Solar, Heliospheric and Ionospheric SWG

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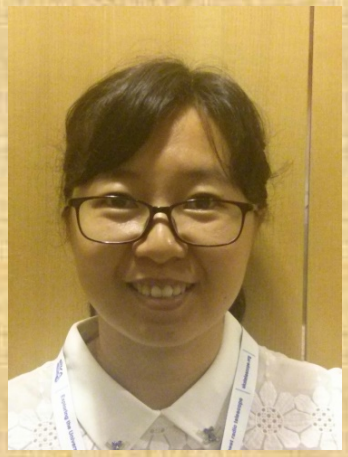

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NAO, China

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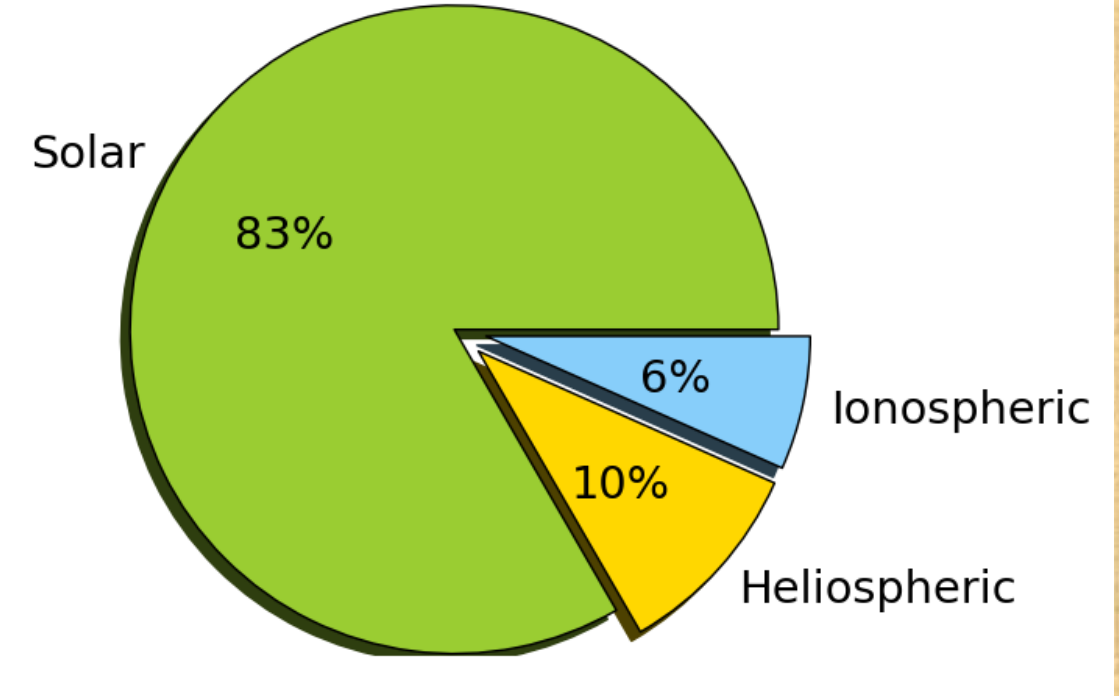
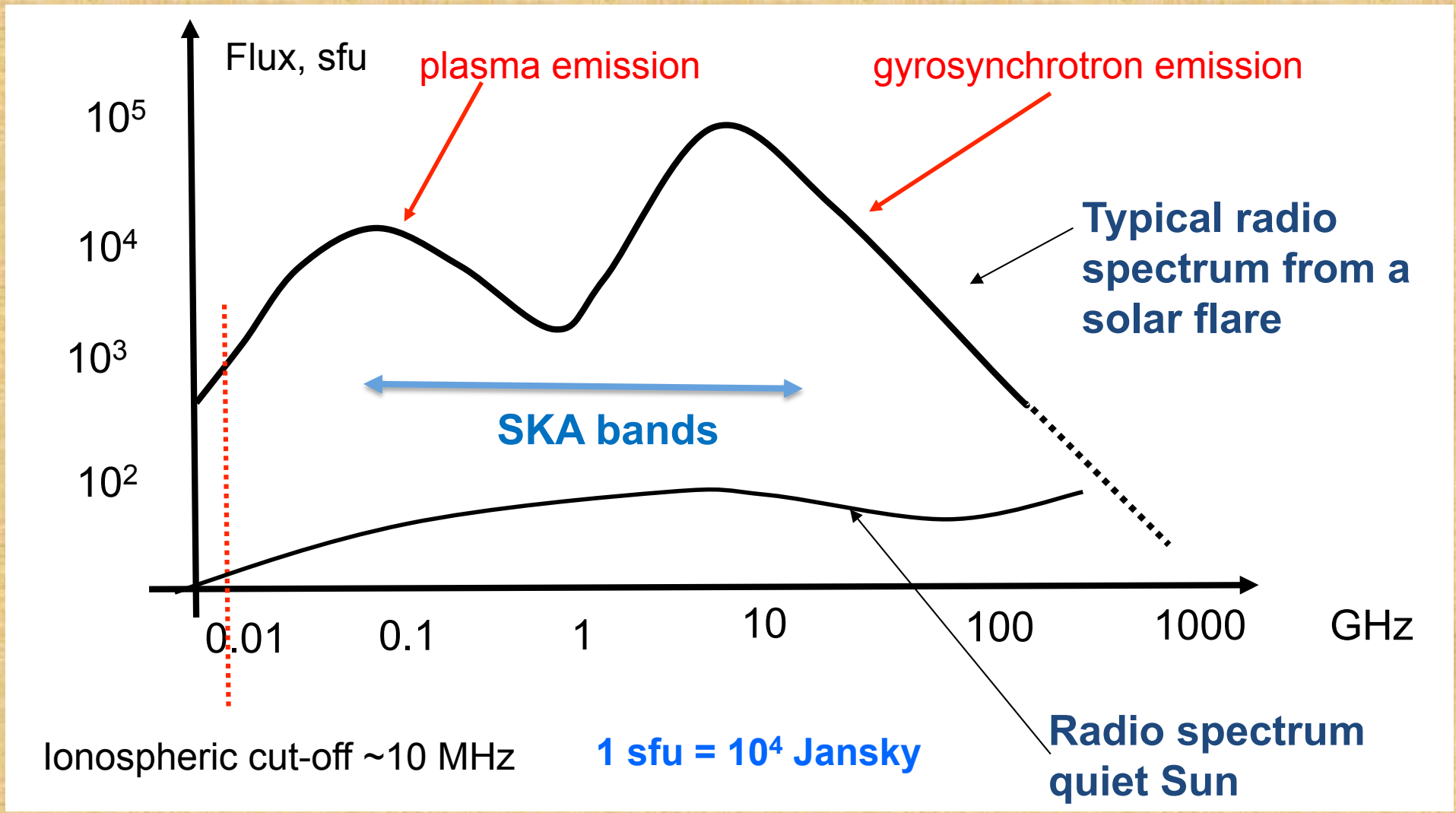
FCUP, Portugal

