



Probing the Epoch of Reionisation with the Murchison Widefield Array

ASTRO 3D

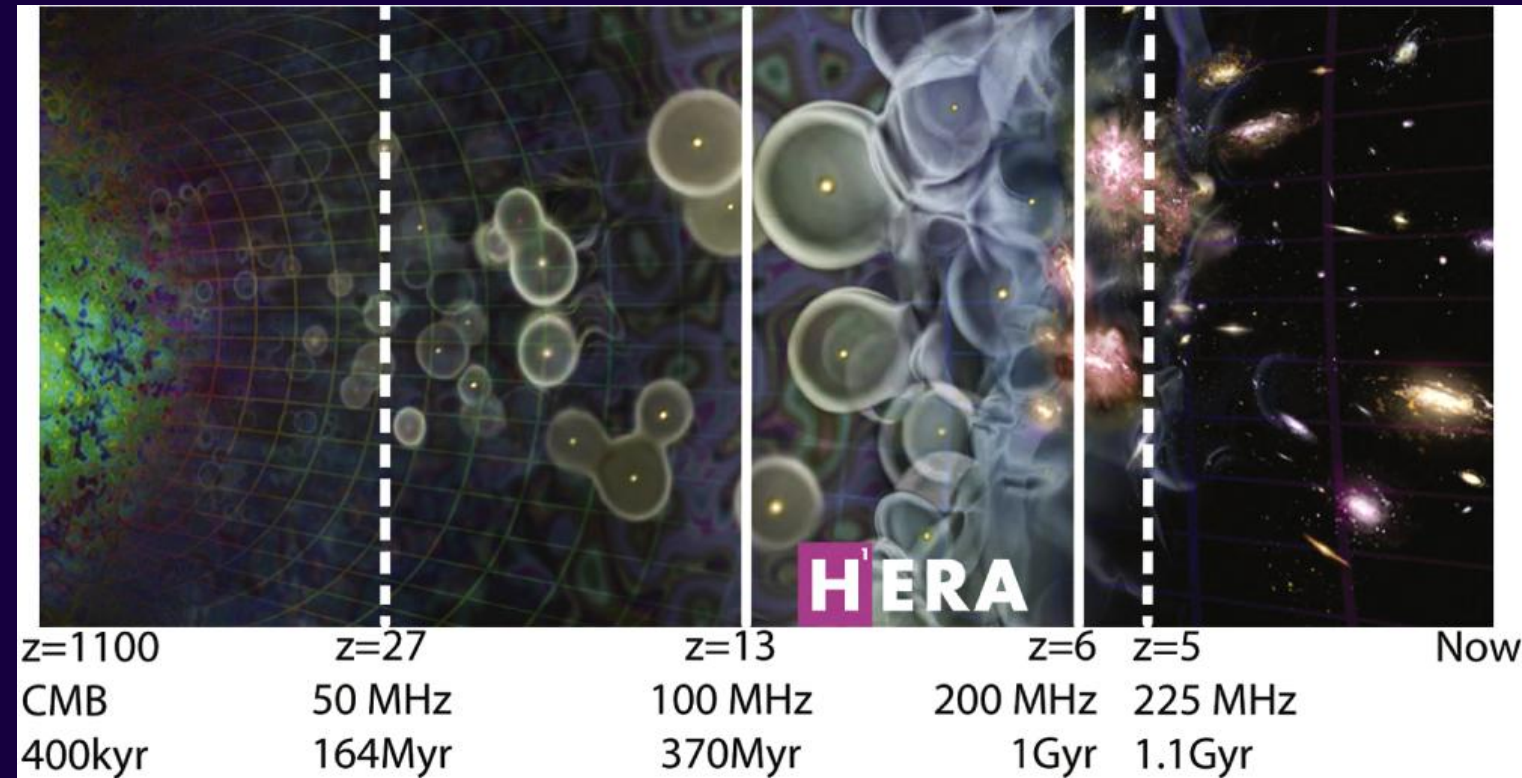
**ARC CENTRE OF EXCELLENCE FOR
ALL SKY ASTROPHYSICS IN 3D**

*Christopher Jordan on behalf of the **MWA EoR** team*

**UNLOCKING THE UNIVERSE,
INSPIRING THE FUTURE**

The Epoch of Reionisation

- Exploring the first billion years of the universe with the 21cm spectral line of hydrogen
 - Small density fluctuations in the CMB collapsed into the “cosmic web”
- $z \sim 1000$
 - Cosmic “dark ages”
- $z \gtrsim 30$
 - First luminous sources
- $z \sim 6$
 - Full reionisation of the intergalactic medium (IGM)



See Furlanetto et al. 2006

DeBoer et al. 2017

<https://iopscience.iop.org/article/10.1088/1538-3873/129/974/045001>

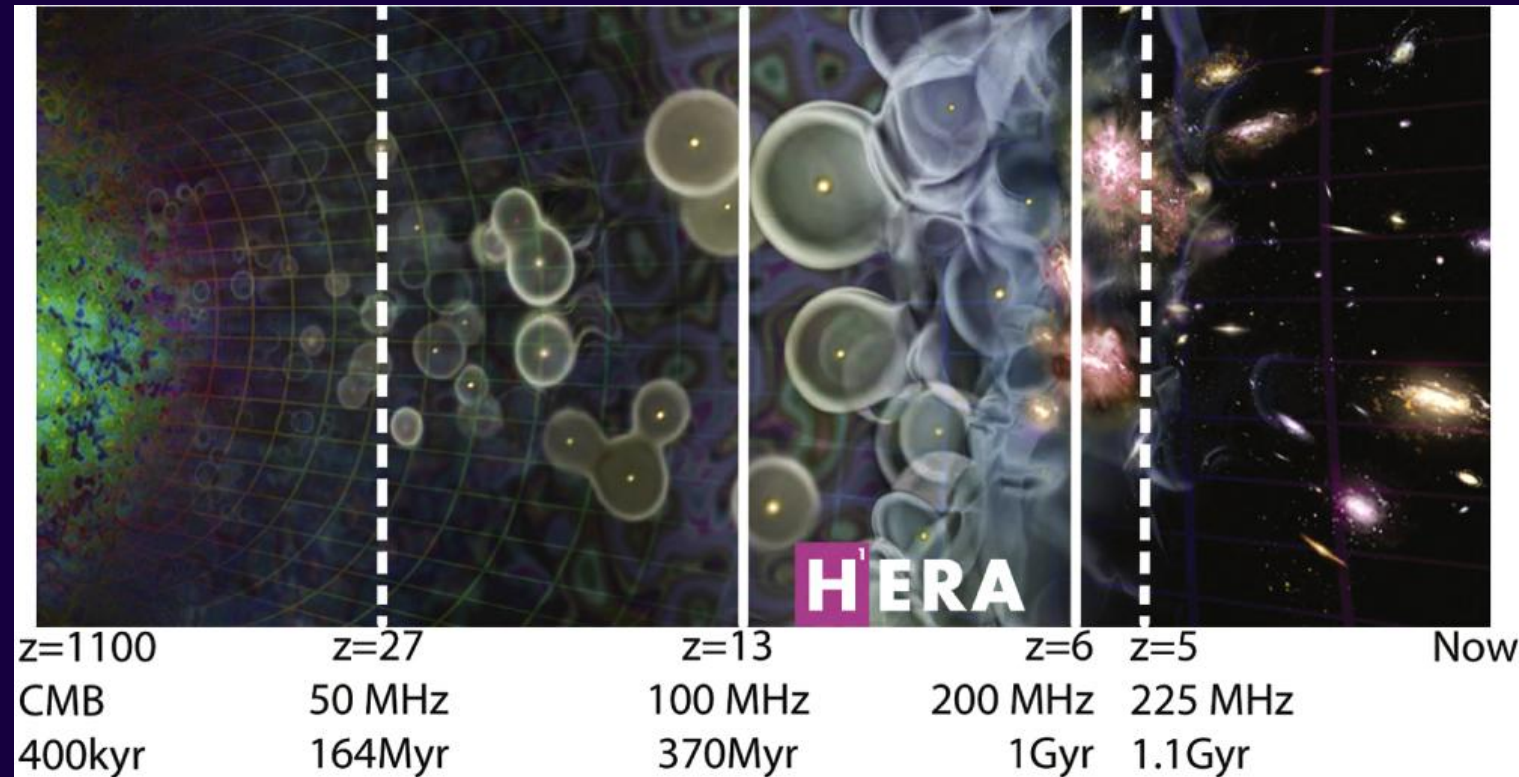
The Epoch of Reionisation

Unanswered questions:

- How did the first stars form?
- How much mass did they have, and do they still exist?
- When were heavy elements created and how were they distributed across the IGM?
- How do supermassive black holes fit in the picture?

These questions are answered by probing the EoR.

See Furlanetto et al. 2006



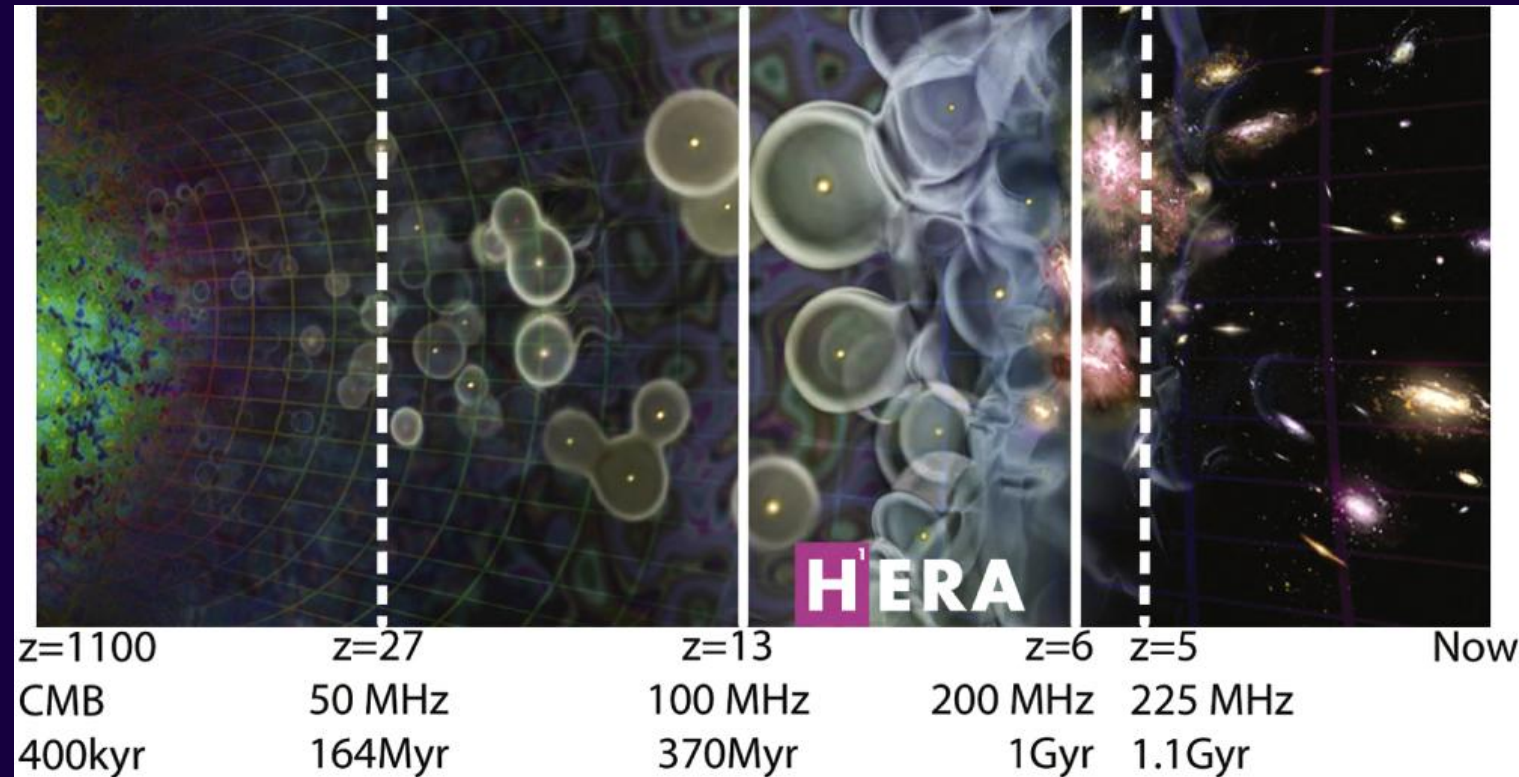
DeBoer et al. 2017

<https://iopscience.iop.org/article/10.1088/1538-3873/129/974/045001>

The Epoch of Reionisation

What's the problem?

