Fermi in the New Era of Radio Astronomy

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Current suite of radio arrays

- Very Large Array
- Westerbork Synthesis Radio Telescope
- Australian Telescope Compact Array
- Giant Metrewave Radio Telescope
- Ryle Telescope
- European VLBI Network
- Very Long Baseline Array

Larger – deeper – faster

- Very Large Array → Jansky Very Large Array
- Westerbork Synthesis Radio Telescope → Apertif
- Australian Telescope Compact Array
- Giant Metrewave Radio Telescope
- Ryle Telescope → Arcminute Microkelvin Imager
- European VLBI Network → e-EVN
- Very Long Baseline Array

New kids on the block

- Low Frequency Array
- Long Wavelength Array
- Murchison Widefield Array
- MeerKAT
- Australian Square Kilometer Array Pathfinder

Square Kilometer Array

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The (near) future looks radio bright!

Square Kilometer Array

Exploring the low frequency radio sky

- Epoch of Reionisation (redshifted HI & CO lines):
  - first structure formation during dark ages
- Deep extragalactic surveys (continuum & lines):
  - high-z galaxies, clusters, cosmic star formation history
  - AGN physics & evolution
- Cosmic magnetism (polarization surveys):
  - magnetic field evolution in galaxies over cosmic time
- Ultra high energy cosmic rays
- Solar science & space weather
- Transient sources

The transient low frequency radio sky

Incoherent emission

- Relatively slow variability
- Found mostly in images
- Explosive events & jet sources
  - Gamma-ray bursts
  - Supernovae
  - Magnetars
  - X-ray binaries
  - Active Galactic Nuclei
  - Tidal disruption events

