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MONITORING HORIZONTAL ELECTRON DENSITY WITH LOFAR PL610 IN SINGLE STATION MODE

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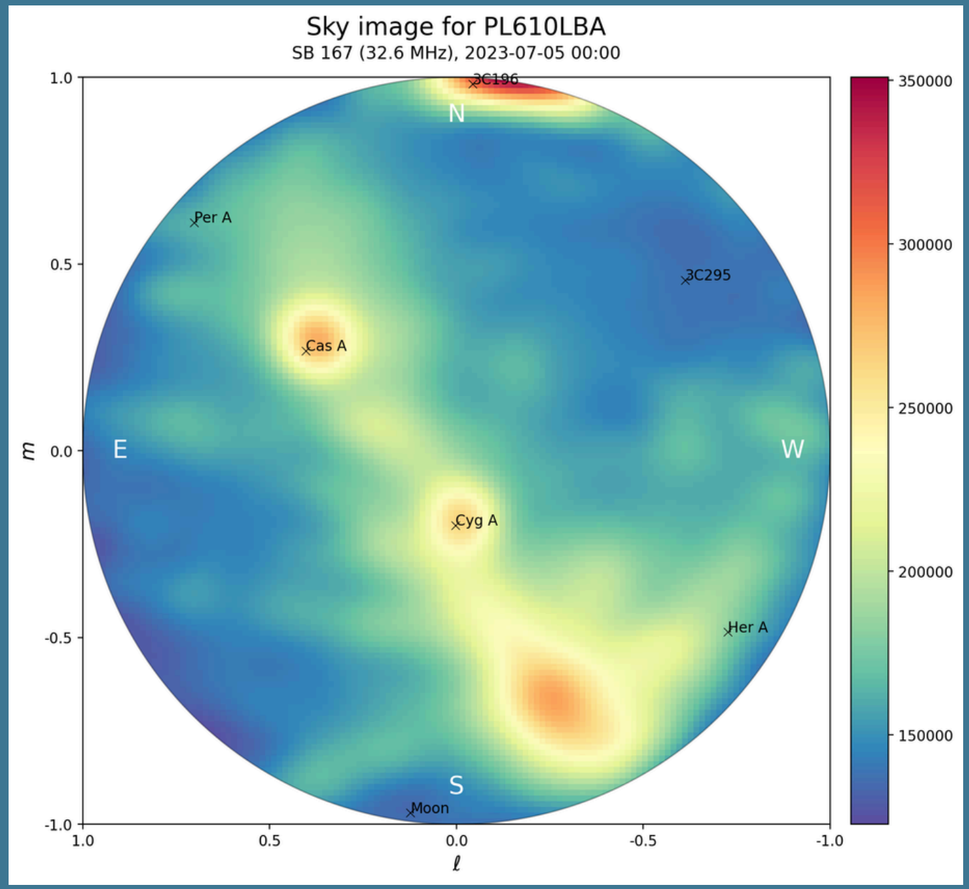
Otuline

- Motivation and Methodology
- Observation of irregularities and signal scintillation
- Geometric limitation
- Statistics of observations
- Examples of structures
- Seasonal dependence
- Case studies

Methodology

- **Station PL610**
- **Subband 167 (32.617 MHz)**
- **Sources: Cas A & Cyg A**
- **Offset calculated with respect to catalogue postitions**



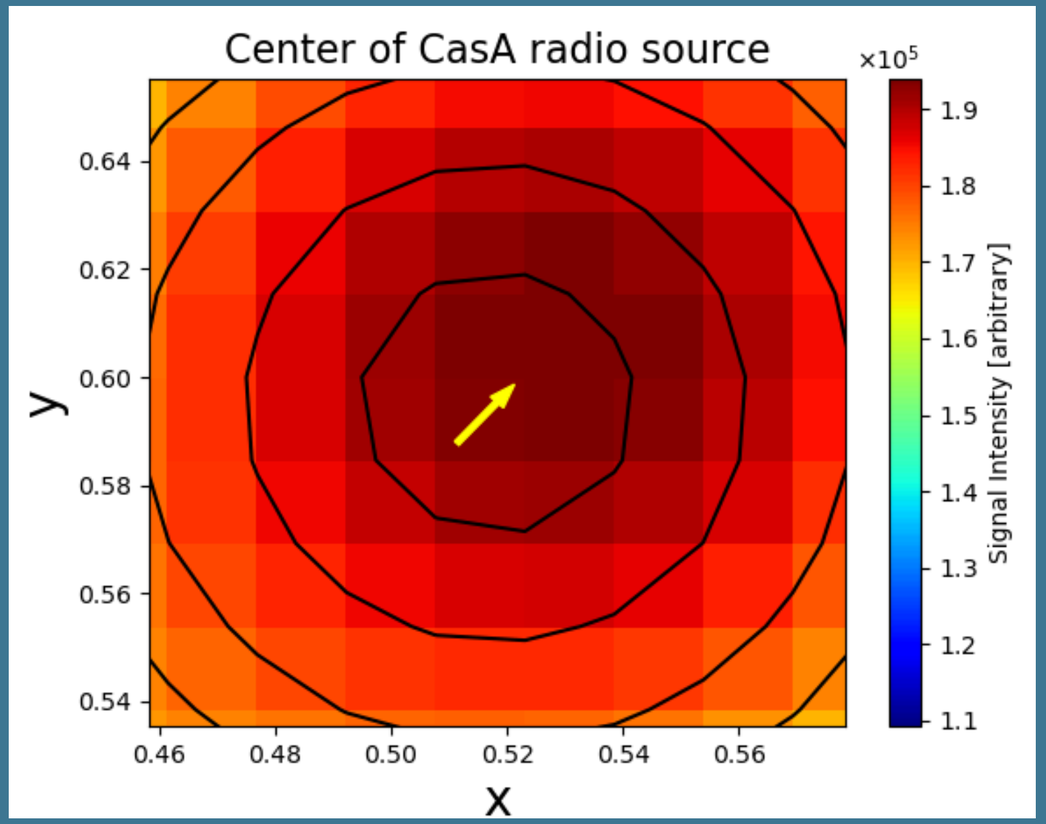
Sky map obtained at station PL610.

Position fit

The calculated brightness distribution can be fitted with the 2D Gaussian function defined above. The parameters μx and μy can then be interpreted as the apparent position of the radio source.

$$g(x,y) = \frac{A}{2\pi\sigma_x\sigma_y} \cdot \exp\left(-\frac{(x-\mu_x)^2}{2\sigma_x^2} - \frac{(y-\mu_y)^2}{2\sigma_y^2}\right)$$

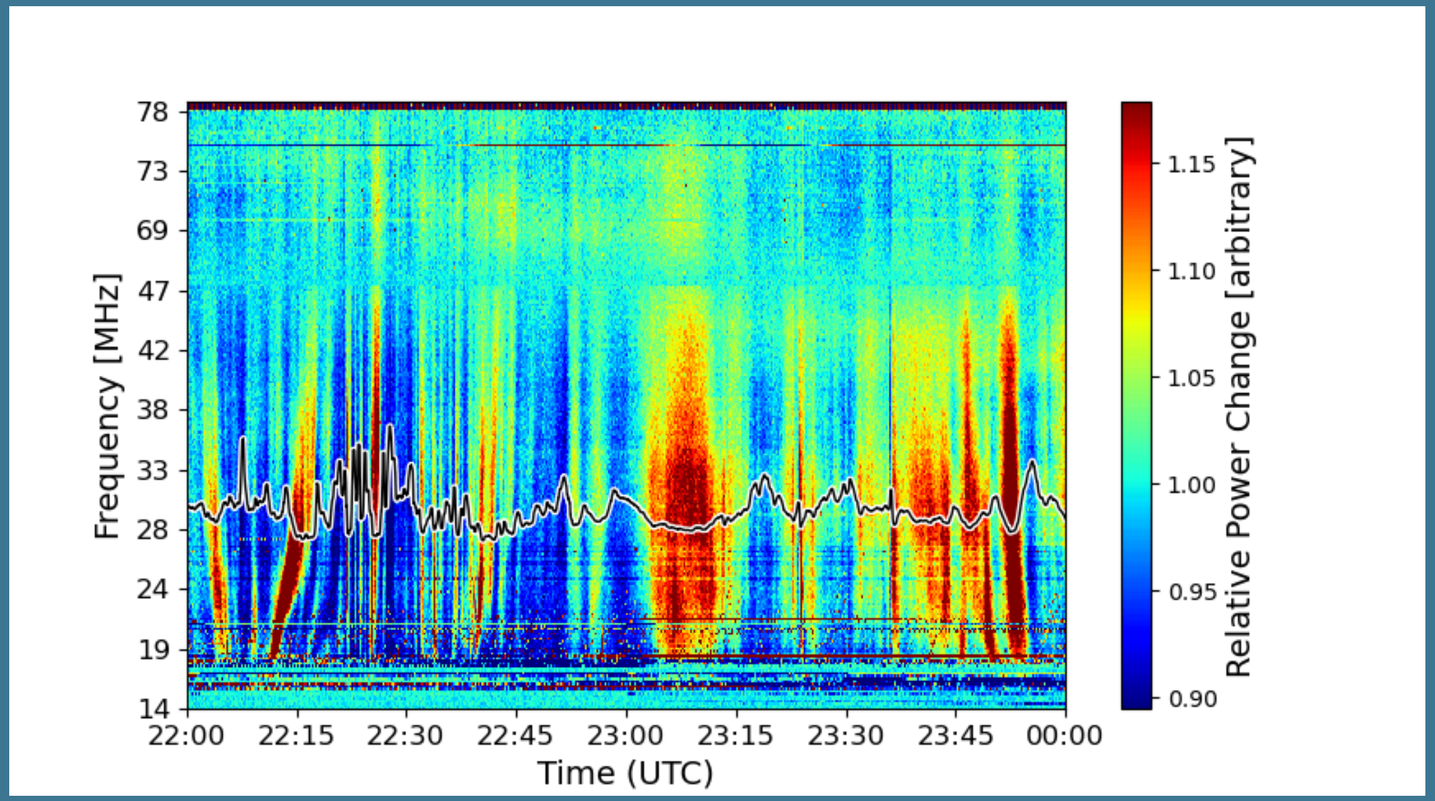
A – amplitude
σ_x, σ_y – distribution width
μ_x, μ_y – position of the maximum



