Ionospheric characterisation above the MRO with MWA EoR datasets

International Centre for Radio Astronomy Research

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Motivation

- The ionosphere:
  - is a plasma screen at the edge of our atmosphere;
  - is dynamic; and
  - has bigger effects at lower frequencies.
- Demanding projects require exquisite calibration
- This is a big headache for low-frequency astronomy!

How does the ionosphere affect us?

Motivation

- The ionosphere is composed of electrons → total electron content (TEC)
- Interferometers only see changes in the TEC
- A pure first-order gradient is a bulk shift → not interesting
- “Higher-order variations” → very interesting!
- MWA is currently small enough not to worry about seeing very different parts ionosphere (regime 3)
- … but LOFAR already has this problem.

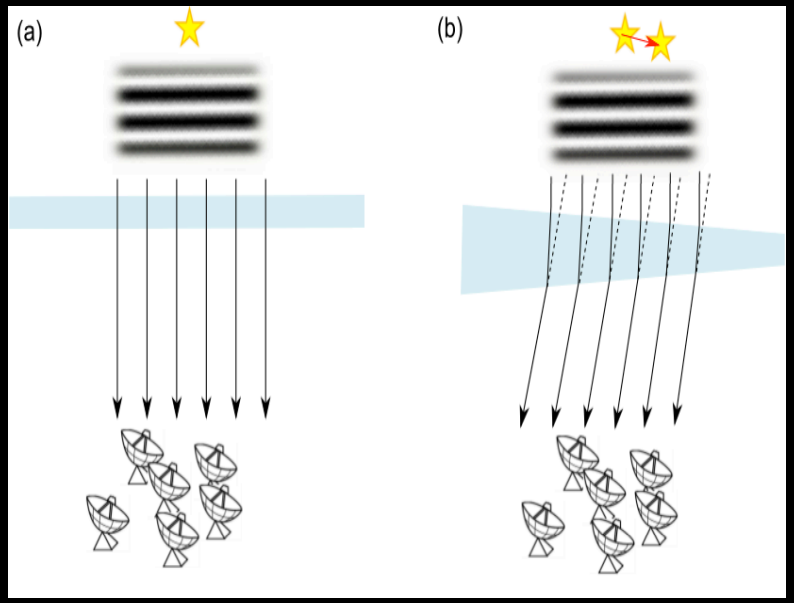


Image credit: Loi+ 2015

Profound ionospheric activity

- Cleo Loi+ found striking, prominent tubes/ducts in the ionosphere with the MWA
- This observation demonstrates the MWA's capability to further understand the ionosphere with its:
  - large field of view,
  - high spatial resolution, and
  - is in a radio-quiet zone
- Are there any other kinds of ionospheric activity?
- How quickly does the activity change?
- Can we predict activity?

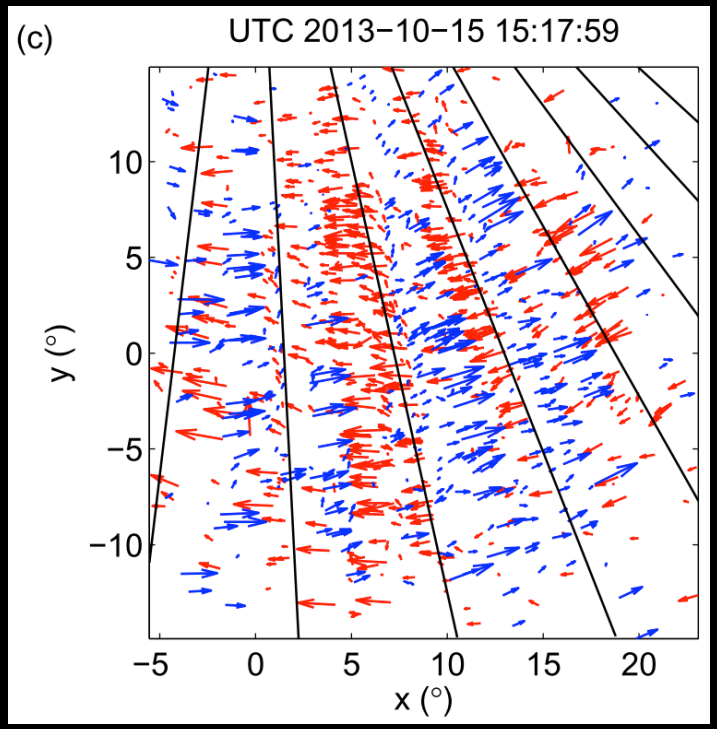
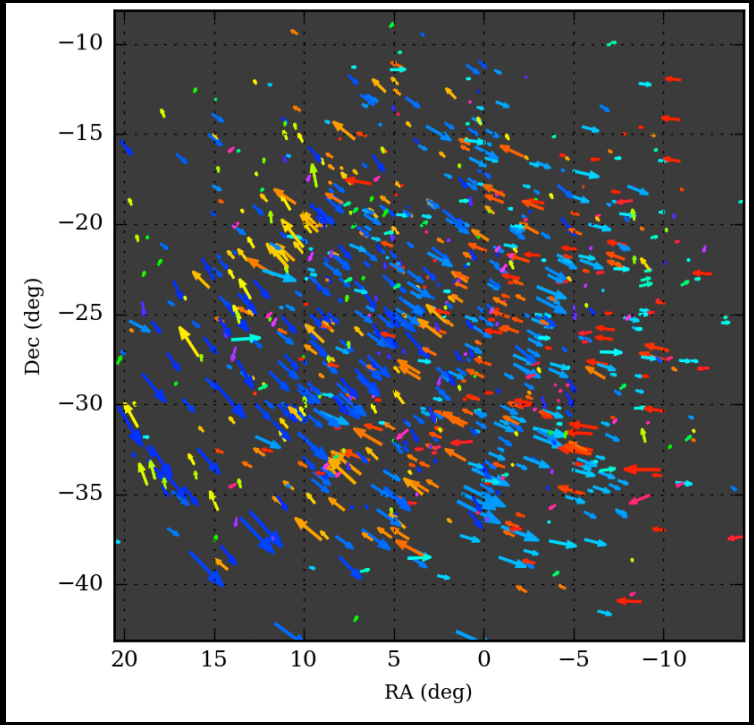


