



CAASTRO
ARC CENTRE OF EXCELLENCE
FOR ALL-SKY ASTROPHYSICS



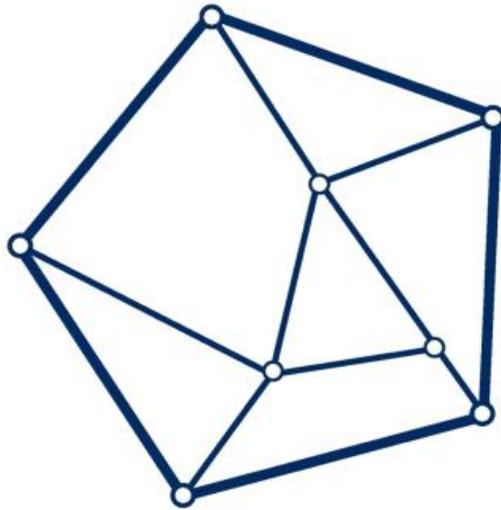
International
Centre for
Radio
Astronomy
Research



Curtin University



**THE UNIVERSITY OF
WESTERN
AUSTRALIA**



Sub-arcsec compact source population and their properties at low frequencies using the MWA

Rajan Chhetri (ICRAR-Curtin)

John Morgan (ICRAR-Curtin)

J-P Macquart (ICRAR-Curtin)

Ron Ekers (CASS)

Elaine Sadler (Usyd)

Marcello Giroletti (INAF)

Joe Callingham (ASTRON)

Steven Tingay (ICRAR-Curtin)



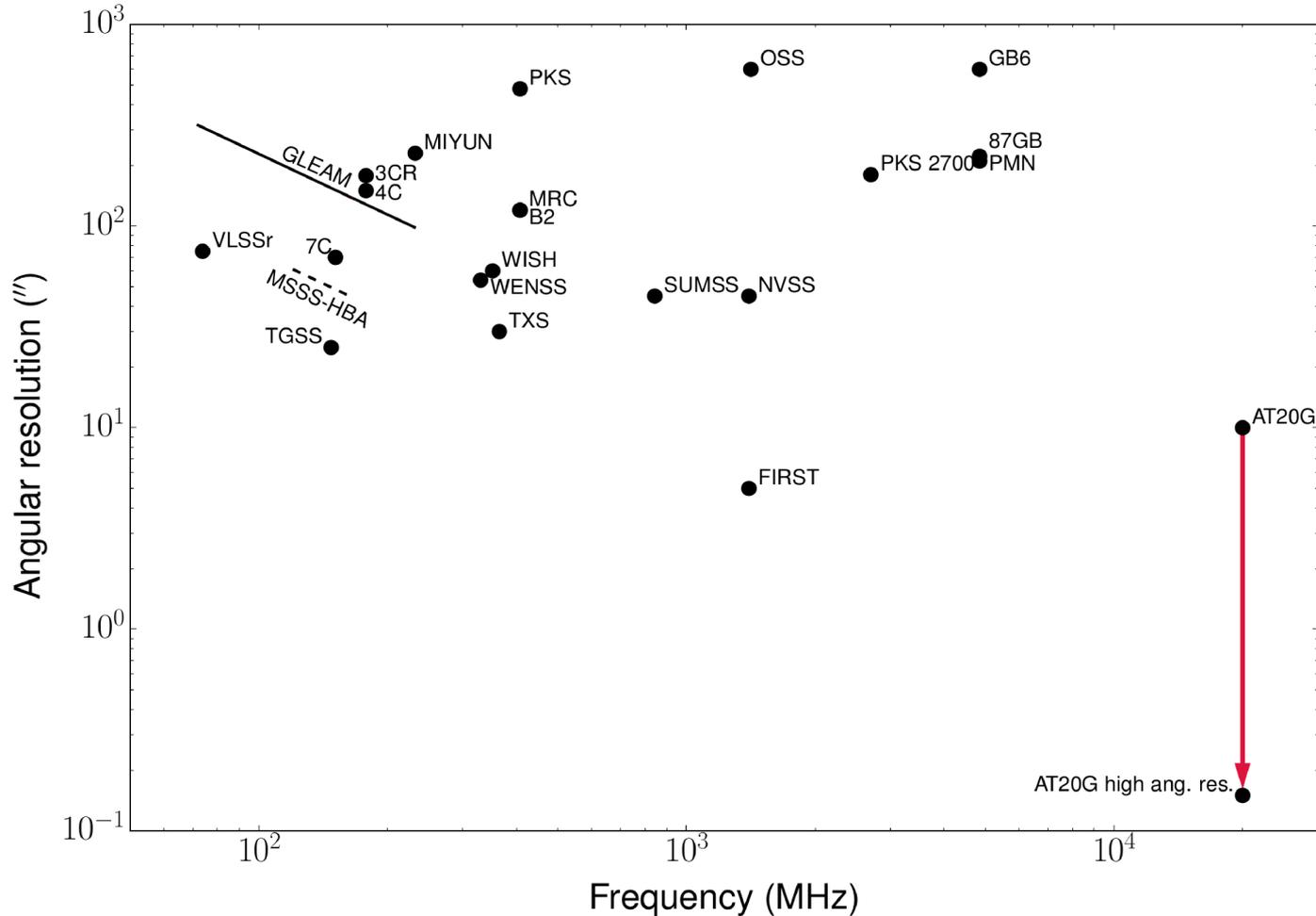
Australian Government

Australian Research Council

SPARCS VII – The Precursors Awaken (19 July 2017)



Large Area Surveys and Angular Resolutions





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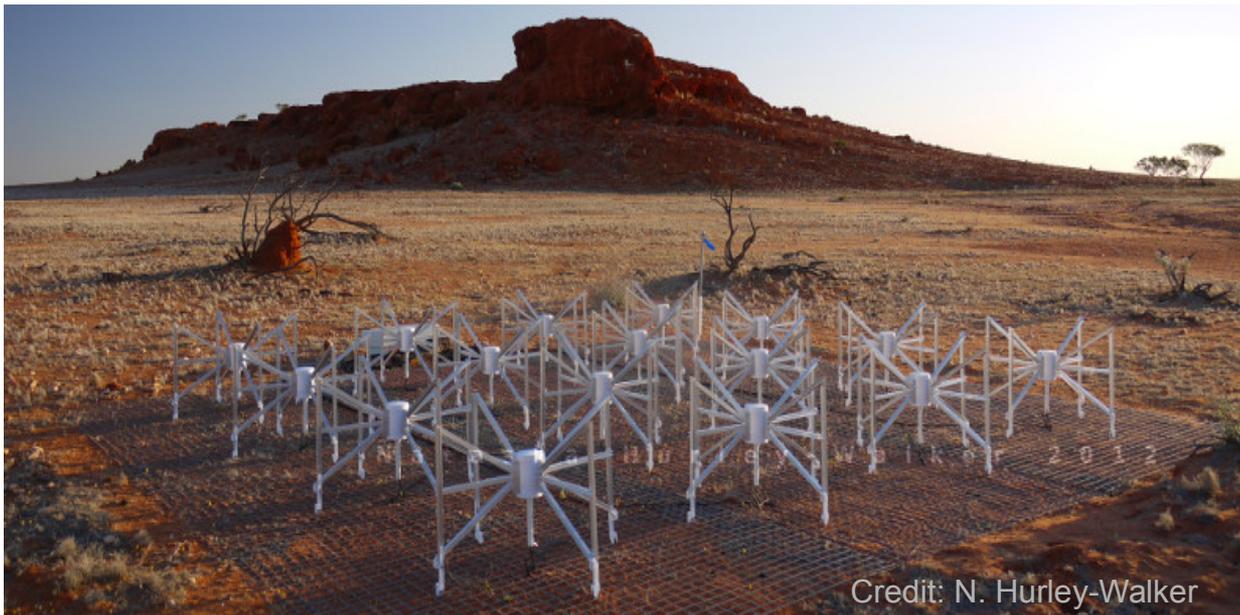
The Opportunity

The Murchison Widefield Array (Western Australia)

128 tiles with 2 x 16 dipoles each

Operating frequencies: 80 – 300 MHz

Bandwidth: 30.72 MHz



Credit: N. Hurley-Walker



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Typical MWA field



Angular resolution $\sim 2'$



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MWA field in TGSS



Angular resolution $\sim 25''$

Field of View: 15 – 50 degrees (200 – 2500 sq degrees)

Very large number of sources in the field of view

Angular resolution (3-km array) at 150 MHz > 2 arcmin

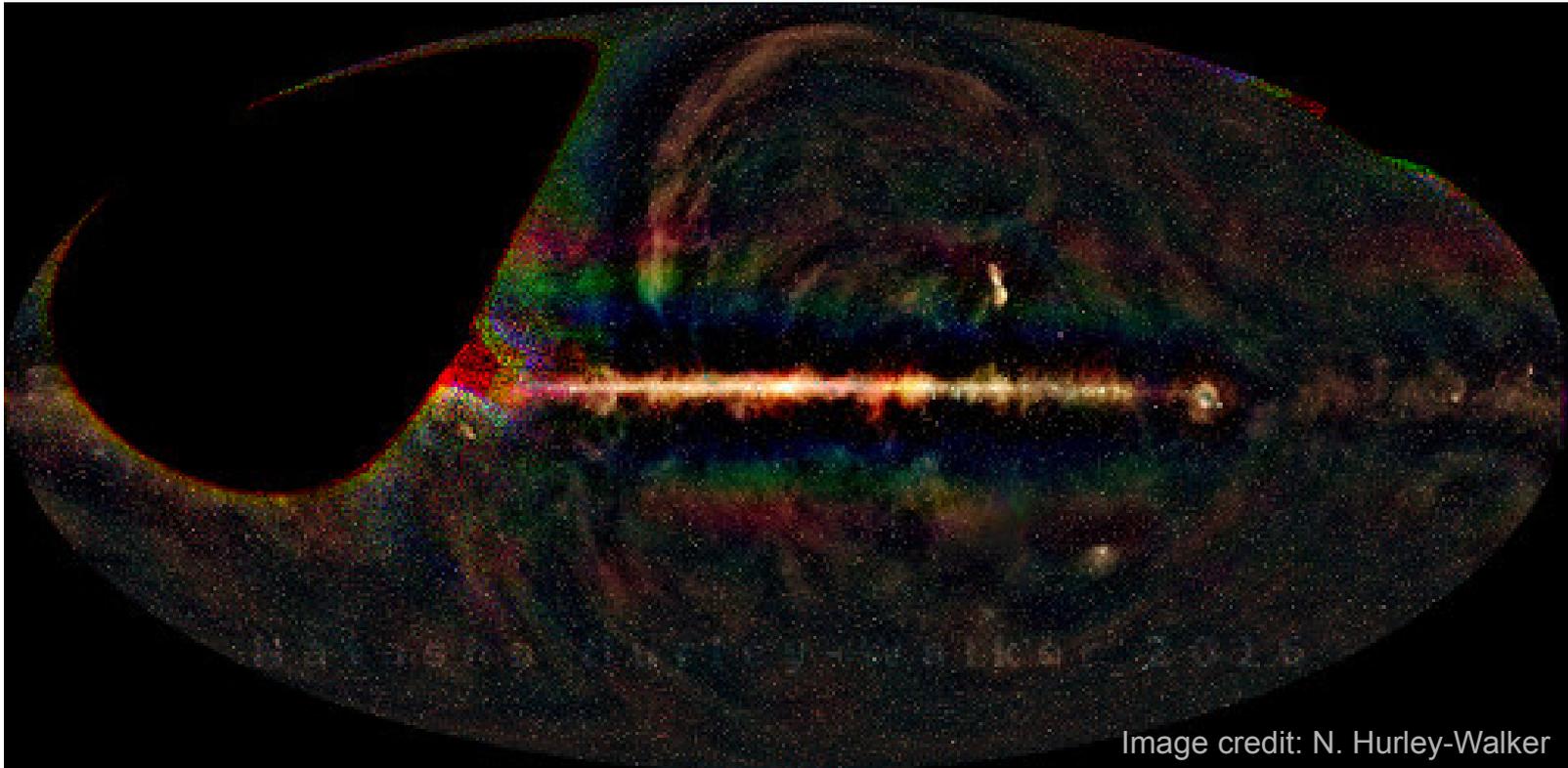


Image credit: N. Hurley-Walker

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VLBI



Networks and telescopes used for IYA2009 24hr e-VLBI. Image by Paul Boven <boven@jive.nl>. Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Field of View: 15 – 50 degrees (200 – 2500 sq degrees)
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Time required

X

Very high
number of
sources



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Is there an alternative?

Image credit: EXPRes website

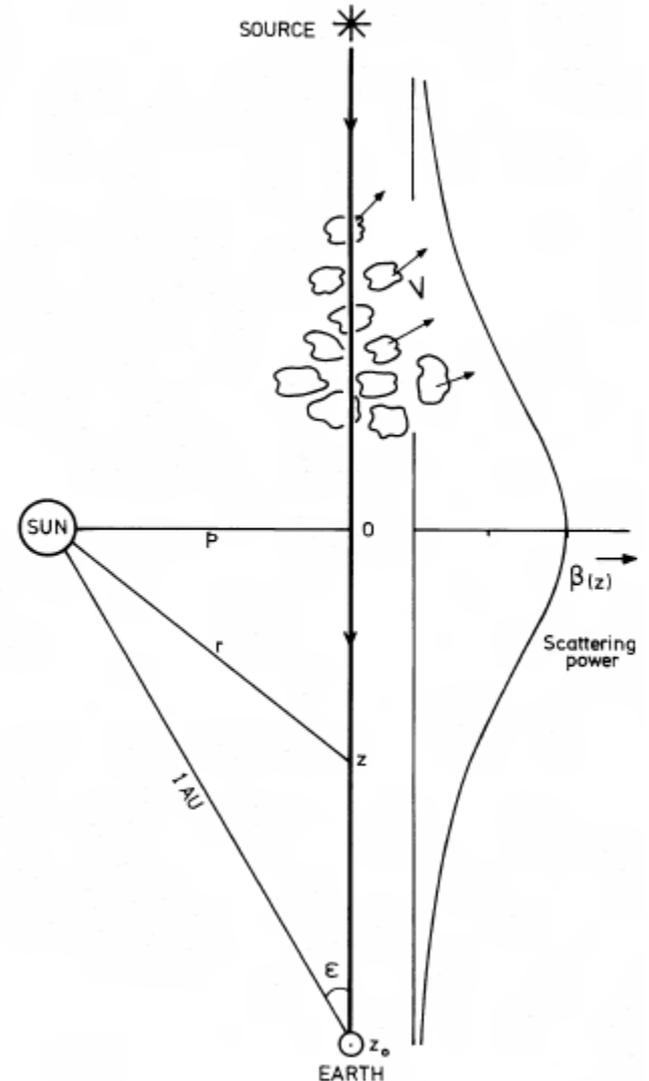


Interplanetary Scintillation

Compact radio sources (< 1 arcsec)
+
Turbulence in interplanetary plasma

=
Scintillation effects
(random fluctuations in flux density)

Analogous to the effects of twinkling of stars in optical wavelengths





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128 tiles with 2 x 16 dipoles each

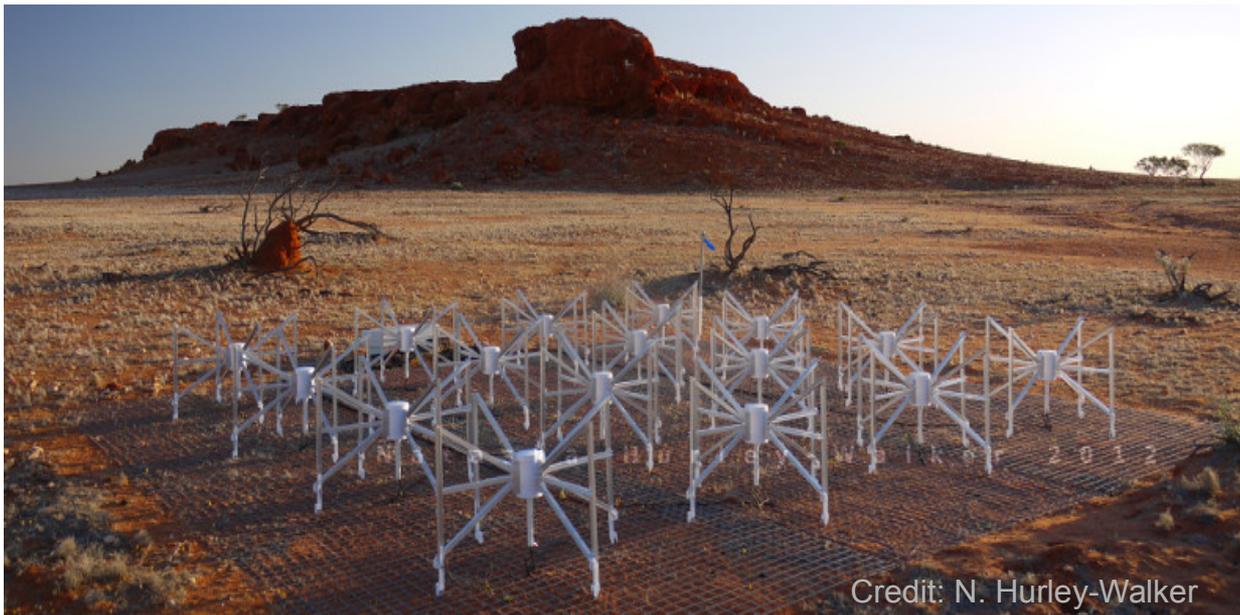
Operating frequencies: 80 – 300 MHz

Bandwidth: 30.72 MHz

Field of View: 15 – 50 degrees (200 – 2500 sq degrees)

Temporal resolution: 0.5 sec

Excellent instantaneous UV coverage



Credit: N. Hurley-Walker



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Background on IPS with MWA

Kaplan et al. 2015 detected a night time IPS.