SKA SHI SWG

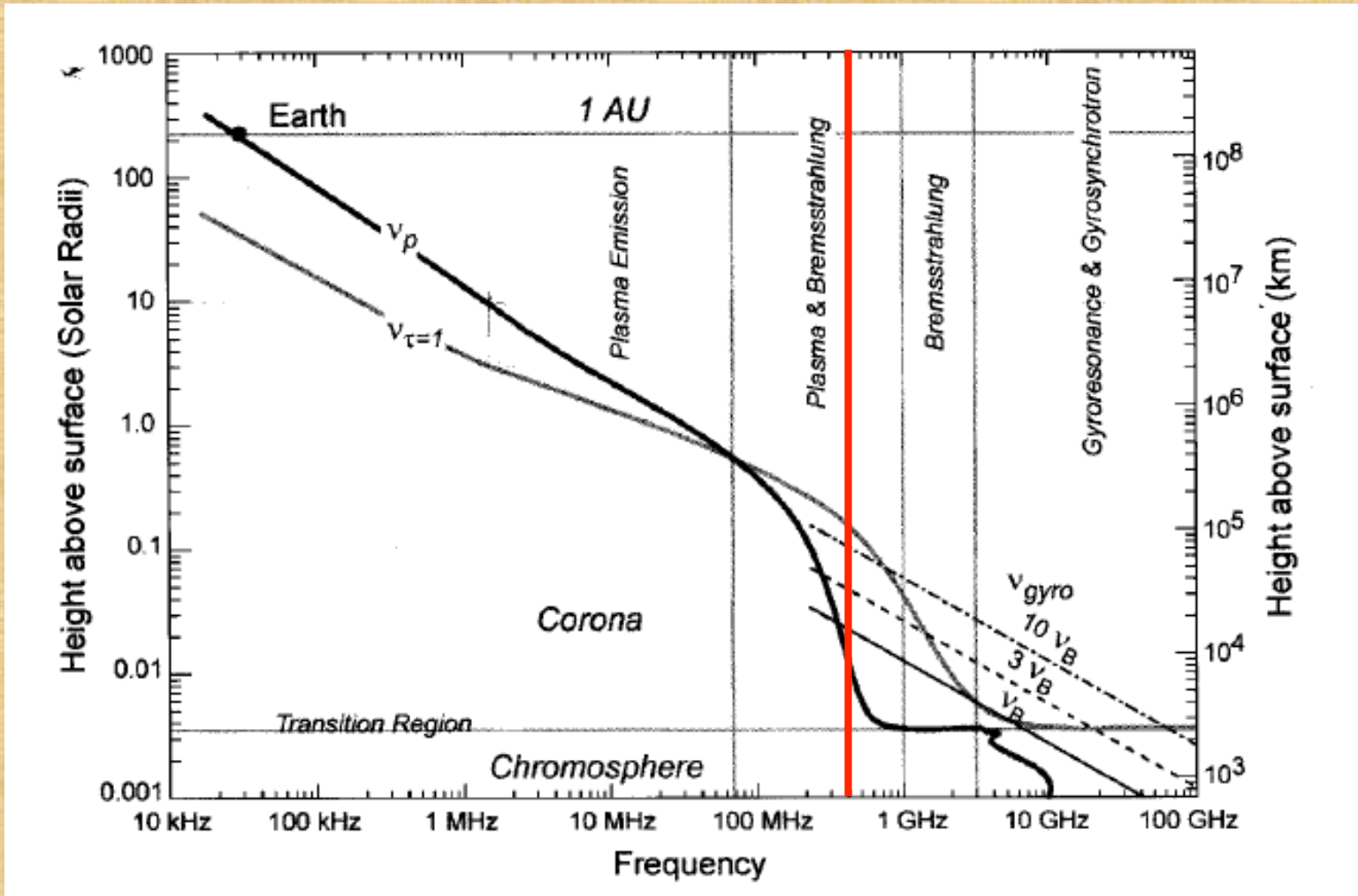
- Solar, Heliospheric and Ionospheric SWG
- Formally established in May 2015
- ~60 members; 22 Countries; 6 Continents
- Scientific Interests



