Current State of Reduced Solar Activity: Space Weather Events in the Inner Heliosphere

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The UN/USA Workshop on International Space Weather Initiative:
The decade after the International Heliophysical Year 2007
31 July – 4 August 2017, Boston College
Remote sensing the inner heliosphere
Interplanetary scintillation (IPS)

In the Sun-Earth distance
Full range of helio latitudes
**Interplanetary Scintillations (IPS)**

- Caused by density irregularities moving radially outward from the Sun
- Appropriate inversion of IPS provides speed and level of density turbulence in the solar wind

![Graph showing scintillation record](image-url)

*Scintillation Record (3C273, 22OCT2009)*

- Intensity vs. Samples (each 20 ms)
Coronal mass ejections (CMEs) are responsible for most of large magnetic disturbances at the Earth.

- CME speed ranges between $\sim 100 – 3000$ km/s
- Evolution of magnetic field, size, speed, direction – important to predict the impact on the Earth
- Plus evolution of shock associated with a CME

IPS technique is useful to track CMEs in the Sun-Earth distance

- Each day IPS can provide snapshot images
- Routine monitoring of IPS on a large number of sources and the tomography reconstruction can provide the 3-D evolution of heliosphere
IPS – Radio Arrays

- Several radio telescopes are employed in IPS studies
  - Ooty Radio Telescope (327 MHz)
  - Solar-Terrestrial Environment Laboratory (327 MHz)
  - MEXART (140 MHz)
  - MWA
  - LOFAR
  - BSA (Russian) array ~110 MHz
  - EISCAT
  - Korea Space Weather Center (327 MHz)
  - Urumqi (NAOC) + Kunming 40m Radio Telescope
    - Solar wind speed
    - Density turbulence level - efforts to combine data
Ooty Radio Telescope

- 327 MHz
- 530m (N-S) x 30m (E-W) – equatorially mounted – (E-W) tracking ~9.5 hours
- North-South beam steering (± 65 deg. declination)
  - Sensitive telescope – observes ~1000 radio sources per day
  - Upgraded (~5 times more sources can be observed)

Ooty IPS measurements provide estimates of

- solar wind velocity
- δNe level (g-value)
- at a heliocentric distance range of 10 – 250 R⊙
- at all helio latitudes
Lines of sight typically observed at Ooty in a day (2-AU cube)

These measurements can provide 3-D view of solar wind speed, and density turbulence of scale size 10 – 500 km
Fast and wide CMEs
June 21 – 24, 2015

Evolution of CMEs
(Sun to 1 AU distance)
CMEs in the inner heliosphere
IPS images during 19 – 26 June 2015
Solar rotation and radial outward flow of the solar wind provide the 3-d structure of the solar wind at different view angles.

Computer Assisted Tomography analysis can remove the line-of-sight integration imposed on the solar wind parameters and also provides high spatial resolution.
UCSD 3-D Reconstruction of Ooty IPS

$n^{\text{norm}} \left( \text{cm}^{-3} \right)$
21 – 27 June 2015 CMEs

SEP Events

Five IP Shocks at 1 AU
+ intense and moderate geo-magnetic storms
UCSD 3-D Reconstruction of Ooty IPS

Manoharan et al. (2016)
IPS observations provide a global view of the heliosphere
IPS observations provide a global view of the heliosphere
“in-situ” measurements close to Earth’s orbit
Thank You