Recent Pulsar & Fast Transient Developments and SKA Phase 1

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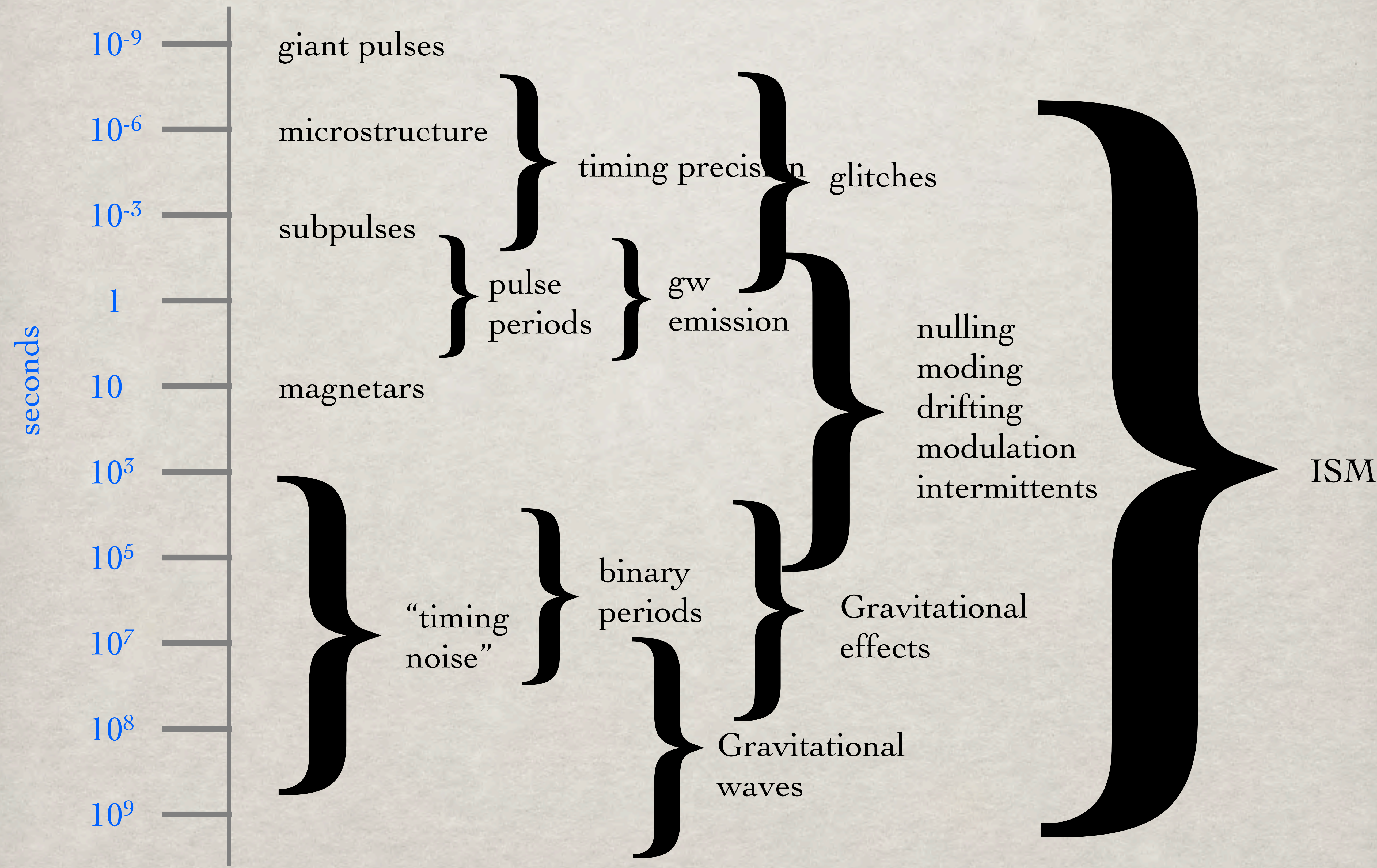
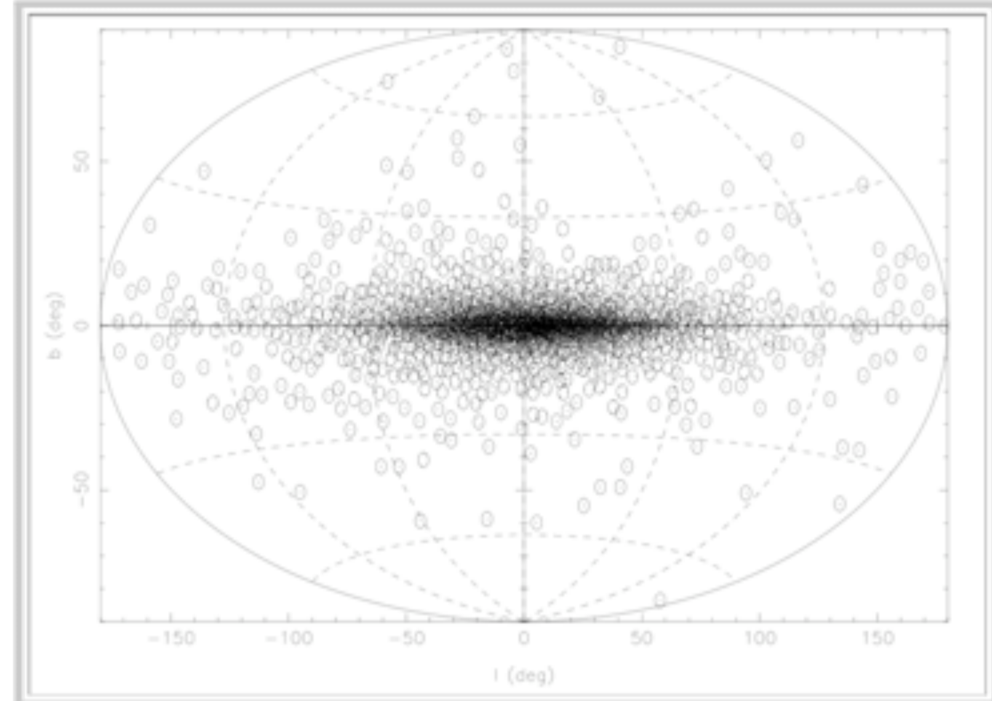
with slides from Hessels, Kramer, Karastergiou, Macquart, Liu, Weber, Law

From NanoSeconds to YEARS



Pulsars & SKA

10,000 - 30,000 pulsars



see Smits et al 2009

- Deep searches to find new and interesting systems
  - All-sky for MSPs and other pulsars
  - Galactic plane for young pulsars and MSPs
  - Galactic center for objects near SMBH
  - Globular Clusters and External Galaxies
- High Precision/SNR follow up observations
  - Timing observations for Gravity studies
  - Multiple freq. polarisation obs for emission
- VLBI observations
  - Parallax/Proper motions i.e. Distances/Velocities
- New Phenomena: e.g. RRATs, Intermittent, Bursts

