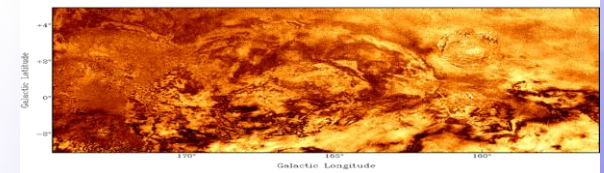
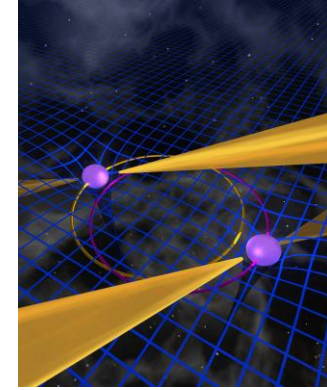
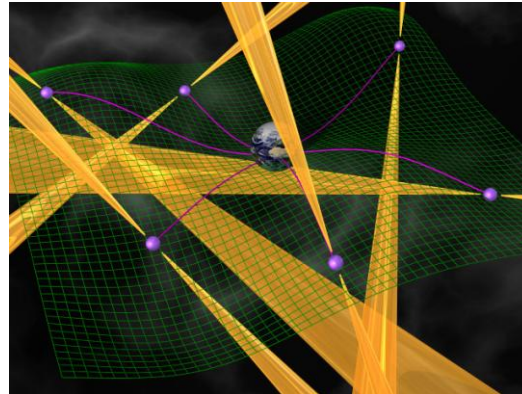
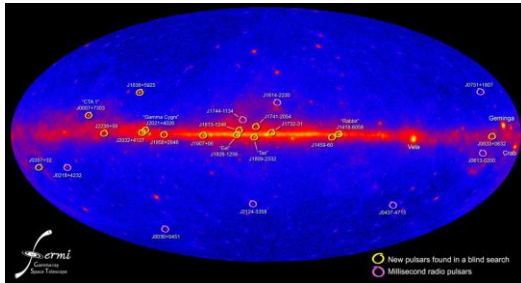




MMICS, multi-pixel receiver and science



M Kramer - MPIfR

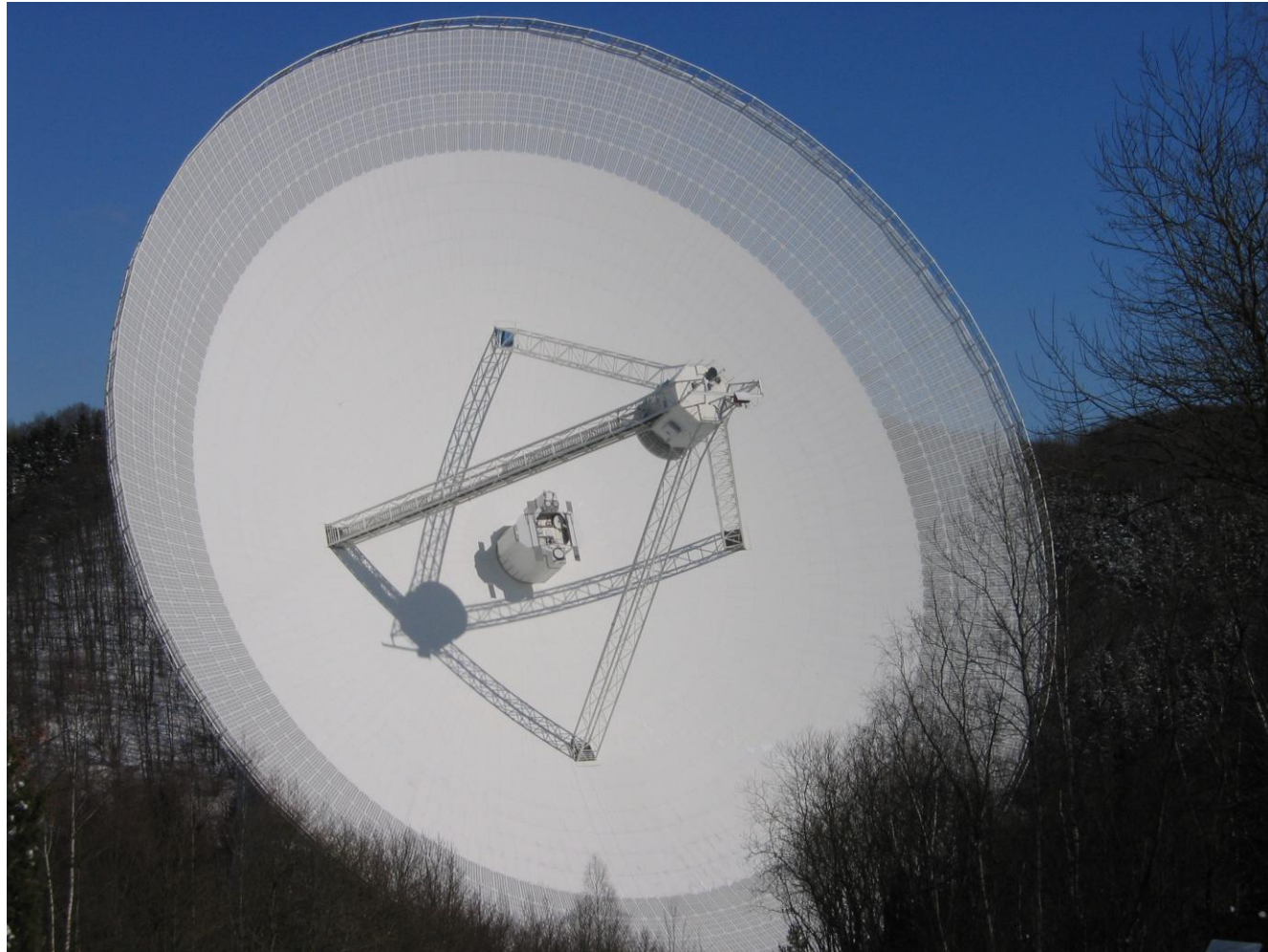


Outline

- The motivation for more than just one beam...
- The motivation for many beams...
- The motivation for MMIC arrays
- What can we expect...? What shall we use it for?