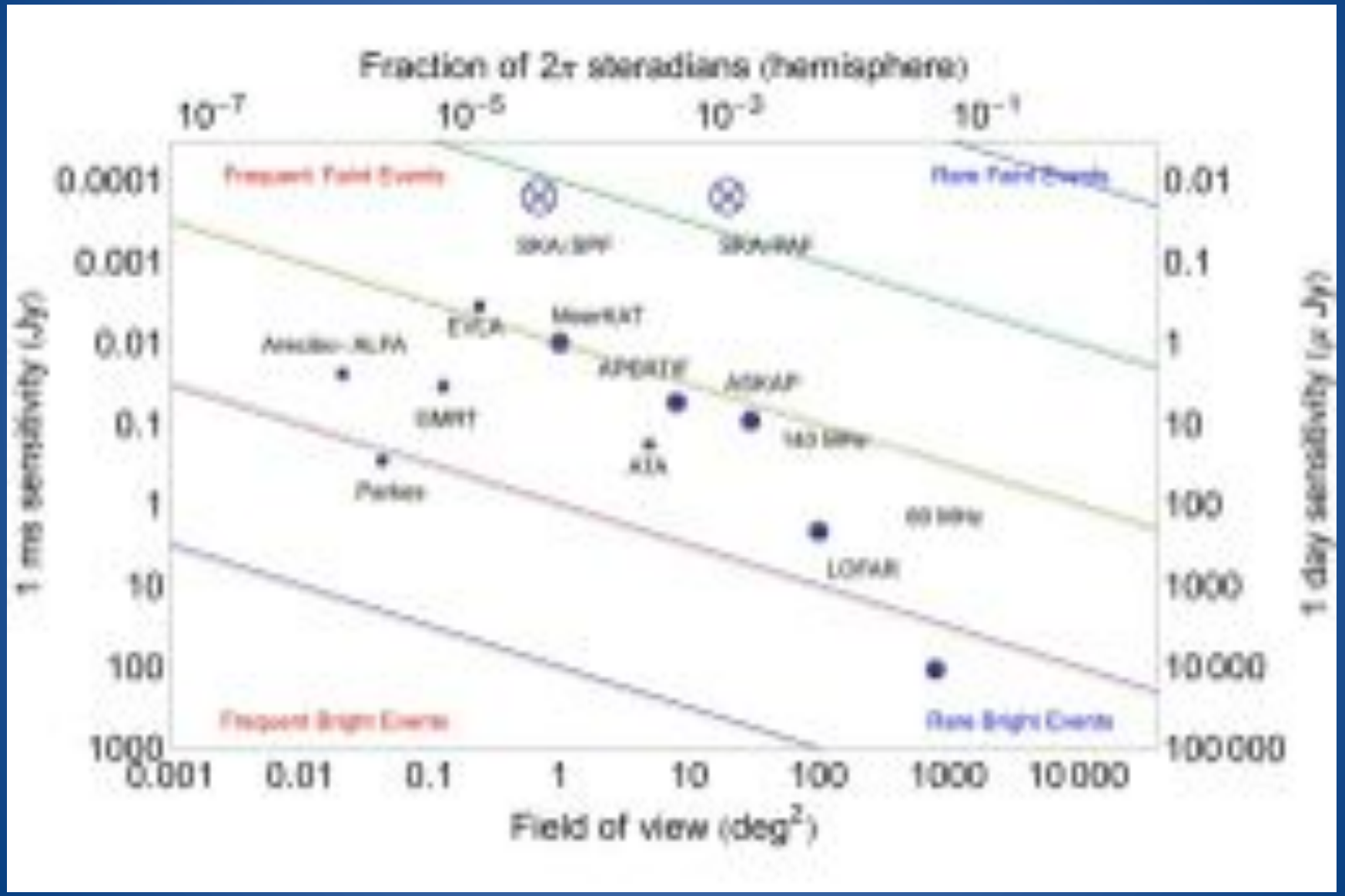
Coherent emission

- Relatively fast variability
- Found mostly in time series
- Largely unexplored, exciting new science
  - Theoretical predictions, e.g. GRBs
  - Possible Lorimer bursts

