NSF's National Solar Observatory

Solar Hα Excess during Solar Cycle 24 from Full-disk Filtergrams of the Chromospheric Telescope

ANDREA DIERCKE

C. KUCKEIN, P.W. CAULEY, K. POPPENHÄGER,
J.D. ALVARADO-GÓMEZ, E. DINEVA, C. DENKER

Introduction

- Usefulness of spatially resolved Hα excess as tracer for solar activity

- Comparison with established solar activity tracers

- Motivation: Hα activity dominated either by changes of the mean intensity or by area coverage fraction of Hα excess regions? → Disentangle the area coverage fraction and active region emission strength for unresolved stellar surfaces

Astronomy & Astrophysics

Solar Hα excess during Solar Cycle 24 from full-disk filtergrams of the Chromospheric Telescope

A. Diercke[1,2,3], C. Kuckein[1,4,5], P. W. Cauley[6], K. Poppenhäger[1], J. D. Alvarado-Gómez[1], E. Dineva[1,2], and C. Denker[1]

[1] Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany
[2] Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Straße 24/25, 14476 Potsdam, Germany
[3] National Solar Observatory (NSO), 3665 Discovery Drive, Boulder, CO, USA 80303
  e-mail: adiercke@nso.edu
[4] Instituto de Astrofísica de Canarias (IAC), Vía Láctea s/n, 38205 La Laguna, Tenerife, Spain
[5] Departamento de Astrofísica, Universidad de La Laguna, 38205 La Laguna, Tenerife, Spain
[6] Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, Boulder, CO 80303, USA
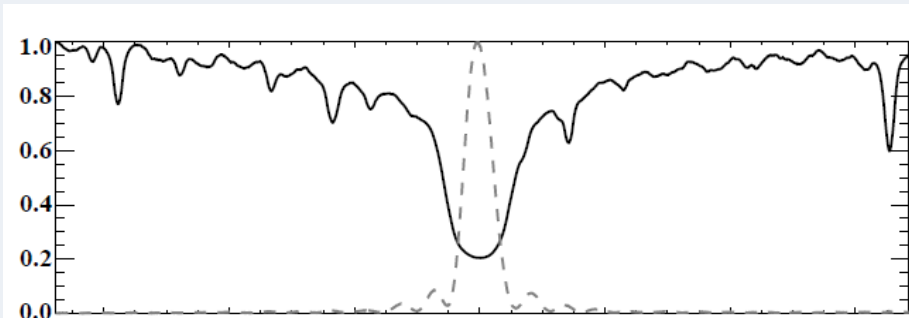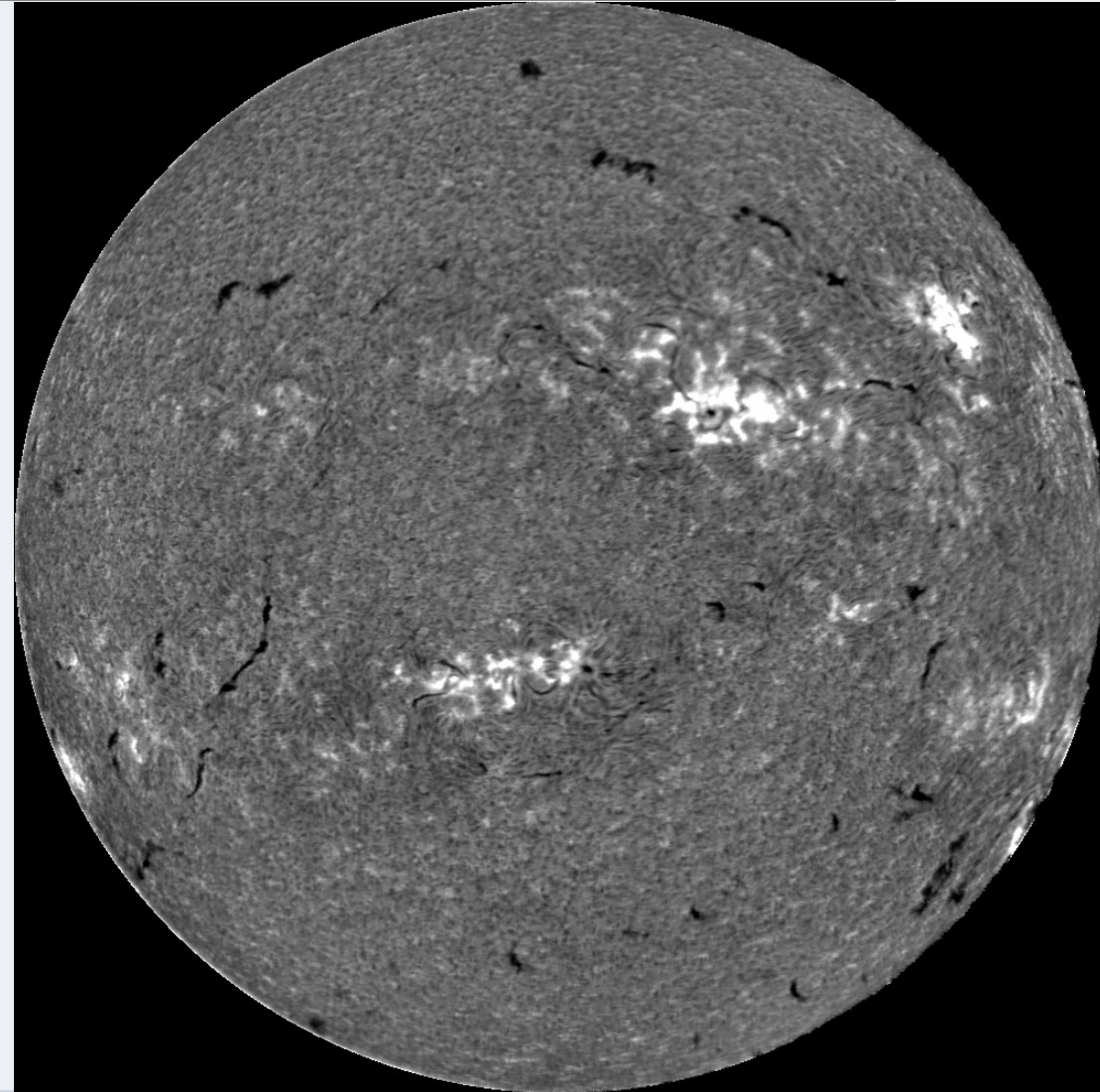
Chromospheric Telescope (ChroTel)