Multiple receiver horns

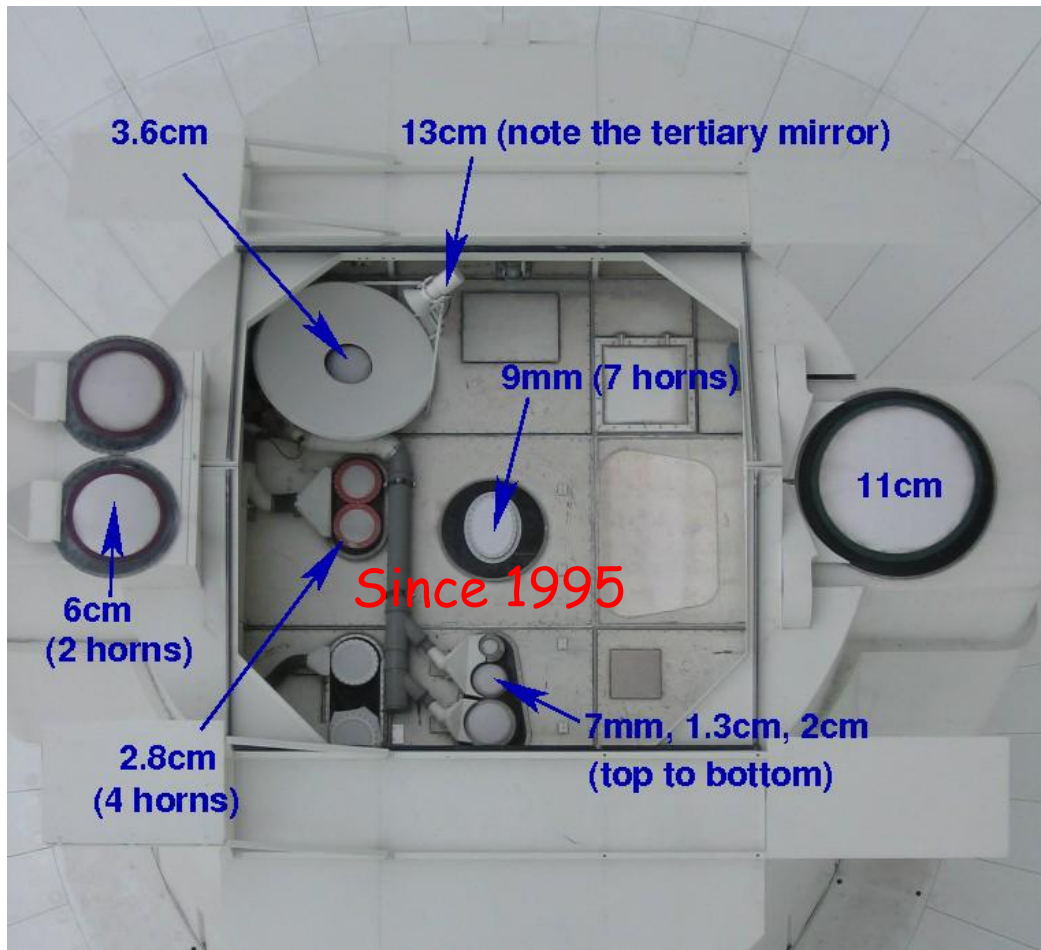




Multiple receiver horns

- Long established technique to remove weather

Since 1981

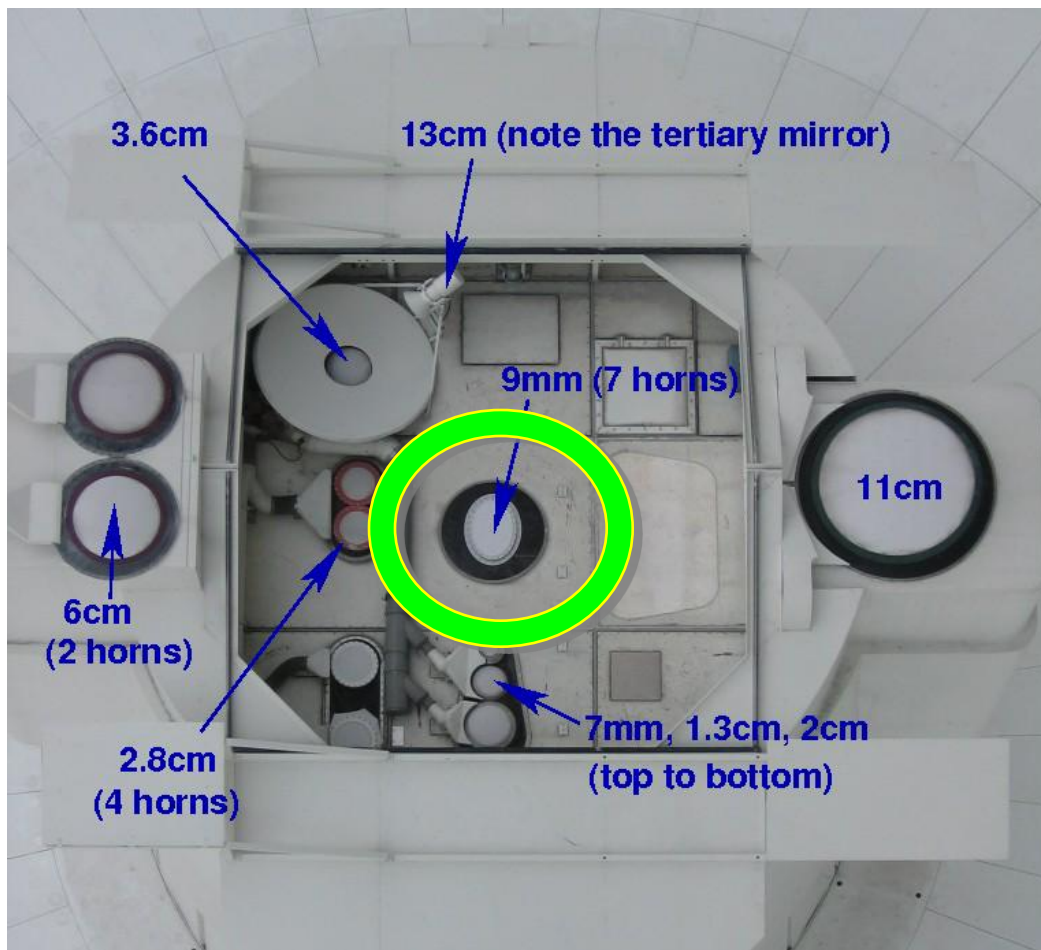


- Software beam switching
- Restoration to "single beam" via algorithm by Emmerson, Klein, Haslam (1979) and later Maximum Entropy Method



"Many" receiver horns

- In the last ~10 years established to increase field-of-view



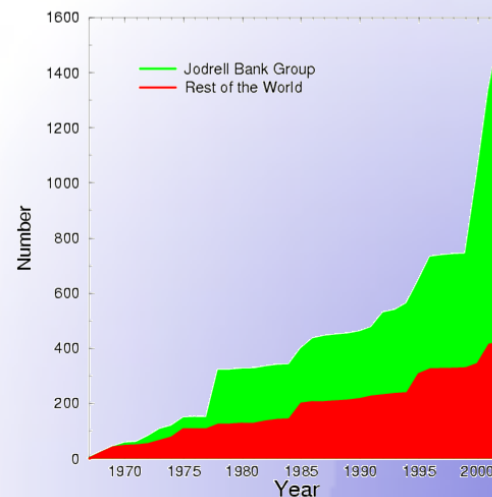
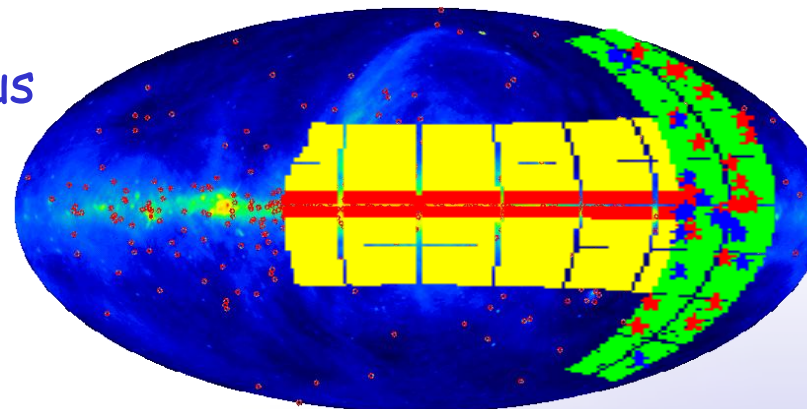
- e.g. Effelsberg 9mm array, OCRA-f
- Parkes L-band MB, MMB
- exciting science...



