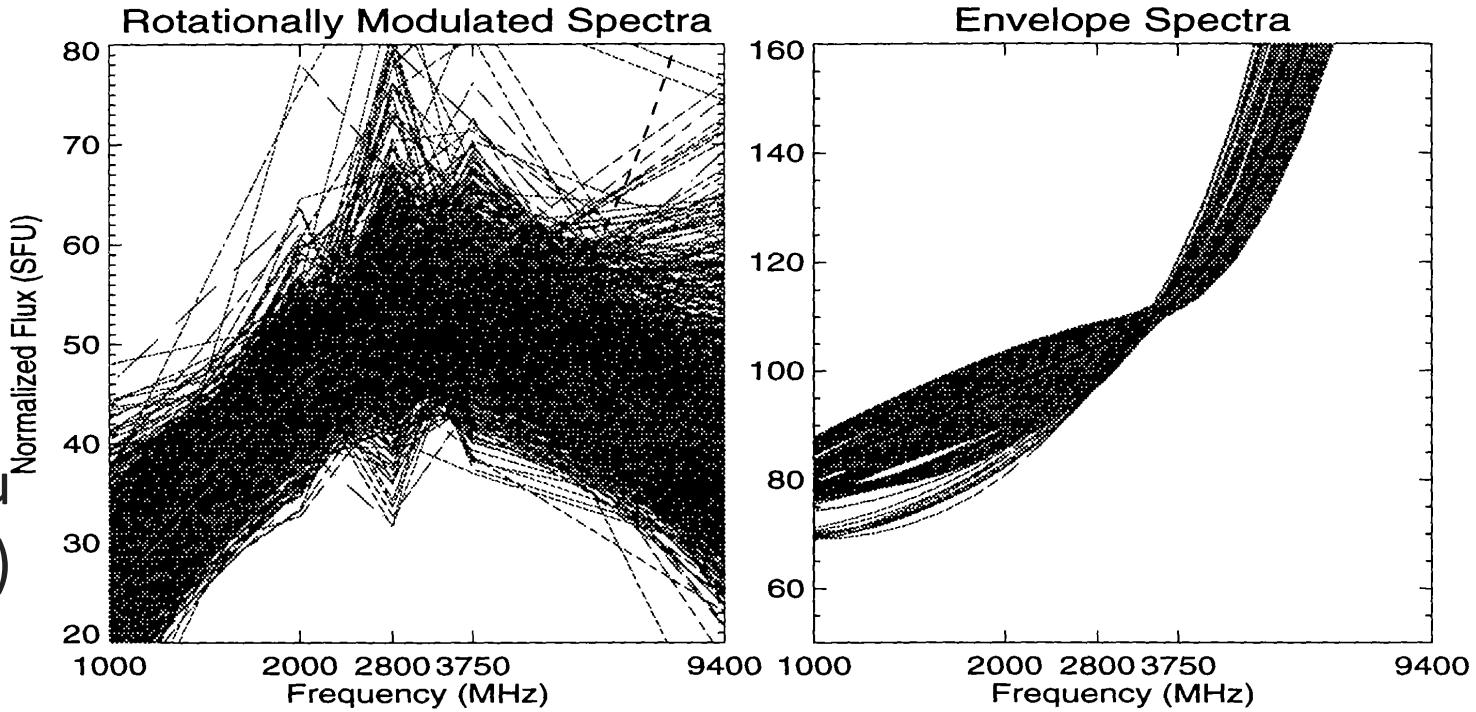
How many “sources” ?