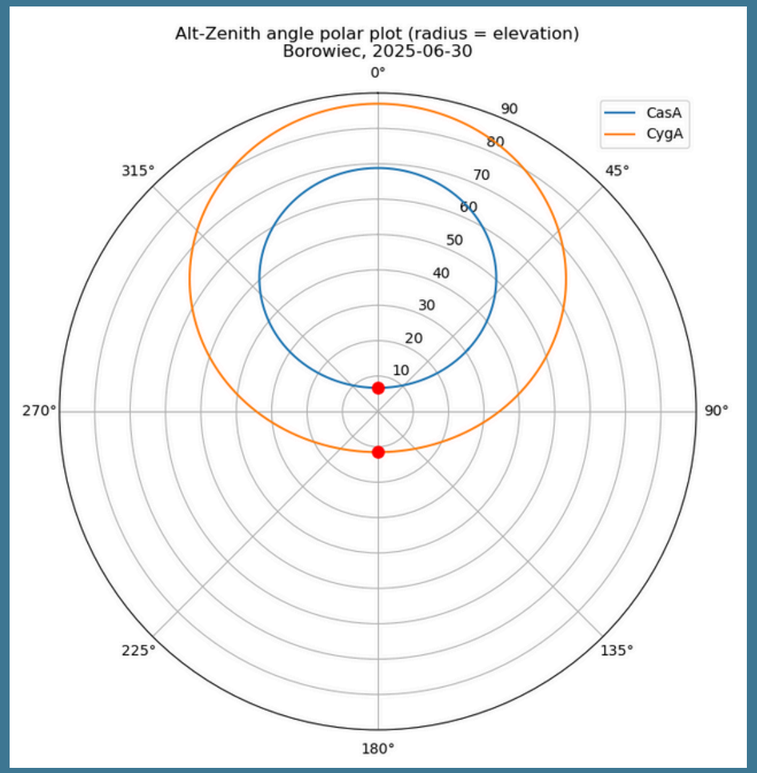
Catalogue position and fitted solution for CasA in l–m projection coordinates. The yellow arrow indicates the positional offset.

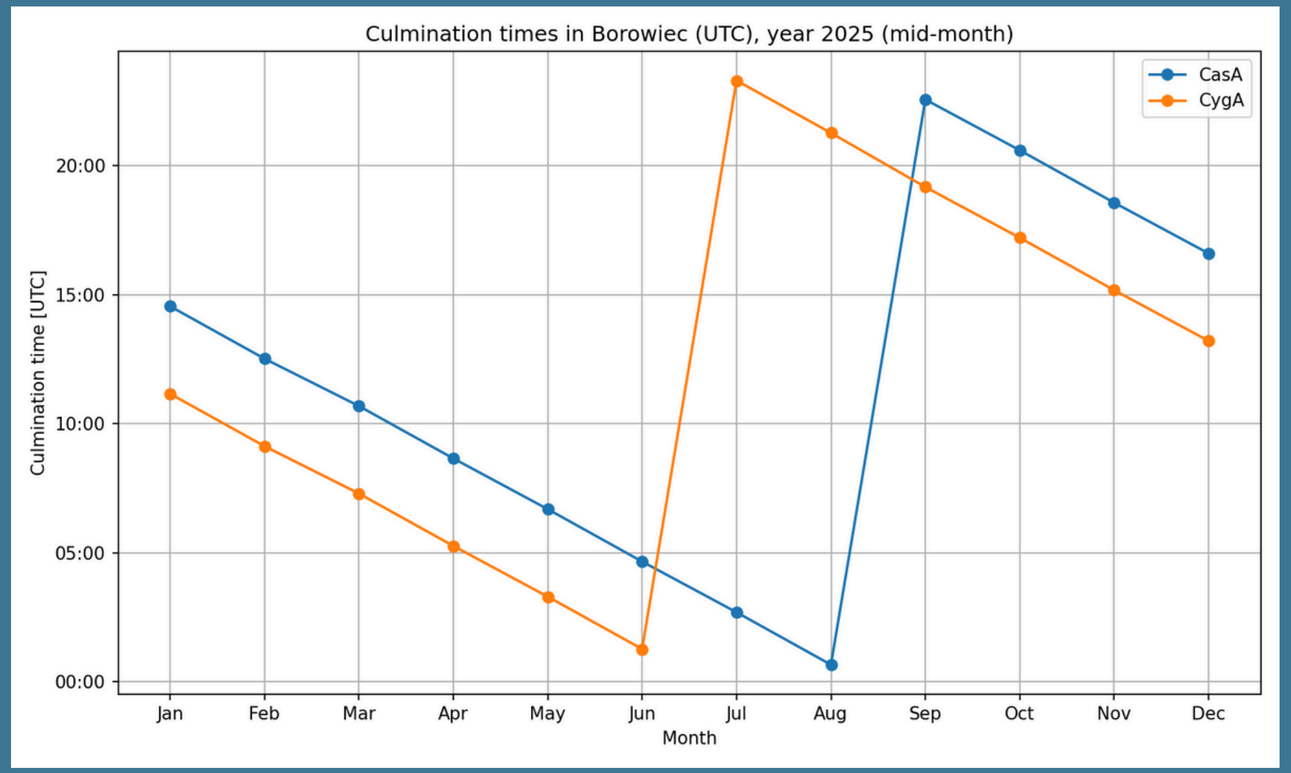
Source shift - amplitude modulation

According to our assumption that electron density gradients in the ionosphere are responsible for the apparent shift of the source position, they should also give rise to amplitude modulations associated with ionospheric scintillations. We present a comparison of the position offset and the signal amplitude in the 14–70 MHz range, recorded simultaneously at the PL610 station.