Solar Spectrum



Characteristic frequencies and emission mechanisms



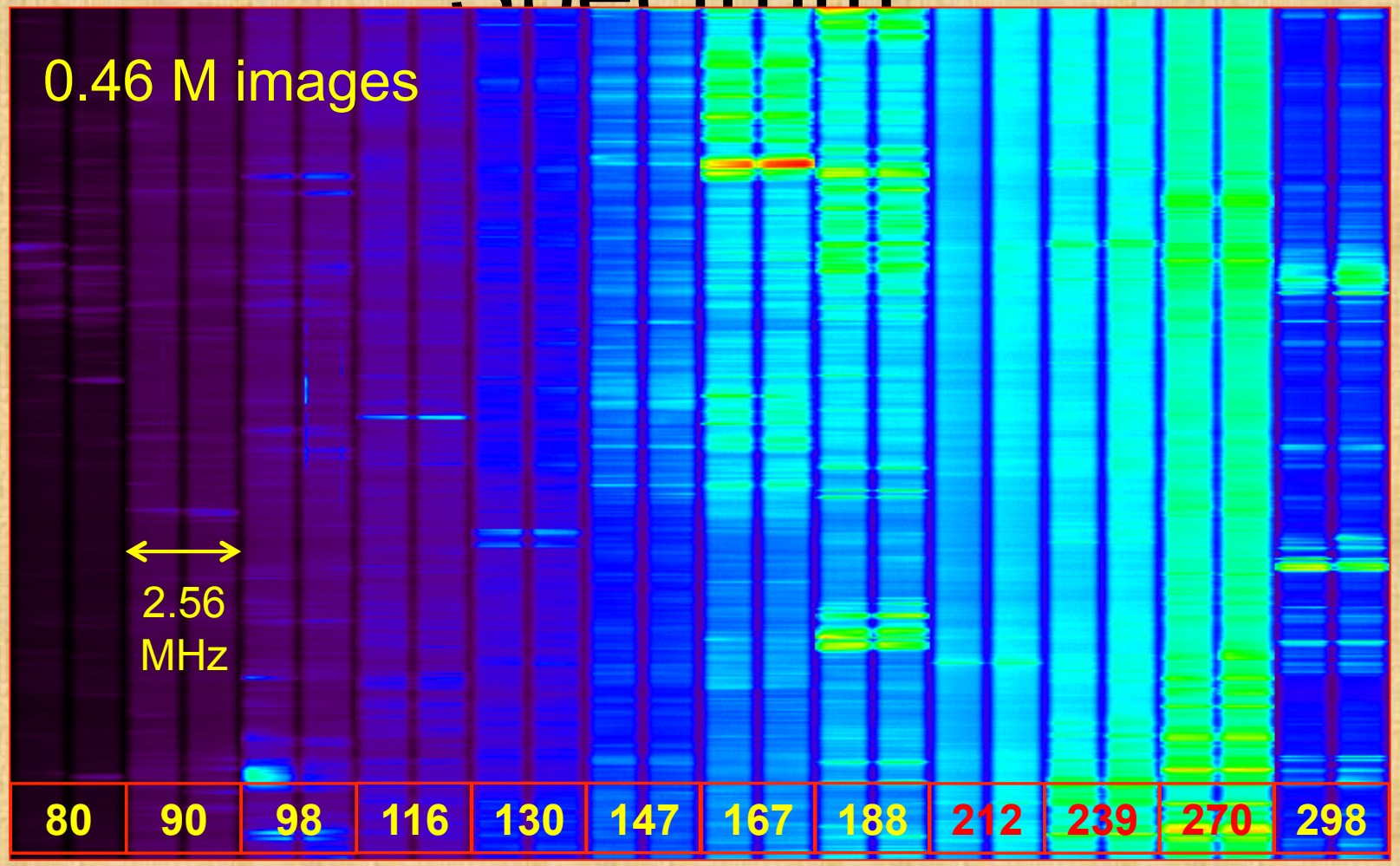
Plasma freq.
$\nu_p \approx 9 \times 10^3 N_e^{1/2}$

Free-free emission
$\nu(\tau_{ff} = 1) \approx 0.5 N_e T_e^{-3/4} L^{1/2}$

e gyro freq
$\nu_B \approx 2.8 \times 10^6 B$

Gary and Hurford, 2004

Sample MWA Dynamic Spectrum



Time (5 min)

Frequency
(12 log-spaced groups of 2.56 MHz spanning 80 – 300 MHz)

Key aspects to consider

- Very strong signal
  - Need solar attenuators? (esp. for higher SKA1-Mid bands)
  - Limited by ‘source noise’
  - Calibration issues
  - Van-Vleck corrections become important
- Dynamic and spectrally complex
  - No time or frequency synthesis
  - Large computational load
  - Extraction of relevant information from images

Key aspects to consider…

- Emission at a large range of scale sizes (deg – arcsec) and complex morphology
  - An array configuration optimized for instantaneous and monochromatic imaging
- Emission mechanisms spanning a huge range in T_B (>10^10 K)
  - Very high imaging dynamic range

Science Targets

- Quiet Sun
- Observations of QPOs
- Active region dynamics
- Particle acceleration
- Shocks
- Coronal heating

Heliospheric Science: The low-radio frequency advantage

- Propagation effects make excellent probes for the Corona and the Heliosphere
  - Interplanetary Scintillation (Ne fluctuations, speed)
  - Faraday rotation (B field, Ne distribution)

Access to small-scale structure and dynamics not accessible by other means (micro-turbulence)

B field orientation in CMEs – key for predicting their geo-effectiveness – huge societal impact

Interplanetary Scintillation

- IPS (time series)
  - SKA1-Low multi-beaming capability
    - Commensal with day time imaging observations?
  - Real time data processing requirements
    - Time series with comparatively coarse time and freq resolution (~10ms, few MHz)
    - Subset of pulsar observing setup
  - Triggered and monitoring observations
- IPS in the image plane?
  - Recent MWA observations show evidence for IPS during night-time observations (ε>140°)

