Studying pulsars in the image plane with the Murchison Widefield Array

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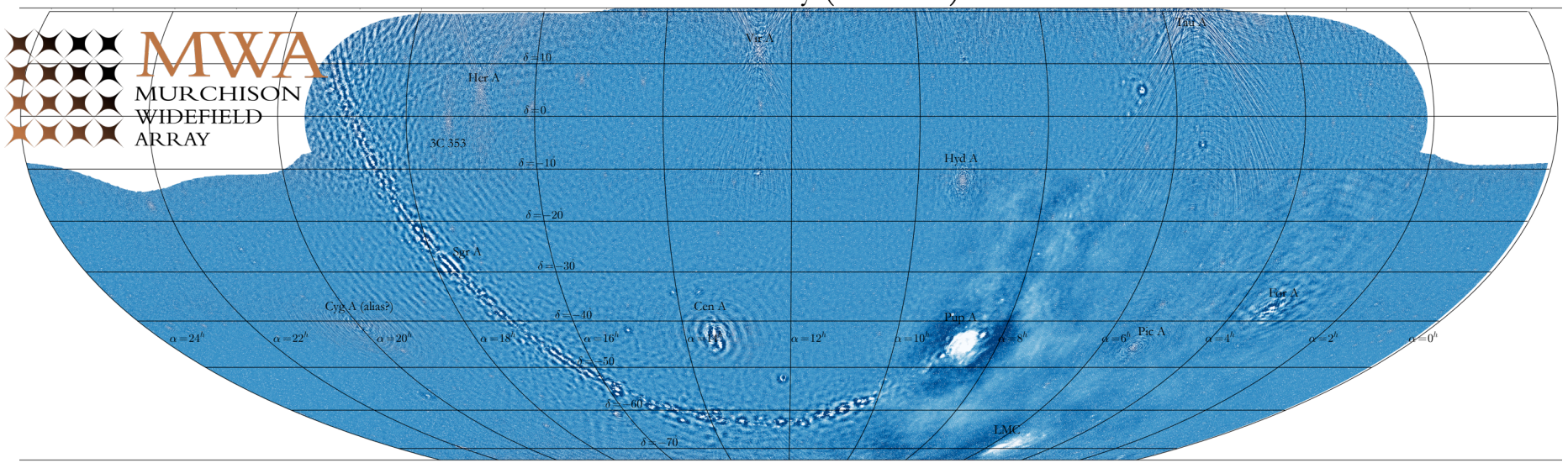
The low frequency Southern sky

