Using the Murchison Widefield Array for Solar-Heliosphere-Ionosphere Science

A. J. COSTER[1], D. OBEROI[2], P. J. ERICKSON[1], D. HERNE[3], I. H. CAIRNS[4], C. J. LONSDALE[1], L. BENKEVITCH[1], J. C. KASPER[5] AND L. D. MATTHEWS[1] AND R. CATON[6]

1) MIT HAYSTACK OBSERVATORY
2) NCRA-TIFR, PUNE, INDIA
3) CURTIN UNIVERSITY, AUSTRALIA
4) UNIVERSITY OF SYDNEY, SYDNEY, AUSTRALIA
5) HARVARD-SMITHSONIAN ASTROPHYSICAL OBSERVATORY
6) AFRL, ALBUQUERQUE, NM, USA

ON BEHALF OF THE MWA COLLABORATION

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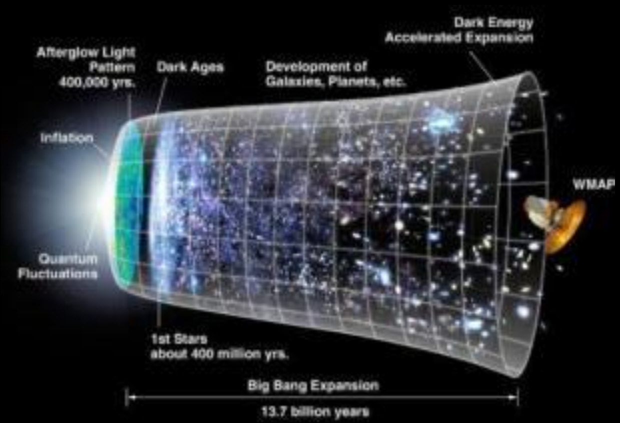
Murchinson Widefield Array 80-300 MHz

2048 dual polarization dipole antennas arranged as 128 tiles each being a 4X4 array of dipoles

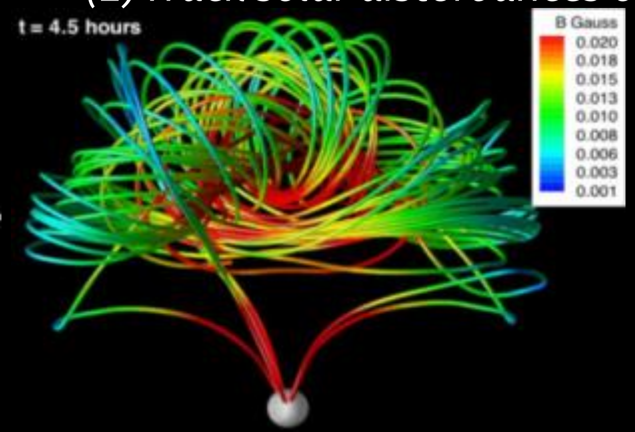
MWA Overview: Four scientific goals

(1) Detect the Epoch of Reionization (EOR)

Monitor 2 fields for about 1000 hours

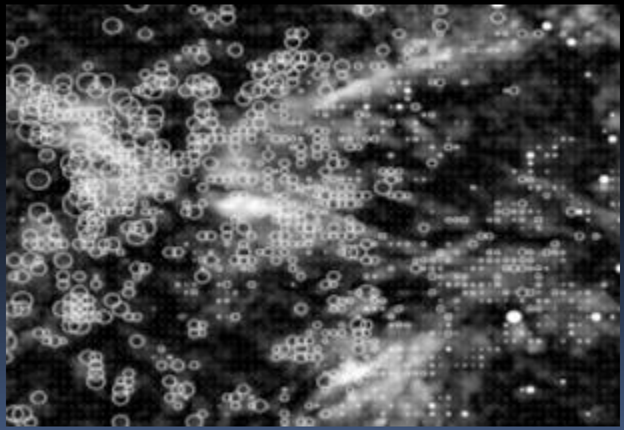


(2) Track solar disturbances out to 1 AU



Optimized to look for changes in radio emission

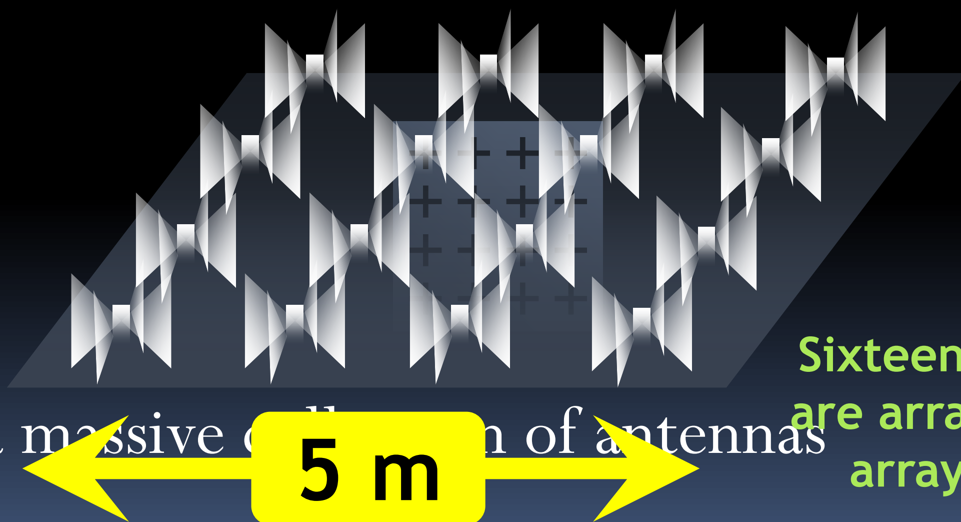
(3) Search for radio transients



Detailed and high fidelity information about the low radio frequency universe

(4) Survey the universe from 80-300 MHz

WHAT DOES IT LOOK LIKE?

