2023 Sun-Climate Symposium

A Century of Solar Observations from Kodaikanal Solar Observatory

New Insights from Ca II K Data

Bibhuti Kumar Jha
SwRI, Boulder

&

Dibya Kirti Mishra, Theodosios Chatzistergos and Dipankar Banerjee

Kodaikanal Solar Observatory (KoSO)

Courtesy: KoSO/IIA

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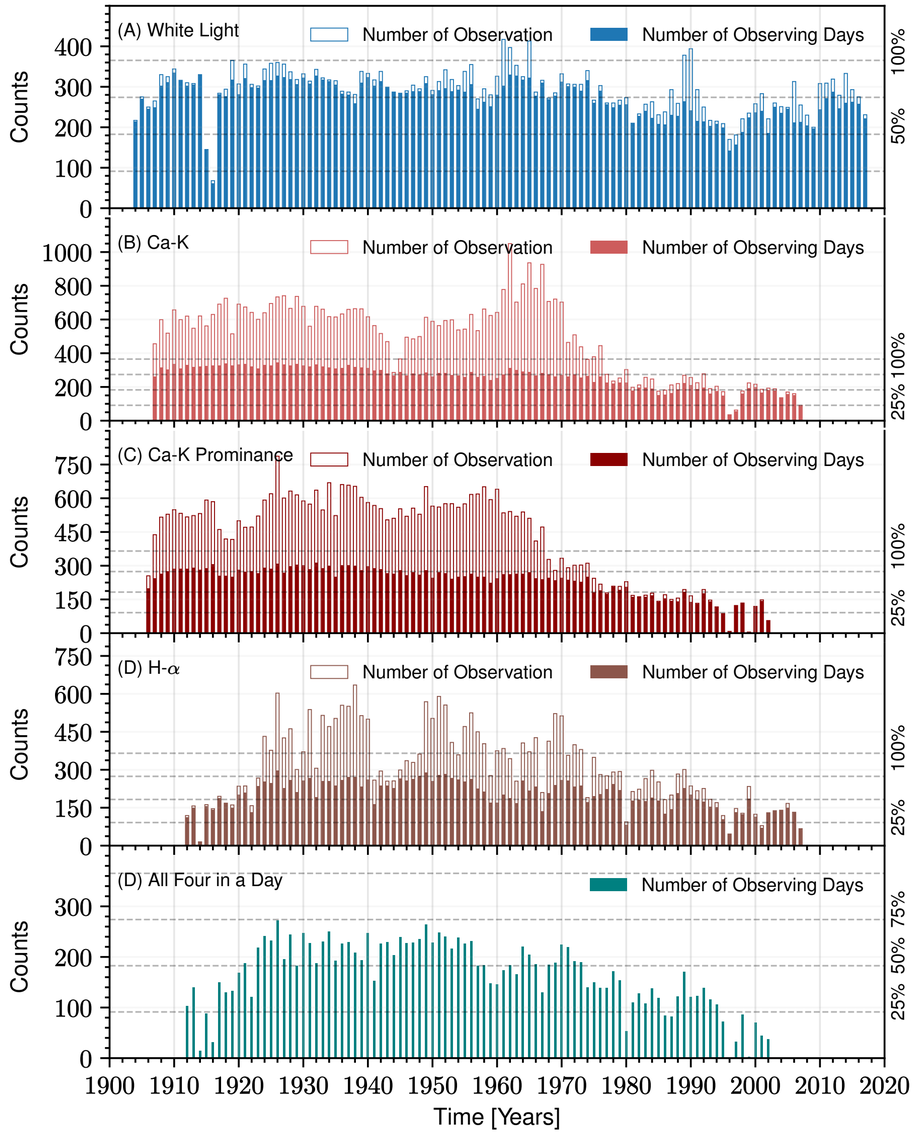

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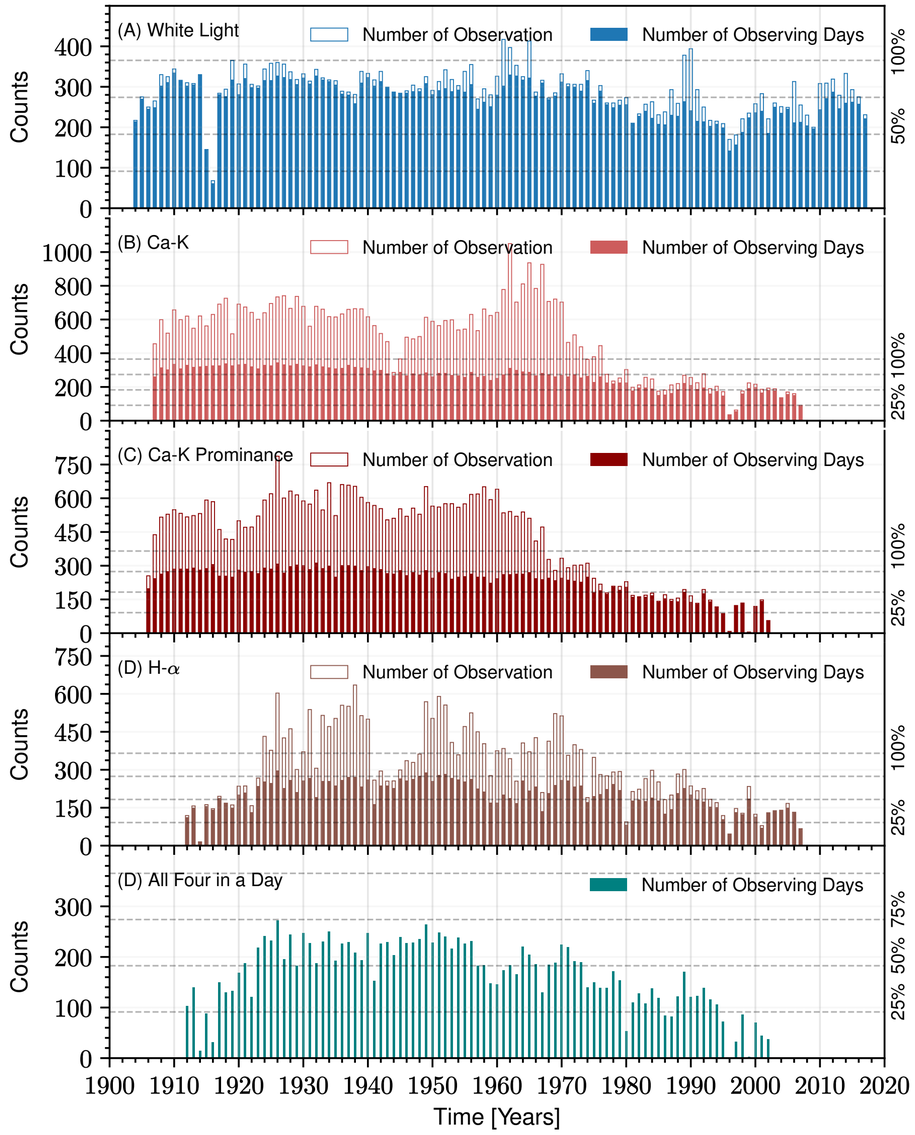

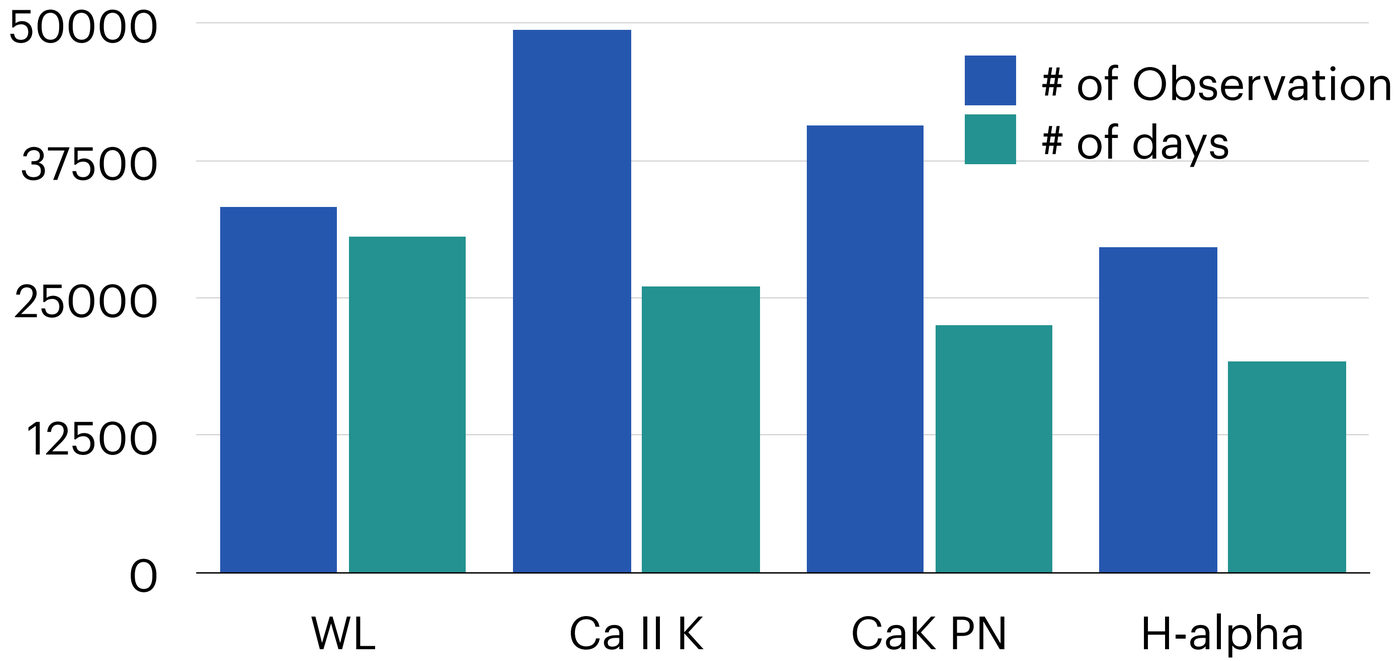

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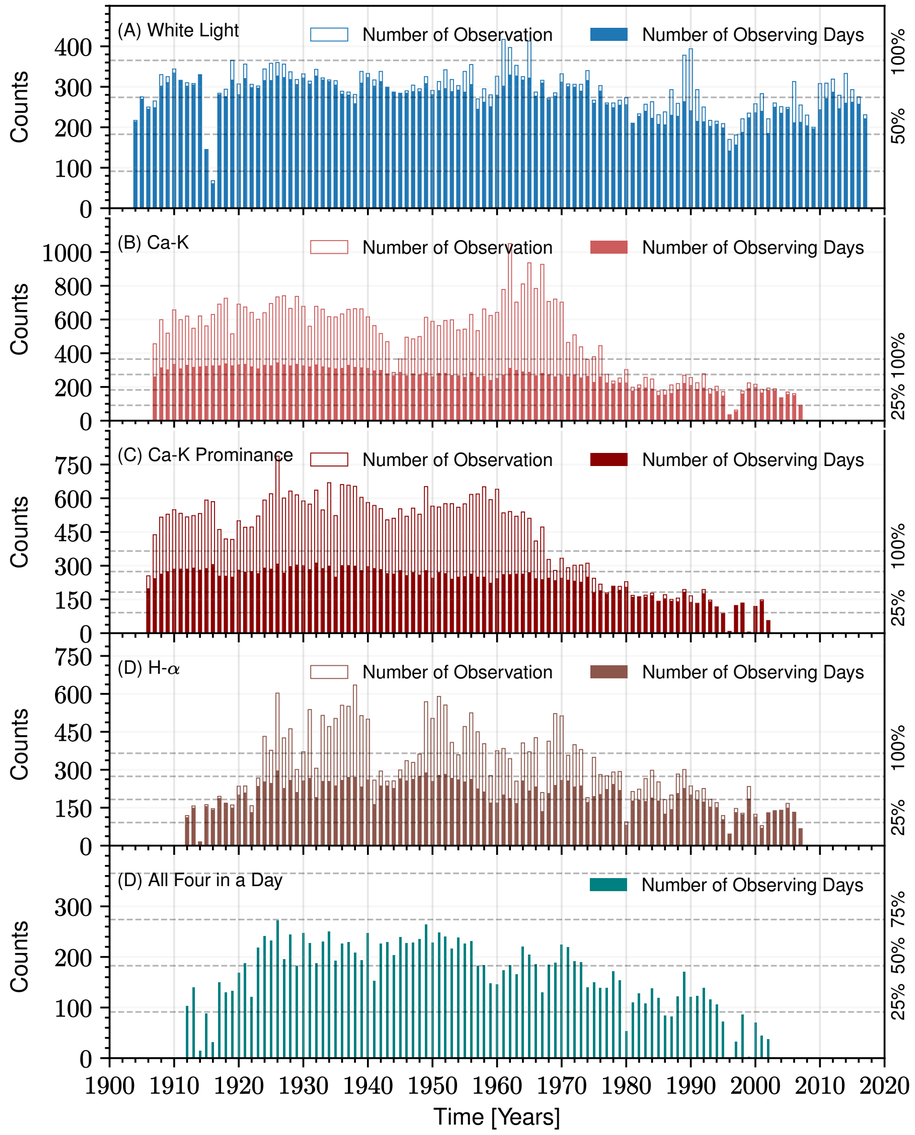

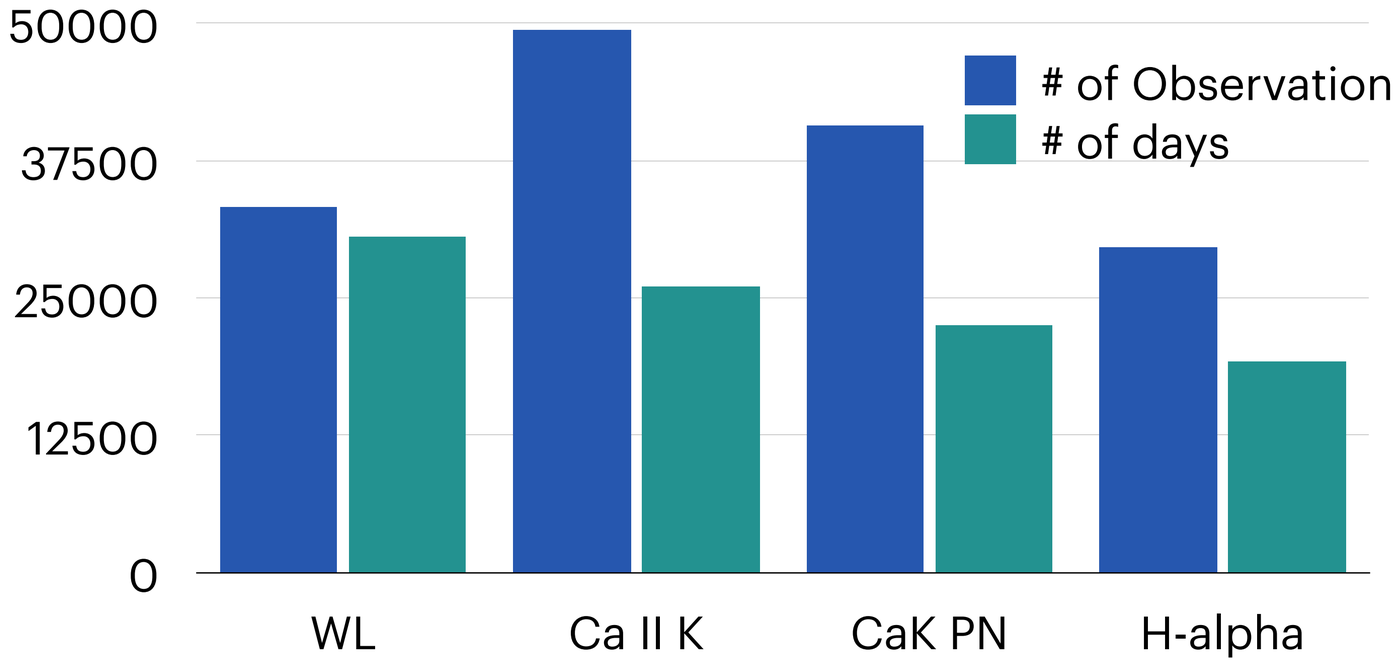

Contact:

Dipankar Banerjee: dipu@iiap.res.in

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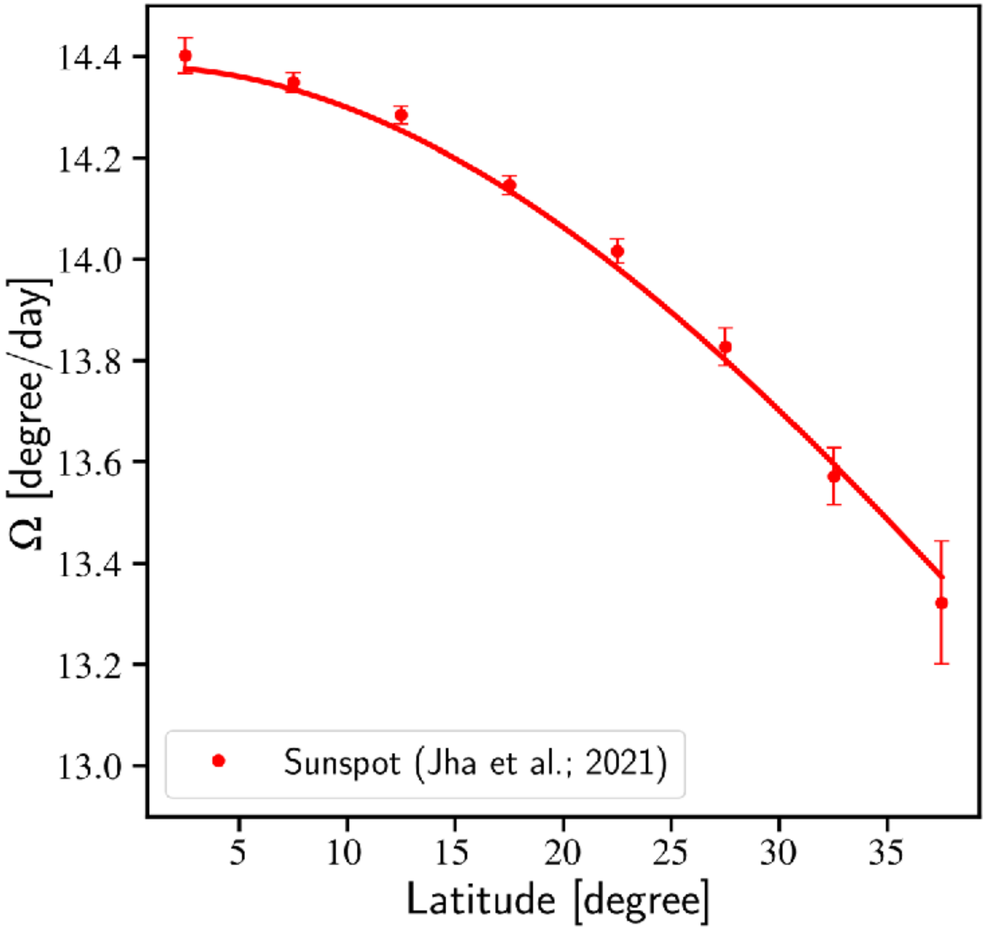

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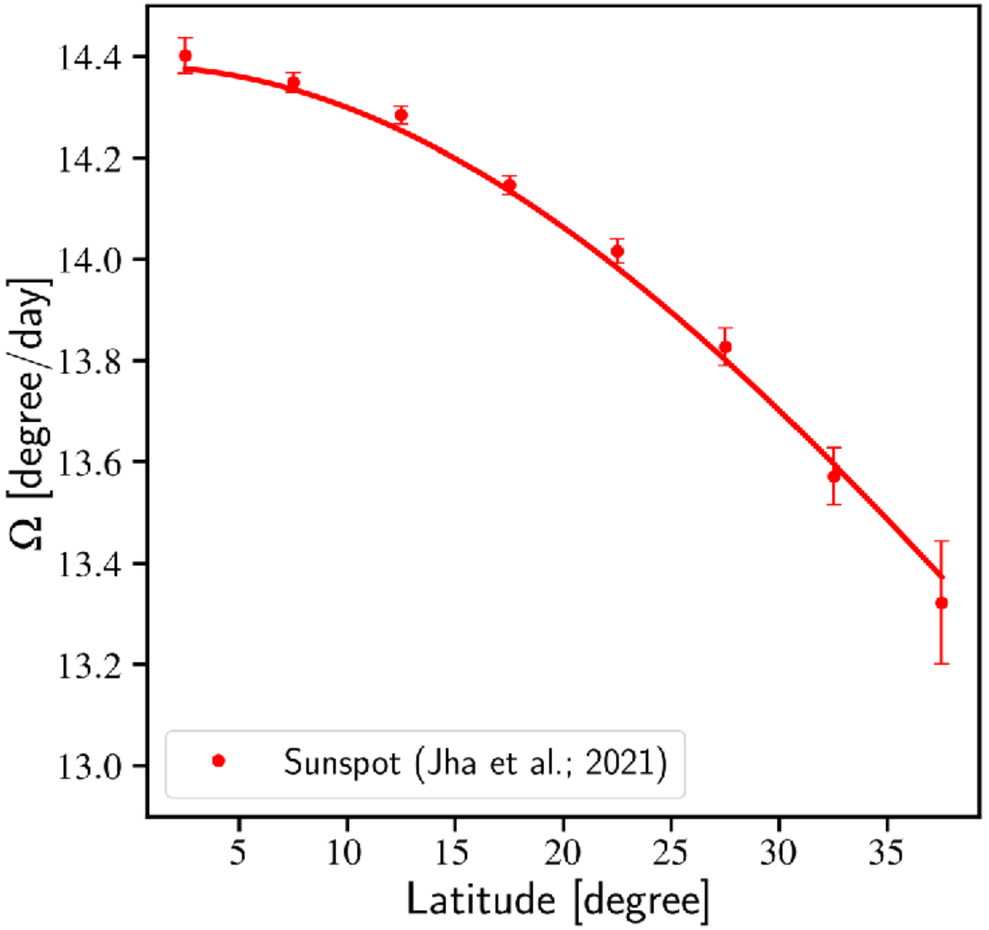

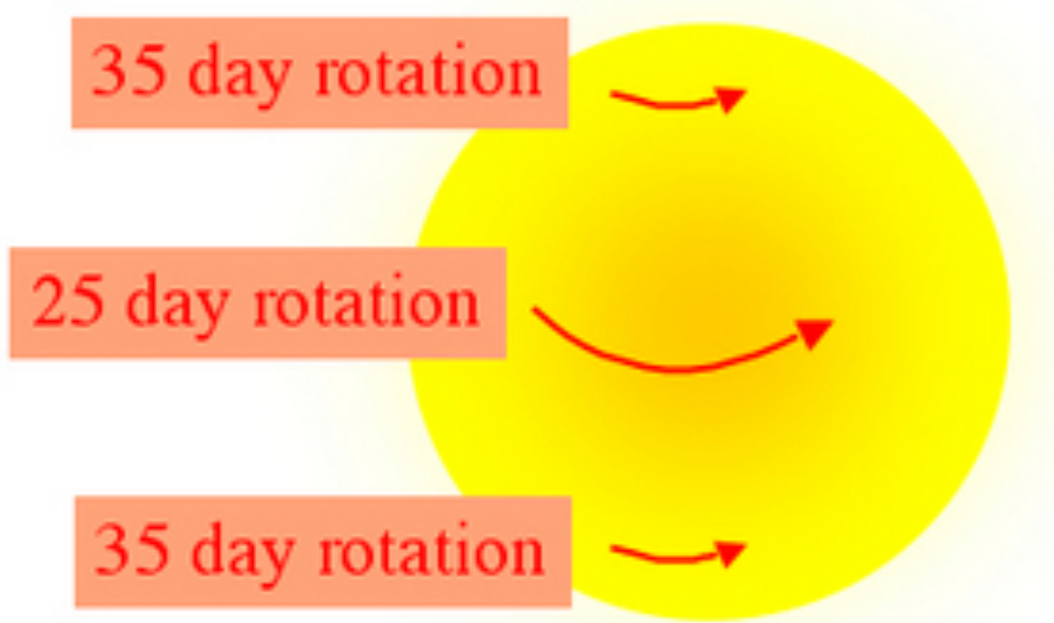

$$\Omega(\theta) = A + B\sin^2\theta + C\sin^4\theta$$

Image Credit: Swinburne University of Technology

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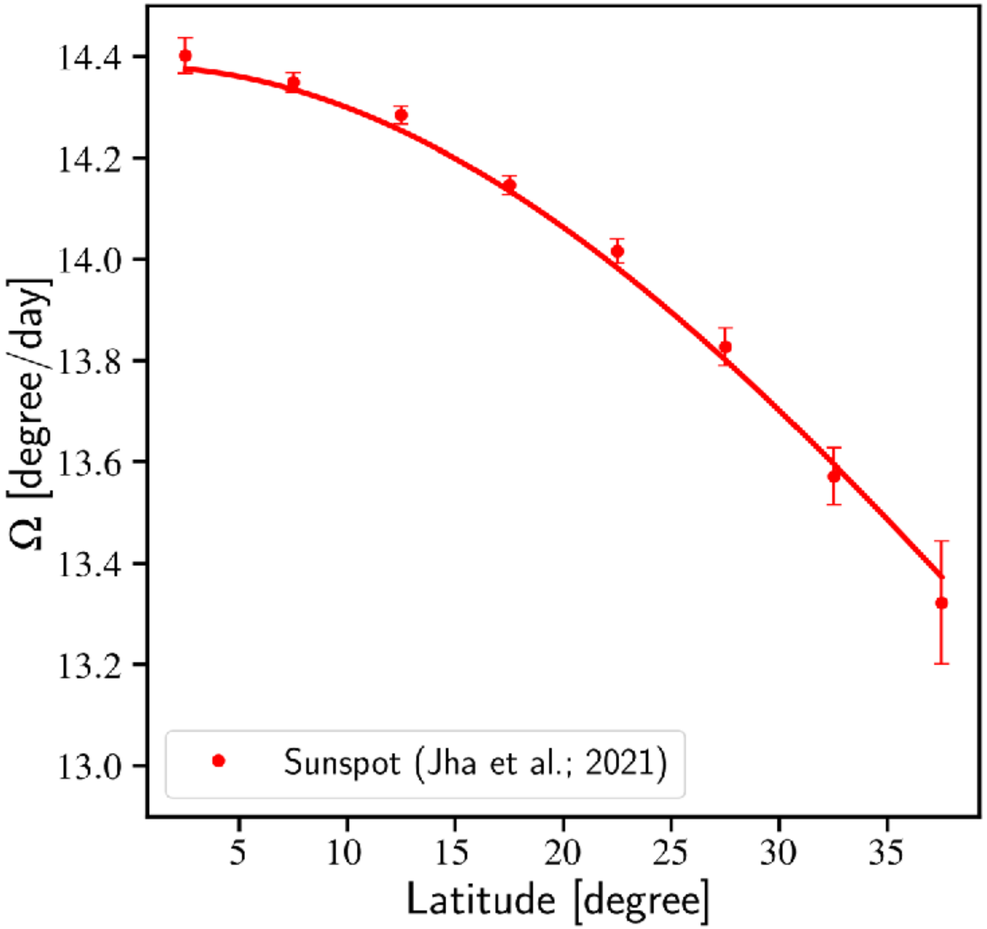