Pilot study on wide-field IPS by J. Morgan, Curtin University

Regular daytime observations (late December 2015 – July 2016)

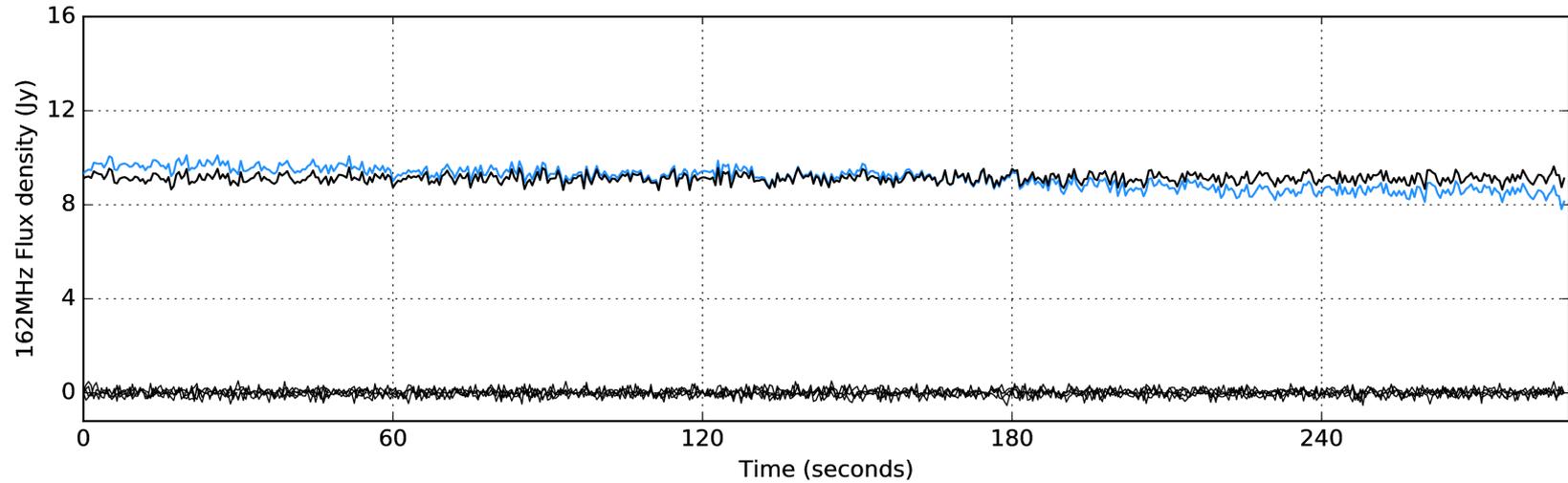
Observations at two bands 80 MHz & 162 MHz

Over 4000 observations made of different parts of sky



Non-scintillators vs Scintillators

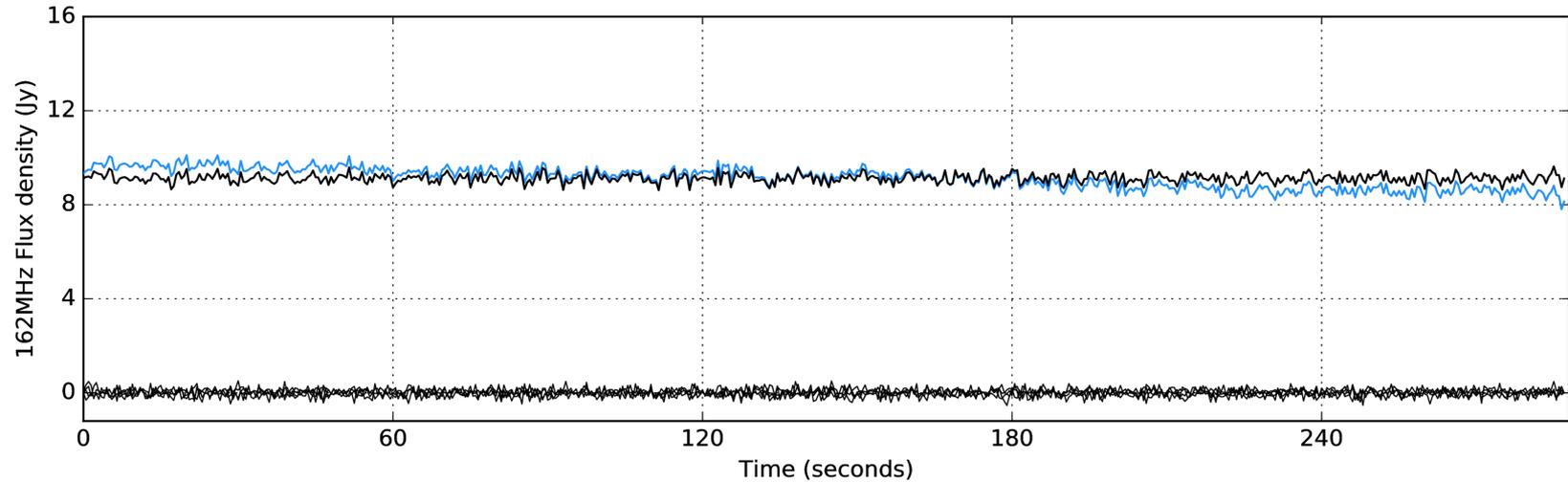
GLEAM J002430-292847



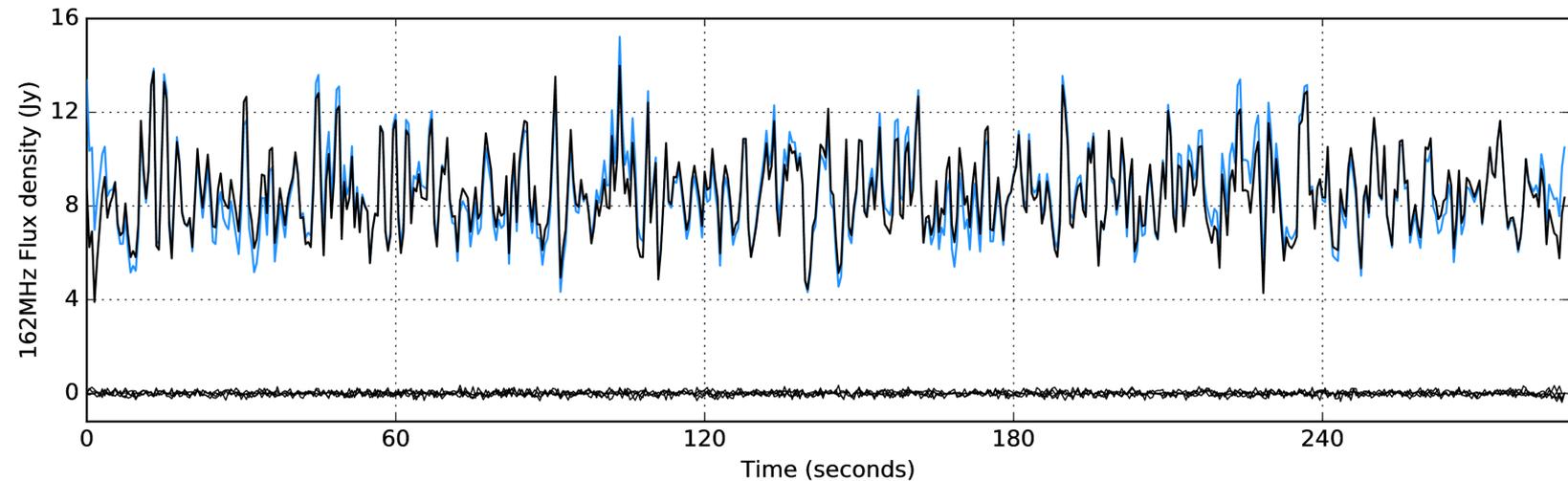


Non-scintillators vs Scintillators

GLEAM J002430-292847



GLEAM J011651-205202





Data processing

Image data as a continuum image

Image at 0.5 second integration in both frequency bands and polarisations

Produce variability (standard deviation) image across ~ 600 images

Run source finding script – Aegean (Hancock et al. 2012)



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Identify sub arcsecond compact components in variability image

~2500 objects in a field (in Stokes I image)



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~2500 objects in a field (in Stokes I image)

~5 minutes of observation

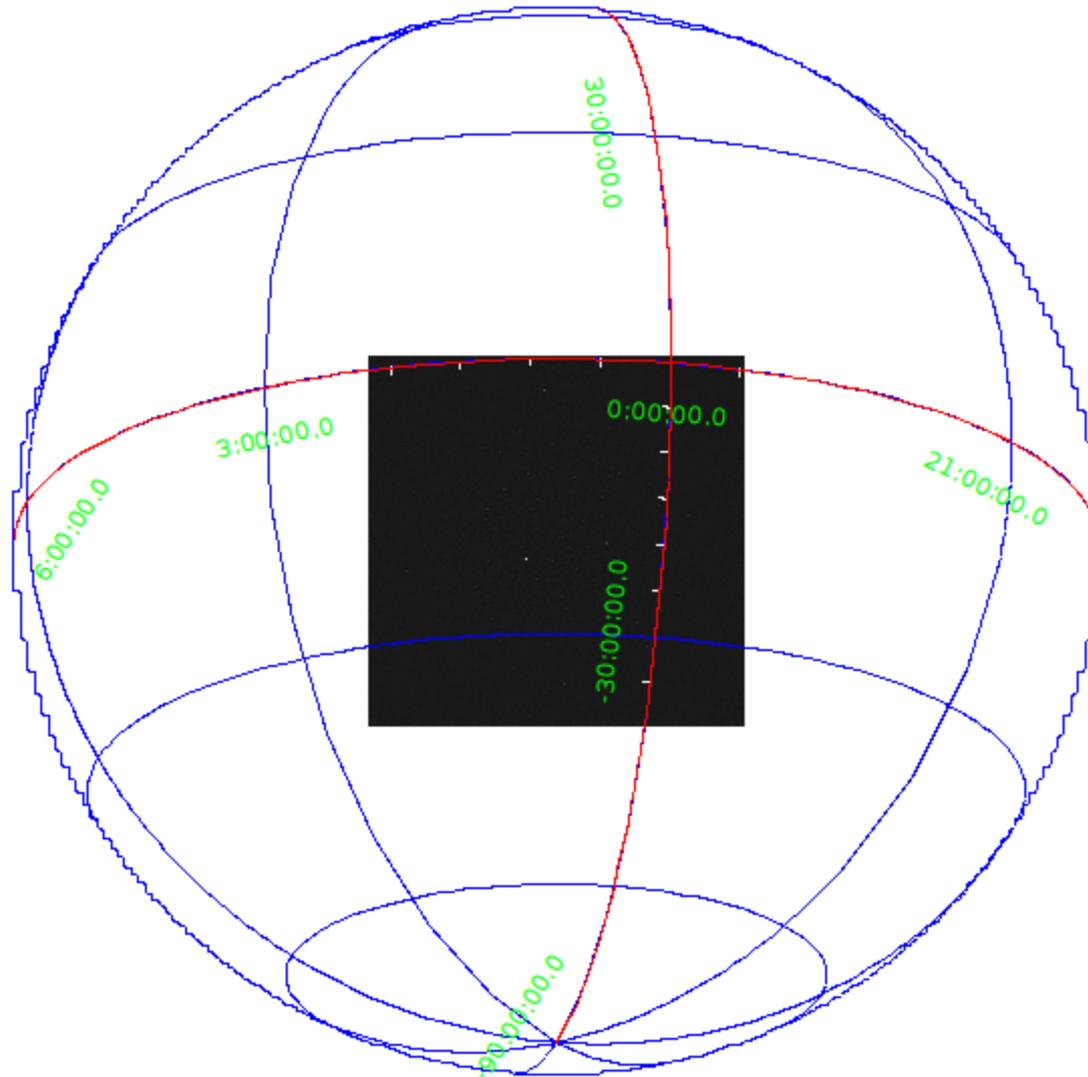


Interplanetary Scintillation with the Murchison Widefield Array I: A sub-arcsecond Survey over 900 square degrees at 79 and 158 MHz

J .S. Morgan,^{1★} J-P. Macquart,^{1,2} R. Ekers,³ R. Chhetri,^{1,2}
M. Tokumaru,⁴ P. K. Manoharan,⁵ S. Tremblay,^{1,2} M. M. Bisi,⁶ and B. V. Jackson⁷