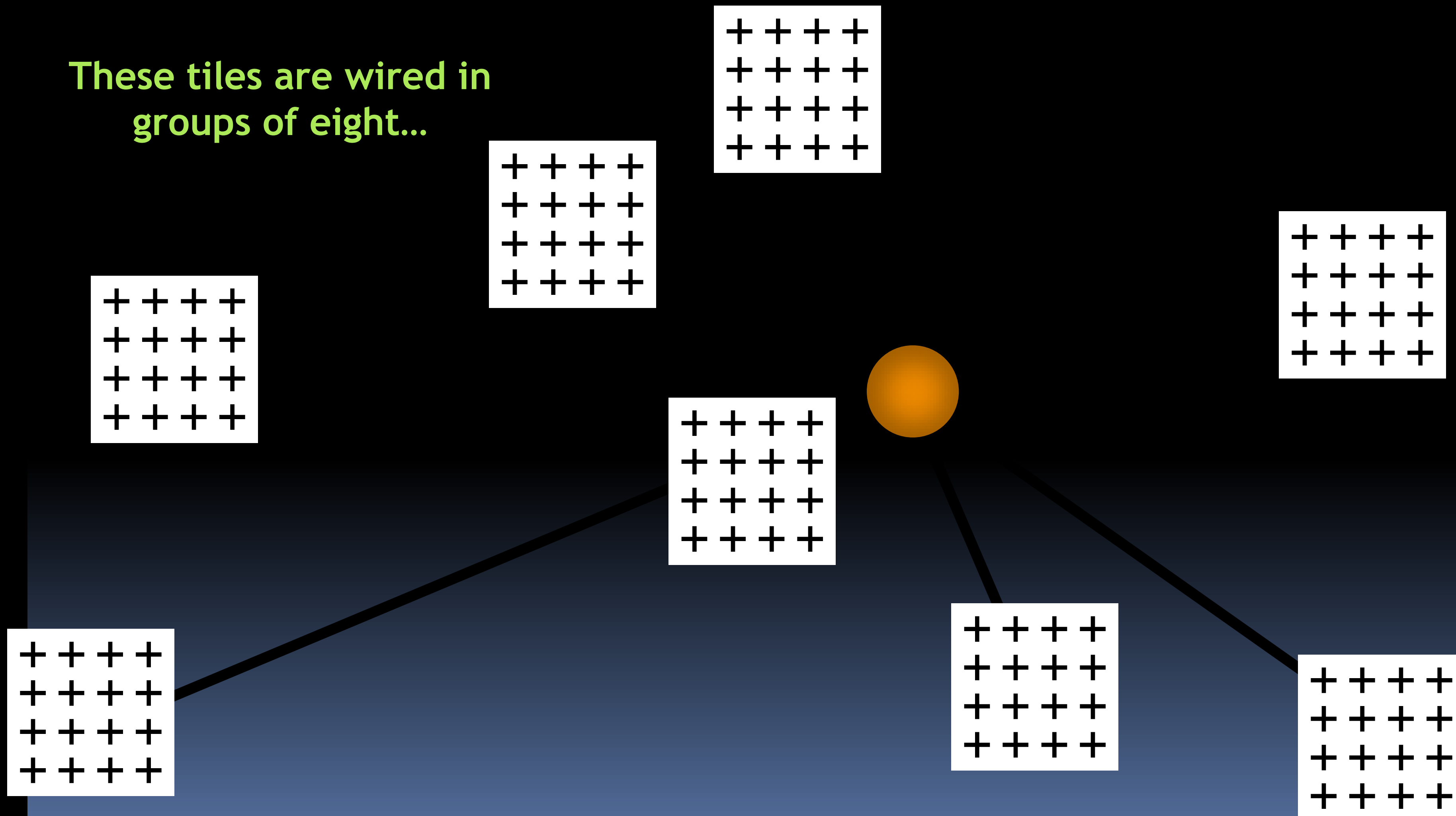


Sixteen bowtie antennas are arranged In a 4x4 tile array on wire mesh.

- The array is a massive collection of antennas
- Has both regular geometry, and random distribution:

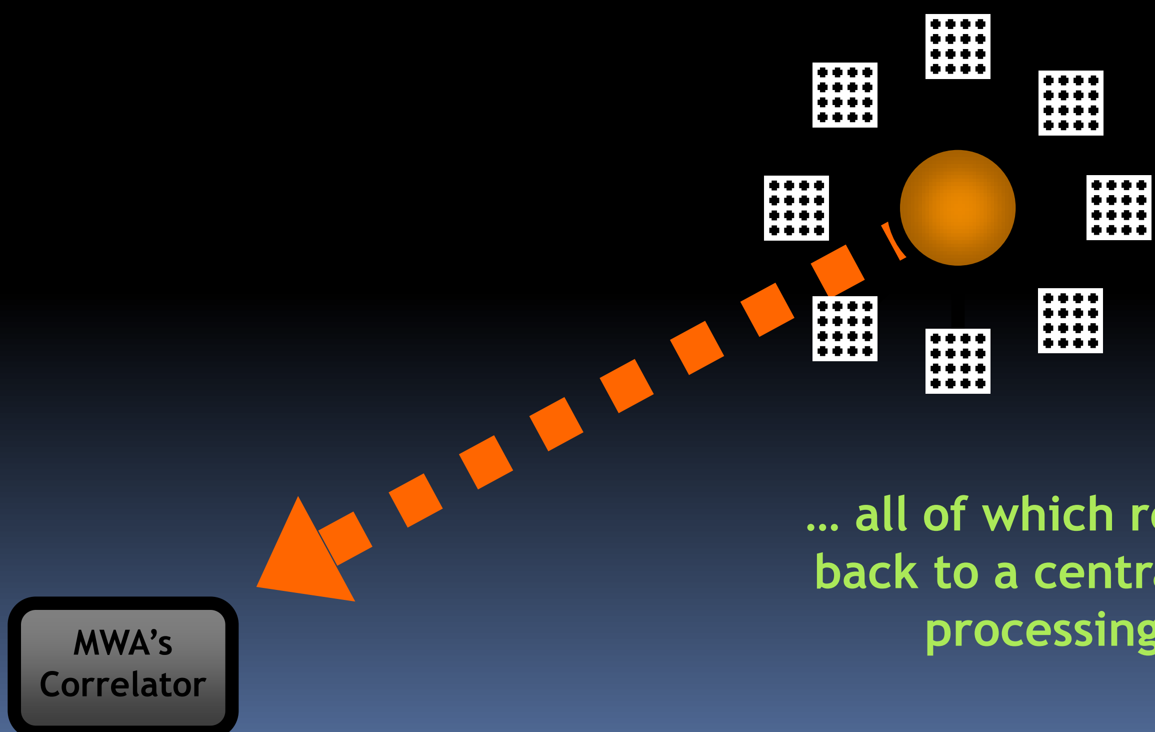
WHAT DOES IT LOOK LIKE?

These tiles are wired in groups of eight…



WHAT DOES IT LOOK LIKE?

… and there are 16 such groups of eight… for a total of 128 tiles…



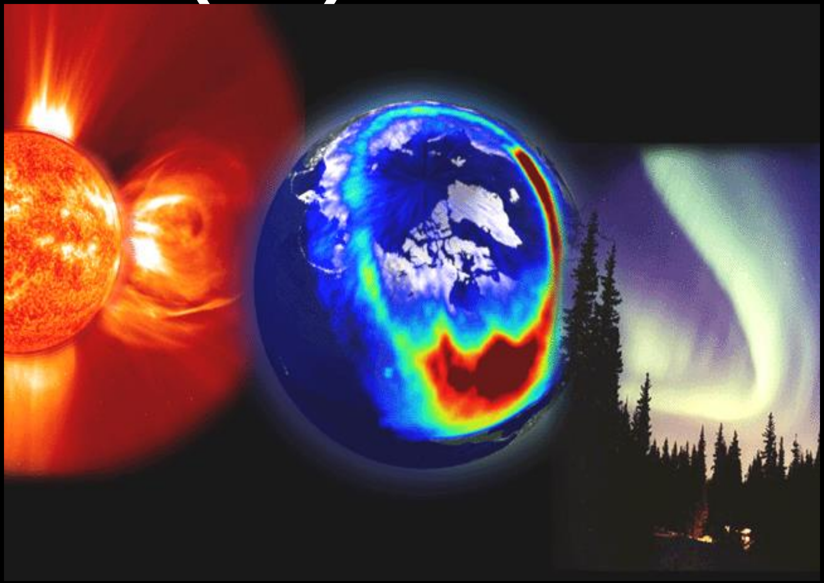
X 16

… all of which report data back to a central, on site processing unit

WHAT DOES IT LOOK LIKE?