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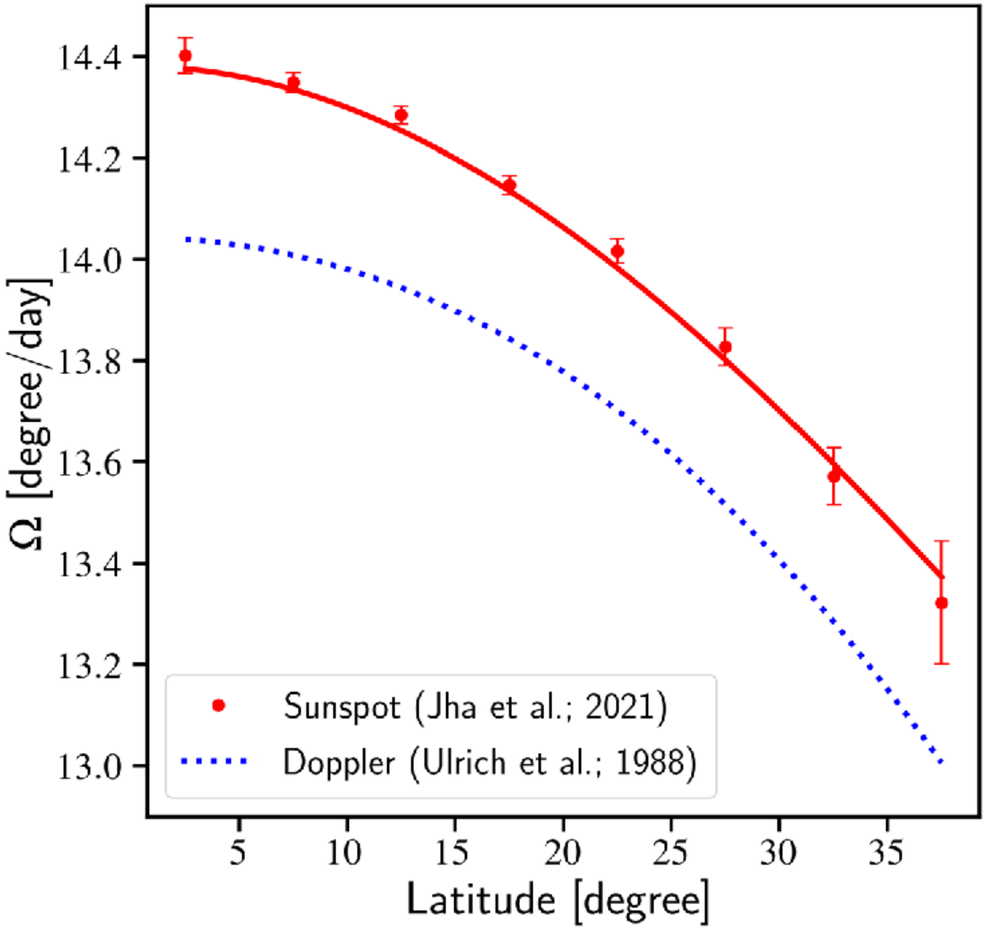

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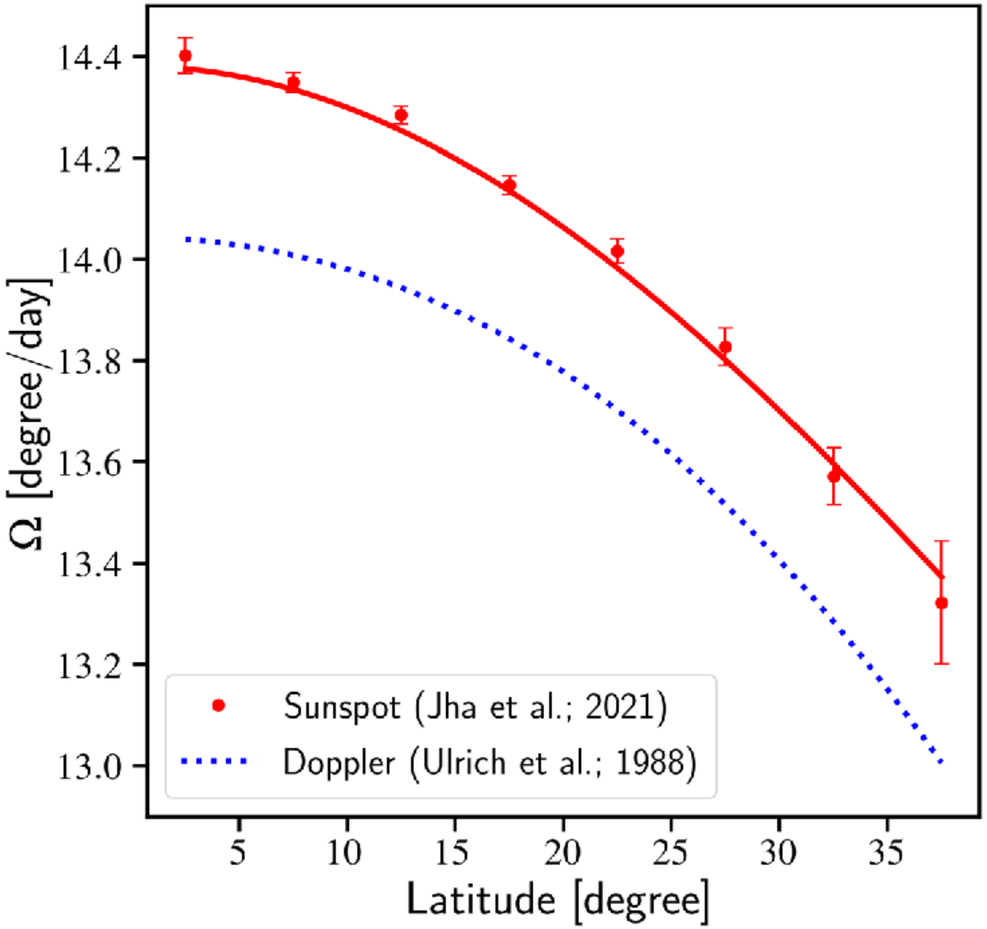

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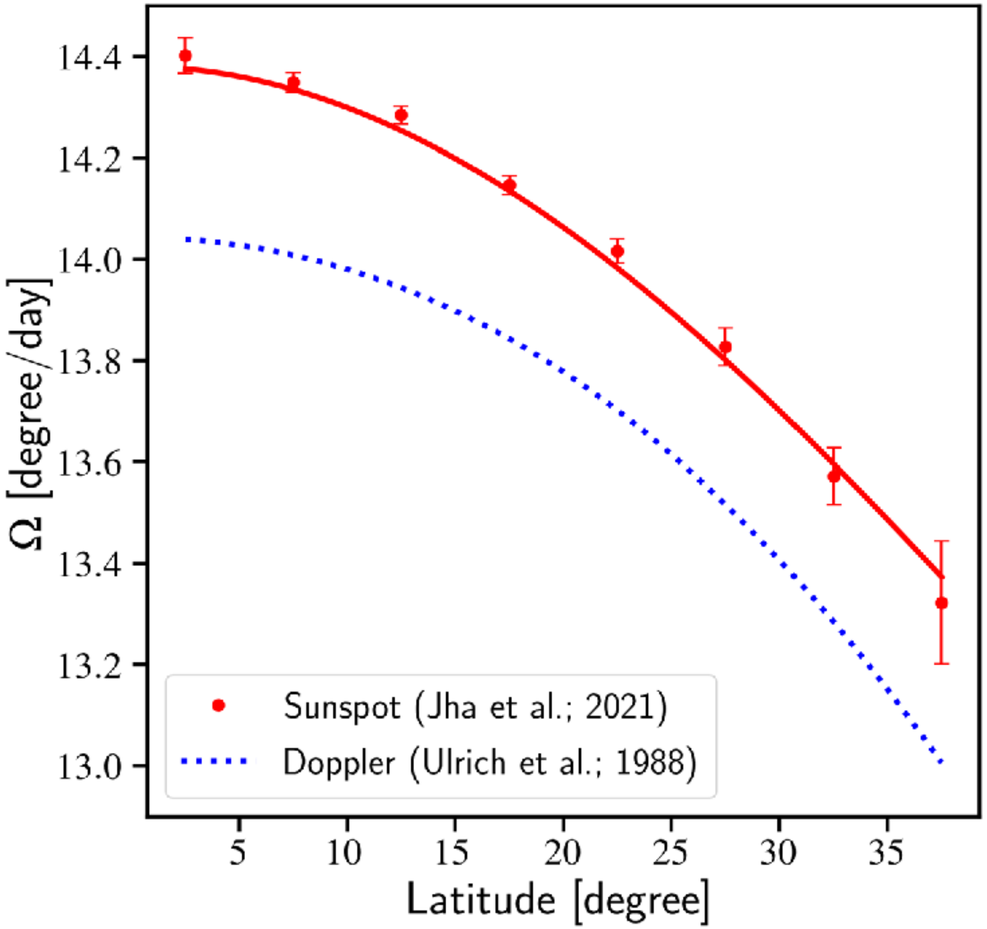

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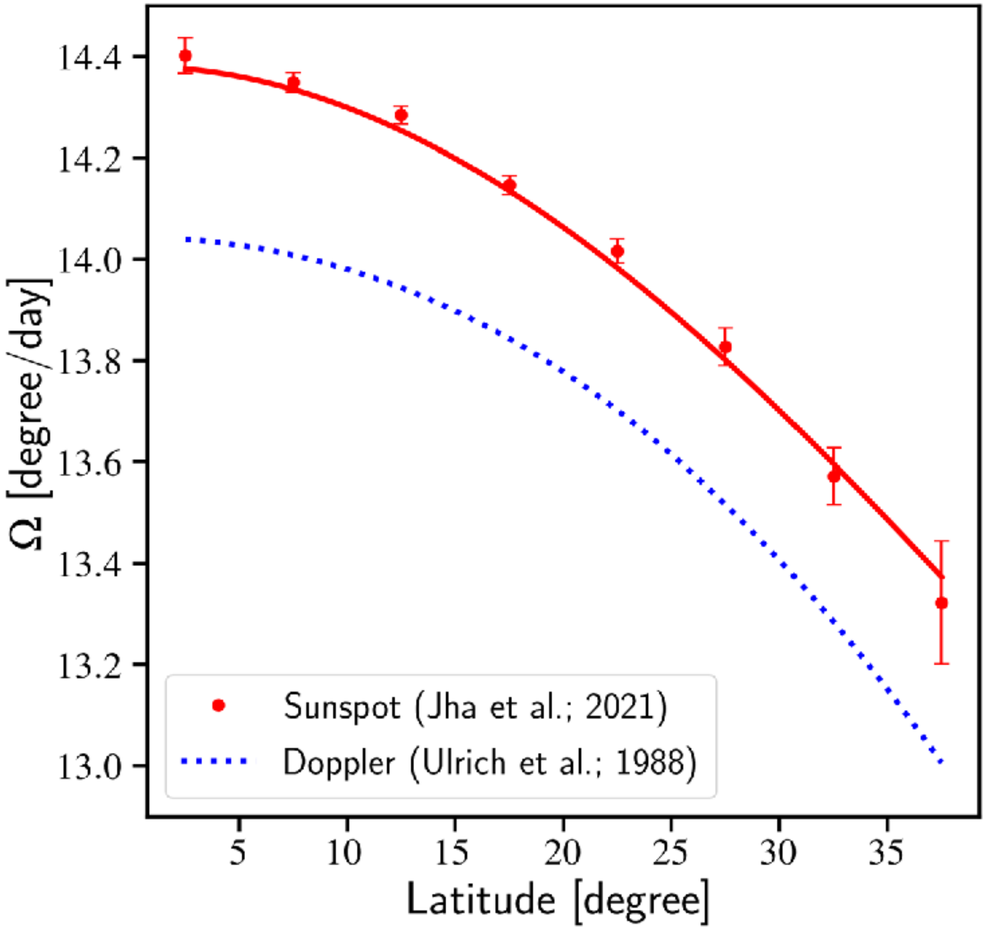

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KoSO provides the Ca II K data which probes the chromosphere.

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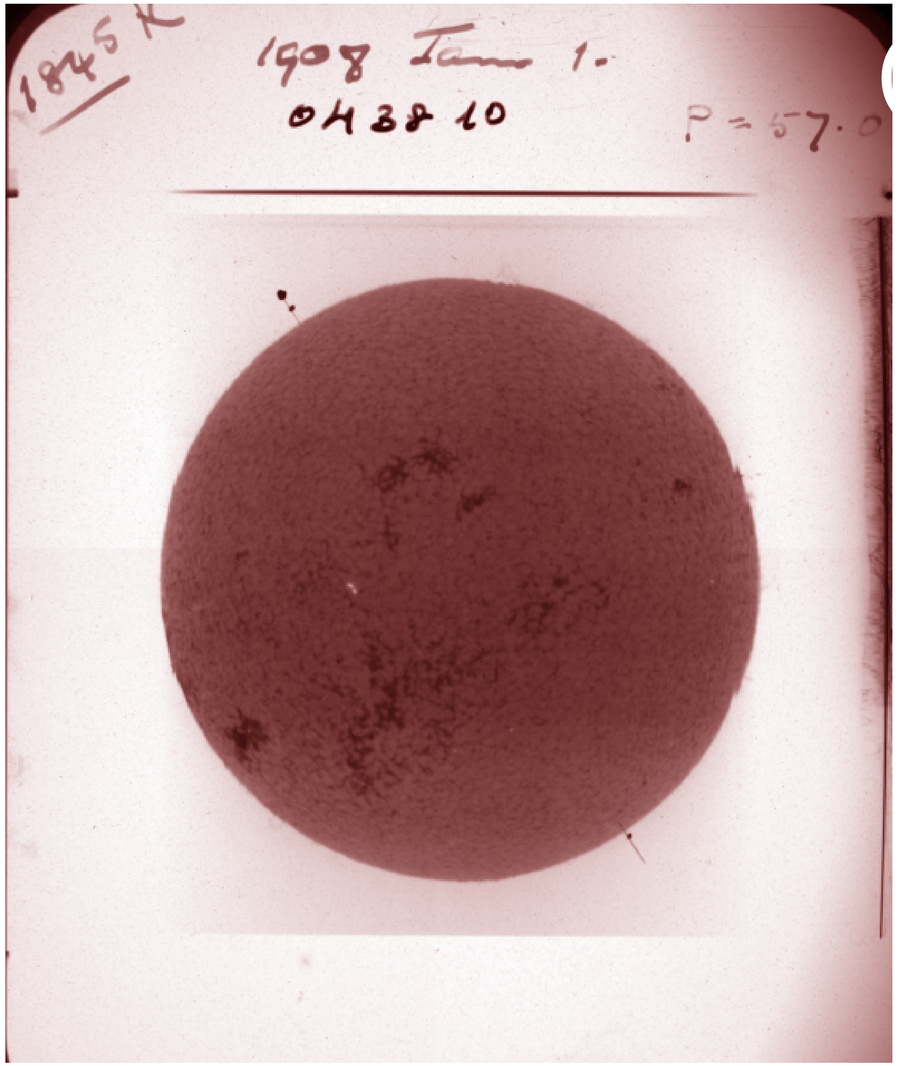

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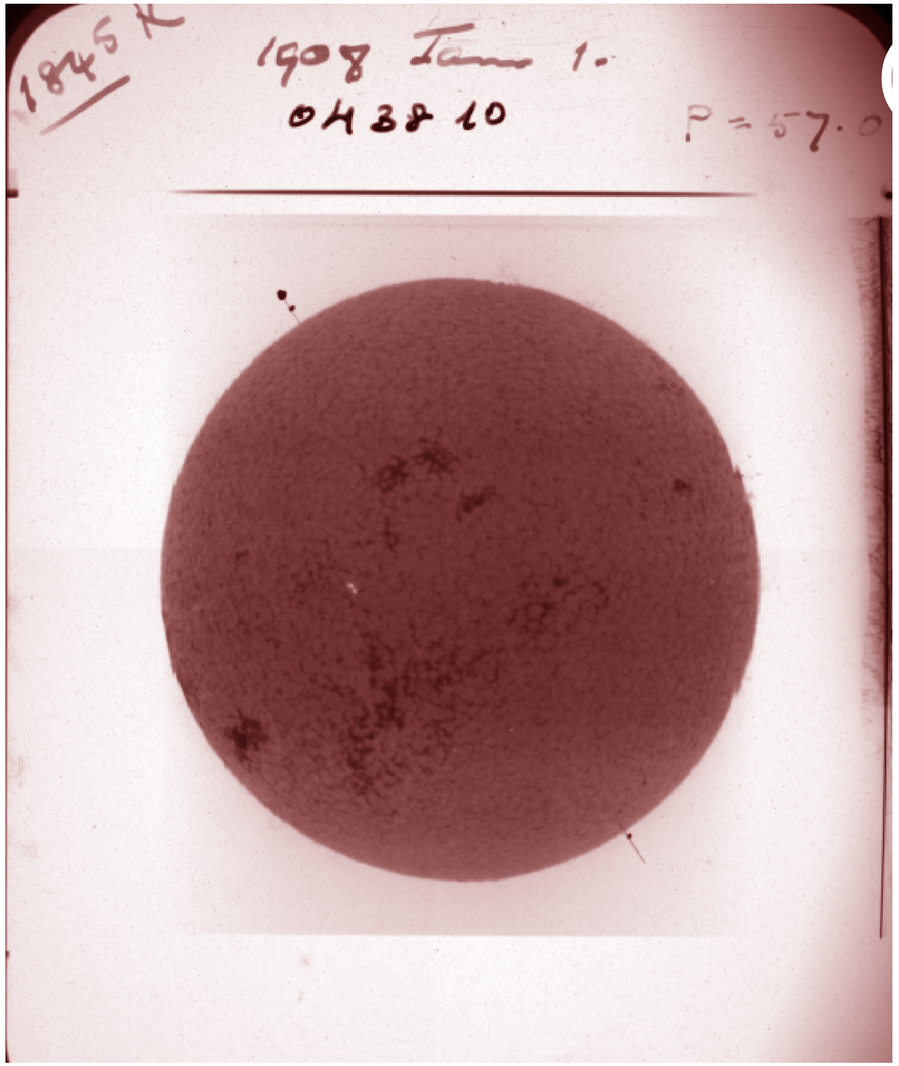

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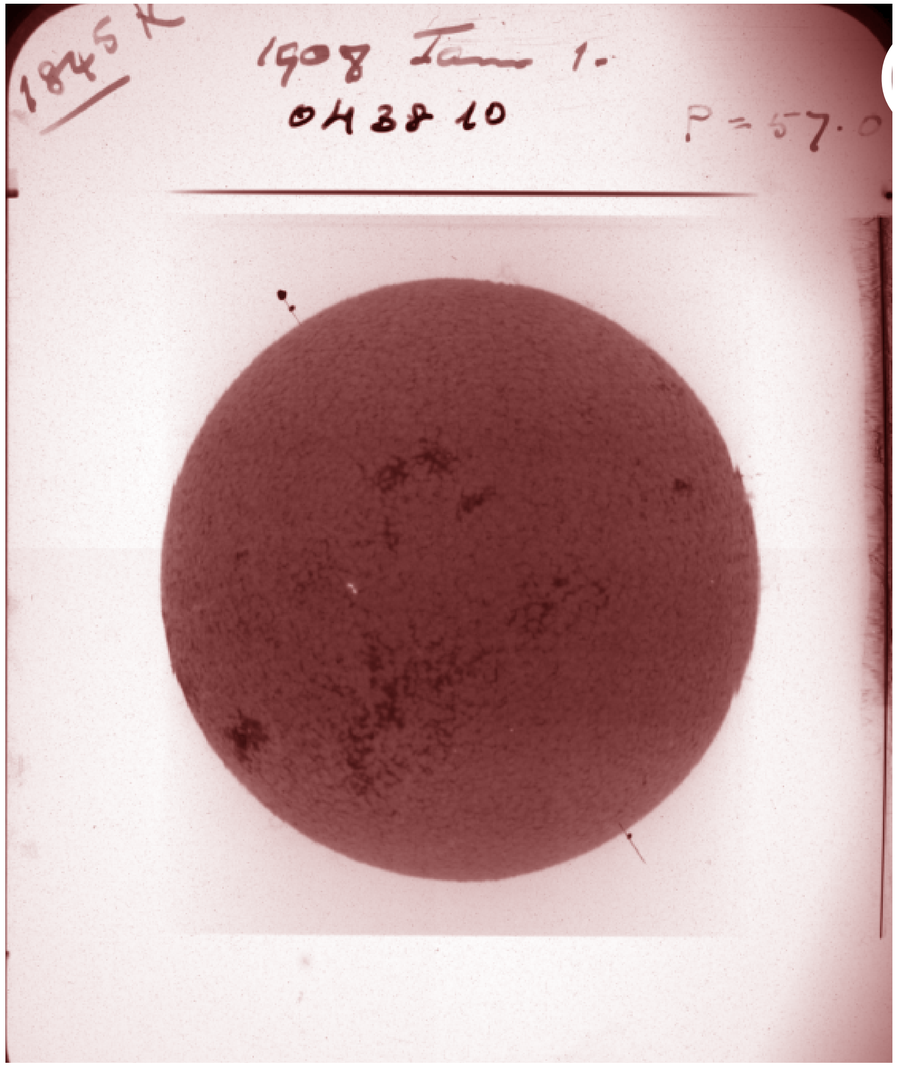

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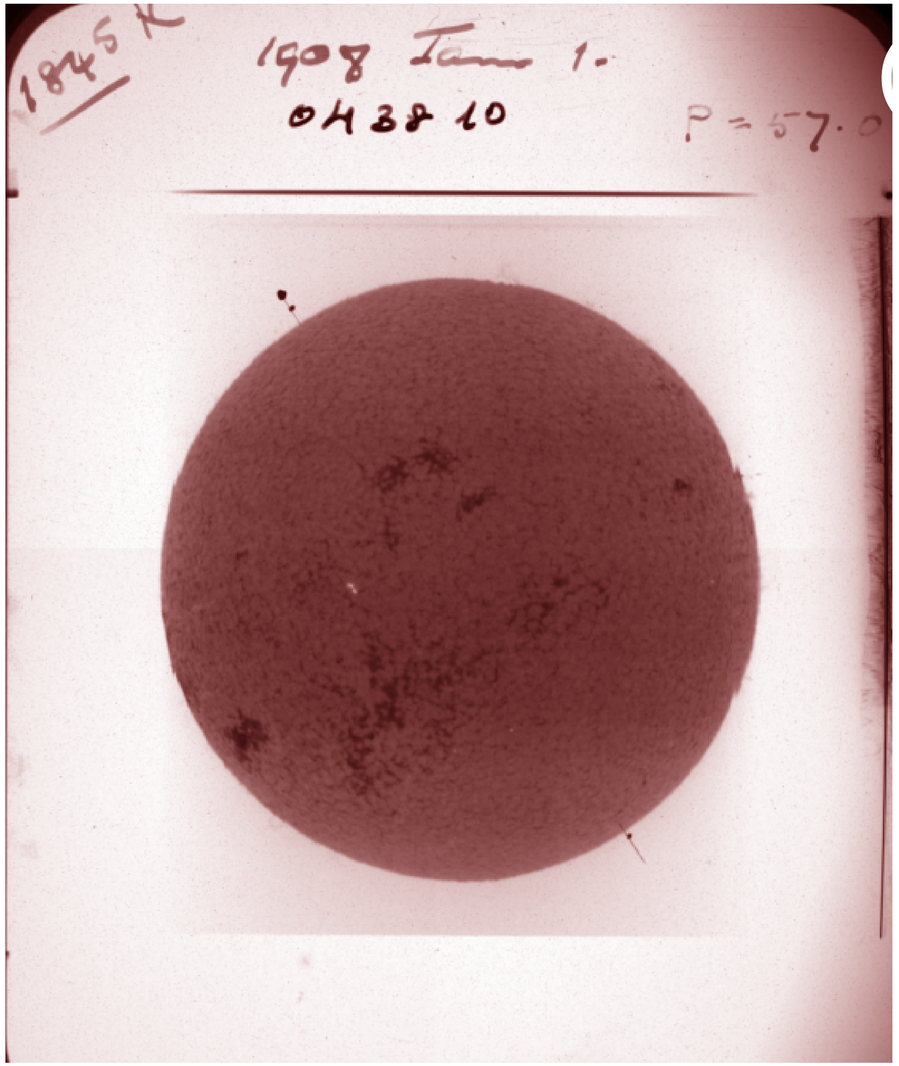