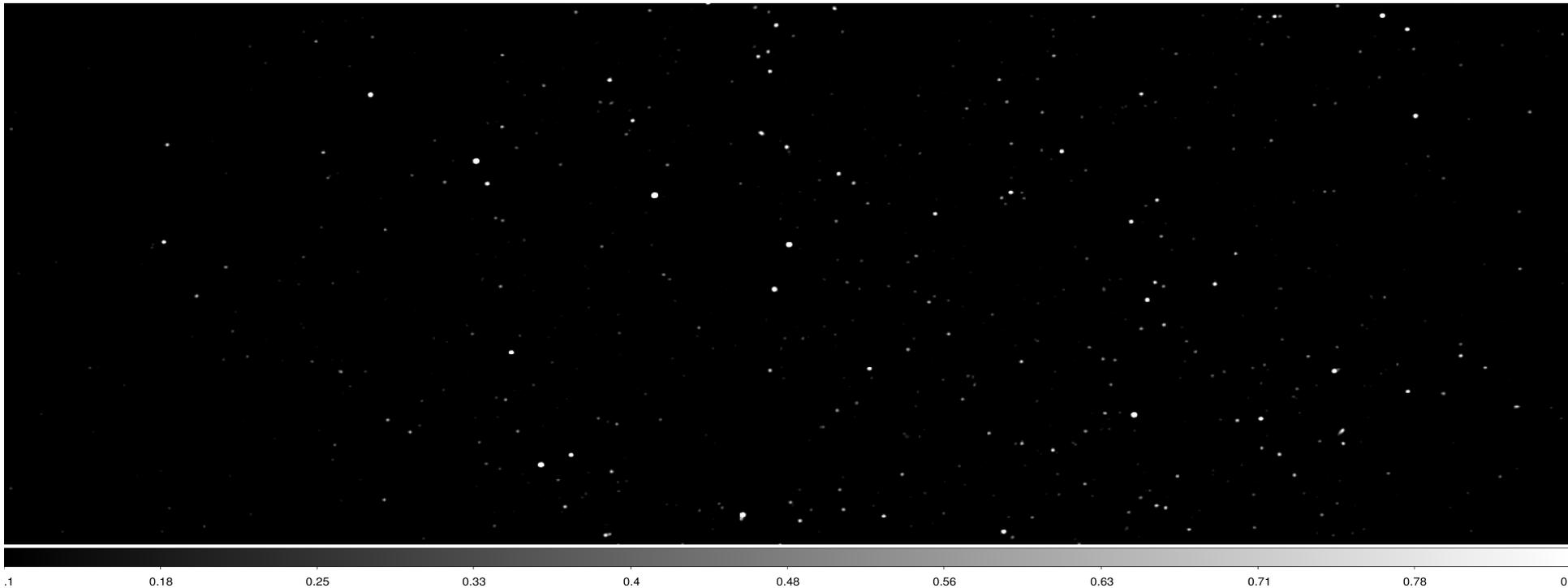
Typical MWA field





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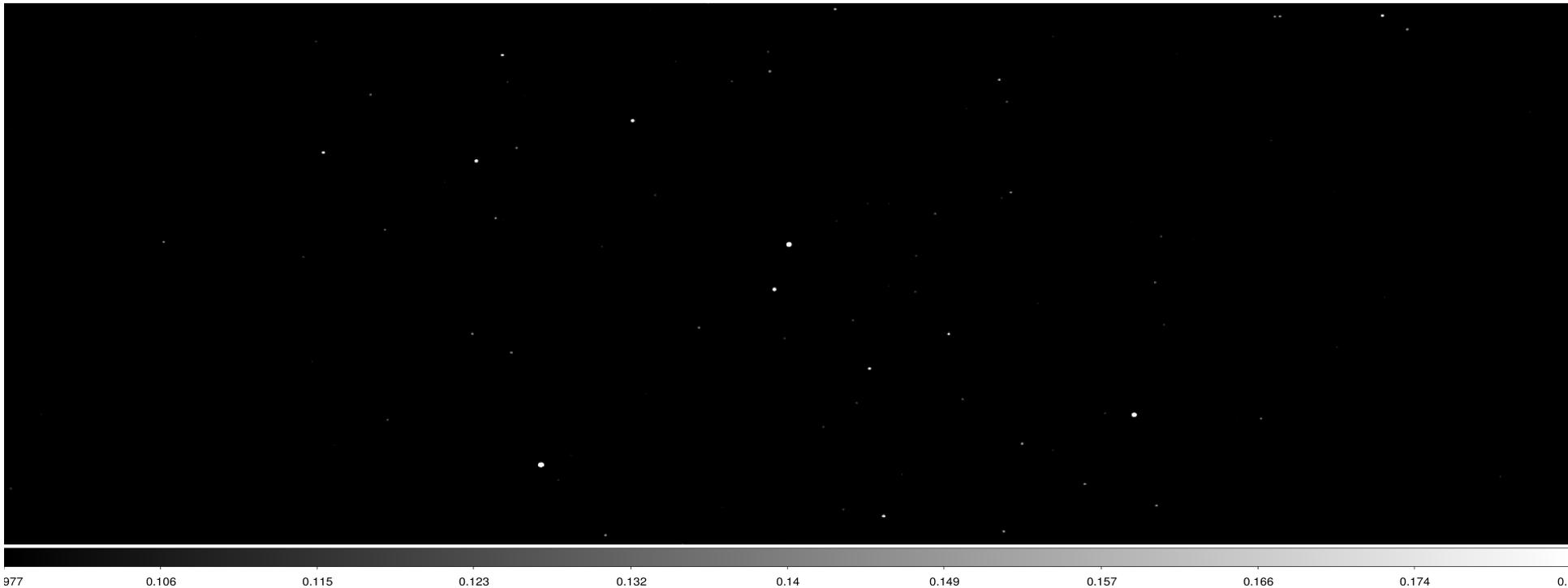


Field size: 23 x 8 sq degrees



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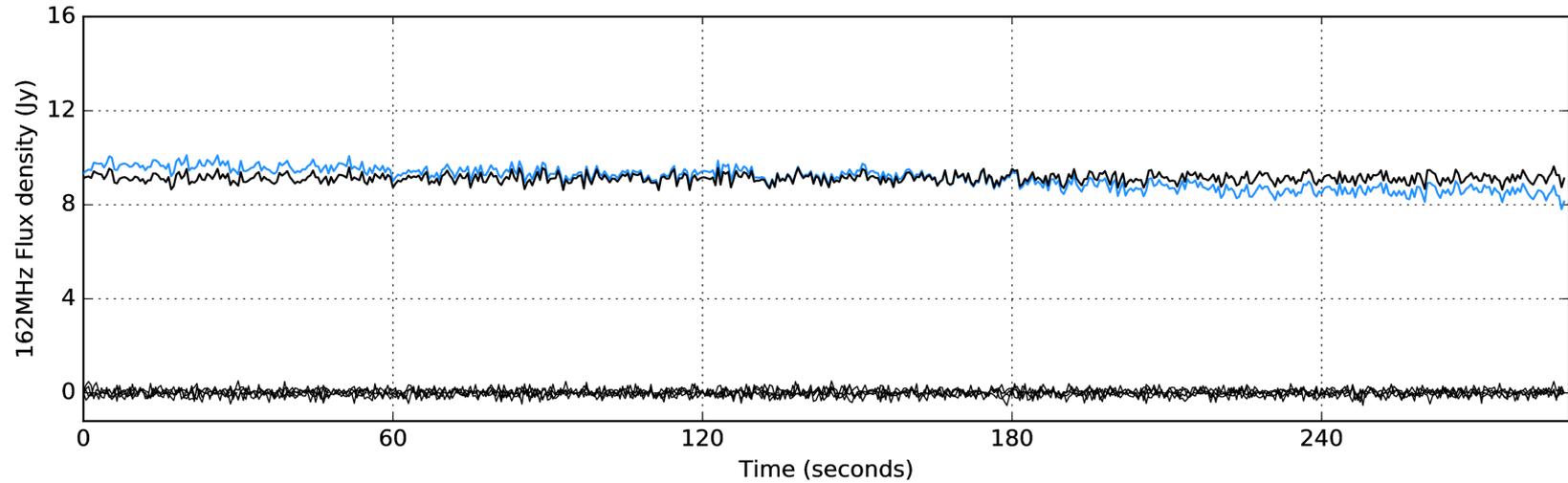
Variability Image