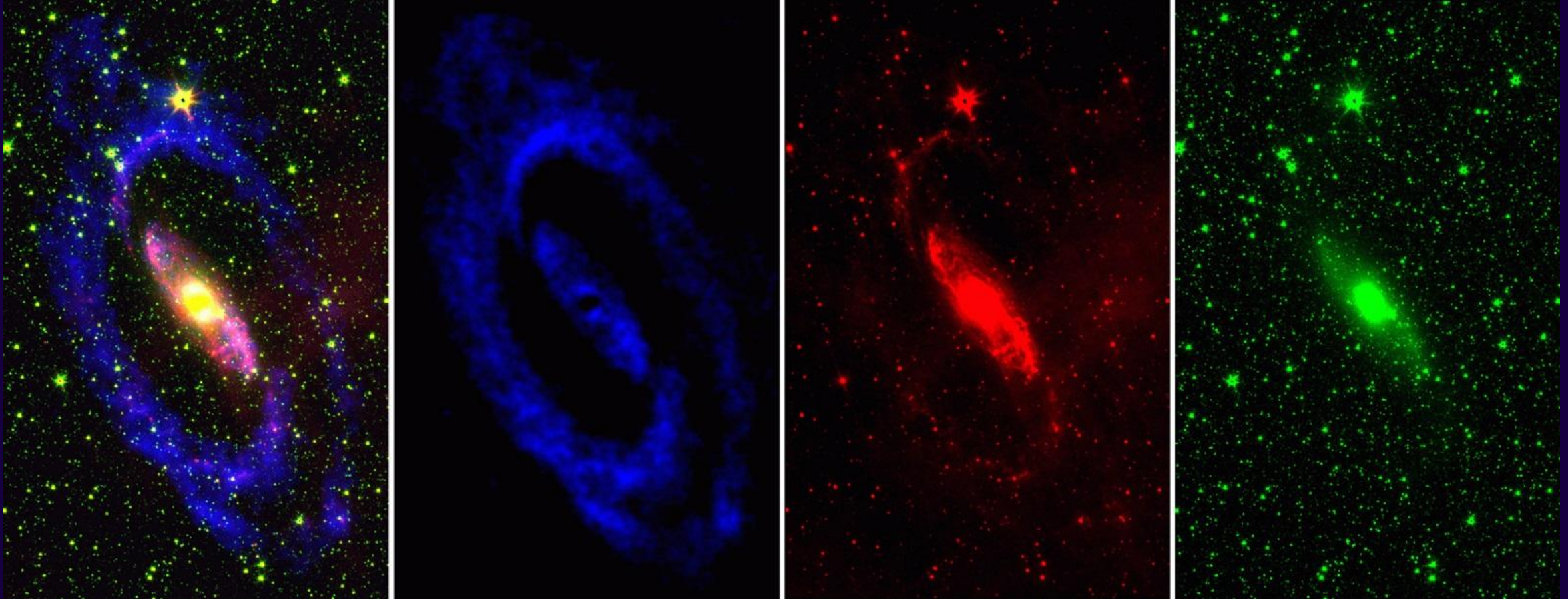
- Signals from the EoR are obscured by foregrounds
- The 21cm hydrogen line is a popular target - but is weak.
- Redshifted down to frequencies < 200 MHz
- Low-frequency radio astronomy.



DeBoer et al. 2017

<https://iopscience.iop.org/article/10.1088/1538-3873/129/974/045001>

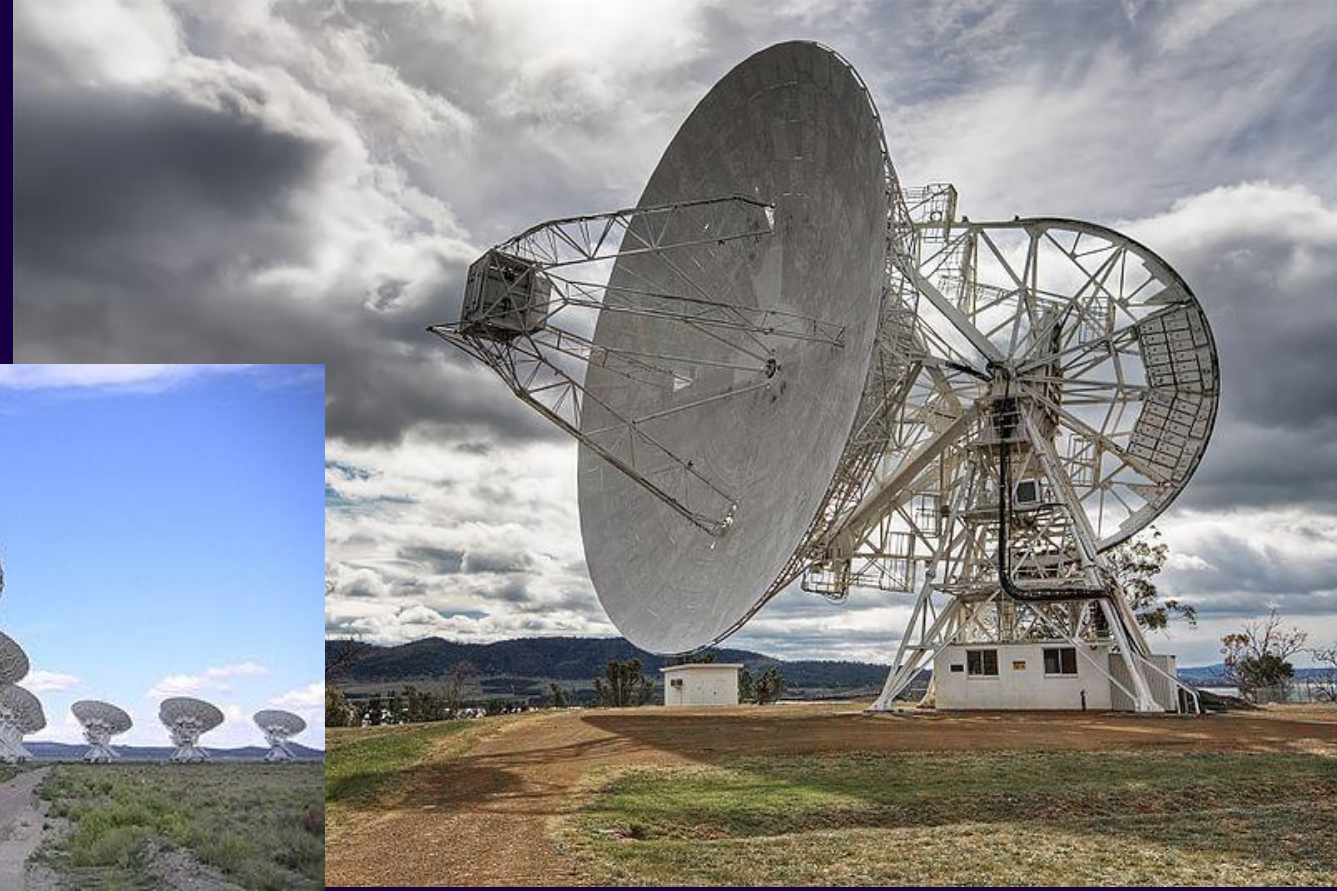
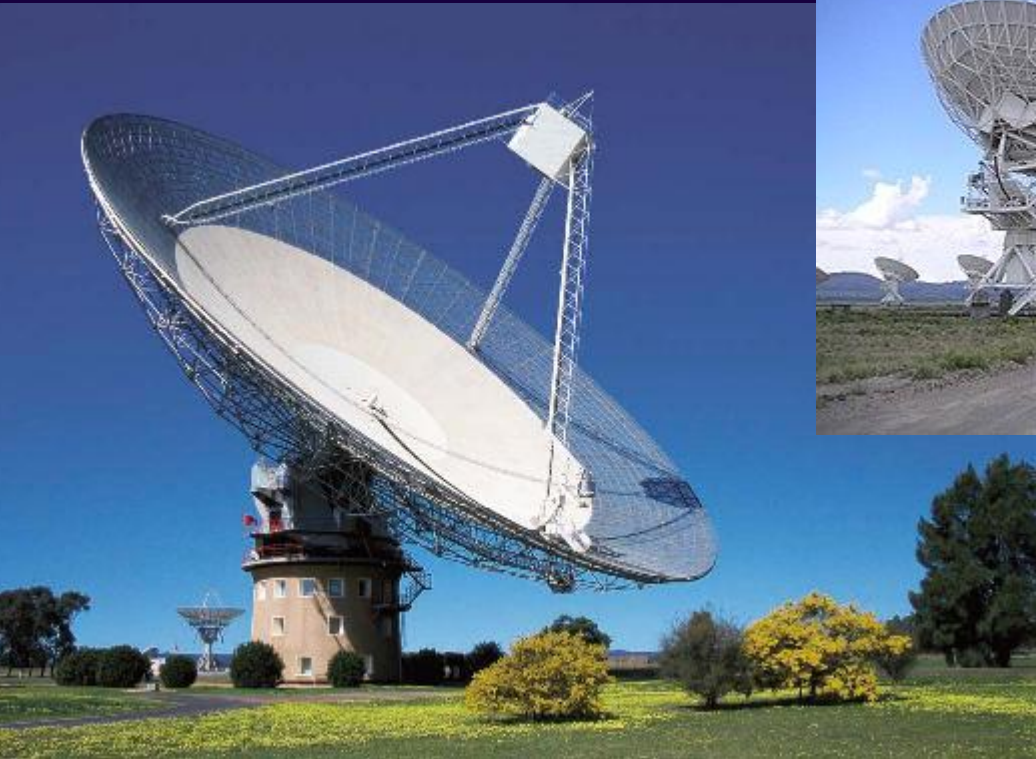
Radio astronomy



<https://www.csiro.au/en/Research/Astronomy/Radio-astronomy/What-is-radio-astronomy>

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Radio astronomy

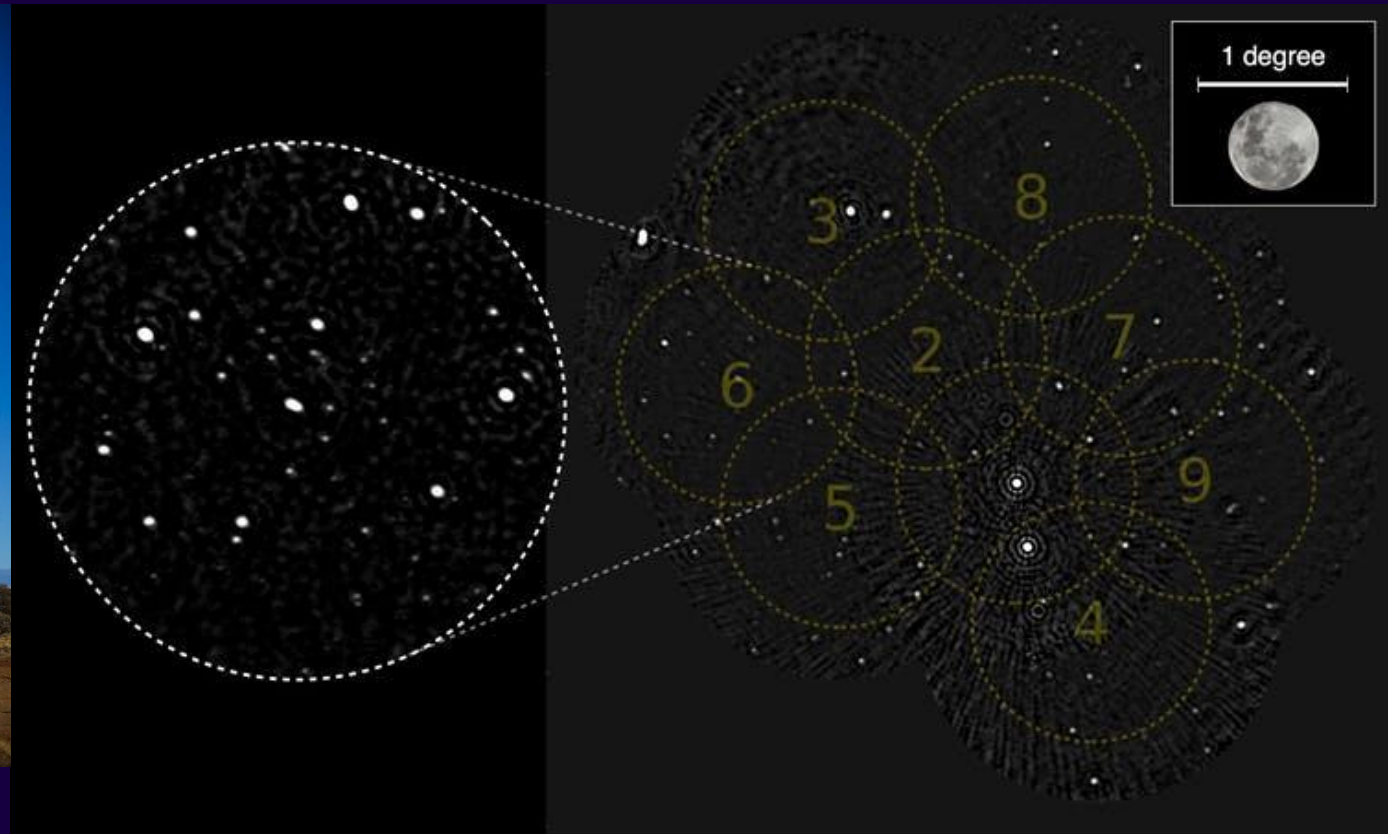


<https://www.cv.nrao.edu/course/astr534/RadioTelescopes.html>

<https://upload.wikimedia.org/wikipedia/commons/thumb/6/63/USA.NM.VeryLargeArray.02.jpg/350px-USA.NM.VeryLargeArray.02.jpg>

https://upload.wikimedia.org/wikipedia/commons/thumb/5/52/Mount_Pleasant_Radio_Telescope.jpg/800px-Mount_Pleasant_Radio_Telescope.jpg