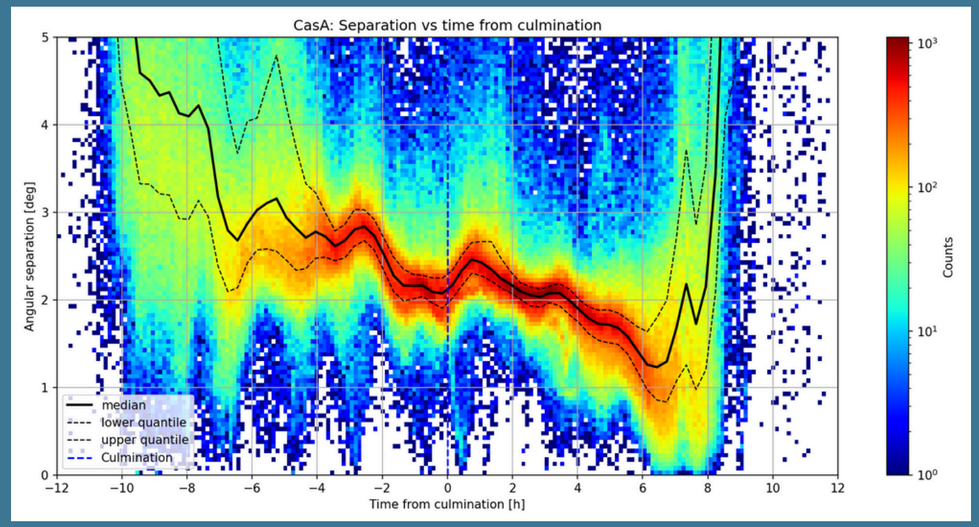
Statistical analyses

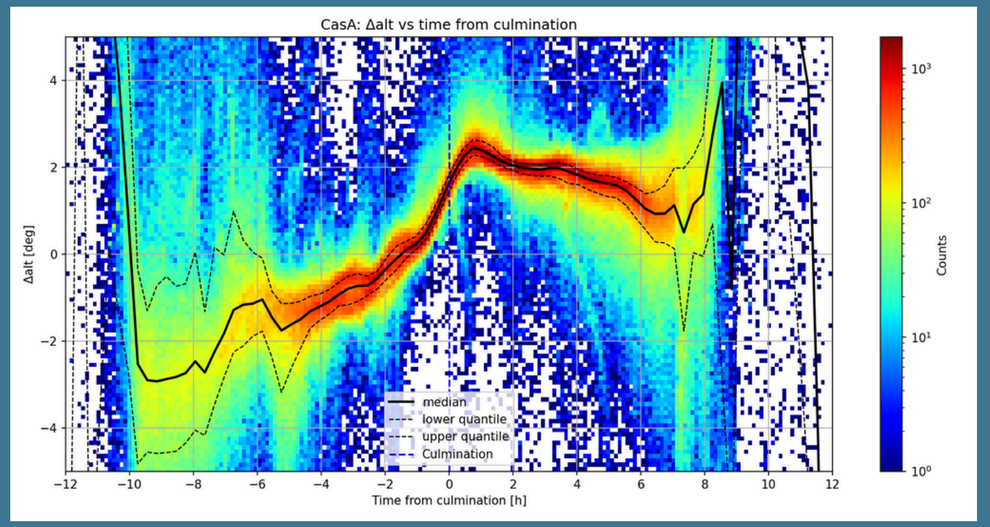


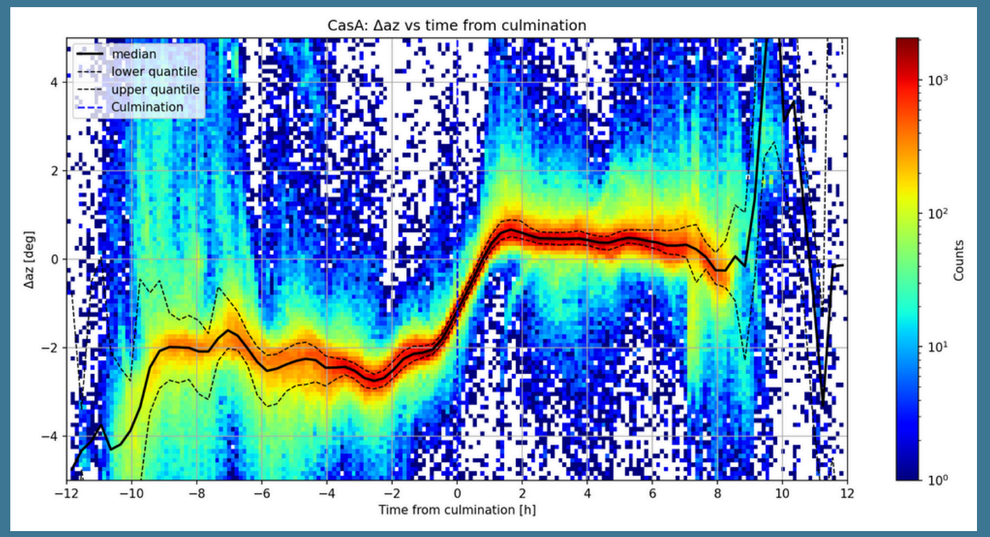


(left) Daily variation of azimuth and zenith angle for CasA and CygA observed from Borowiec PL610;
(right) UTC culmination times of CasA and CygA as a function of month

Annual observation CasA

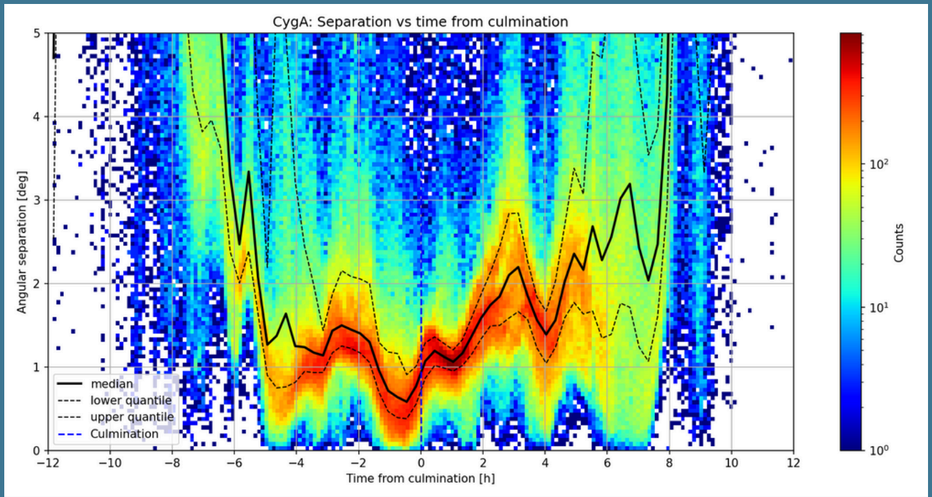


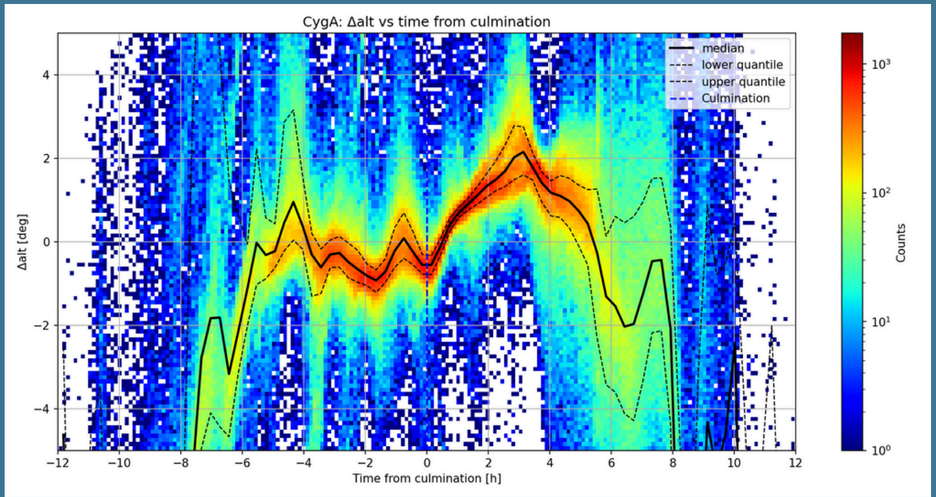


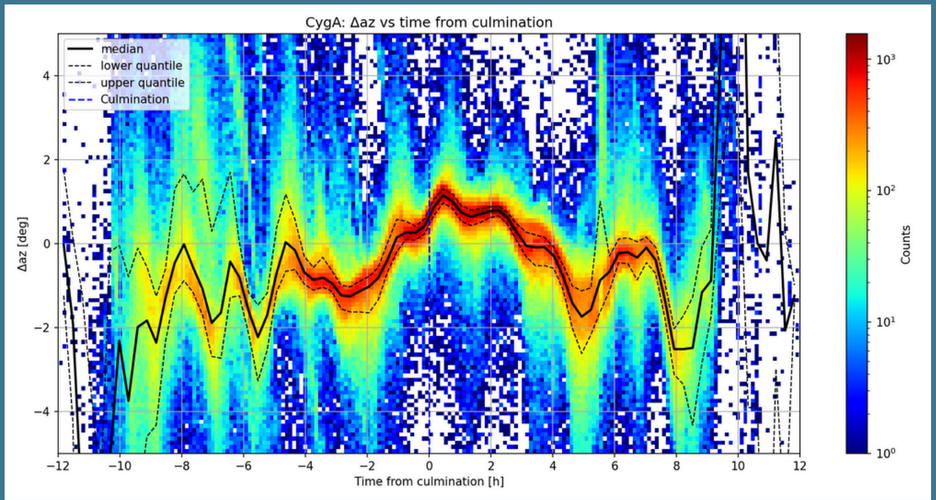


Median, quantiles, and counts for CasA as a function of time offset from culmination. The plots show (top left) angular separation, and (top right, bottom right) the elevation and azimuth offsets from the catalog position.