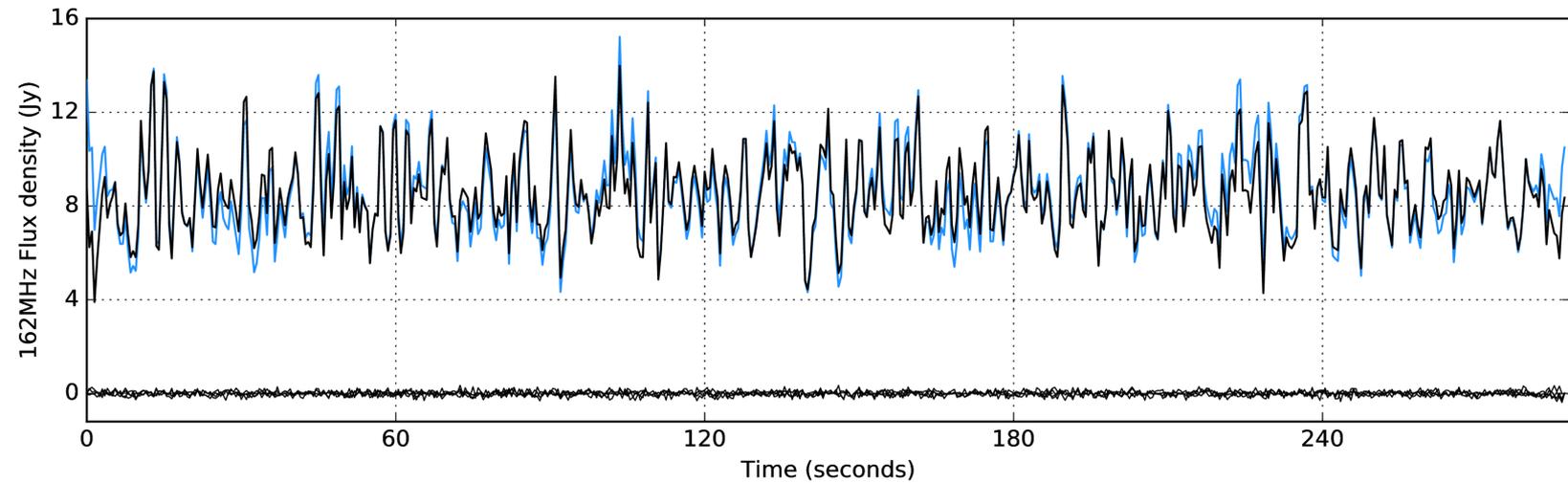
Field size: 23 x 8 sq degrees

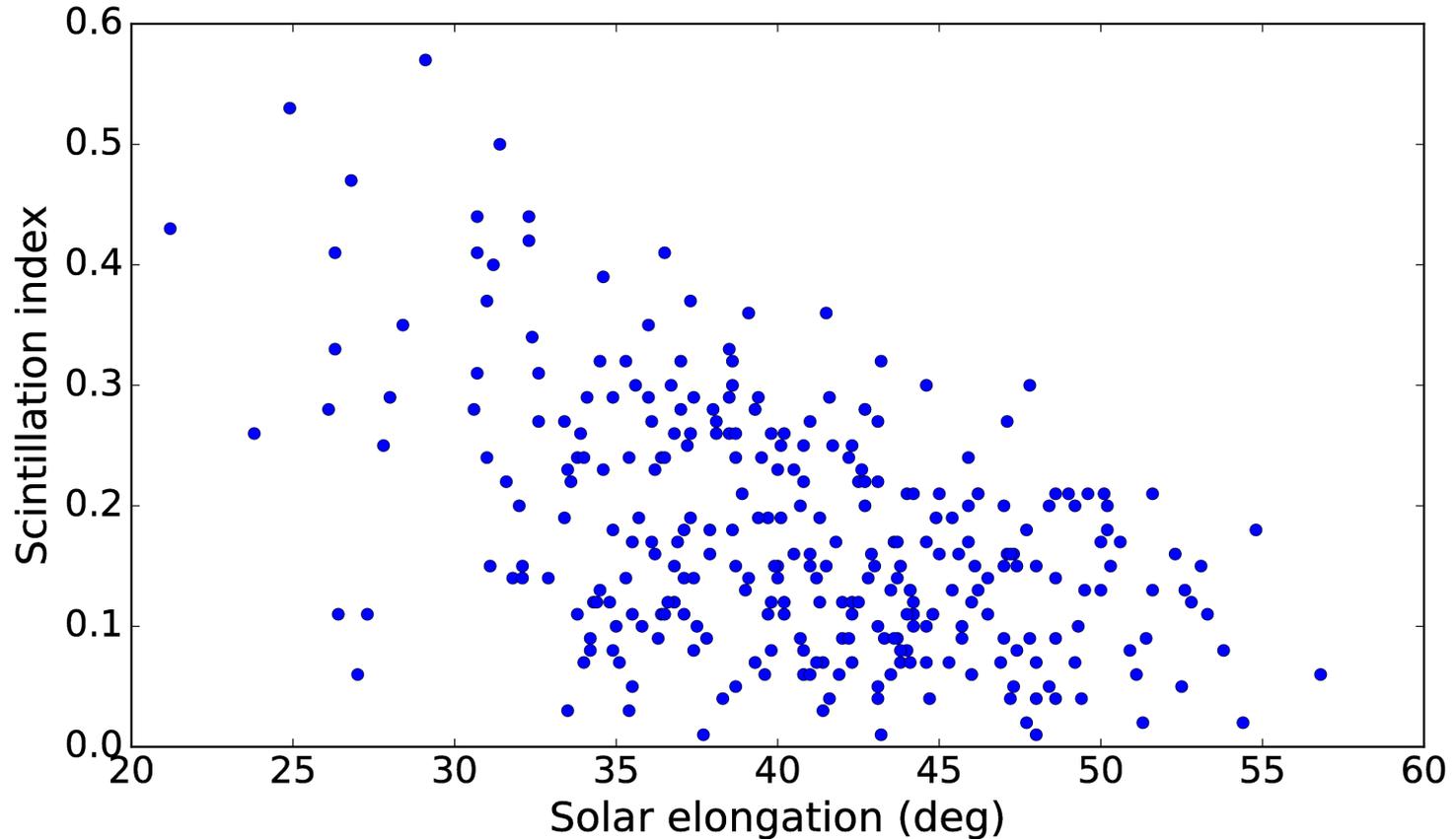


GLEAM J002430-292847

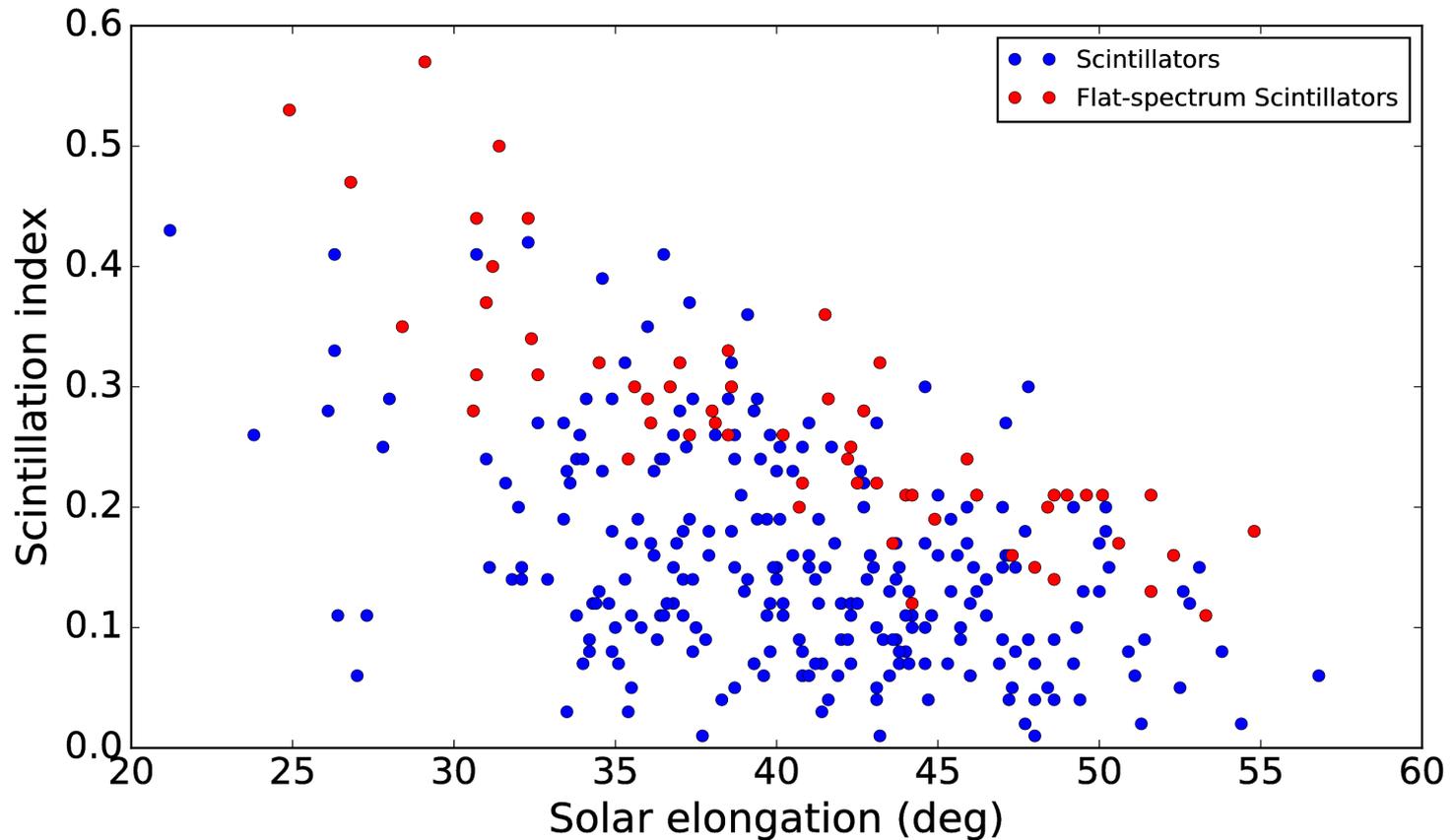


GLEAM J011651-205202

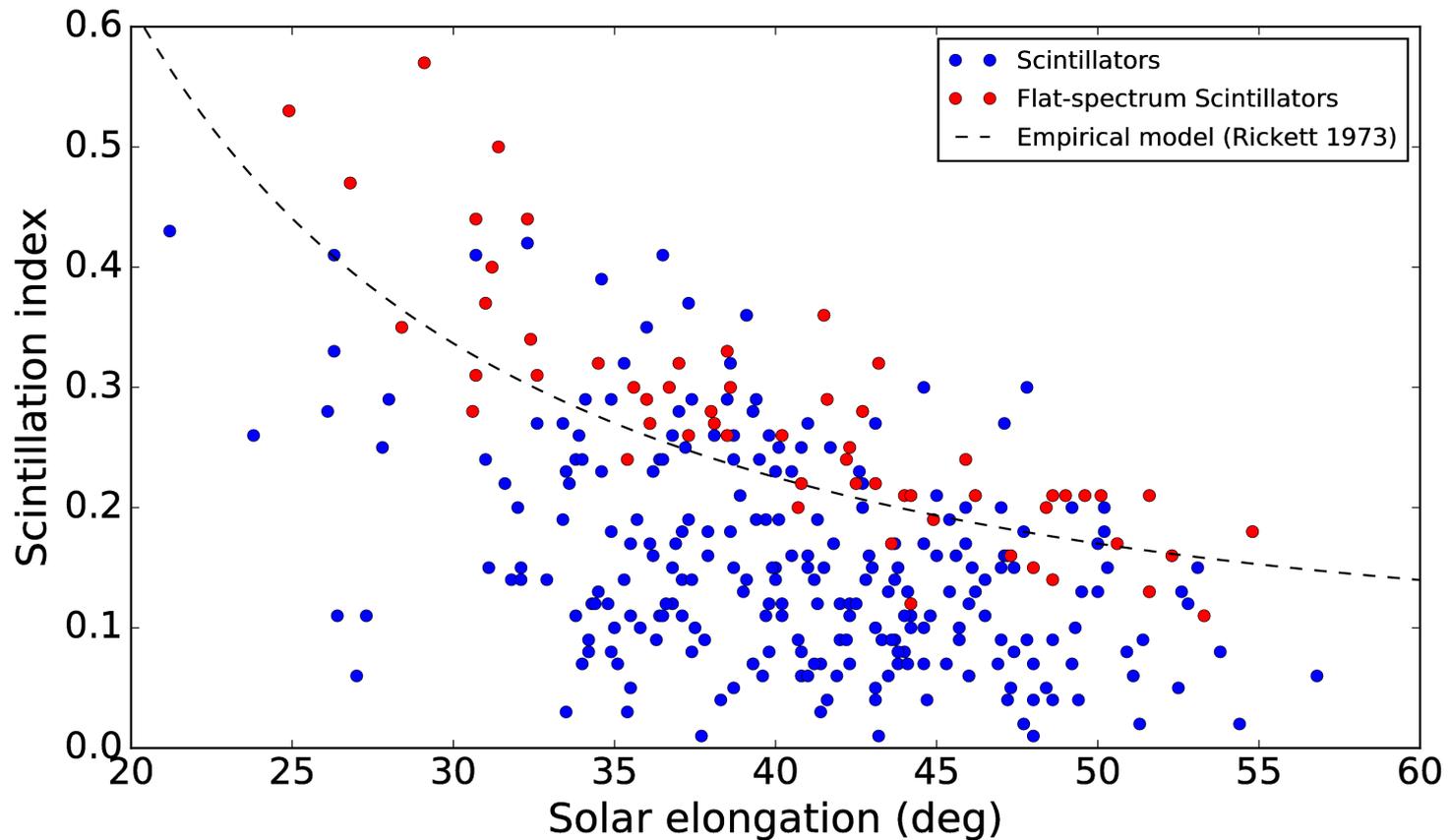




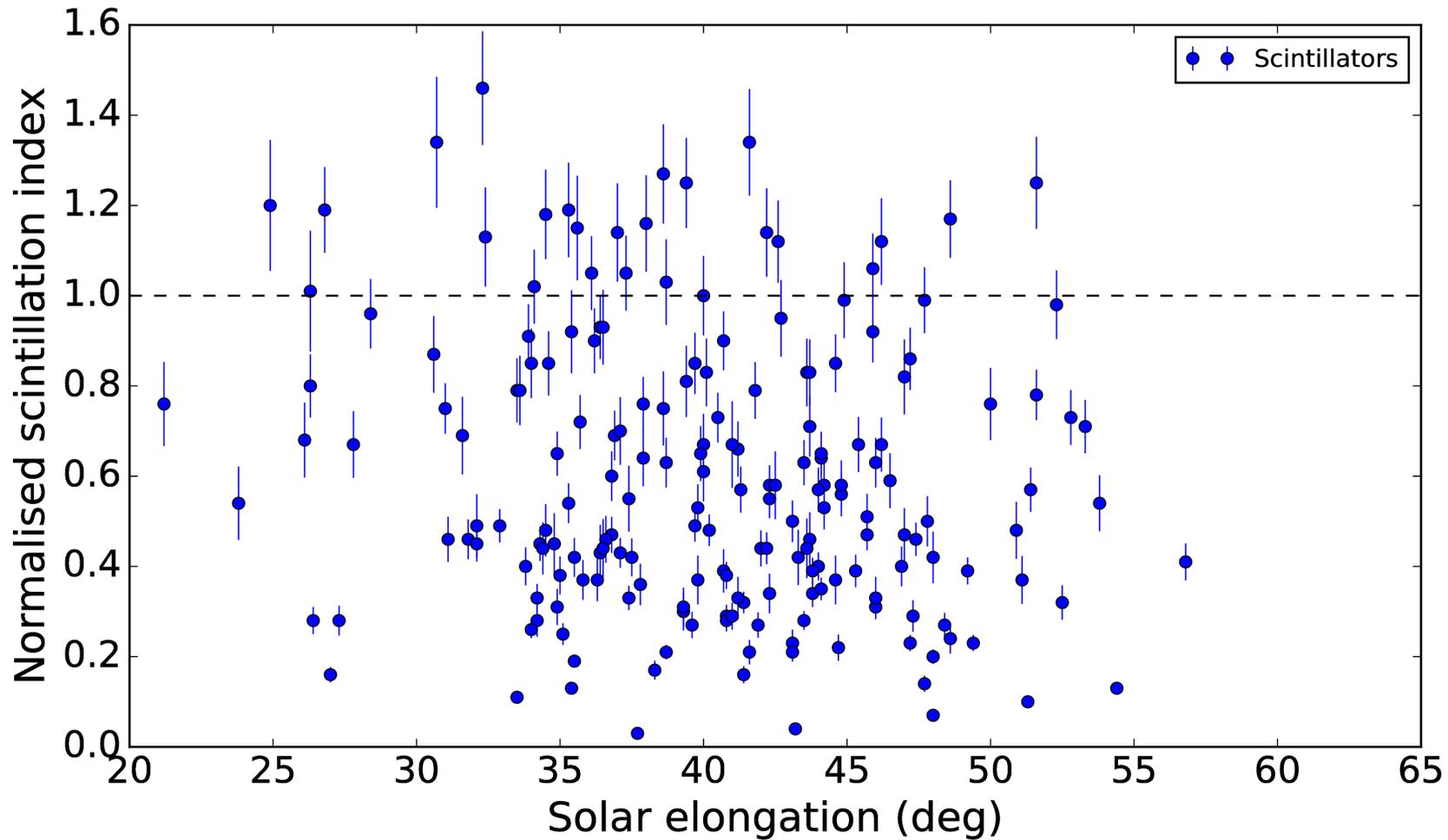
Detect scintillation on 302 out of 2550 objects (12%)

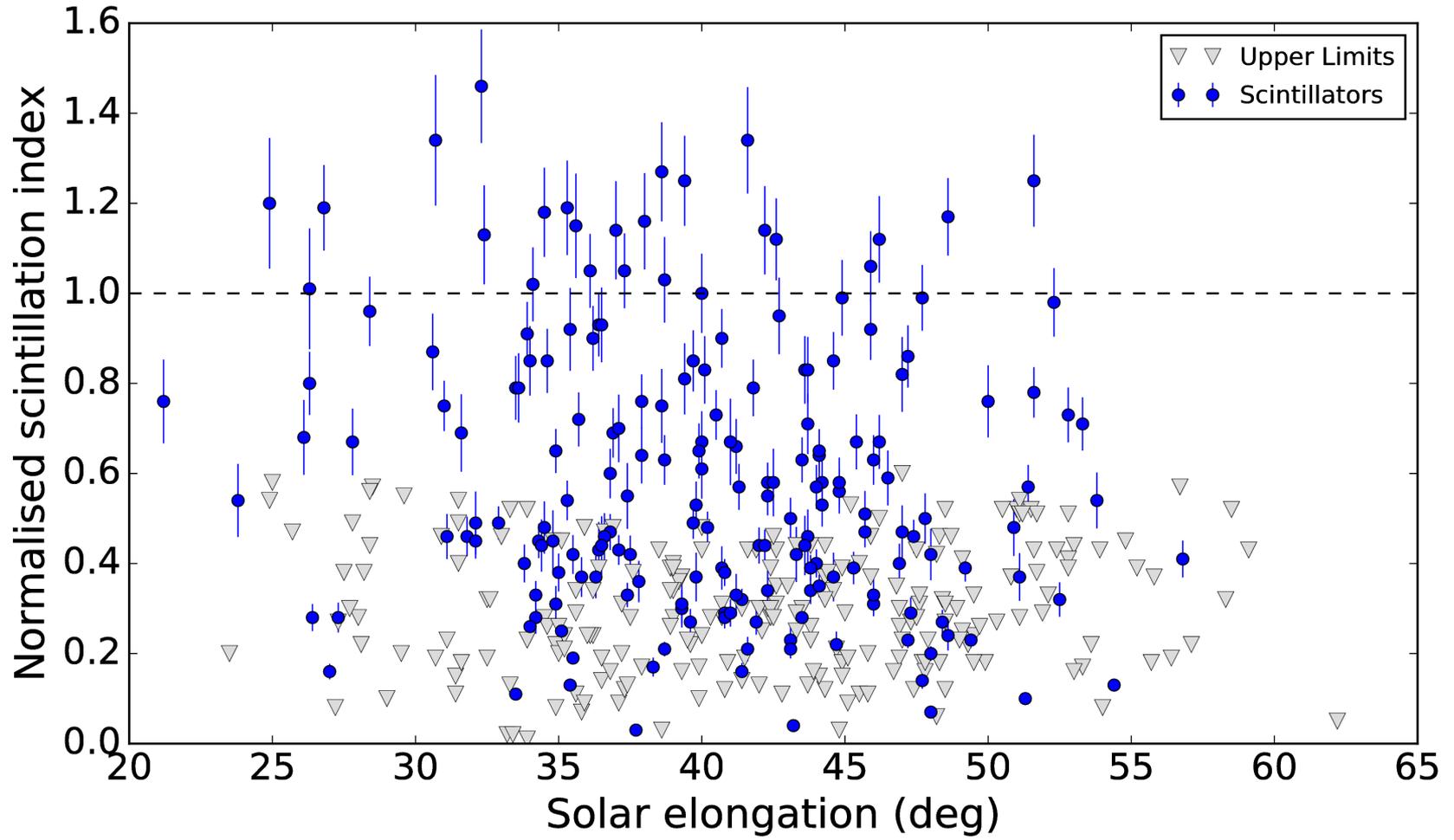


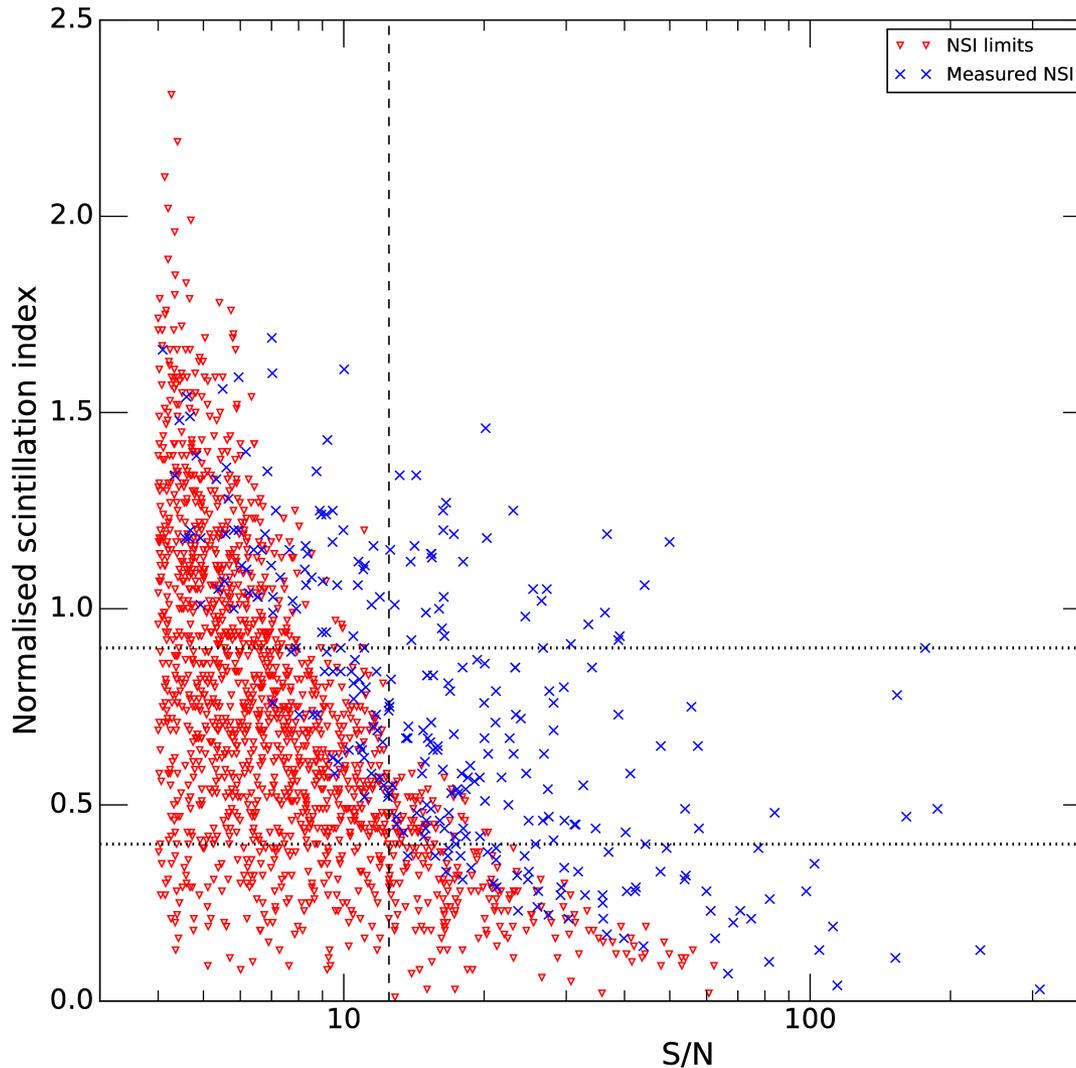
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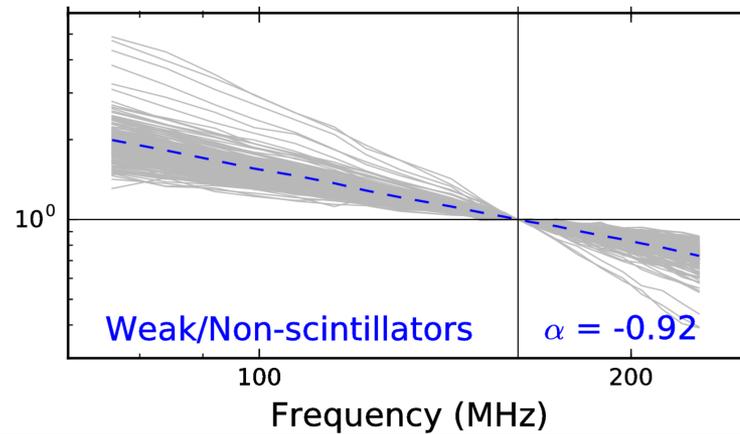