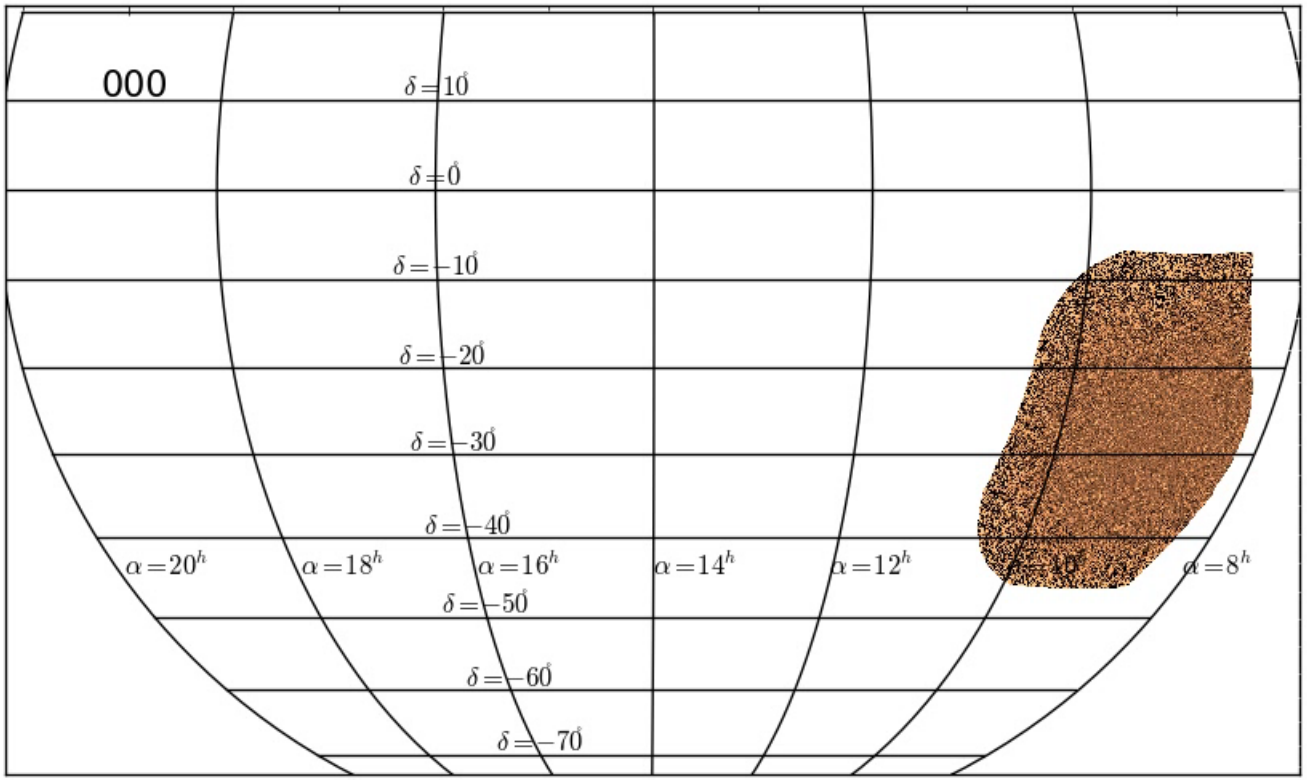
~16,000 square degrees

MWA Transient Survey (MWATS)



Credit: M. Bell (CSIRO), T. Murphy, A. Musaeva (Sydney), D. Kaplan (UWM) on behalf of the MWA Collaboration

Observing strategy



Movie courtesy of D. Kaplan.

Observational summary

Frequency: 154 MHz.
Method: Drift scans at +1.6, -26 and -55 degrees.
Cadence: One night per month.
Integration time: Two minutes.
Sensitivity: ~20 mJy per two minutes.
Survey length: Two years (0.25 PB data)

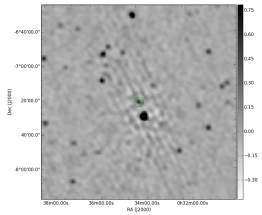
MWATS data reduction plan:
1.) Phase 1 data reduction of whole sky. DONE
2.) Phase 2 data reduction of all pulsar fields. ALMOST DONE
3.) Phase 2 data reduction of remaining MWATS observations. NEXT

Pulsar data reduction pipeline:
1.) Identify pulsars in phase-1 MWATS mosaics using ATNF pulsar catalog.
2.) Make “A-team” pulsar list.
3.) Re-reduce all available observations with phase 2 pipeline.
4.) Gain correction (using VAST pipeline)
5.) Light-curve generation (using new priorized Aegean fitting).
6.) Mosaicing and static catalog generation. SED fitting.