MWA's r/t software

MWA
Solar, Heliospheric, and Ionospheric (SHI) Science



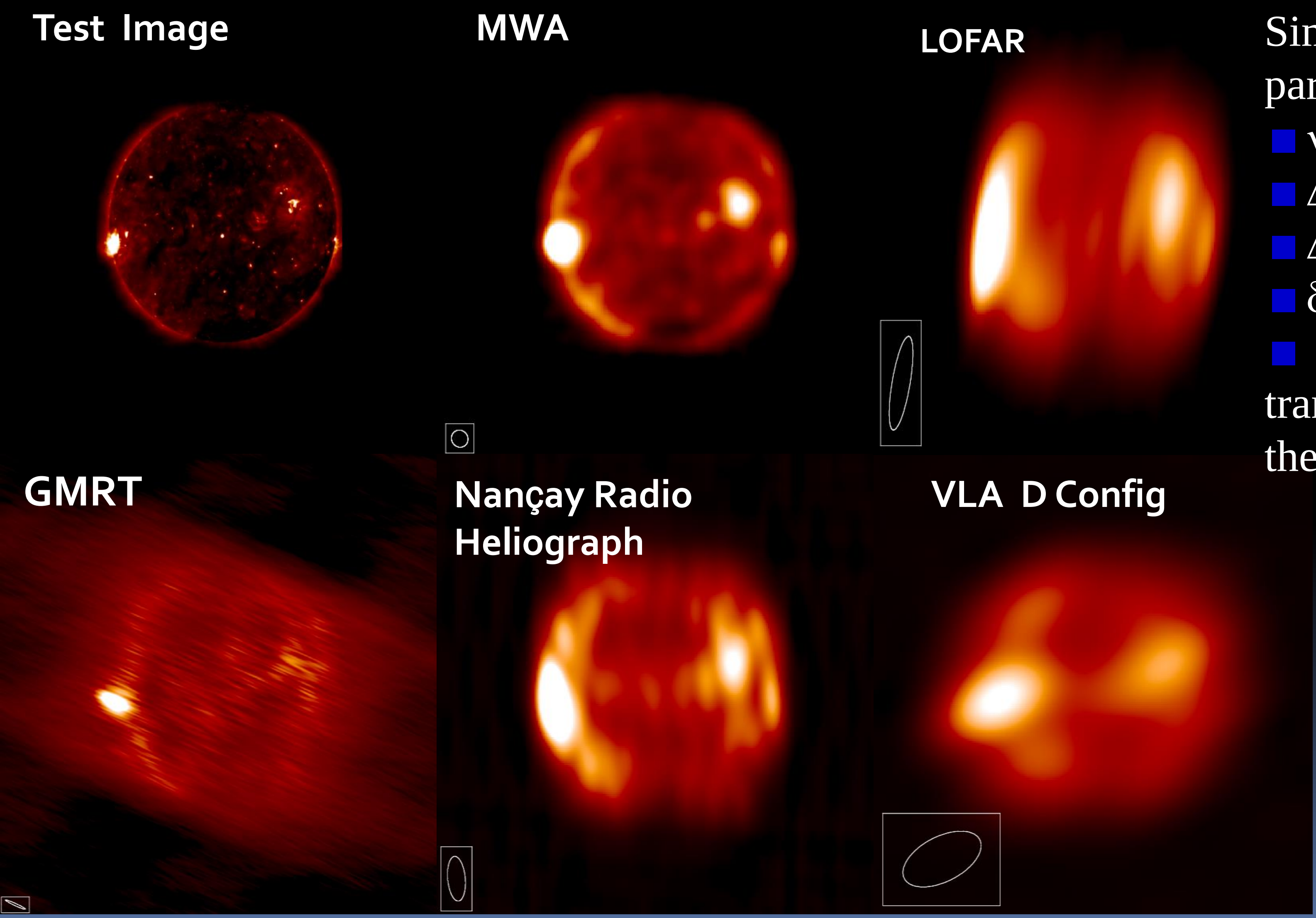
Observe from the Sun through the heliosphere to Earth

- Solar Radio Burst Type II and Type III
  - Imaging with Fine Angular Resolution
- Interplanetary Scintillation
- Magnetic Field in Heliosphere and in CME
  - Faraday Rotation of Polarized Radio Sources
- Ionospheric Structure on small temporal and spatial scales
  - MWA calibration

Solar Imaging

- Sun is a difficult source to image
  - Temporal variations from < ms to solar cycles
  - Spectral variations down to a few kHz
  - Complex and dynamic morphology
  - Large intrinsic contrast between thermal and non-thermal emission features
- Observational requirements
  - High time and spectral resolution imaging with a good angular resolution, and high dynamic range and fidelity

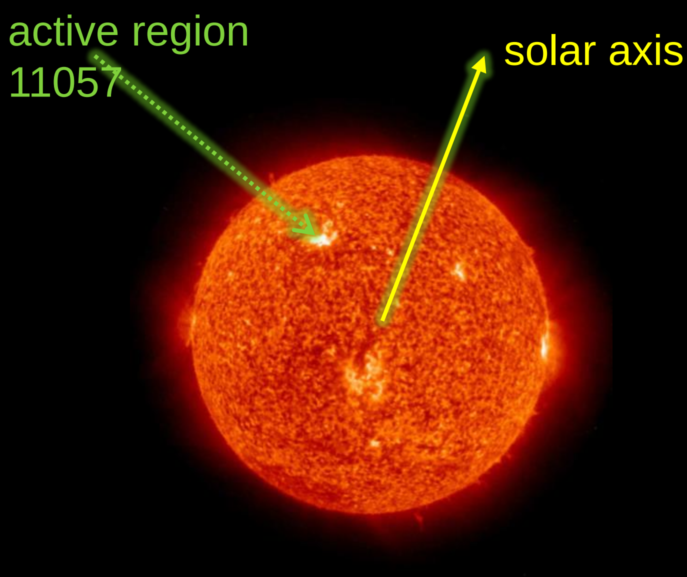
Comparison of imaging performance



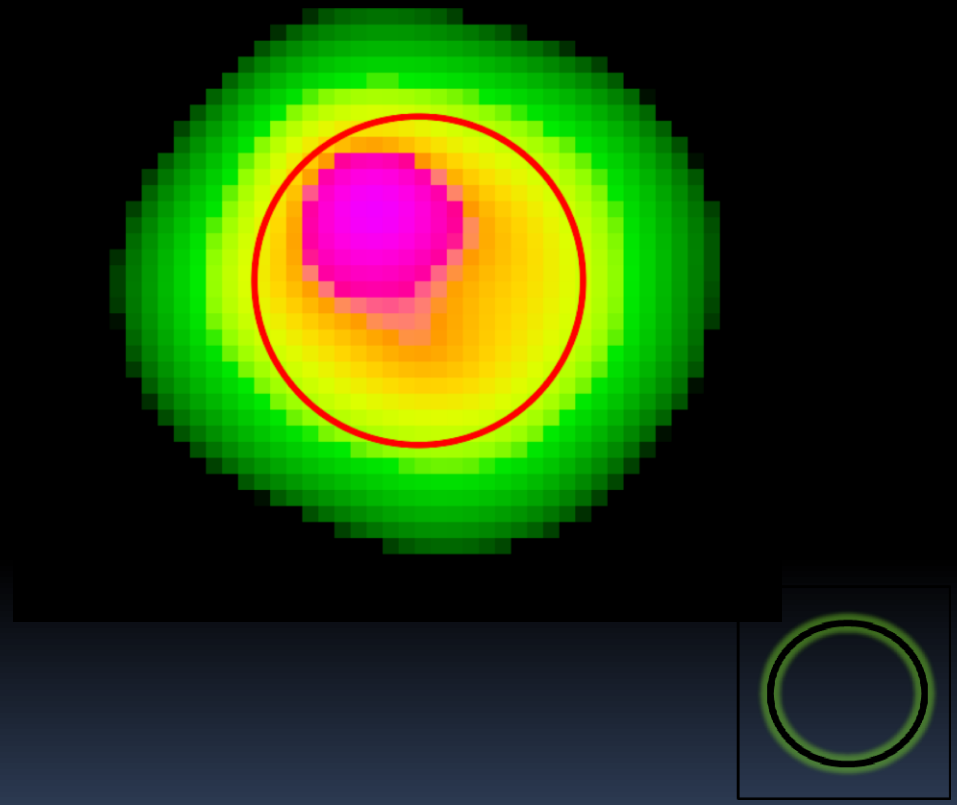
Simulation parameters

- ν = 160 MHz
- $\Delta\nu$ = 1.6 MHz
- Δt = snapshot
- $\delta_{\odot}$= -24°
- Observed at transit for each of the instruments.