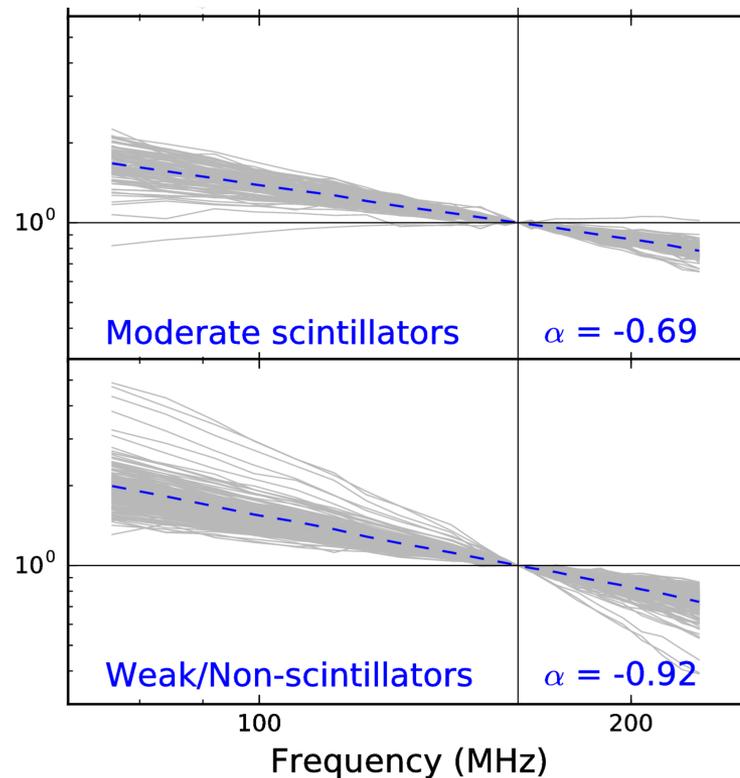
High S/N: 414 objects

- **Strong Scintillators**
(NSI ≥ 0.9)
9%
- **Moderate Scintillators**
($0.4 \leq$ NSI < 0.9)
23%
- **Weak/non Scintillators**
(NSI < 0.4)
53%
- **Unrestrictive NSI limits**
All have NSI < 0.6
14%



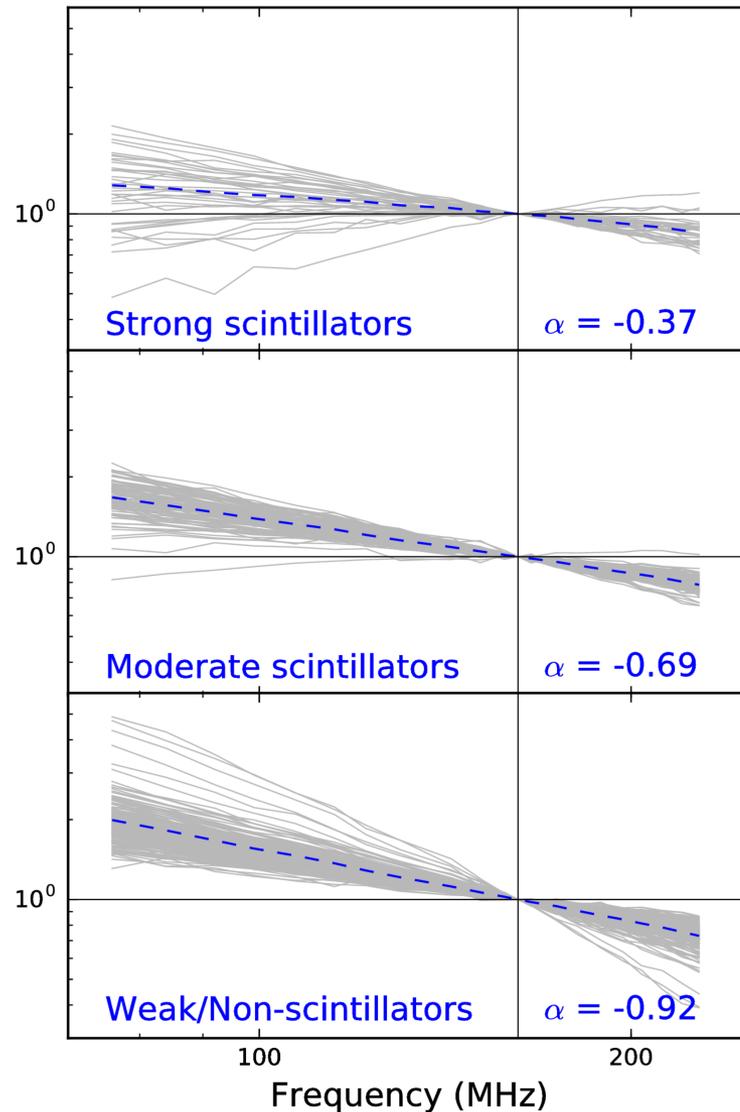


Properties of compact objects



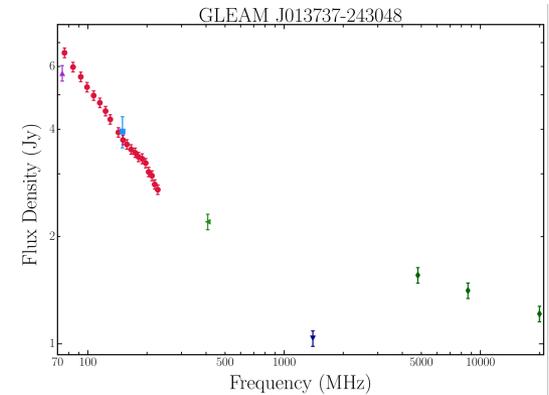
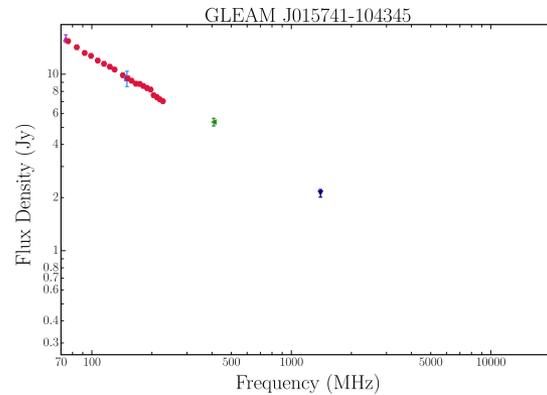
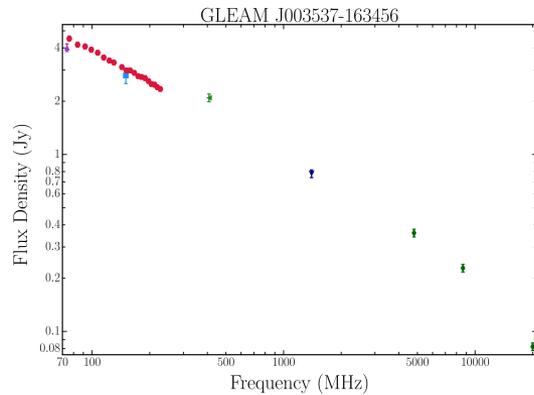


Properties of compact objects



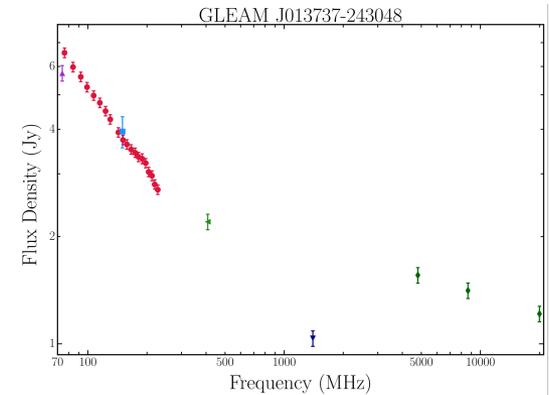
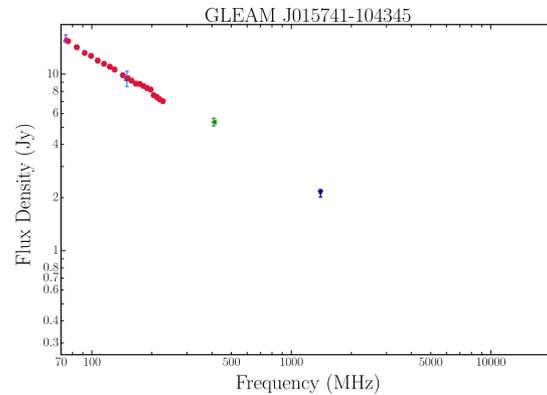
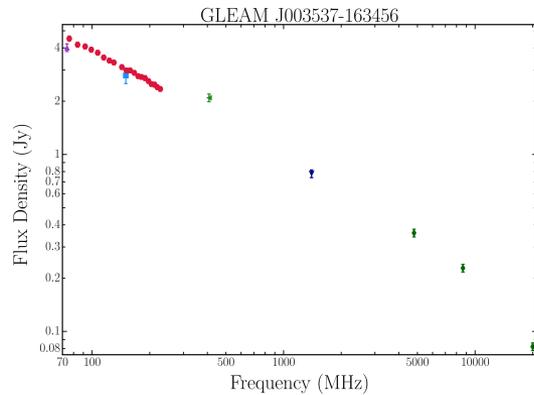


Weak Scintillators

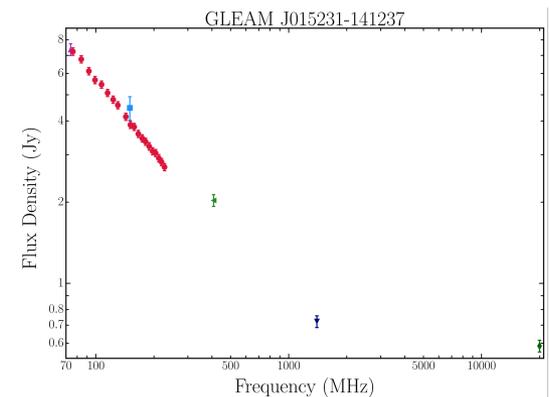
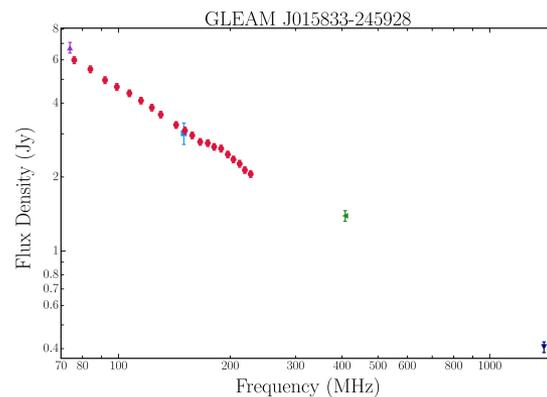
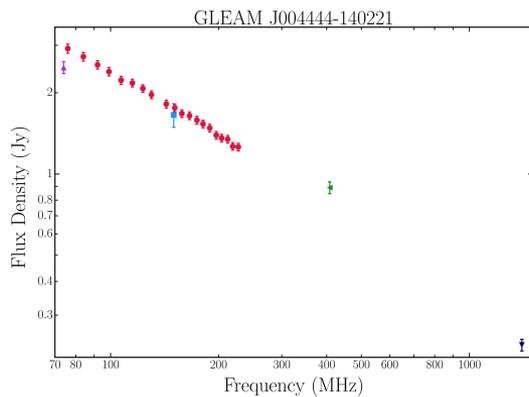




Weak Scintillators

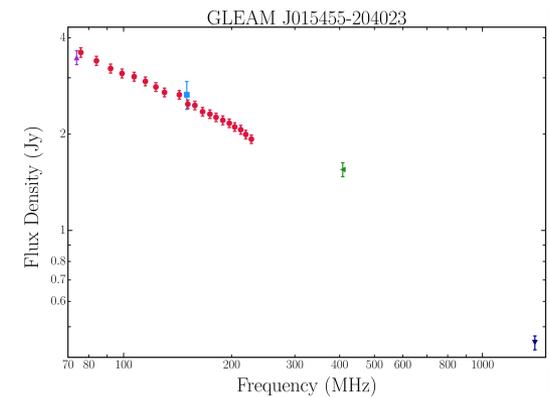
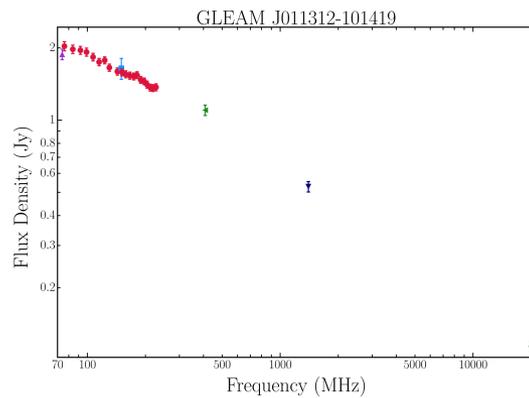
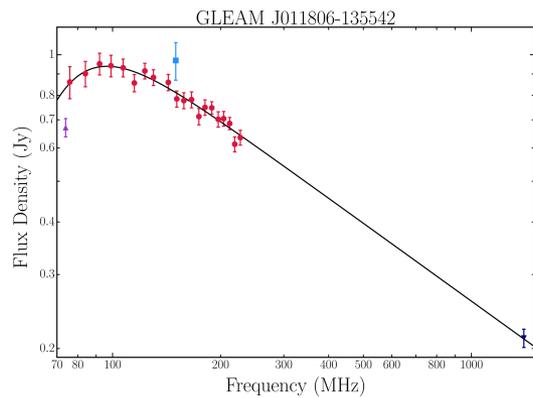
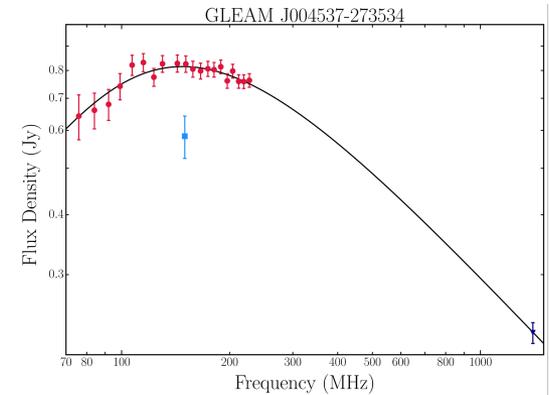
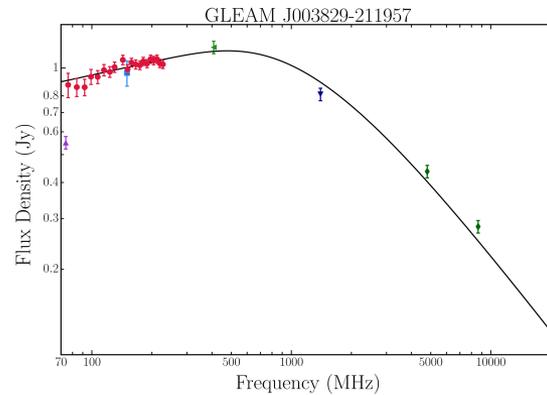
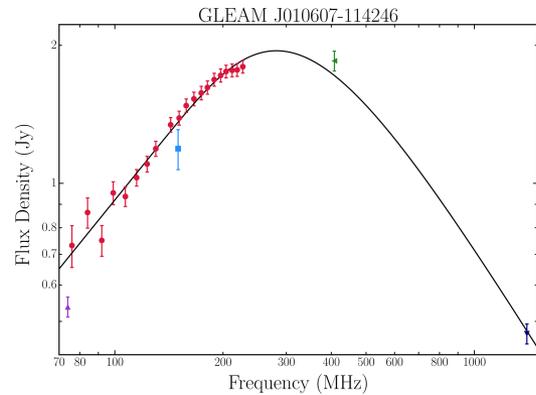