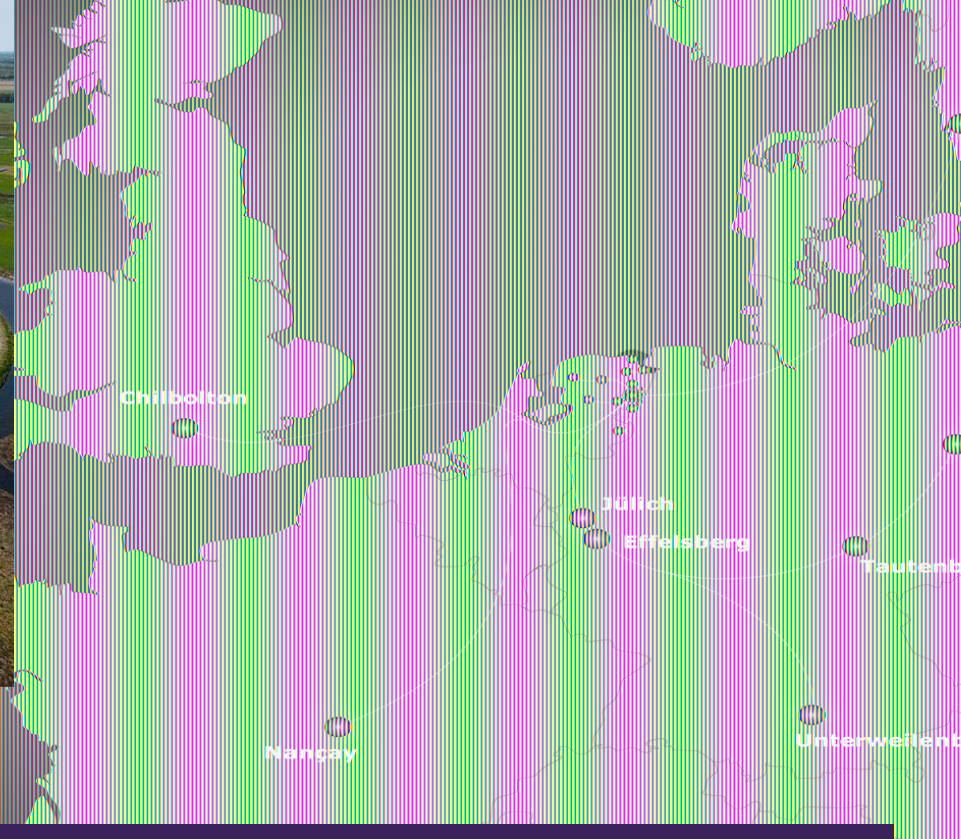
Low-frequency radio astronomy



http://www.atnf.csiro.au/projects/askap/images/2018_CSIRO_E9A2638.jpg

<https://images.theconversation.com/files/51639/original/7yr2hwxr-1403159061.jpg?ixlib=rb-1.1.0&q=45&auto=format&w=754&h=452&fit=crop&dpr=1>

Low-frequency radio astronomy



https://upload.wikimedia.org/wikipedia/commons/thumb/c/c1/A_low-band_antenna_of_LOFAR.jpg/449px-A_low-band_antenna_of_LOFAR.jpg

https://upload.wikimedia.org/wikipedia/commons/thumb/3/36/LOFAR_Superterp.jpg/799px-LOFAR_Superterp.jpg

<https://www.skatelescope.org/wp-content/uploads/2013/11/LOFAR-map-Europe.screen.jpg>

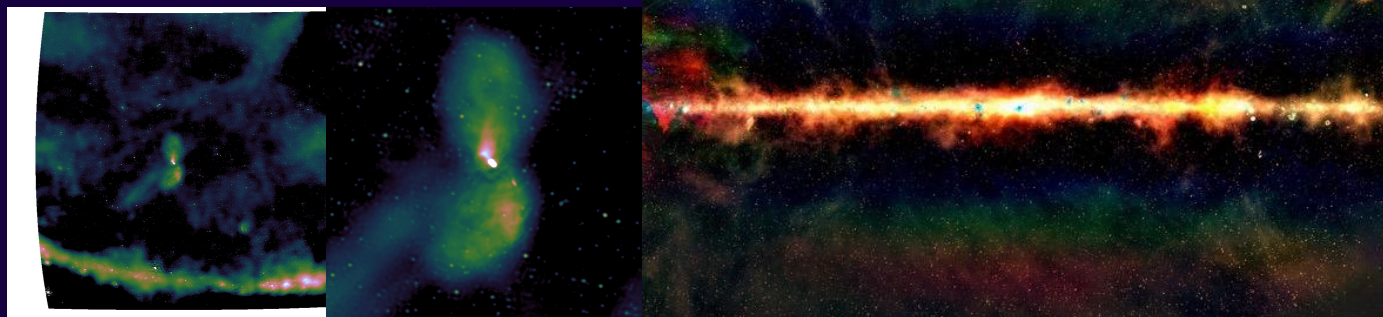
The Murchison Widefield Array (MWA)

- 70 - 300 MHz
- At 200 MHz, FOV $20 \times 20 \text{ deg}^2$
- Square Kilometer Array precursor
 - MWA acts as a “training ground” for the immense power and data volumes generated by the SKA