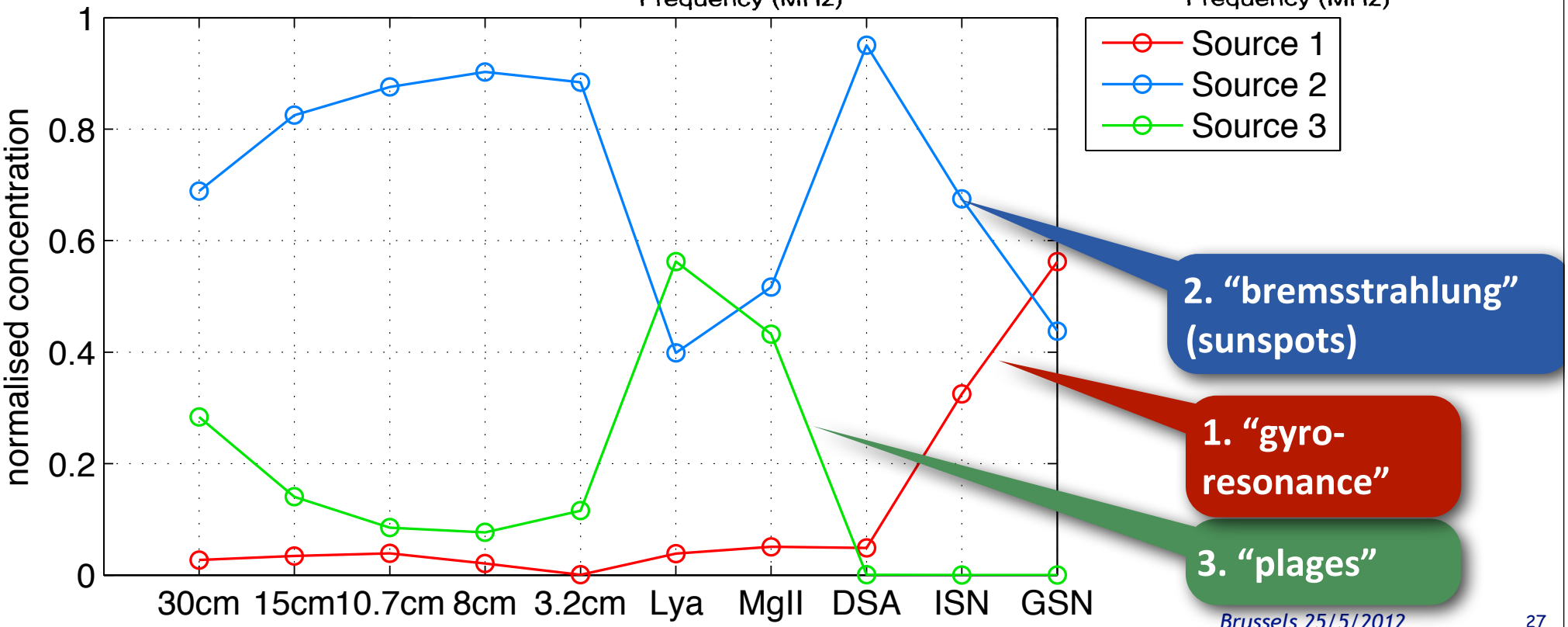
- There is no unique answer to that question.
- However, a SVD (Singular Value Decomposition) analysis and deeper inspection suggests that **3 sources are at play**
  - the data contain 3 degree of freedom

What does each source contribute to ?



Schmahl & Kundu (1998)