Parkees Multi-beam Survey

- Survey at Parkes, follow-up producing science with Lovell telescope
- Most sensitive large-scale survey ever
- More successful survey than all previous surveys put together
- Dwell time of 35 min
- More than 800 new pulsars
- Still counting...
- Very exciting discoveries of all kinds:

Pulsars with massive companions, in SNRs, magnetar-like, young and millisecond pulsars and some previously unknown types of sources

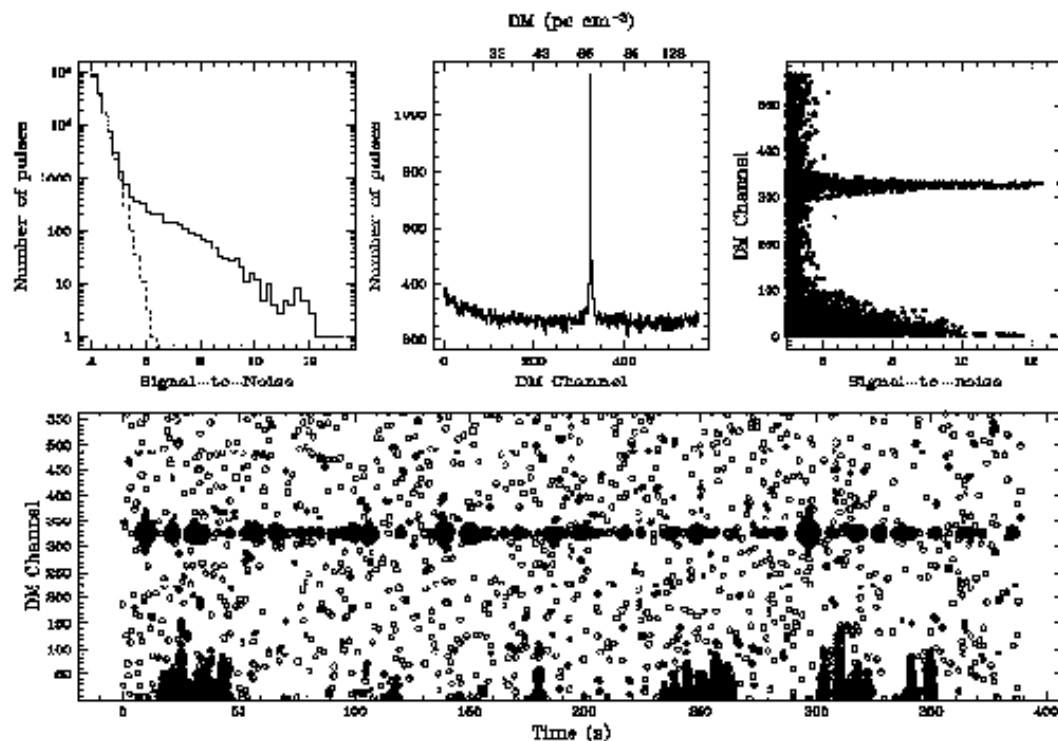




Transient Event Search

- Normal pulsars are better detected with FFTs, but...
- Good sensitivity to pulsars with occasional "giant" pulses

- Low immunity to RFI
- Multiple beams allow to gauge reality of signals



- A search for single, dispersed transient events in the Parkes Pulsar Multibeam Survey data set using method by McLaughlin & Cordes (2003)

- largest-scale search ever for transient radio sources

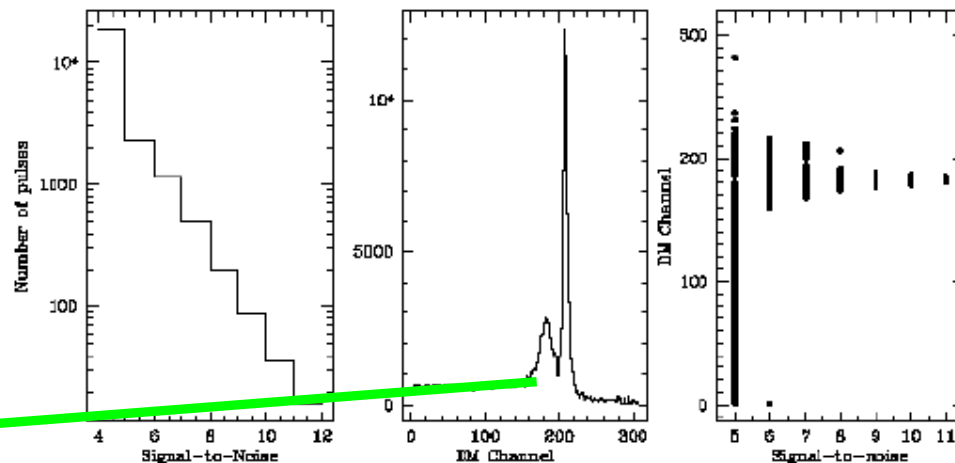


PKSMB Transient Search

- Roughly 1/3 (now 2/3! See later!) of all pulsars detected with FFT also detected in transient search
- Effective even for multiple pulsars in beam