SOHO 304 Å image (01:19 UT)

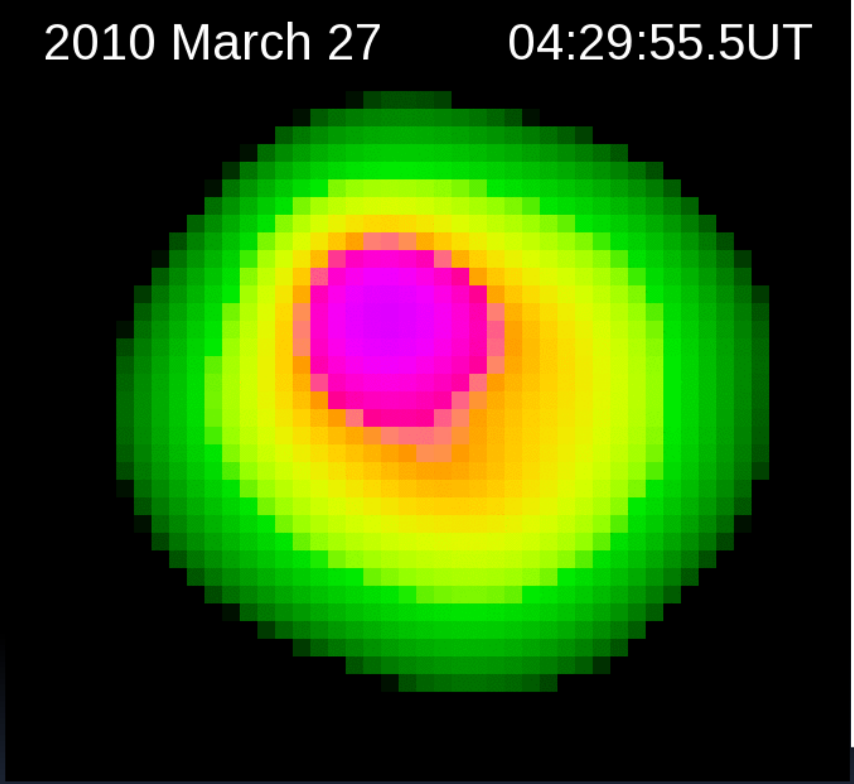


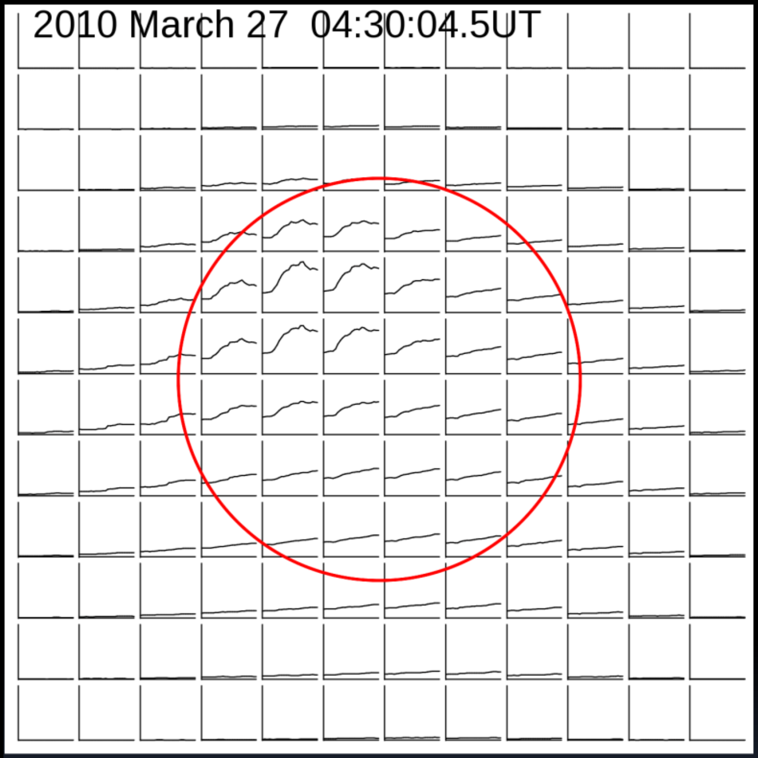
32T 193 MHz image (04:26:38 UT)
(800″x 800″ restoring beam)



Active region 11057 is prominent in the radio images, even during “quiescent” intervals

Spectroscopic Imaging Capability

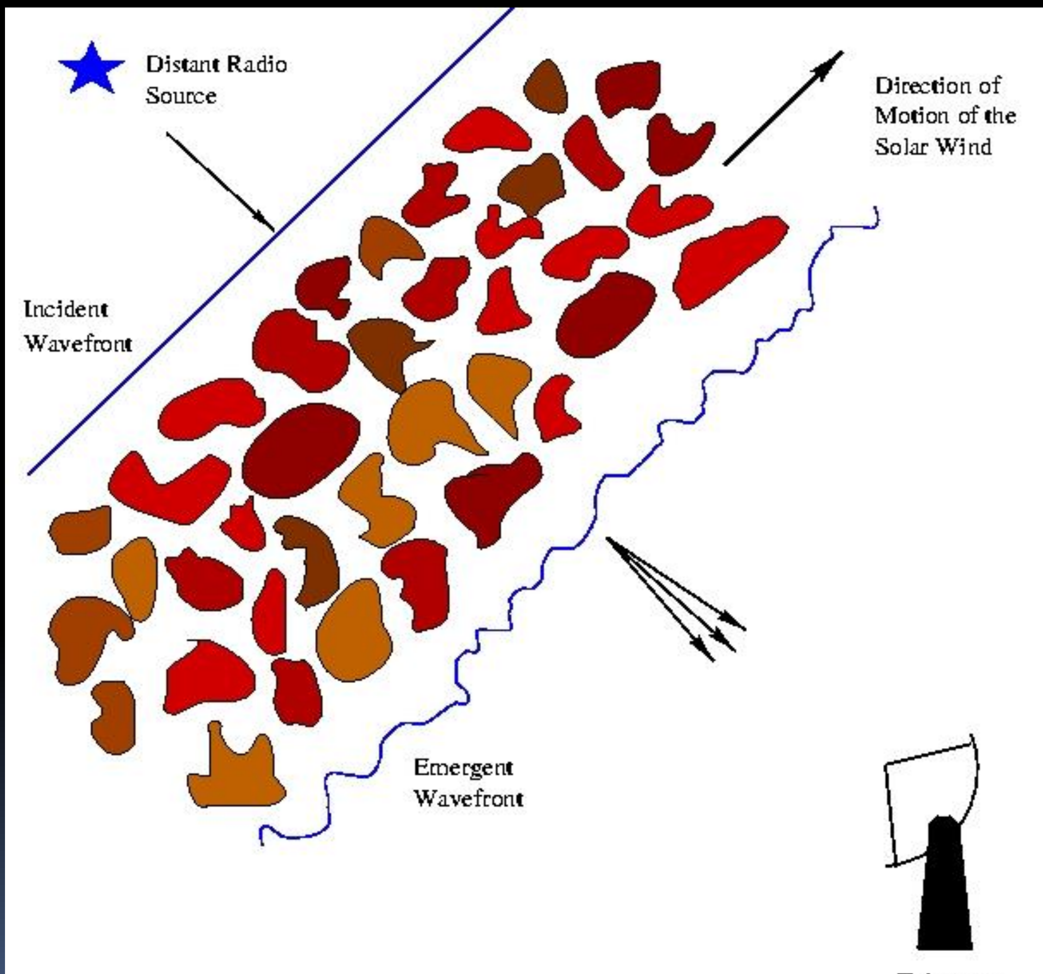




- Unprecedented ability to simultaneously track coronal dynamics in temporal, spectral and spatial dimensions
- Solar activity characterized as ‘Quiet’ to `Very Quiet’