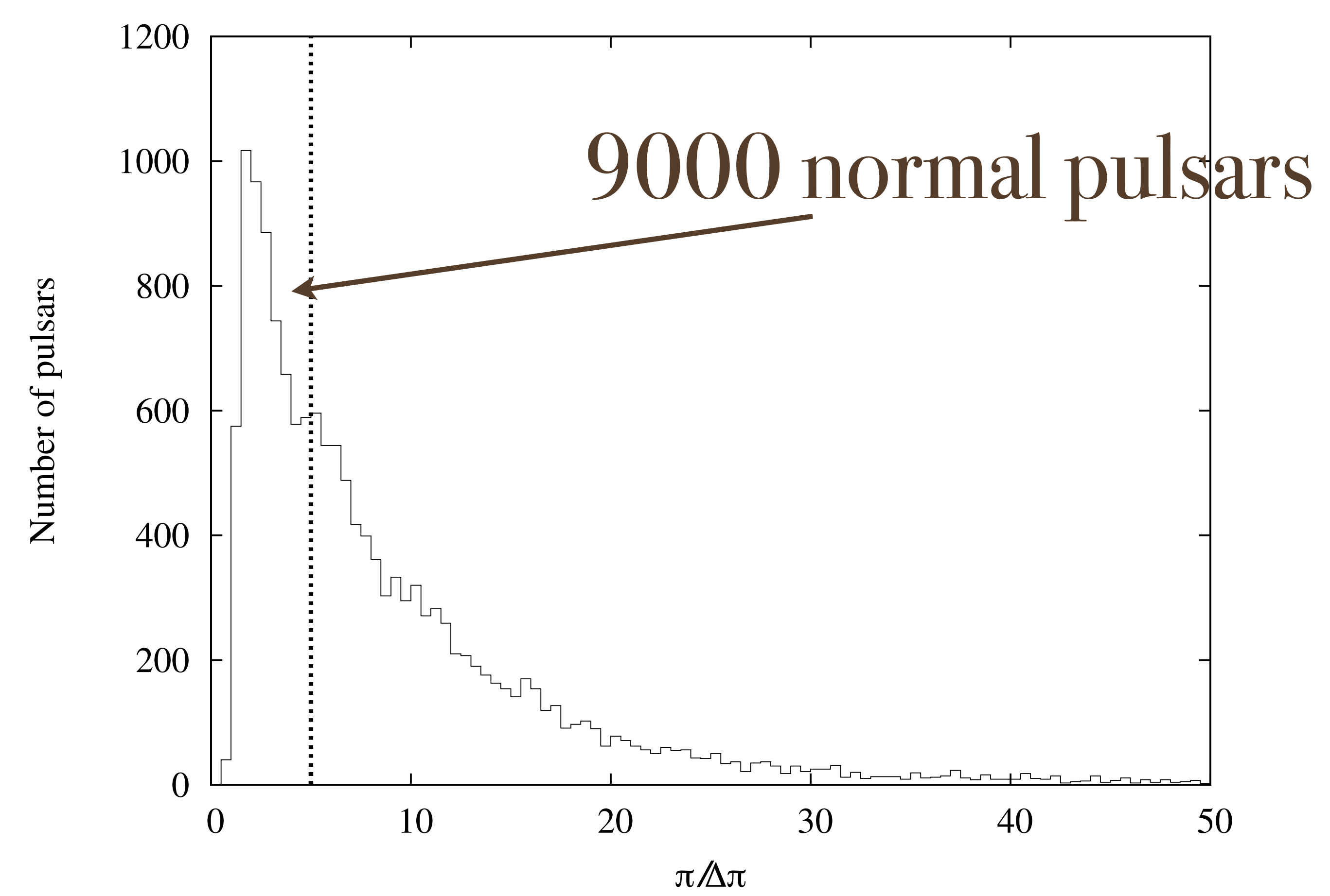
Gravity Tests

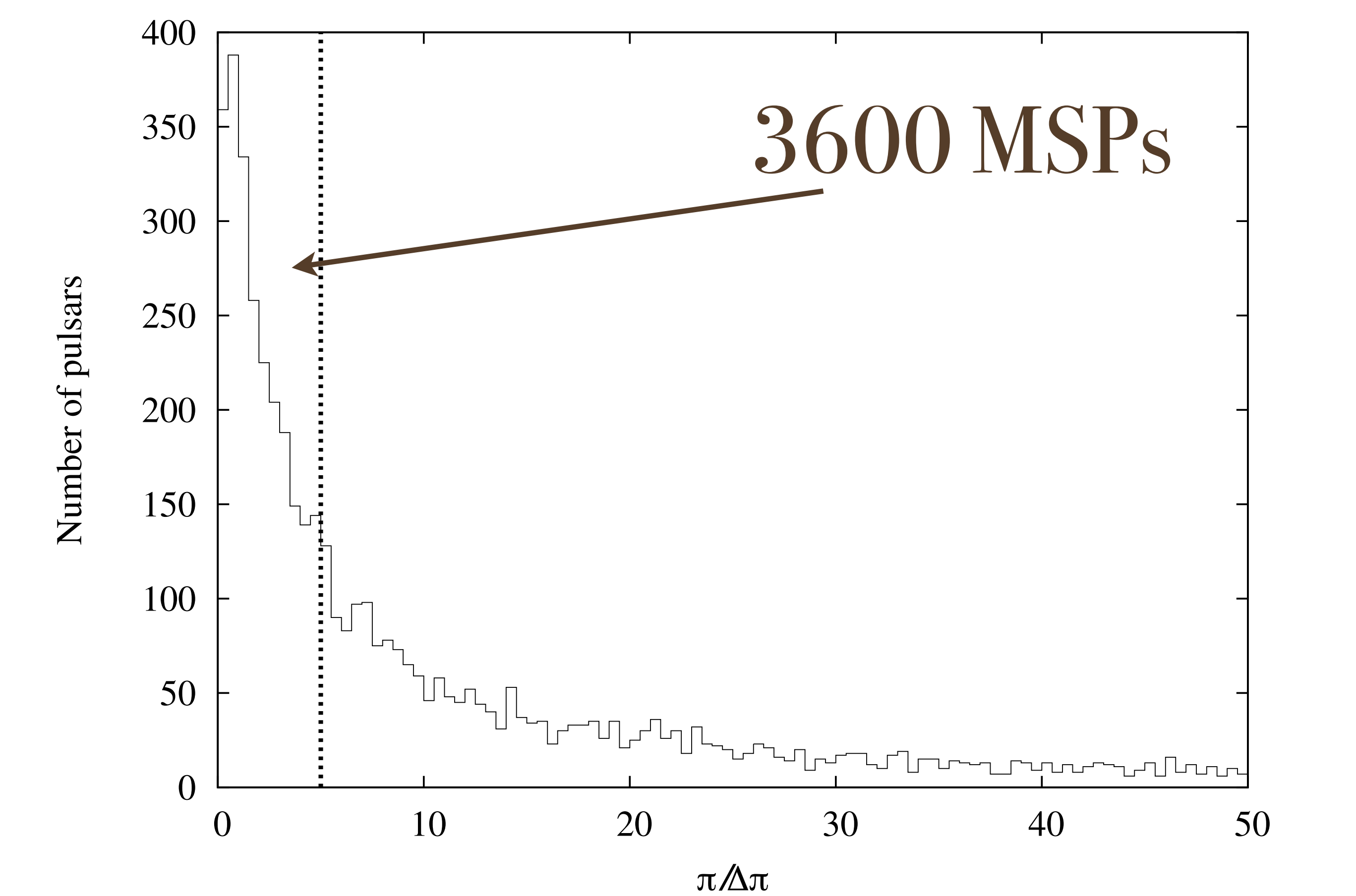
- PFE Antenna Array
- PTA for GW detection
- PSR-BH system
- Measure BH properties
- Supermassive BH in GC
- Testing GR with BHs