Image plane pulsars detections

*MWATS is a great survey to study image plane pulsars.
*~100 detections above 3 sigma.
*~30 detections bright enough to generate light curve statistics.
* Some examples below.

Mosaic images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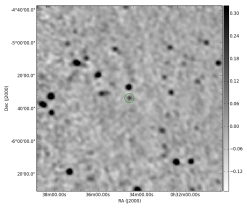
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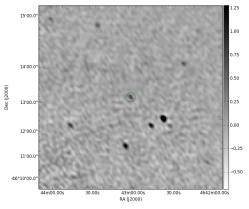
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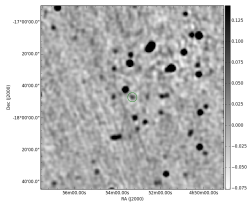
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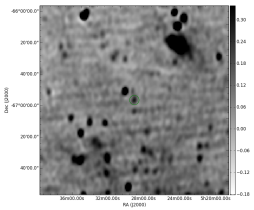
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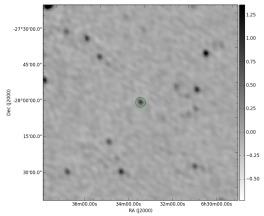
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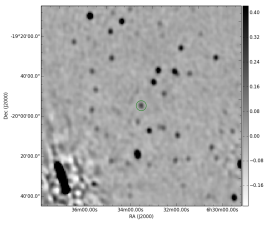
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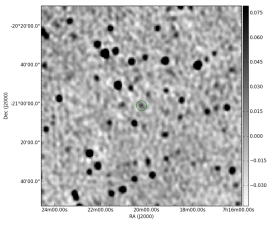
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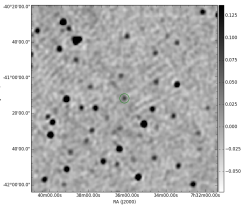
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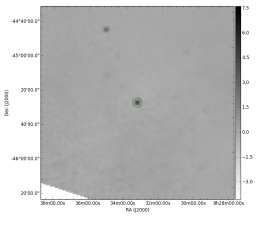
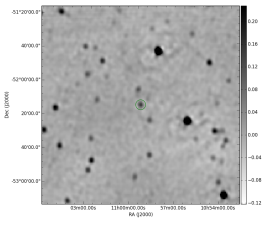