Image credit: Loi+ 2015

Approach of MWA EoR

- Real-Time System (RTS)
  - Measures ionospheric-induced effects toward many calibrators
  - Provides a high spatiotemporal resolution view of the ionosphere
  - Captures variations in flux density, but we focus on apparent spatial shifts for now



TEC reconstruction

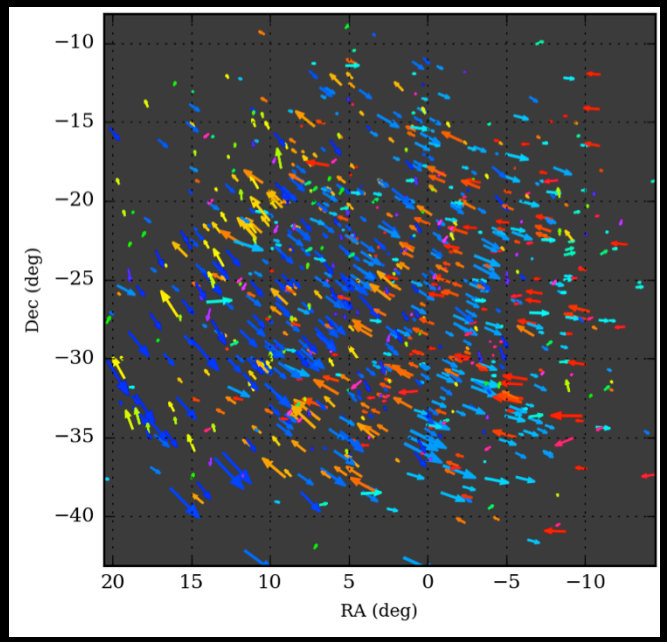
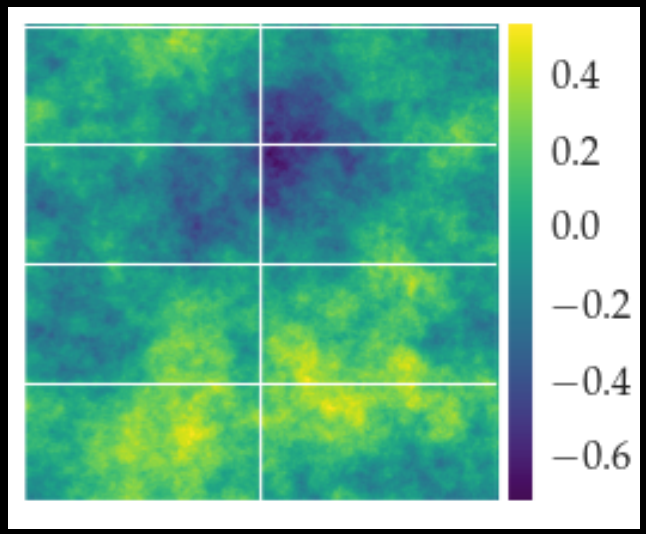
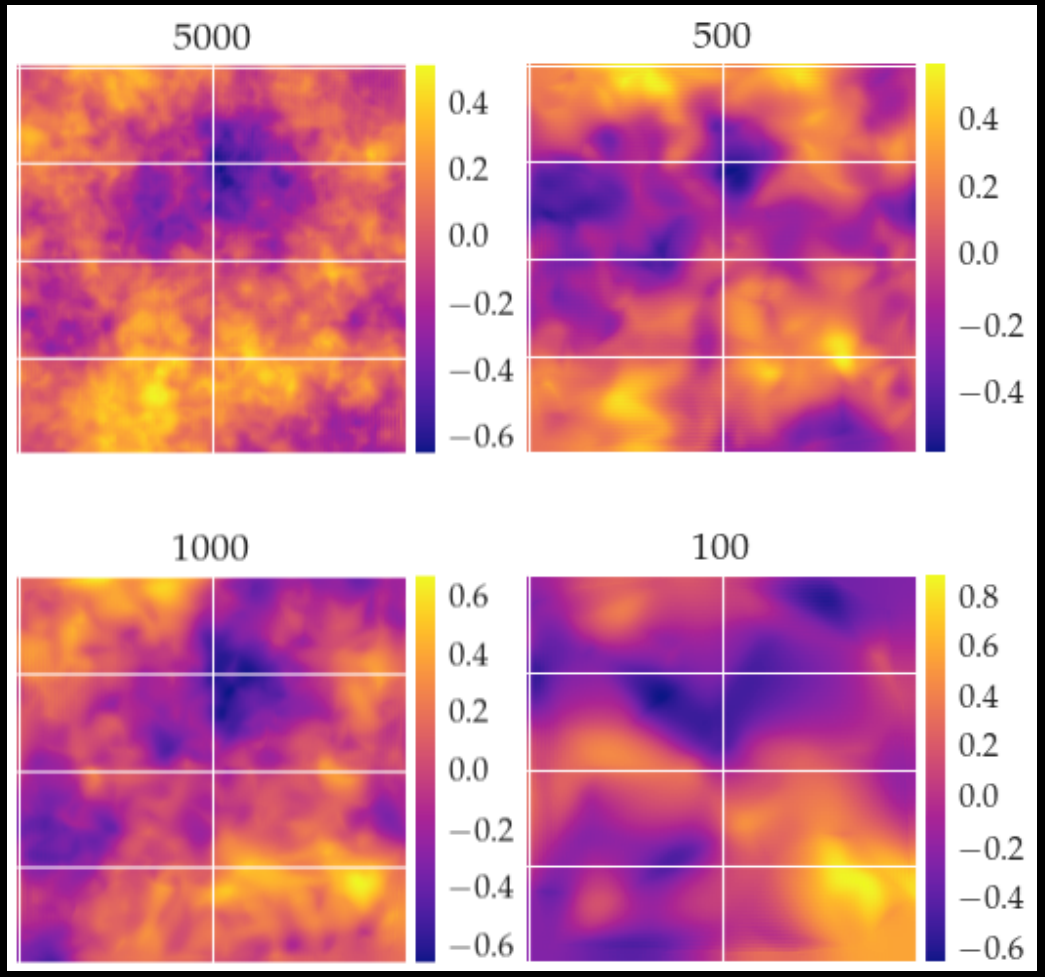