    Kaplan et al., 2015

FR: High risk but high returns

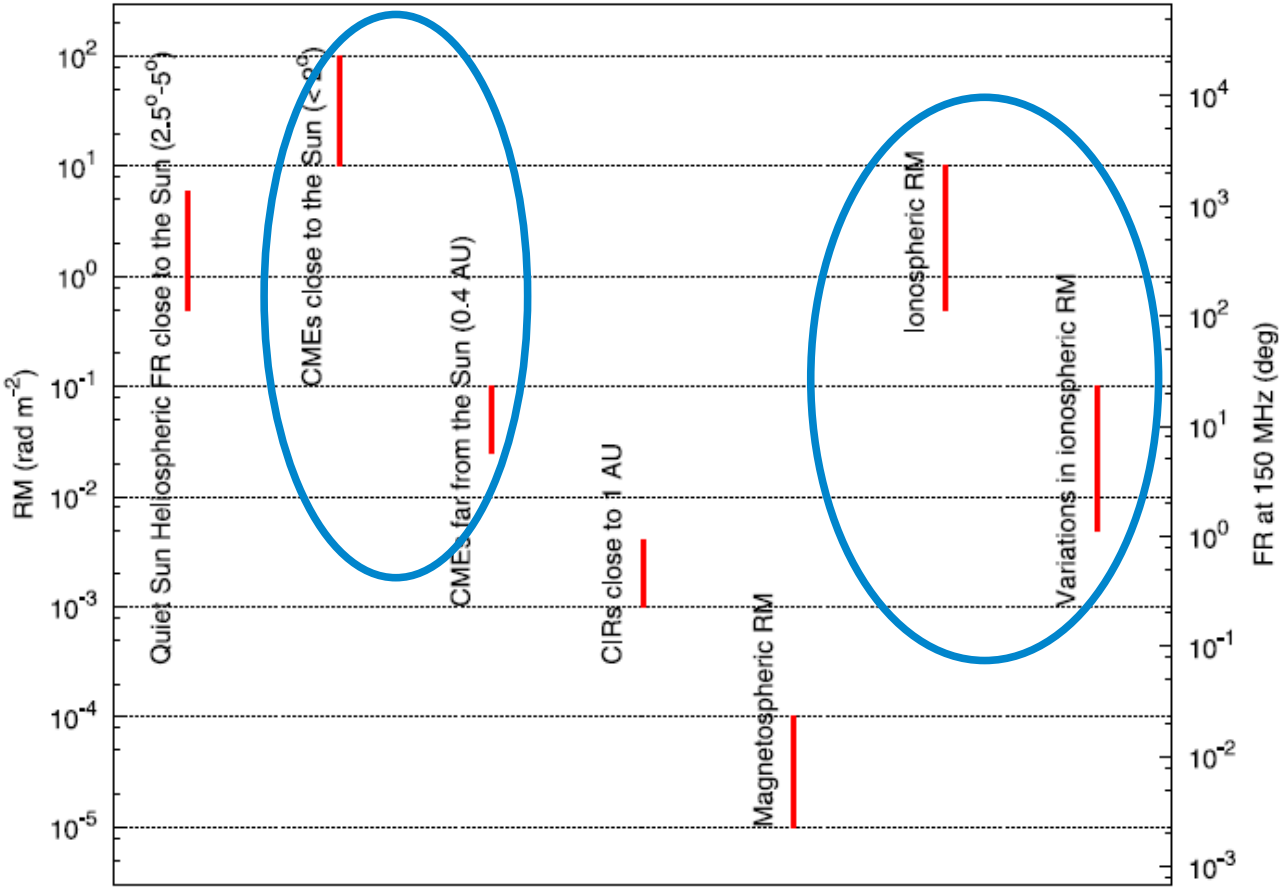


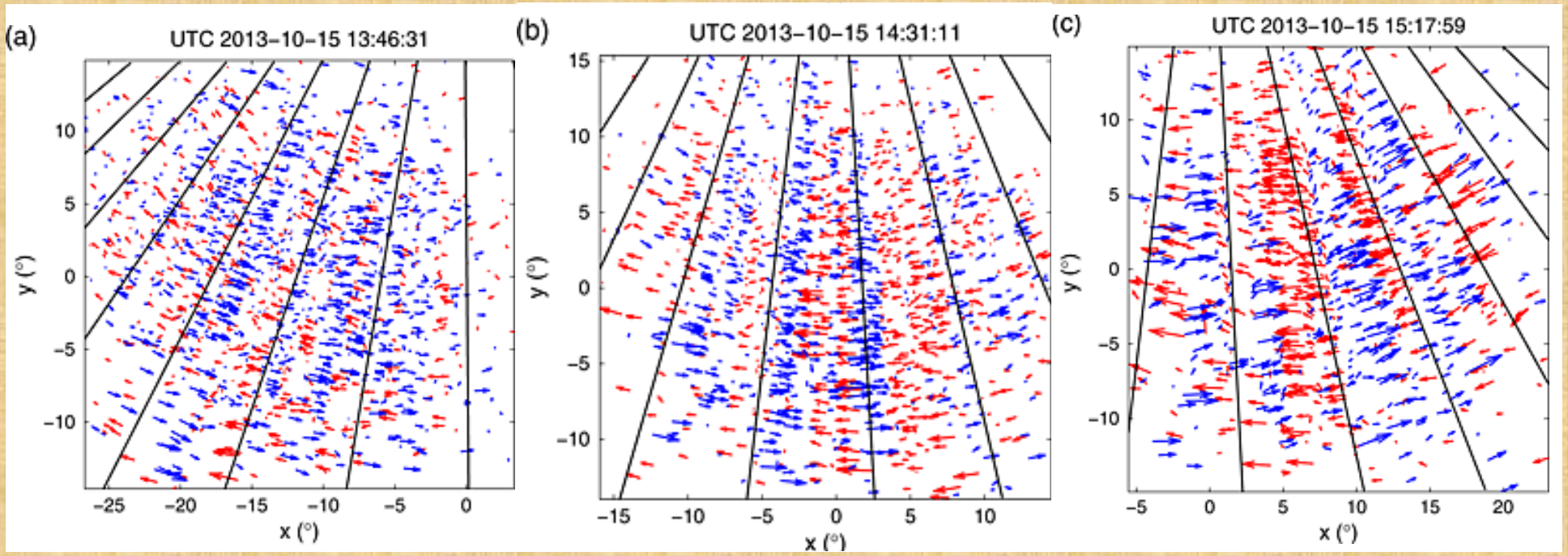
Figure 2. Figure 2 provides an overview of the expected magnitudes of RM due to the heliospheric, magnetospheric and ionospheric (and plasmaspheric) plasmas. The corresponding FR (in deg) at 150 MHz is also indicated. A range of a factor of two below and above the numbers computed in the text has been assumed where needed.

Oberoi and Lonsdale, Radio Science 2012

Impact of ionospheric propagation

- Refractive shifts and distortion in image plane
  - Gradients in Ne along the ray path
- Change in plane of linear polarization
  - Ne profile and component of **B** along LoS
- *Need an independent measurement of Ne (GPS TEC)*
  - *Interferometric phase insensitive to total Ne*
  - *FR depends on the total Ne*
- Attenuation
- Time and direction dependent
- Known spectral dependence