Vela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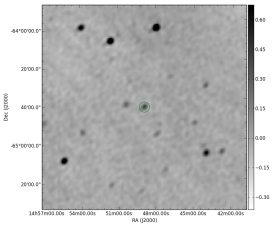
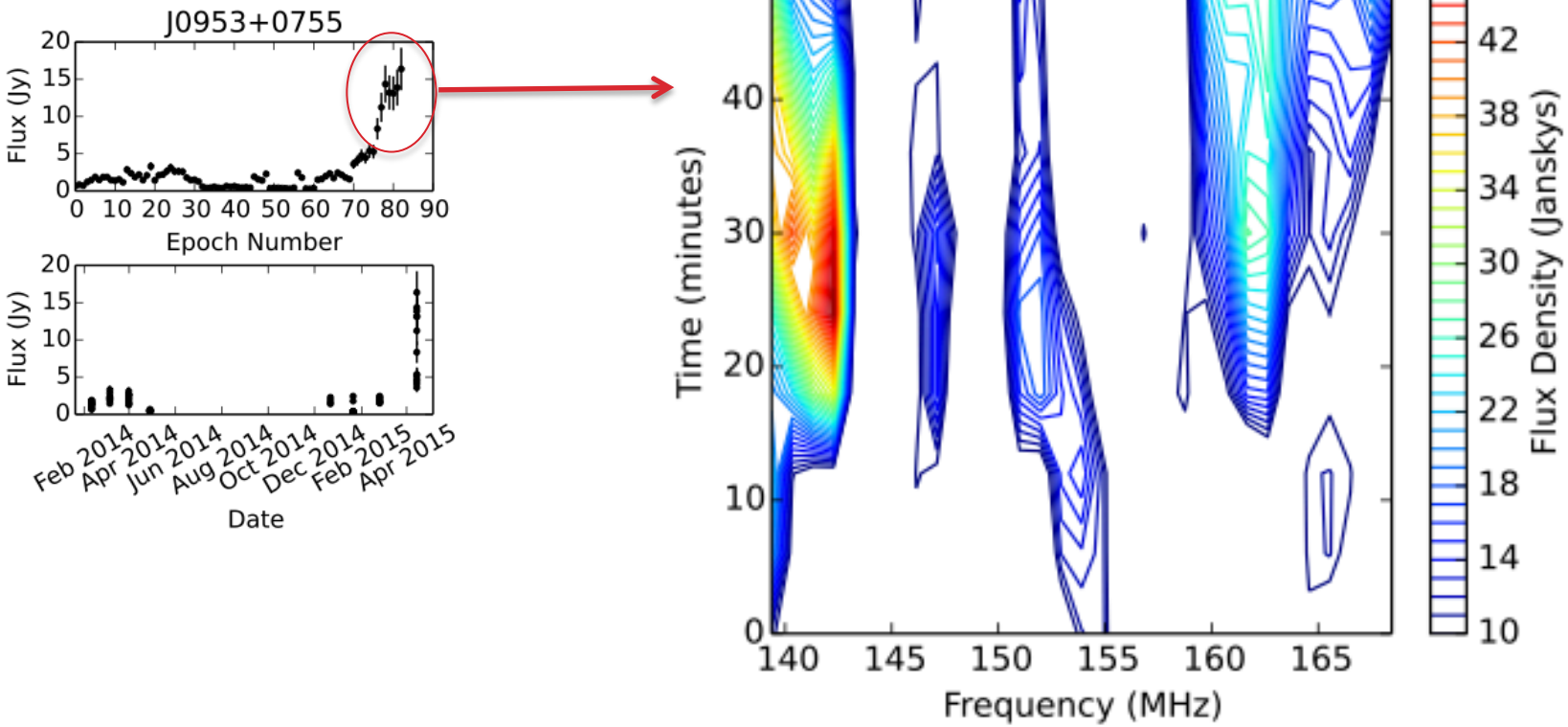