Annual observation (CygA)



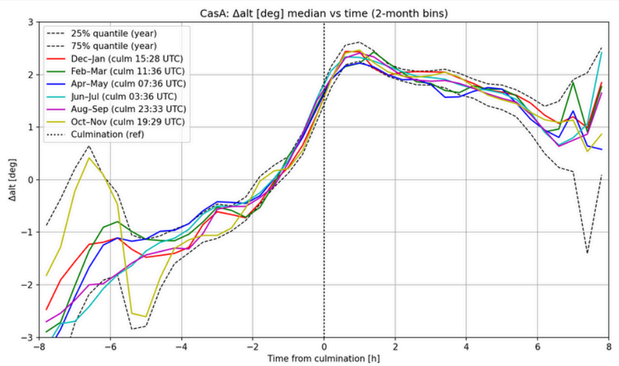


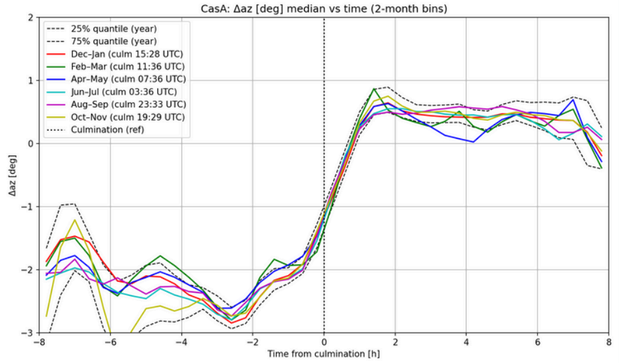


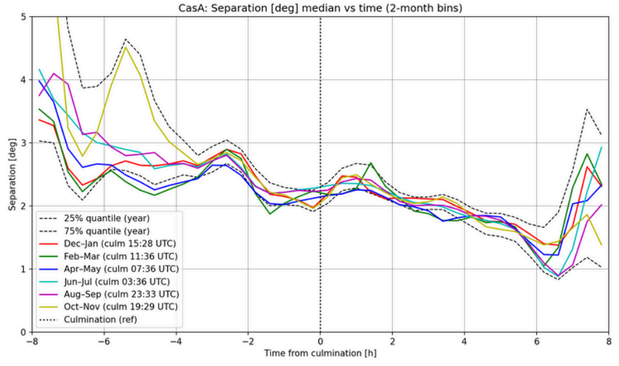
Median, quantiles, and counts for CygA as a function of time offset from culmination. The plots show (top left) angular separation, and (top right, bottom right) the elevation and azimuth offsets from the catalog position.