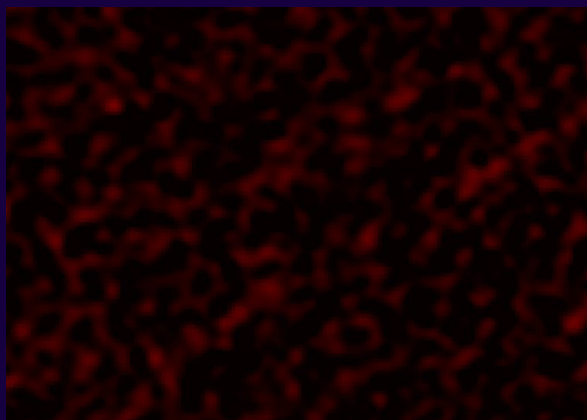
MWA science projects

Galactic and extra-galactic surveys

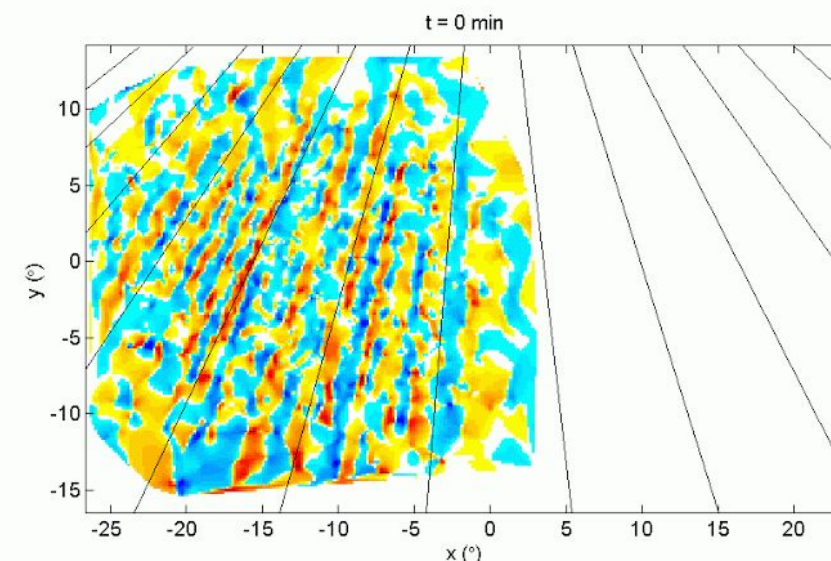


Time-domain astrophysics

- Pulsars and Fast-Radio Bursts (FRBs)
- Transients



Solar, Heliospheric and Ionospheric science



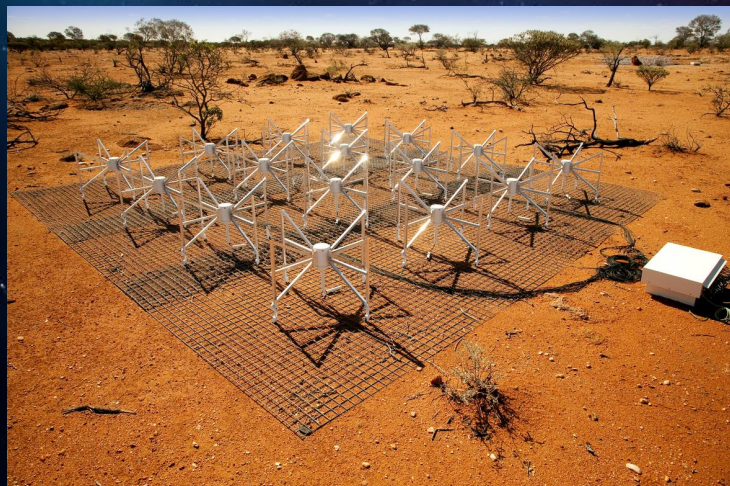
Epoch of Reionisation

The Curtin MWA EoR team

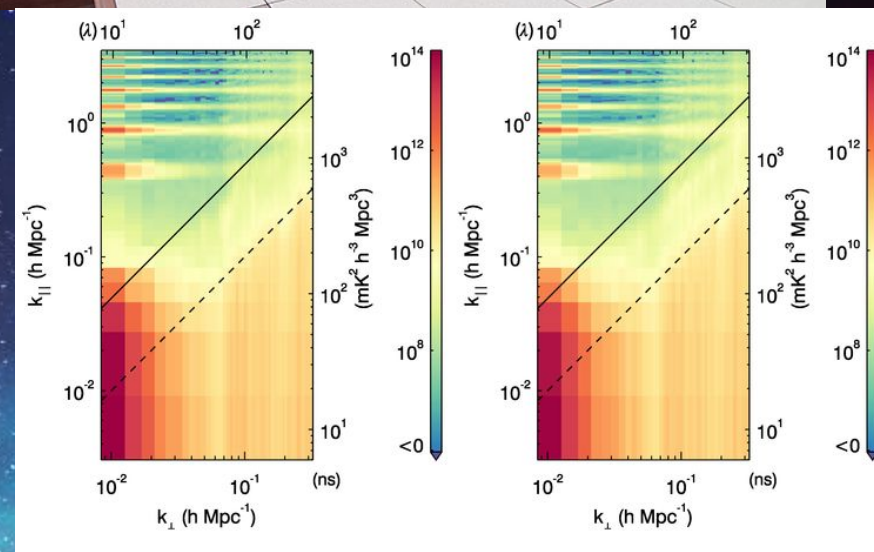
Bella Nasirudin
Mahavir Sharma



Data processing pipeline



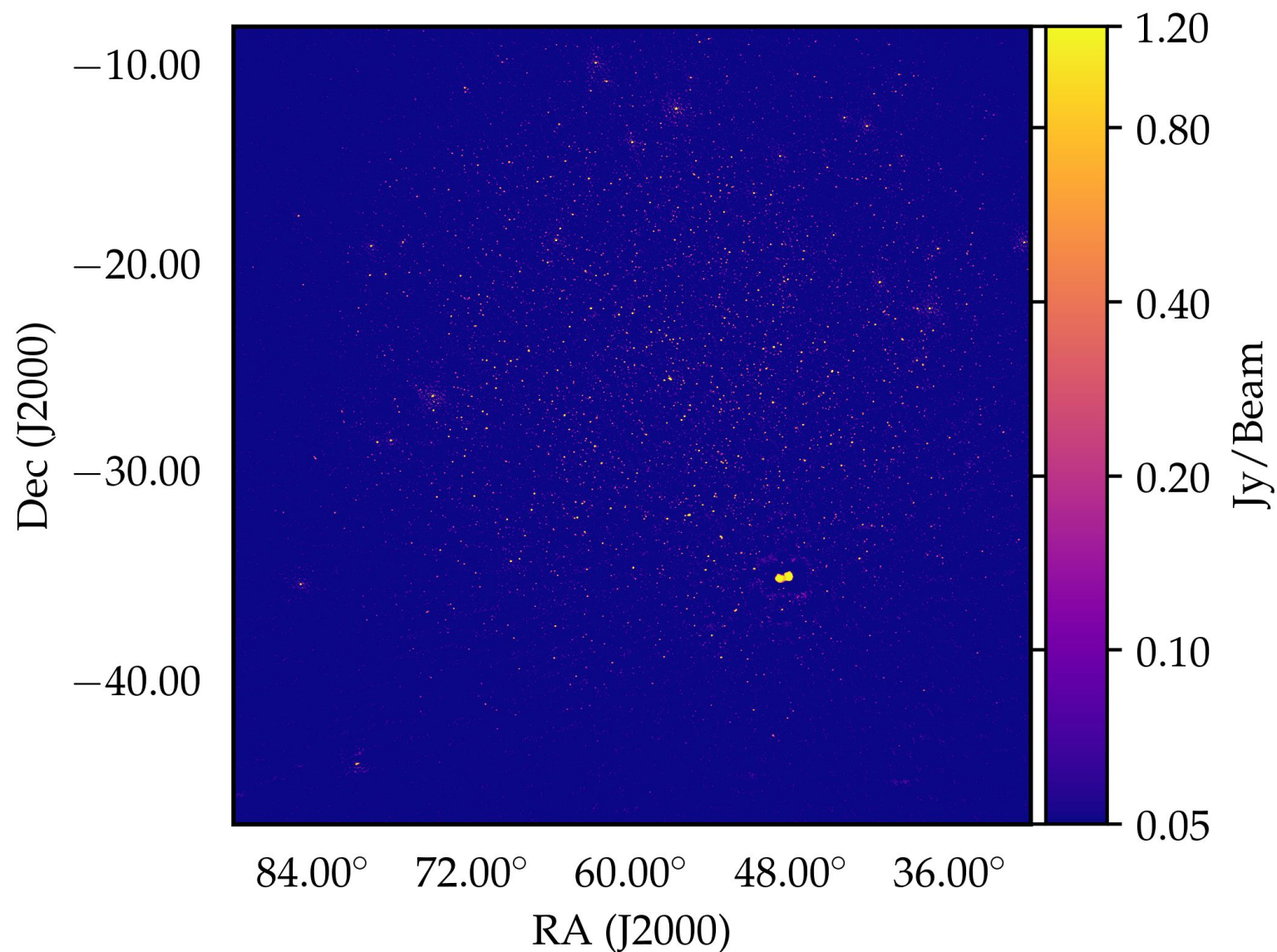
Real-Time System (RTS)
CHIPS



Recent work

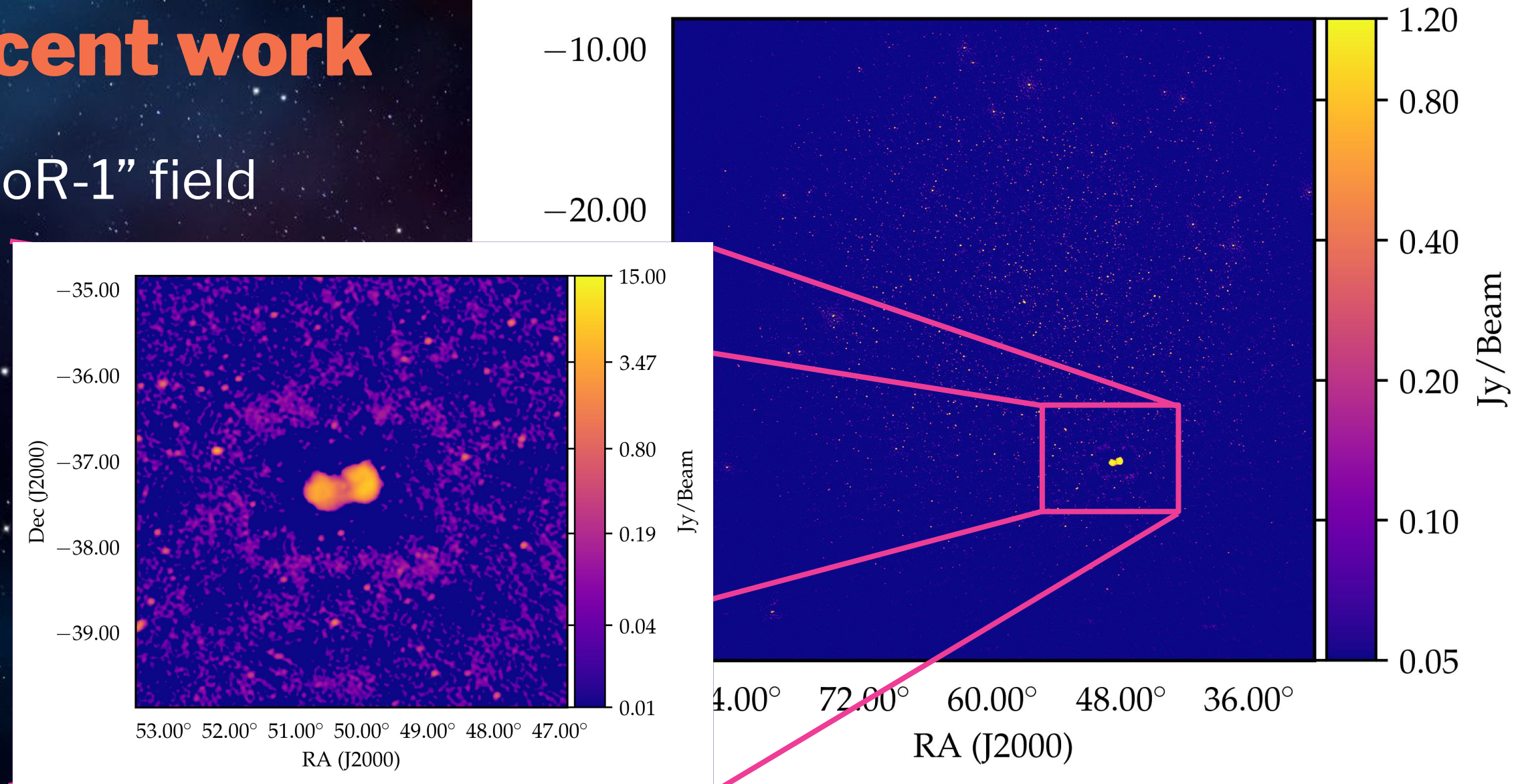
Recent work

- “EoR-1” field



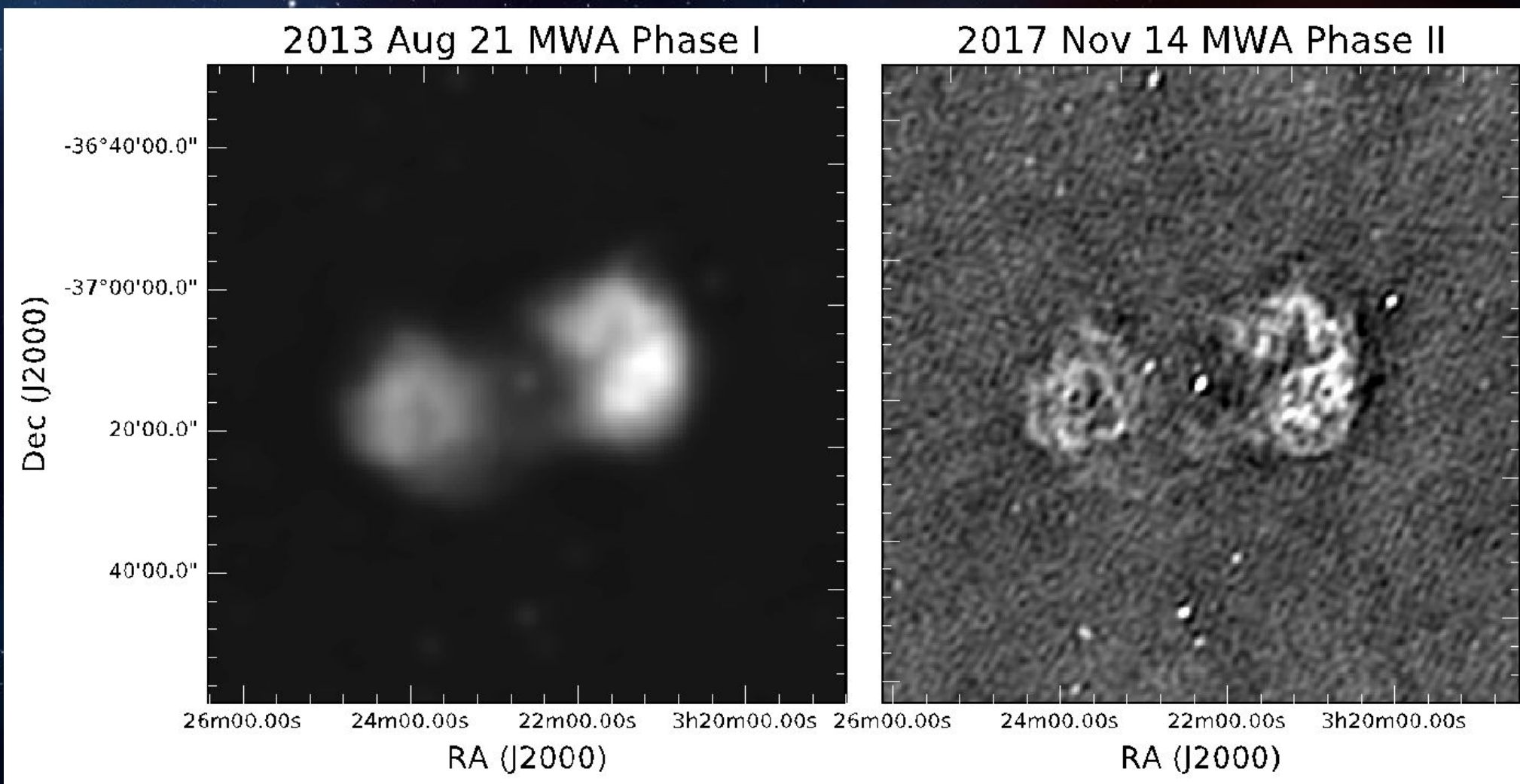
Recent work

- “EoR-1” field



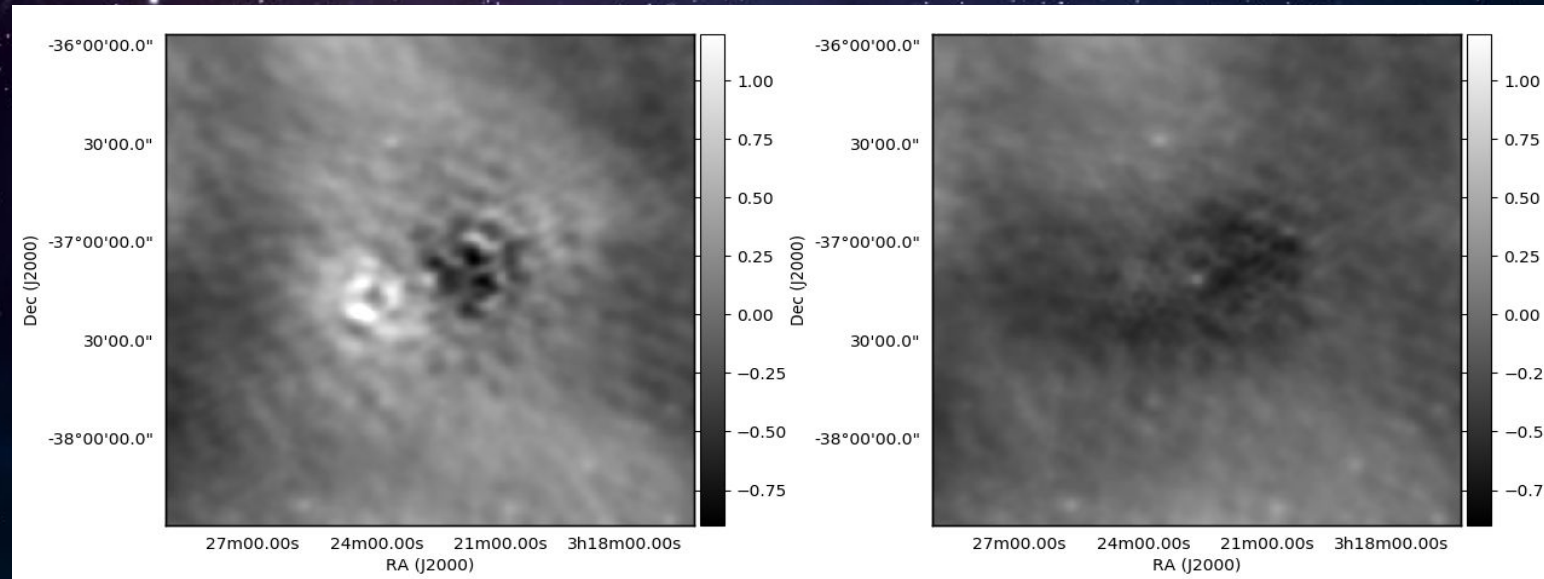
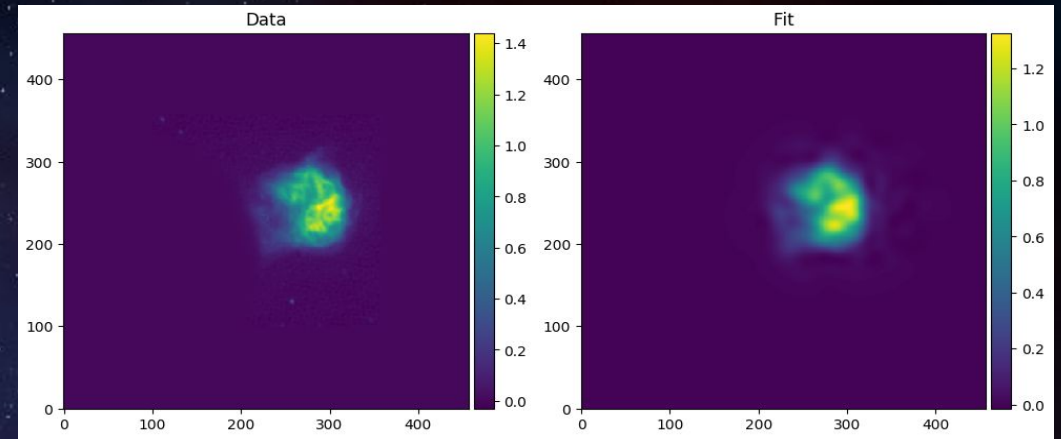
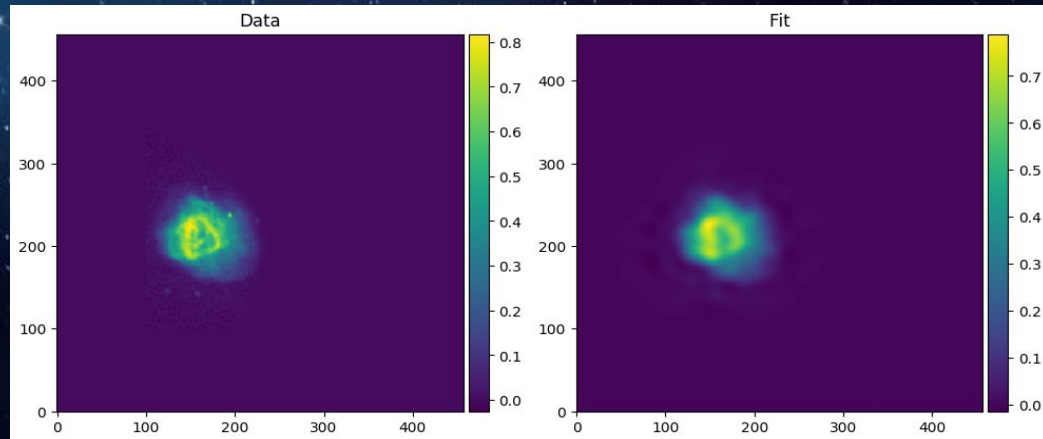
Recent work