Image credit: https://www.yktravelphoto.com/places/wp-content/uploads/2009/02/_mg_3501.jpg

TEC reconstruction

“The Harker-O’Leary method”
(Harker M., O’Leary P., 2015)





TEC reconstruction

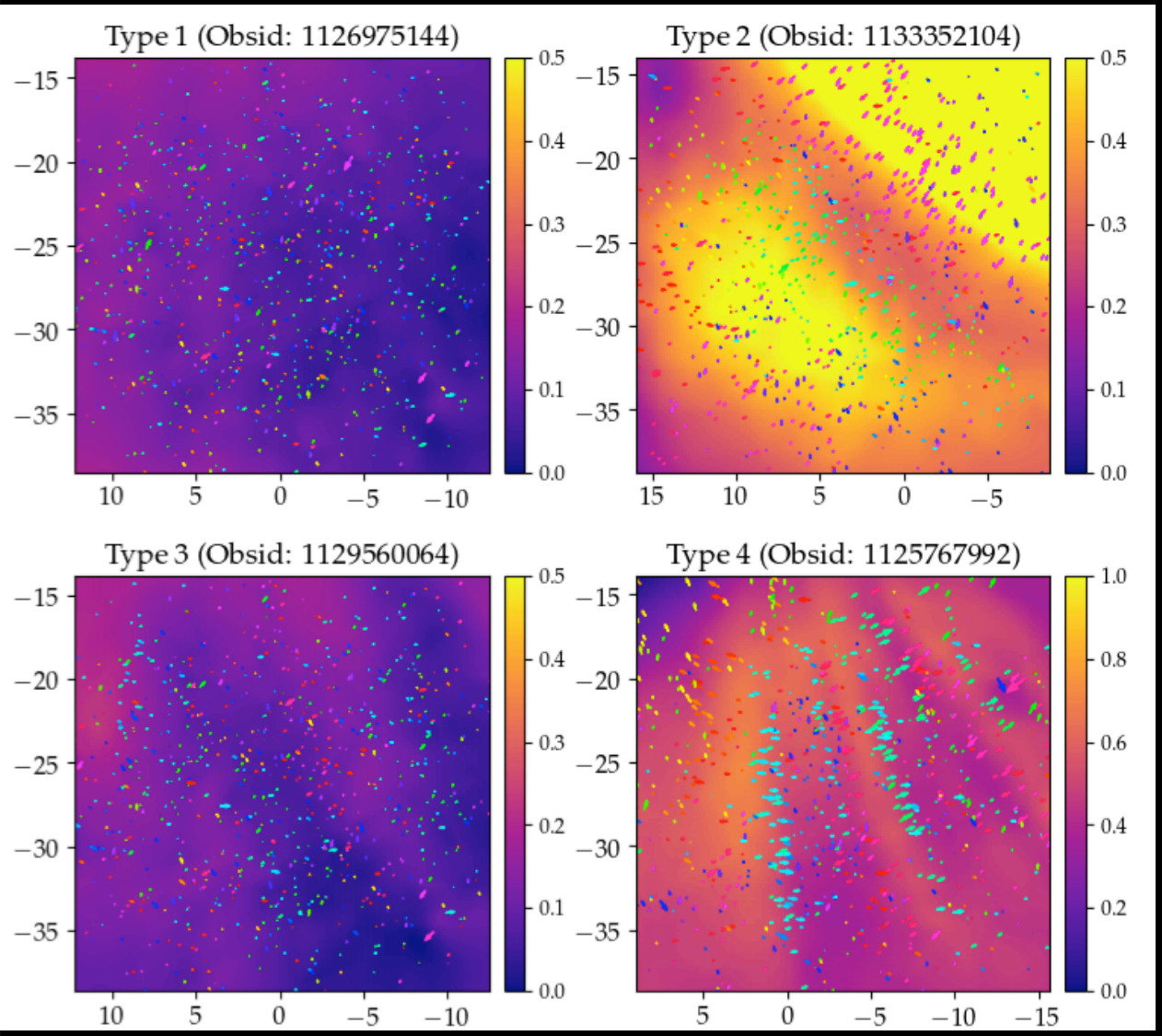
<movie 1>

“Characterisation of the ionosphere above the Murchison Radio Observatory using the Murchison Widefield Array”