Astrometry

- New section in the DRM
- Can measure the parallax (to about 20% accuracy) out to distances of 13 & 9 kpc for normal and MSPs respectively
- Required input for:
  - Models of RM and DM distributions in the Galaxy
  - Improved accuracy of WD and NS cooling models
  - Precision tests of theories of gravity.

- frequency of 1.4 GHz and a 3 000 km maximum SKA baseline
- assumes gating and dedispersion.





(Smits et al. 2011 & Godfrey et al 2011)

Astrometry: DRM

Huynh, Lazio et al

Table 7.1. Scientific Requirements

Parameter	Value
Positional Accuracy	0.25 mas
Sky coverage	> 2π sr

Table 7.2. Pulsar Astrometry Technical Requirements

Parameter	Requirement	Comment
Observing Frequency	2 – 3 GHz	High SNR, resolution, ionosphere
Angular Resolution	< 0.13 arcsec	Positional accuracy, SNR
Maximum baseline	> 200km	Angular resolution
Accessible Area	> 0.25 deg	In-beam calibrators
Pulsar gating	Enable correlator to only record when pulsar is 'on'	Improve SNR of the pulsar

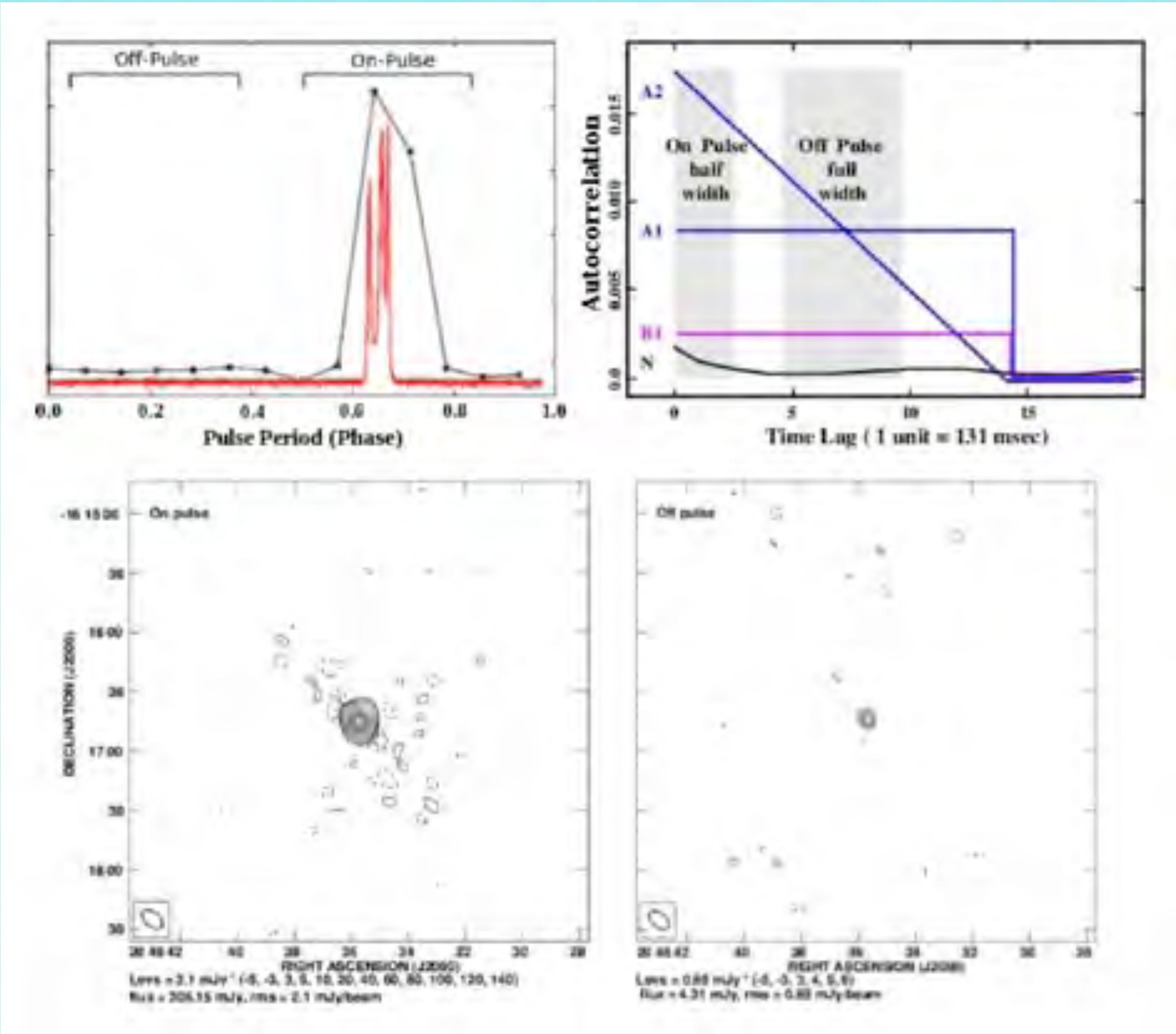
- S > 0.1 mJy kpc^2 pulsars at 1 kpc, S > 0.4 mJy kpc^2 pulsars at 2 kpc and S > 1 mJy pulsars at 3 kpc. This would be good enough to get 0.25 mas positional accuracy for a pulsar such as PSR J0737-3039A/B (7 mJy kpc^2) if it was at 8 kpc and probably parallaxes if it was at 6 kpc (0.12 mas single-epoch positional uncertainty, 0.17 mas parallax signal at 6 kpc).

Gating & Binning

- Main science goals are to improve SNR in observations to determine pulsar astrometry and to determine "what lies beneath".