Christene Lynch



Recent work

Jack Line

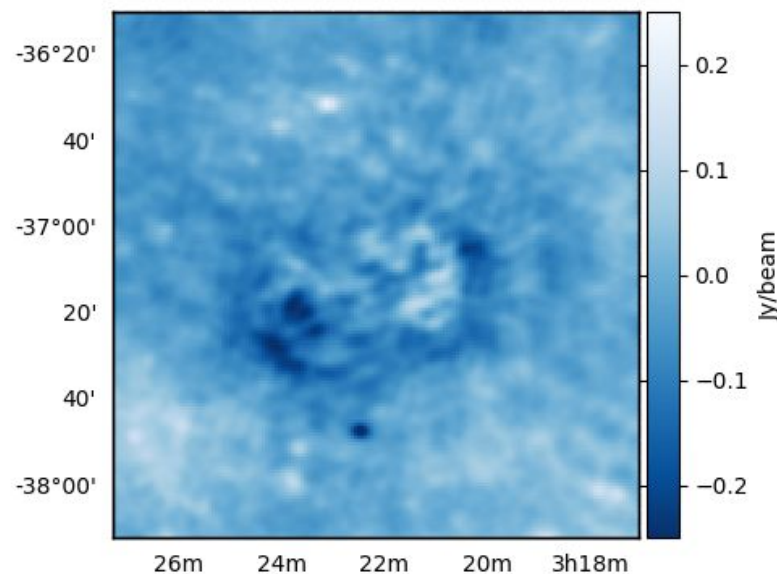


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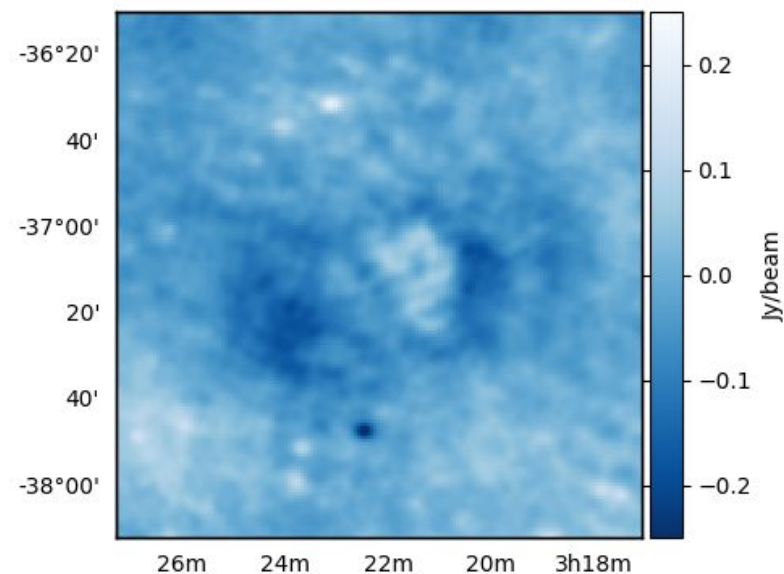
Recent work

Jack Line

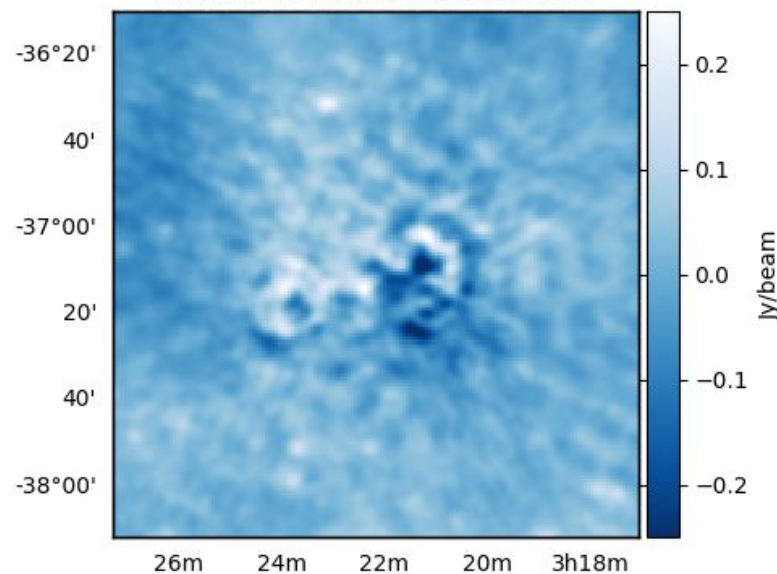
Andre c1000 Cal: 12m16s Peel: 65m47s



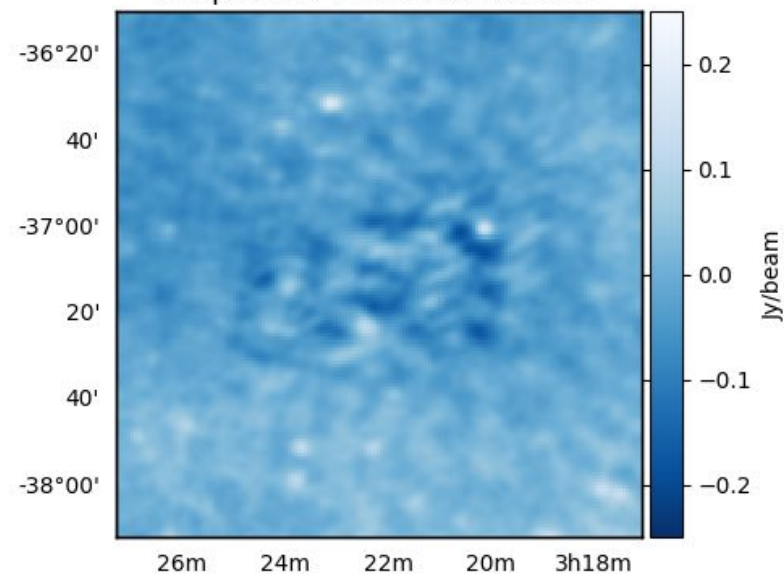
Andre full Cal: 20m40s Peel: 97m26s



FHD Cal: 17m44s Peel: 85m11s



Shapes Cal: 7m5s Peel: 45m22s

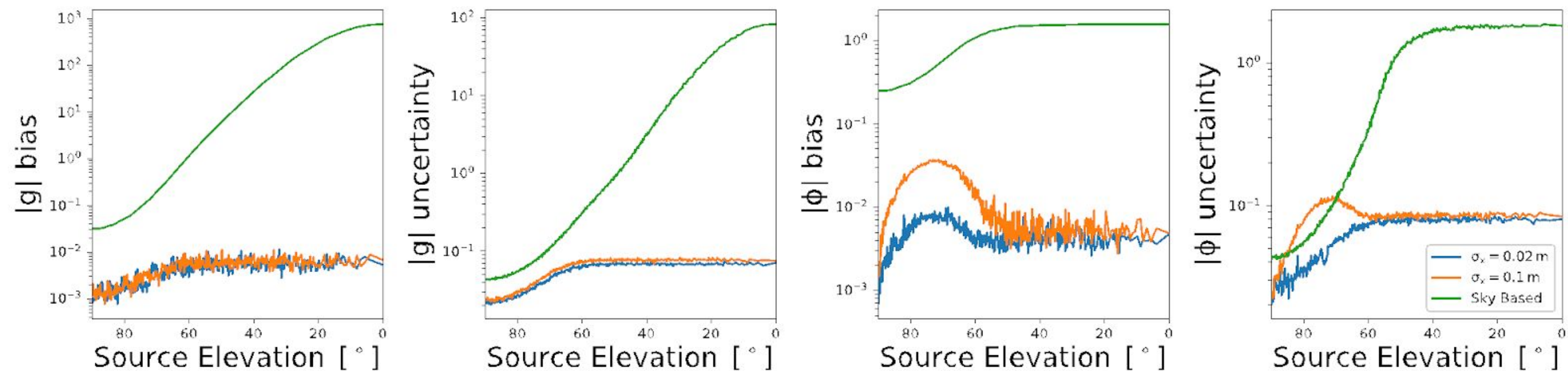


Recent work

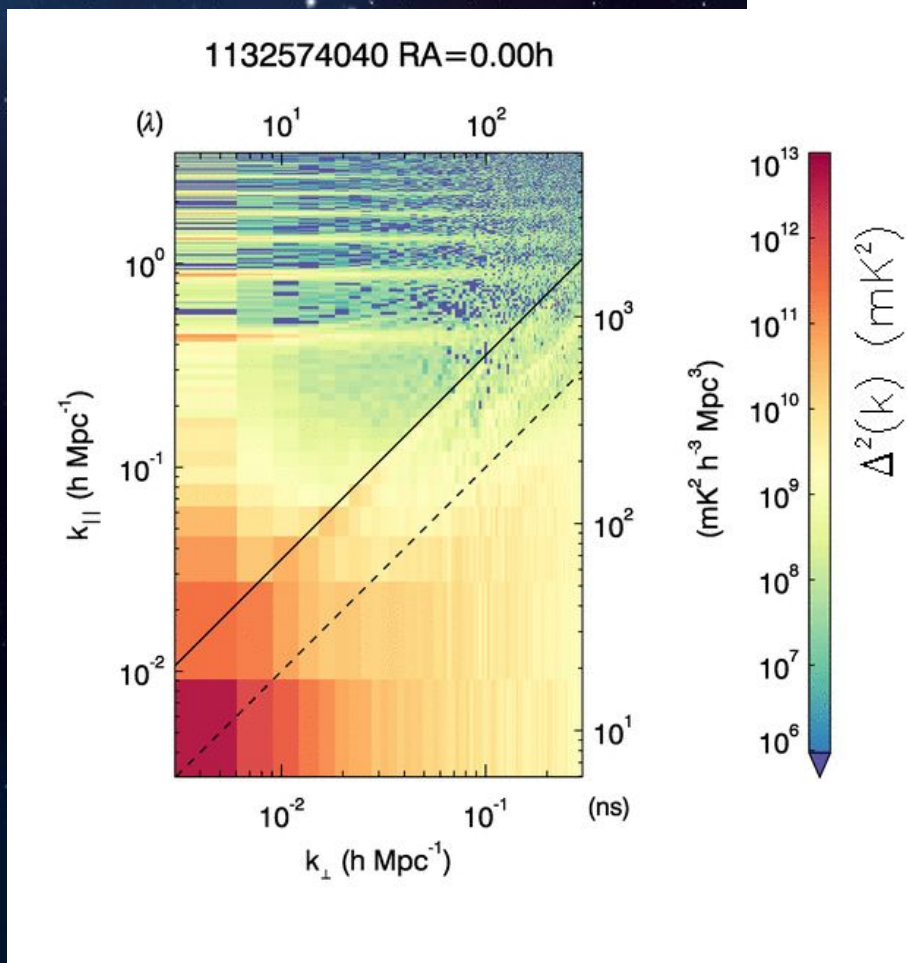
Ronniy Joseph

Comparison of sky-based and redundant calibration for different sky brightness distributions and array non-redundancy