Oberoi et al., 2011, ApJ, **728**, L27

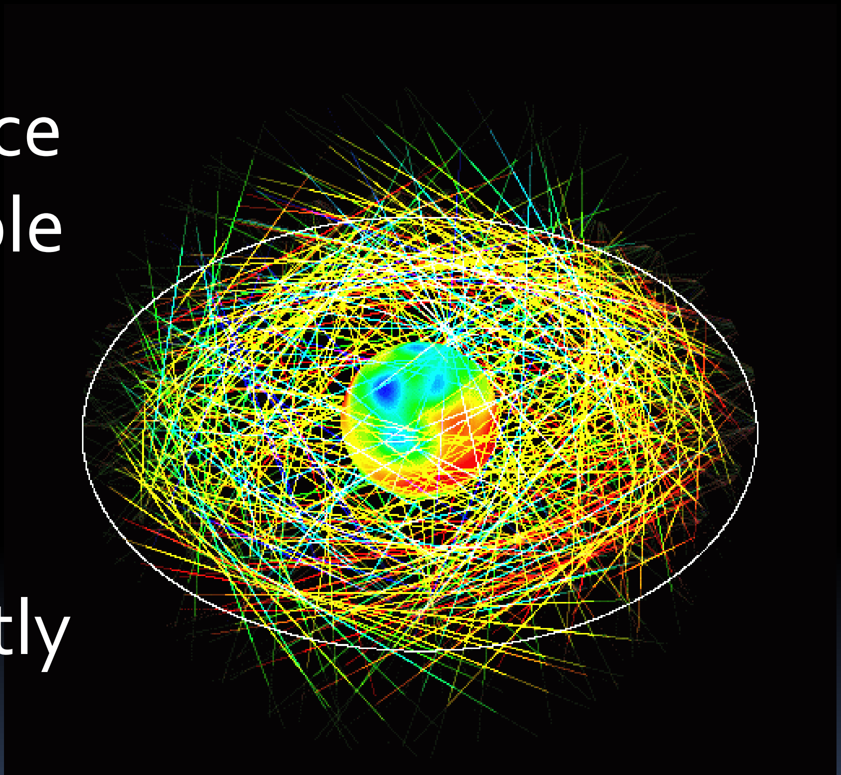
Interplanetary Scintillation (IPS)



- Radio analog of optical twinkling of stars
  - Star -> Compact radio source
  - Atmosphere -> Solar Wind
- Solar wind -> set of thin 2D screens with electron density fluctuations
- Radio waves pick up an imprint of these fluctuations as they traverse this screen
- The resulting interference pattern sweeps past the telescope due to the motion of the solar wind leading to IPS

Interplanetary Scintillation studies with MWA

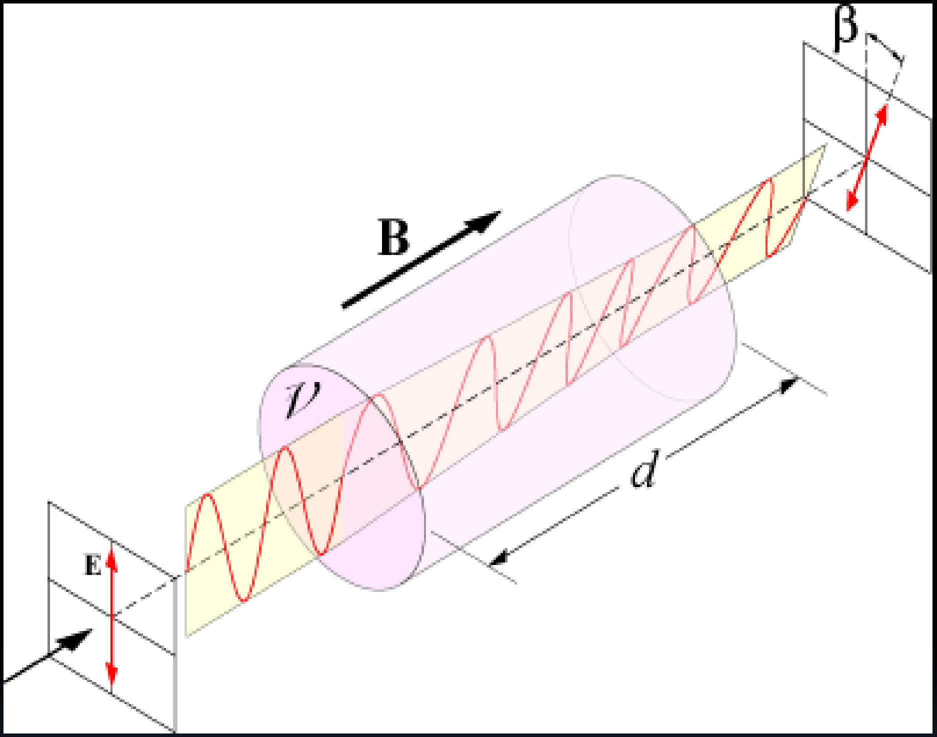
- A well established remote sensing technique
- Provides access to turbulence characteristics, not accessible by any other means
- MWA will provide 16 simultaneous beams which can be pointed independently anywhere within the large FoV of the MWA



Kojima, M., STELab

Faraday Rotation

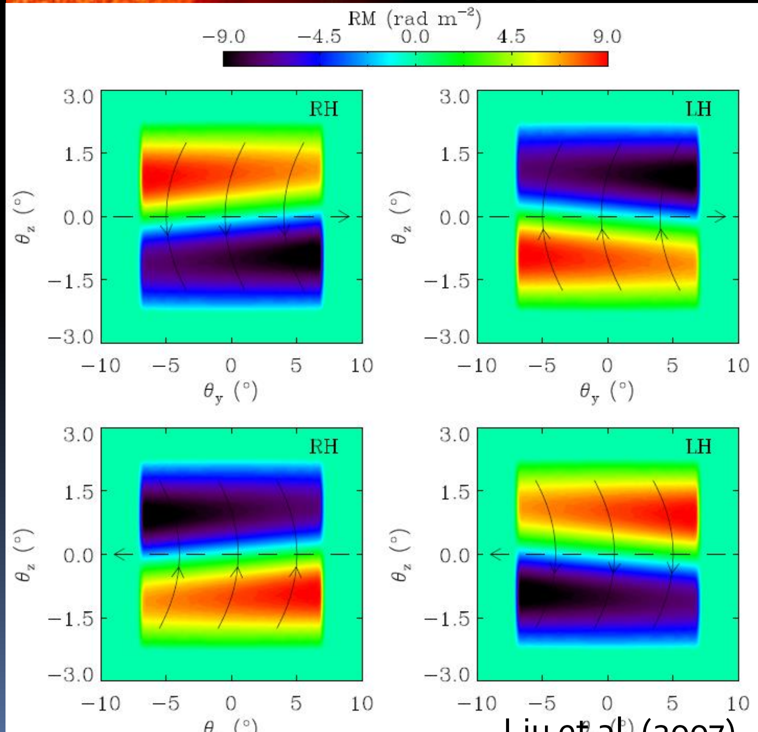
- Magnetic fields can be measured at the photosphere and at single points > 0.3 AU from the Sun ***<u>but not in between</u>***
- MWA measurements of Faraday Rotation can close this observational gap
- Follows successful work with the Very Large Array, by measuring changes in the polarization angle of emission from galaxies due to FR



$$\Delta\phi = \lambda^2 C \int n_e \vec{B} \cdot d\vec{s} = \lambda^2 RM$$

Probing CME geo-effectiveness

- CME geo-effectiveness crucially depends on the presence of a Bz component in the CME magnetic field
- Simulations show that observations of Faraday Rotation due to CME plasma can, in principal, constrain the magnetic field topology sufficiently to determine their geo-effectiveness
- The MWA will attempt to make such measurements