J1453-6413

J0953+0755

*Pulsar J0953+0755.
*Spectacular variability.
*Distance 127 pc.
*DM = 2.96

J0953+0755 Dynamic Spectrum



J0953+0755: can we explain this with scintillation?

> Phillips and Clegg (Nature 1995)
> Arecibo observations at 50 MHz.
> Report average scintillation bandwidth of 31.75 KHz.
> $\Delta\upsilon_d \propto \upsilon^{-4.4}$: scaling to 154 MHz we expect 4.5 MHz.
> Report average scintillation timescale of 280.3 seconds (4.5 minutes)
> $\Delta t_d \propto \upsilon^{-1.2}$: scaling to 154 MHz we expect 1081.1 seconds (18.0 minutes)

Prediction at 154 MHz:
Scintillation bandwidth = 4.5 MHz
Scintillation timescale = 18 minutes

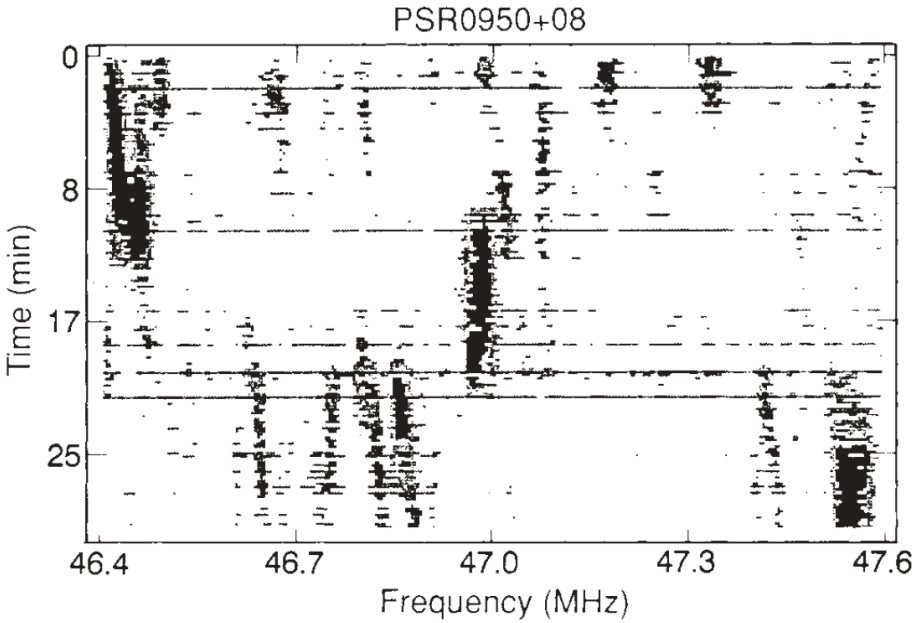
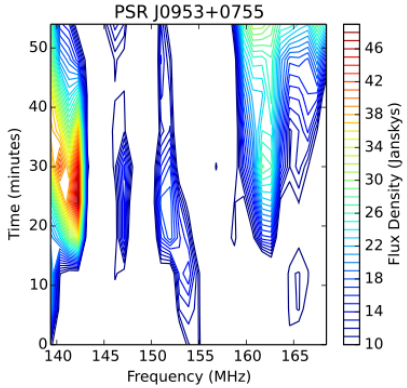
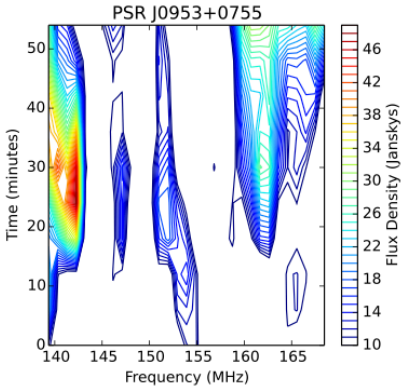


FIG. 1 Dynamic spectrum of PSR0950+08 obtained at 47 MHz on 1989 November 26. The grey scale represents flux density as a function of time and frequency, with black indicating strong flux density. The black horizontal lines are terrestrial interference.