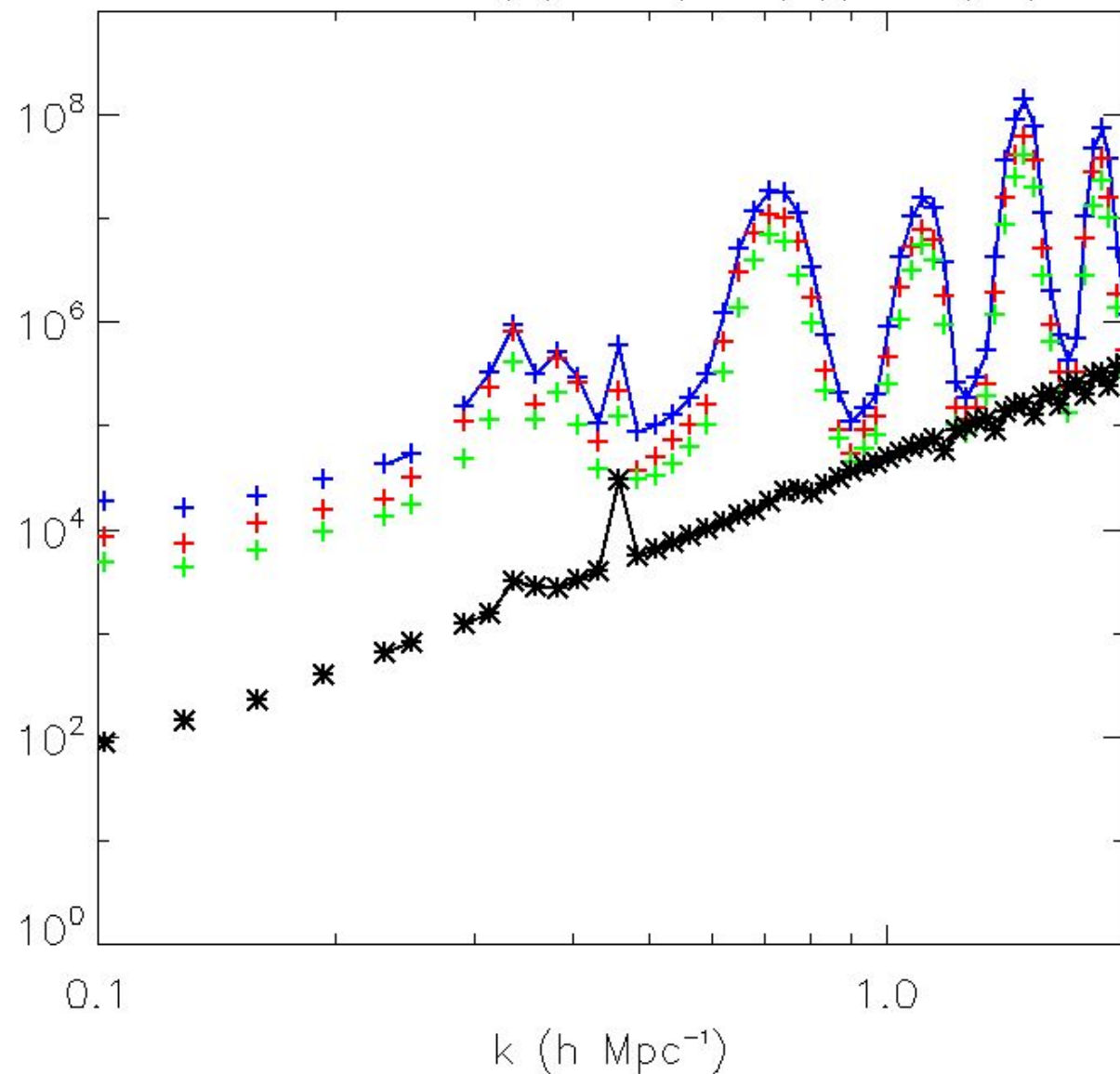
Tile position offsets introduce biases in the phase component of redundant calibration solutions. These biases depend on the location of radio sources in the field.



Recent work

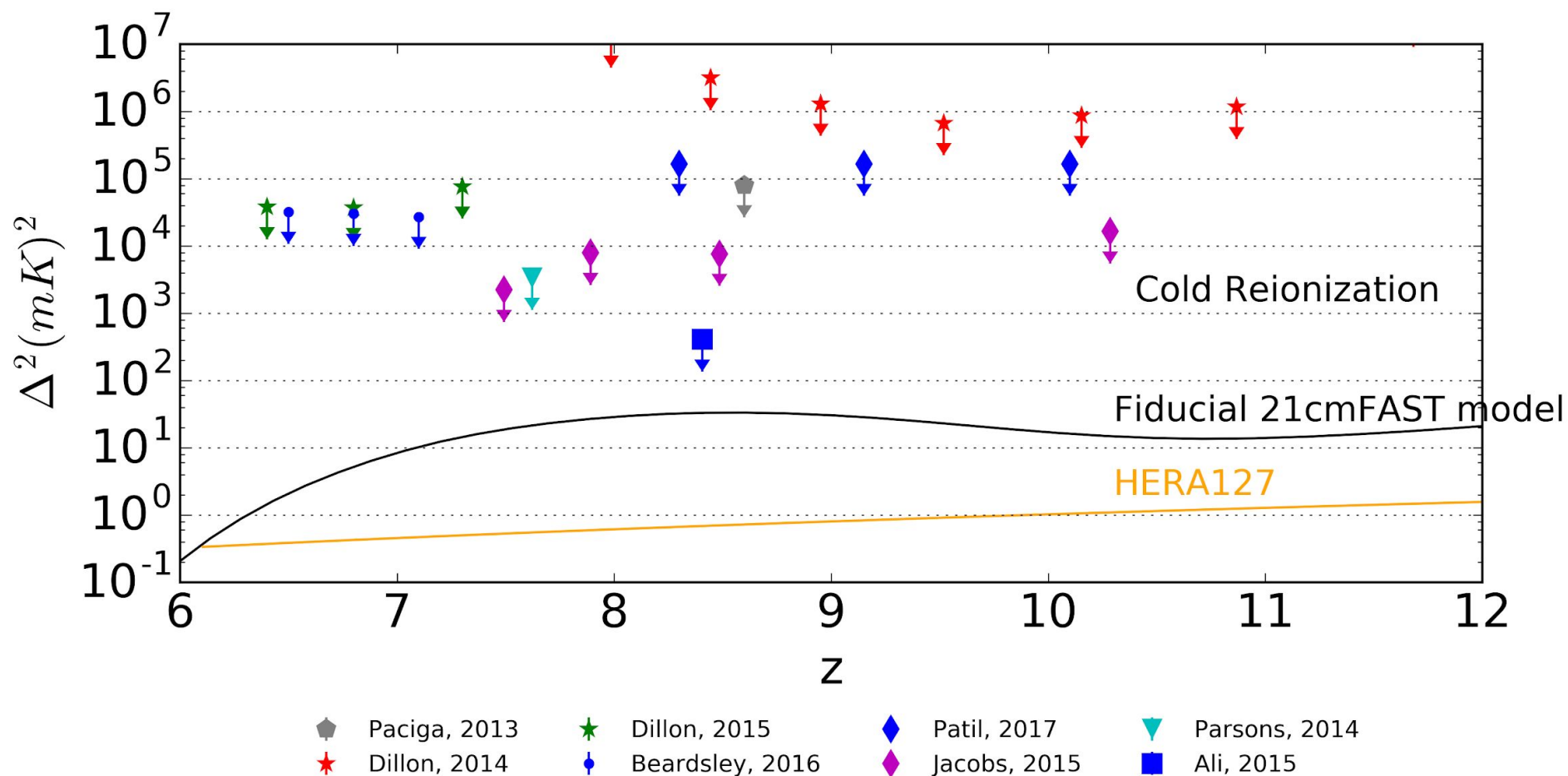
Cathryn
Trott

$$z=7.9, 8.3, 9.0 \quad \Delta^2(k) = (k^3 P(k) / 2\pi^2) \text{ (mK}^2\text{)}$$