Moderate Scintillators



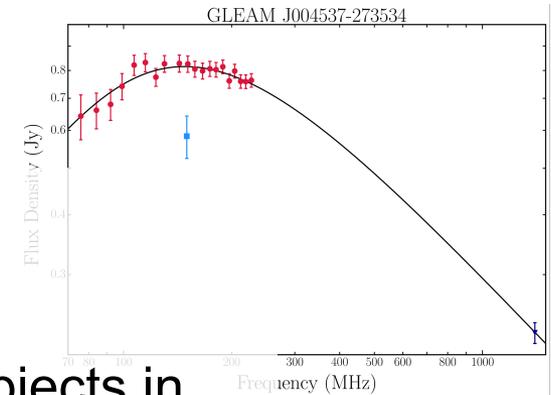
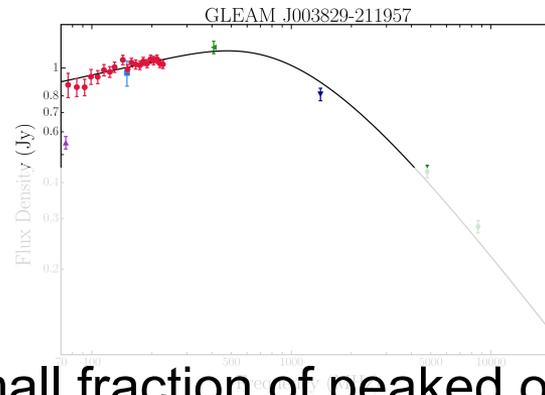
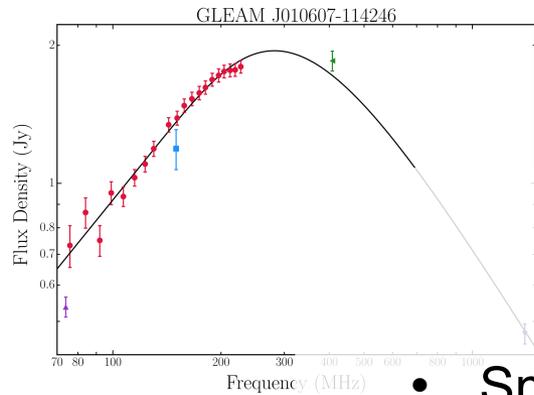


Strong Scintillators

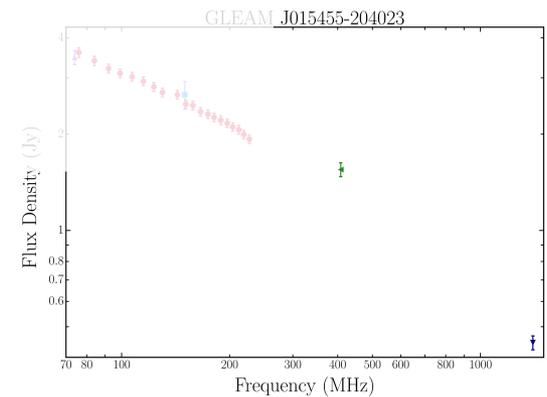
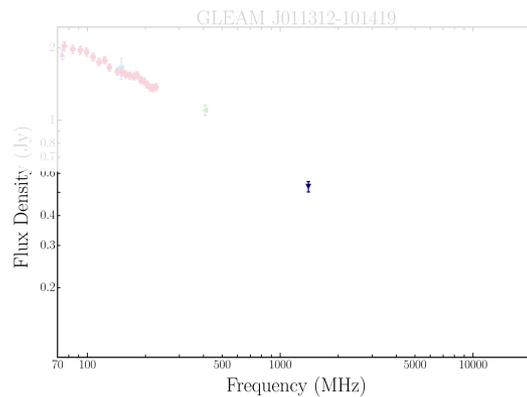
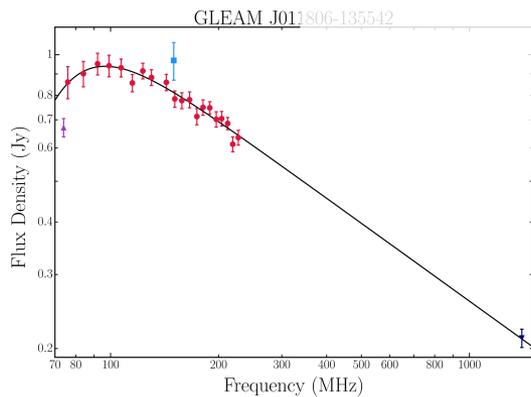




Strong Scintillators

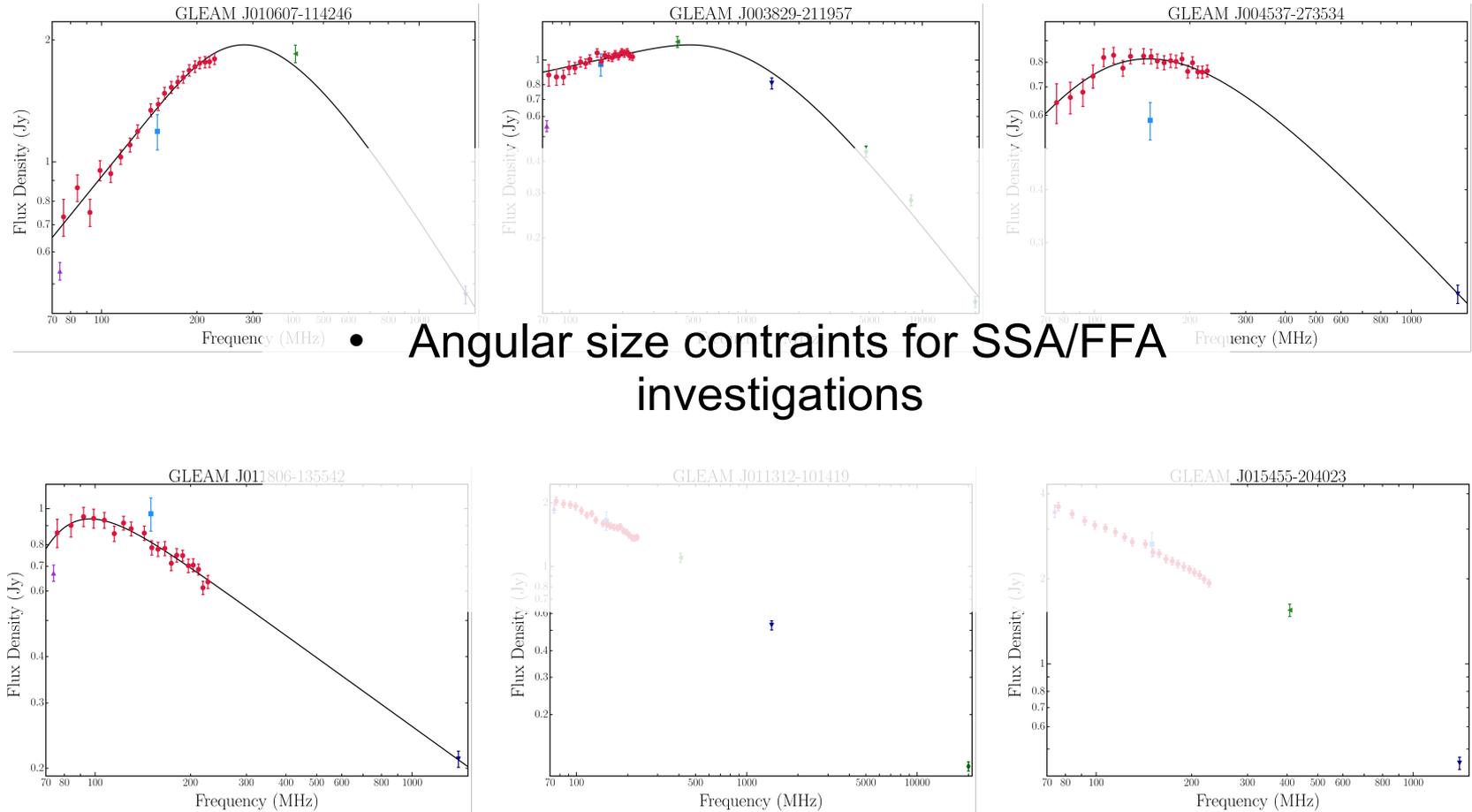


- Small fraction of peaked objects in GLEAM now a majority (46%)





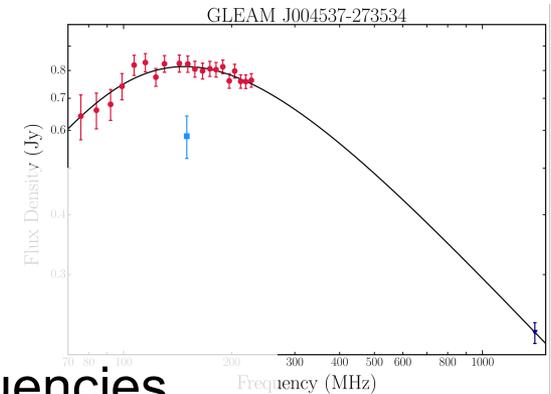
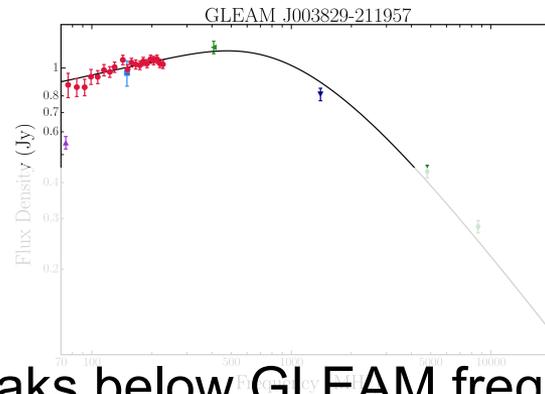
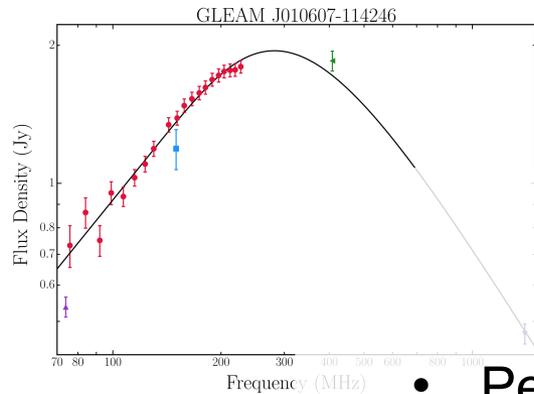
Strong Scintillators



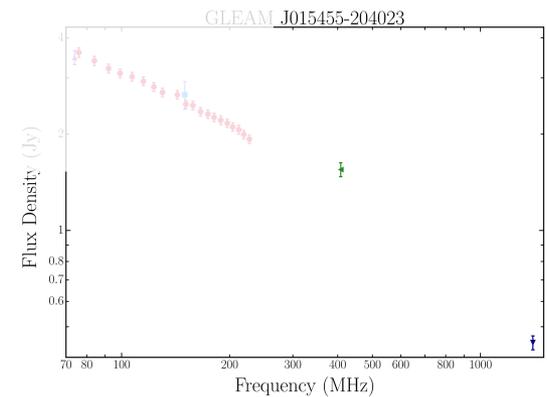
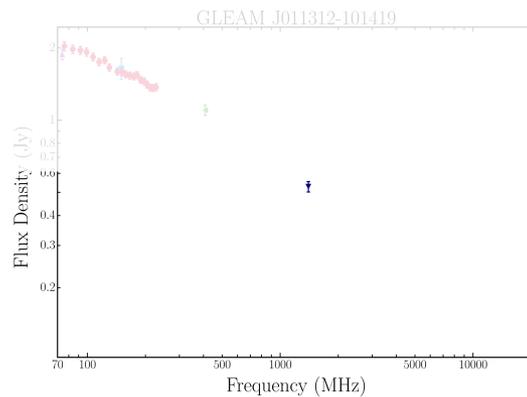
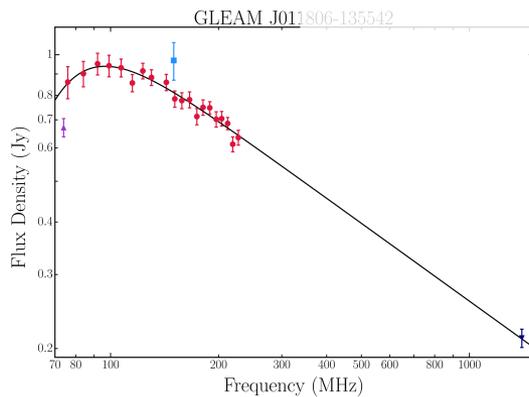
- Angular size constraints for SSA/FFA investigations



Strong Scintillators

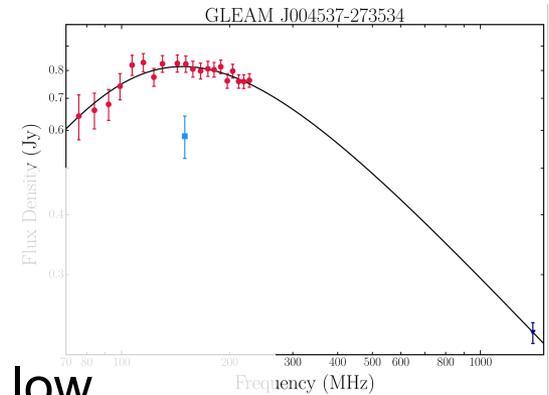
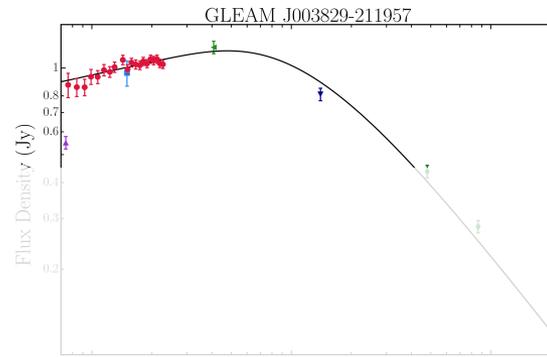
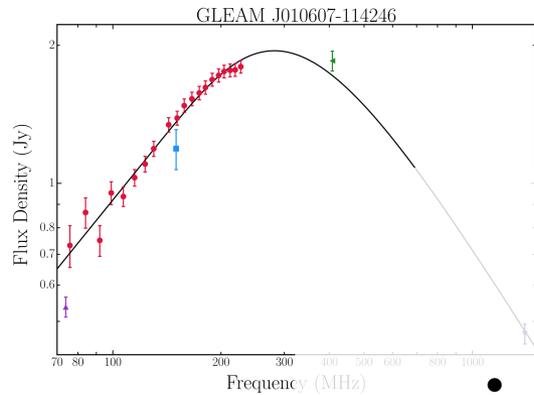


- Peaks below GLEAM frequencies, possible high redshift objects?