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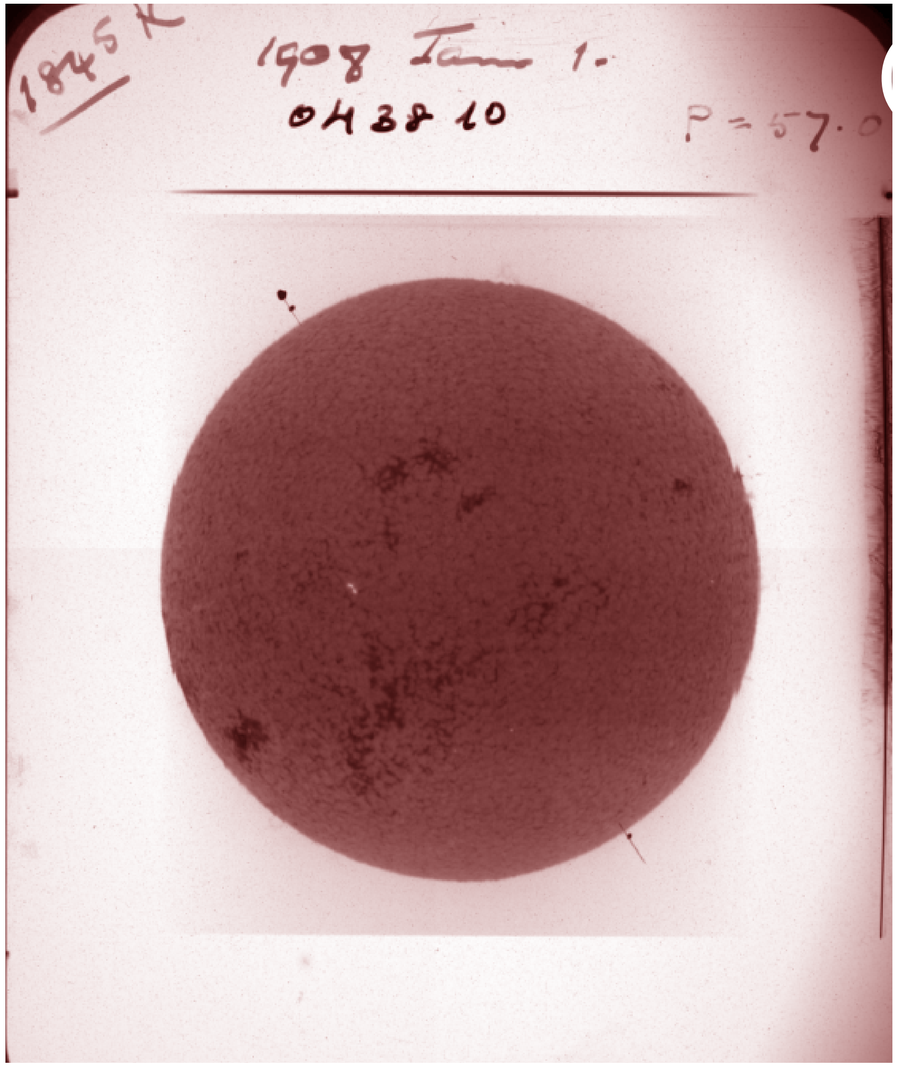

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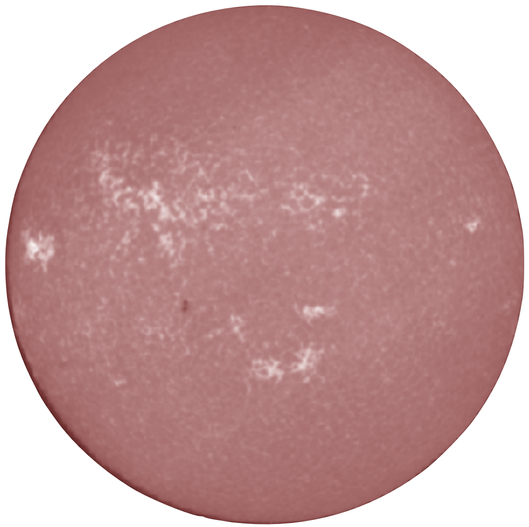

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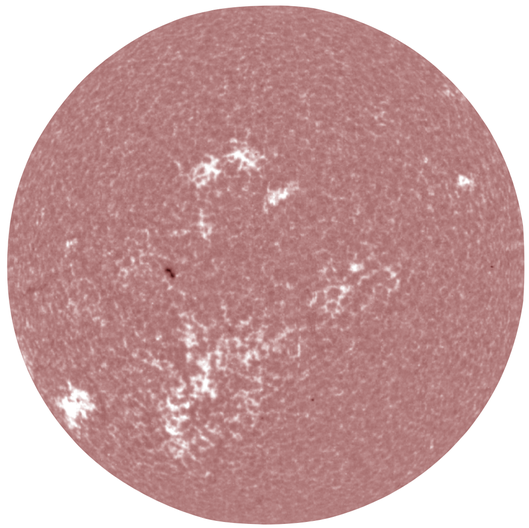

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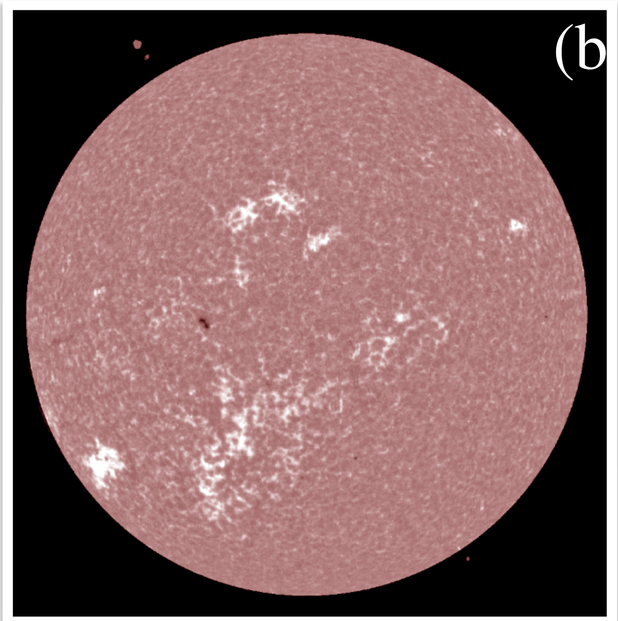

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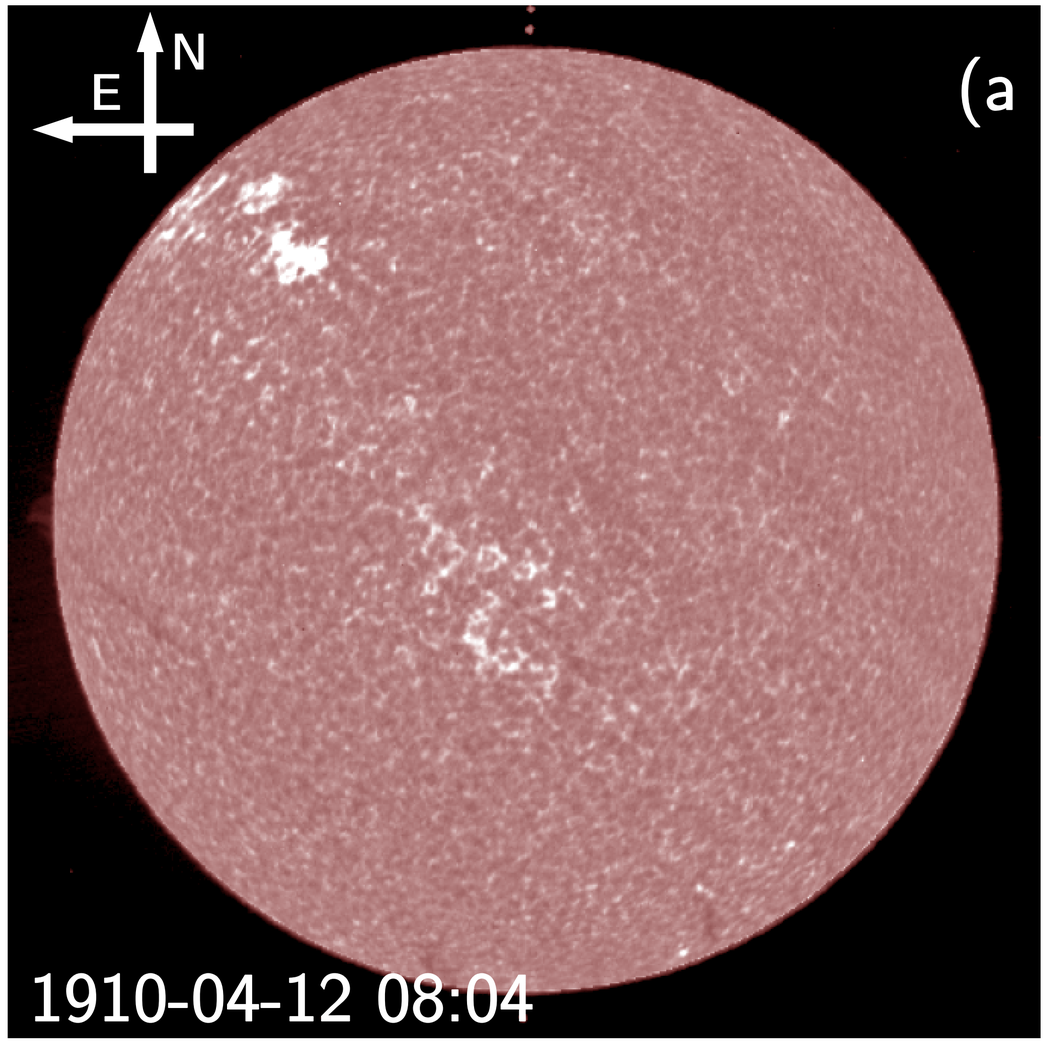

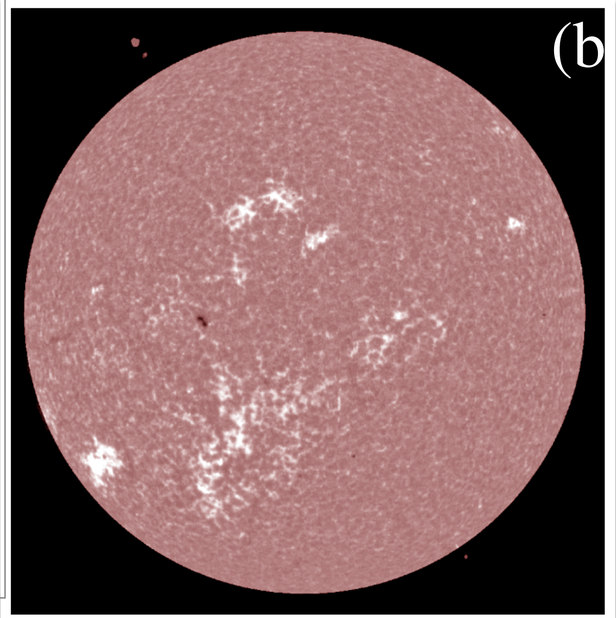

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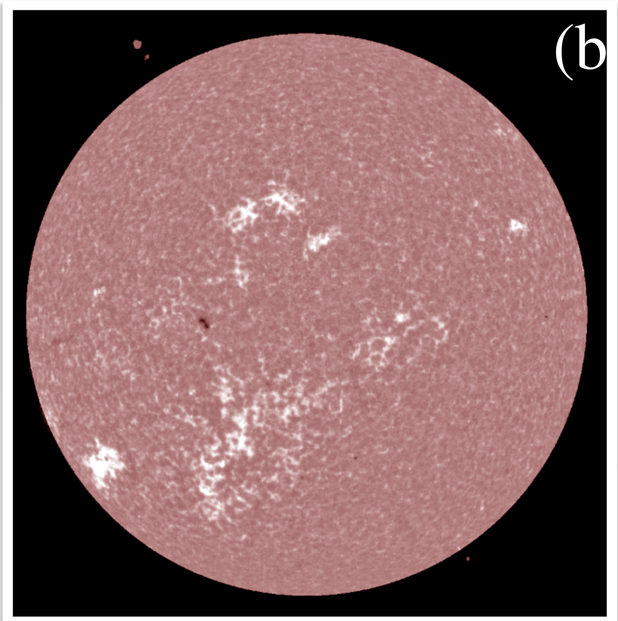

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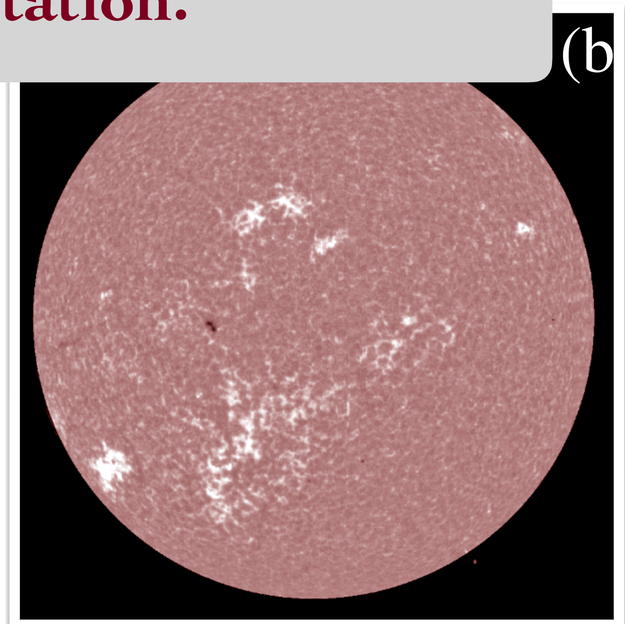

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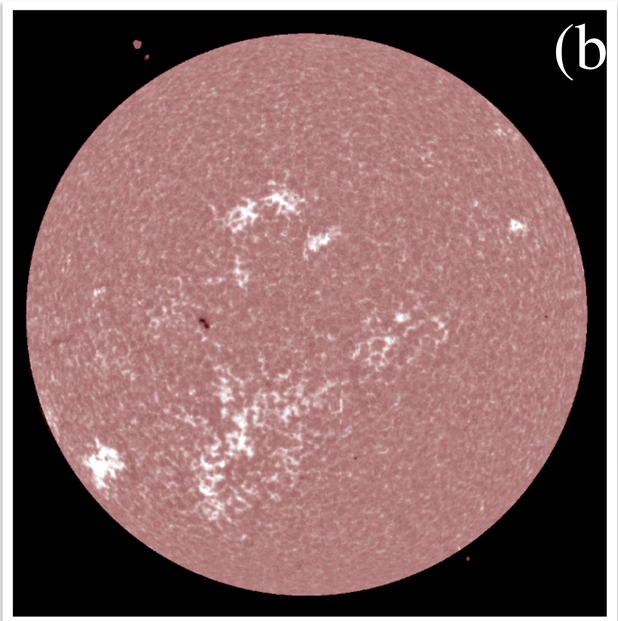

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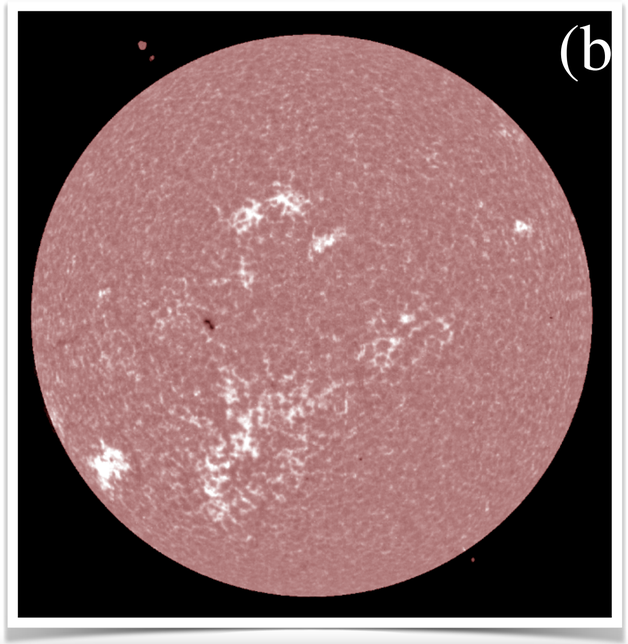

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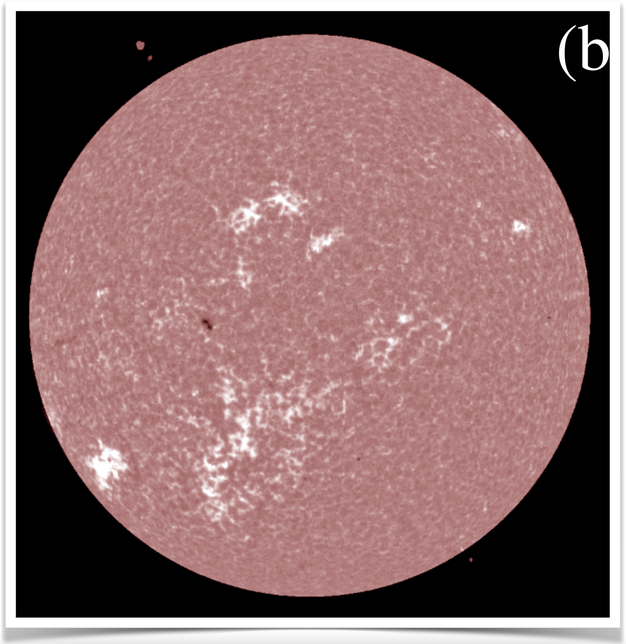

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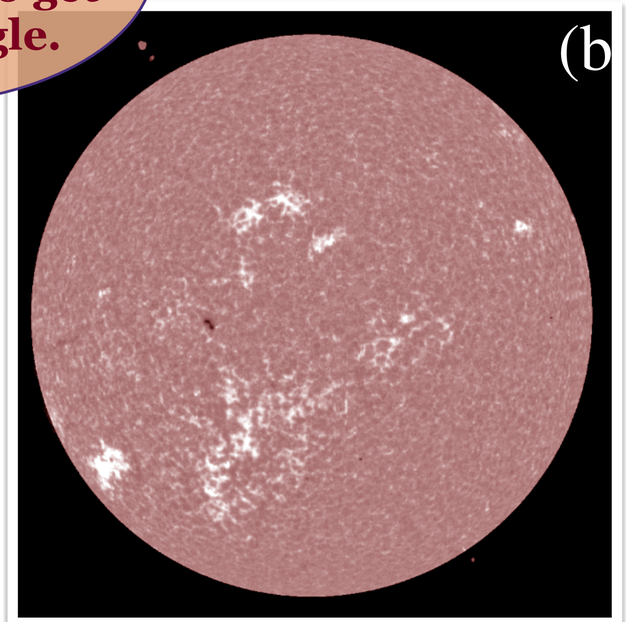
We need correct time of observation to get the pole angle.



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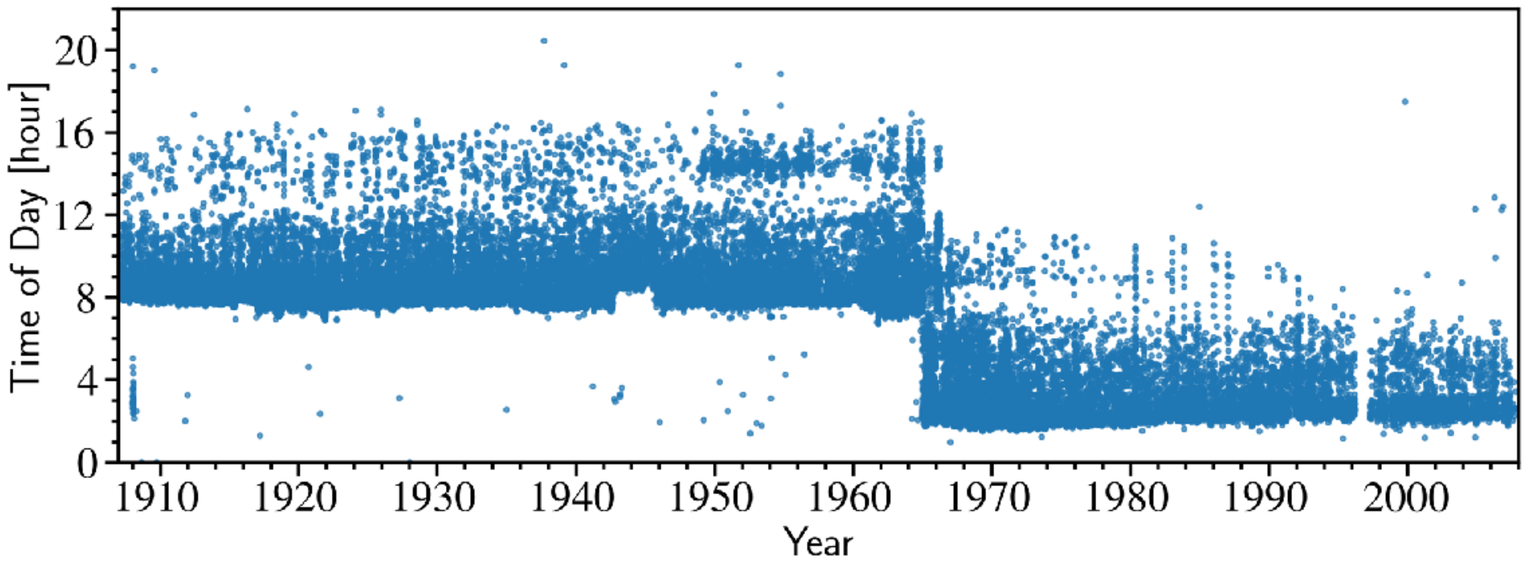

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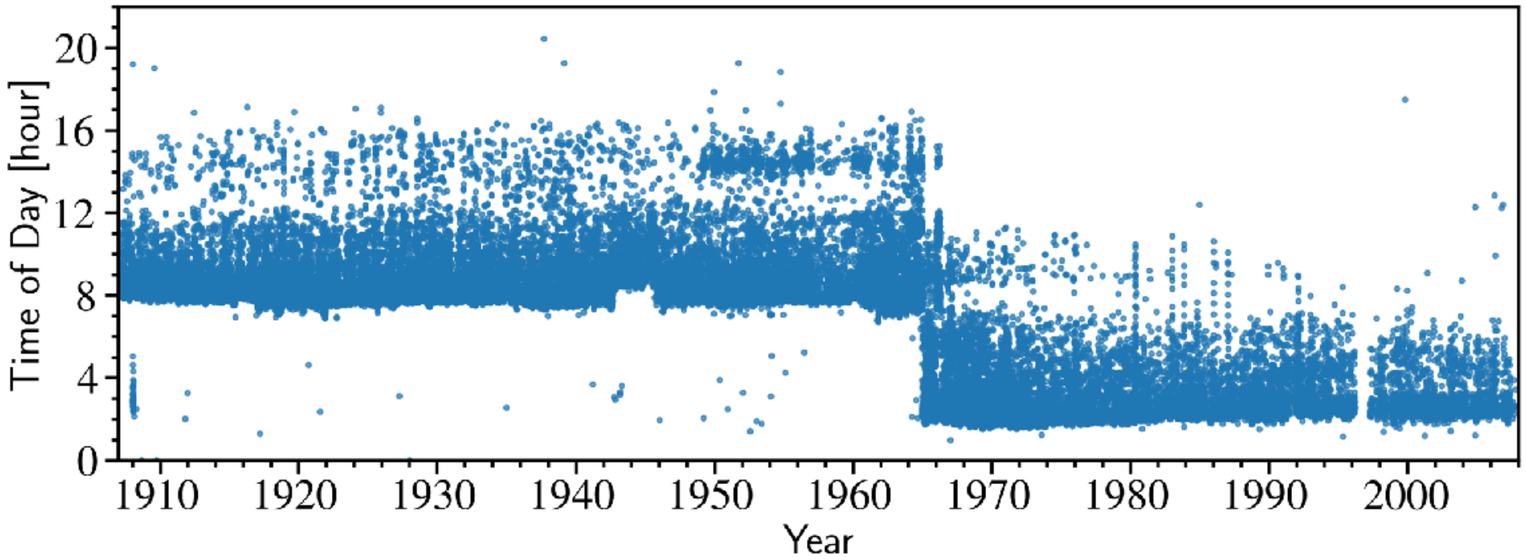