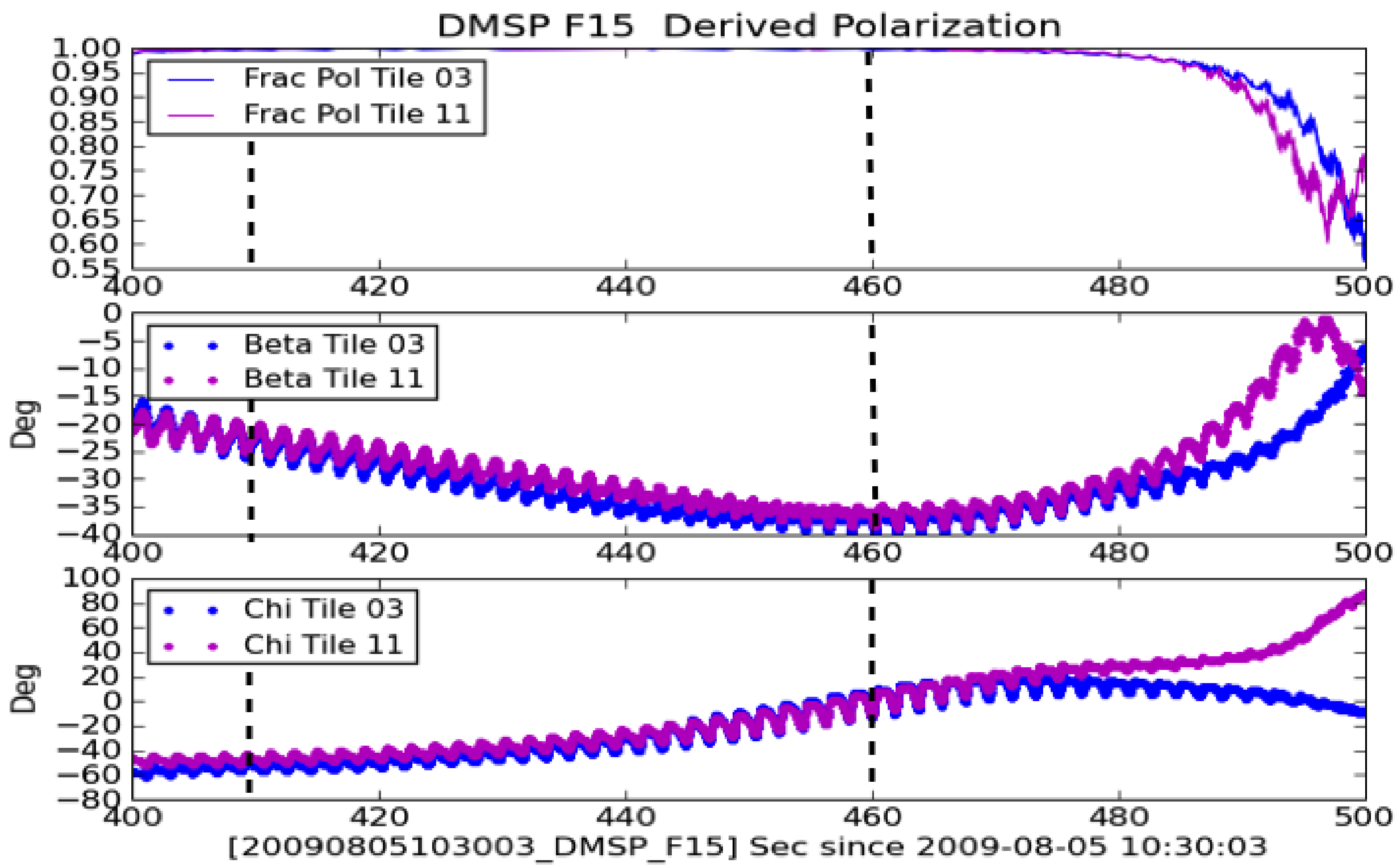
Liu et al. (2007)

Faraday Rotation at the MWA

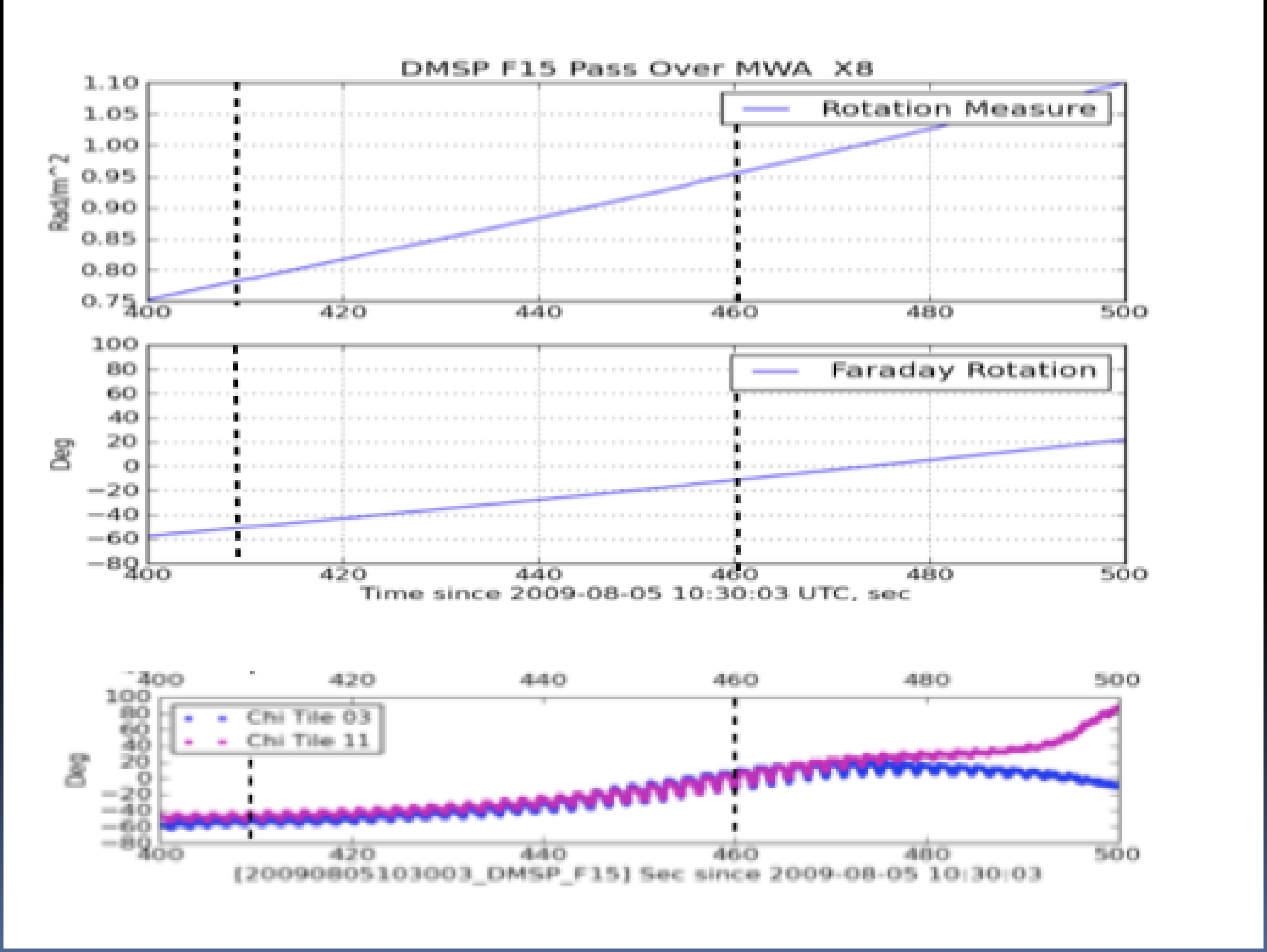
- The interstellar medium will cause the polarized MWA sky to evolve on timescales of months to years.
- The heliosphere produces strong FR near the sun, but negligible at solar angles of more than a few tens of degrees. <u>Disturbances in the solar wind will cause temporal and spatial gradients in FR.</u>
- The magnetosphere produces Faraday rotation too small to be important for the MWA.
- The plasmasphere and ionosphere together produce large amounts of FR, with the ionosphere dominating by an order of magnitude.