Two-mothly median value

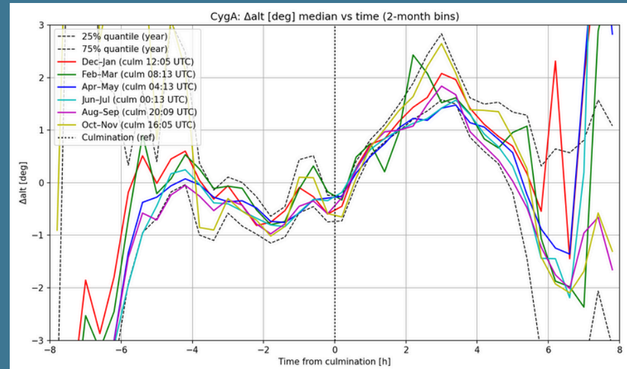
CasA

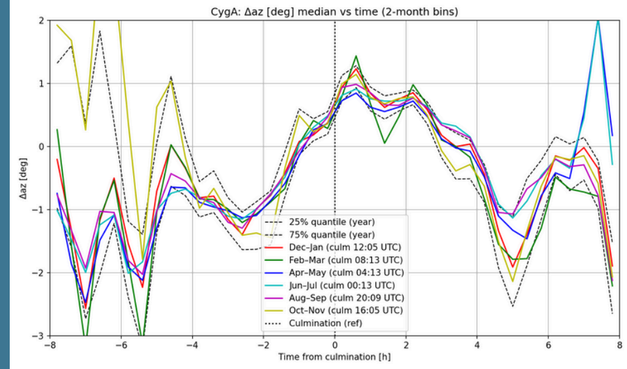


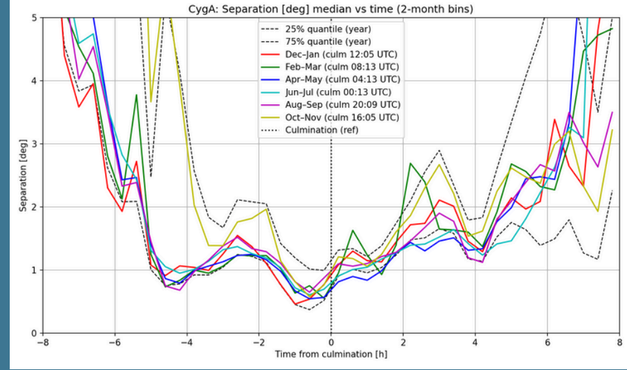




CygA

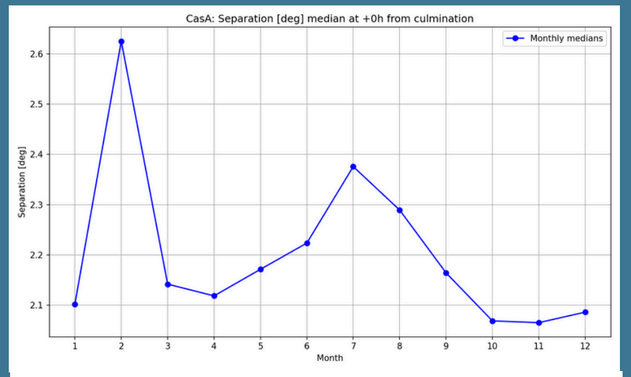


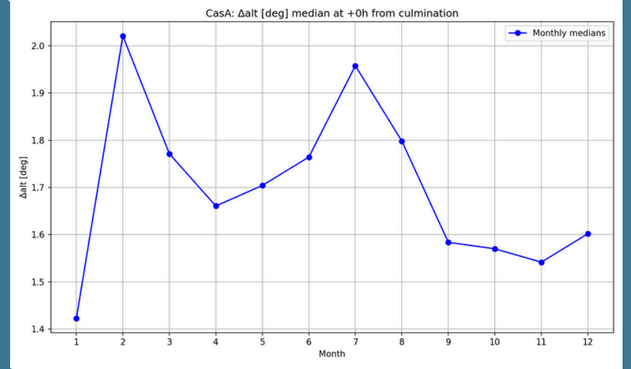


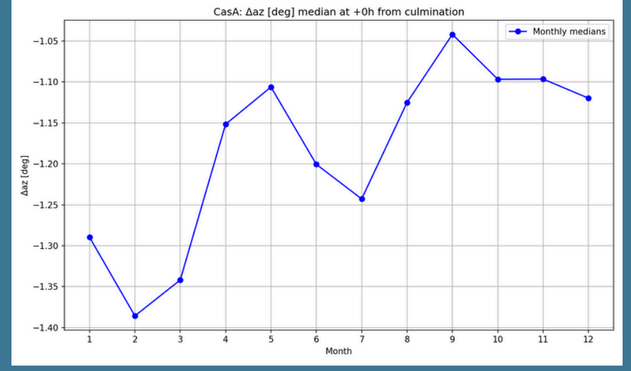


Value near culmination during year

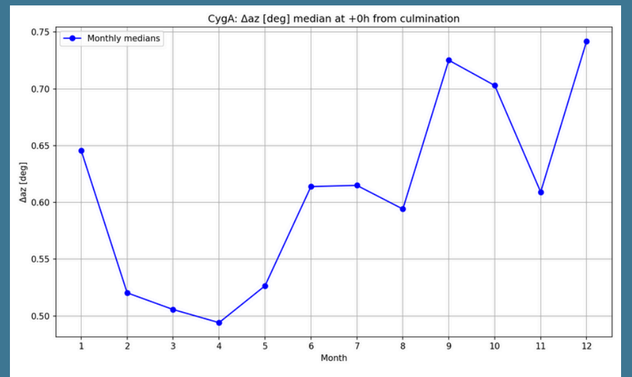
CasA