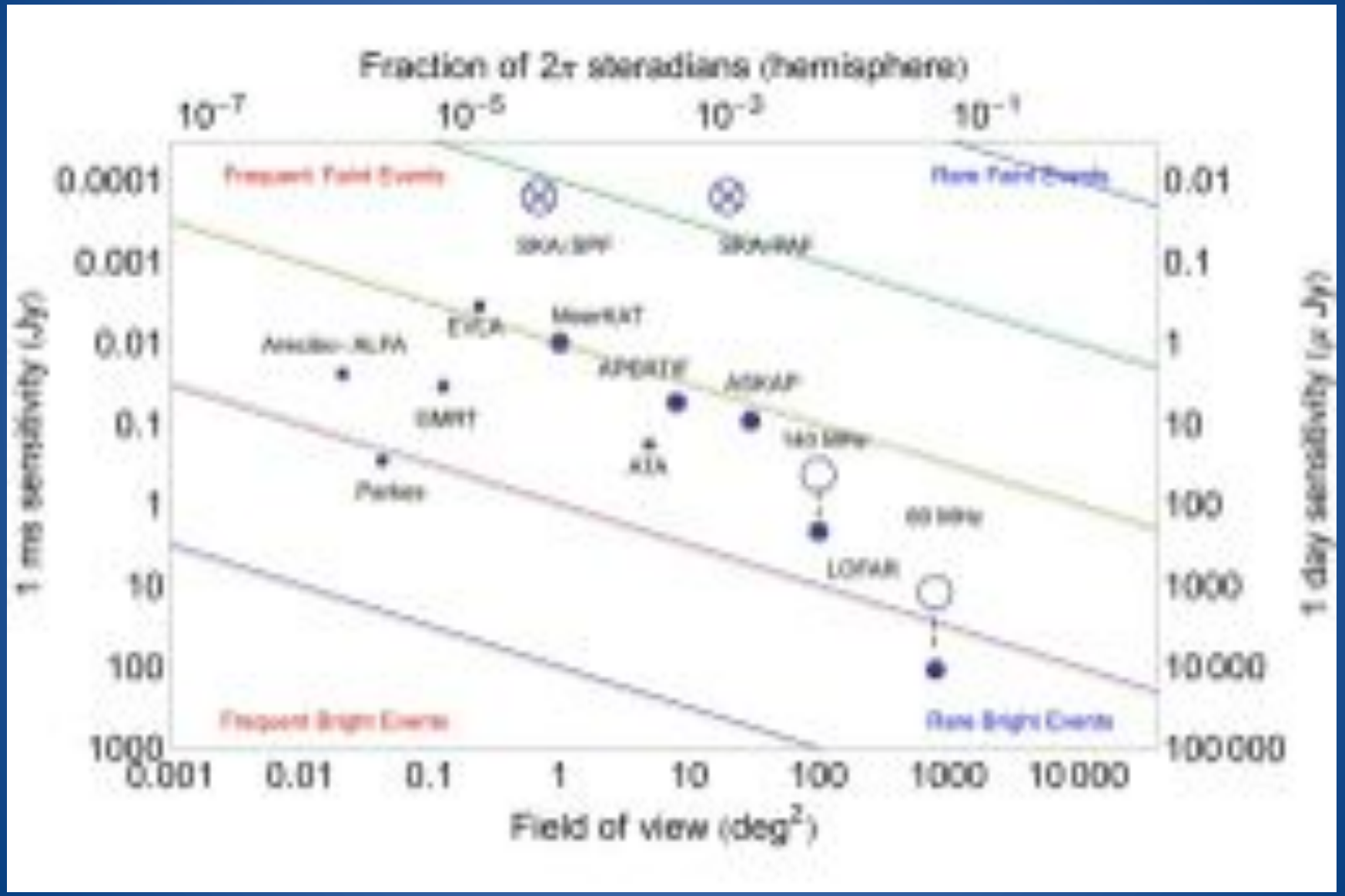
Low Frequency Array (LOFAR)