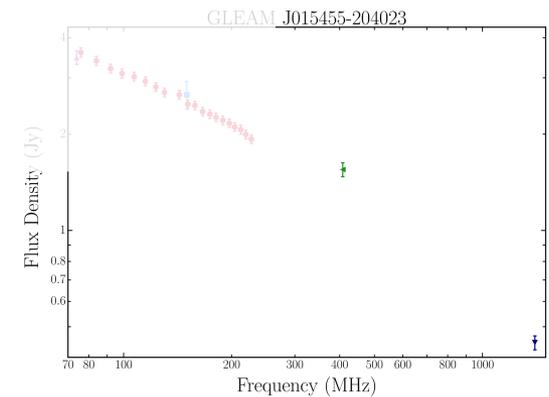
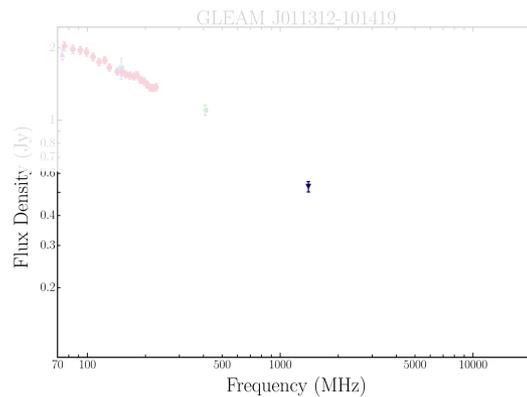
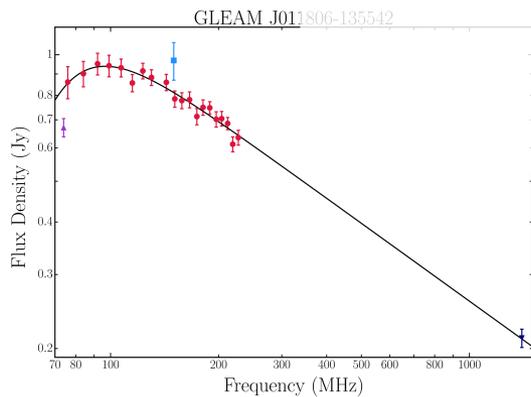




Strong Scintillators

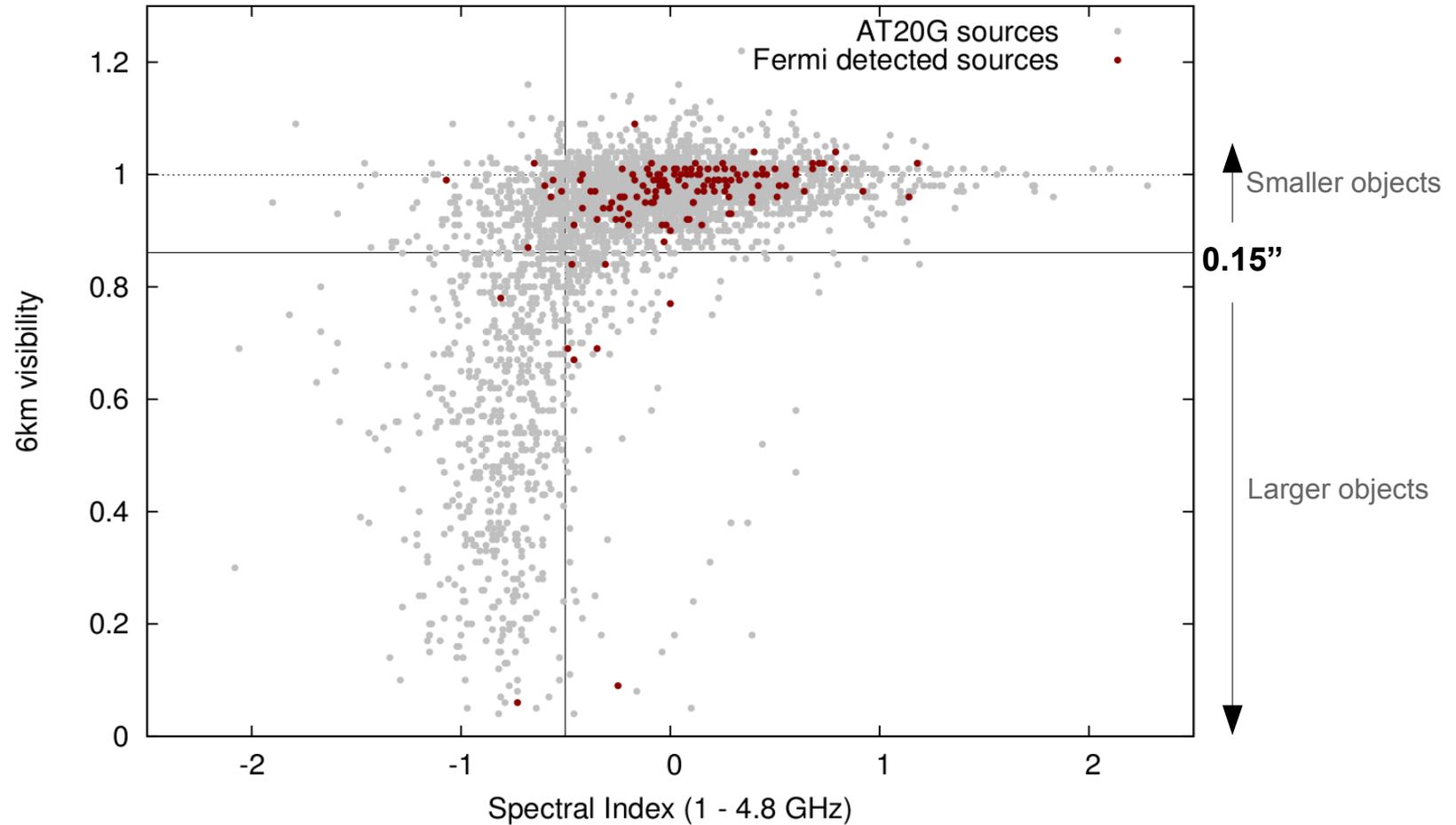


• Excellent calibrators for low frequency instruments



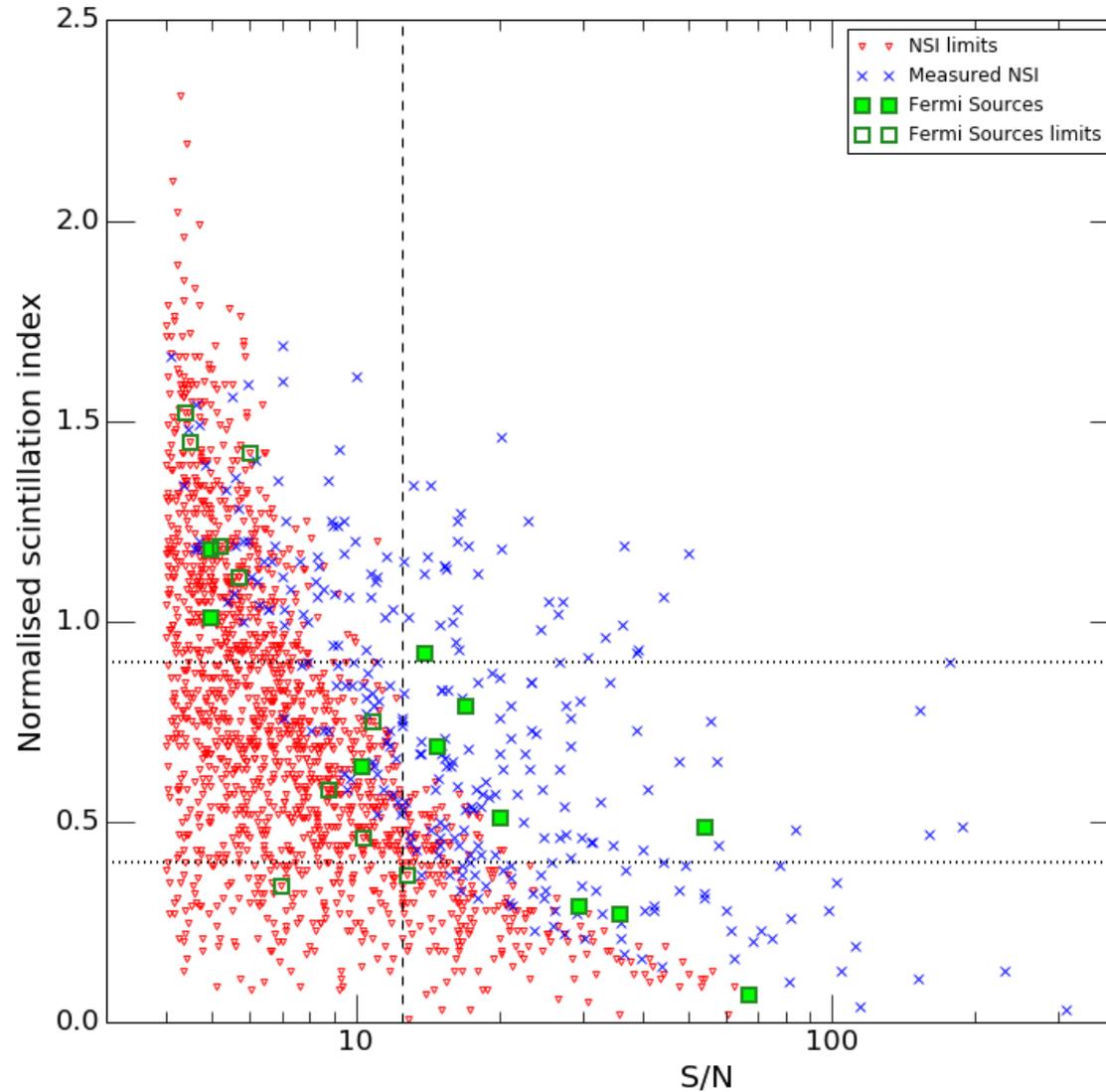


What about the high frequency subarcsecond objects?



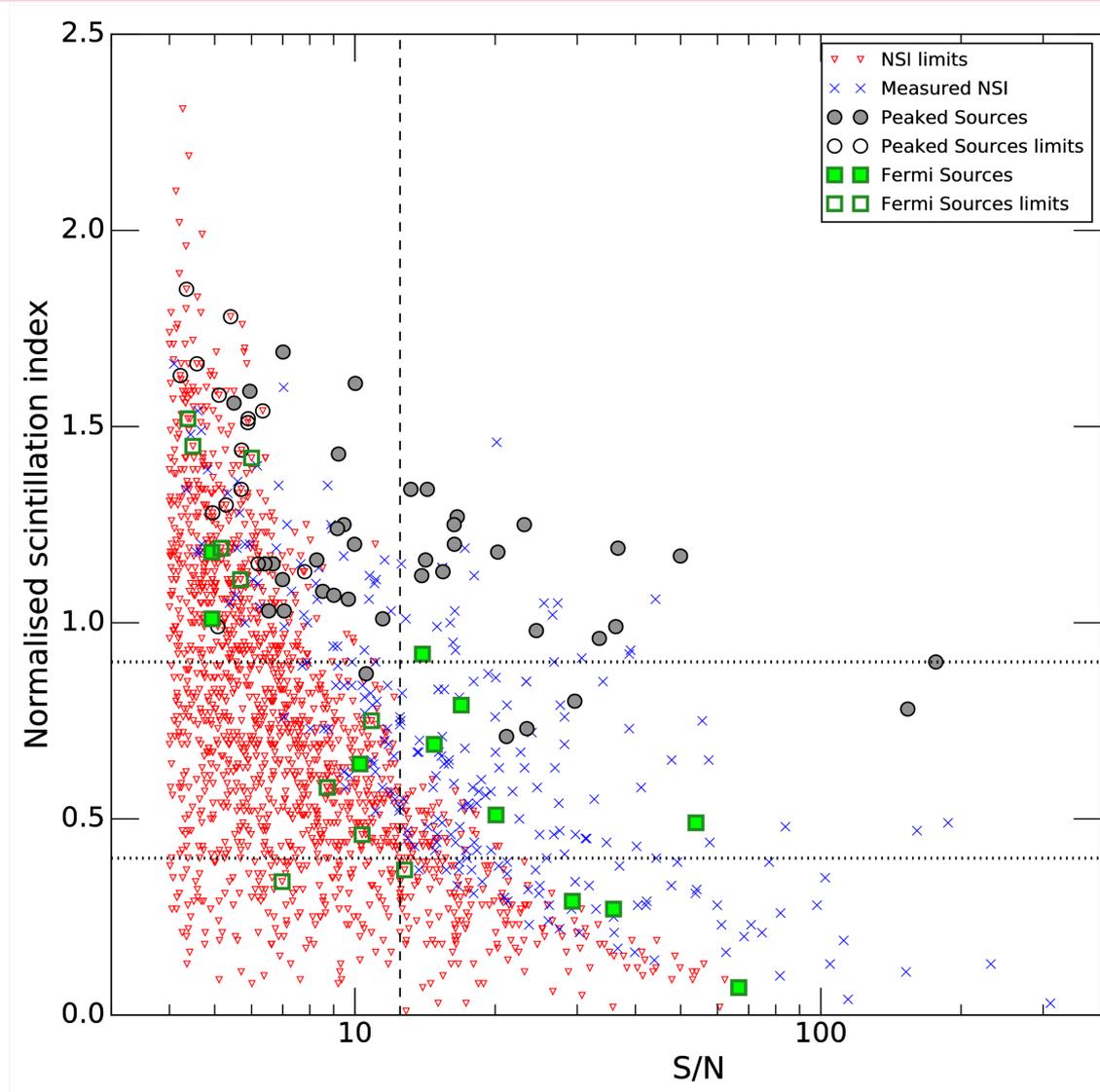


High frequency subarcsecond objects in MWA





High frequency subarcsecond objects in MWA





PSR J0034-0721

Detected with S/N of 4.6 in I image

5.6 in variability image

Normalised scintillation index 1.92 ± 0.49

(Highest in the field)



PSR J0034-0721

Detected with S/N of 4.6 in I image
5.6 in variability image

Normalised scintillation index 1.92 ± 0.49
(Highest in the field)

Using IPS ($NSI > 0.9$)
= candidate pulsars $\sim 9\%$

+ spectra (< -0.7)
= Reduction in contamination by AGNs $\sim 45 \times$



PSR J0034-0721

Detected with S/N of 4.6 in I image

5.6 in variability image

Normalised scintillation index 1.92 ± 0.49
• At the limits of sensitivity threshold
for detection

(Highest in the field)

- Technique can be applied to
the sensitive SKA

Using IPS ($NSI > 0.9$)

= candidate pulsars ~ 9%

+ spectra (< -0.7)

= Reduction in contamination by AGNs ~ 45 x



Interplanetary Scintillation studies with the Murchison Wide-field Array II: Properties of sub-arcsecond compact sources at low radio frequencies

R. Chhetri,^{1,2*} J. Morgan,¹ R. D. Ekers,^{1,3} J-P Macquart,^{1,2} E. M. Sadler,^{2,4} M. Giroletti,⁵
J. R. Callingham⁶ and S. J. Tingay¹



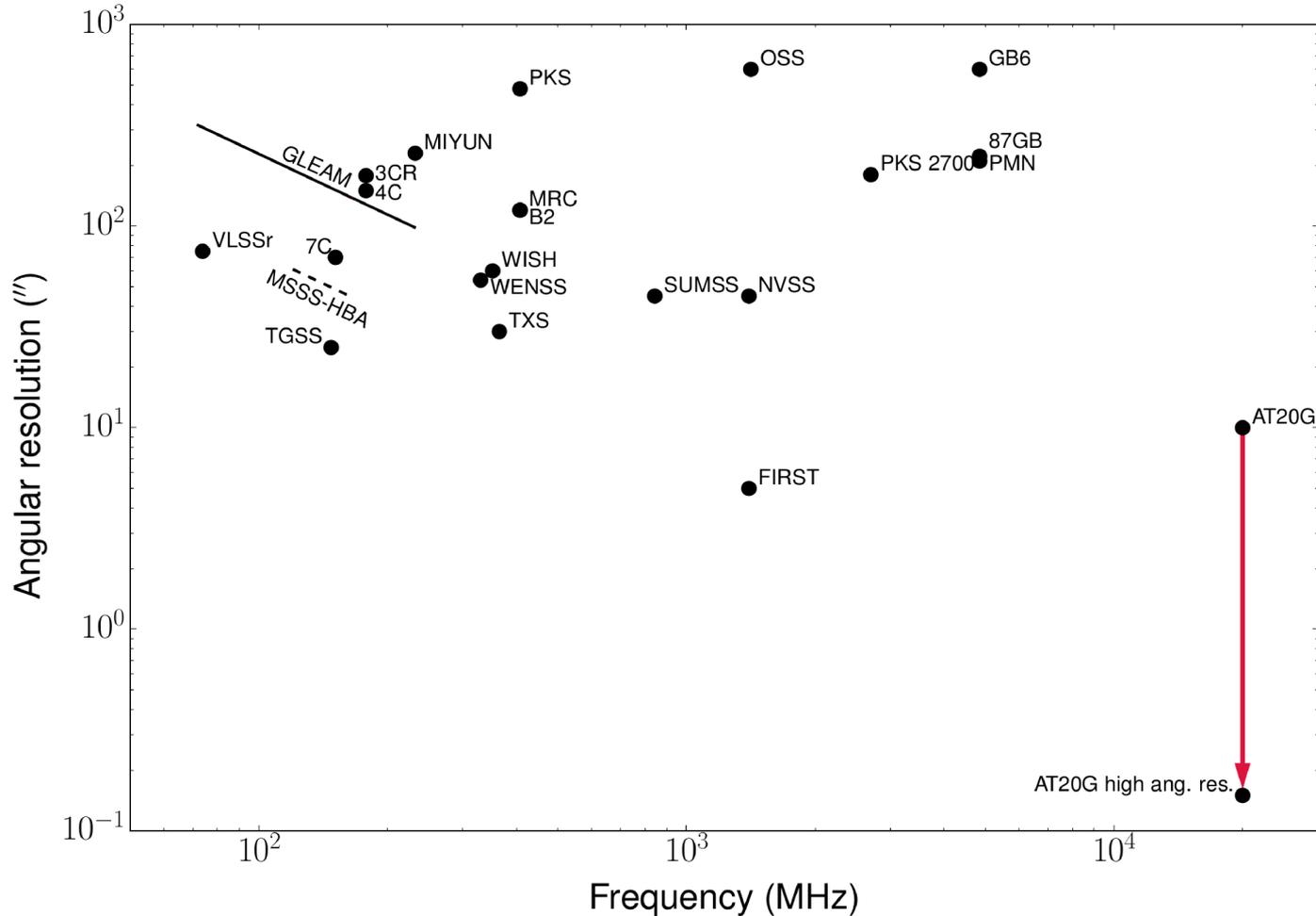
Interplanetary Scintillation studies with the Murchison Wide-field Array II: Properties of sub-arcsecond compact sources at low radio frequencies