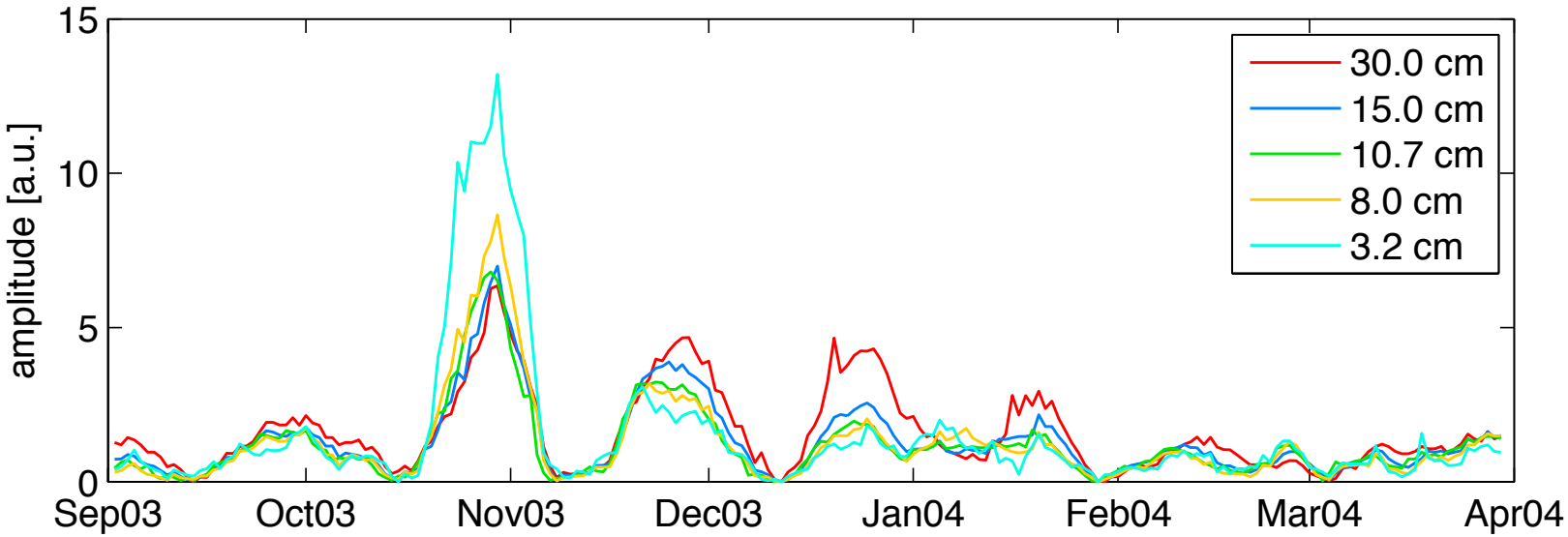


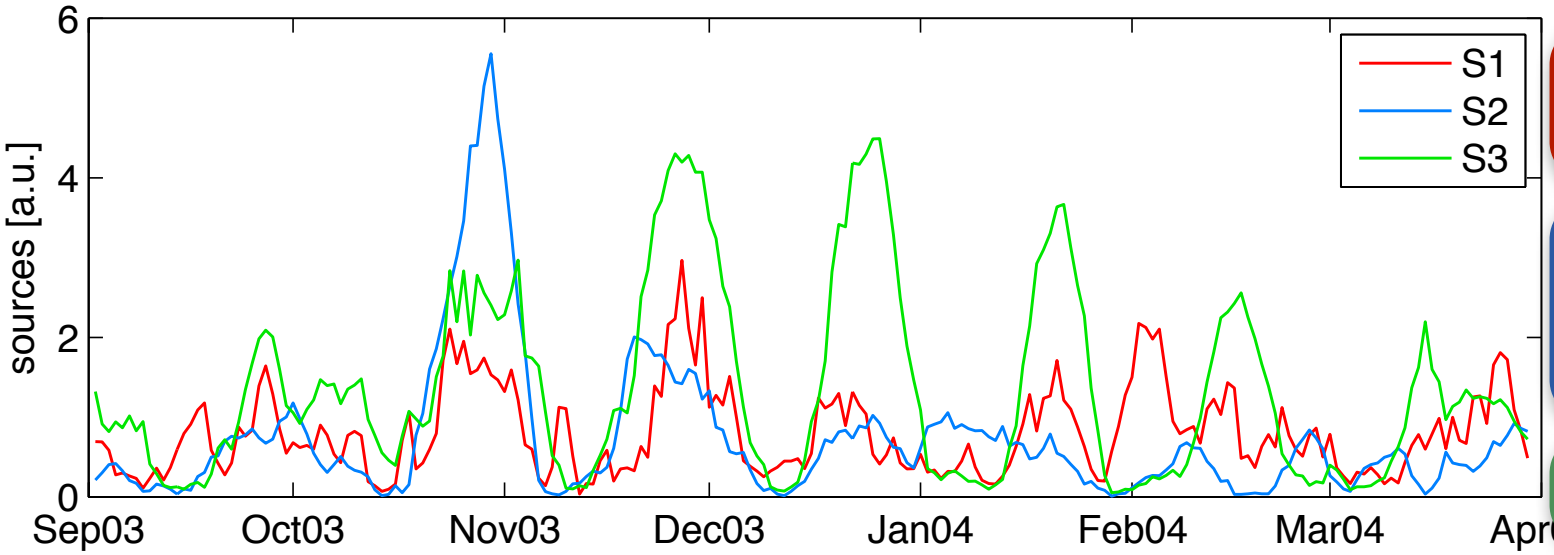
2. "bremsstrahlung" (sunspots)

1. "gyro-resonance"

3. "plages"

Time evolution of each source : example





1. "gyro-resonance"