- 927 two minute observations in 2015
- Analyses demonstrating our ability to determine ionospheric activity

- MNRAS, submitted (accepted shortly)

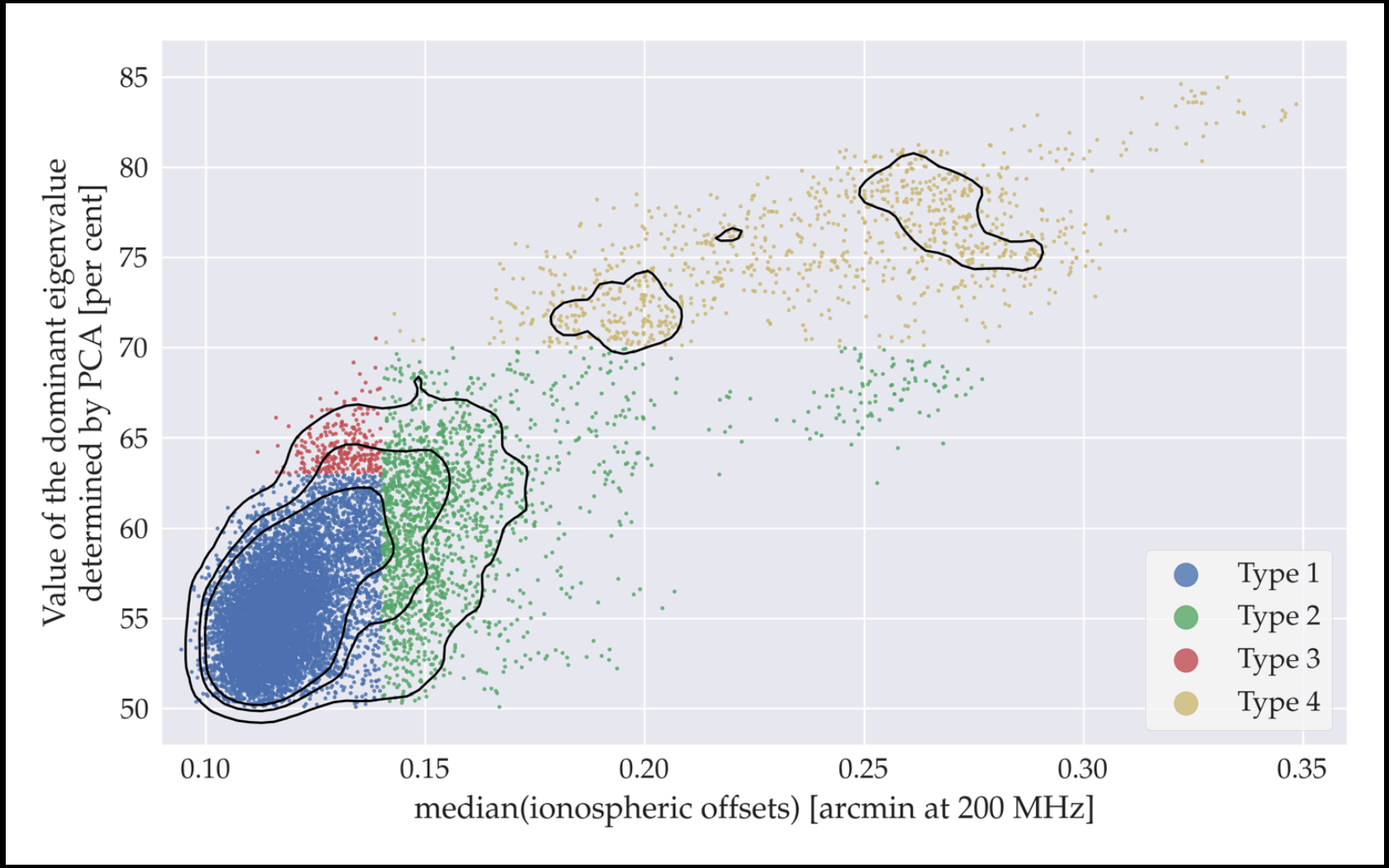
Ionospheric types



Four “types” identified:

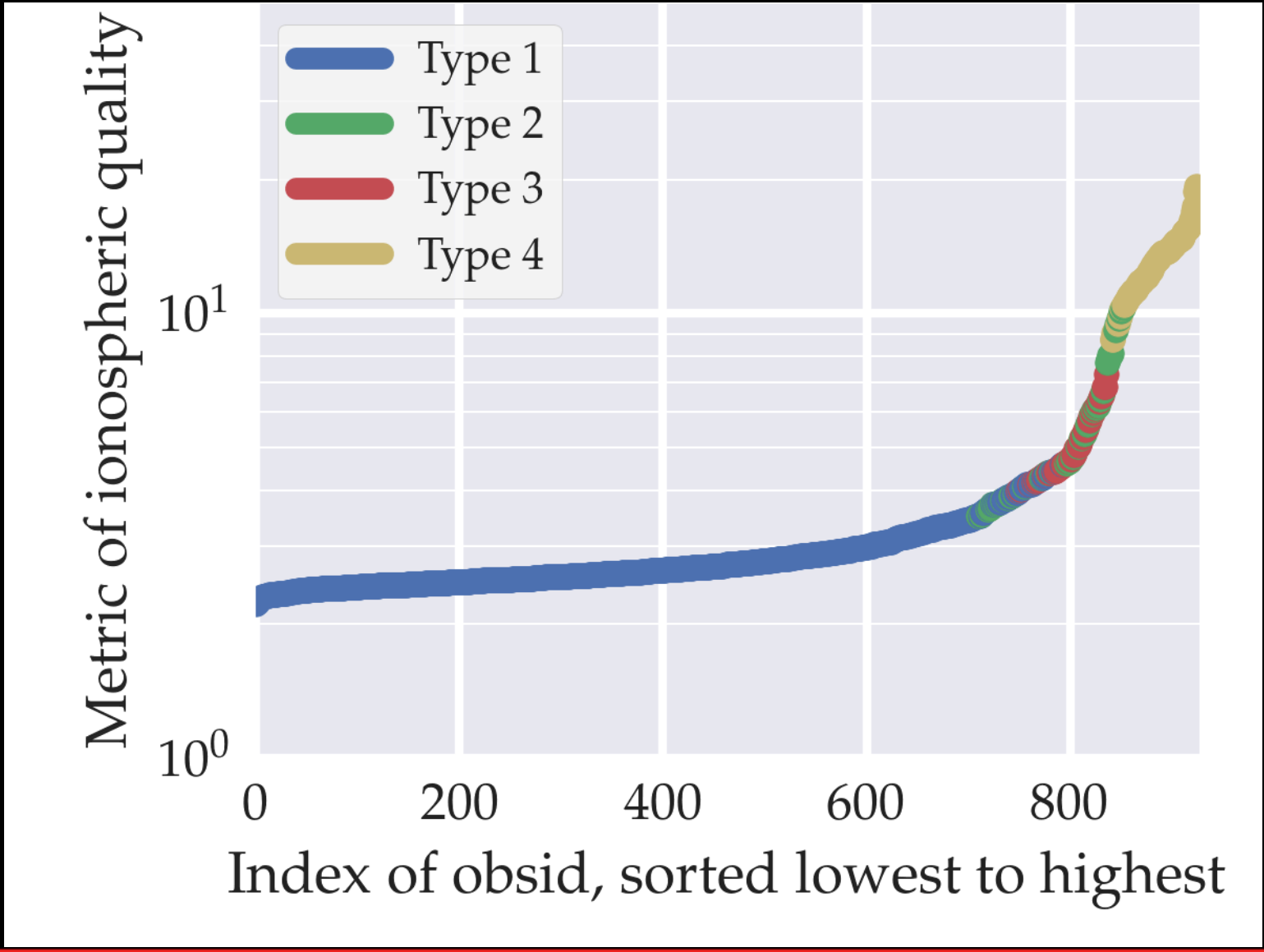
- “quiet”
- “large scale”
- “anisotropic”
- “stormy”