Kentischer et al. 2008, Proc. SPIE Vol. 7014

- 10-cm aperture, spatial resolution: 0.96"/pixel
- Three Lyot filter: Ca II K, Hα, He I 1083 nm
- Observations: 2012 – 2020 (1056 observing days)
- Hα: 656.2nm, FWHM Δλ = 0.05 nm
- Dark filaments & bright plage regions

Bethge et al. 2011, A&A 534, A105

Imaging Hα Excess and Deficit

- Limb darkening correction, intensity correction with Zernike polynomials

- Masks: Threshold + morphological image processing

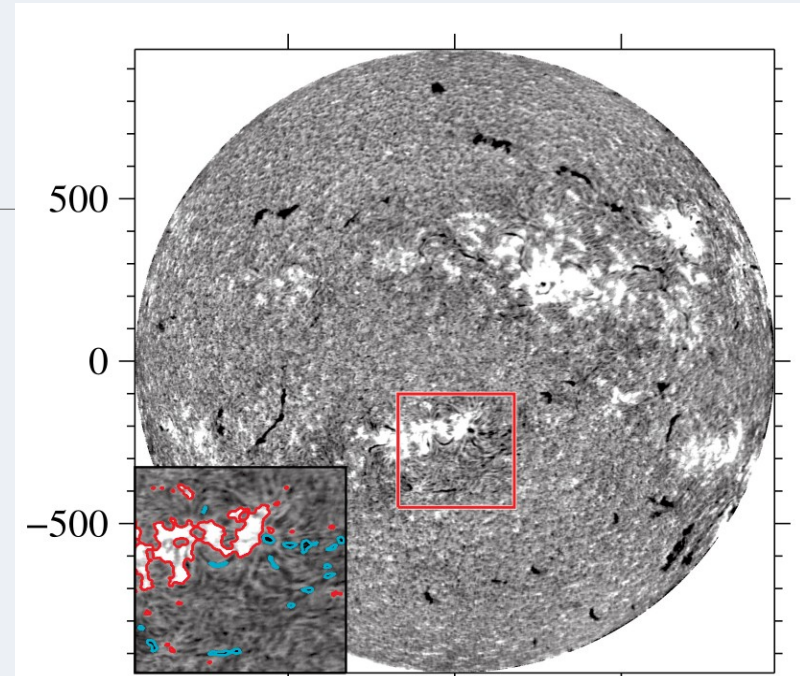$$T_{100}^{\mathrm{E}} = I_{\mathrm{med}} + 0.1 \times I_{\mathrm{med}} \qquad T_{100}^{\mathrm{D}} = I_{\mathrm{med}} - 0.1 \times I_{\mathrm{med}}$$

- Imaging Hα Excess and Deficit

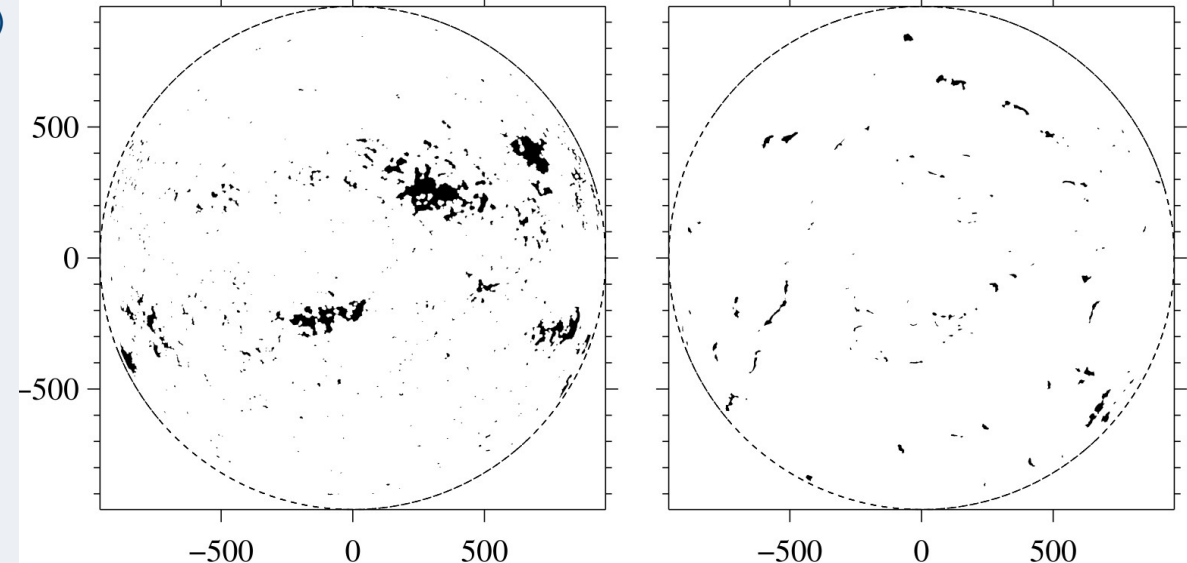 (Johannesson et al. 1998, Sol. Phys., 177, 265; Naqvi et al. 2010, AN, 331, 696)