J0953+0755: 2d correlation function



< ACF >



> Take FWHM of ACF in time and frequency to ascertain scintillation bandwidth in frequency and time.

Prediction at 154 MHz:
Scintillation bandwidth = 4.5 MHz
Scintillation timescale = 18 minutes

vs

Measured:
Scintillation bandwidth = 4.1 MHz
Scintillation timescale = 24 minutes

J0437-4715

J0630-2834

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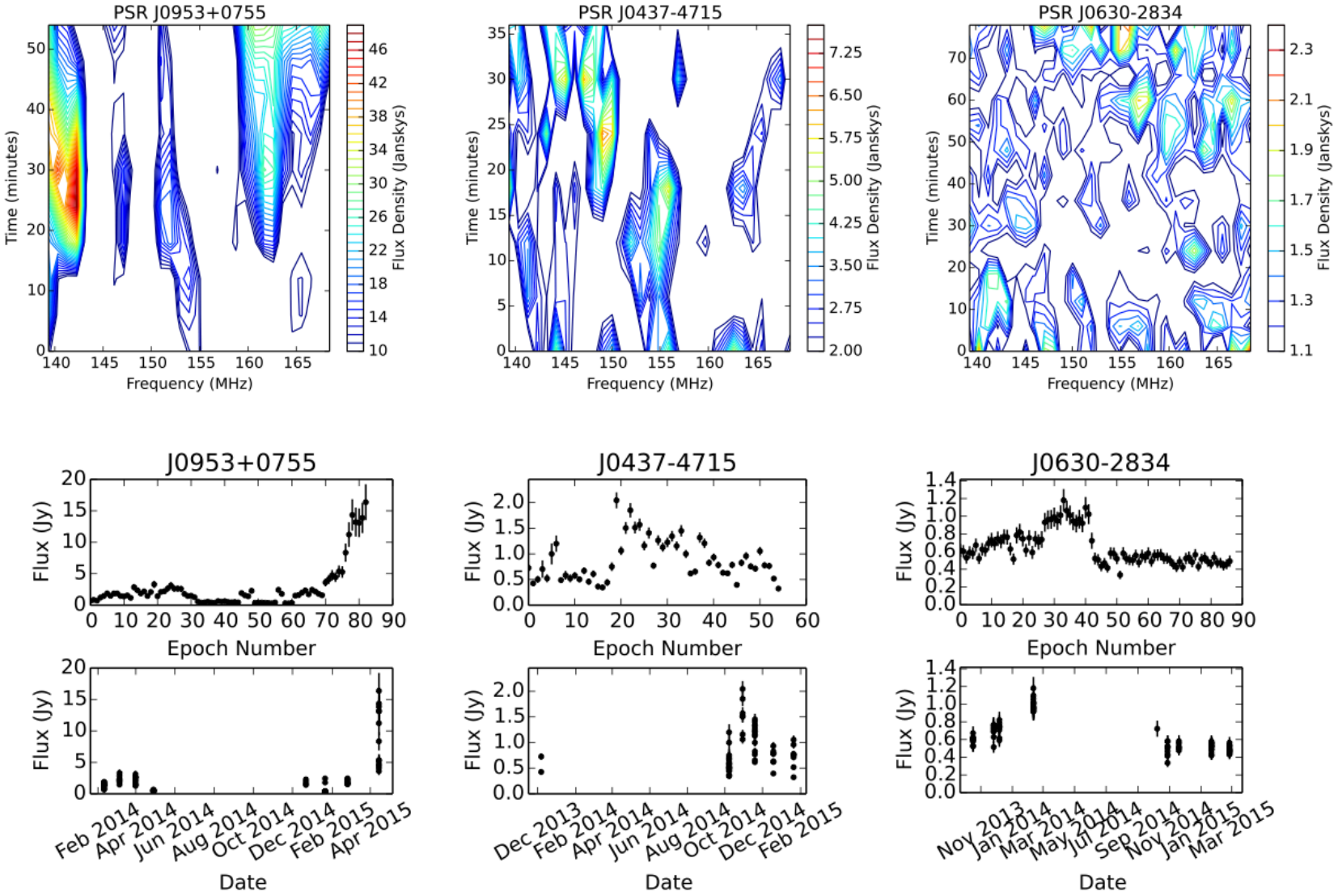
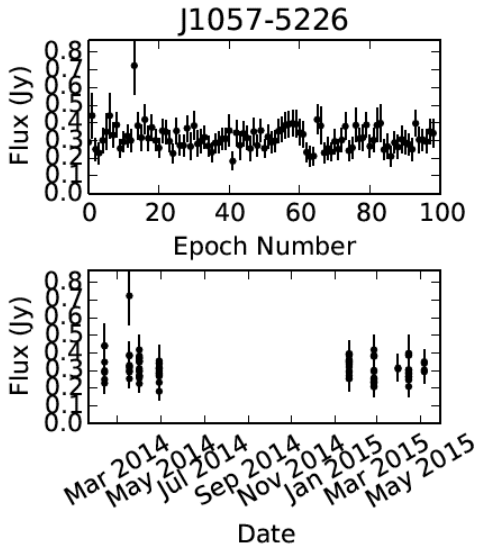
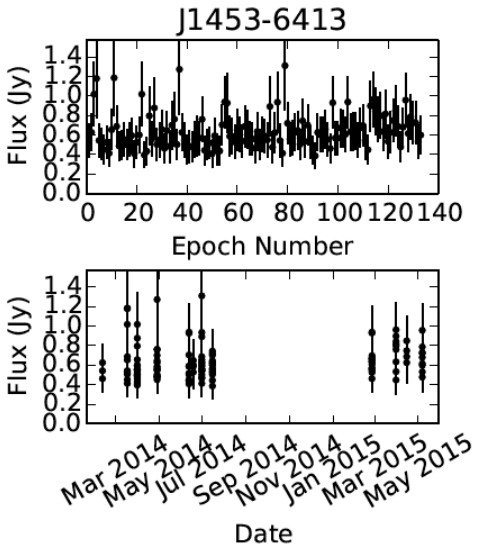
FOR ALL-SKY ASTROPHYSICS