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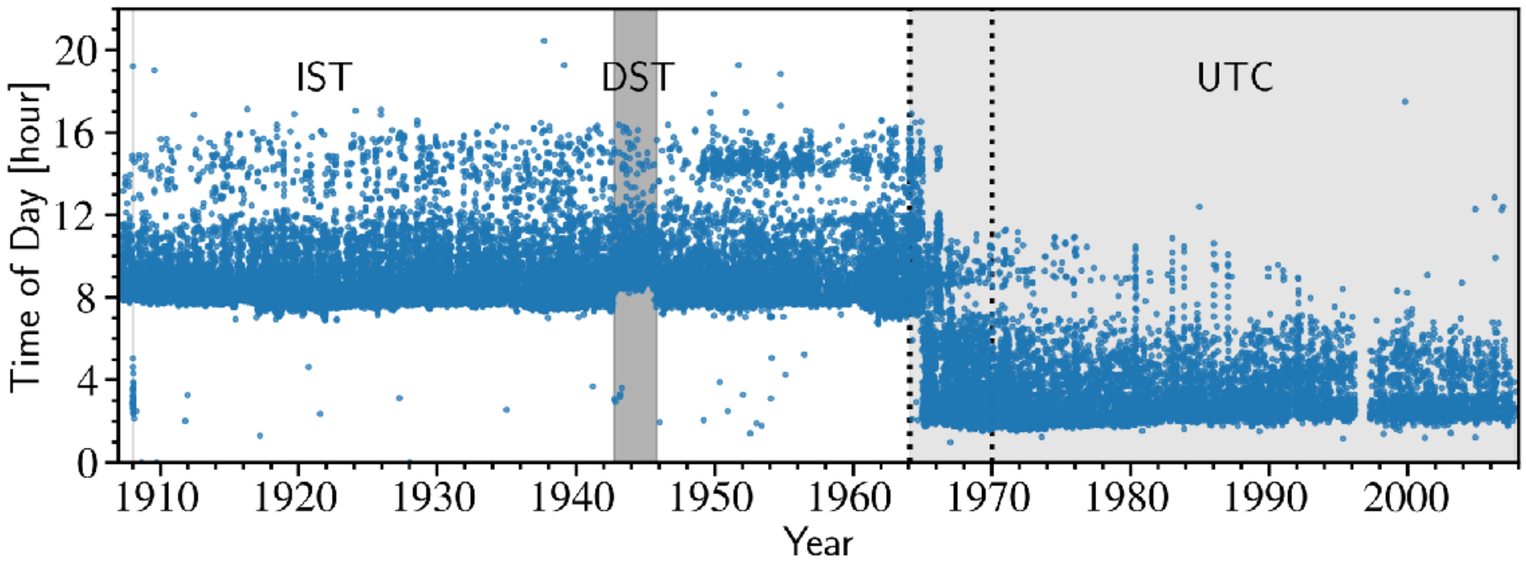

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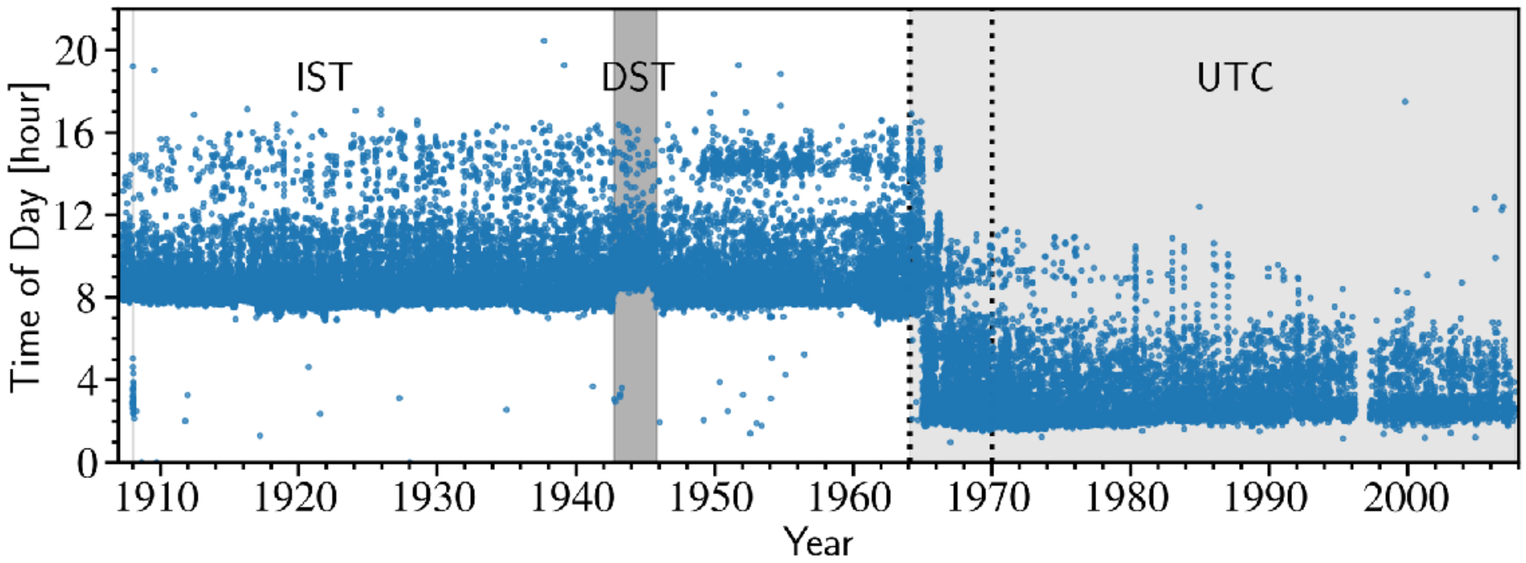

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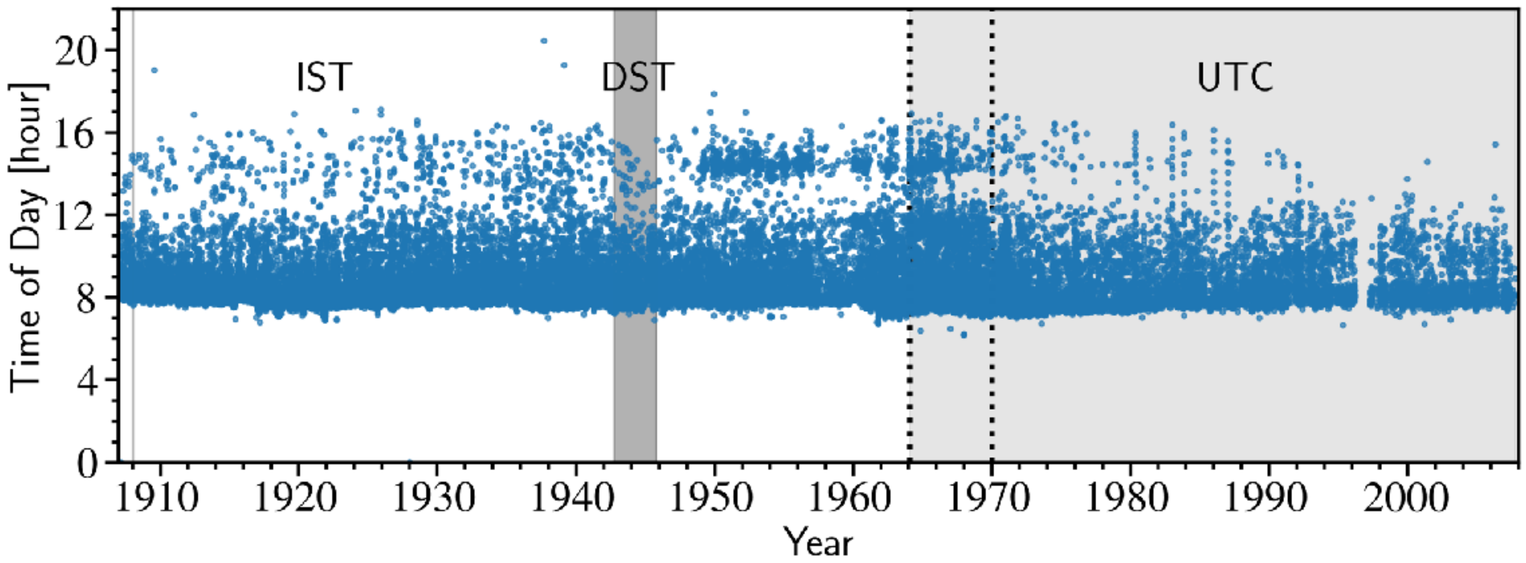

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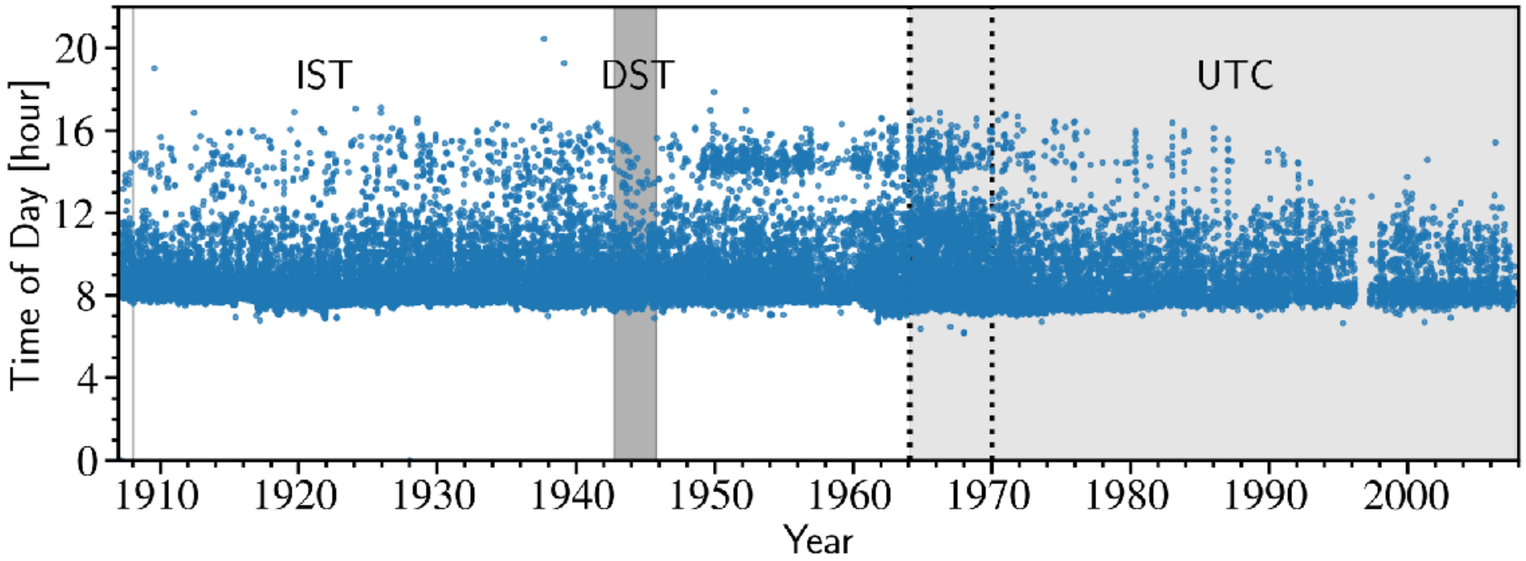

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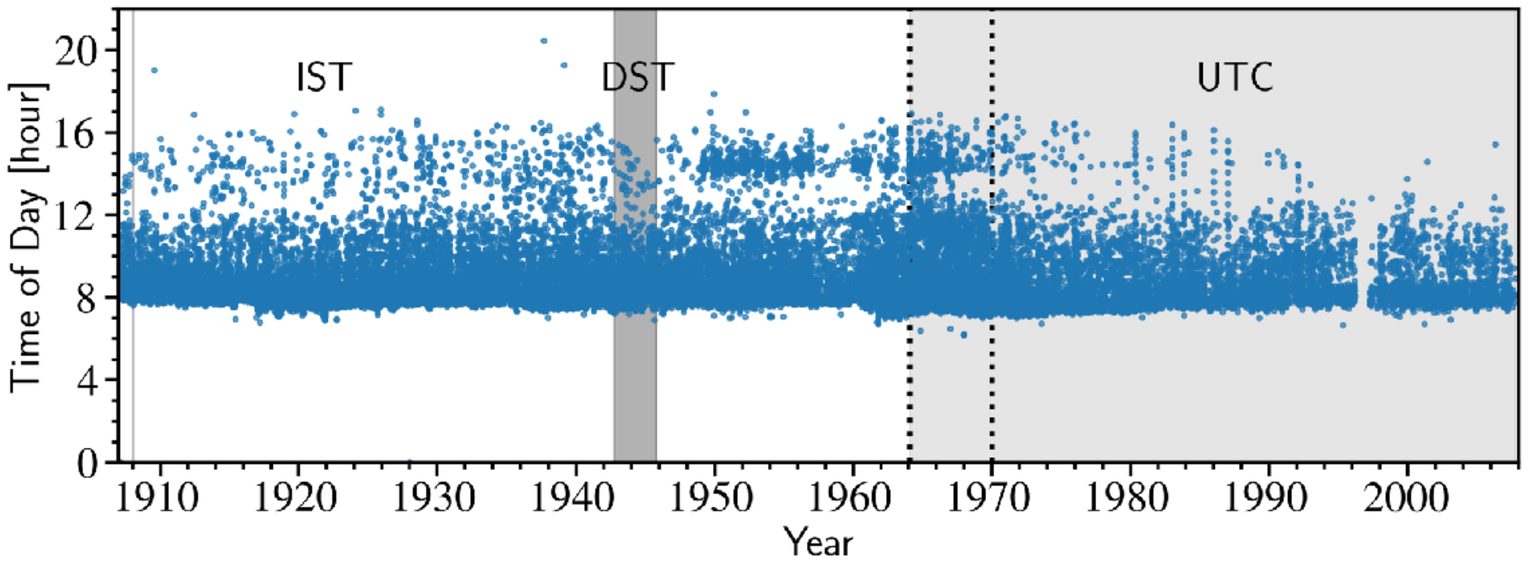

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Mistakes made by observers, mistakes during the naming the file during digitization, random time zone conversion, etc.

We need an algorithm to identify these images with incorrect time of observation!

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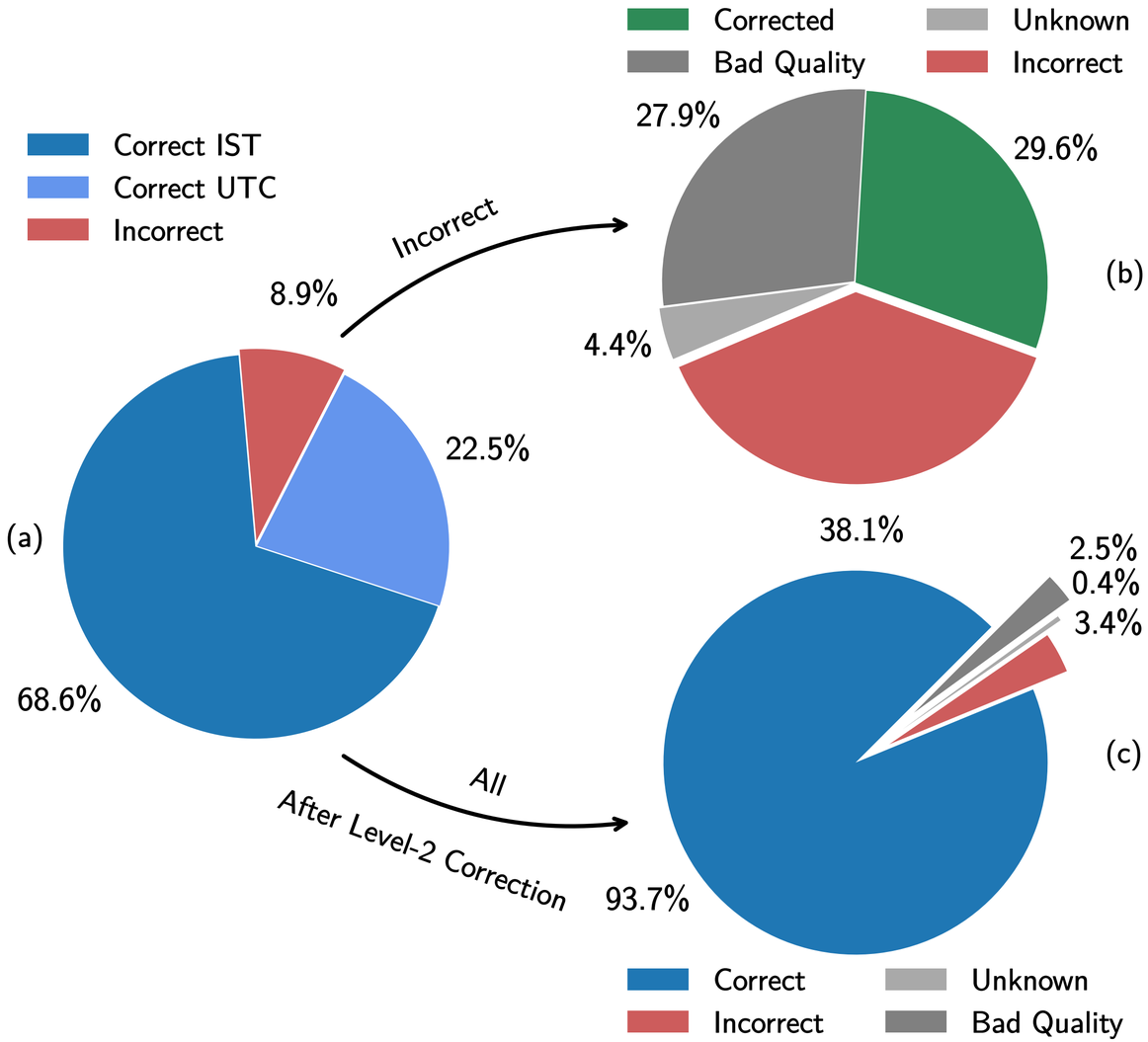

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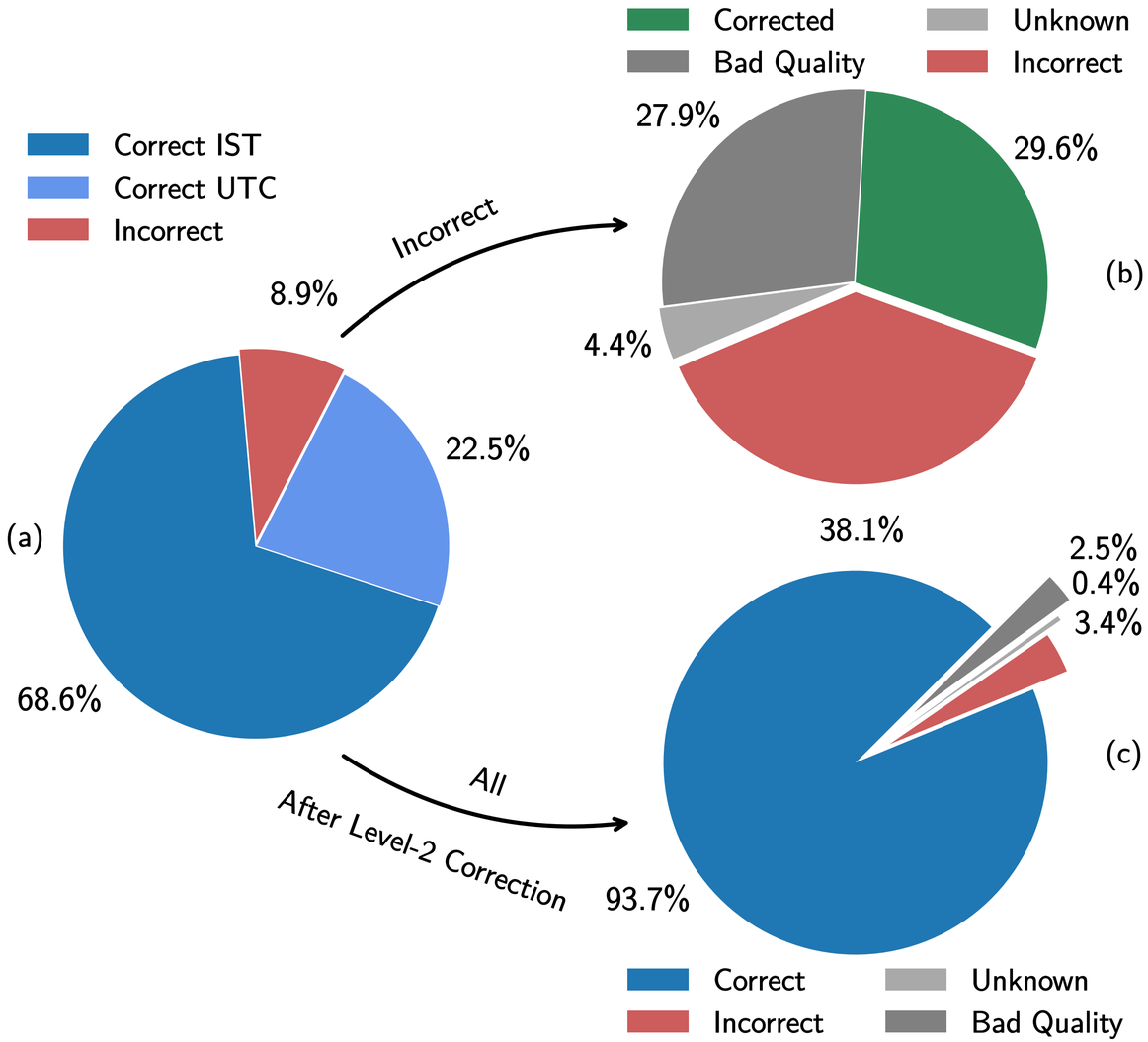
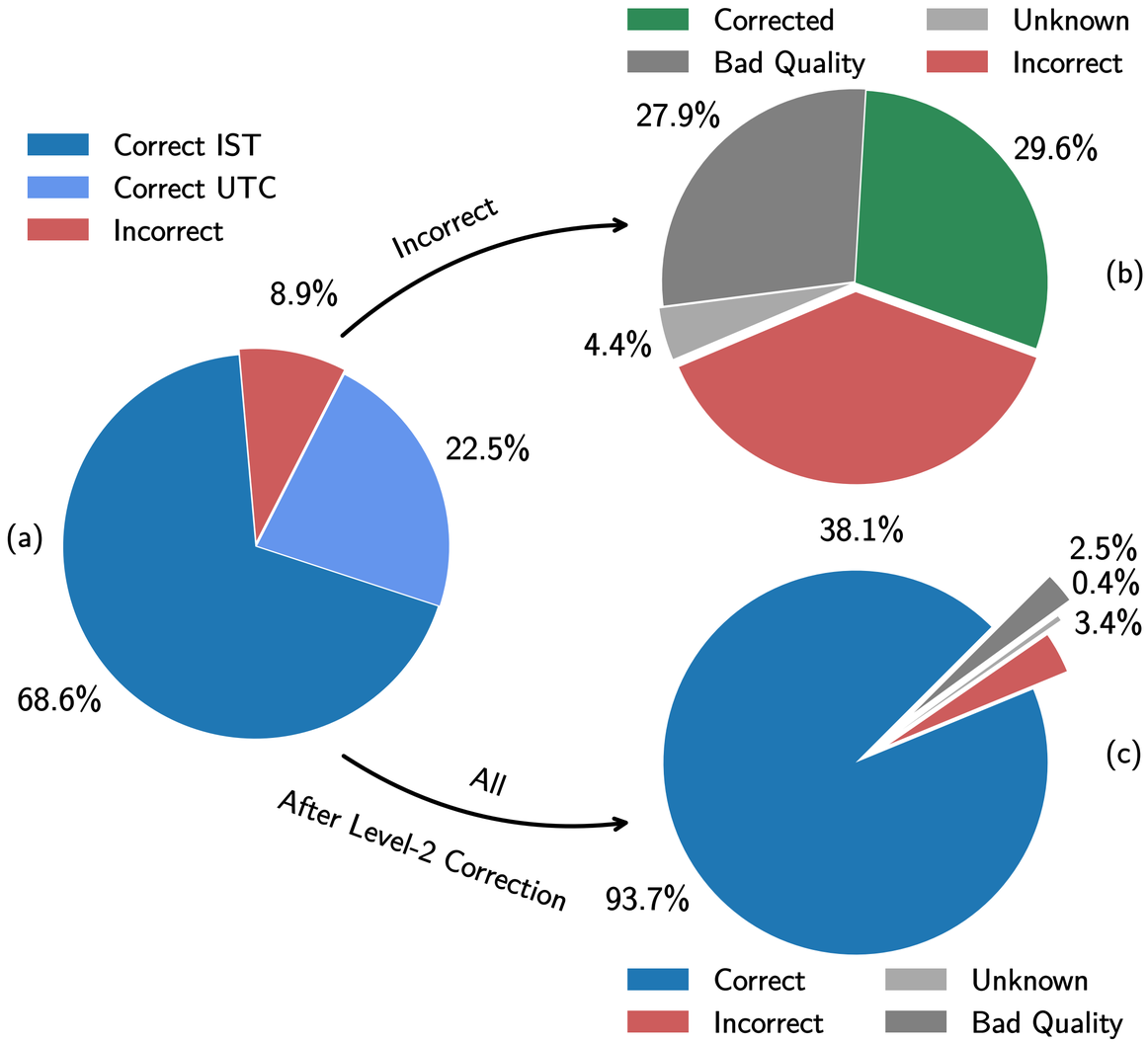