$$E_{100} = \frac{1}{1000} \sum_{ij} f_{ij} \quad \text{with} \quad \begin{cases} f_{ij} = I_{ij} - T_{100}^{\mathrm{E}} & \text{if } I_{ij} \geq T_{100}^{\mathrm{E}} \\ f_{ij} = 0 & \text{if } I_{ij} < T_{100}^{\mathrm{E}} \end{cases}$$

$$D_{100} = \frac{1}{1000} \sum_{ij} f_{ij} \quad \text{with} \quad \begin{cases} f_{ij} = |I_{ij} - T_{100}^{\mathrm{D}}| & \text{if } I_{ij} \leq T_{100}^{\mathrm{D}} \\ f_{ij} = 0 & \text{if } I_{ij} > T_{100}^{\mathrm{D}} \end{cases}$$
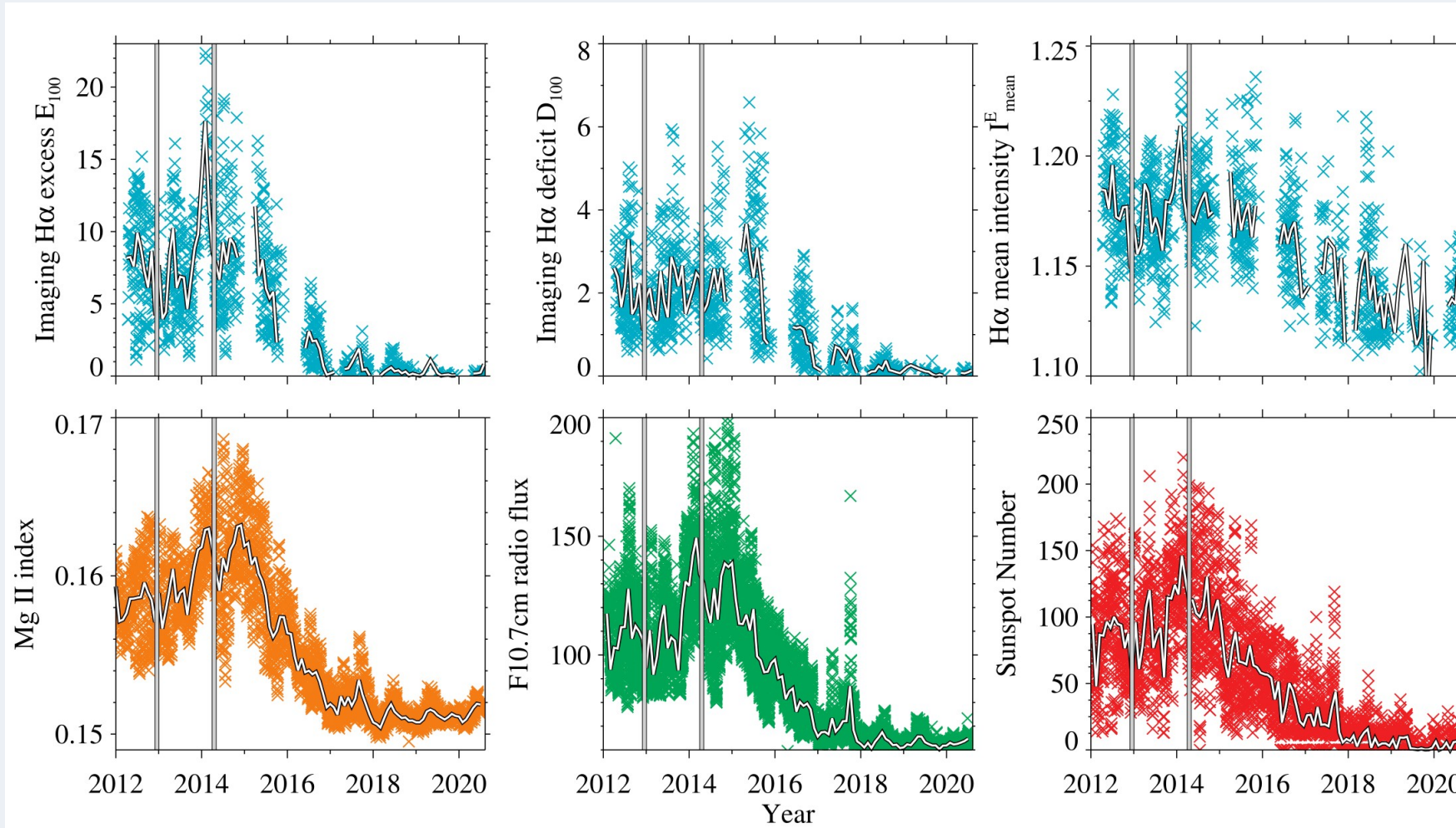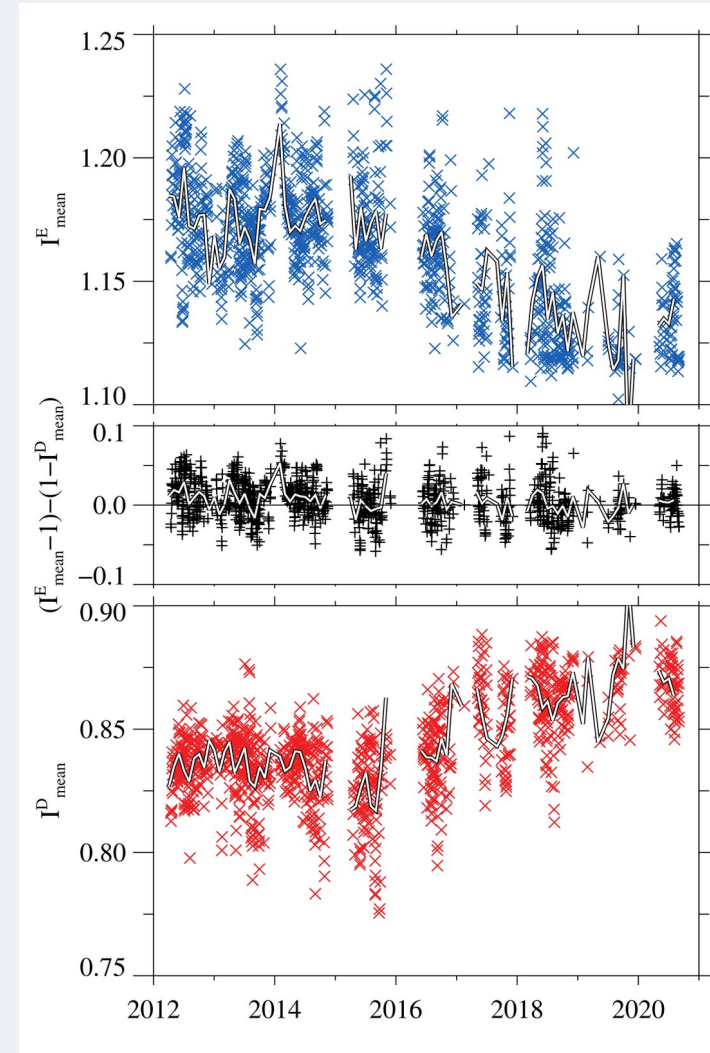
Excess