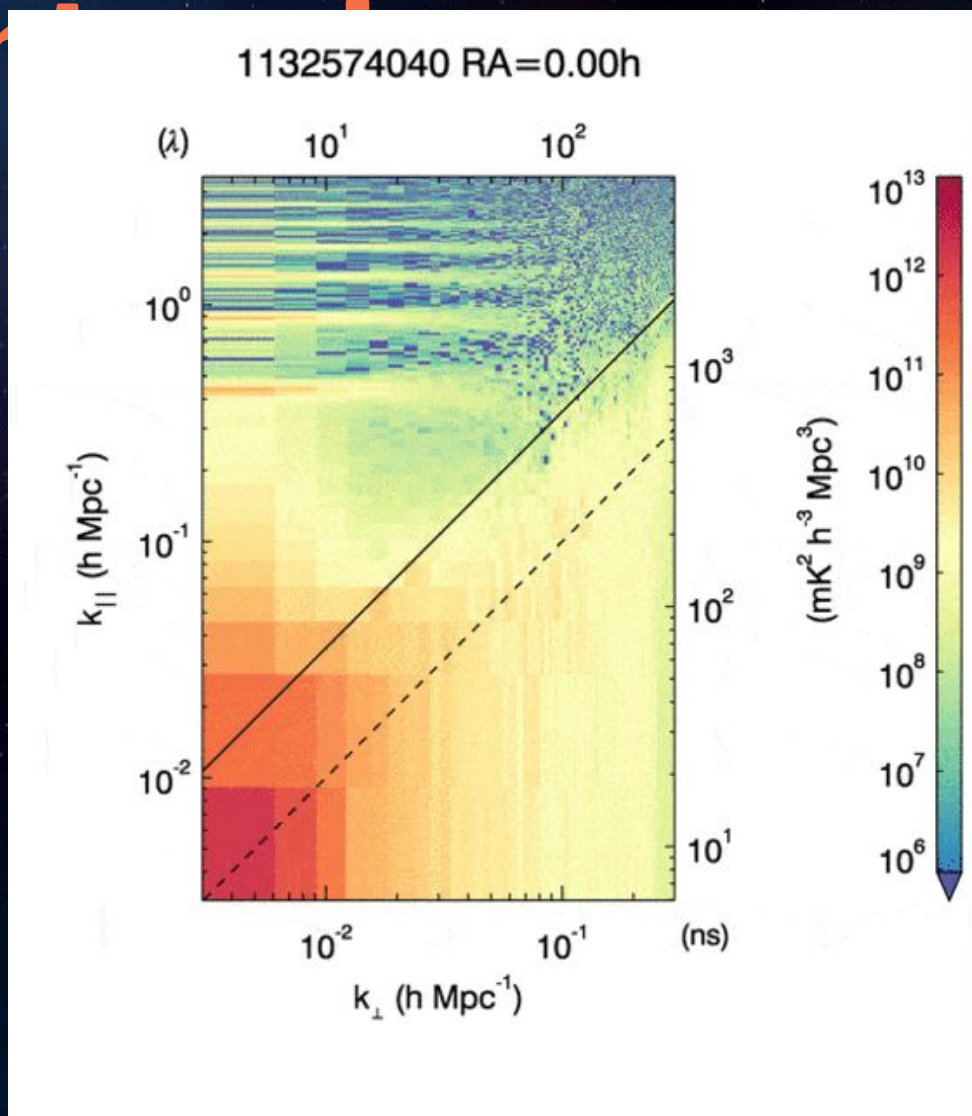


Recent work

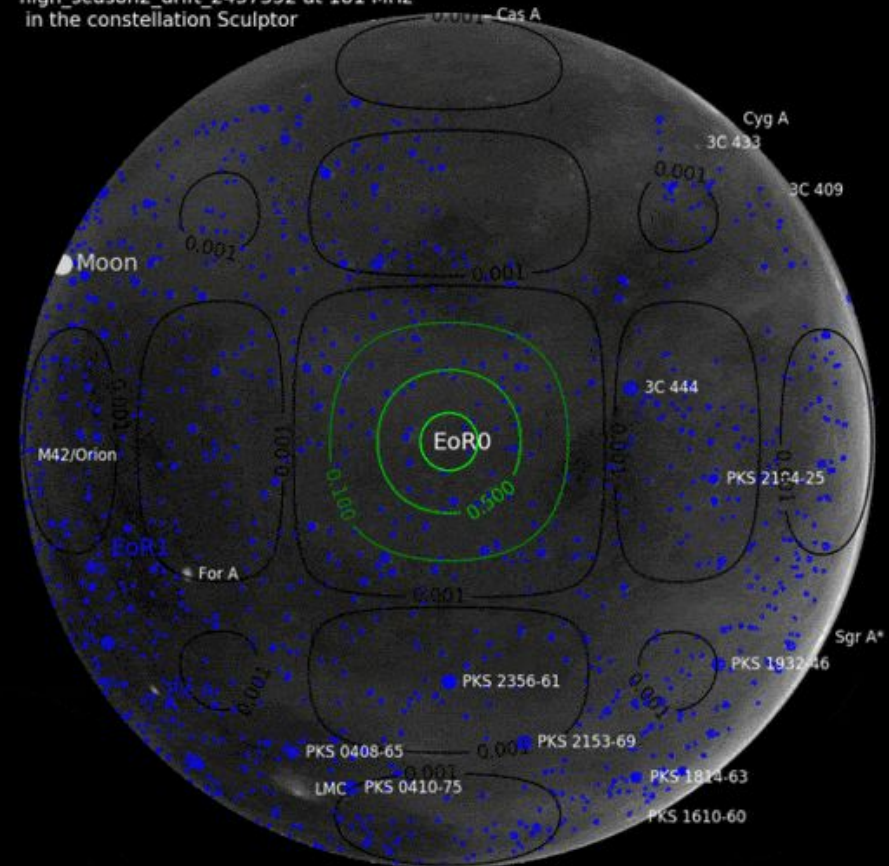
Cathryn
Trott



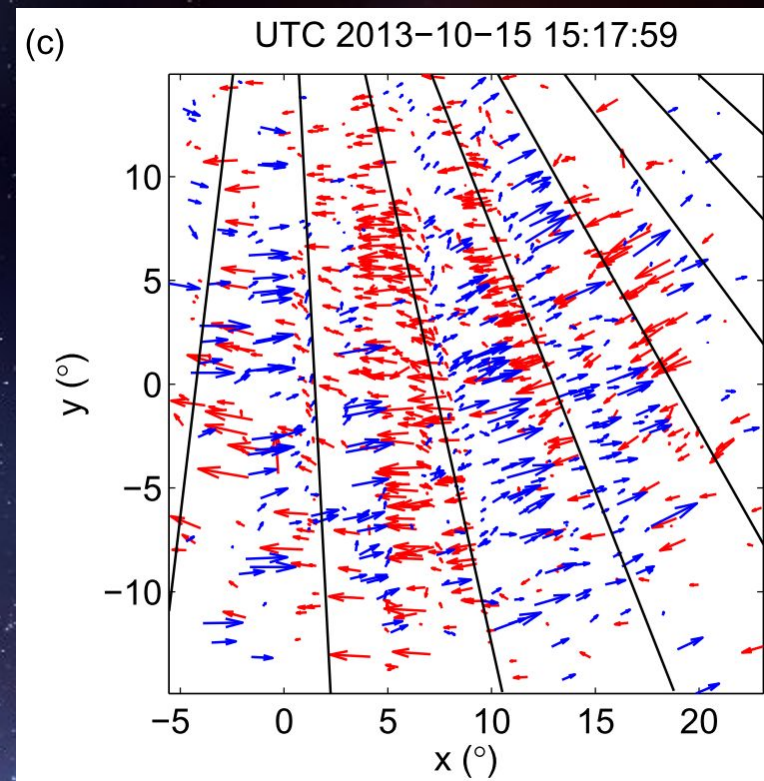
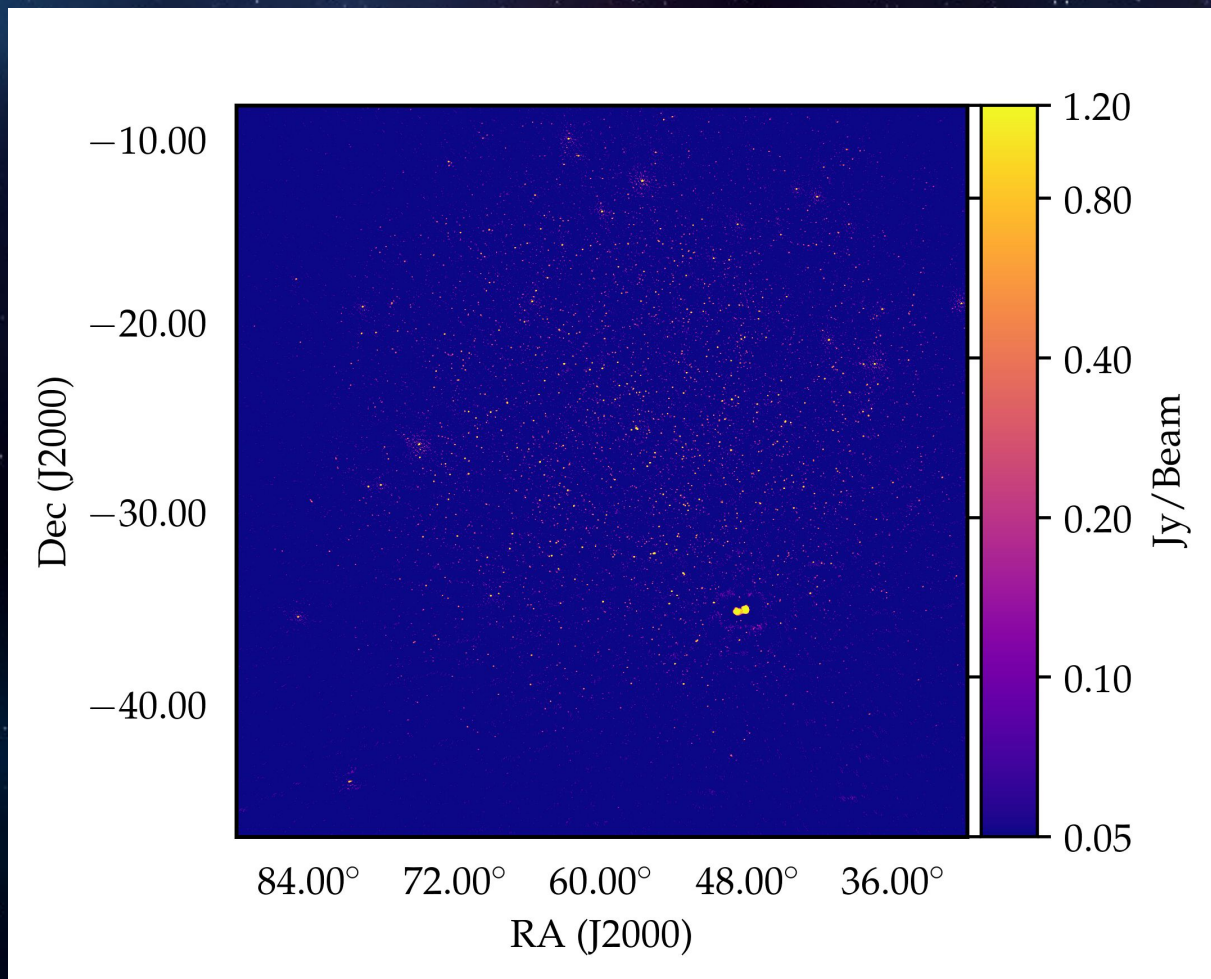
Recent

Cathryn
Trott

Obs ID 1132574040 with delays [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
 at 2015-11-26 11:53 UT:
 high_season2_drift_2457352 at 181 MHz
 in the constellation Sculptor



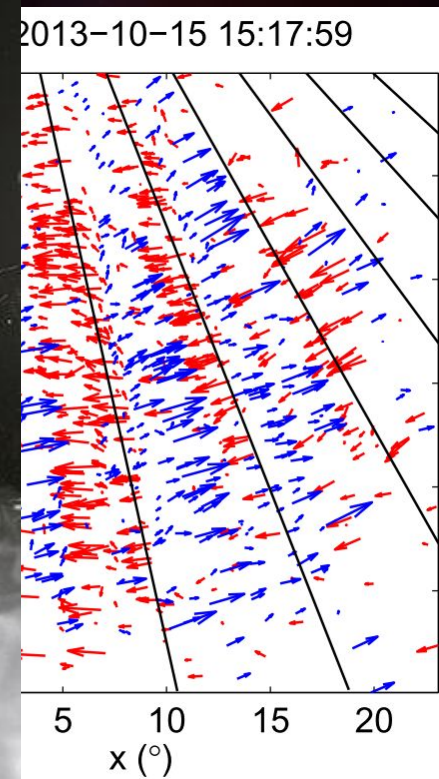
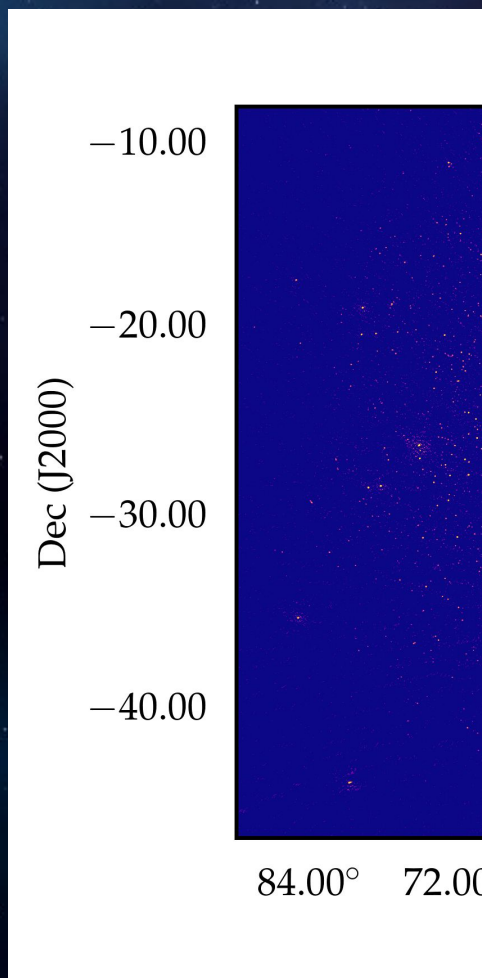
Recent work



Loi+ 2015

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Recent work

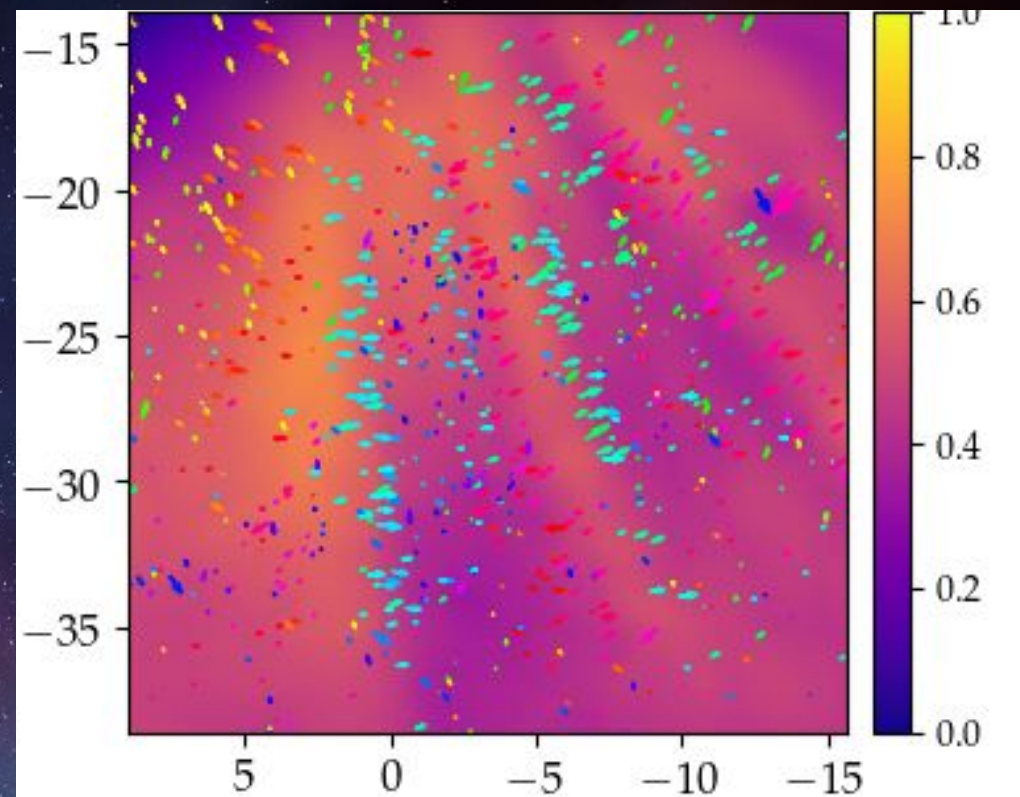
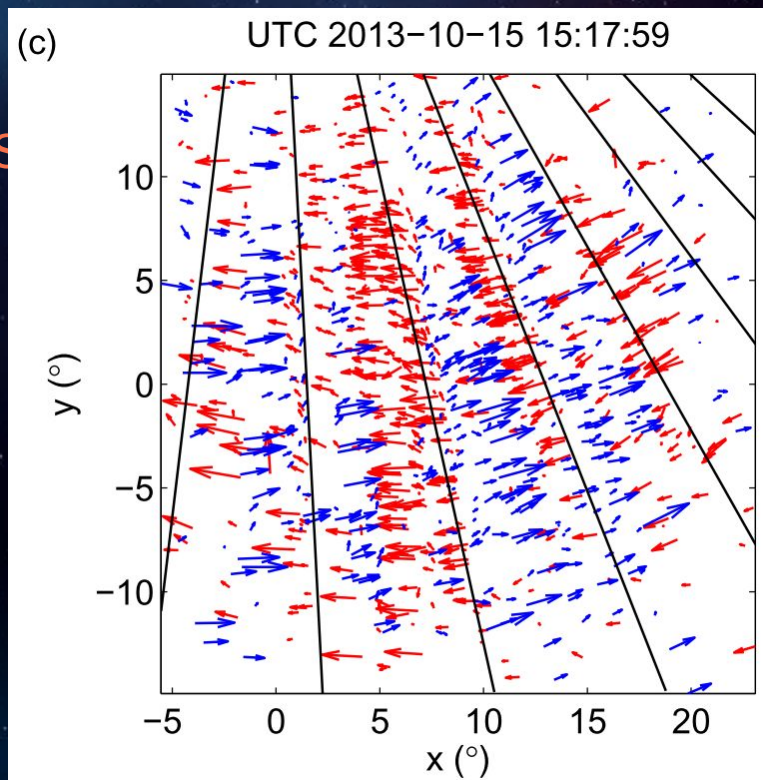