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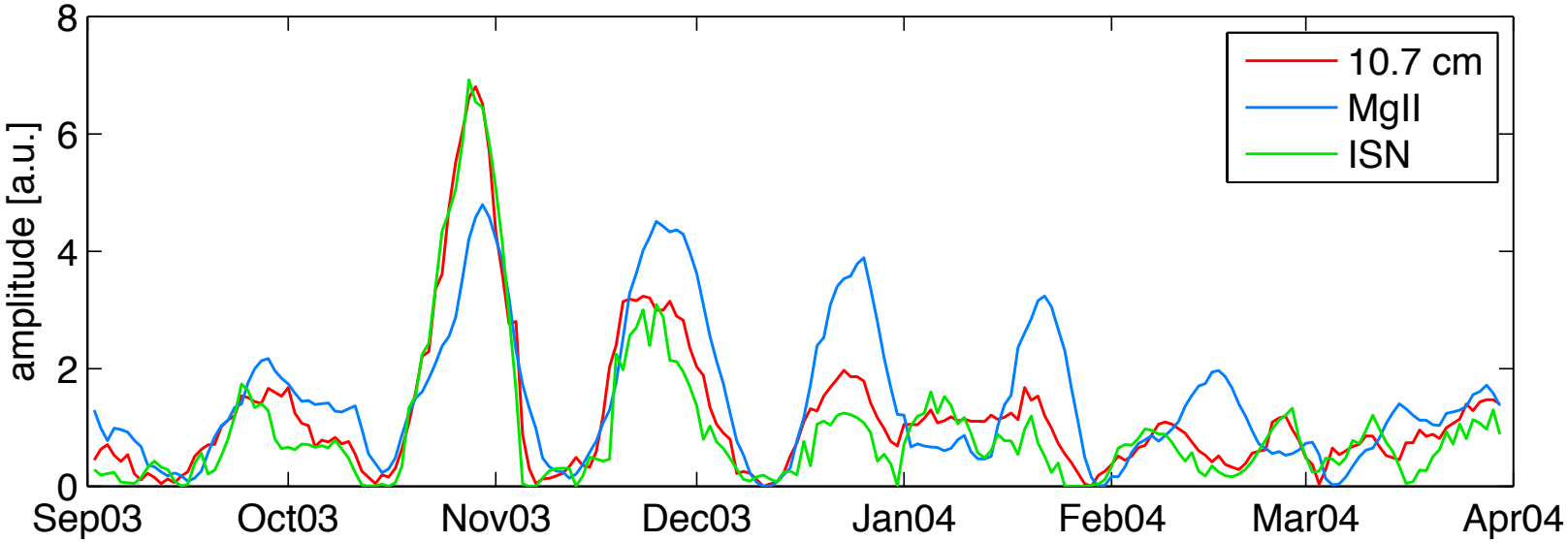
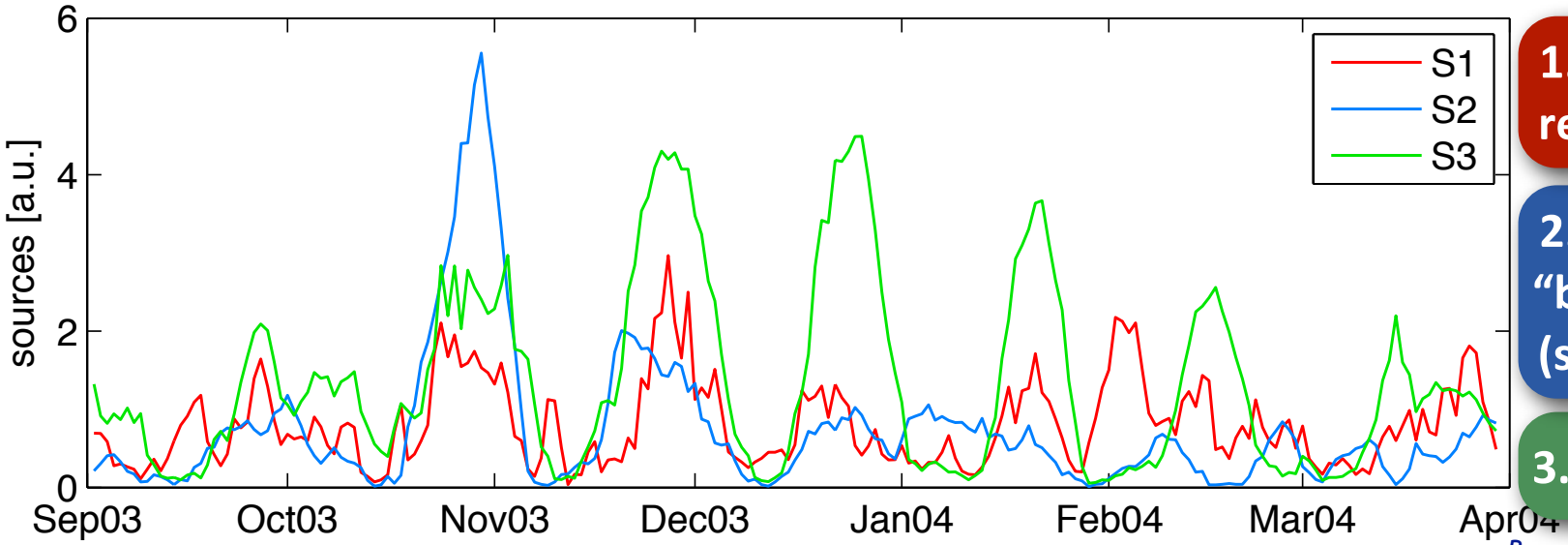
Time evolution of each source : example





1. "gyro-resonance"

2. "bremsstrahlung" (sunspots)

3. "plages"

Conclusions

- This approach is **statistical** and **empirical**

and yet

- It gives new insight into the different contributions of solar variability
  - first full separation between group and Wolf sunspot numbers
  - possibility to reconstruct various solar proxies from multi-wavelength radio observations (in particular MgII index)
  - the “gyro-resonance” contribution is much stronger in sunspots than it is in the radio flux
  - the Group and Wolf sunspot number DO capture different physics