Deficit

Hα Excess and Deficit for Solar Cycle 24


- Cyclic behavior of imaging Hα excess and deficit
- Comparison to other tracers: Mg II index, F10.7cm radio flux, sunspot number
- Best correlation of Excess with Mg II index
- Best correlation of Deficit with F10.7cm
- Deficit: filament cycle visible, peak later then for other tracers

Hα mean intensity for excess and deficit regions

- Mean intensity for Hα excess regions and Hα deficit regions
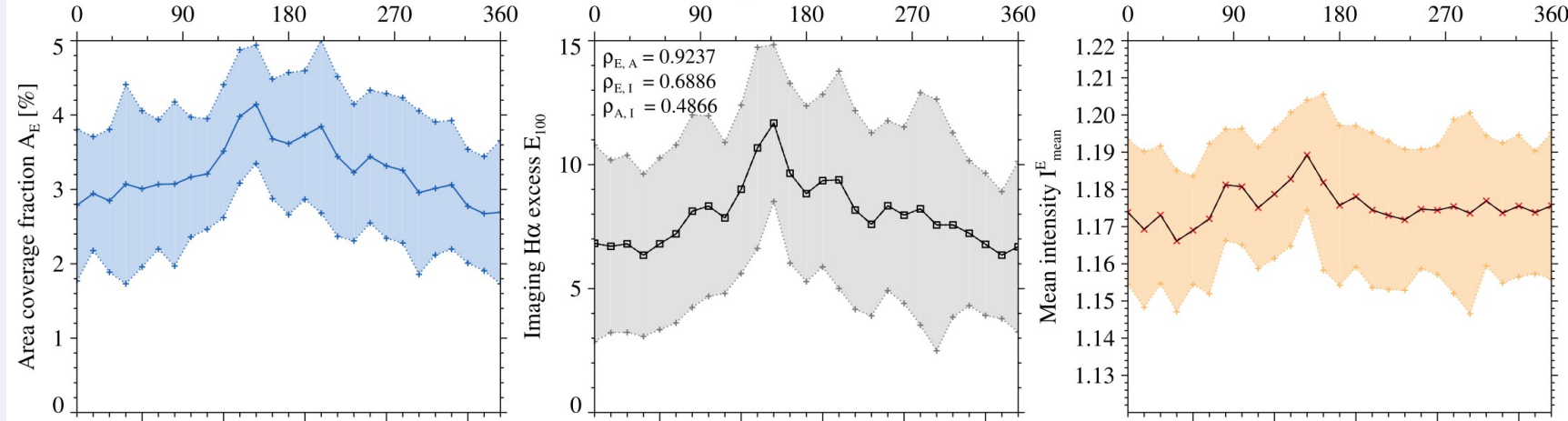- Monthly mean of difference of mean intensity
- Similar behavior of both quantities
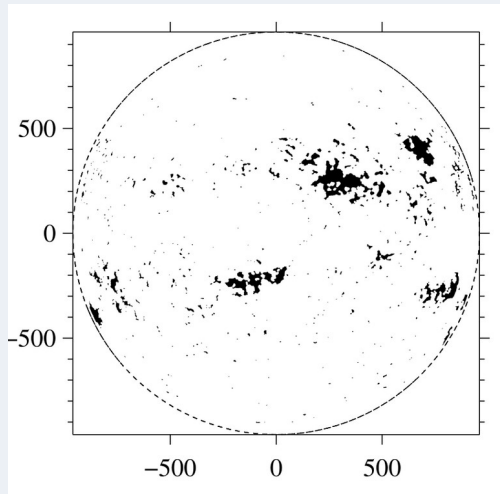
- Histogram of mean intensity of individual patches of Hα excess
- Active Sun: 2012 – 2015 (202 991 patches)
- Inactive Sun: 2016 – 2020 (25 426 patches)
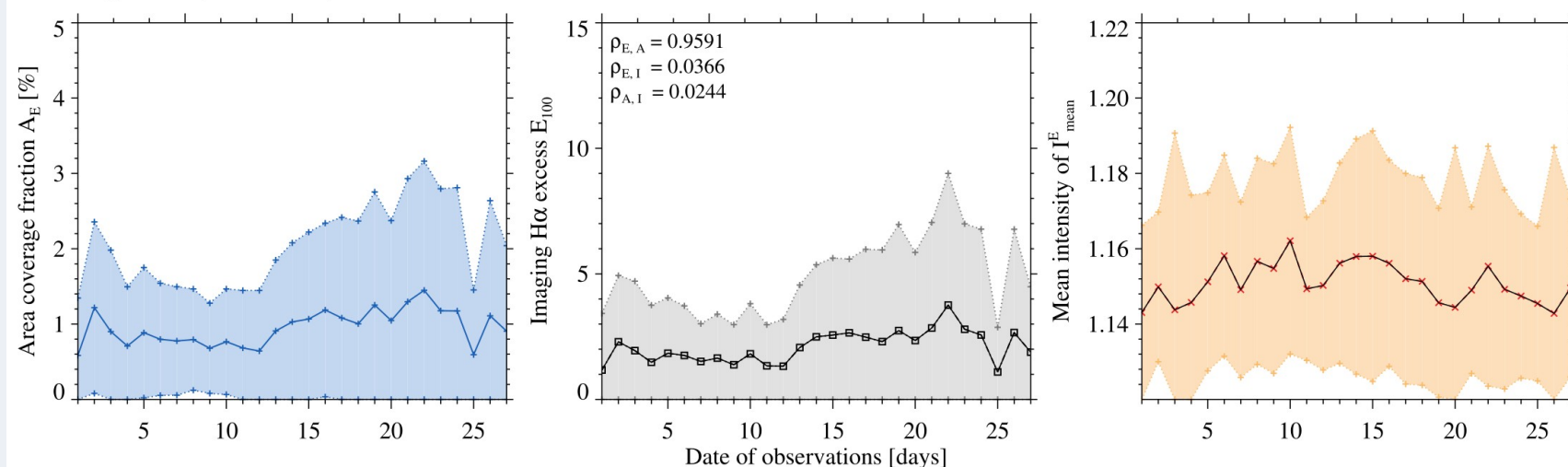- Similar skewed Gaussian distribution for both active and inactive Sun
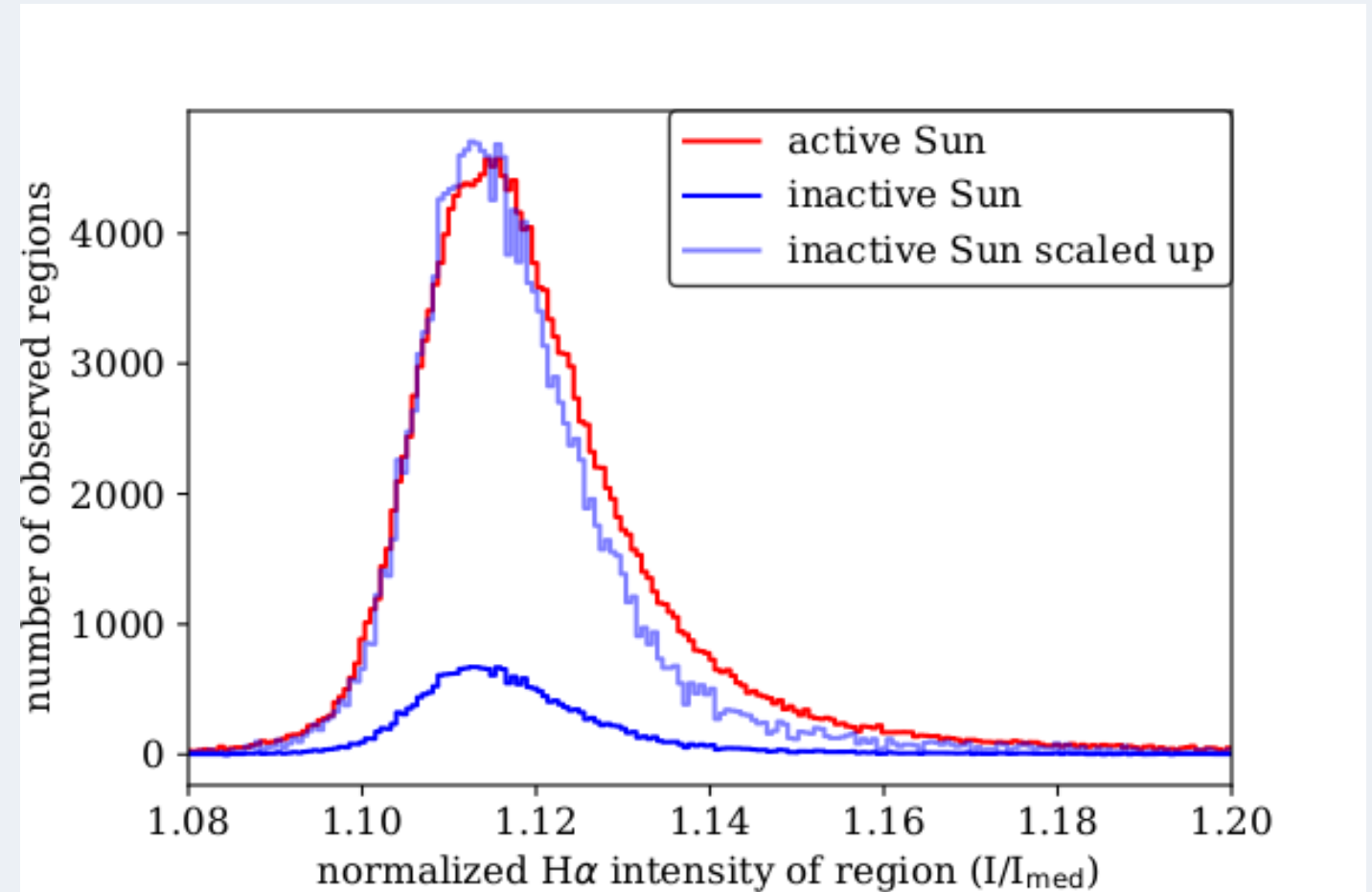
Active Longitude for Solar Cycle 24 – Hα Excess