International LOFAR Telescope

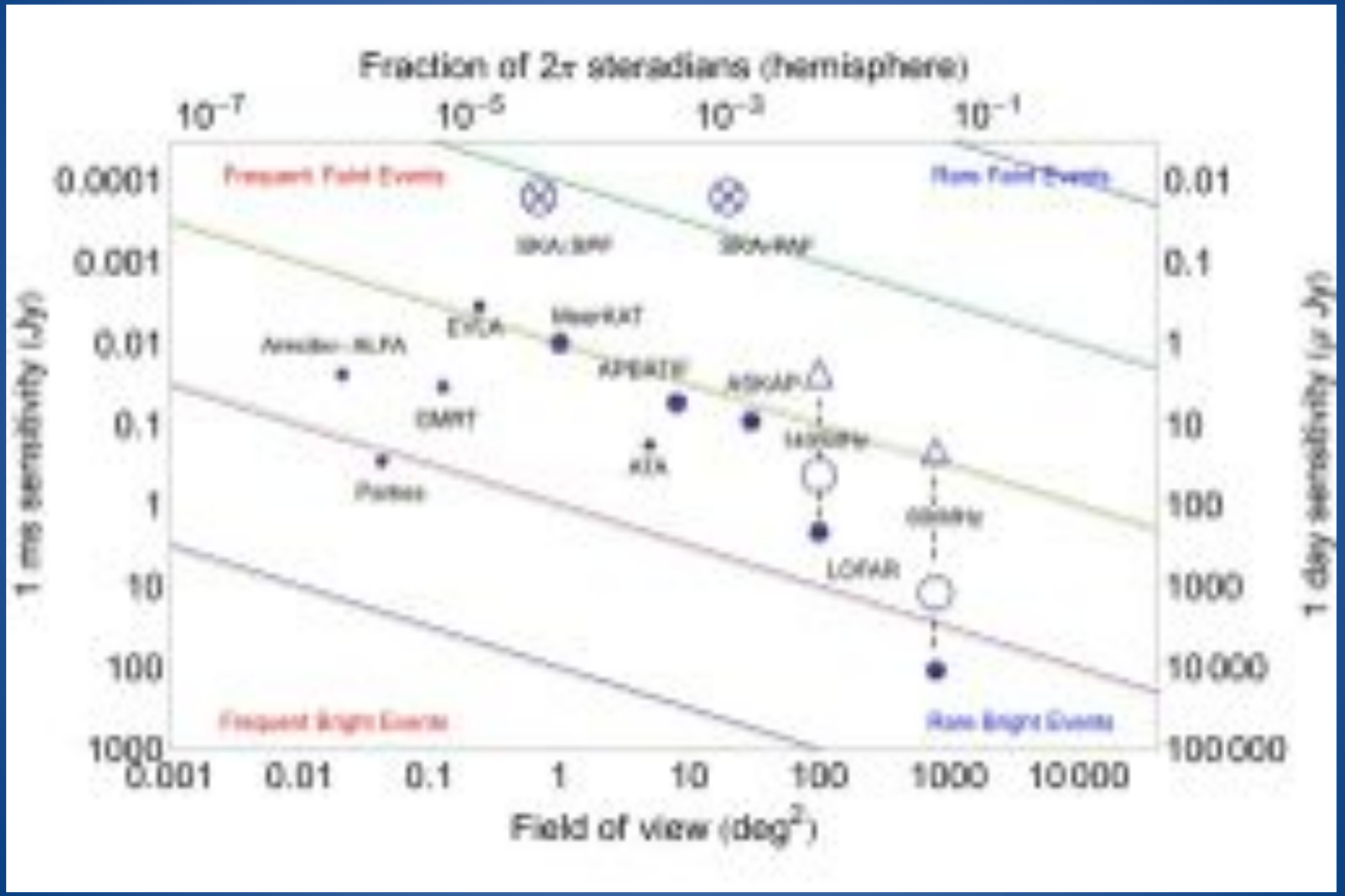
Imaging survey speed



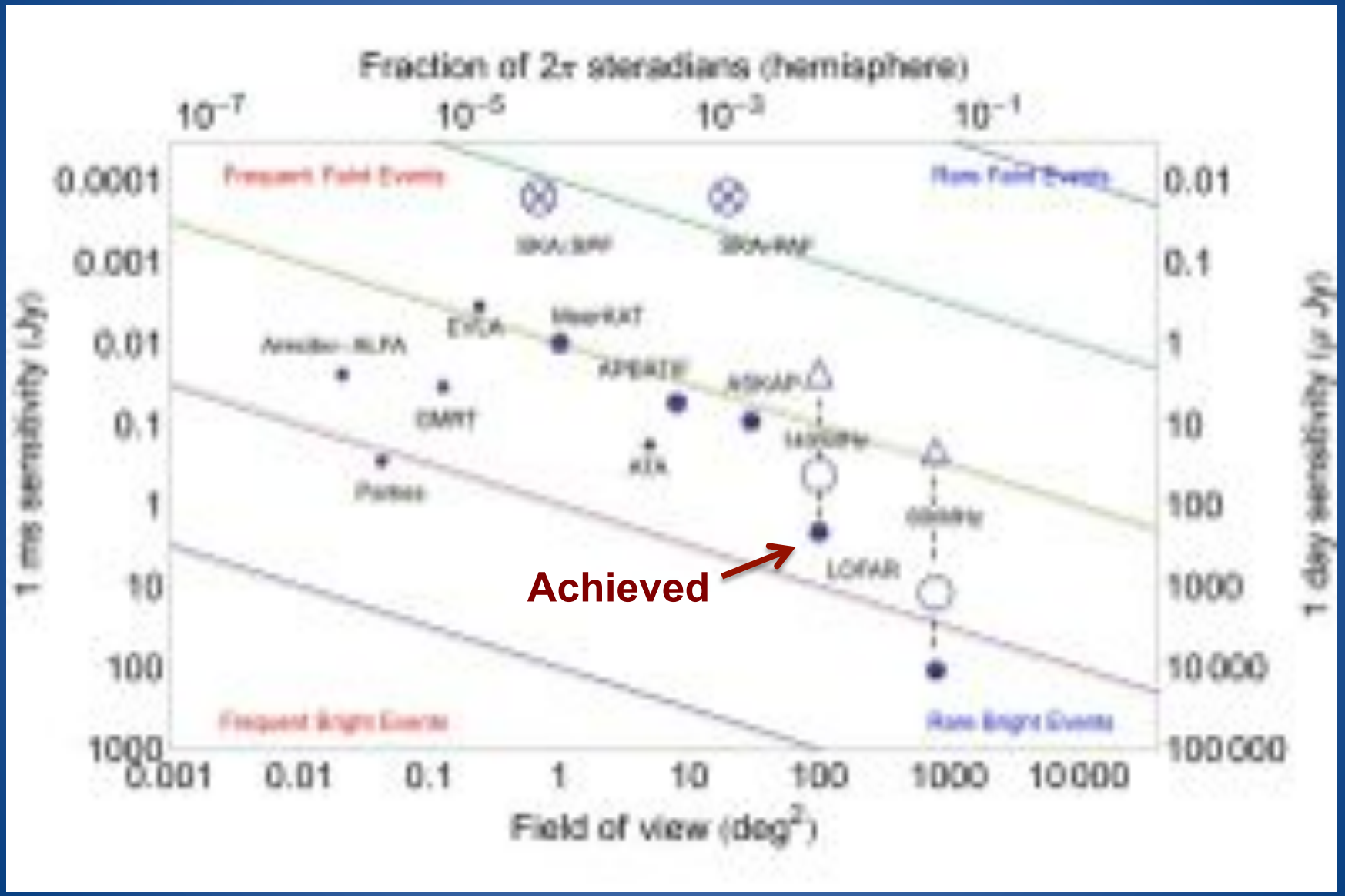
LOFAR with -0.7 spectral correction



LOFAR with -2.0 spectral correction