High-elevation DMSP F15 pass

Aug 05, 2009 10:30-10:45 UT.

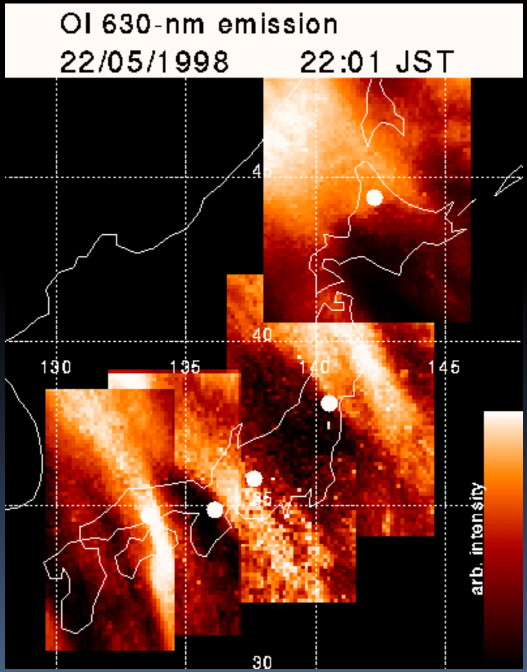


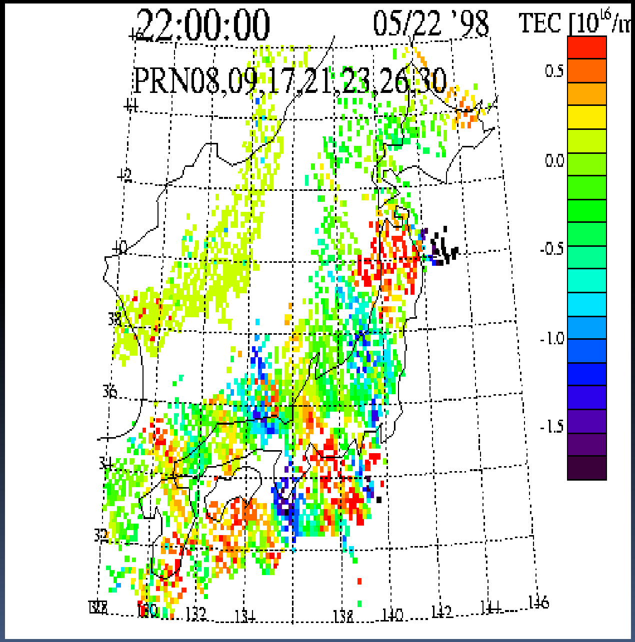
Faraday Rotation Model

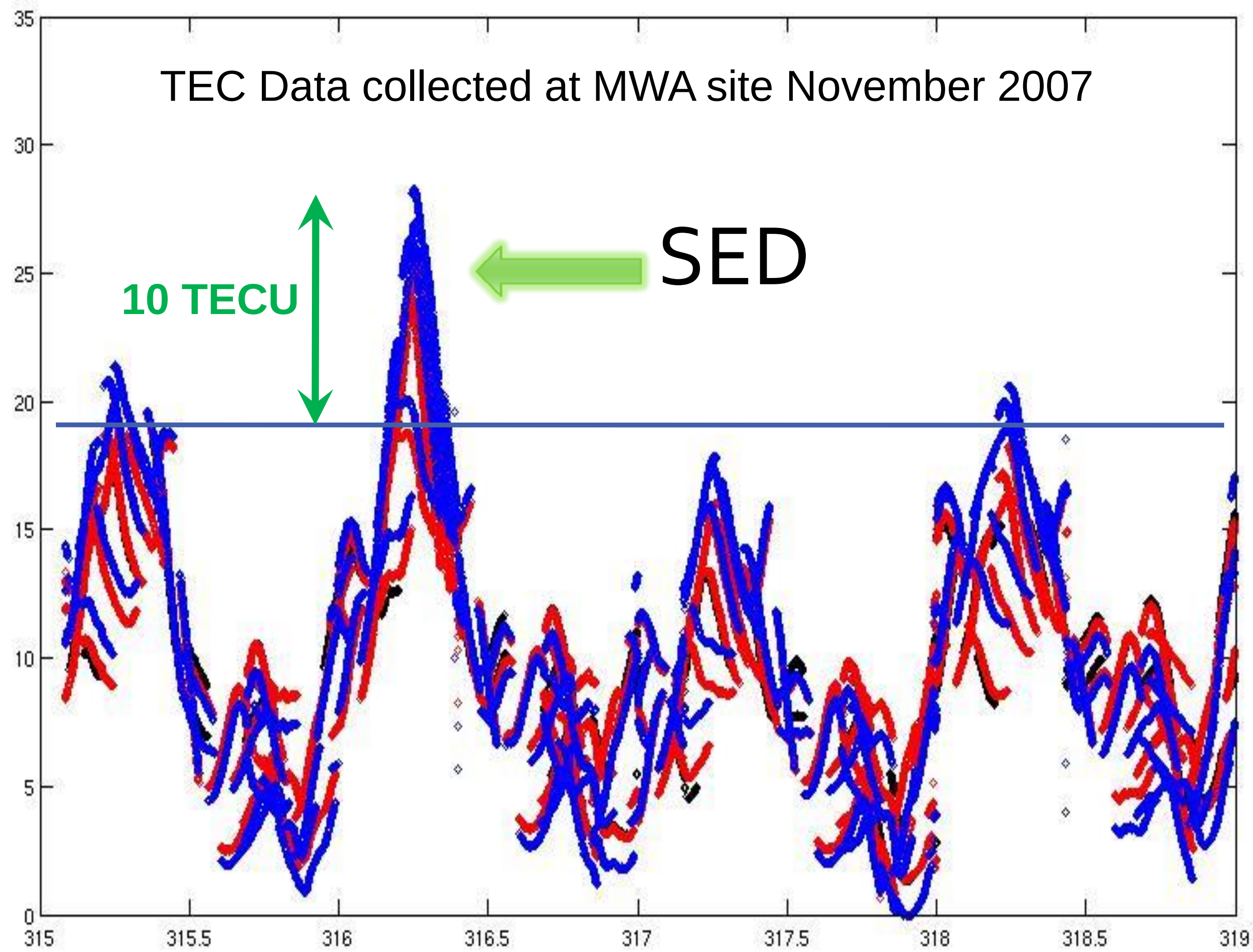


Ionospheric Science at the MWA

- Storm Enhanced Density in Southern Hemisphere
- Traveling ionospheric disturbances (TIDs) and scintillation