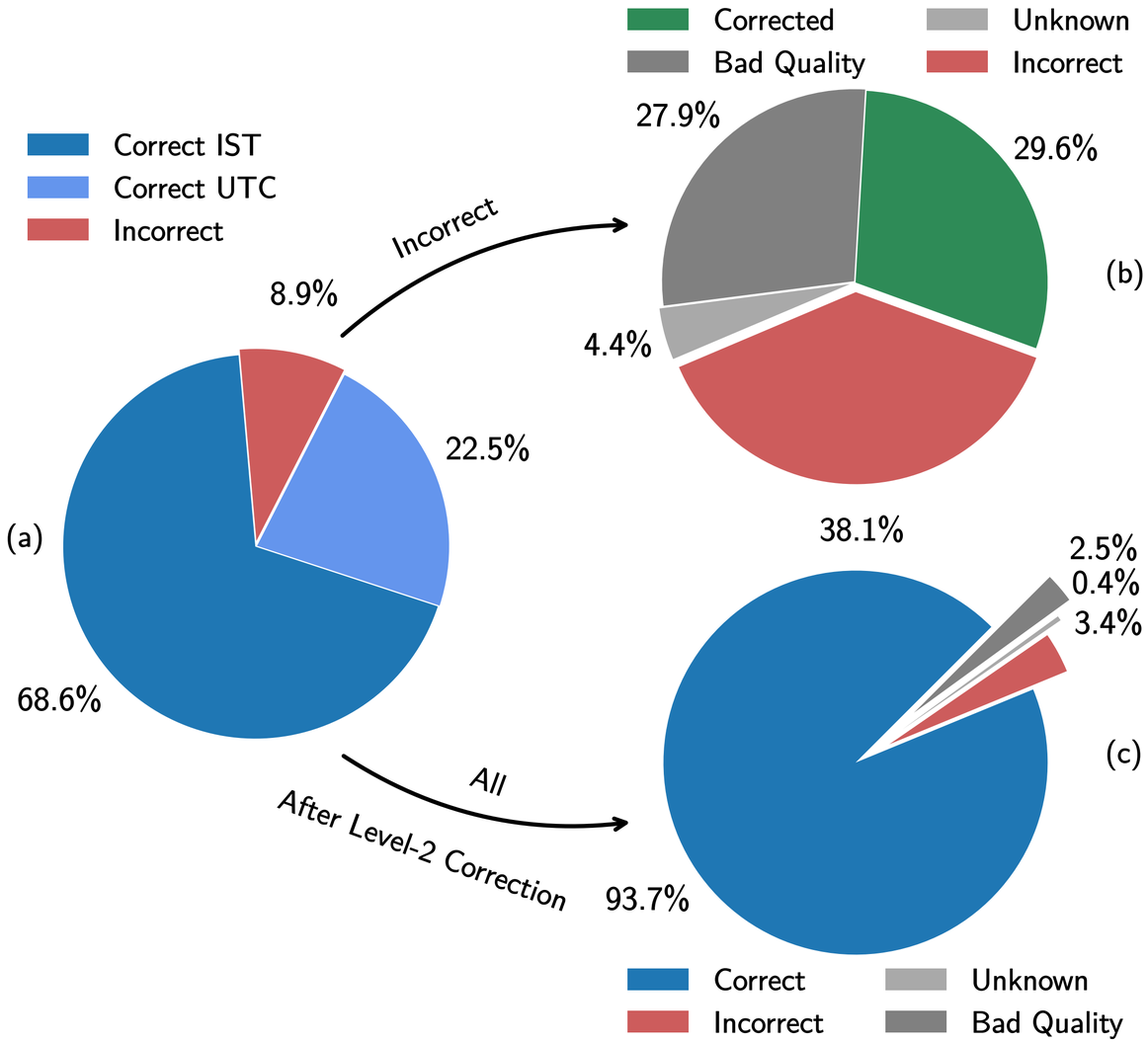
- Identified the images with incorrect T_{OBS}: **50,000 images quite a few times**

Time of Observations



- Identified the images with incorrect T_{OBS}: **50,000 images quite a few times**
- Multiple levels of correction: **2.5% incorrect T_{OBS}**

Time of Observations



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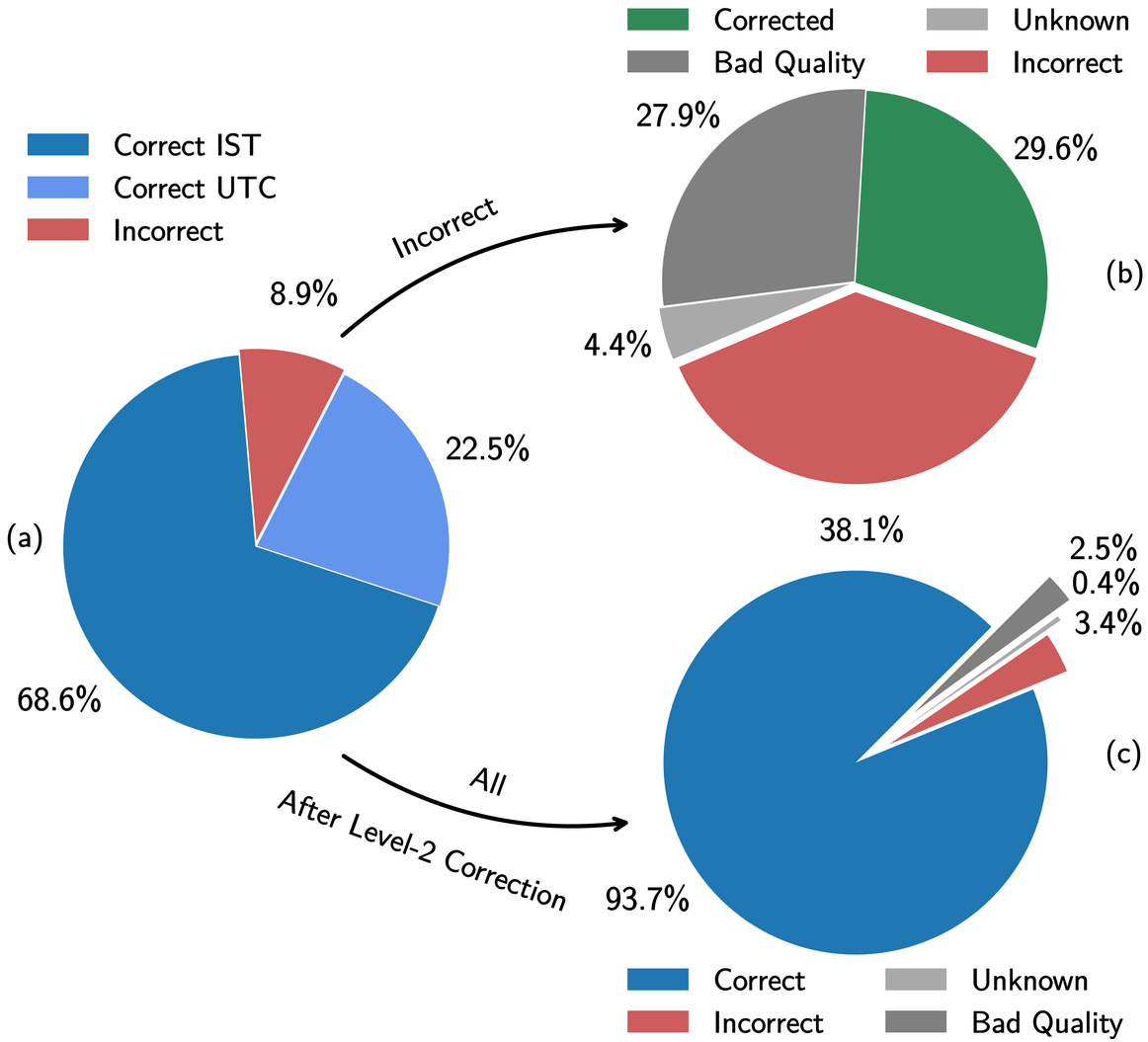
- 2.5% images corrected: **Image correlation technique.**

Time of Observations



- Identified the images with incorrect T_{OBS}: **50,000 images quite a few times**
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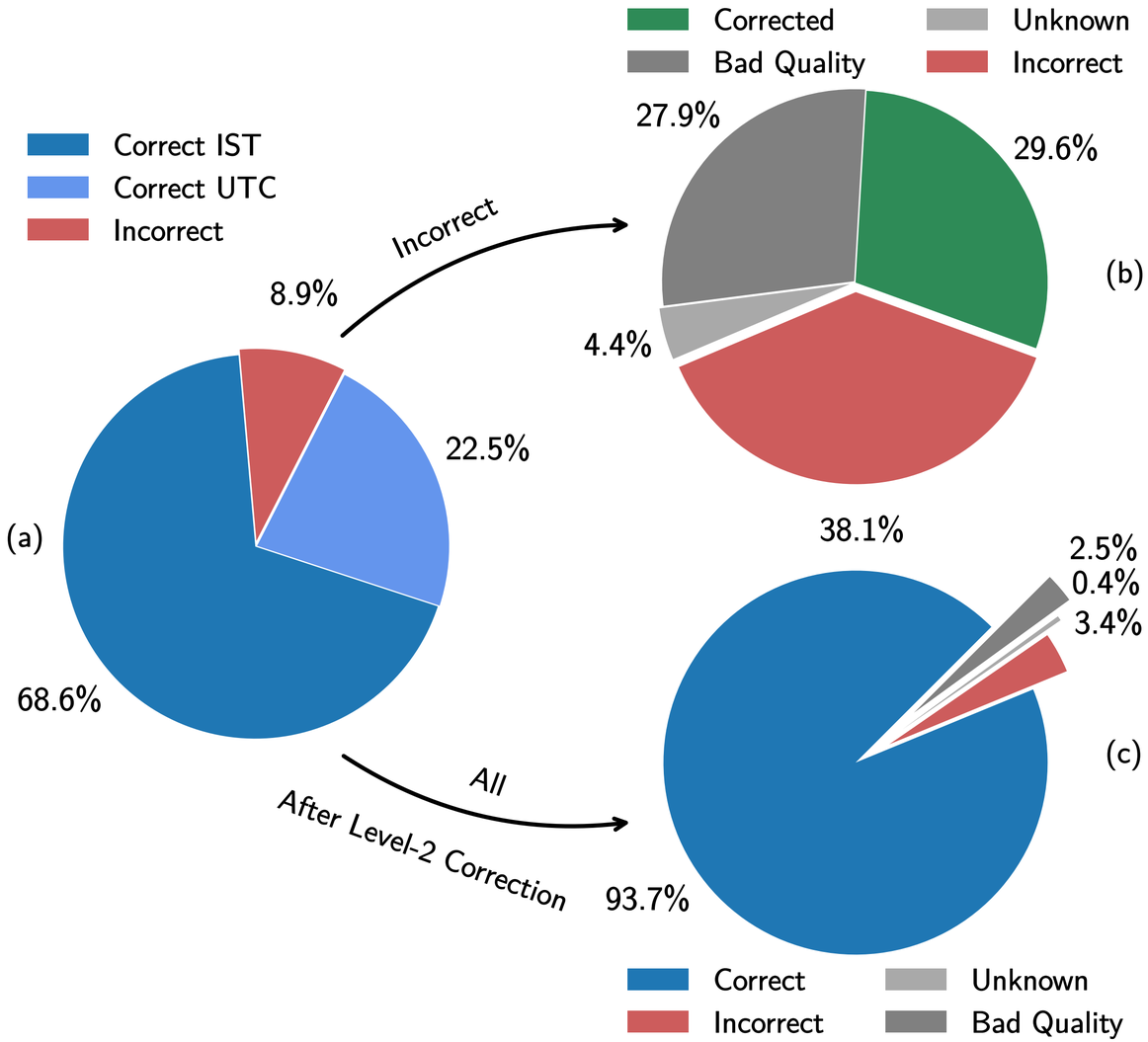
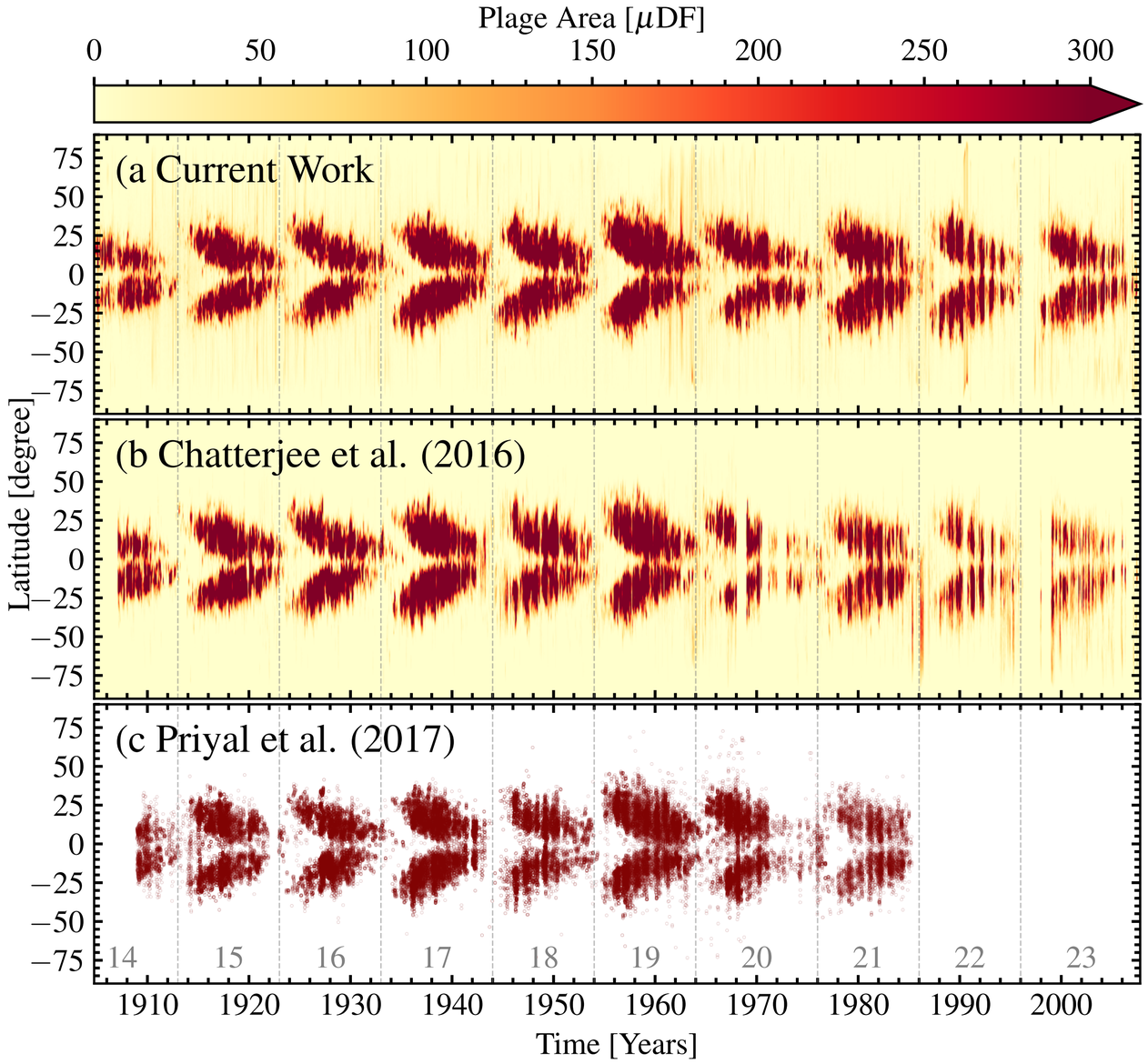
- Verified**: Manually Corrected Time using Image Correlation**

Time of Observations

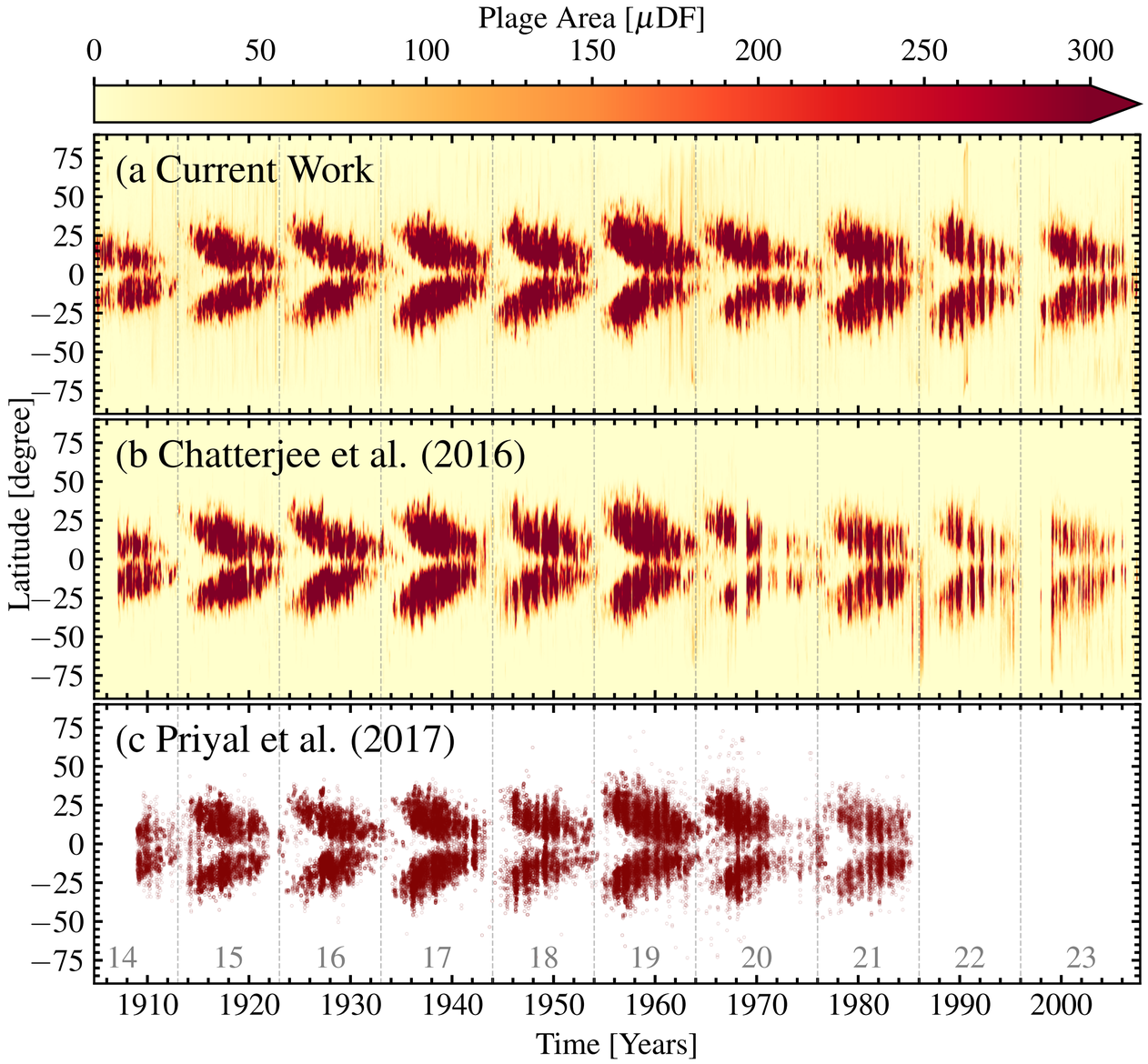


- Identified the images with incorrect T_{OBS}: **50,000 images quite a few times**
- Multiple levels of correction: **2.5% incorrect T_{OBS}**
- 2.5% images corrected: **Image correlation technique.**
- Verified**: Manually Corrected Time using Image Correlation**
- Data 1904–1906: **Recovered T_{OBS}**

Plage Butterfly Diagram



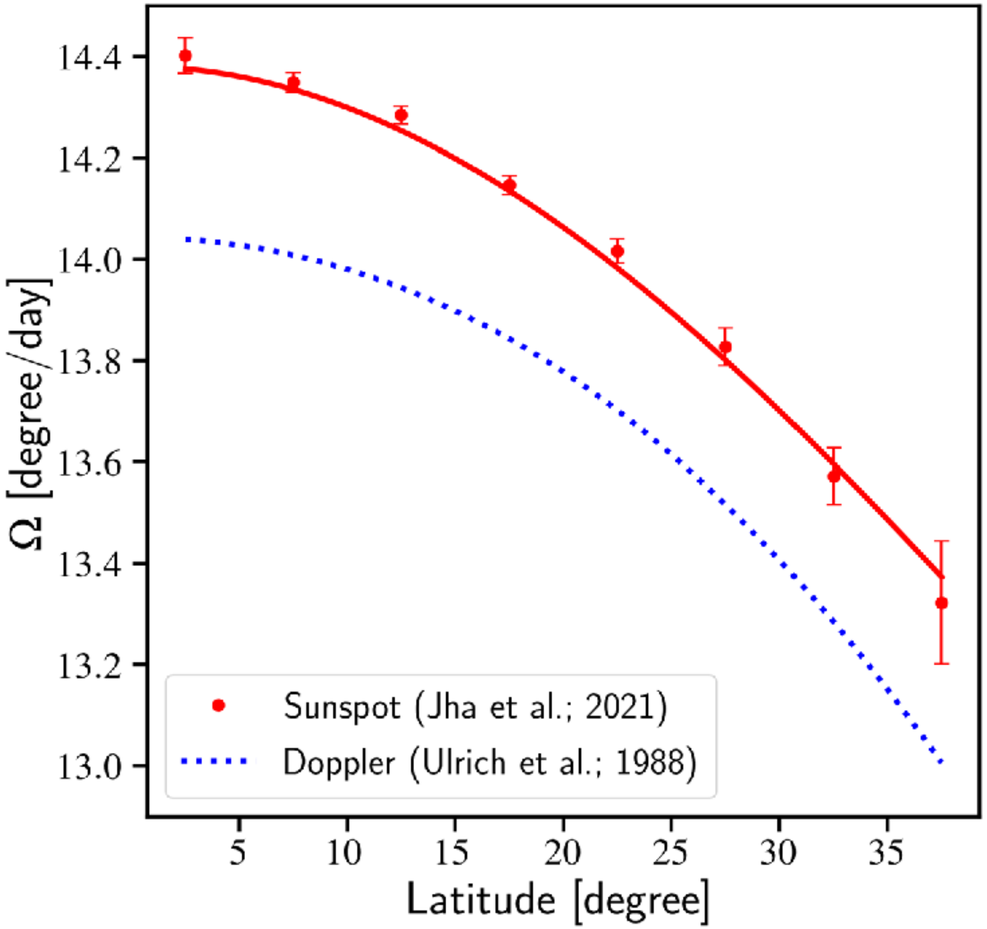
Plage Butterfly Diagram



Finally, we have corrected data!

Soon will be available on ArXiv.

Solar Differential Rotation



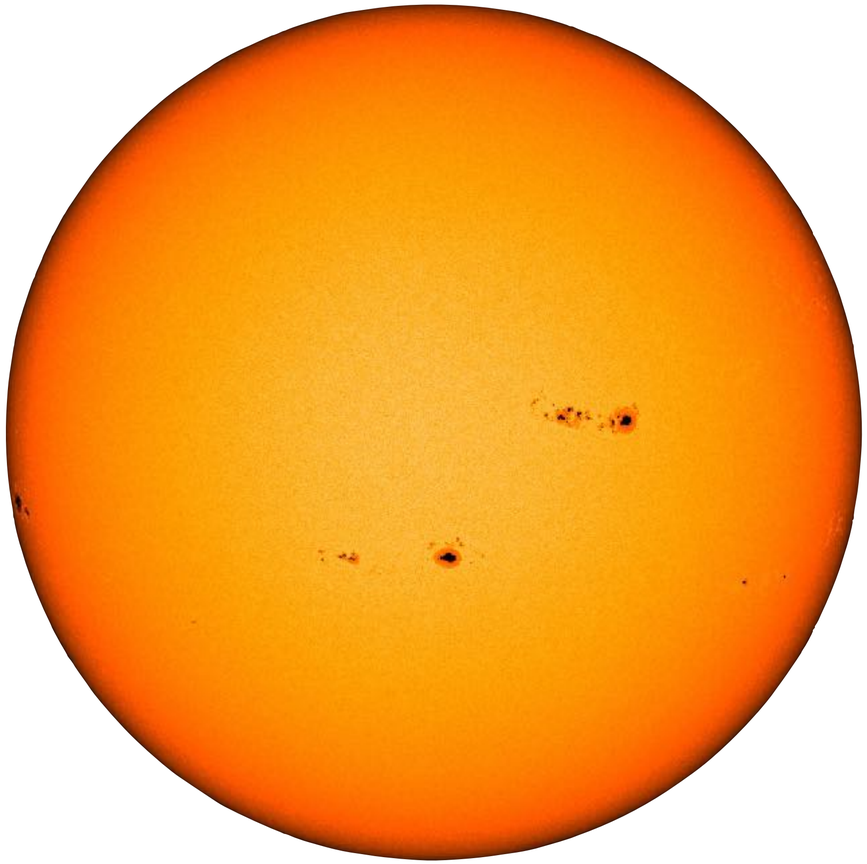
Can we measure the solar differential rotation higher in the atmosphere?