Ionospheric types

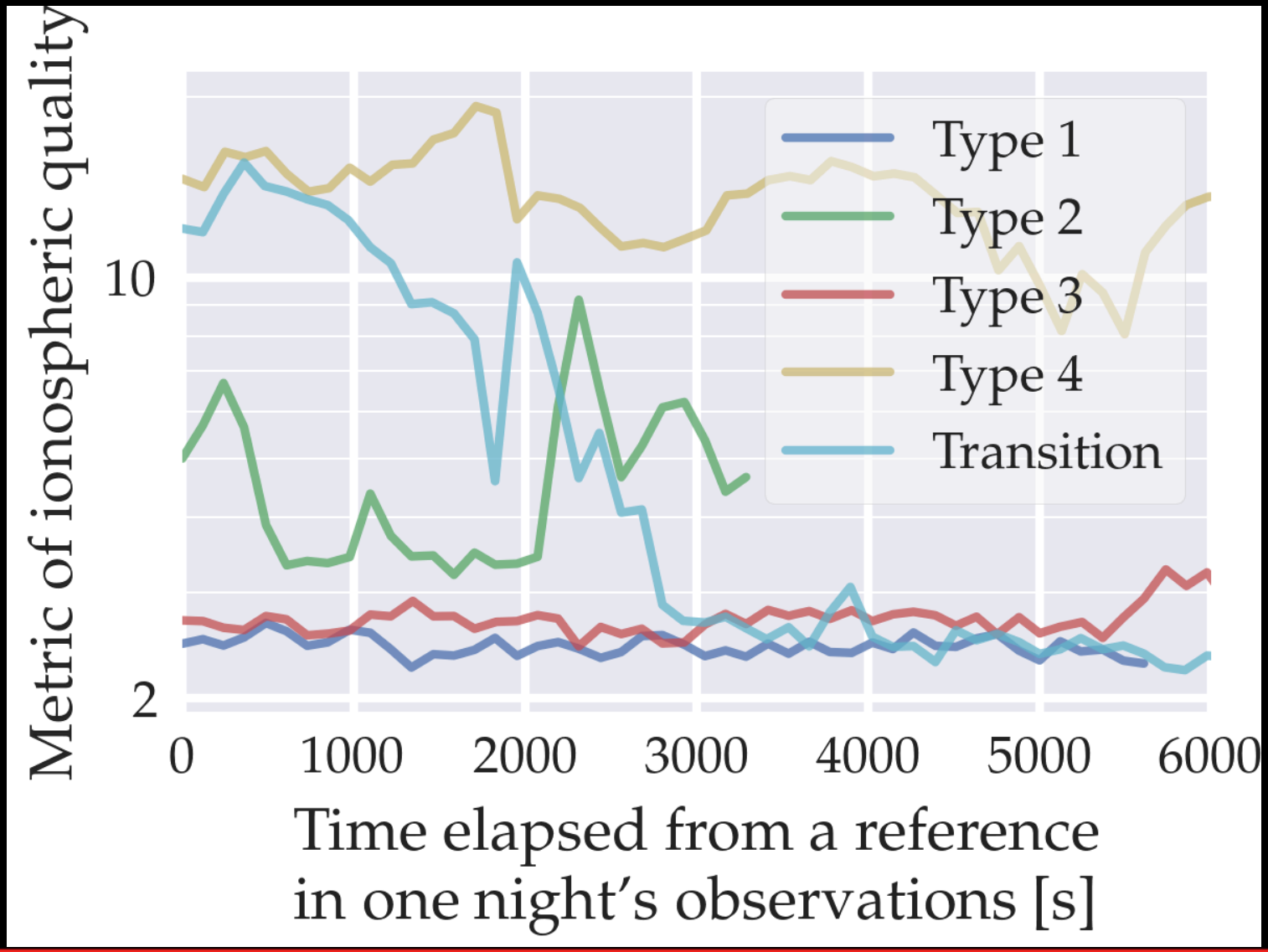


Types 1-4: 74%, 15%, 2.3%, 8.4%

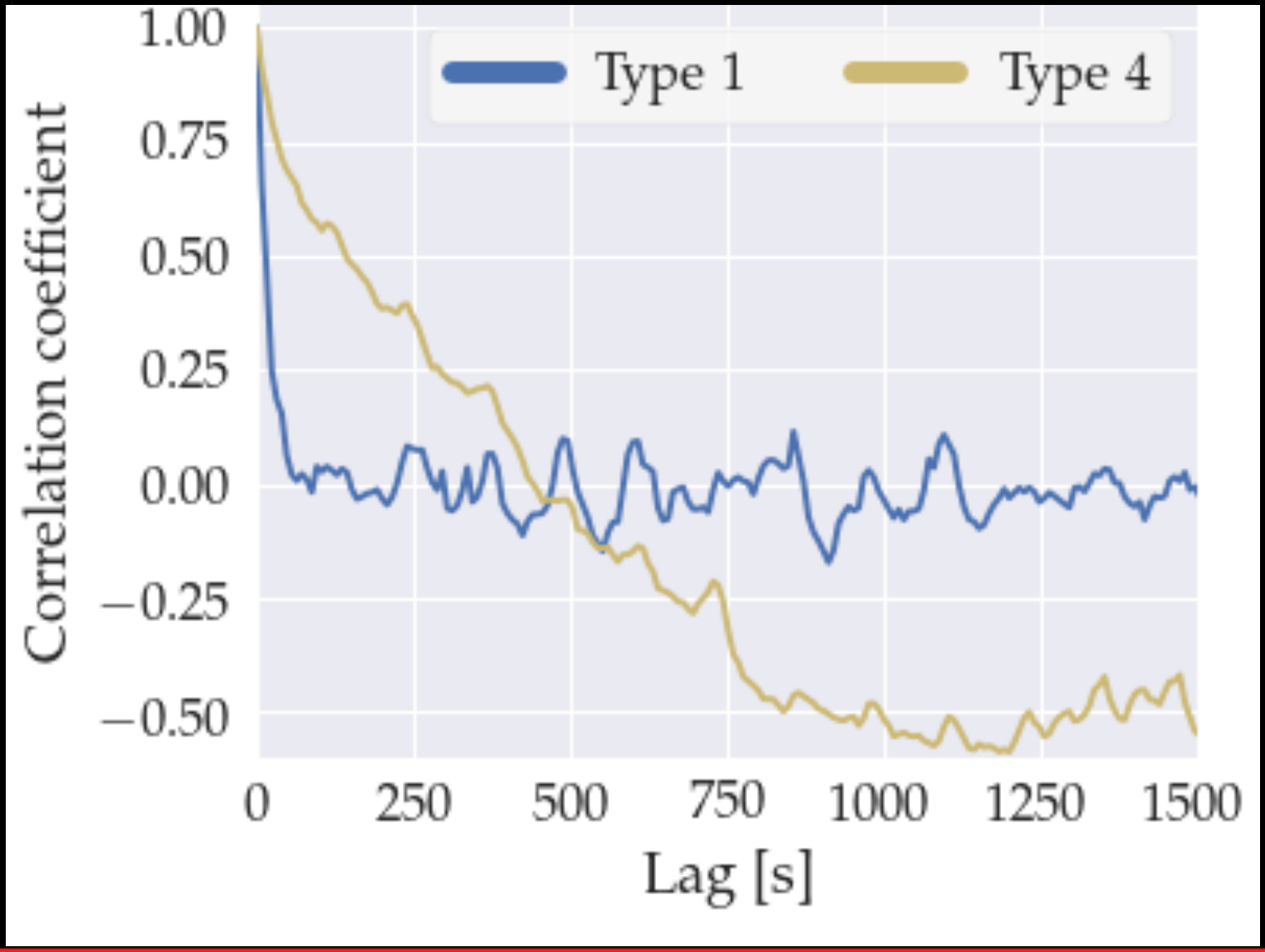
Ionospheric types



Ionospheric types



Temporal correlations



Comparison with Kp indices

- K indices measure geomagnetic activity
- Kp - “Planetary” indices derived from the average across 13 observatories
- Despite observatories being biased, results were consistent with Gingin and Canberra
- K indices primarily attributed to solar activity