PM0089 00311

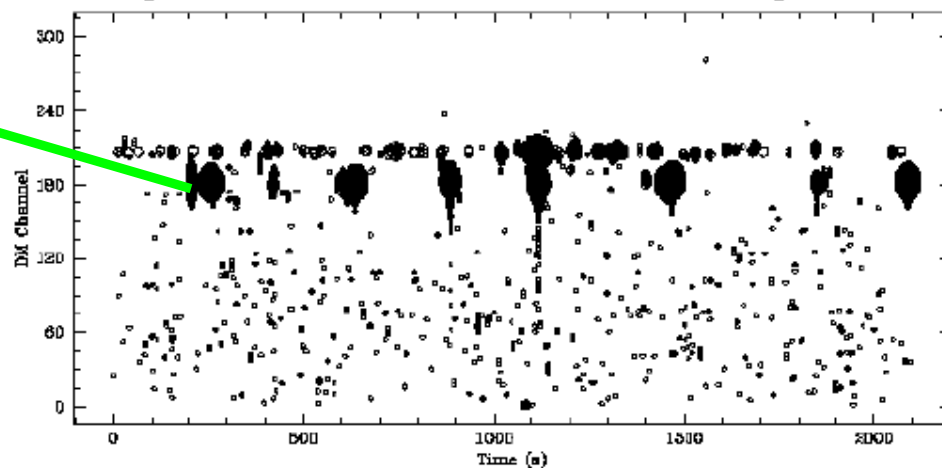
Aug 14 13:11:55 2003



J1840-0821

$P = 1.1 \text{ s}$

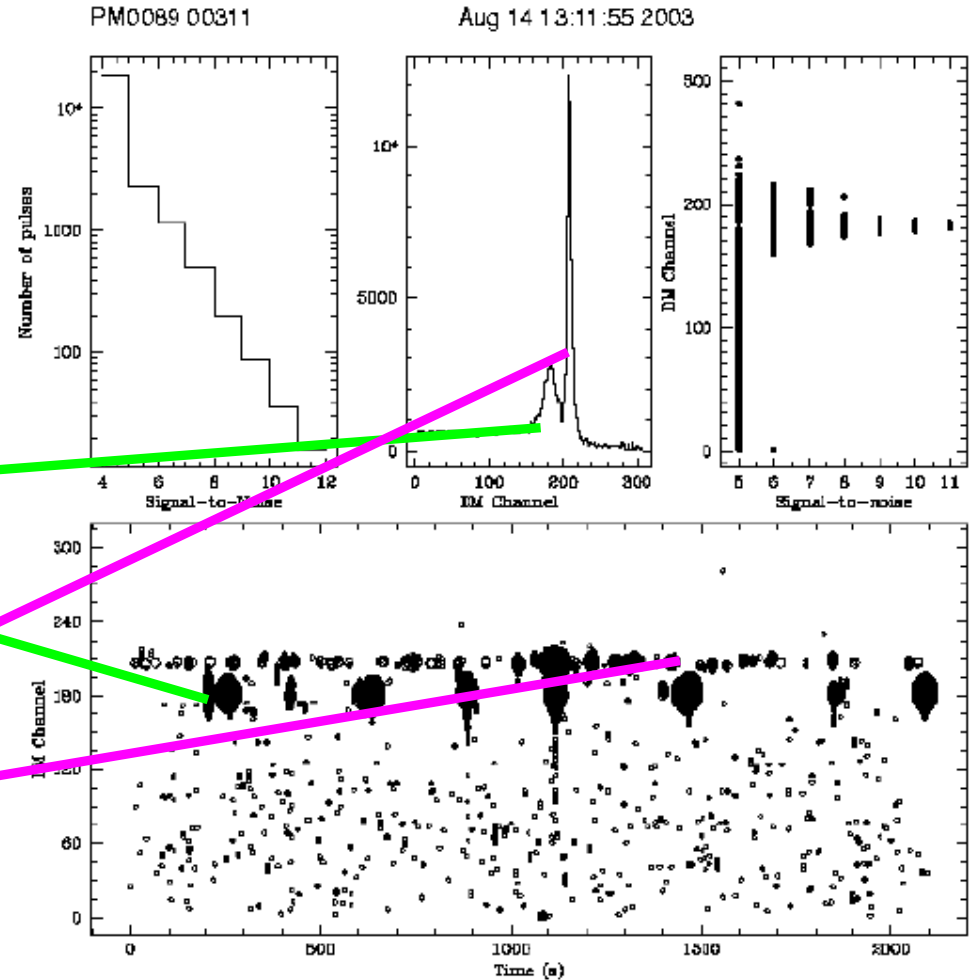
$DM = 225 \text{ pc cm}^{-3}$





PKSMB Transient Search

- Roughly 1/3 (now 2/3! See later!) of all pulsars detected with FFT also detected in transient search
- Effective even for multiple pulsars in beam



J1840-0821

$P = 1.1 \text{ s}$

$DM = 225 \text{ pc cm}^{-3}$

J1840-0808

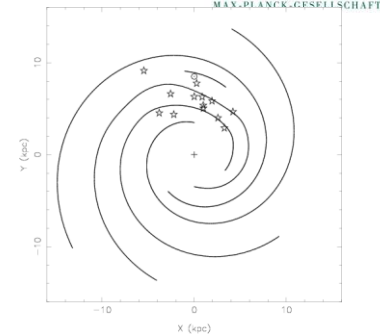
$P = 0.96 \text{ s}$

$DM = 353 \text{ pc cm}^{-3}$

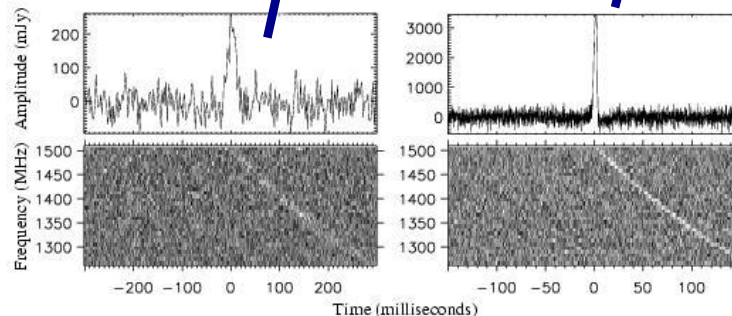
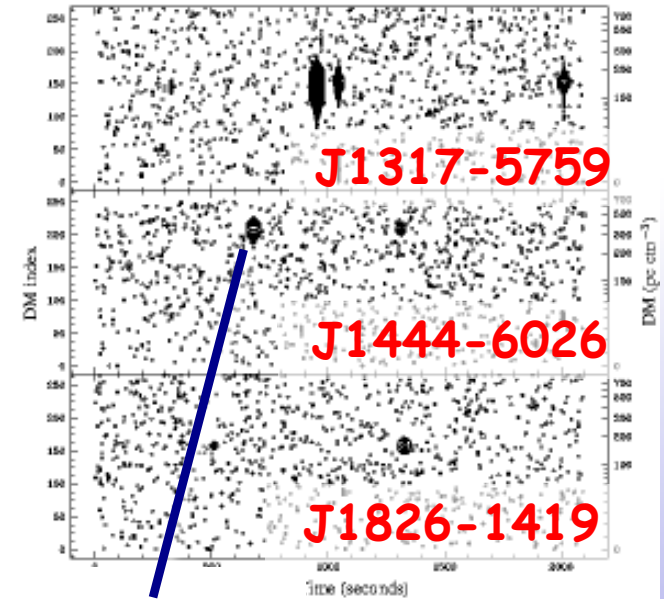
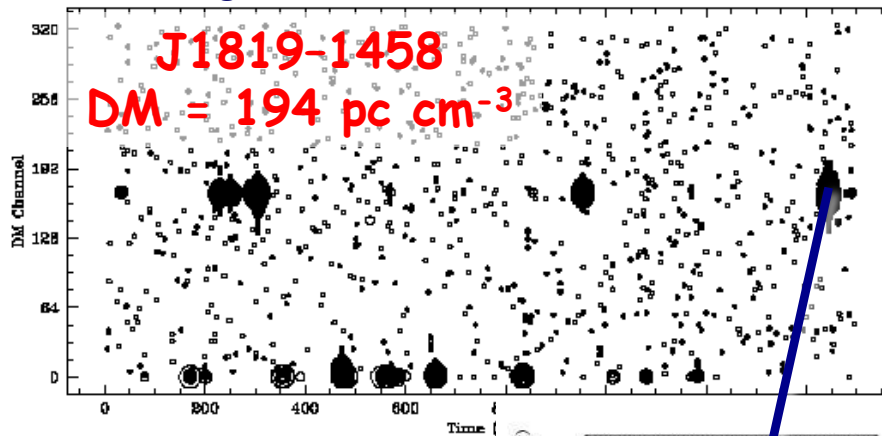