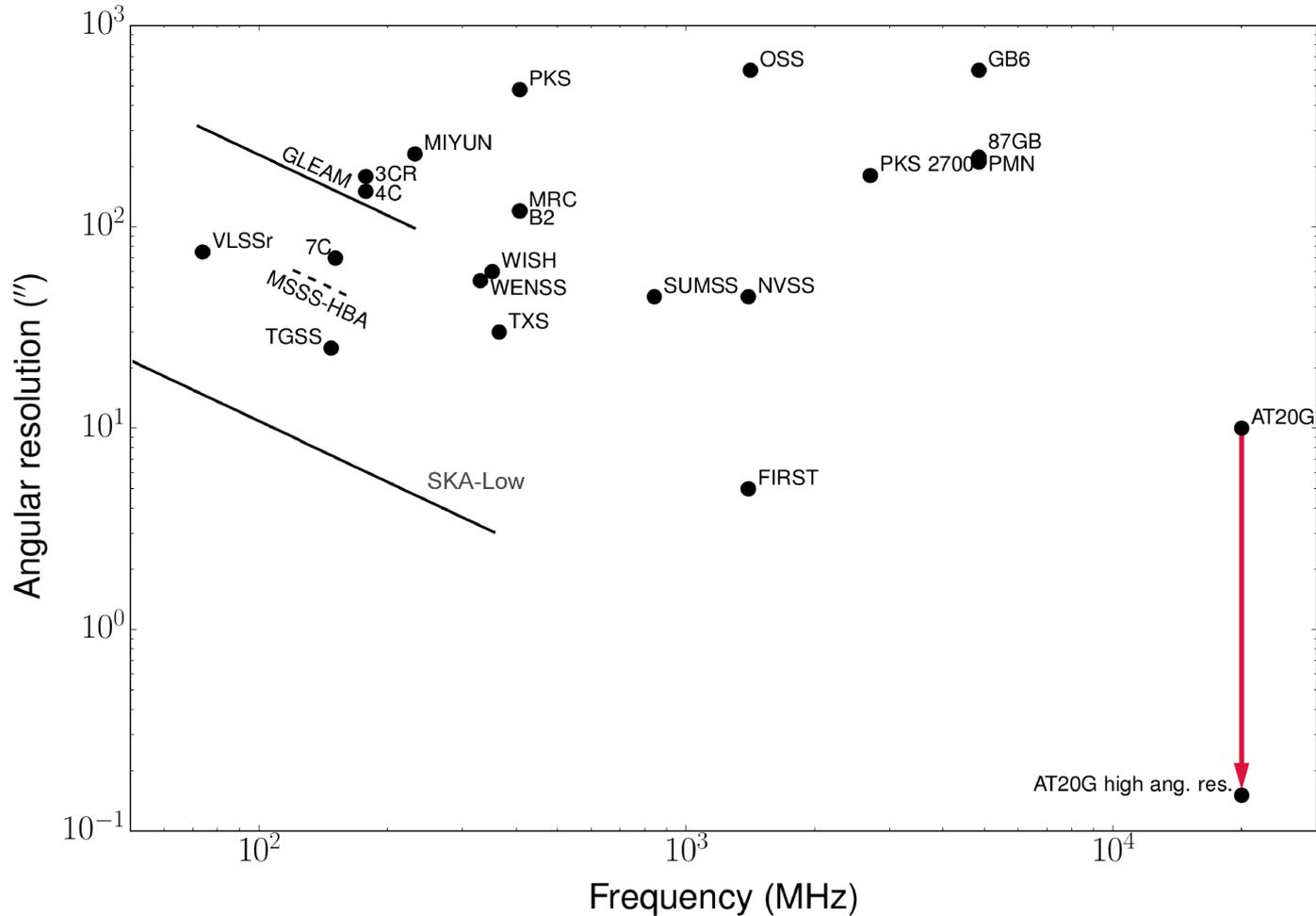
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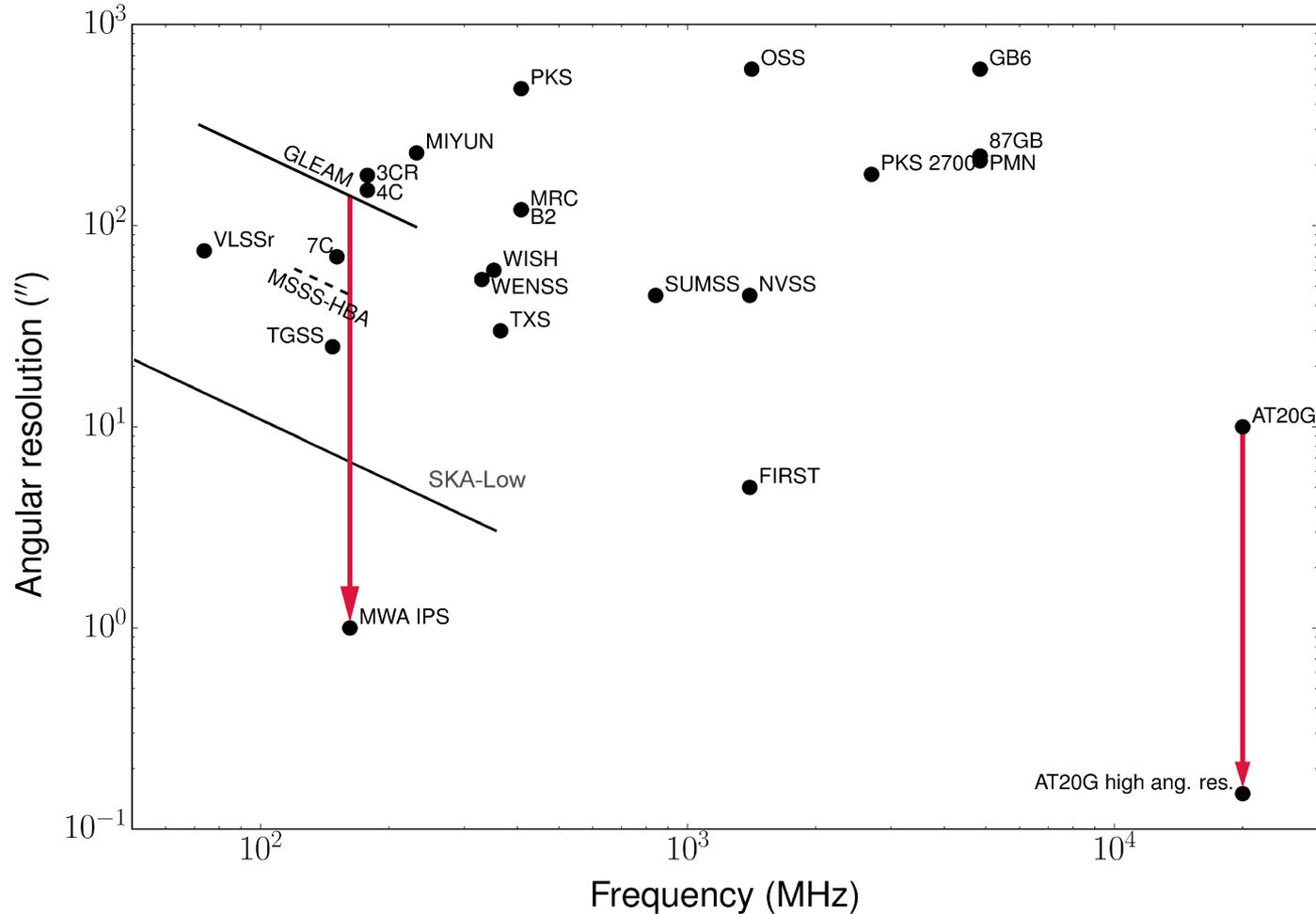
Undergoing final MWA Collaboration
review



Large Area Surveys and Angular Resolutions









Extremely efficient technique to search large parts of sky

- Pulsars (at the threshold of sensitivity)
- Subarcsecond extragalactic population (eg. AGNs)
- Calibrators for low frequency instruments

Technique can be implemented on SKA-Low for angular resolution gain

Low frequency compact population

- Dominated by a different (peaked) source population
- Enable tests for SSA vs FFA
- Compactness not an indicator source hosts blazar core

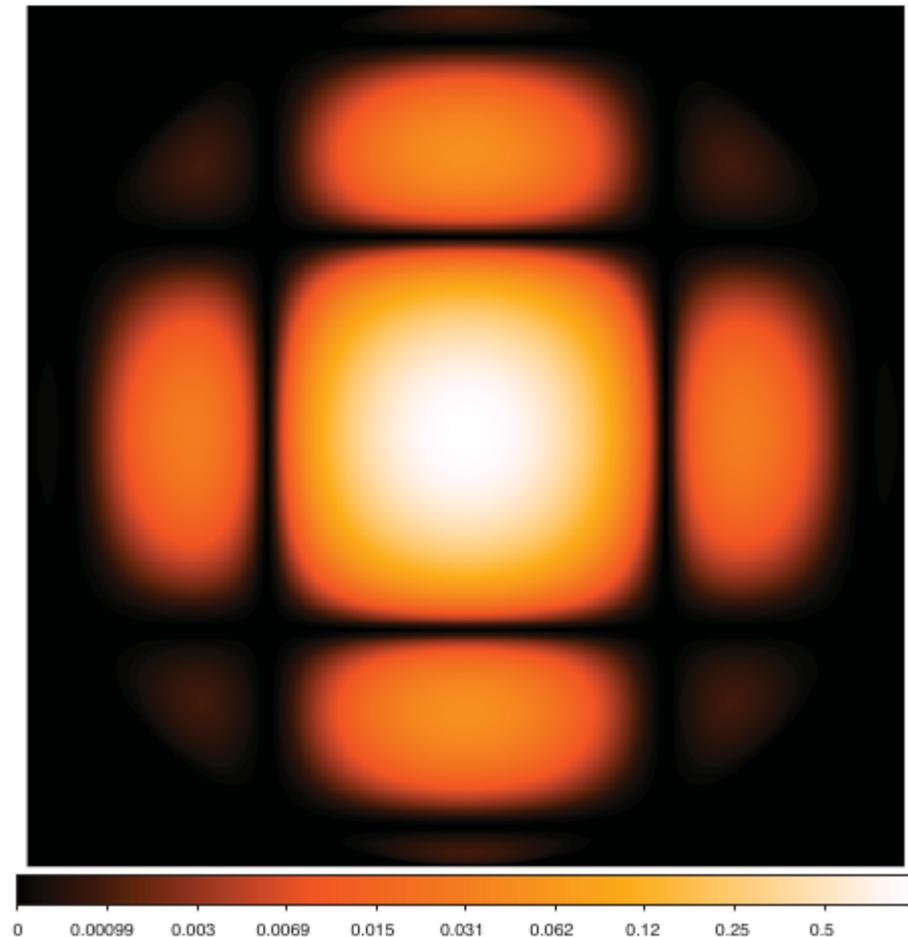


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Thank you



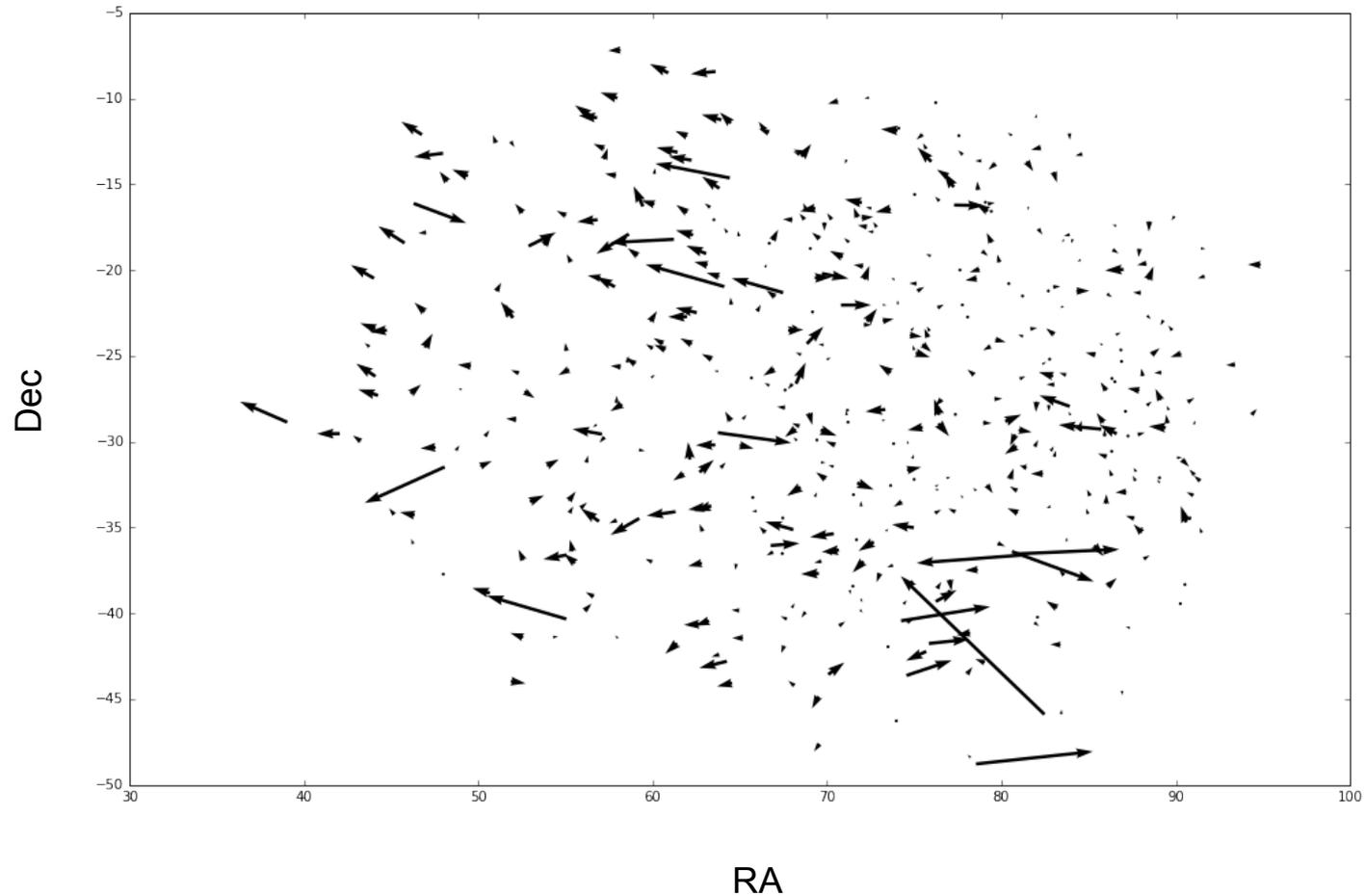
Simulated MWA beam at 150 MHz



Credit: Tingay et al. 2012



IPS affected by ionospheric effects?





The visibility-spectra plot