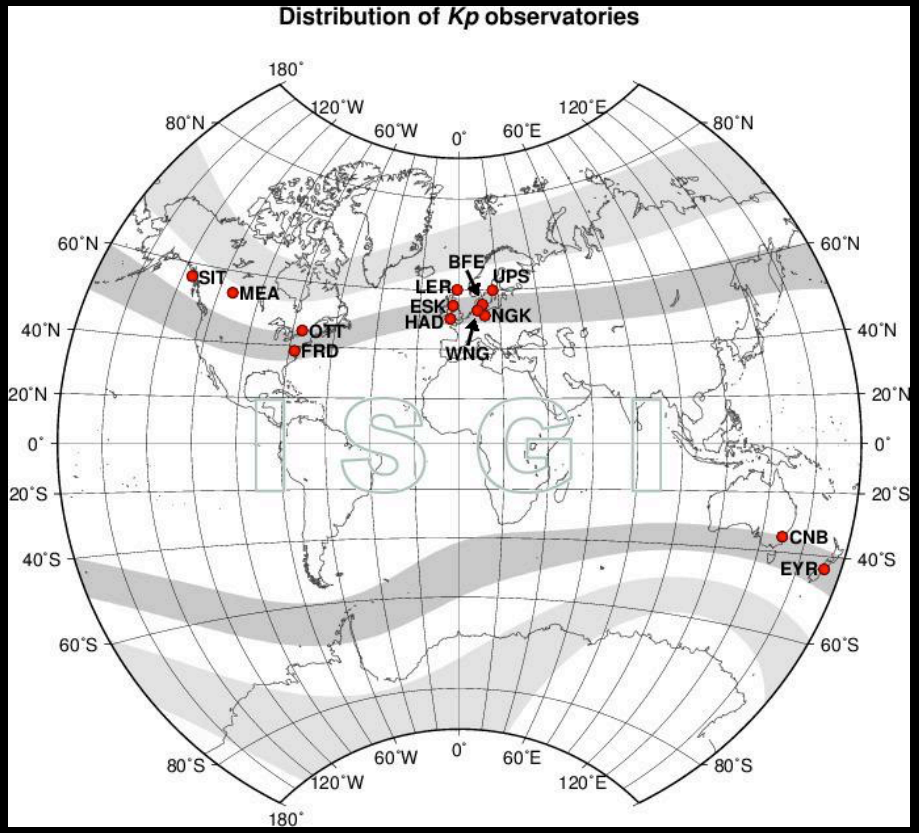
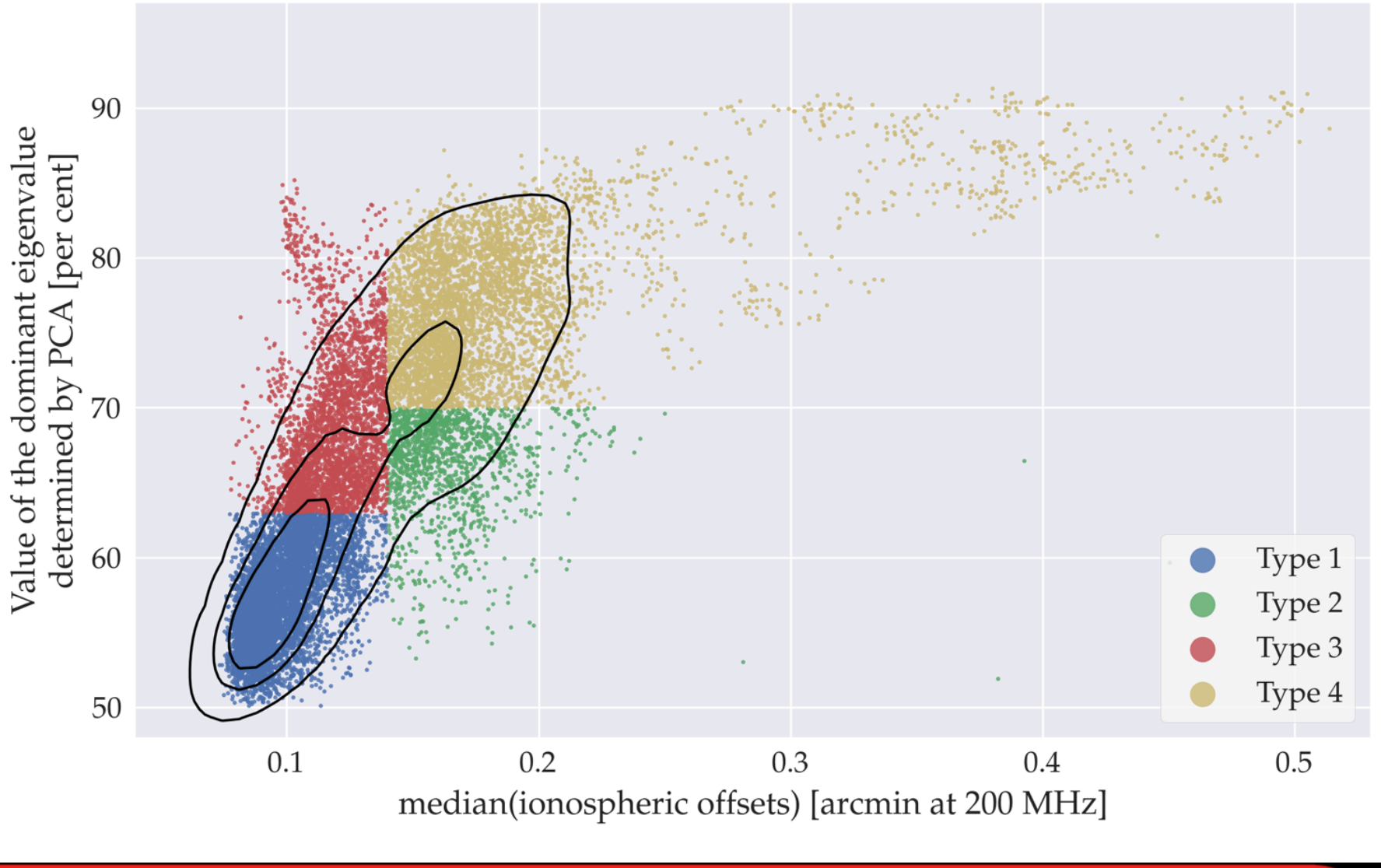