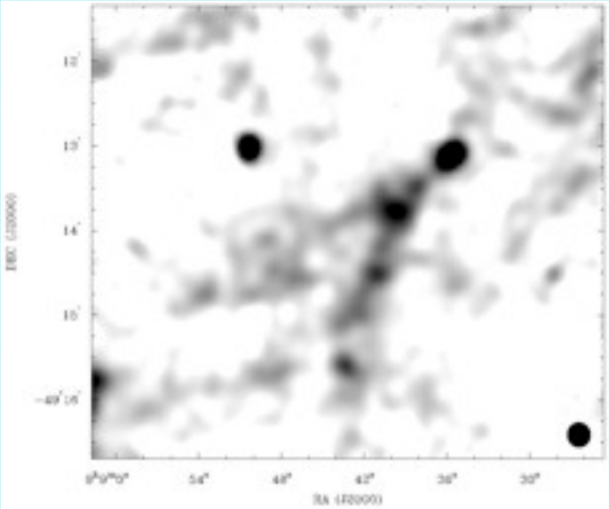
- Gain by sqrt(duty cycle), but depends on bin size/number

Off pulse emission / GMRT

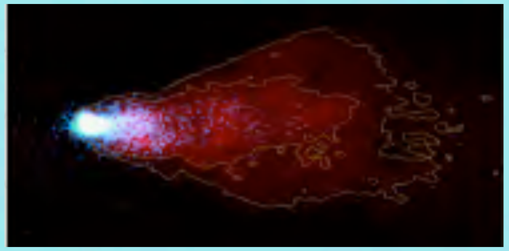


Basu et al 2011

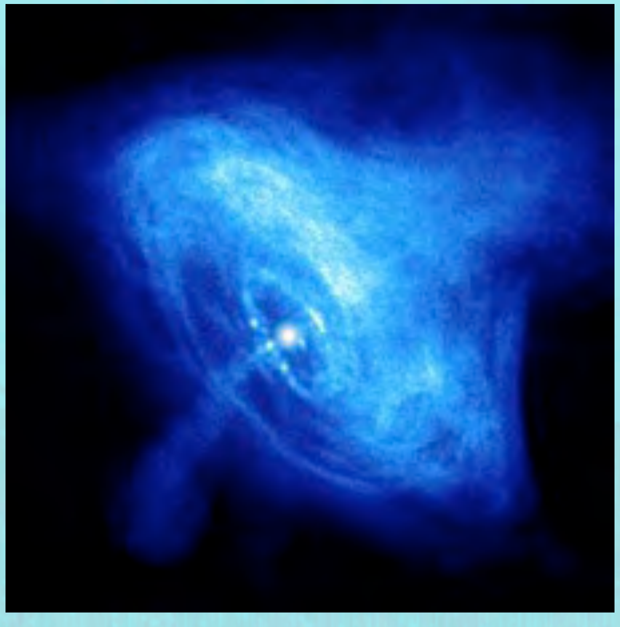
Nebulae



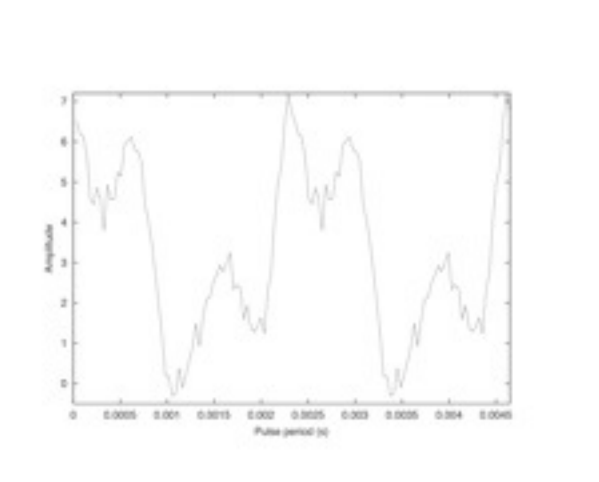
Stappers et al



Gaensler et al



- Study the compact form of jets in the radio.
- Relationship with larger structures
- Energetics cf. shocks/ winds