New transient sources

- Discovery of 11 dispersed transient radio sources (McLaughlin et al. 2006)
- Bursts with durations between 2 and 30 ms
- 1400-MHz peak flux densities from 0.1 to 3.6 Jy
- Average intervals between events from 4 min to 3 hr



McLaughlin et al. (Nature, 2006)

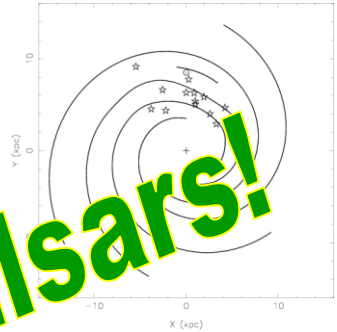




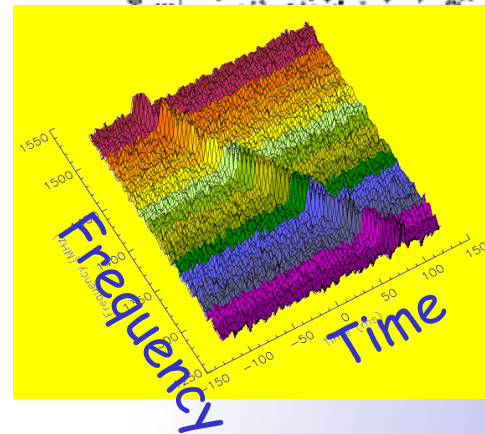
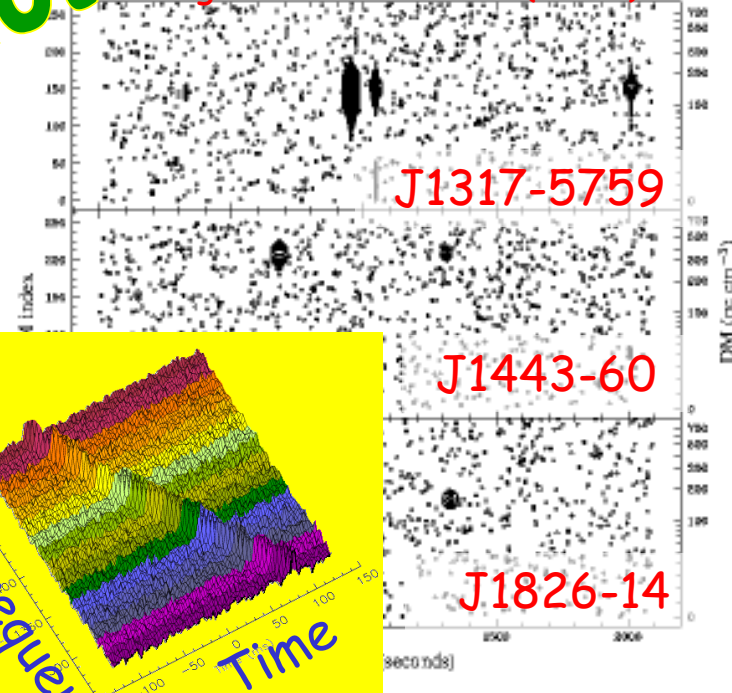
Rotating Radio Transients (RRATs)

- Large-area transient event search of PM survey data
- Largest and most sensitive window to transient sky yet
- Discovery of **unknown dispersed radio sources**, named RRATs
- Initially, 11 sources of repeating transient signals
- Intervals between events 4 min to 3 hr
- No periodicities from Fourier analysis
- But **periodicities** from time-difference analysis (from 0.4 to 0.25)
- Average period ~ 3 s
- Period increasing
- **Rotating neutron stars**
- At least one source with high B-field
- **Emitting only 0.1-1s per day!!!!**
- Guaranteed sources for SKA & LOFAR

4x more RRATs than active pulsars!



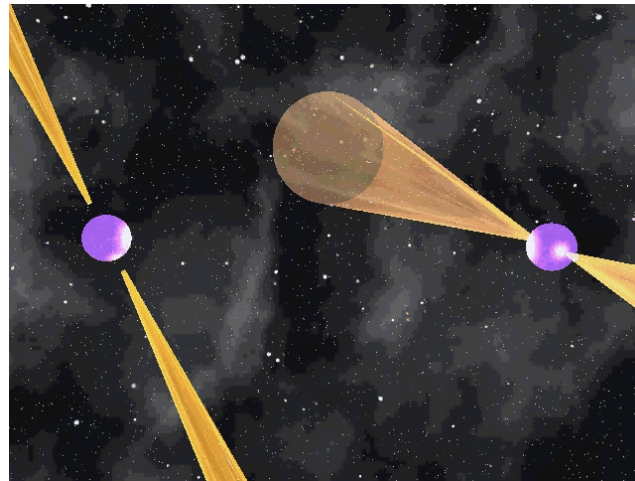
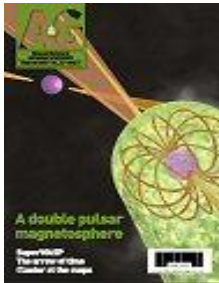
McLaughlin et al. Nature (2006)





The first double pulsar system

- Discovered in PM extension (Burgay et al. 2003, Lyne et al. 2004)
- A young 2.8-s pulsar in a 2.4-hr orbit with an old 23-ms pulsar

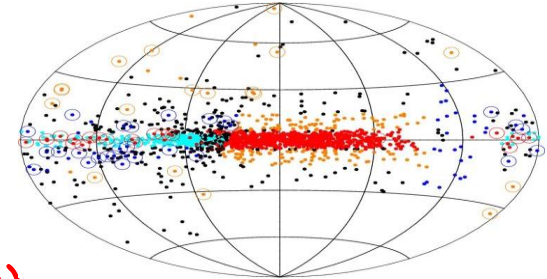


- Orbital velocities of 1 Million km/h!
- Dramatic confirmation of theories about binary evolution
- Unique lab for gravitational physics, plasma physics and our understanding of pulsar magnetospheres and radiation