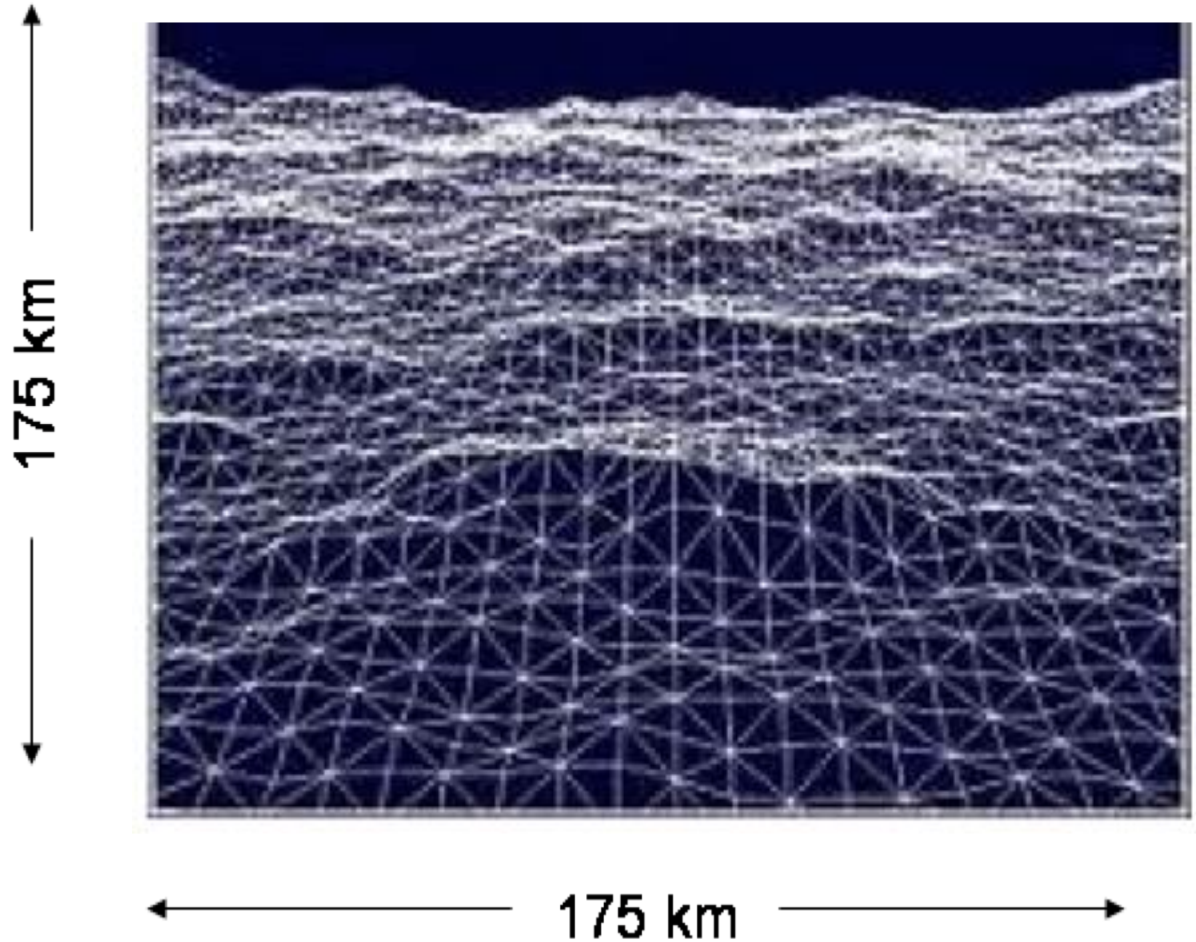


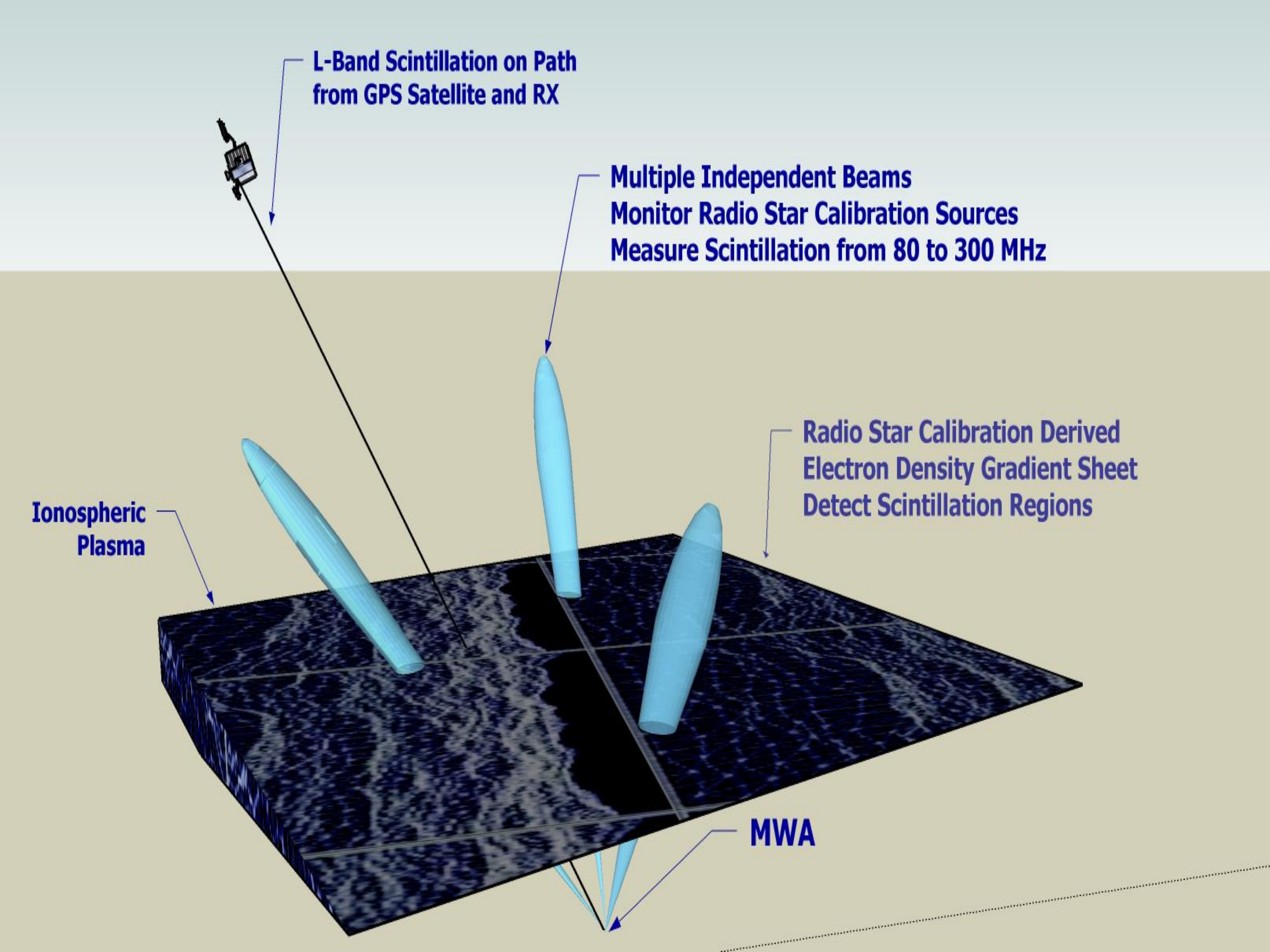




TEC Data collected at MWA site November 2007
SED
10 TECU
35
30
25
20
15
10
5
0
315
315.5
316
316.5
317
317.5
318
318.5
319

Differential TEC derived from Measured Offsets of Radio Sources




L-Band Scintillation on Path
from GPS Satellite and RX
Multiple Independent Beams
Monitor Radio Star Calibration Sources
Measure Scintillation from 80 to 300 MHz
Radio Star Calibration Derived
Electron Density Gradient Sheet
Detect Scintillation Regions
Ionospheric
Plasma
MWA


Hydra A
SNR
Vela
(SNR)
Puppis A
(SNR)

Current Status

- On track for commencement of regular observing cycles from June 2013.
- The 1st 6 months will be only for Project Members
- Beyond that there will be some Open Access observing time. The MWA is required to follow an 'Open Skies' policy. It will be possible for people from across the world to apply for observing time and use it.