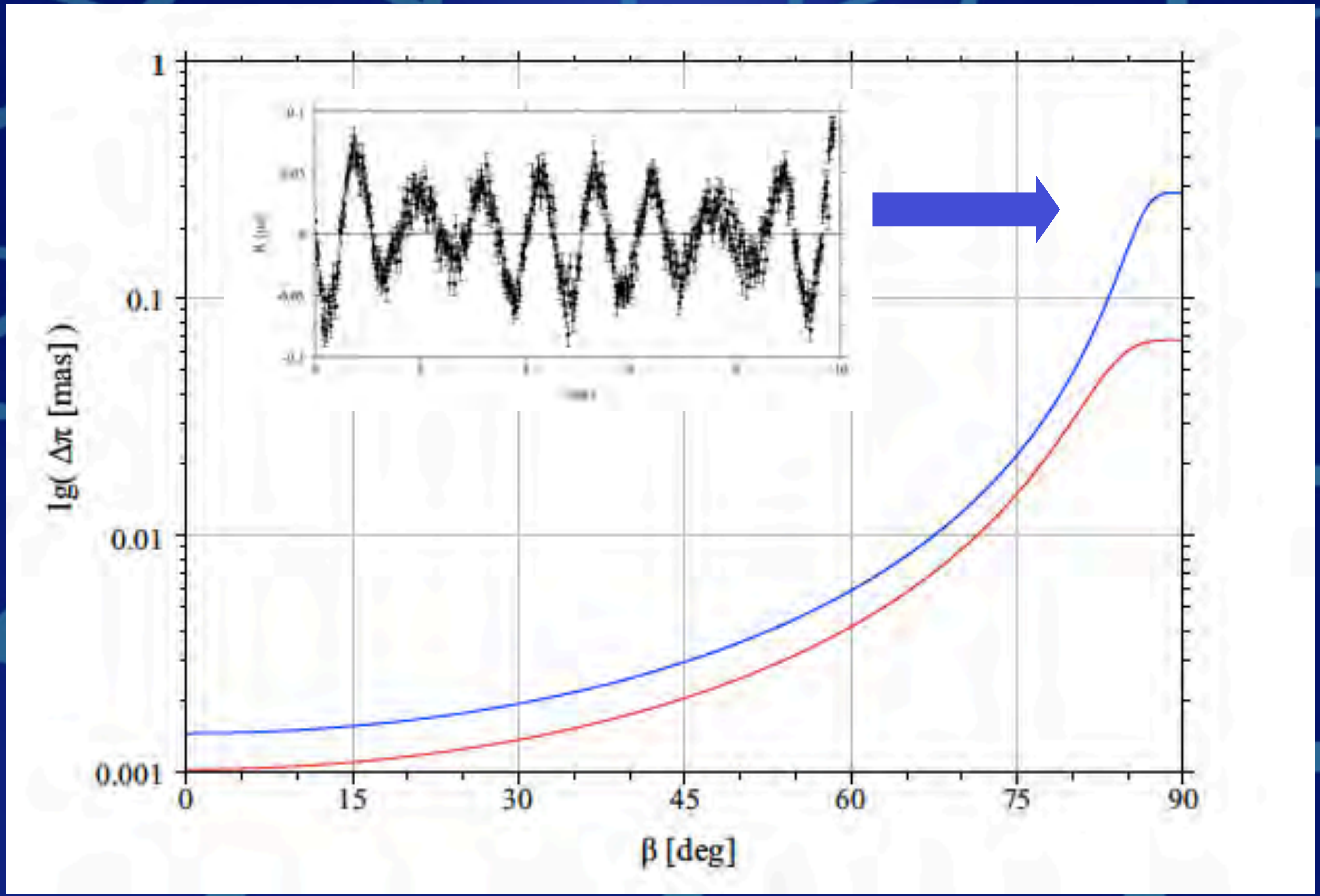
Gating vs Binning

- Gating is fine if one is dealing with simple pulse profiles and if the gates are variable in size to make sure to get maximum return from the duty cycle.
- However if the pulsar ephemeris is poorly know, as is likely with a newly discovered pulsar then multiple bins gives you more robustness to including only the pulsar
- If dispersion delay across the band is significant compared to the pulse period then gating may not work unless the gates can have different phases in different frequency channels
- simple two gates do not allow for more detailed study of off-pulse emission nor underlying nebulae
- Between 16/32 bins is probably sufficient for most purposes
- Is there a possibility of trading correlator capacity, i.e. station inputs or bandwidth/channels such that more bins can be formed? I have some ideas :-)

SKA Astrometry (Smits et al. 2011)

- Interferometric – applicable to all pulsars (for ~9,000 sources)
- Timing parallax – applicable to millisecond pulsars:

  Here, we measure the curvature of the incoming wave front, resulting in worse precision for higher ecliptic latitude sources!



Assuming 10ns, 5/10 yr:

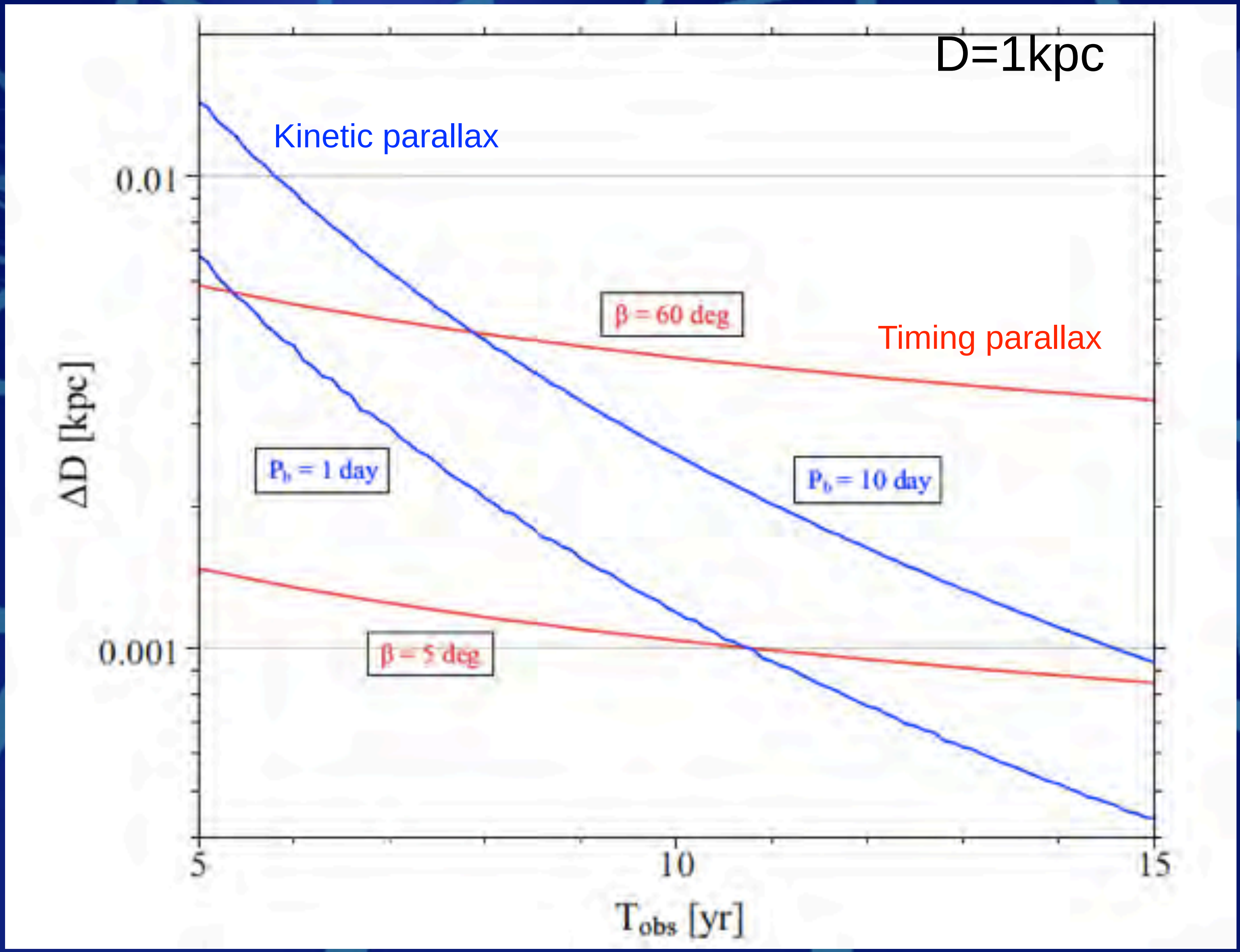
10 kpc

1000 kpc

SKA Astrometry (Smits et al. 2011)