Yes!

KoSO provides the Ca II K data which probes the chromosphere.

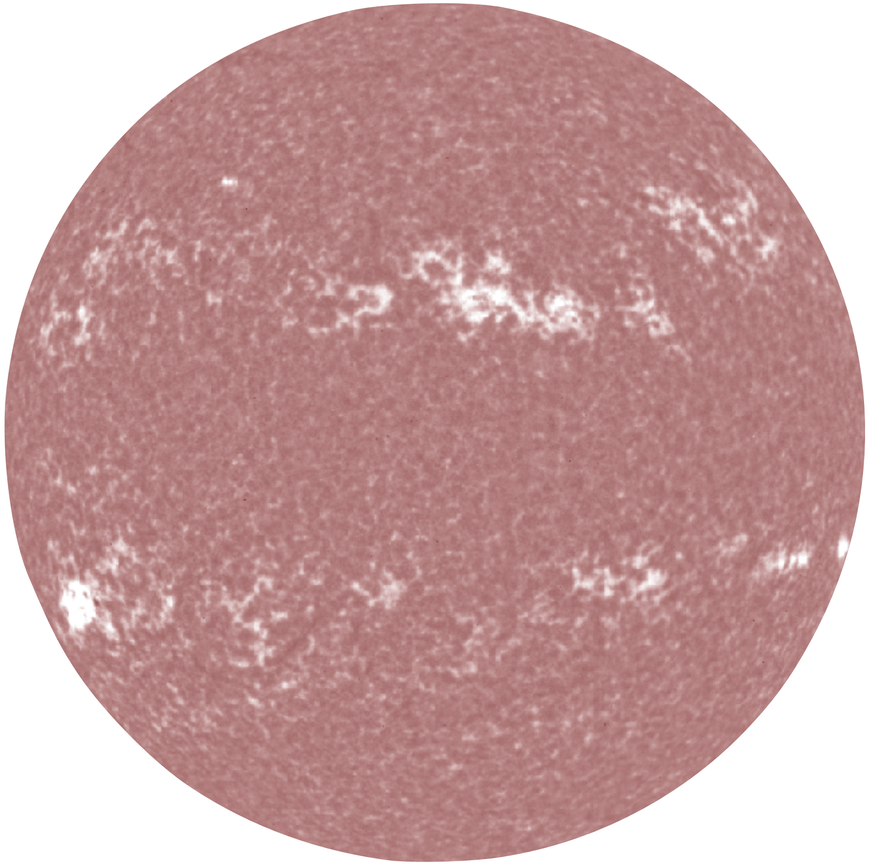
Sunspot Vs Plages

Sunspot



SOHO/HMI

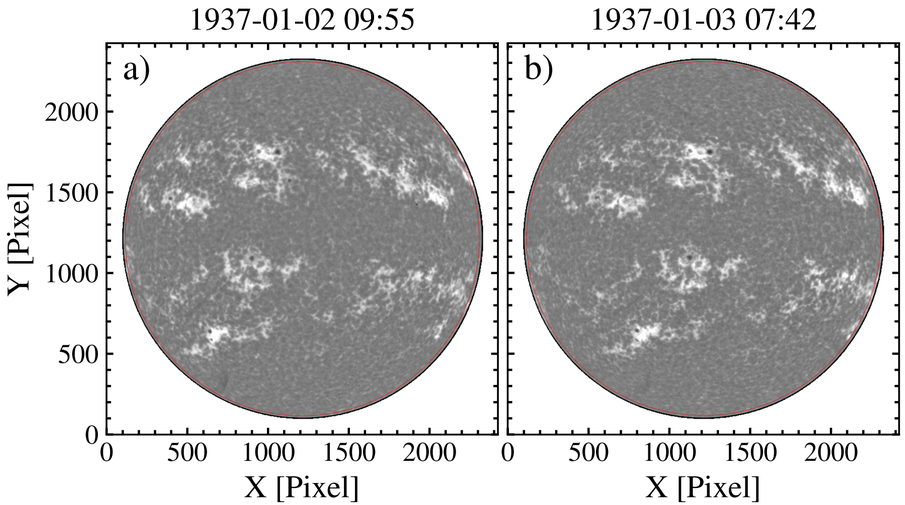
Ca K Plages



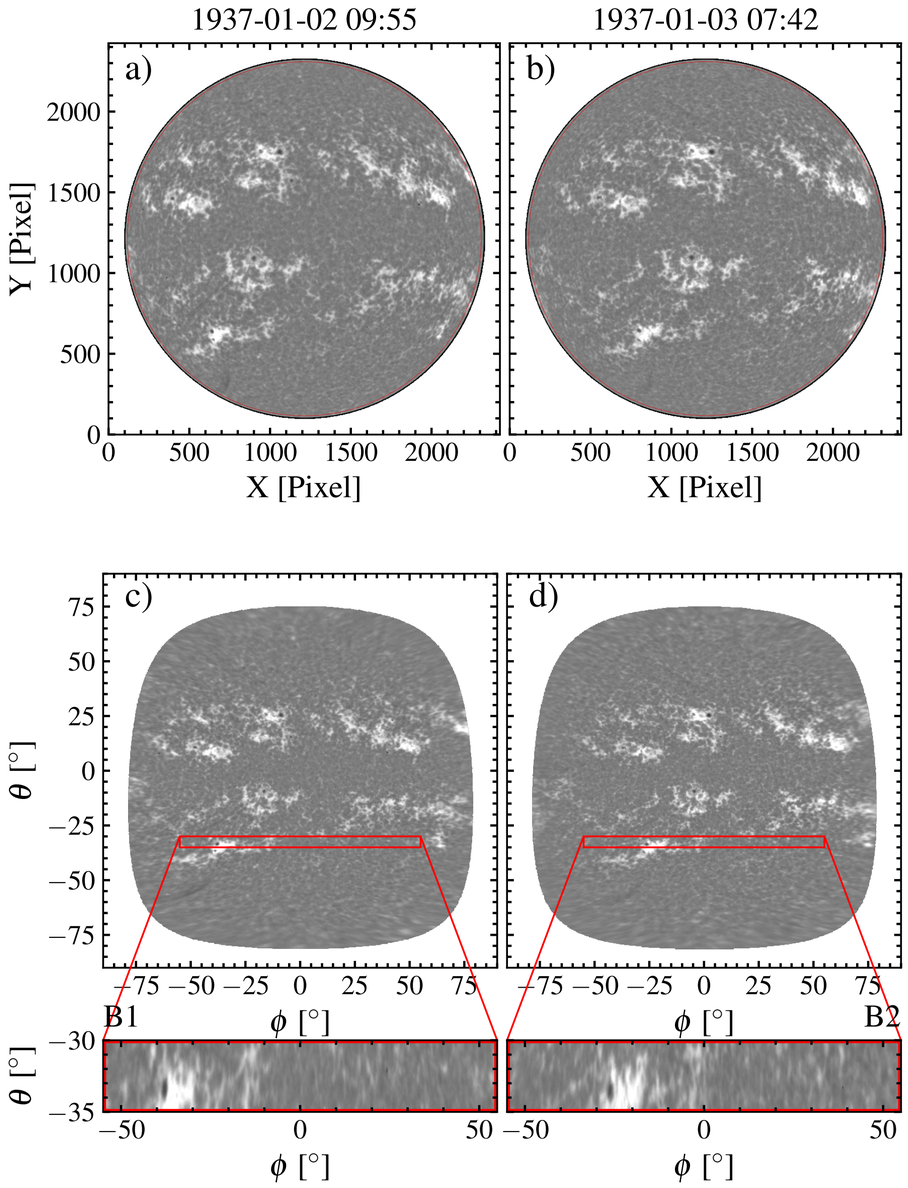
KoSO

Chromospheric Rotation

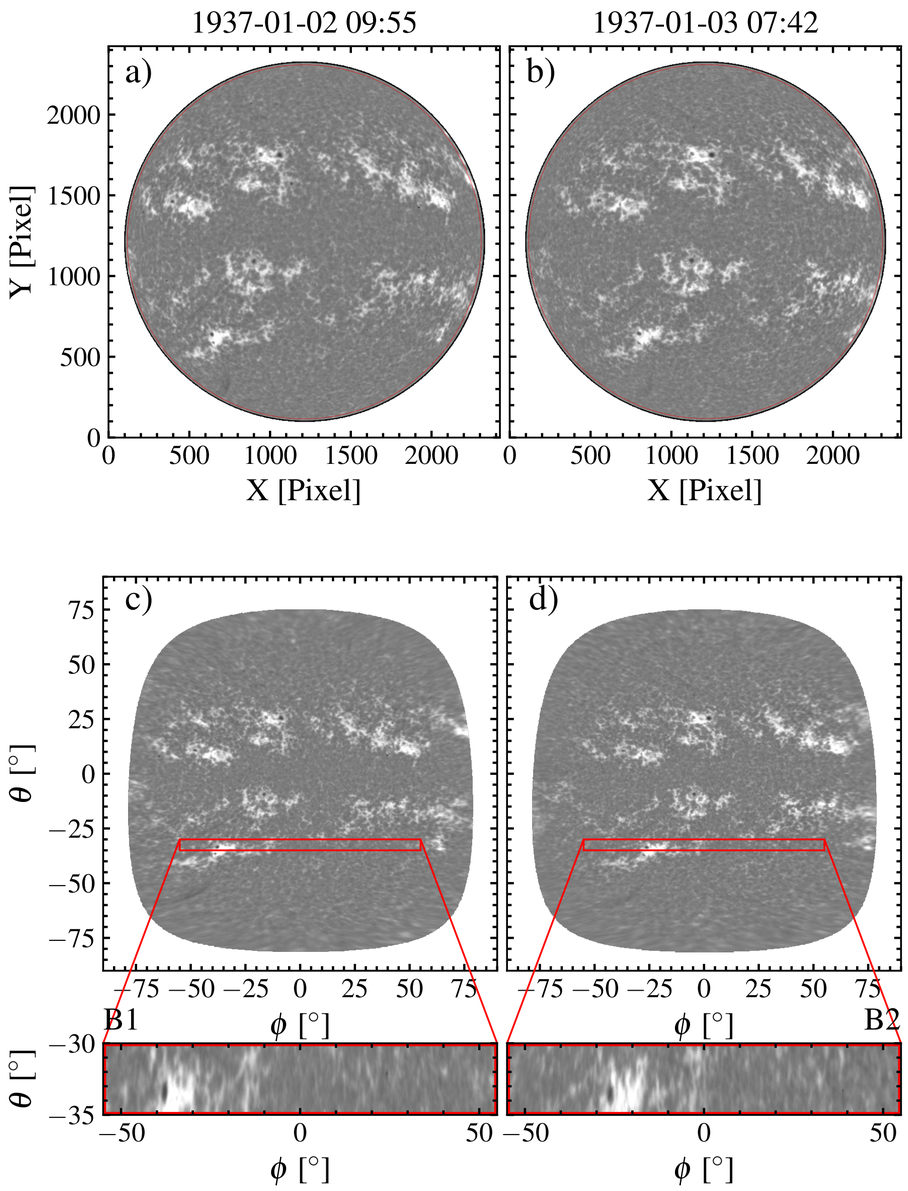
Chromospheric Rotation

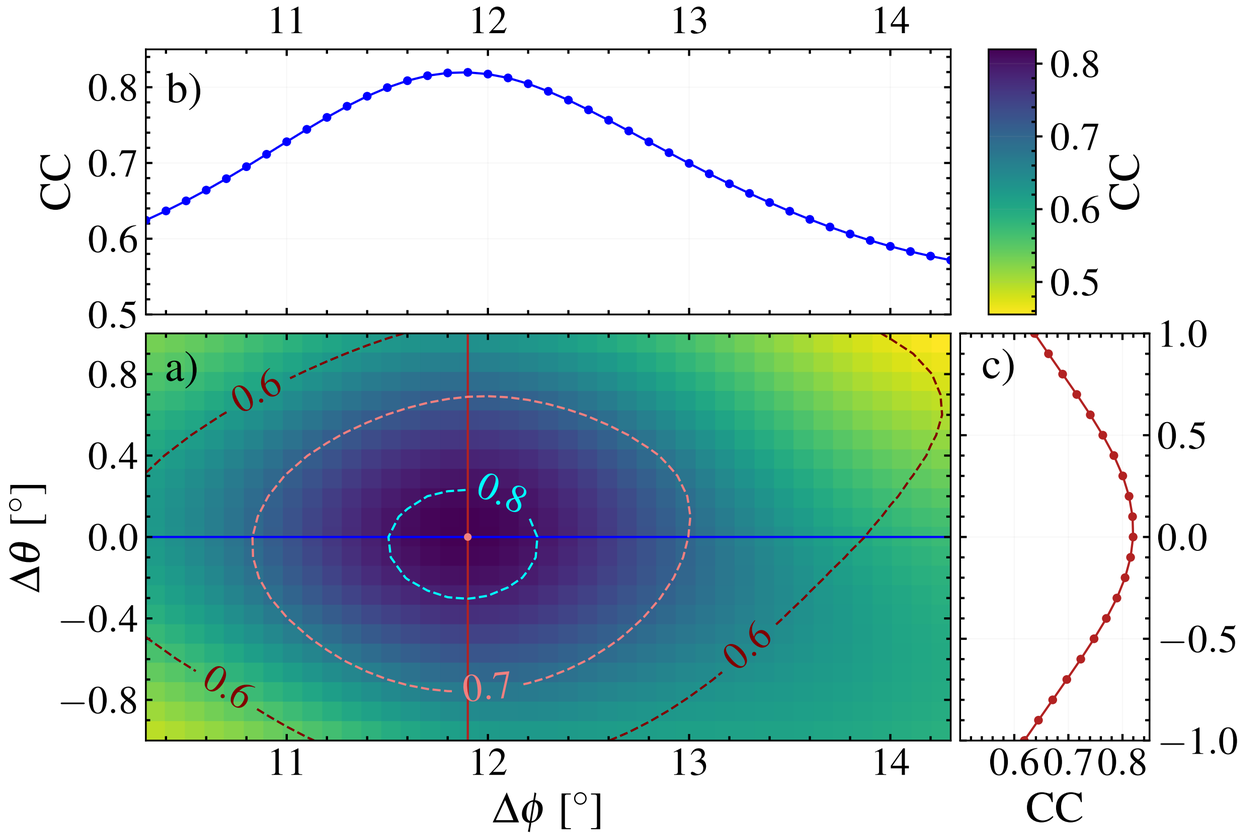


Chromospheric Rotation

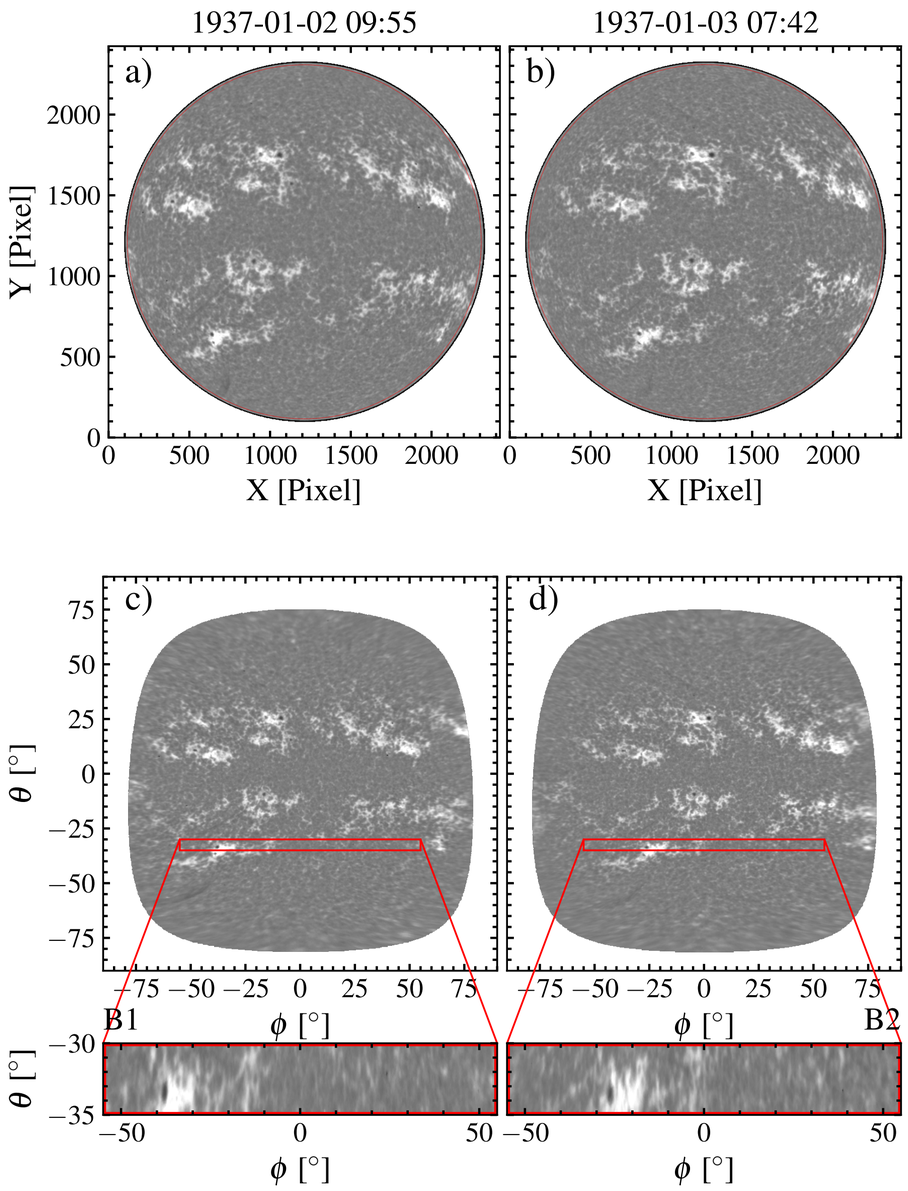


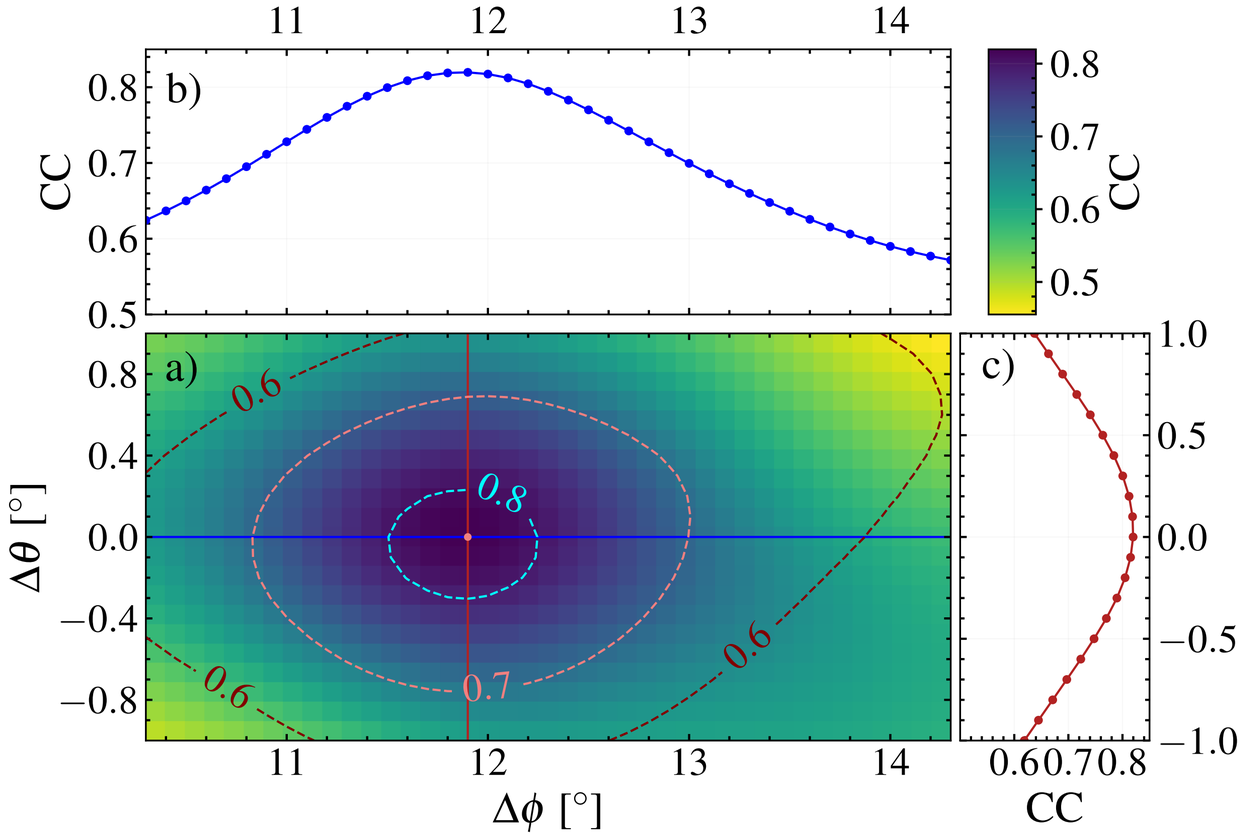
Chromospheric Rotation





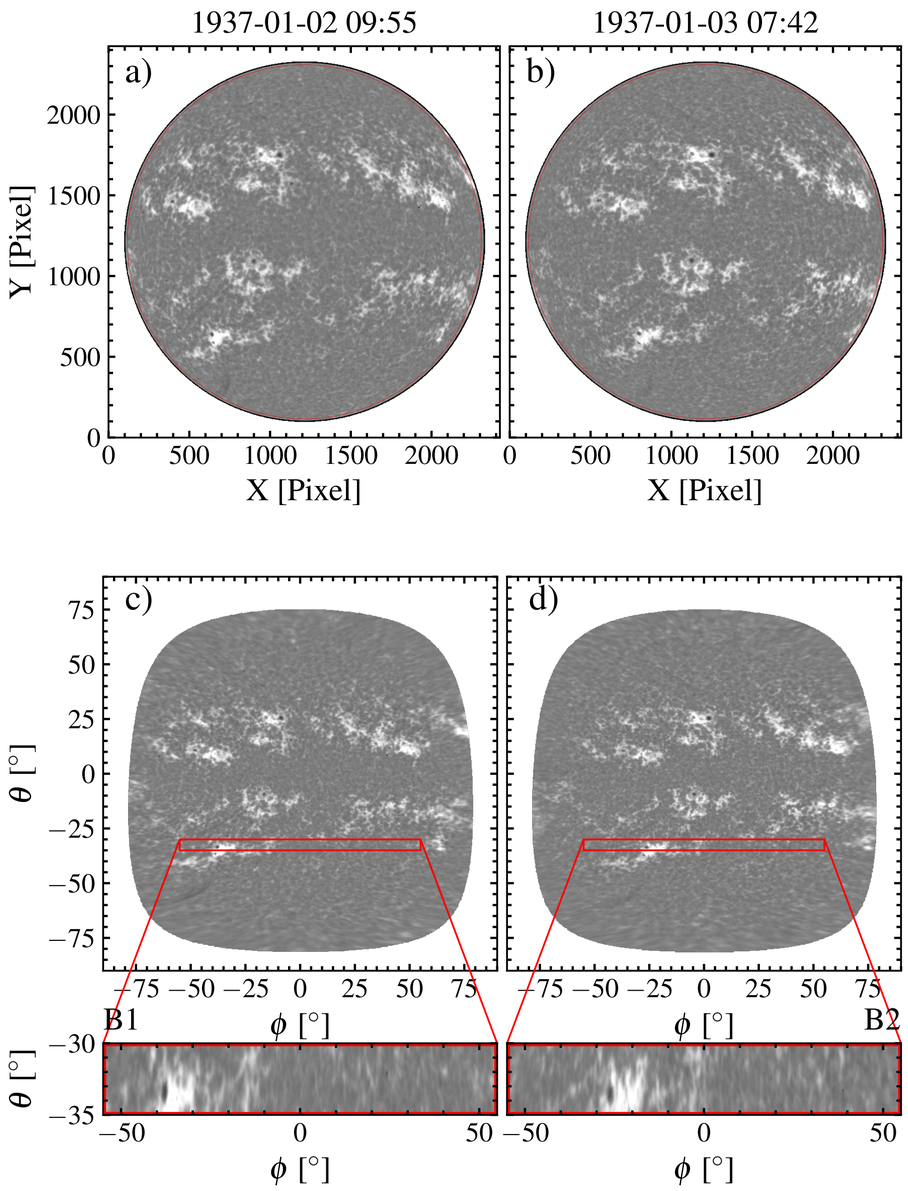