High Time Resolution Universe Survey

- Survey of the whole Northern & Southern sky for pulsars and transients with Effelsberg & Parkes
- Using the 7-beam & 13-beam L-band systems
- Observing time adjusted to galactic latitude:
 - deep survey in the plane (relativistic binaries)
 - medium-deep survey at high latitudes (MSPs)
 - shallow high-latitude survey (old pulsars)
- Deeper than all previous surveys
- High-time resolution ($32\mu\text{s}$), fine frequency
- resolution (0.5 MHz) and 8 bits sampling
- Probing **8 x more volume in Galaxy!**
- Up to 500/530 normal & 100/130 millisecond pulsars
- **Data processing in partnership with AEI (Hannover)**
- **Follow-up and exploitation of discovered sources**





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Finding new exciting sources

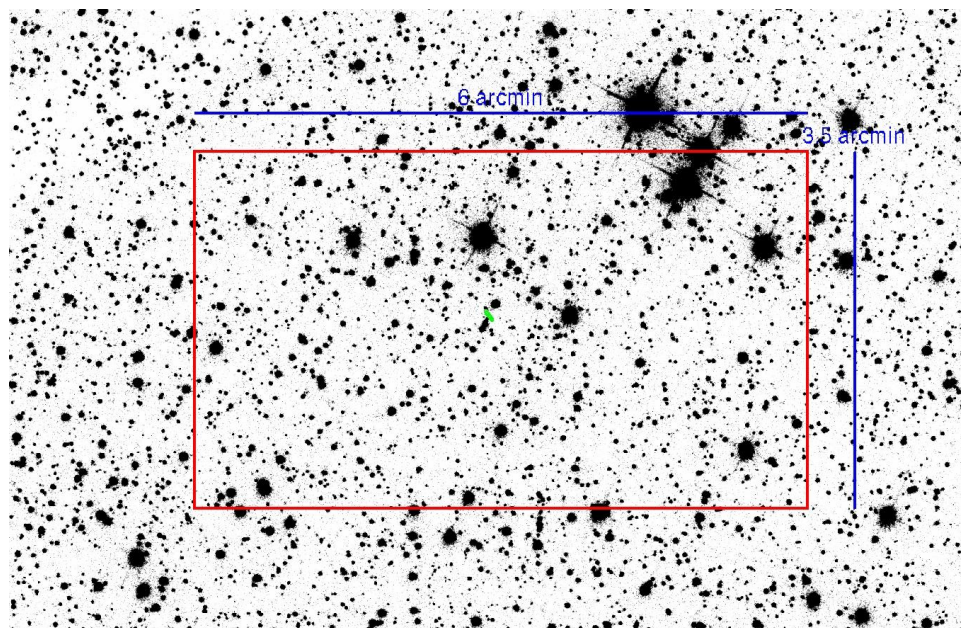
- already lots of new discoveries in previously searched areas:
 - more than 60 new pulsars
 - >10 millisecond pulsars (incl., bright, eclipsing, planet - stay tuned!)
 - and **some unexpected ones...!**



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Van Straten et al. (in prep).

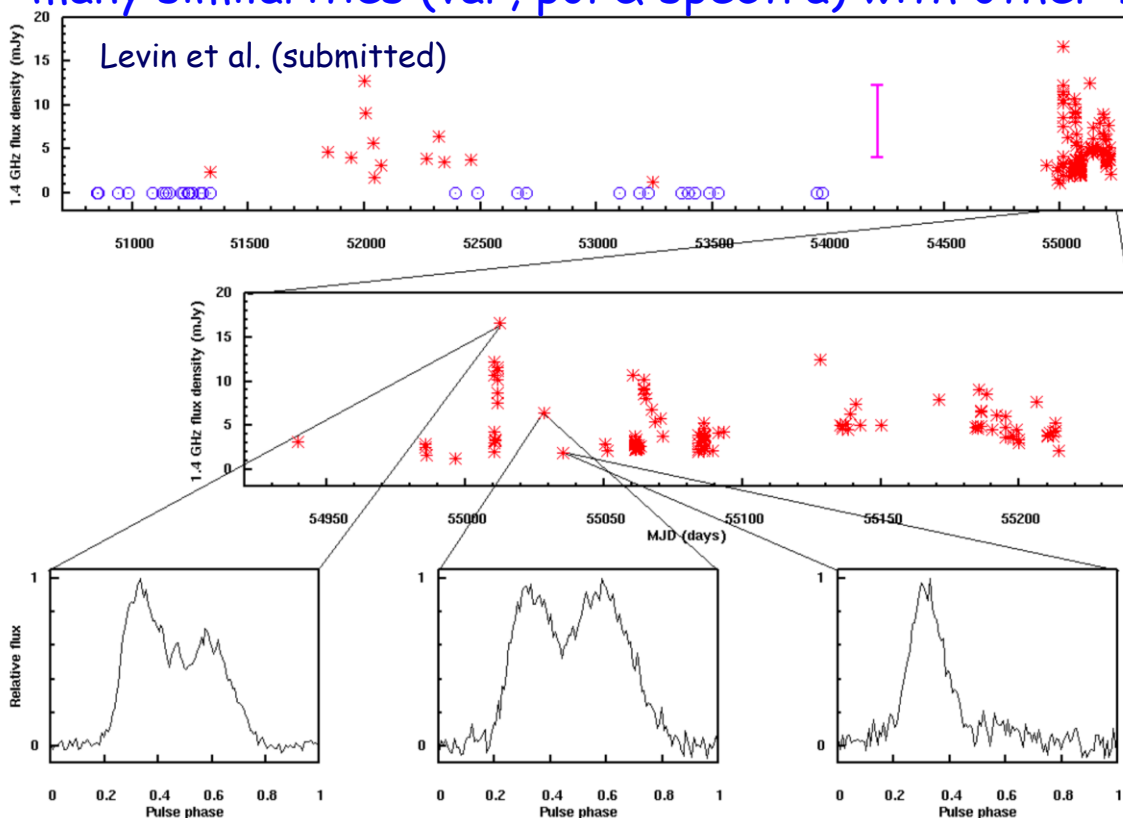


- 5.8 ms pulsar in 2.2-hr orbit with 1.2 M_{jupiter} mass companion...

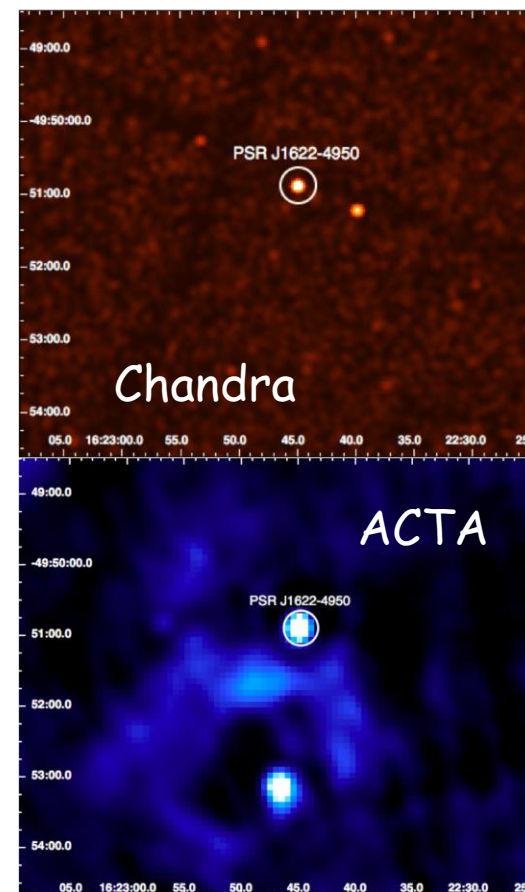


First magnetar found in blind radio search

- a radio-loud magnetar in x-ray quiescence (Levin et al. 2010)
- PSR J1622-4950: $P = 4.3$ s, $B = 3 \times 10^{14}$ G, $L_x = 0.3$ dE/dt
- many similarities (var, pol & spectra) with other two known radio magnetars:



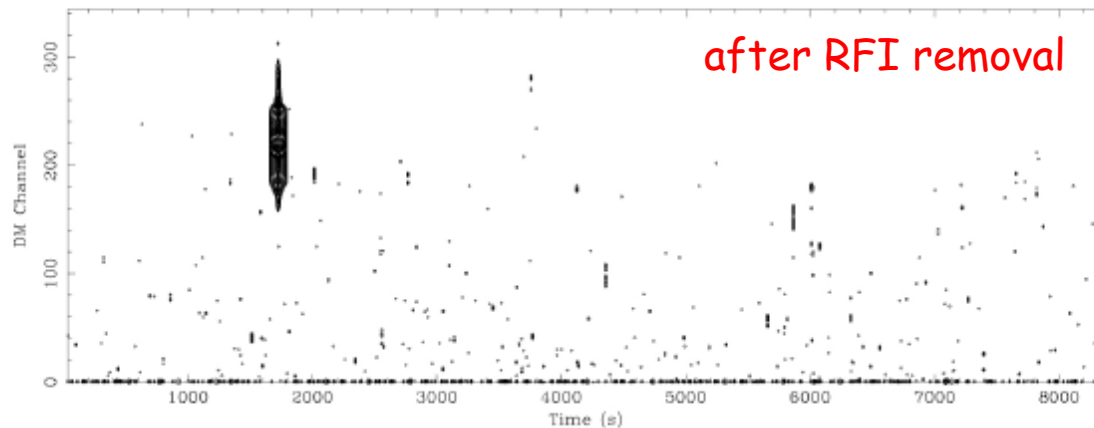
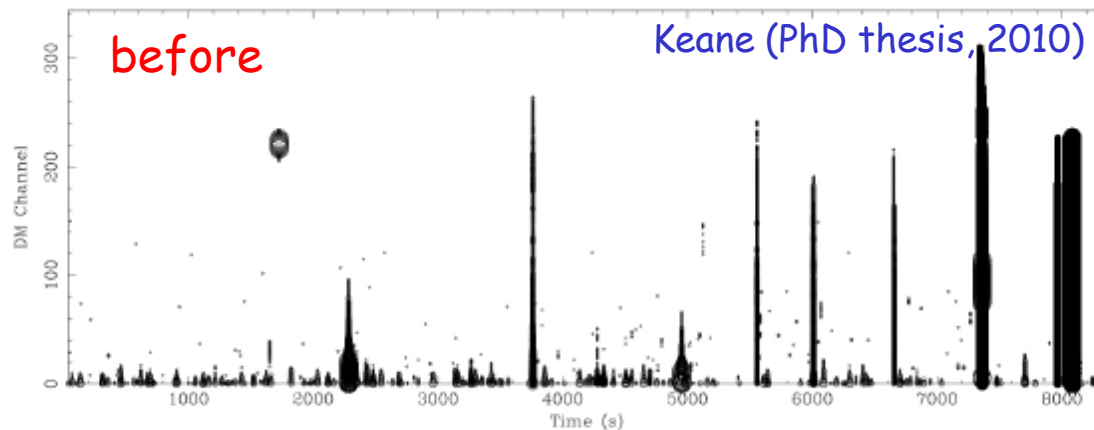
- many similar sources expected
- reverse triggering across EM spectrum





Advantages

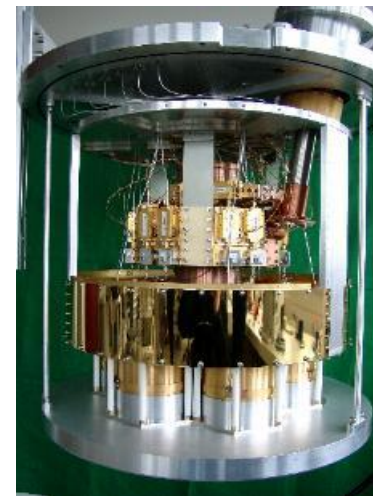
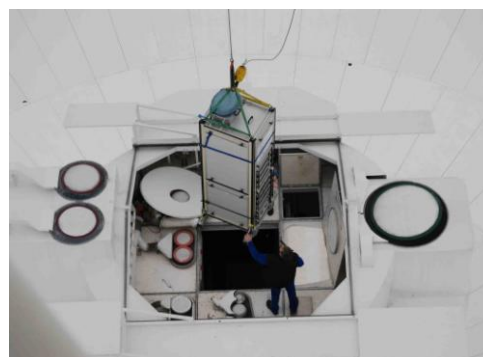
- Increase in field-of-view and hence survey speed: sensitivity!
- Use information provided by beams for RFI mitigation (e.g. Keane et al.):
remove common signals or reference beam from data





Ideally, many more beams

- Aim: 100+ and more beams for receiving systems for existing telescopes. Compactness and costs are important issues:



- Needed also for SKA and pathfinders: mass production
- Hence, MMICS are ideal solution

What is the killer applications?