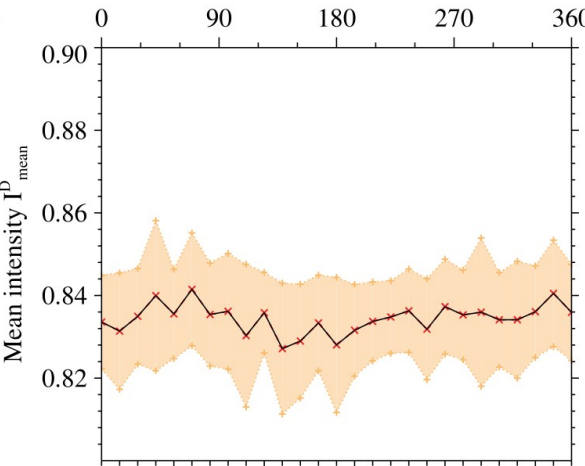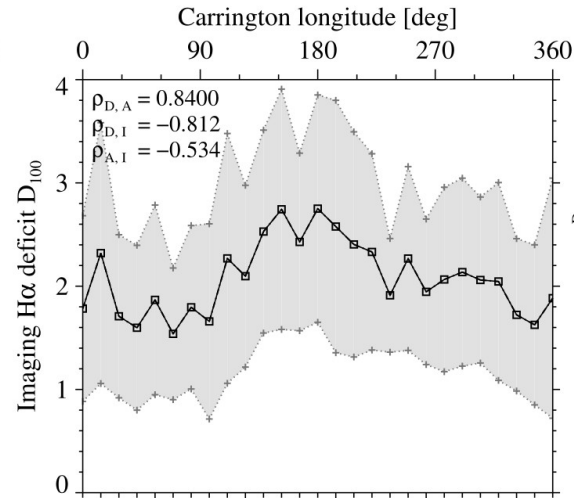- Comparison of Hα excess, area coverage fraction and mean intensity
- Average of all 84 Carrington rotations (rotation period: 27.27 days)
- High correlation of Hα excess and area coverage fraction
- Active Sun: Active longitude at about 150° for Hα excess and area coverage fraction
- Inactive Sun: no clear active longitude

Active Longitude for Solar Cycle 24 – Hα Deficit
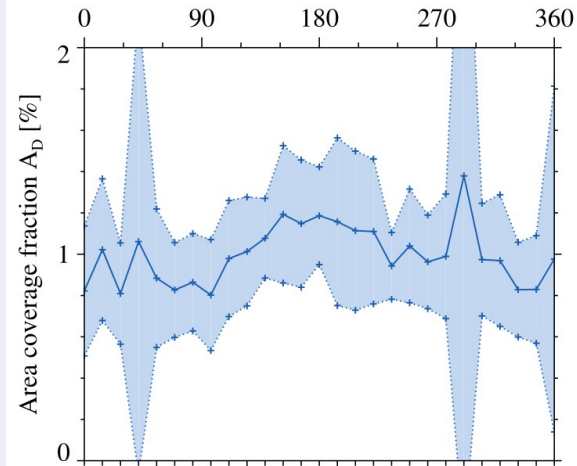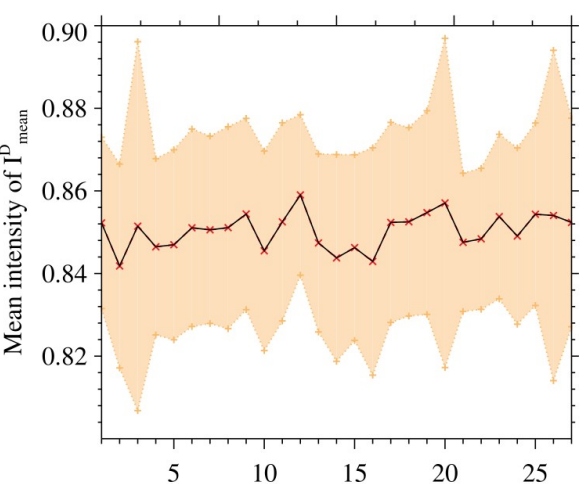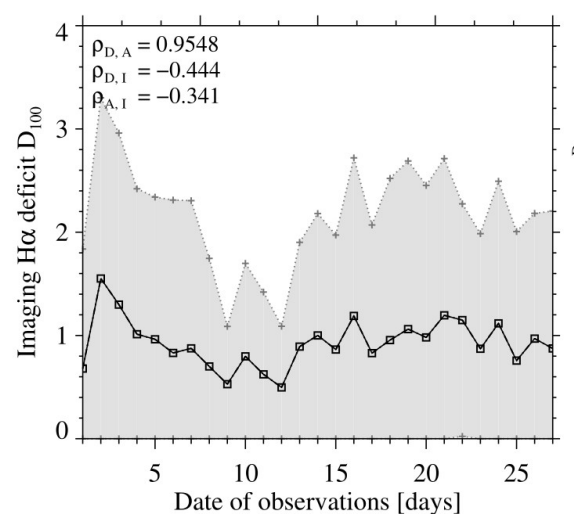

- Comparison of Hα deficit, area coverage fraction and mean intensity
- Average of all 84 Carrington totations (rotation period: 27.27 days)
- High correlation of Hα excess and area coverage fraction
- Active Sun: Active longitude between 150° and 180° for Hα deficit and area coverage fraction
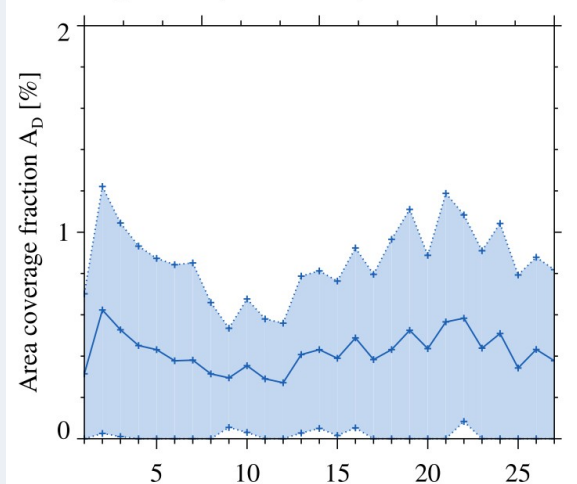- Inactive Sun: no clear active longitude
- Spikes in area coverage fraction maybe due to large filaments