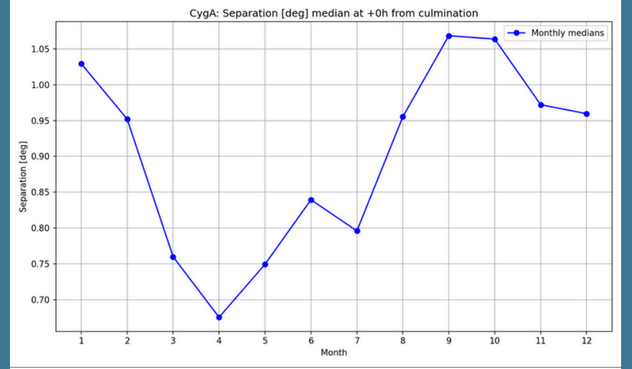


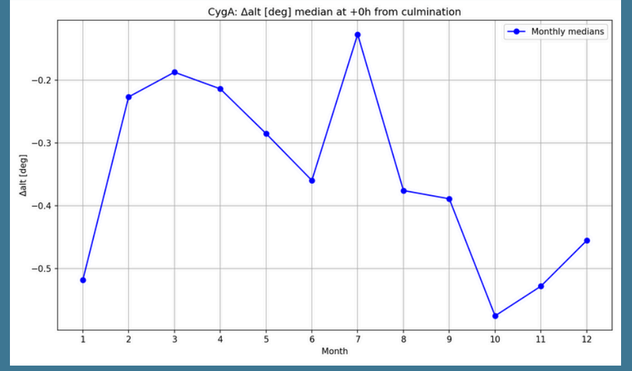




CygA

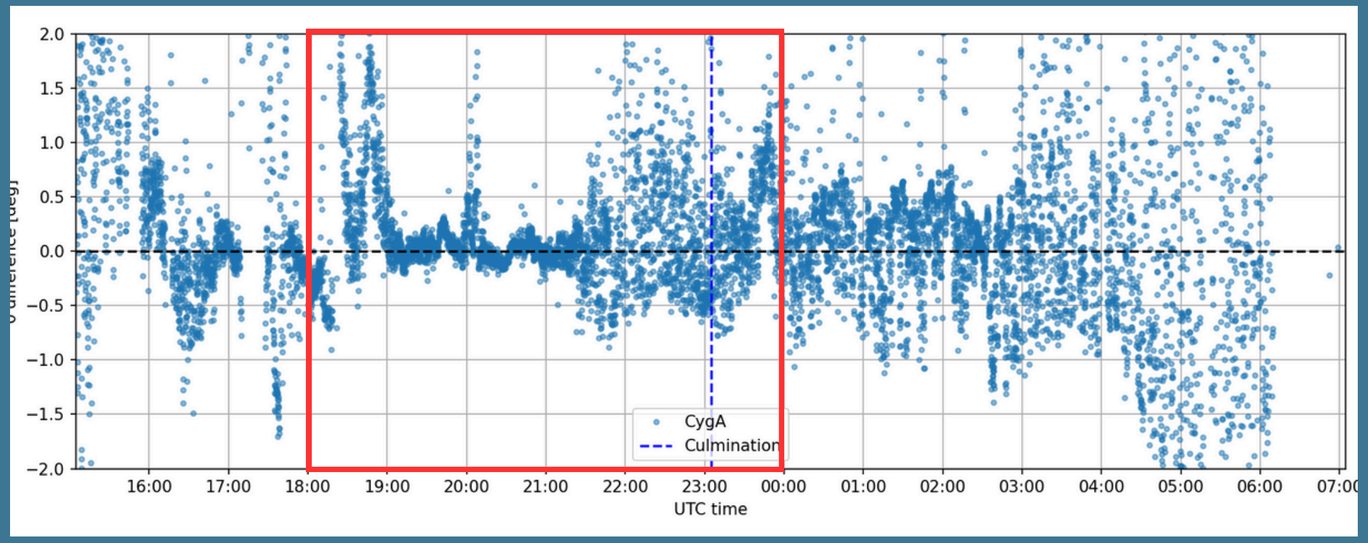


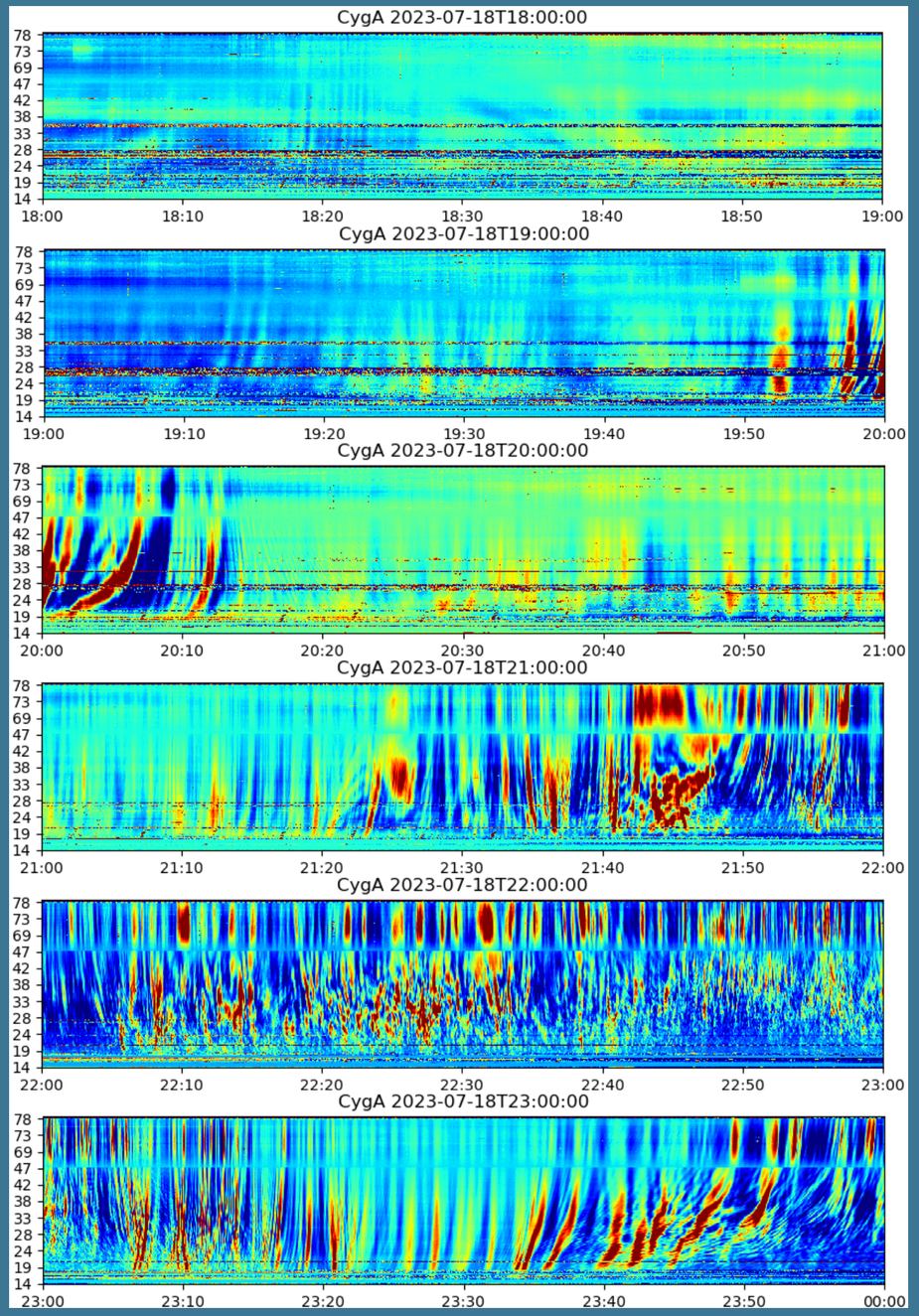




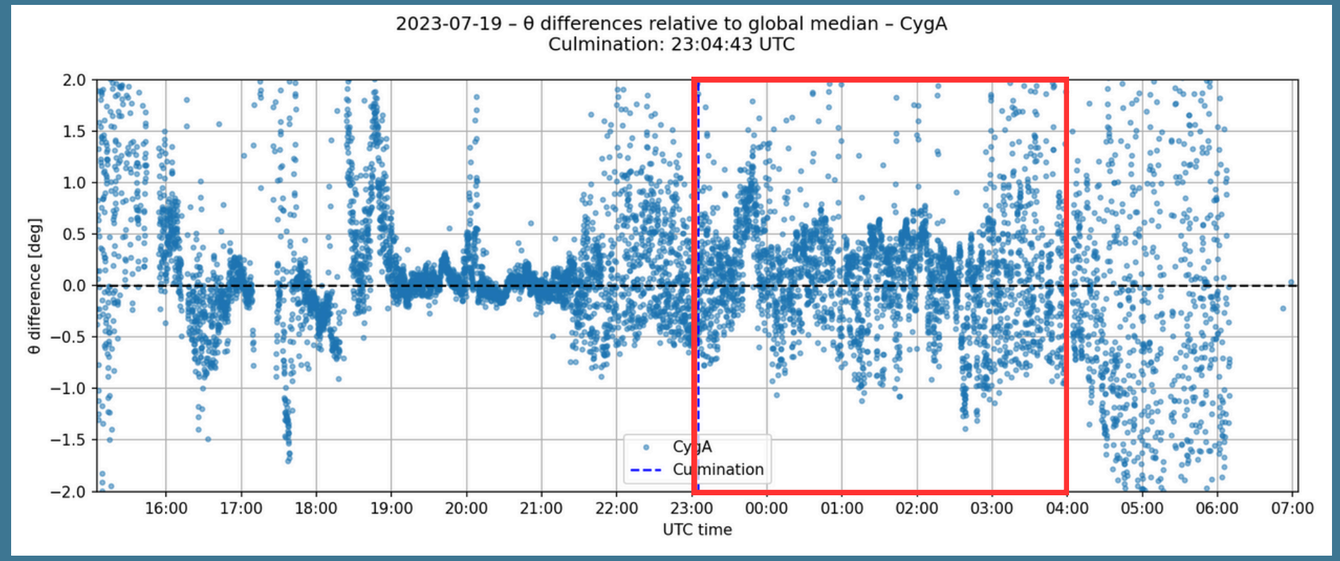
Separation between the measured and calculated position, elevation offset, and azimuth offset over the course of a year for Cas A (left) and Cyg A (right).