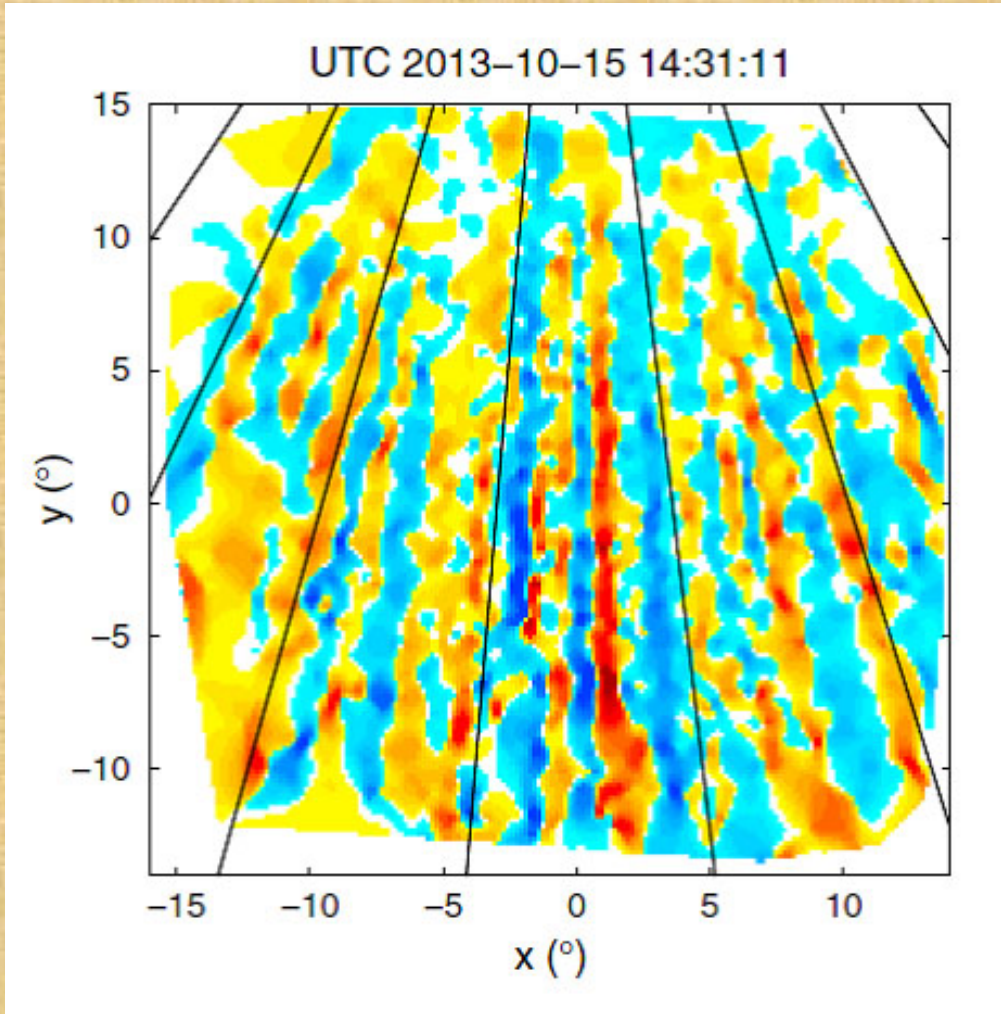
Refractive shifts due to ∇TEC



- 183 MHz, BW=30.72 MHz
- 30°x50° patch of sky
- 1.5 hr period (15 Oct, 2013)
  - (21:45-23:18) local time
- ~1000 sources
- Arrows 50x actual refractive shifts
- 1°=10 km @ 600 km altitude

Loi et al, GRL, 2015, **42**,

Gradient field



- Reds – 0verdense
- Blues – Underdense
- Height ~600 km

- First direct detection of field aligned plasma ducts connecting plasmasphere and ionosphere using the MWA

Loi et al, GRL, 2015, **42**,

Commensal Observations

- Ionospheric Science
  - All SKA1-Low observations
- Heliospheric Science
  - Likely all SKA1-Low observations (ORT catalogue ~3000 sources).
- Solar Science
  - None for SKA1-Mid
  - Probably none for SKA1-Low
- Strong overlap/Commanalities
  - Techniques and tool kits
  - Data products from other KSPs/SWGs

Observing Needs

- Monitoring observations
  - Sun and Heliosphere
- Ability to respond to triggers (order ~min)
  - Satellite based (X-ray flares, Coronagraphs)

Activities of the SHI SWG

- Monthly telecons
- A list of science objectives and volunteers identified for writing ‘use cases’ for each of them.
  - Do we need any Engineering Change Proposals?
- Plan to feed them back to the SKA Project Office.

Use Cases

1. **Solar Science**
    1. Quiet sun, activity level threshold?, excluding known solar radio bursts (the emission outside active regions)
    2. Quasi-periodic oscillations (MHD waves)
    3. Relativistic (high energy particles), gamma-ray producing electrons (>100 keV)
    4. Particle acceleration
    5. Transport of Escaping electrons (type III)?
    6. Type II shocks and CMEs
    7. Active regions /coronal heating
    8. Signatures of reconnection at radio frequencies (MHD scales of flaring)?
    9. Long-term variability (evolution) of the solar radio emission
2. **Heliospheric Science**
    1. Interplanetary Scintillation
    2. Faraday rotation
3. **Ionospheric Science**

Conclusion

- High impact key science drivers
- Unprecedented range of complementary information from a host of other observatories
- A scientific community willing to put in the effort to pursue them
- Plan to engage with other SWGs and the SKA Project Office (esp. over the next few days)
  - Identify commonalities and areas of overlap
  - Feedback needs of SHI science to the SKA Project