Image credit: http://isgi.unistra.fr/Images/reseau_Kp.jpg

… and more to come…



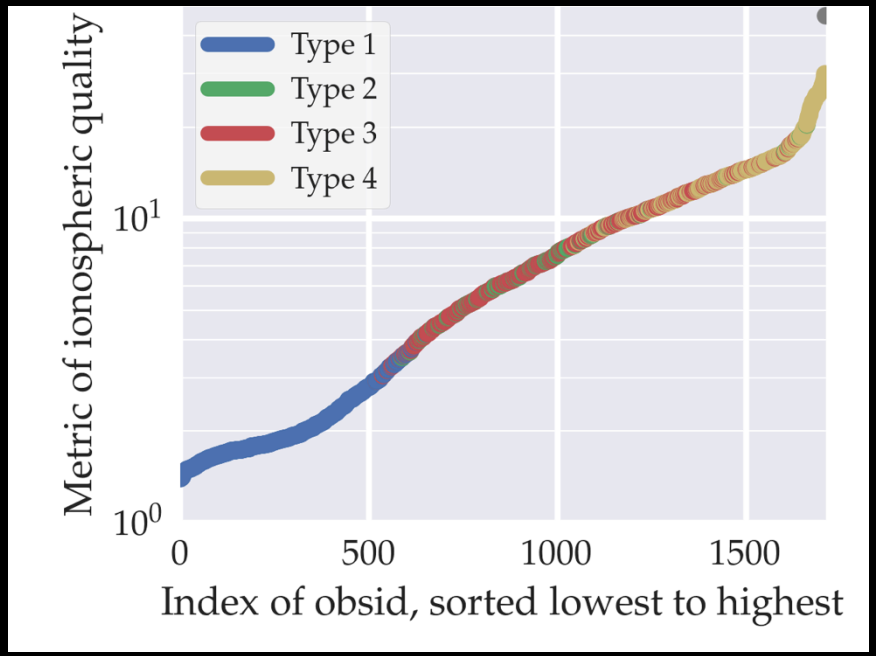
… and more to come...

<movie 2>

Summary

- Proof of concept established
- Paper on the horizon to understand ionospheric effects on EoR
- Performing a census
- Investigating other ionospheric analyses

Grazie!



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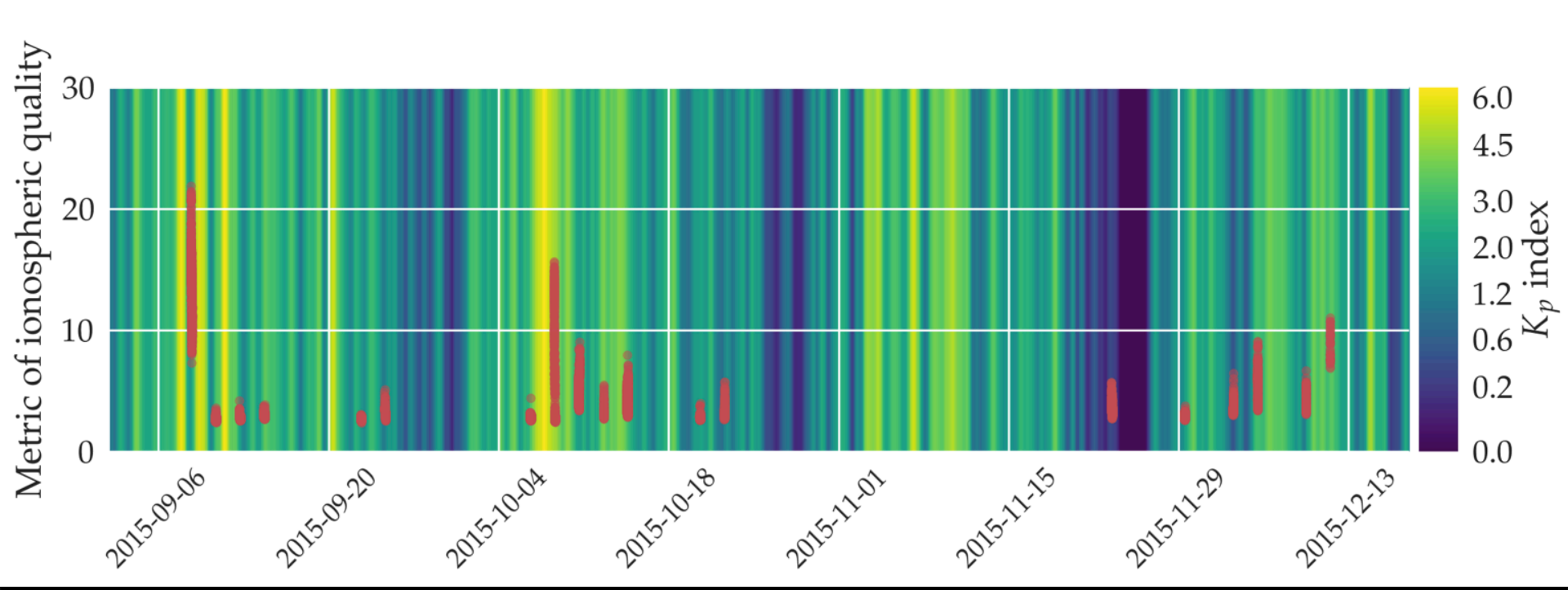

Inconclusive