Hα Excess of Active Regions

- Sample of 15 active regions between 2012 and 2020
- Sequence of disk passage
- Different activity samples (with and without flaring activity)
- Comparison of Hα excess, Number of pixels, and mean intensity
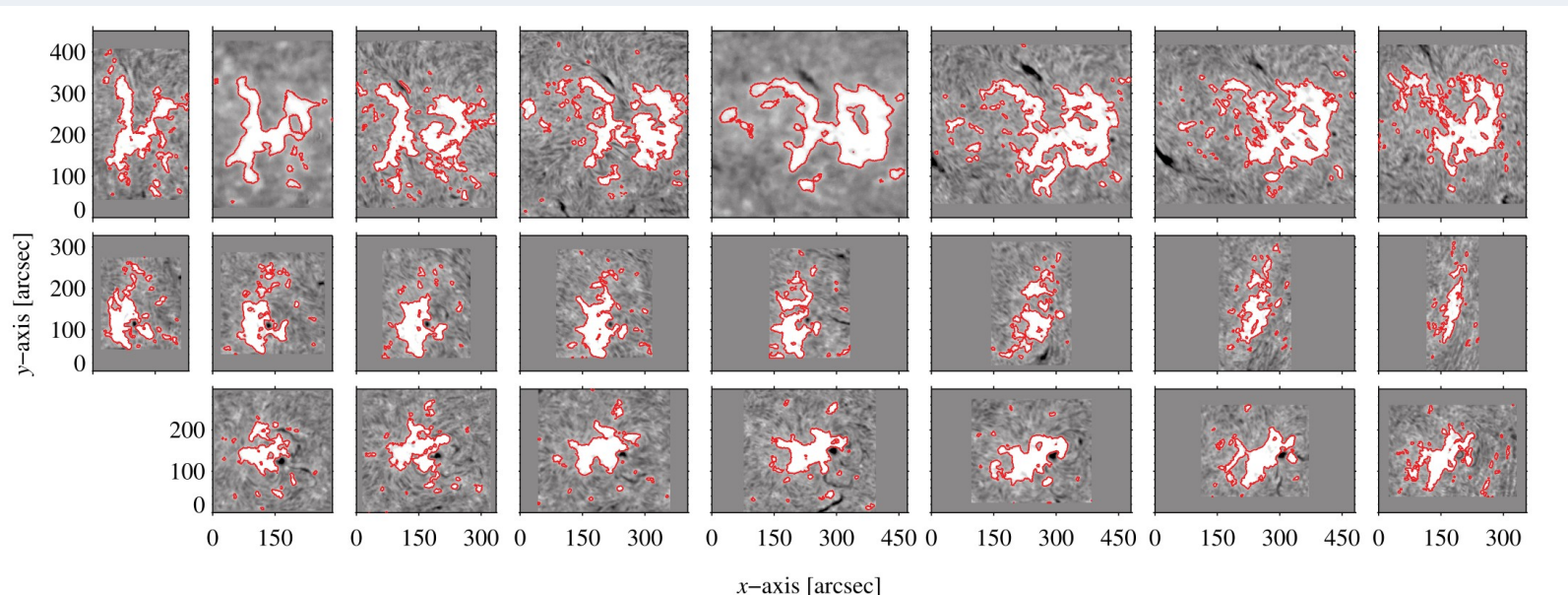
NOAA	Observing period
11476**	2012/05/09 – 2012/05/16
11555	2012/08/26 – 2012/09/04
11818**	2013/08/10 – 2013/08/20
11835	2013/08/25 – 2013/09/05
11850*	2013/09/19 – 2013/10/01
12049*	2014/04/29 – 2014/05/08
12139*	2014/08/11 – 2014/08/22
12389*	2015/07/24 – 2015/08/03
12578	2016/08/15 – 2016/08/26
12686	2017/10/24 – 2017/11/01
12709	2018/05/08 – 2018/05/19
12712*	2018/05/24 – 2018/06/04
SPoCA 21904†	2018/07/08 – 2018/07/18
12767	2020/07/22 – 2020/08/01
12769	2020/08/01 – 2020/08/13

†   NOAA identification not available
★   Flaring active regions (C-class)
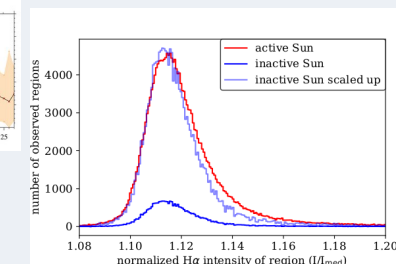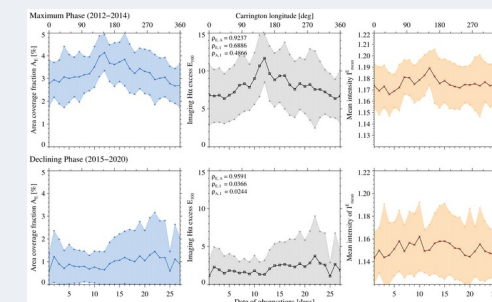★★   Flaring active regions (M-class)