Chromospheric Rotation

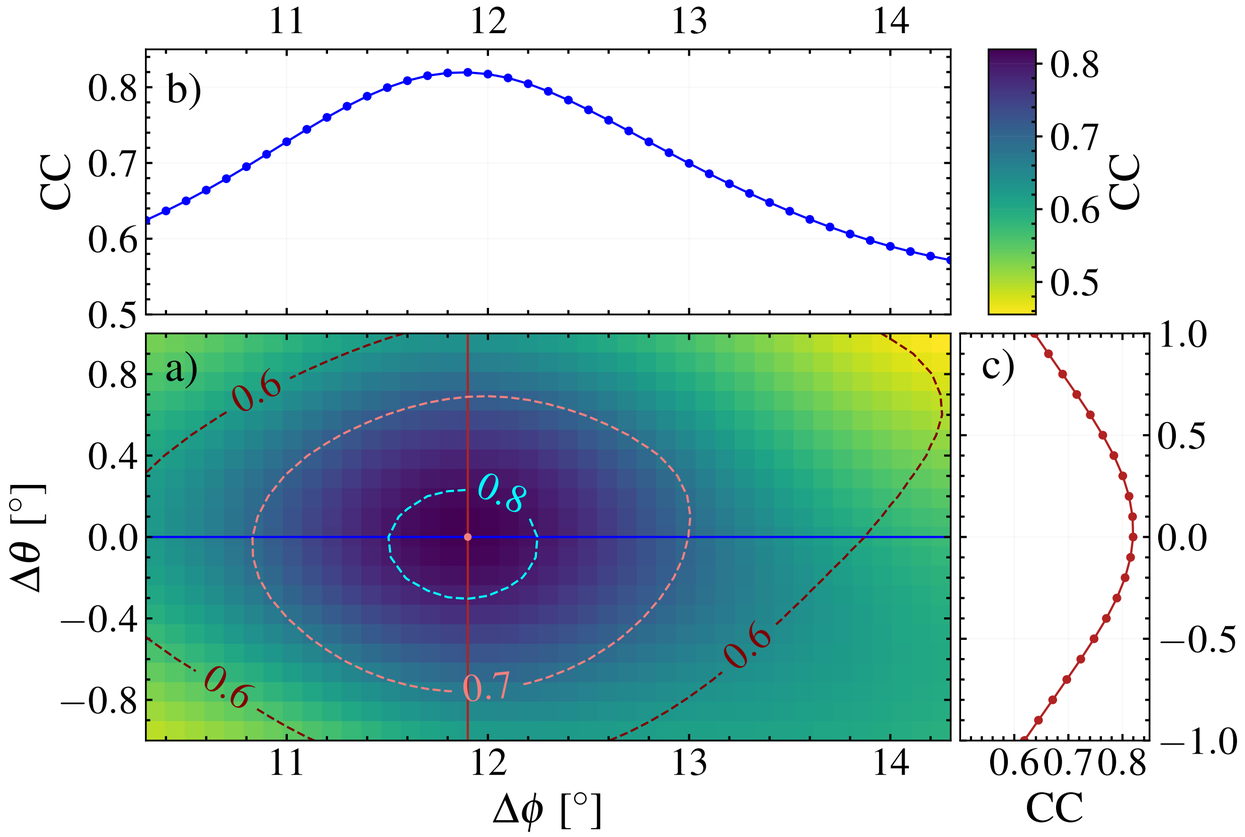




- Restricted ourselves ±55° longitude and latitude.

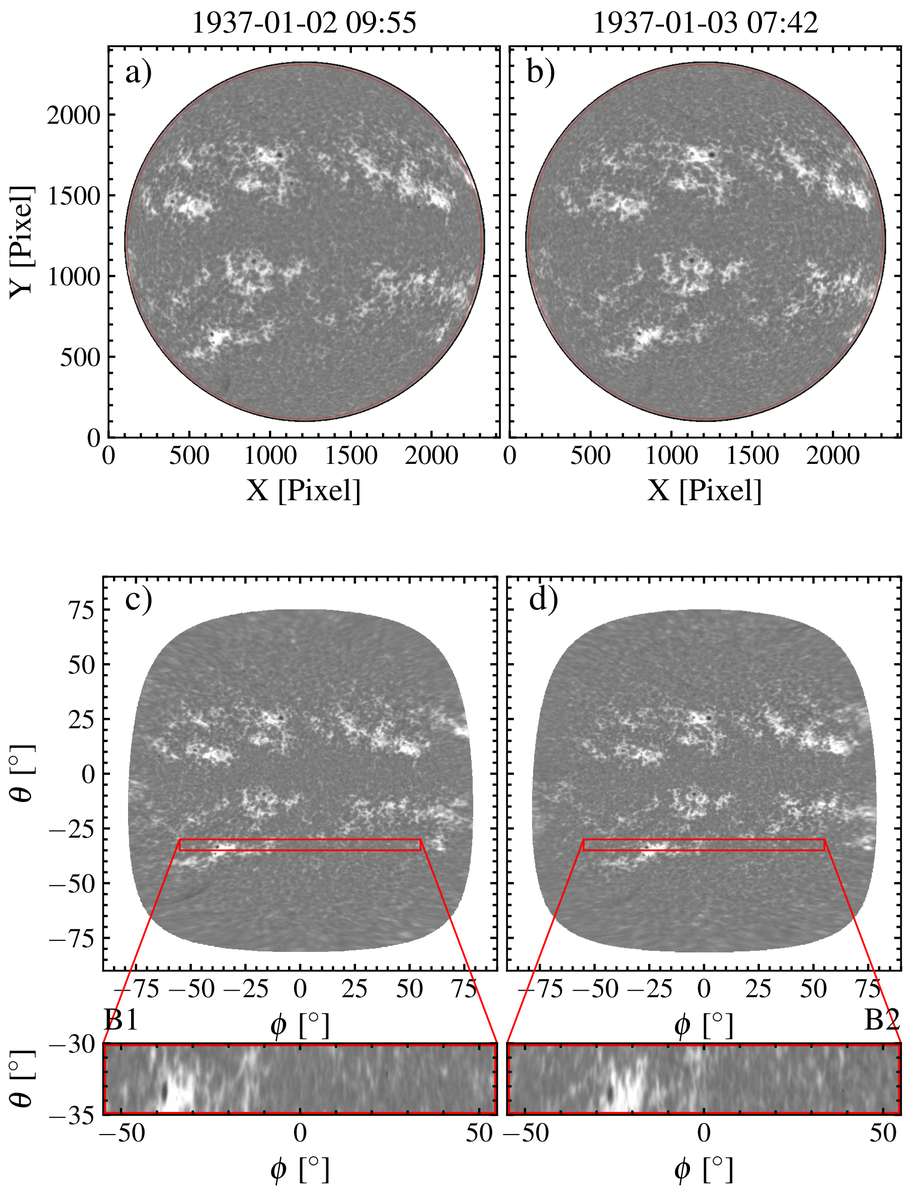
Chromospheric Rotation

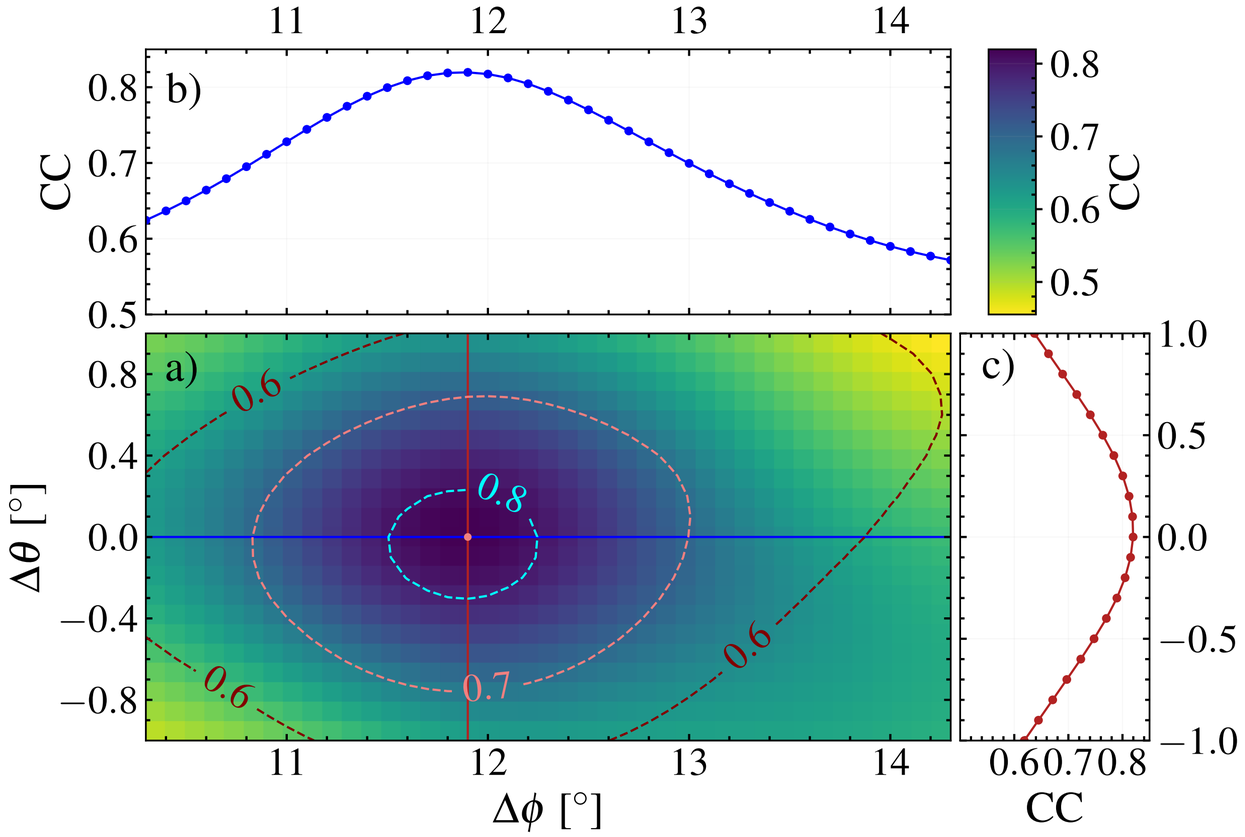




- Restricted ourselves ±55° longitude and latitude.
- We rejected the cases where correlation is < 0.2.

Chromospheric Rotation

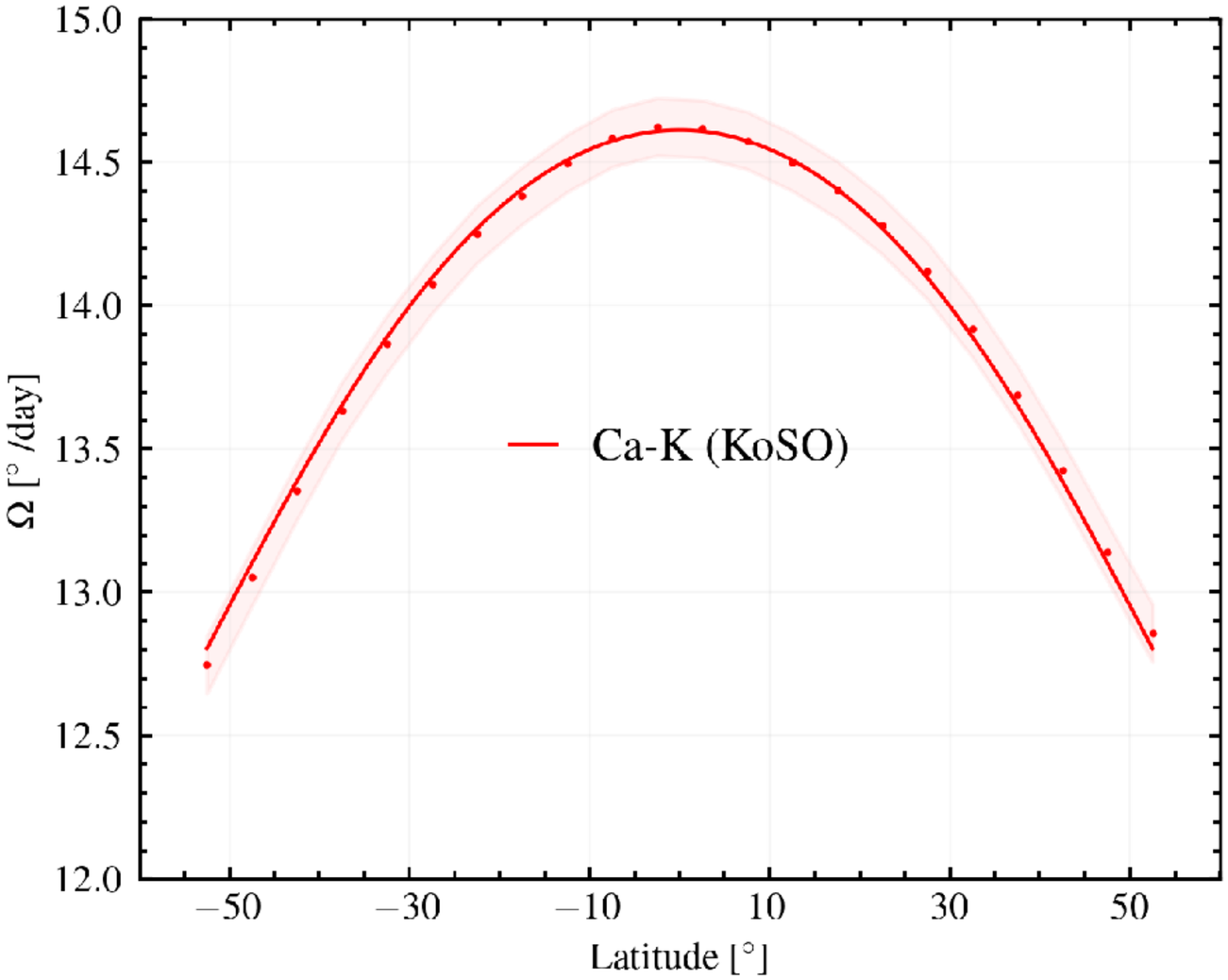




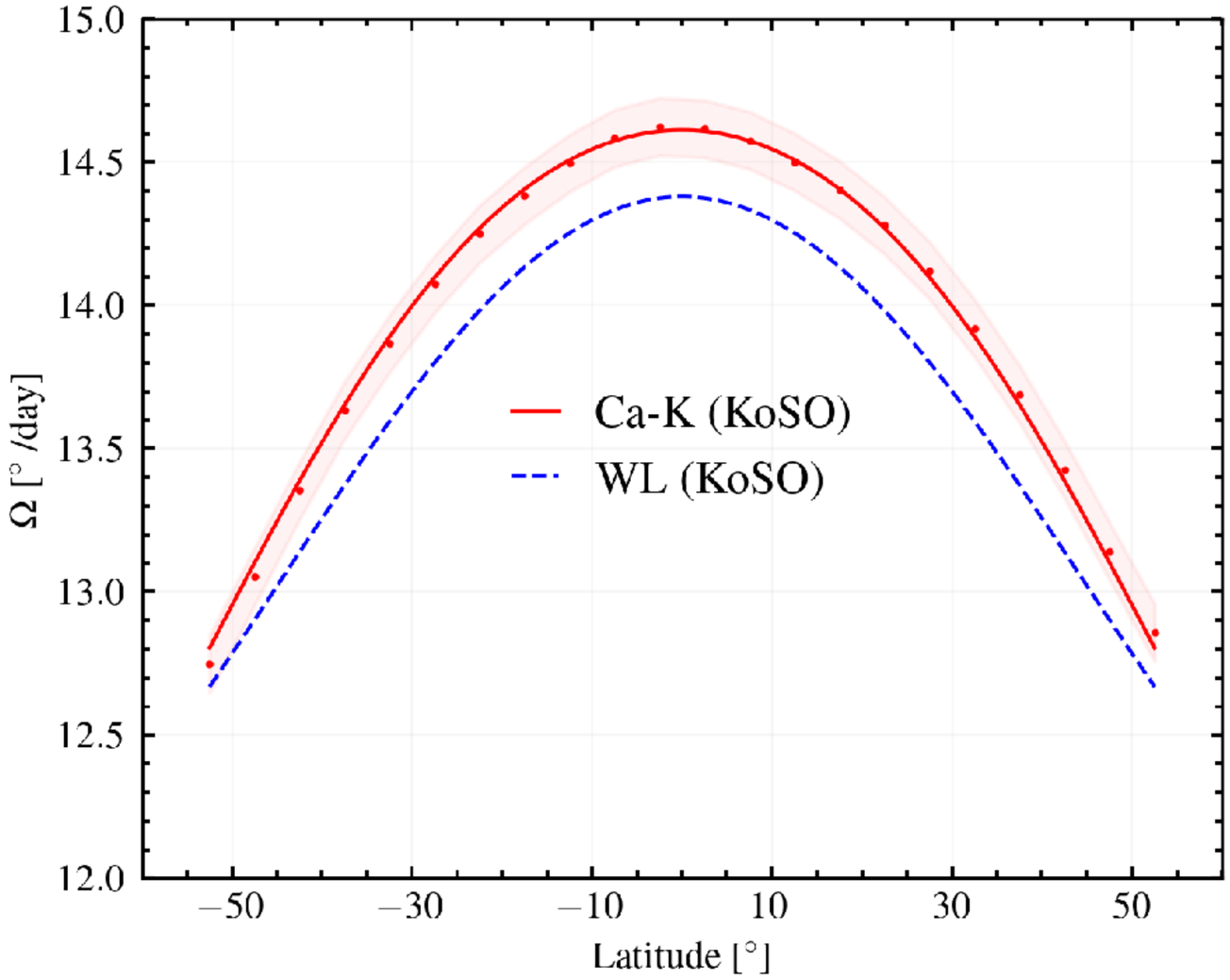
- Restricted ourselves ±55° longitude and latitude.
- We rejected the cases where correlation is < 0.2.
- No maxima in correlation.