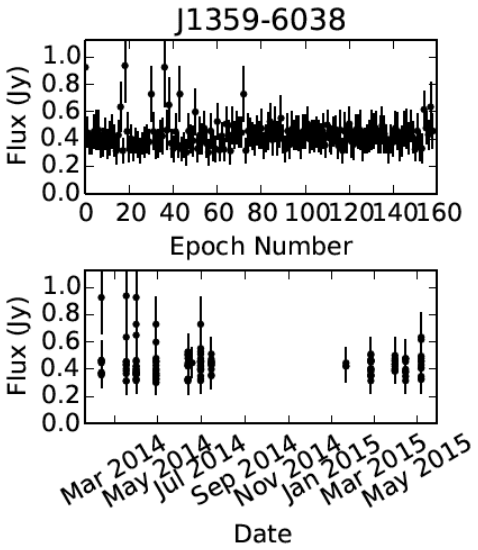
More dynamic spectra

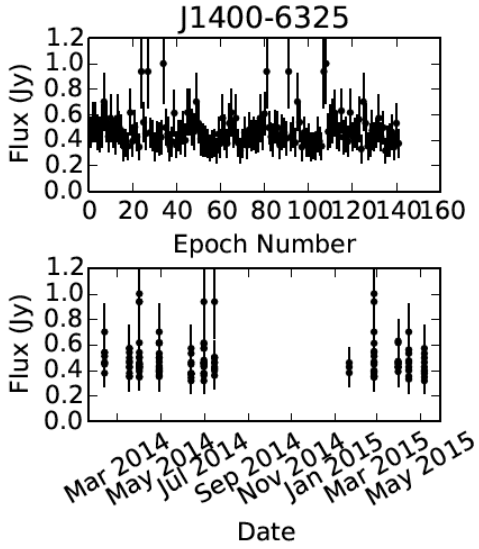


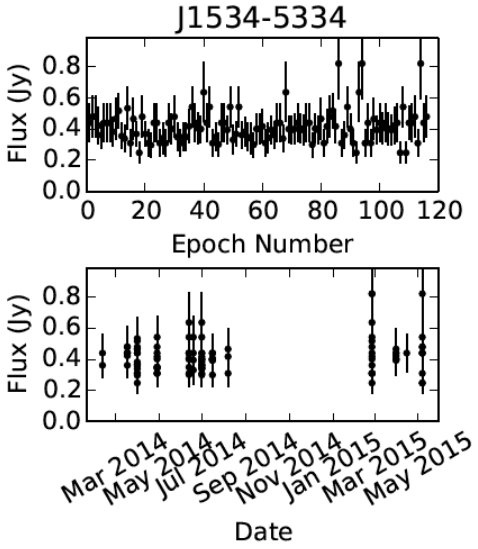
More light-curves

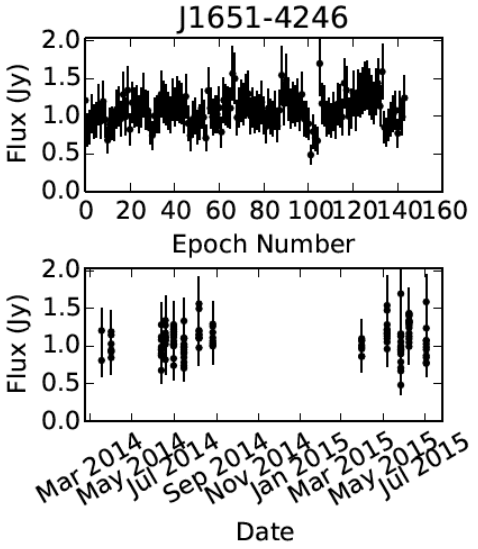




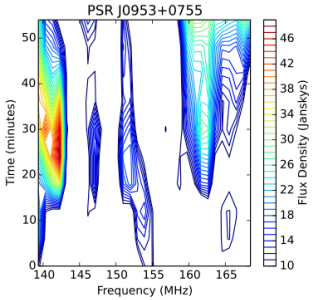


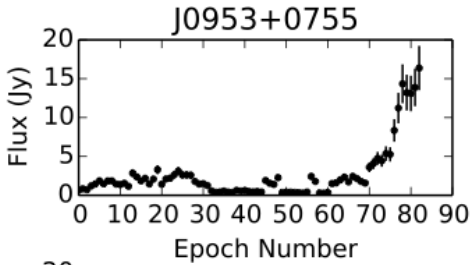


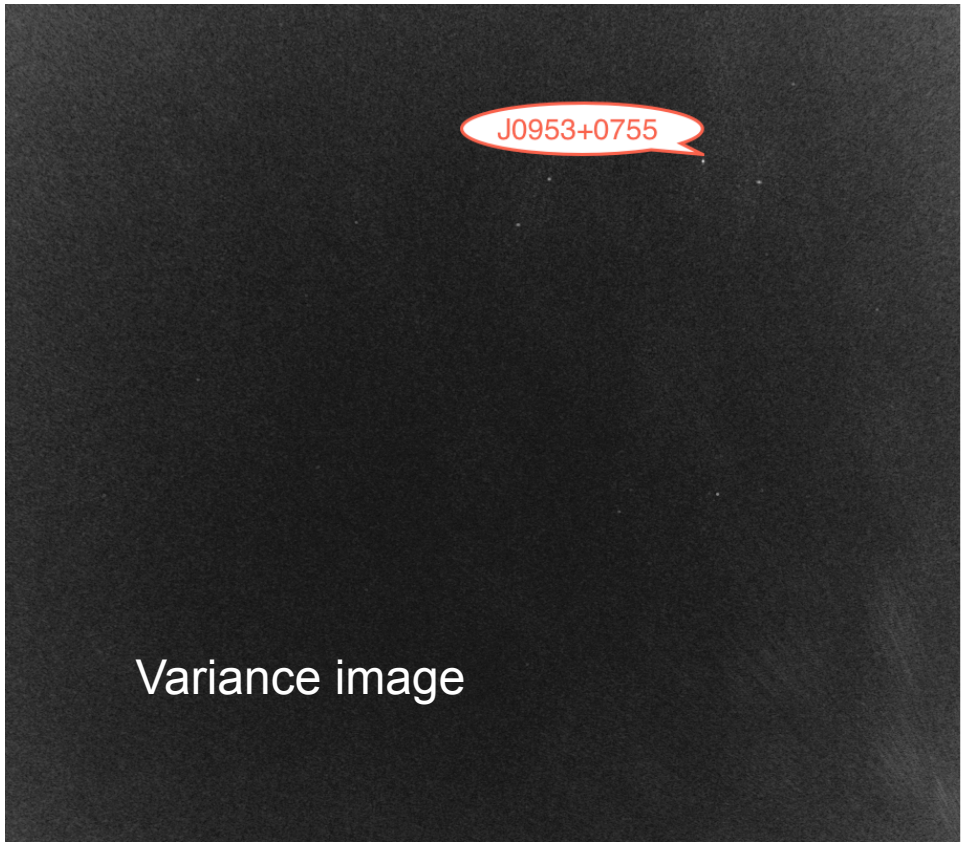


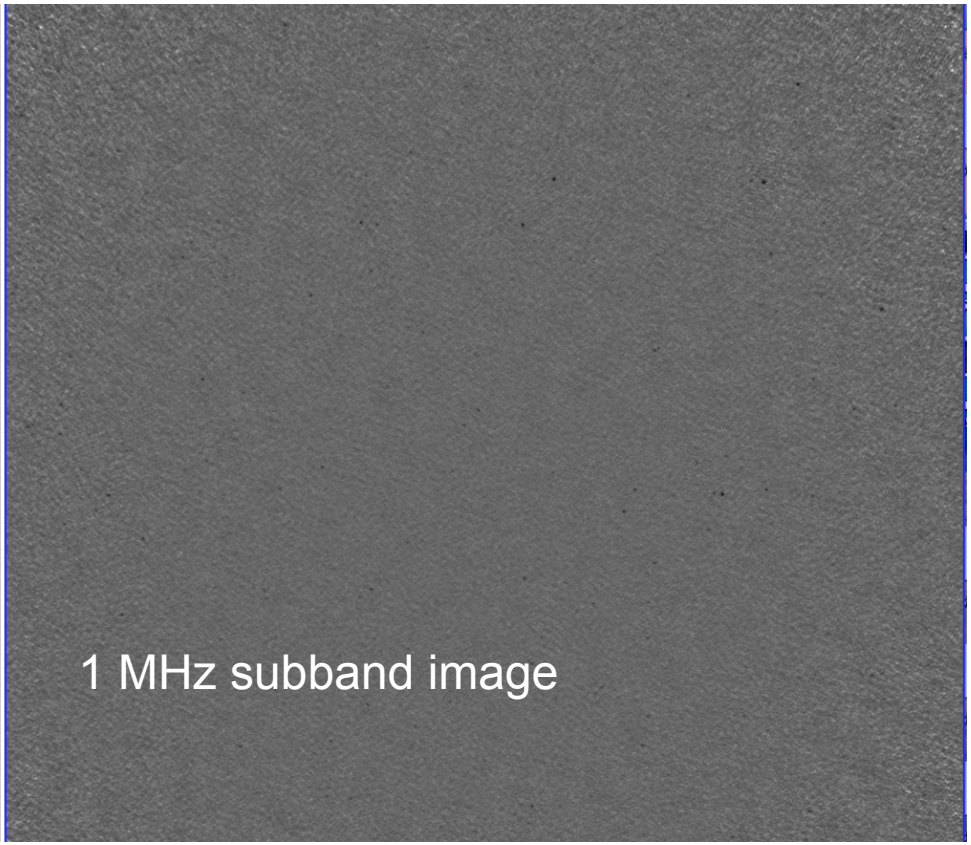


A note about variance imaging









Conclusions

- Three pulsars show significant scintillation.
- Paper Bell et al. (2015) in prep.
- This paper should cover ~30 bright pulsars: light-curves, SEDs, catalog.
- Some of the pulsars clearly turn over. We should explore these more.
- Stokes V search has identified pulsar candidates.
- Full MWATS survey is on the way.

- Predictions for SKA:
- Scintillation gets washed with greater DM. Are we probing the all we can see with MWA?
- Is this a realistic pulsar detection method for SKA. i.e. data rates in high time resolution mode will be very high.
- What could we do with MWA Phase 2 / 3 or SKA?