+ 2015

<https://i.pinimg.com/736x/b5/41/18/b54118c04c551e9c8818bb2df0ba6bb4.jpg>

Recent work

Chris

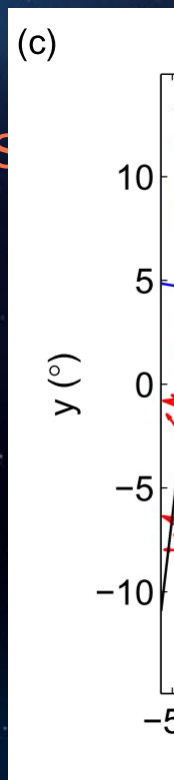


Loi+ 2015

<https://gitlab.com/chjordan/cthulhu>

Recent work

Chris

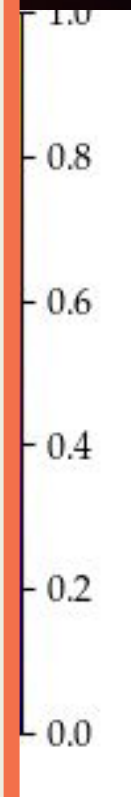


927x

**Characterisation of the ionosphere above
the Murchison Radio Observatory using the
Murchison Widefield Array**

Jordan+ 2017

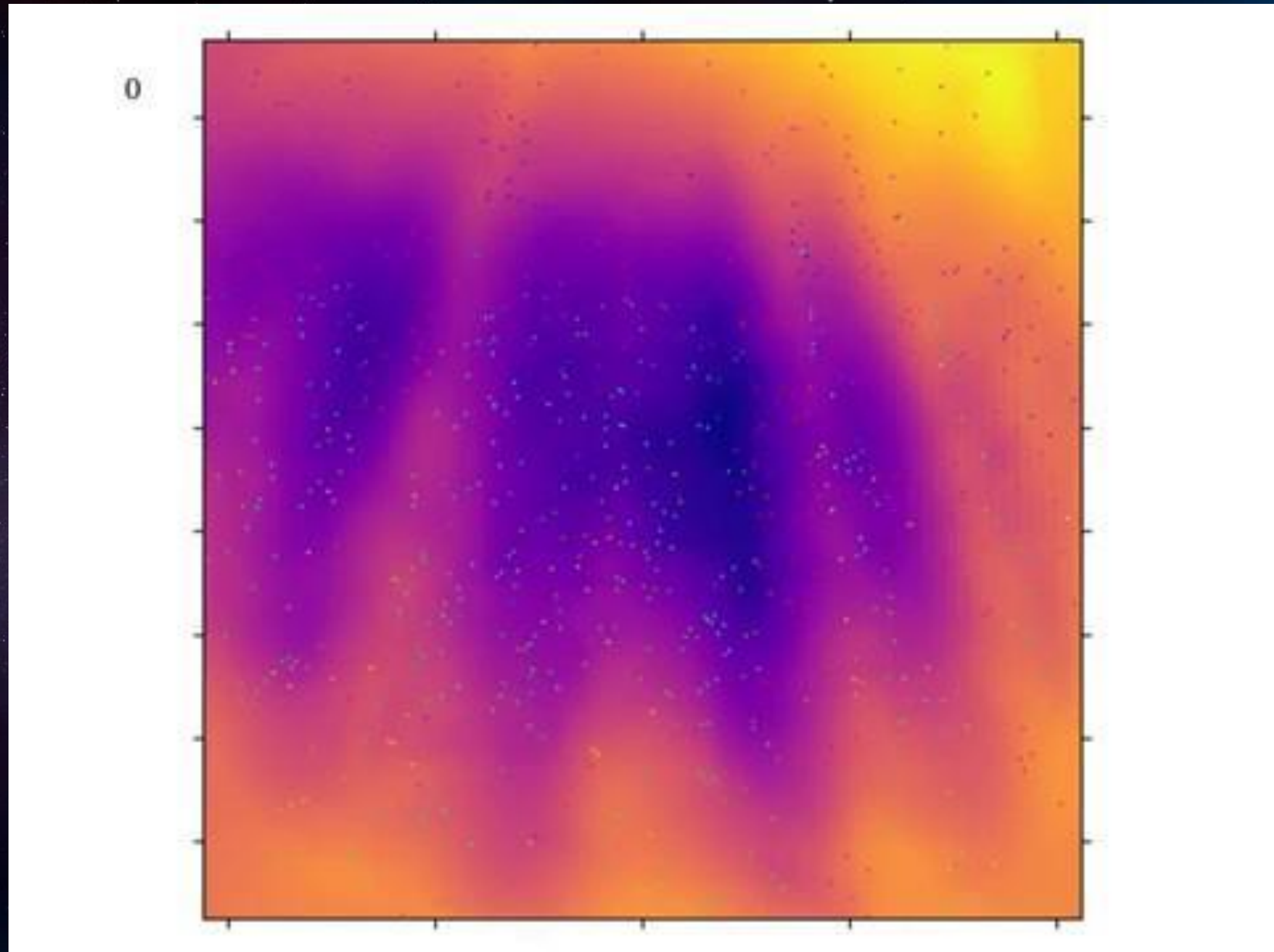
<https://arxiv.org/abs/1707.04978>



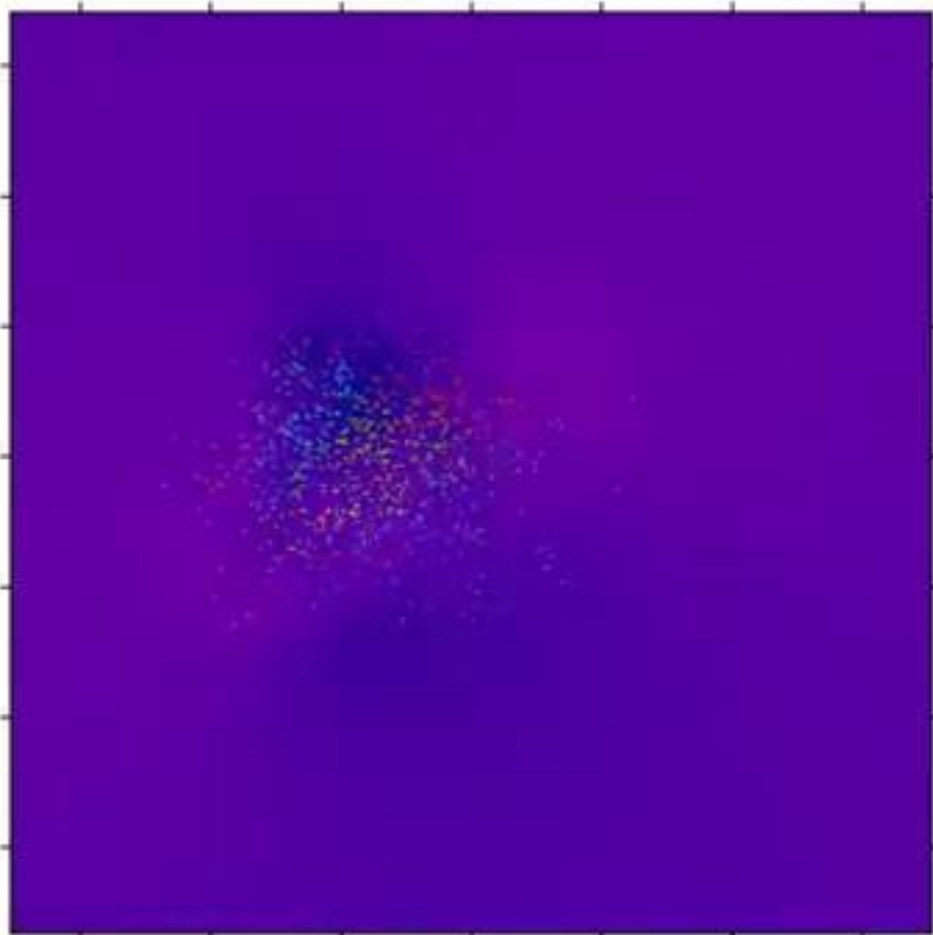
mulhu

Recent work

Christopher Jordan

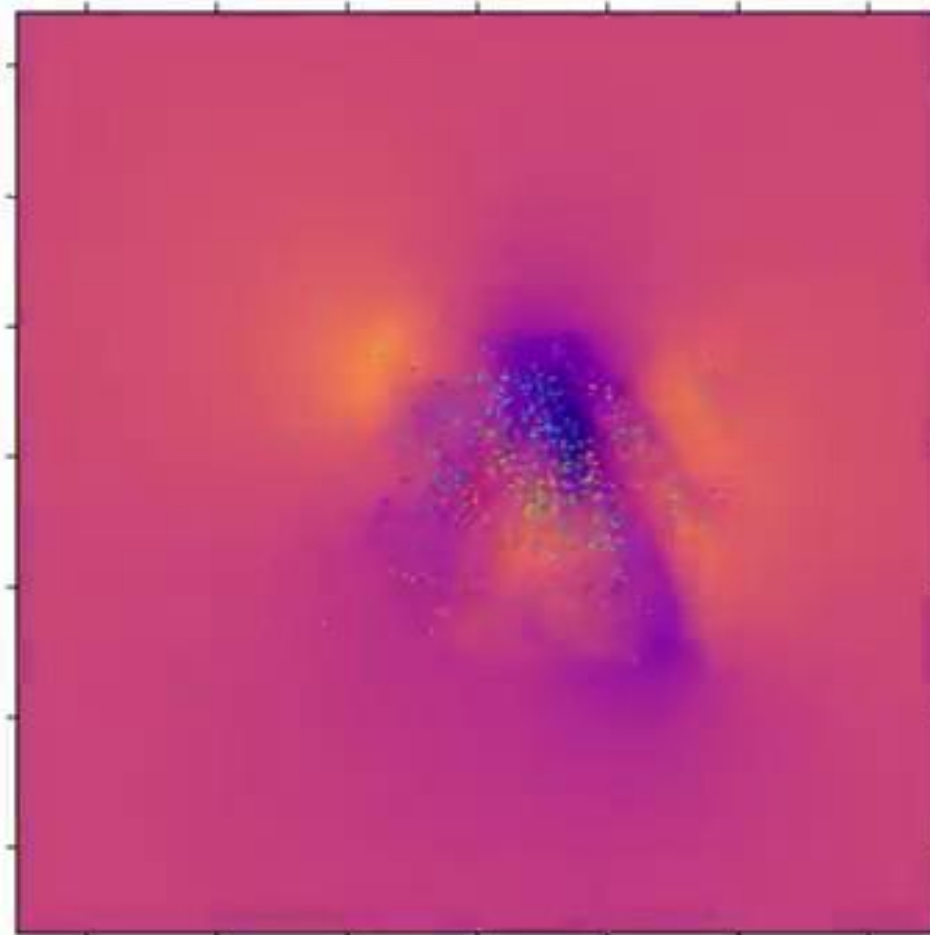


3816



“The fighter jet”

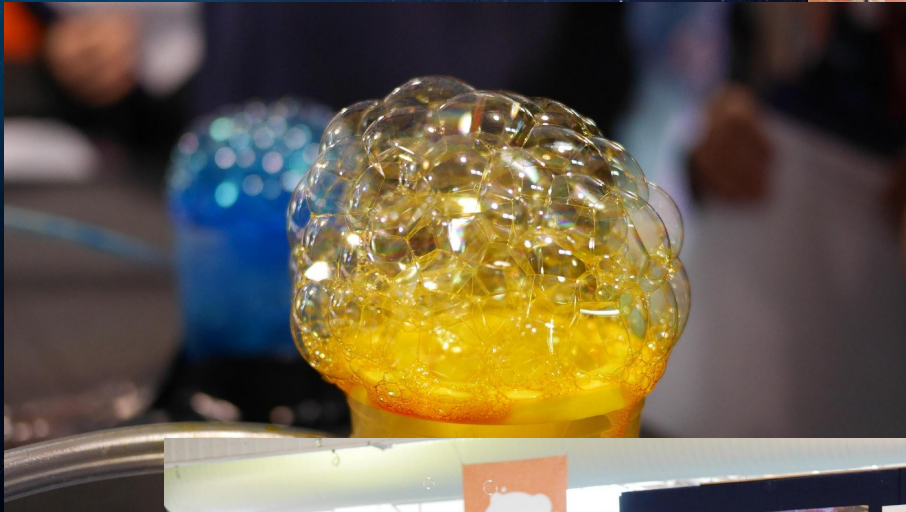
22856



“The jilted lover”

ASTRO 3D

Perth Science Festival!



Summary

- Detection of EoR is very difficult!
- Many unexpected developments occur along the way → serendipitous science
- We welcome new collaboration
- Radio astronomy is just beginning
- Thank you for inviting me!

・ ありがとうございます