Average Chromospheric Rotation

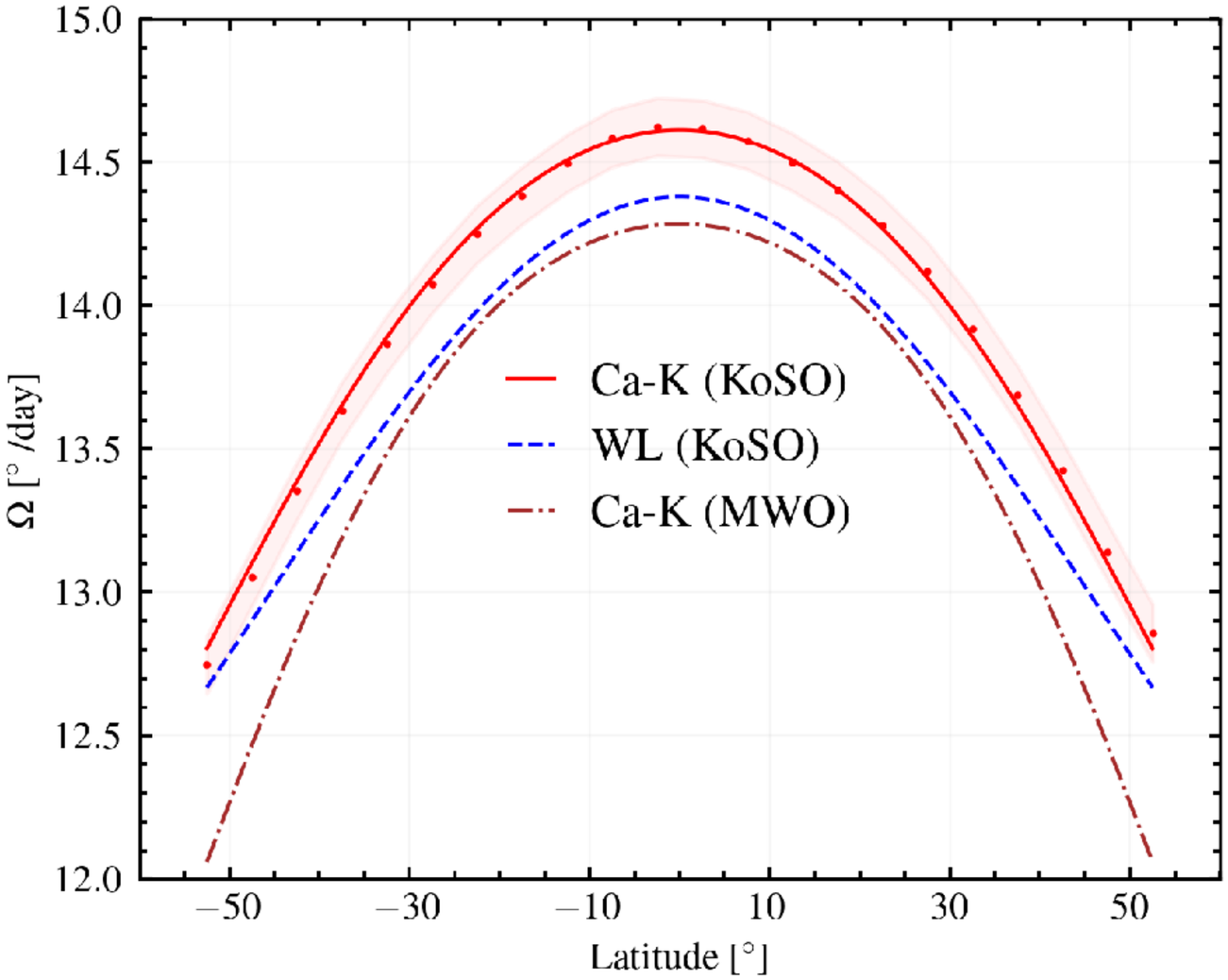
Average Chromospheric Rotation



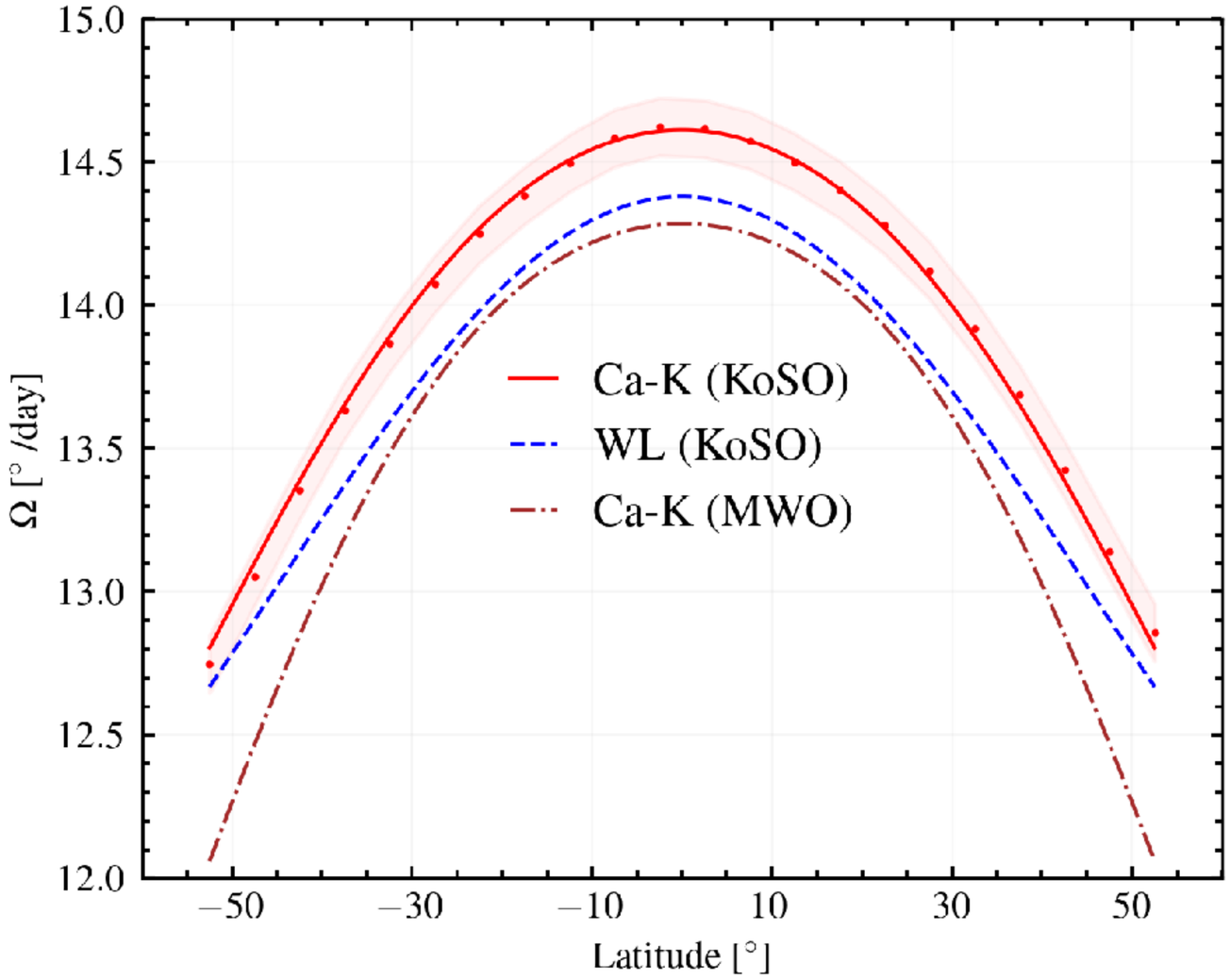
Average Chromospheric Rotation



Average Chromospheric Rotation

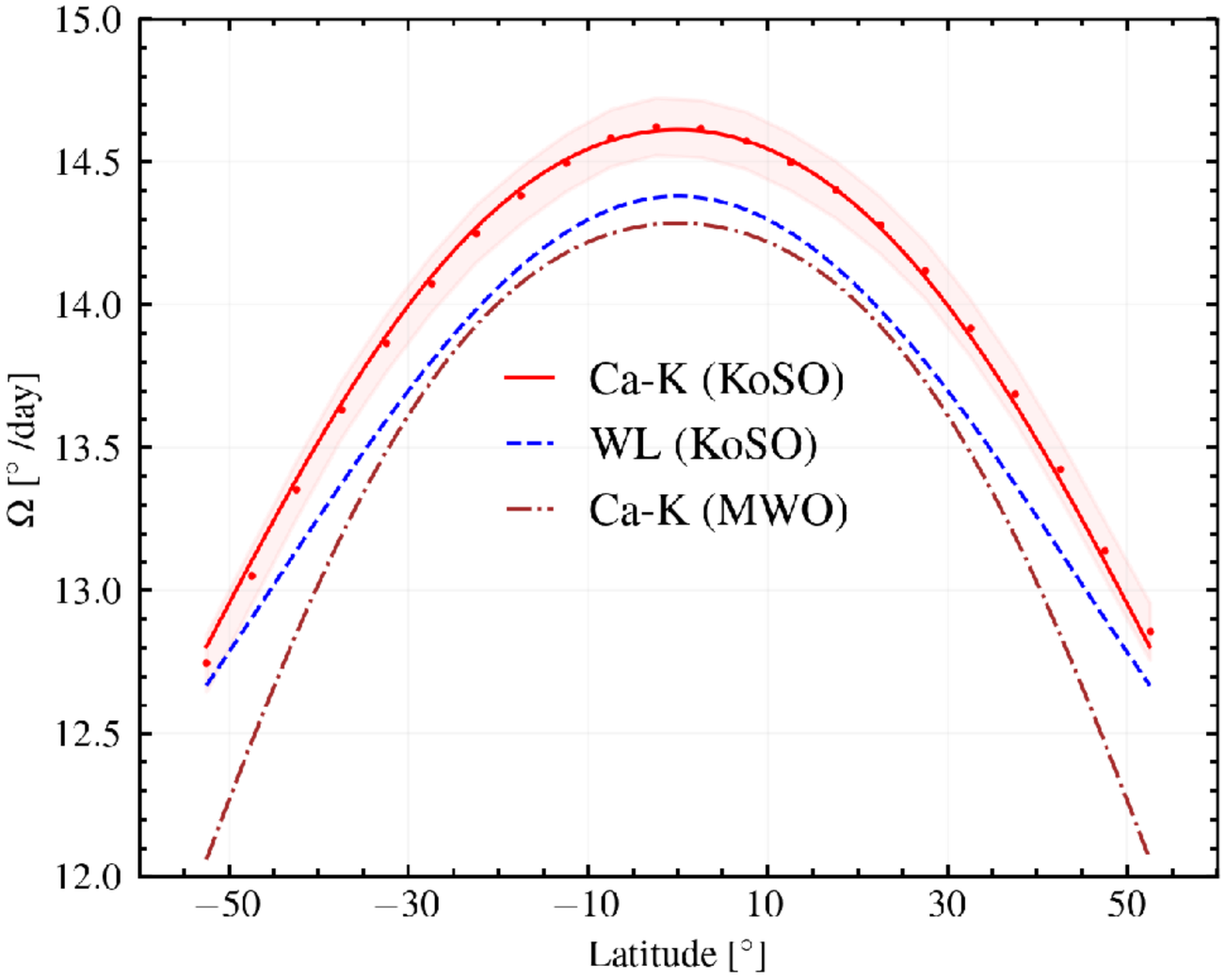


Average Chromospheric Rotation



Observatory	Central Wave.	Pass Band
KoSO	393.367 nm	0.05 nm
MWO	393.367 nm	0.035 nm
Meudon	393.367 nm	0015 nm
PSPT/Rome	393.367 nm	0.25 nm

Average Chromospheric Rotation



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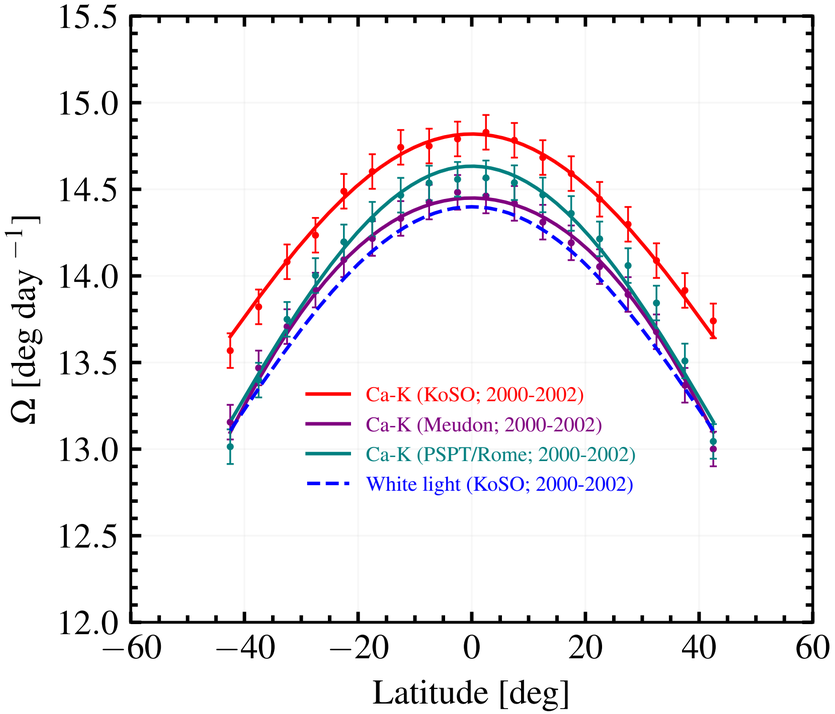
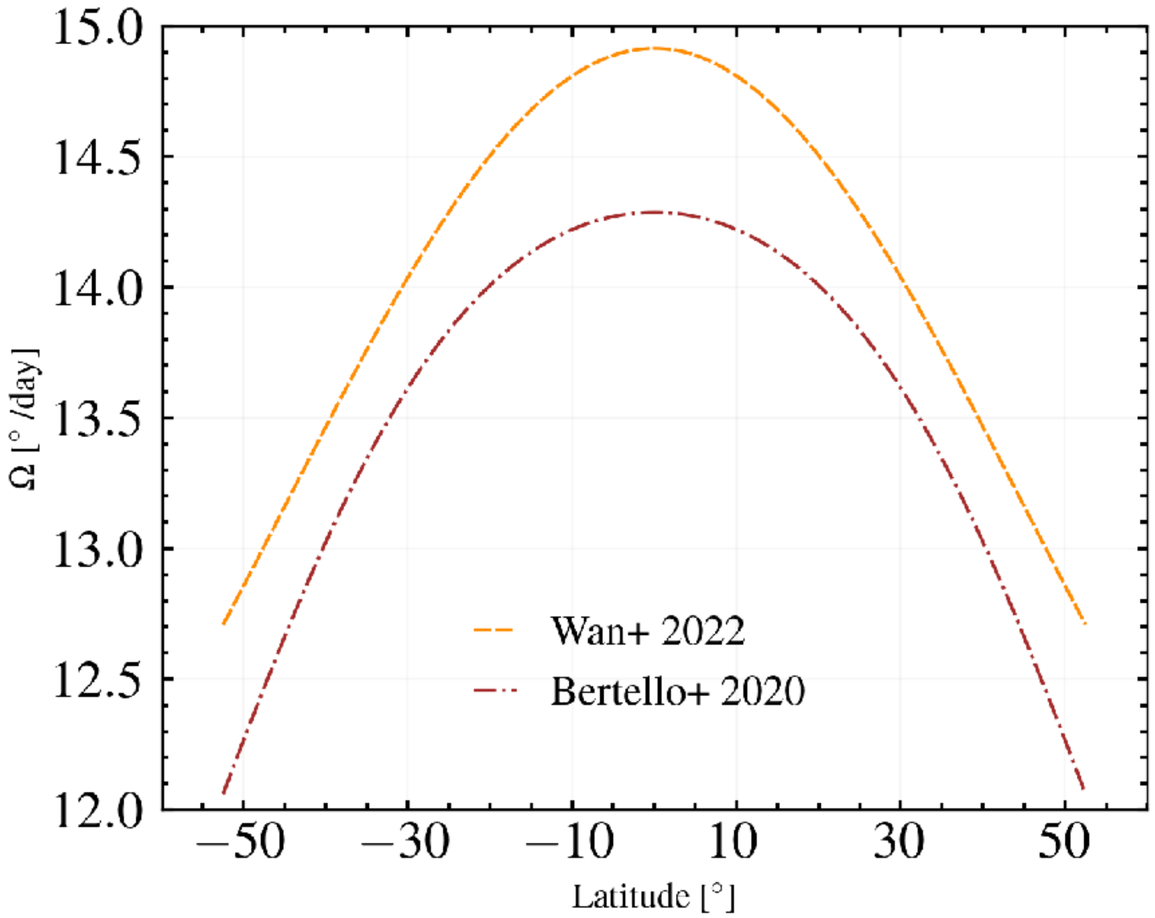
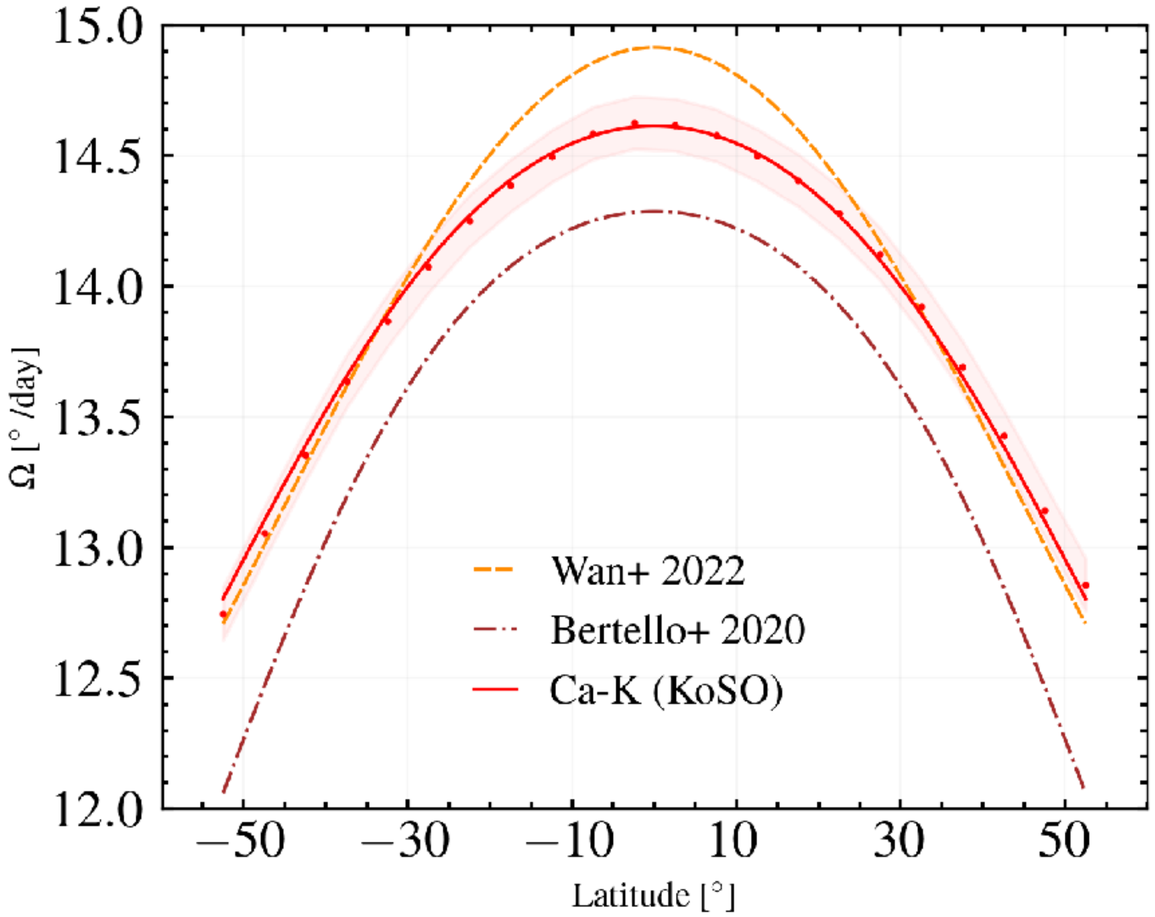


KoSO Vs MWO

KoSO Vs MWO


15.0
14.5
14.0
13.5
13.0
12.5
12.0
Ω [° /day]
−50
−30
−10
10
30
50
Latitude [°]
Wan+ 2022
Bertello+ 2020

KoSO Vs MWO


15.0
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14.0
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13.0
12.5
12.0
Ω [° /day]
−50
−30
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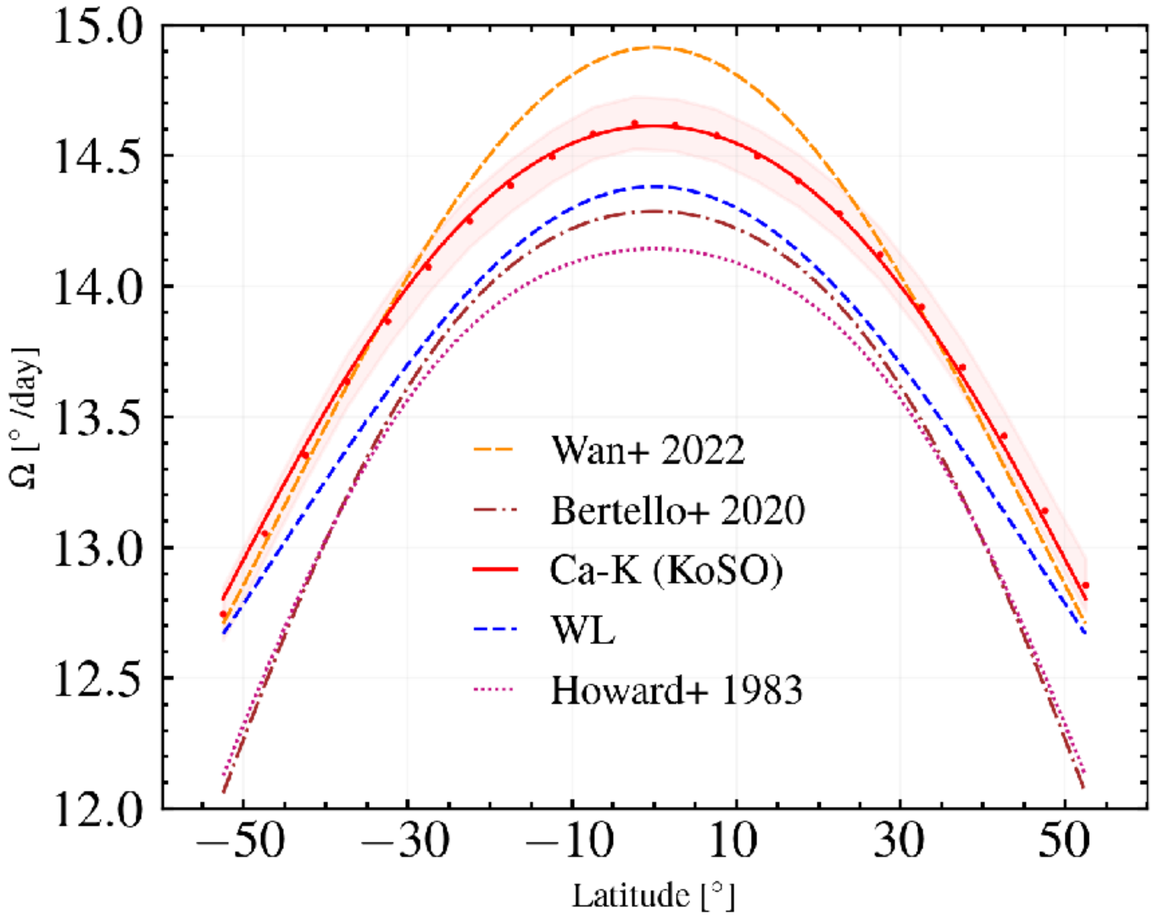
10
30
50
Latitude [°]
Wan+ 2022
Bertello+ 2020
Ca-K (KoSO)

KoSO Vs MWO


15.0
14.5
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13.5
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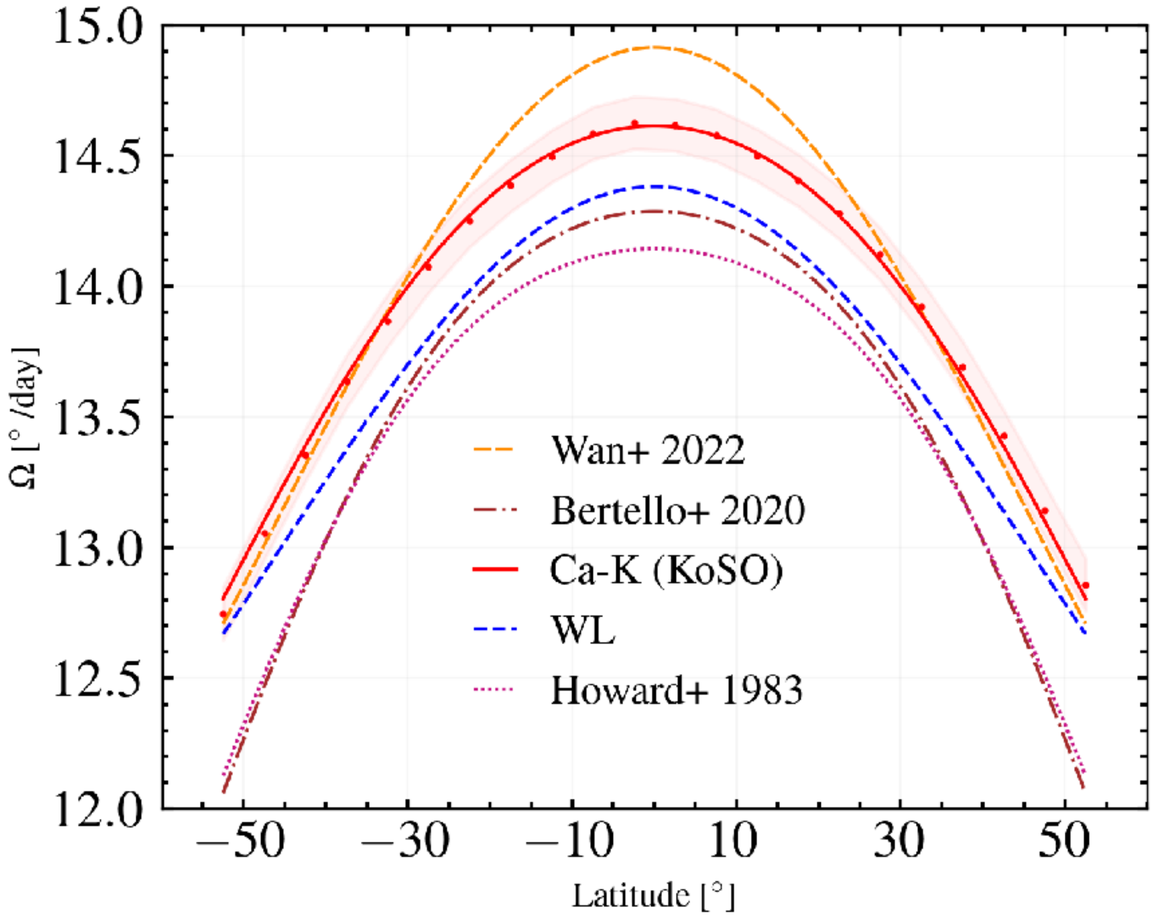
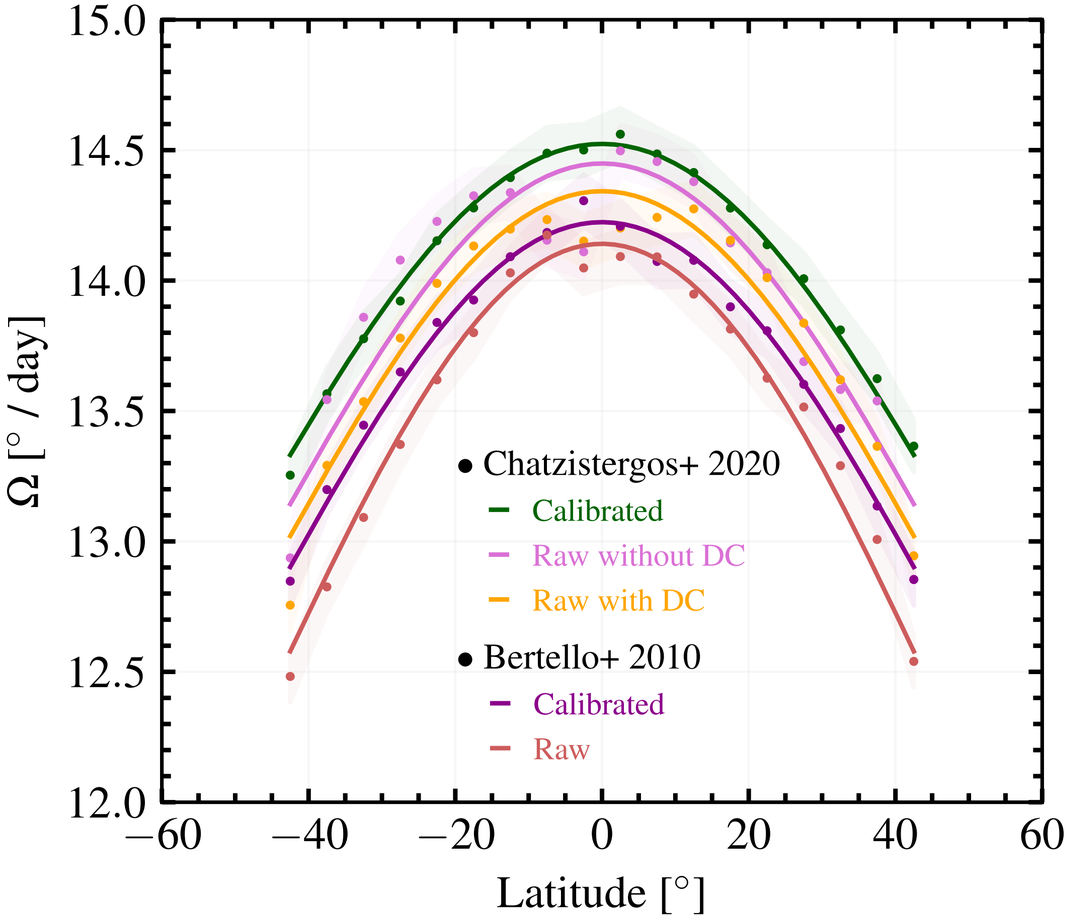
12.5
12.0
Ω [° /day]
−50
−30
−10
10
30
50
Latitude [°]
Wan+ 2022
Bertello+ 2020
Ca-K (KoSO)
WL
Howard+ 1983

KoSO Vs MWO





DC: Disk Circularization

Conclusion

- Part I (Jha et al. 2023, In prep):
  - We found inconsistency in the T_{OBS} in KoSO Ca II K data.
  - ~9 % of data was identified with incorrect timestamp.
  - After all the correction we left with~2.5 % data with incorrect T_{OBS}.
  - Image correlation technique has been implemented to estimate the correct orientation of 2.5% of data.

- Part II (Mishra et al. 2023, Submitted):
  - Sunspot (A, B, C):
  - Based on image correlation technique plages gives 1.6% faster rotation rate than sunspot.
  - Clear effect of calibration methods and non-uniformity in the disk as well as methods.
  - We are extending this work using AIA data and it seems very very interesting, stay tuned!

I would like to express my gratitude to the organizers for the Thomas Metcalf Travel Award, which have provided me with the opportunity to present my work to all of you.

Thank You

तन्नो आदित्यः प्रचोदयात् ॥

Let the Sun Inspire Us.

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Thank You for your attention!