Hα Excess of Active Regions
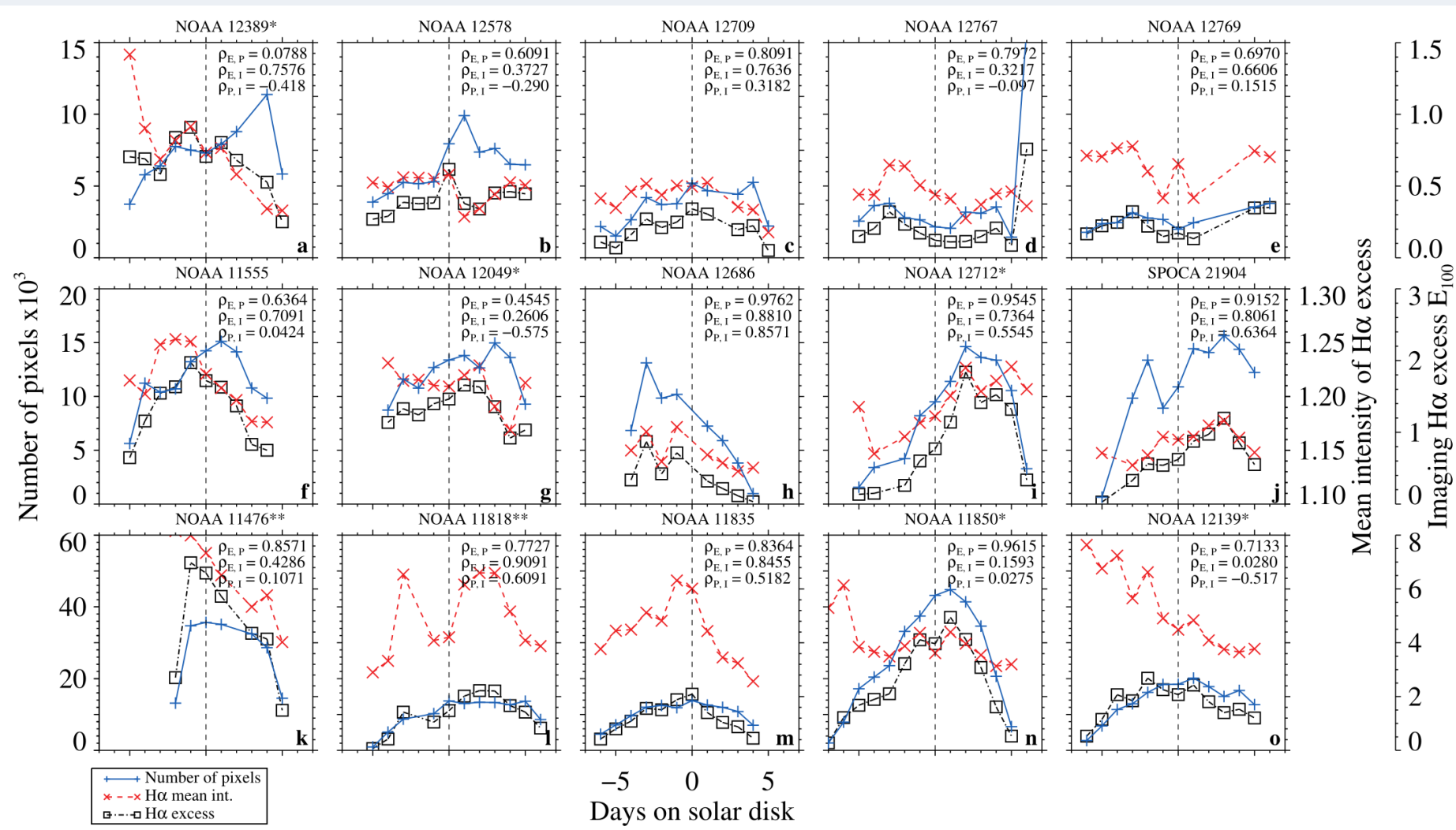
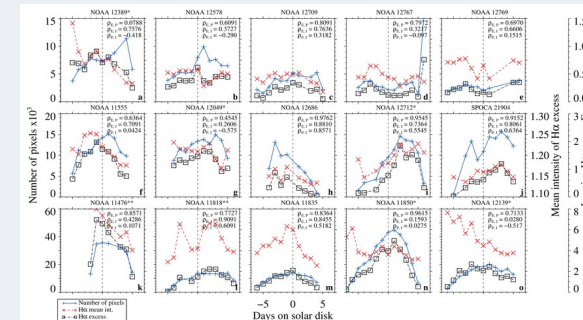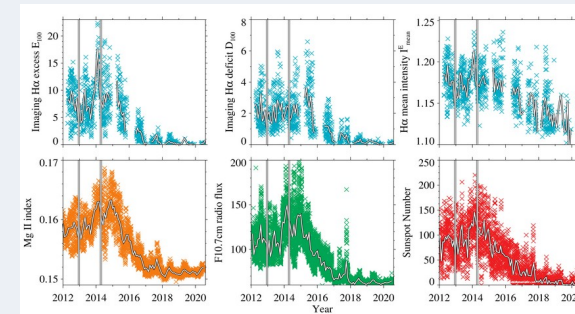

- High correlation for Hα excess and number of pixels
- Some examples with high correlation of Hα excess and mean intensity
- Mean intensity high influenced by flaring activity
- No clear correlation between size of the region and mean intensity

Conclusions

□ Hα excess and deficit **reflect solar activity cycle**

□ Hα activity dominated either by changes of the mean
intensity or by area coverage fraction of Hα excess regions?
→ **no direct relationship found**: impact on the modeling of
stellar active regions, area coverage fraction and the
intensity of Hα emitting regions are required to accurately
represent chromospheres of solar-like stars.

□ **Active latitude of sunspots** is visible with the Hα excess
and deficit in a Carrington reference frame averaged over the
maximum phase of the solar cycle.

□ **Intensity distribution of Hα excess regions** for the
maximum and minimum of the solar cycle revealed a similar
shape, but reduced by a factor of four in the minimum

□ Hα ground-based images almost continuously available, e.g.
Hα Network or GONG; going back until 1914

Thank you for your attention!