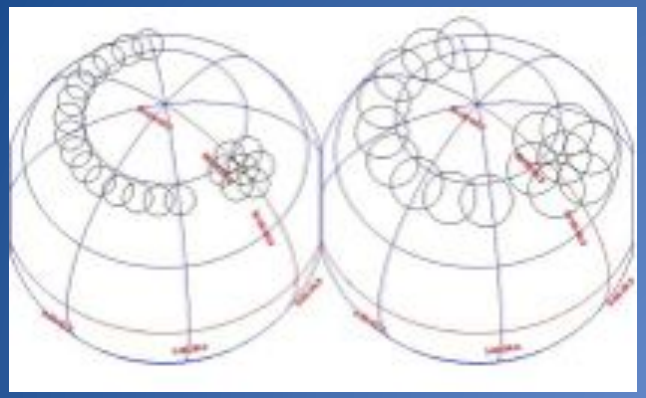


LOFAR with -2.0 spectral correction



Transient hunting with LOFAR

- Radio Sky Monitor / Zenith Monitoring Program

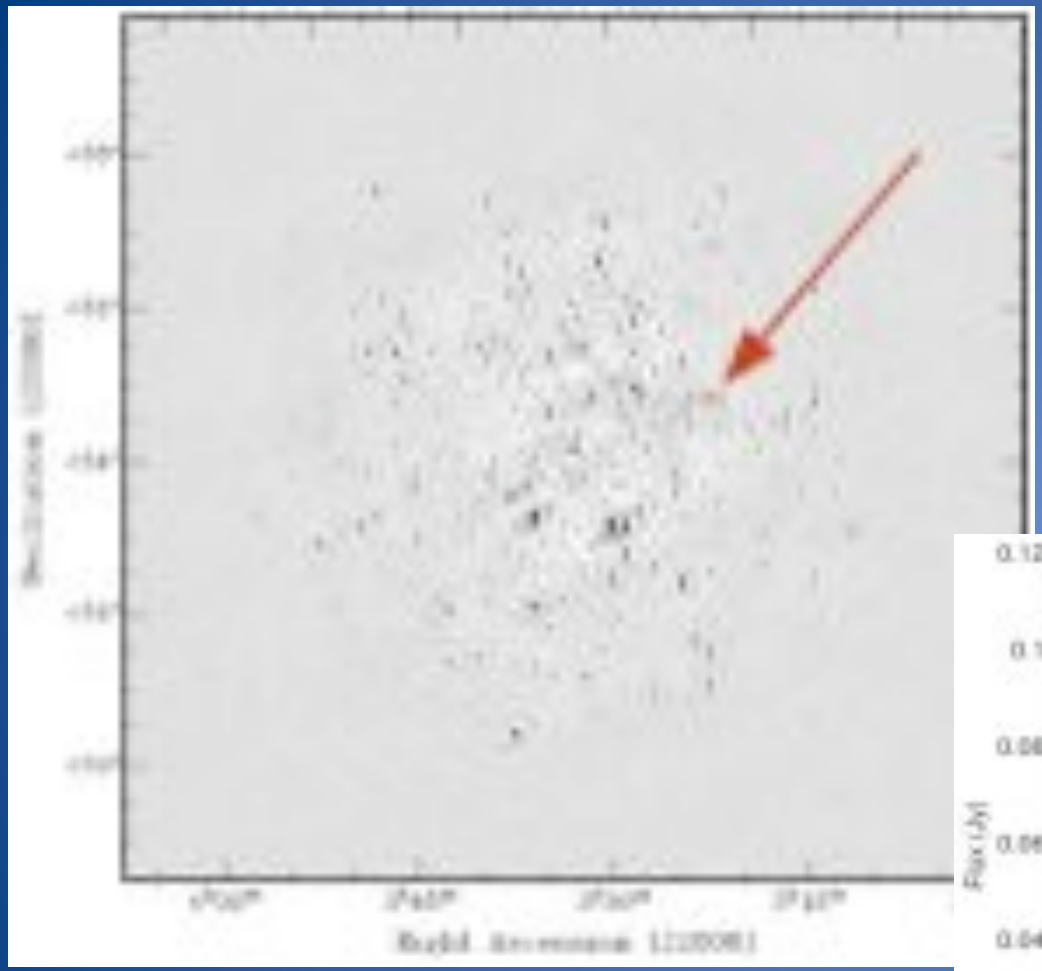


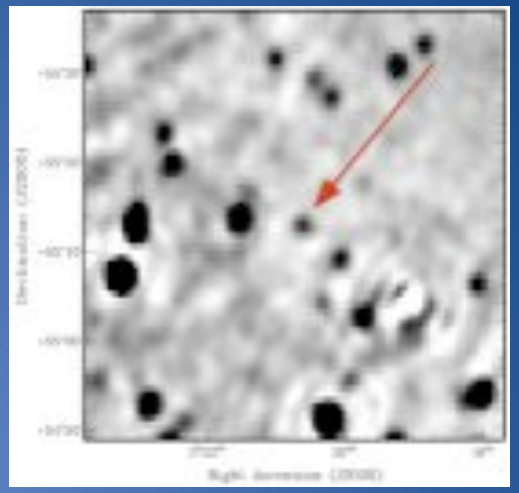
  - Eight 7-beam LBA tiles (4500 deg^2)
  - Fourteen HBA tiles (1400 deg^2)
  - Phases with daily monitoring
    → mJy sensitivity