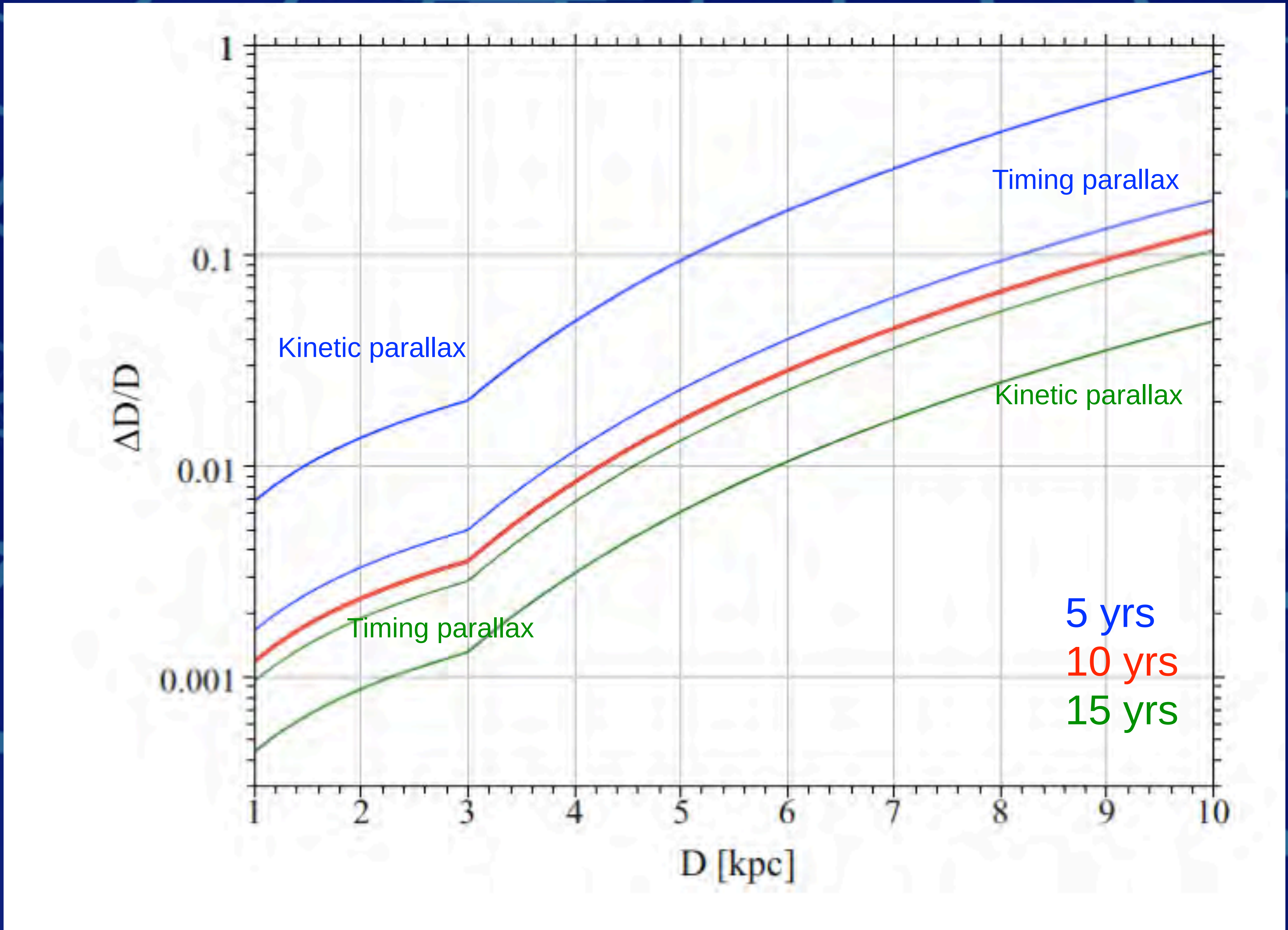
- Interferometric – applicable to all pulsars (for ~9,000 sources)
- Timing parallax – applicable to millisecond pulsars:
- "Kinetic parallax" - for binaries, we can also assume that GR is correct and attribute any deviation from GR solely to secular acceleration:

$\Delta(dP_b/dt) \rightarrow v_T \rightarrow D$



SKA Astrometry (Smits et al. 2011)

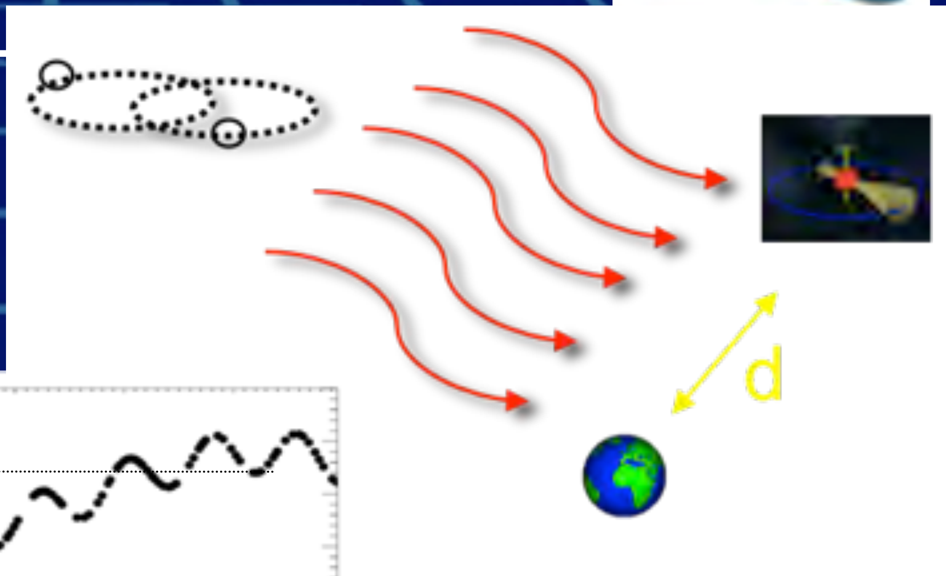
- Flux density and hence timing precision decreases with distance:



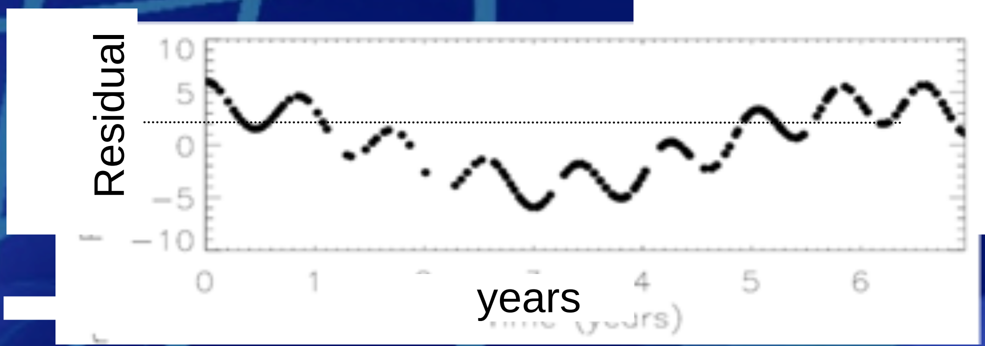
Superb precision for gravity tests! But useful for much more …!