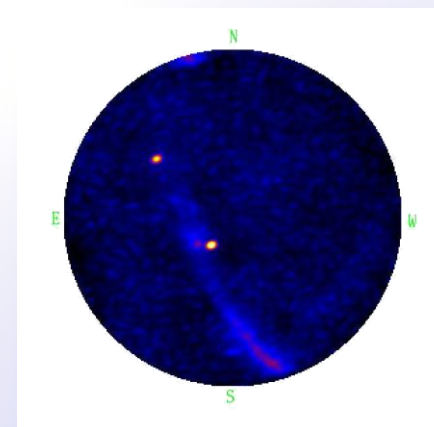
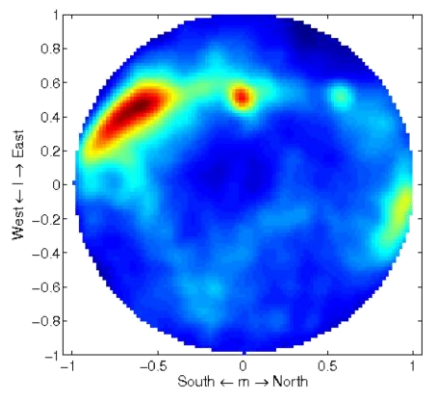
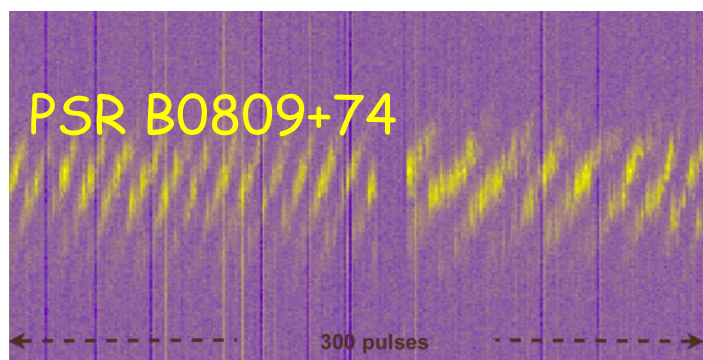
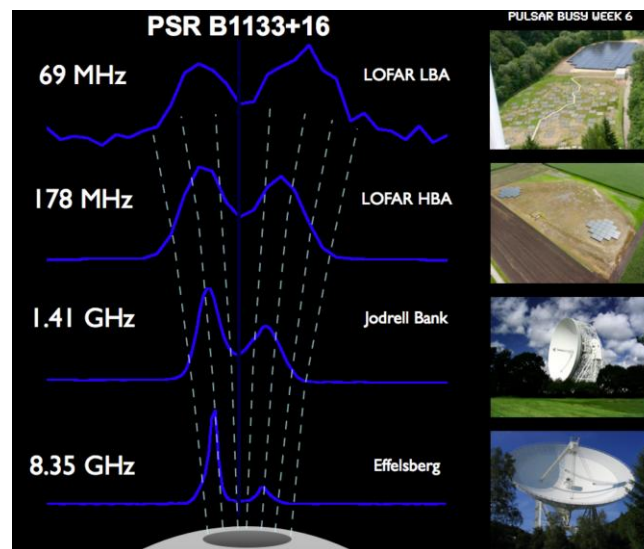
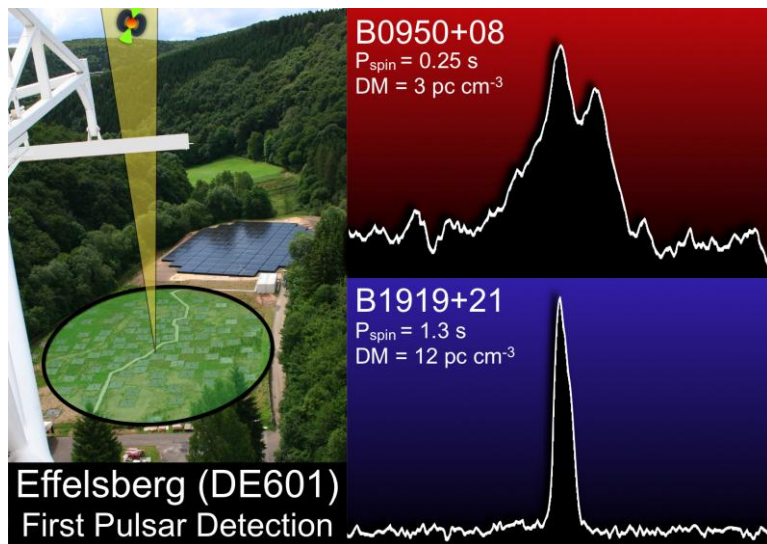


Where shall we use MMICs?

- New generation array telescope obvious targets (numbers!)
- Possibility to produce many beams on the sky
- **Survey projects are ideal**, e.g. CMB, foreground etc
- Backends can be demanding
- One must also consider time-domain processing (pulsars & transients)
- Due to large number of beams, RFI mitigation may be possible even in previous inaccessible beams (robustness of system and backend!)
- Promises powerful new role for “old” telescopes, in particular single dishes, e.g.
- Zero-spacing, time-domain snapshots of sky, deep surveys
- Access to polarisation information desirable..!



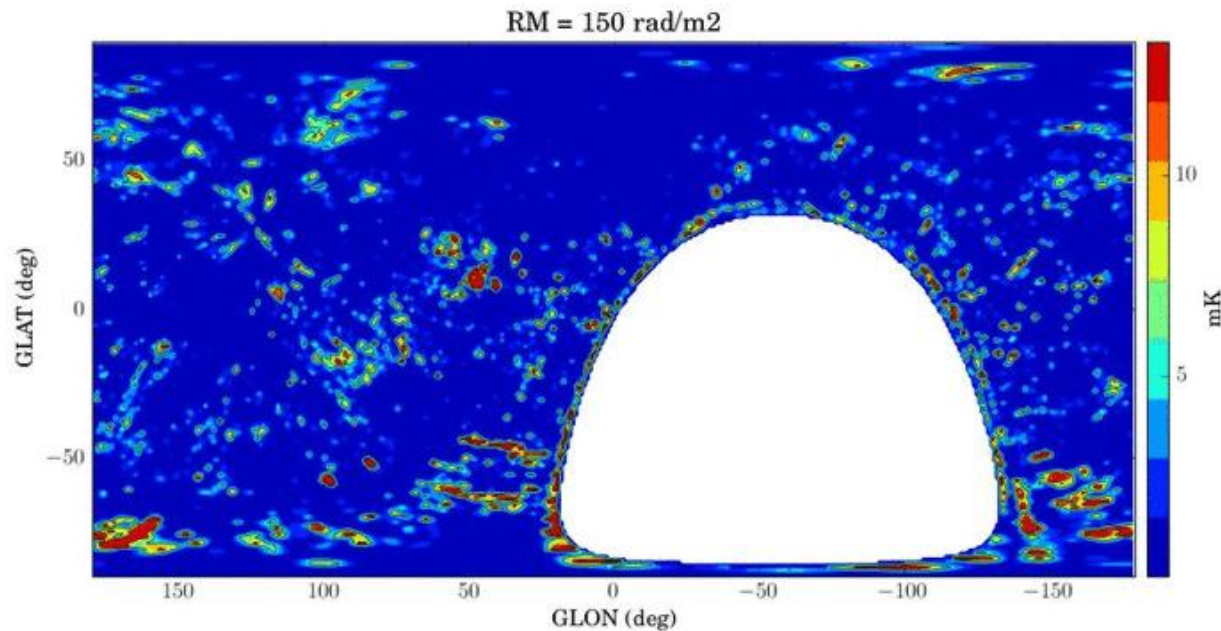
Complementary to new windows





Galactic Polarisation Studies

Continued polarisation surveys, e.g. GMIMS (Global Magneto-Ionic-Medium Survey) all-Sky RM Survey: 300 - 1800 MHz (Wolleben)



- or survey between 12-18 GHz to study spinning dust...
- etc. etc.



Needed and/or desired

- Wide-bandwidth MMIC covering most of radio spectrum applications across frequencies
- Good polarisation performance essential
- On- and off-line RFI mitigation potentially using UNIBOARD, reference antenna, robust receivers
- Coordination between institutes make use of MMIC mass production
- Powerful processing and backend required frontend is only part of the story