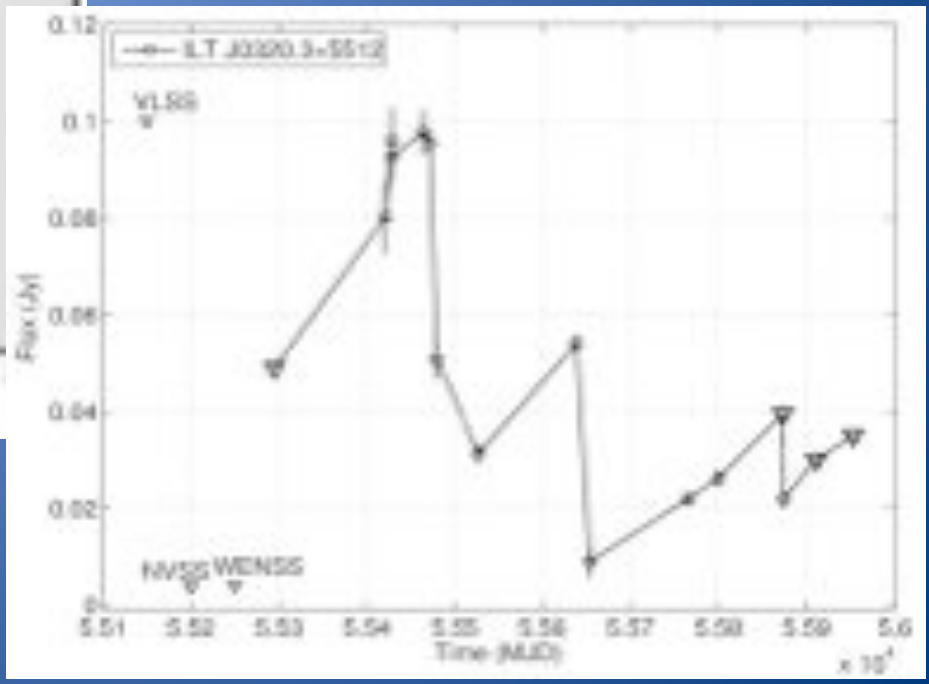
- AARTFAAC
  - 24/7 all-sky monitor with 6 central stations
  - Piggy-back mode in all LOFAR observations
  - LBA: whole sky, HBA: 1000 deg^2

- Transient Buffer Boards
  - 5 second storage
  - Dispersion delay → subband approach

First LOFAR transient







- ~100 mJy, varying by factor 10
- No counterpart or pulsations
- Nature unkown

Broderick et al. 2012

LOFAR transient searches

- Multifrequency Snapshot Sky Survey
  - Transient search in all fields, incl. 10 minute snapshots
  - Simultaneous observations of North Celestial Pole:
    280 images so far → no transients found at Jy level
- LOFAR Cycle 0 starting in December
- Proposed coordinated observations with PanSTARRS and Palomar Transient Factory
- Very recently: LOFAR UK-Chibolton responding to Fermi & Swift GRB triggers (1 hour follow-up)
  → first data taken after 20 seconds!

LOFAR-GBM correlative studies

- Fermi Guest Investigator program
  - AJvdH, Kouveliotou, Younes, Wijers, Fender, Stappers
- Large fields of view & transient search capabilities
- Gamma-ray bursts:
  - Searching for radio coherent emission → GBM triggers
  - GRB energetics: prompt gamma-rays vs late-time radio
- Magnetars:
  - Bursts and pulsed emission
  - Giant flares
- Serendipity

Conclusions

- Dawn of a new radio era:
  - Upgrades of new facilities
  - Square Kilometer Array pathfinders
  - Large fields of view
  - Unprecedented sensitivity in broad radio bands
  - Extensions of the frequency & time domains
- Synergy with Fermi:
  - Extragalactic surveys
  - Transients at various timescales