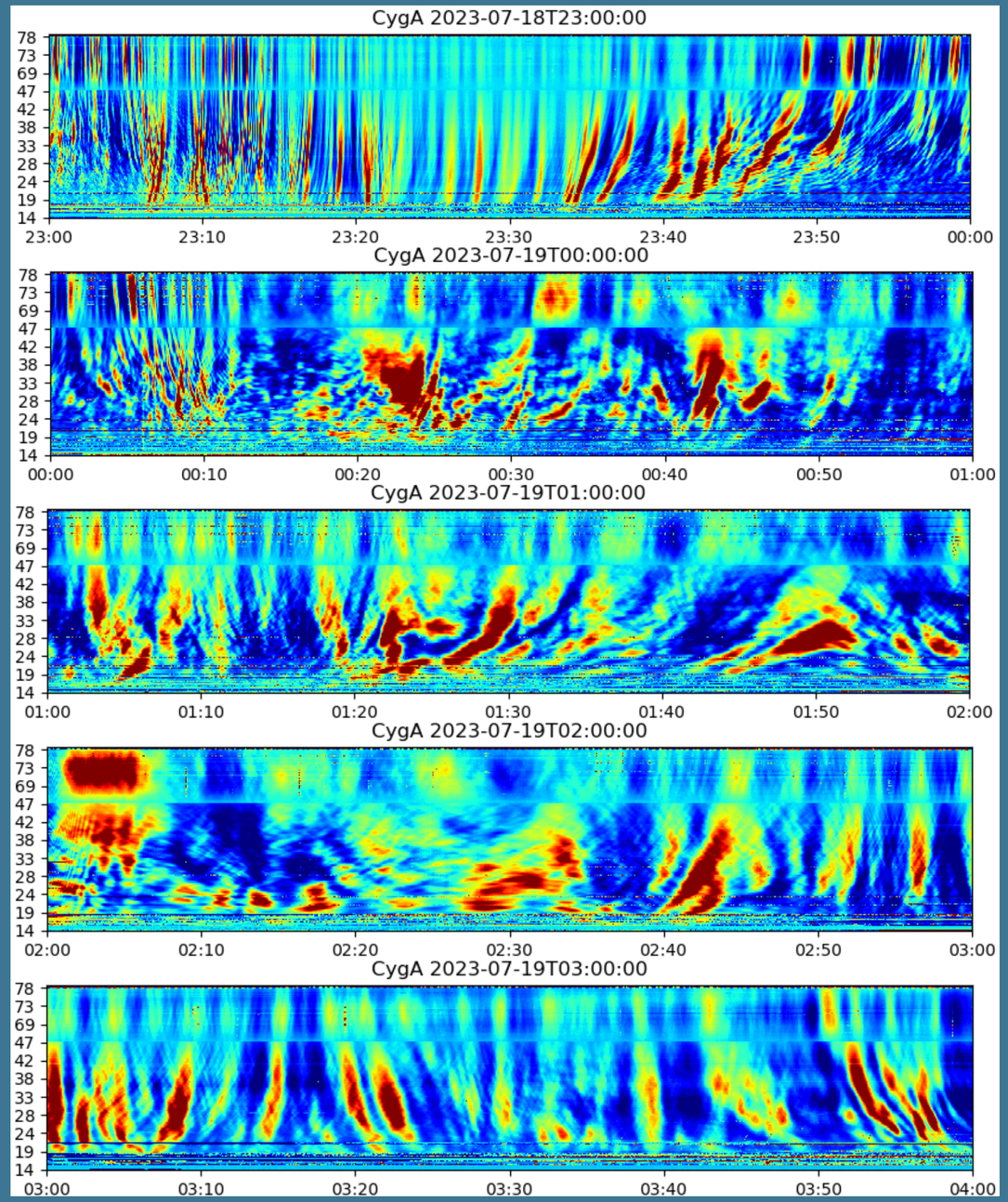
CygA 2023-07-18



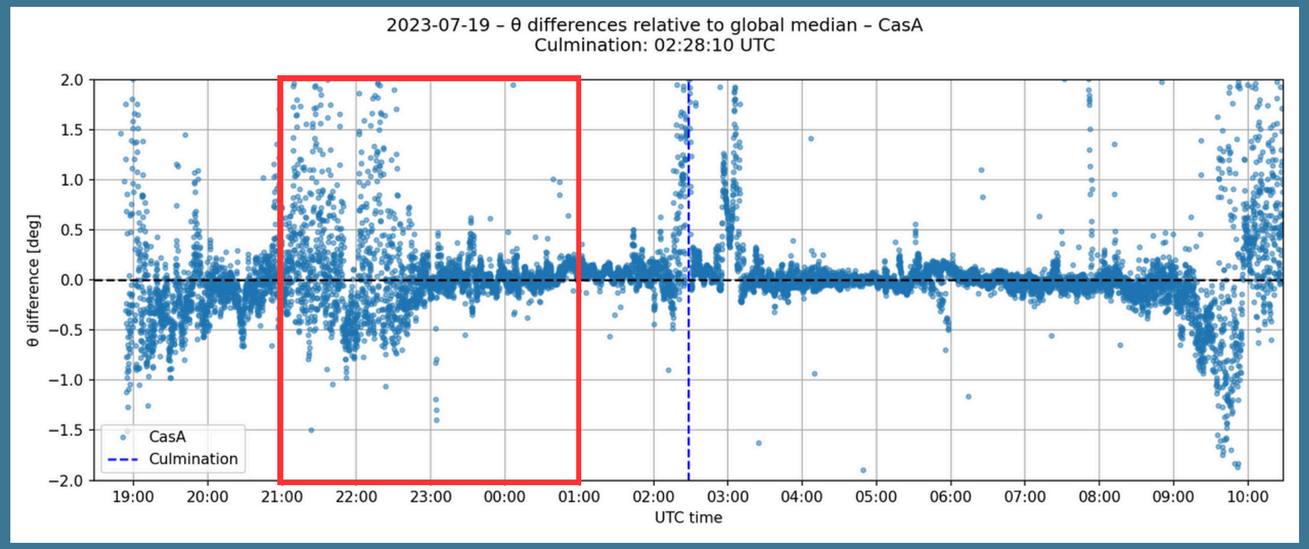


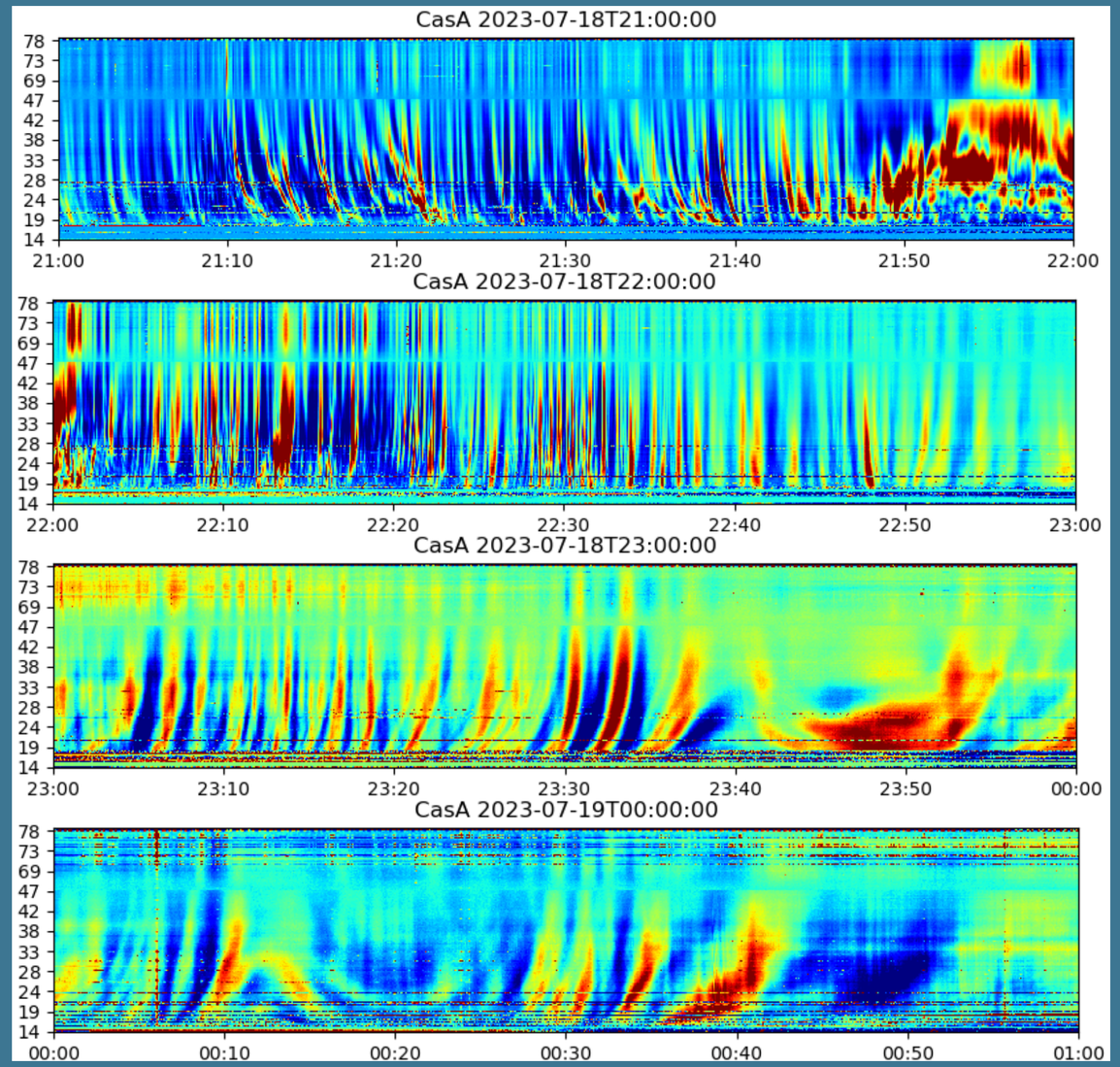
CygA 2023-07-18



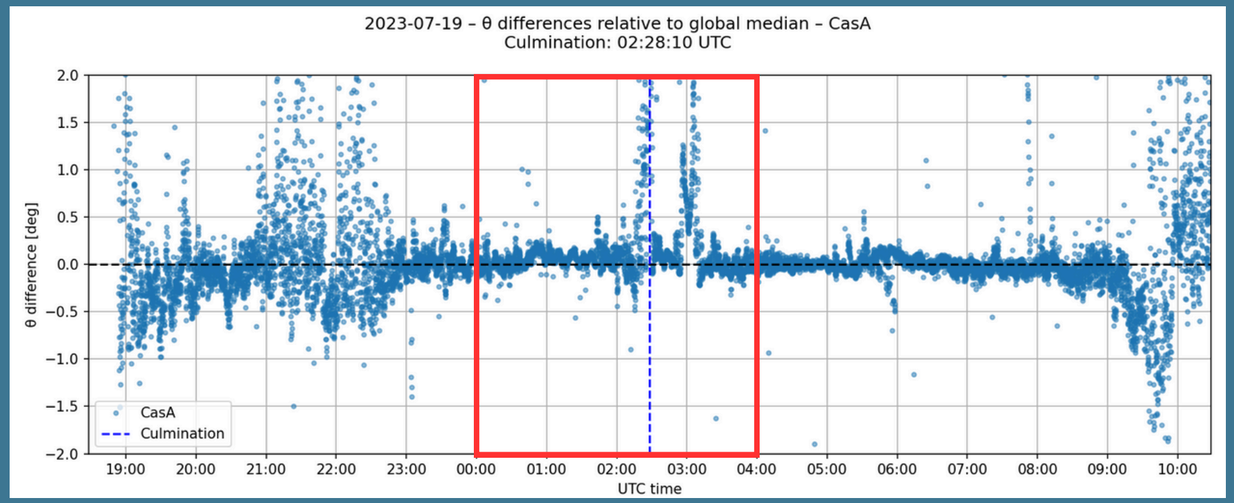


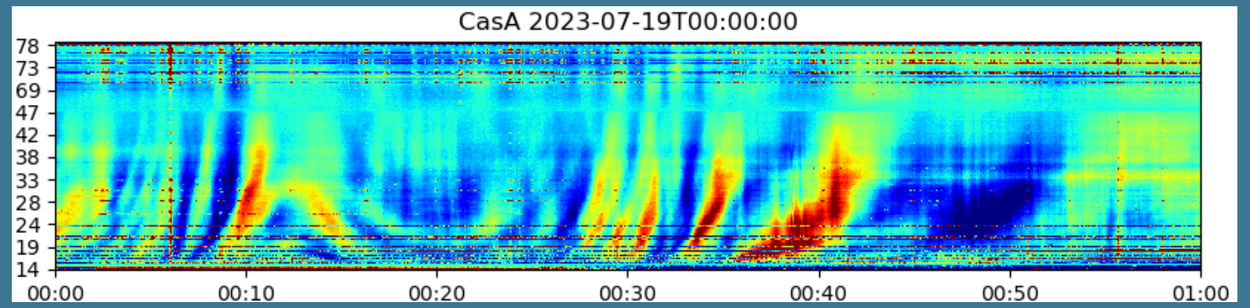
CasA 2023-07-18

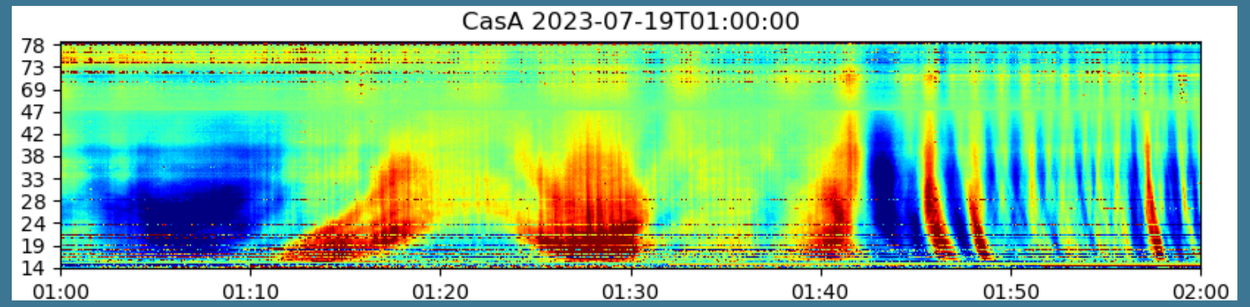


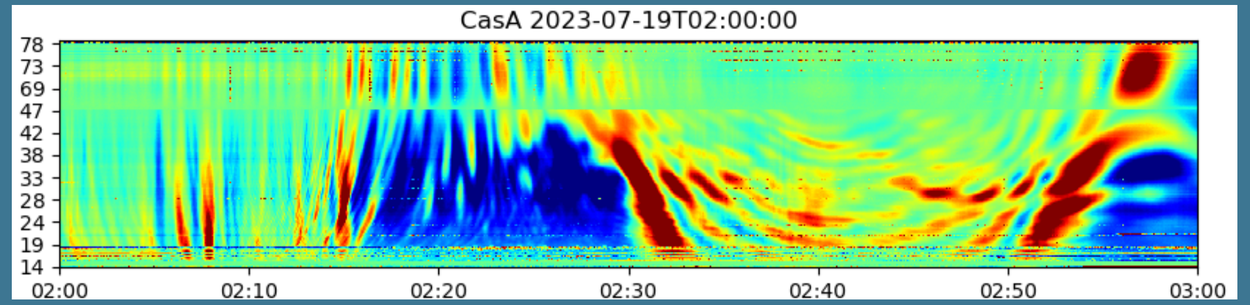


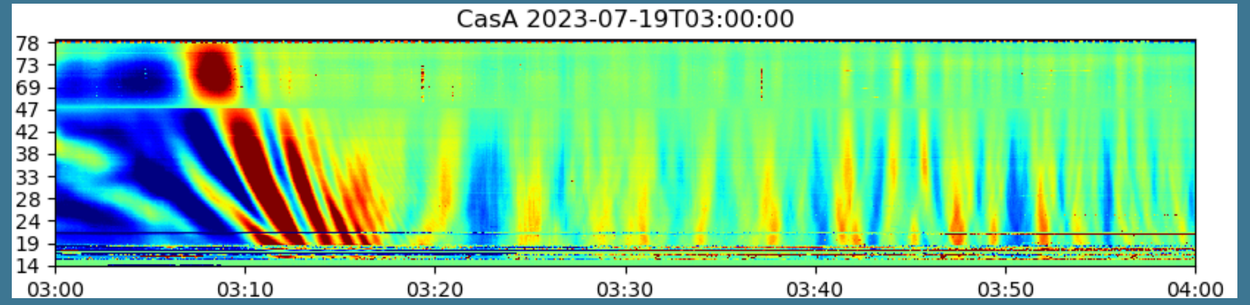
CasA 2023-07-18



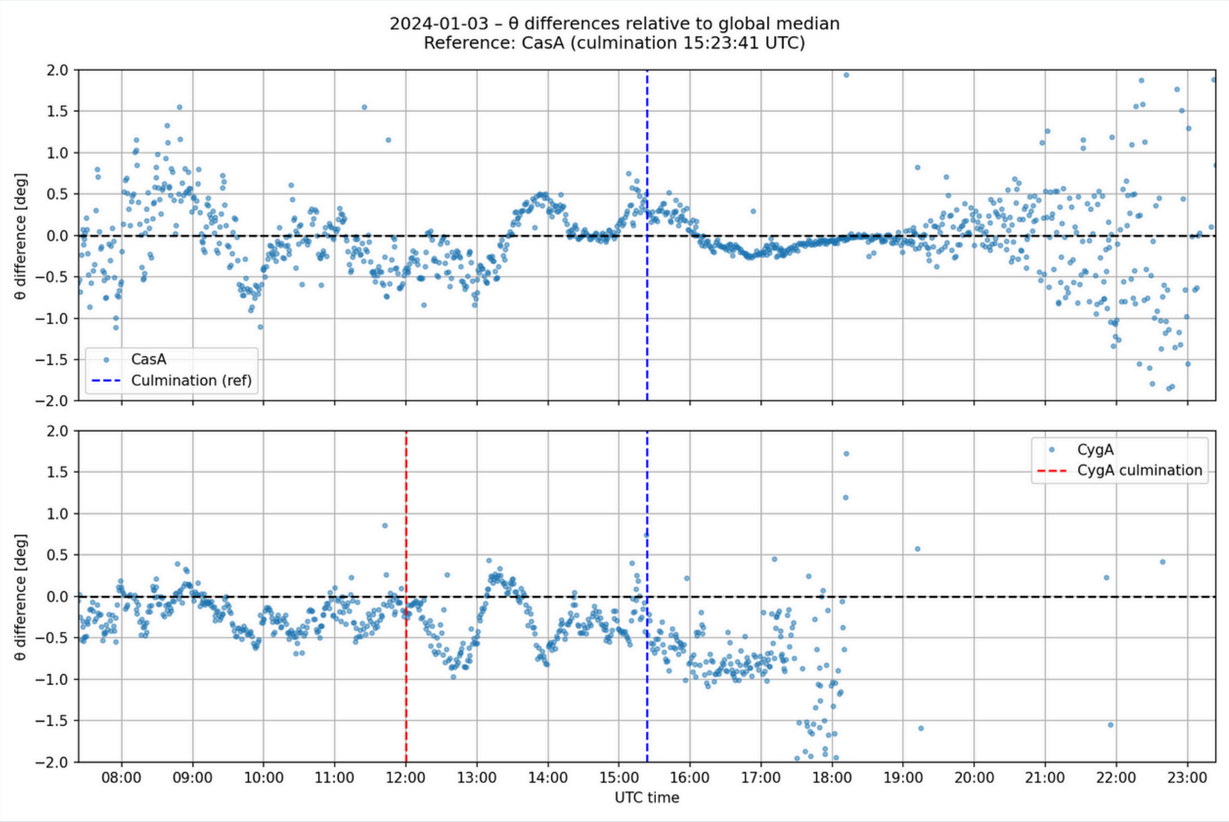


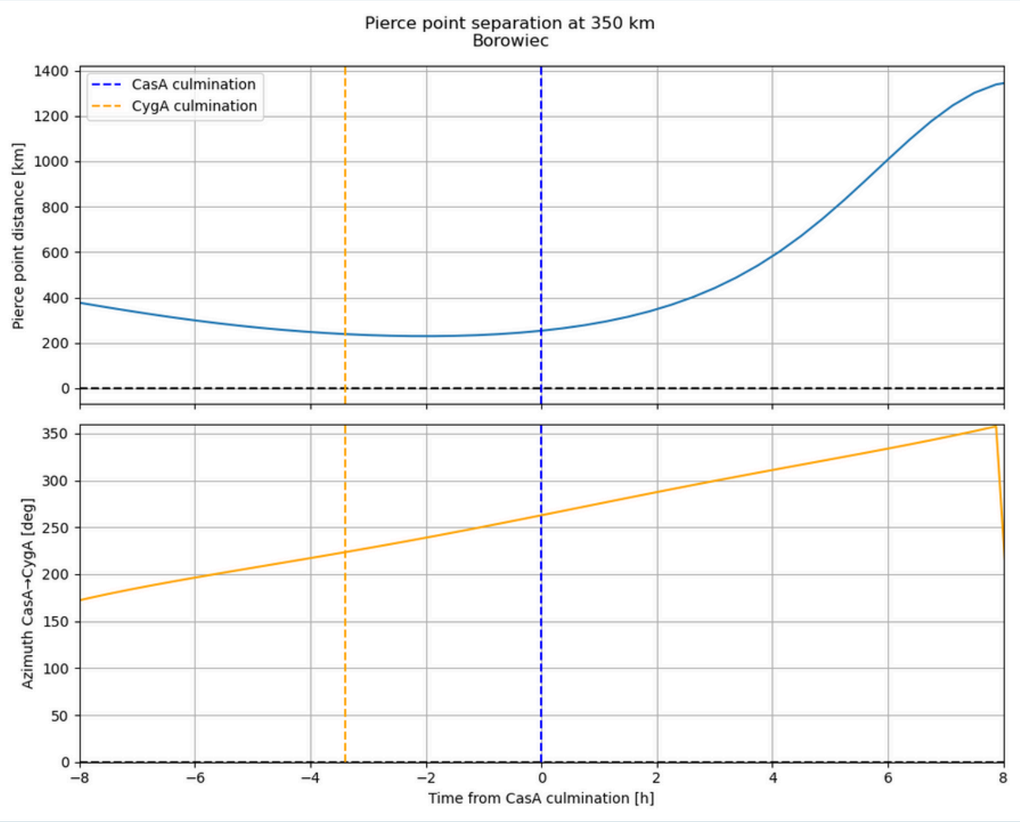






Mutual obseration





- **Same structure observed in both sources**
- **~ 100m/s AGW (?) - not visible in dynamic spectrogram**

Conclusion

- The observations confirm the ionospheric origin of the deviations - dynamic spectra confirm the effect.
- However, a significant error remains, caused by the lack of calibration of the method.
- For structures visible simultaneously, it is possible to determine the time shift.
- However, with data from a single station only, it is not possible to determine the propagation velocity.

Acknowledgements

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THANK YOU :-)