Single source detection

- Single binary super-massive black hole produces periodic signal
- Signal contains information from two distinct epochs: t and t-d/c

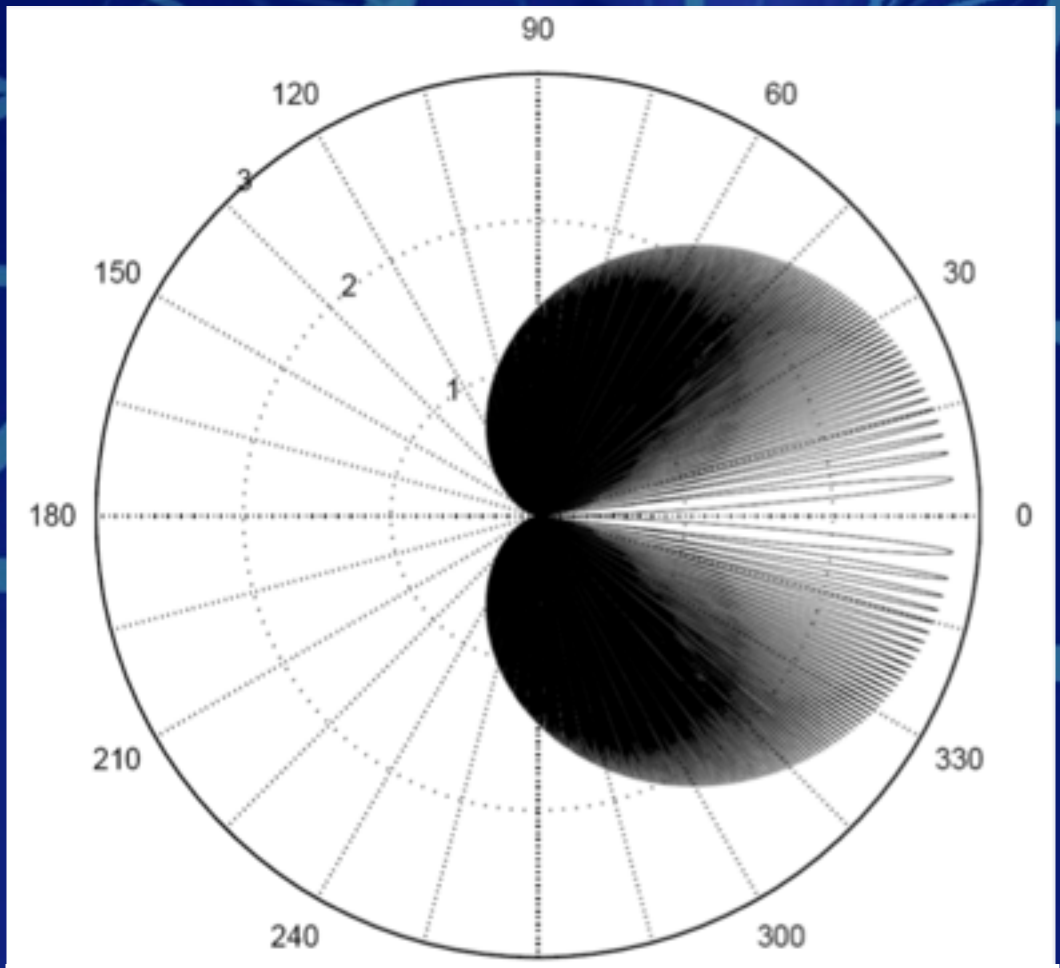


Lee et al. (2011)



- We can pinpoint a single GW source:

Possible by amazing astrometry of SKA!



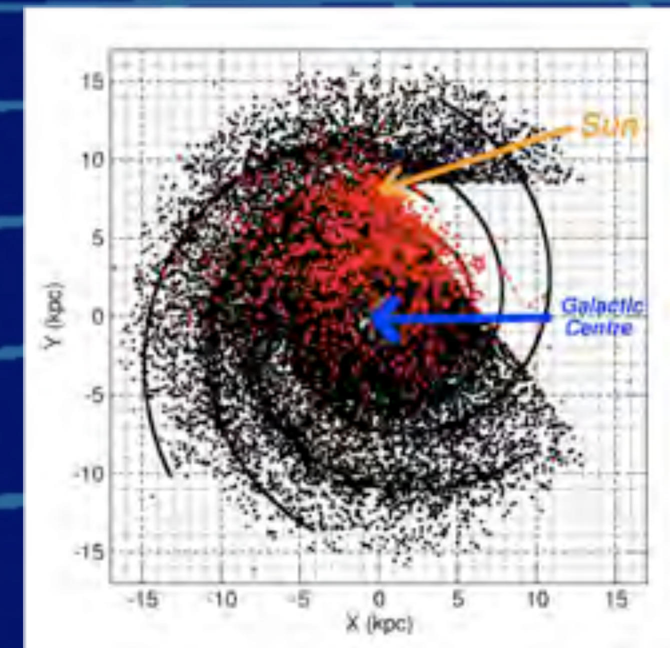
Response pattern H of a single-pulsar timing response to a single monochromatic GW source.

Position accuracy GW source.

1′

Galactic census with the SKA

With the SKA'S collecting area and increase in survey speed:



- ~30,000 normal pulsars
- ~2,000 millisecond psrs
- ~100 rel binaries
- first pulsars in Galactic Centre
- first extragalactic pulsars

Once pulsar in GC found, the experiment will be simple…

The University of Manchester Jodrell Bank Observatory

Monday, October 24, 2011

Property measurements of Sgr A*

- Hamiltonian of a rotating black hole: $H = H_N + H_{PN1} + H_{SO} + H_Q + \ldots$

  - Independent measurements of the black hole mass (m), spin (χ) and quadrupole moment (q) will lead to a test of the cosmic censorship conjecture ($\chi \leq 1$, Penrose, 1979) and the no-hair theorem ($q = -\chi^2$, Hansen, 1974).

- The mass of Sgr A* can be obtained by measuring the pulsar signal delays induced by the relativistic orbital motion of the pulsar (Lorimer & Kramer 2005).

- Relativistic advance of pericenter:

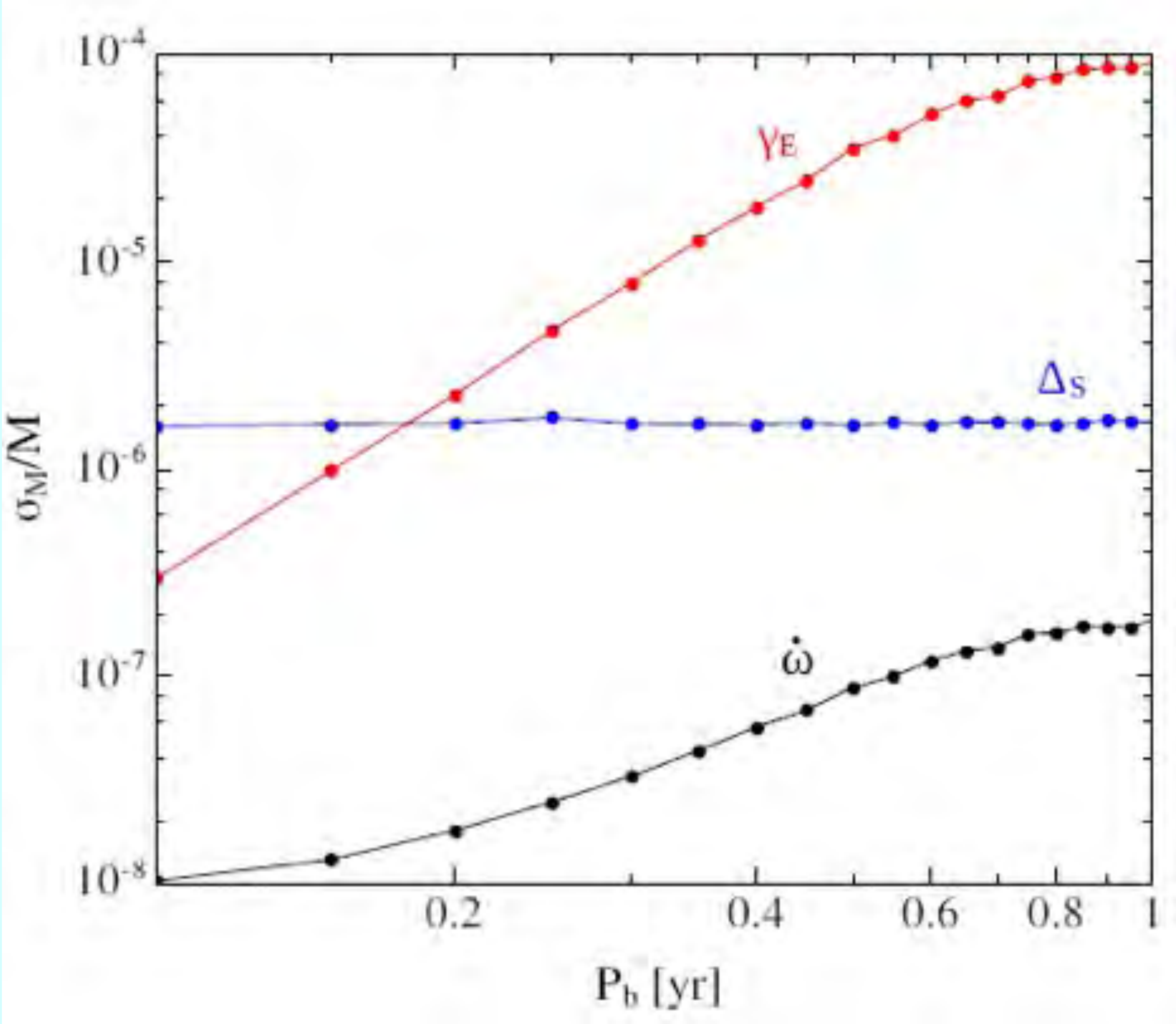
$$\begin{aligned}\dot{\omega} &\simeq \frac{3}{1-e^2}\left(\frac{2\pi}{P_\mathrm{b}}\right)^{5/3}\left(\frac{GM_\mathrm{BH}}{c^3}\right)^{2/3} \\ &\simeq (0.269\,\mathrm{deg/yr})\,\frac{1}{1-e^2}\left(\frac{P_\mathrm{b}}{1\,\mathrm{yr}}\right)^{-5/3}\left(\frac{M_\mathrm{BH}}{4\times10^6\,M_\odot}\right)^{2/3}\end{aligned}$$

- Einstein delay:

$$\begin{aligned}\gamma_\mathrm{E} &\simeq 2e\left(\frac{P_\mathrm{b}}{2\pi}\right)^{1/3}\left(\frac{GM_\mathrm{BH}}{c^3}\right)^{2/3} \\ &\simeq (2500\,\mathrm{s})\,e\left(\frac{P_\mathrm{b}}{1\,\mathrm{yr}}\right)^{1/3}\left(\frac{M_\mathrm{BH}}{4\times10^6\,M_\odot}\right)^{2/3}\end{aligned}$$

- Shapiro delay:

$$\begin{aligned}\Delta_\mathrm{S} &\simeq \frac{2GM_\mathrm{BH}}{c^3}\ln\left(\frac{1+e\cos\varphi}{1-\sin i\sin(\omega+\varphi)}\right) \\ &\simeq (39.4\,\mathrm{s})\left(\frac{M_\mathrm{BH}}{4\times10^6\,M_\odot}\right)\ln\left(\frac{1+e\cos\varphi}{1-\sin i\sin(\omega+\varphi)}\right)\end{aligned}$$



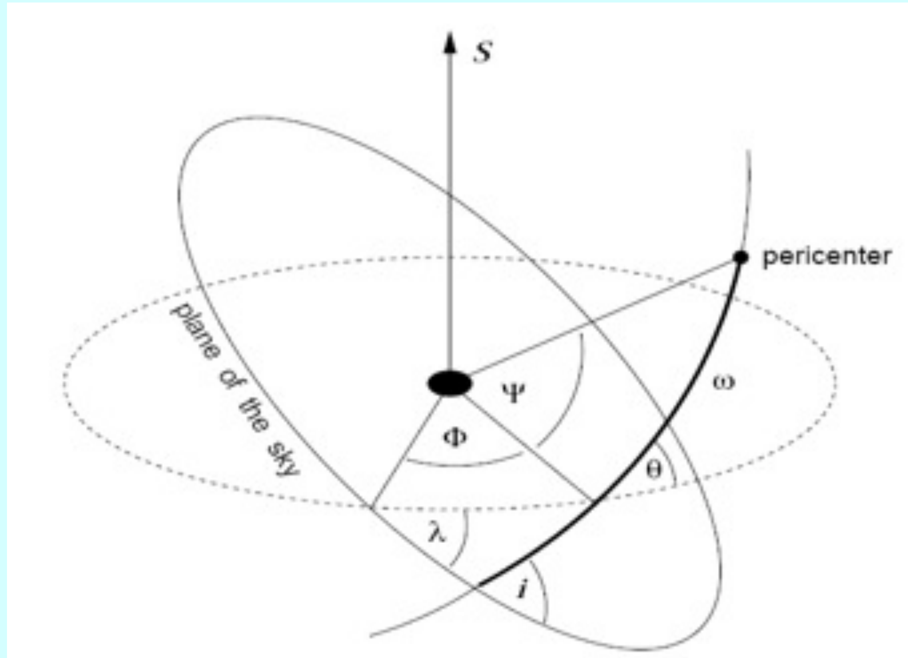
Liu et al. 2011, submitted

Property measurements of Sgr A*

- The spin contribution will induce a precession of the pulsar orbit, which can be measured by pulsar timing and used to determine the spin of Sgr A*.

$$
\begin{aligned}
\dot{\Phi} &= \Omega_{\rm LT} \\
\dot{\Psi} &= -3\,\Omega_{\rm LT}\cos\theta
\end{aligned}
$$

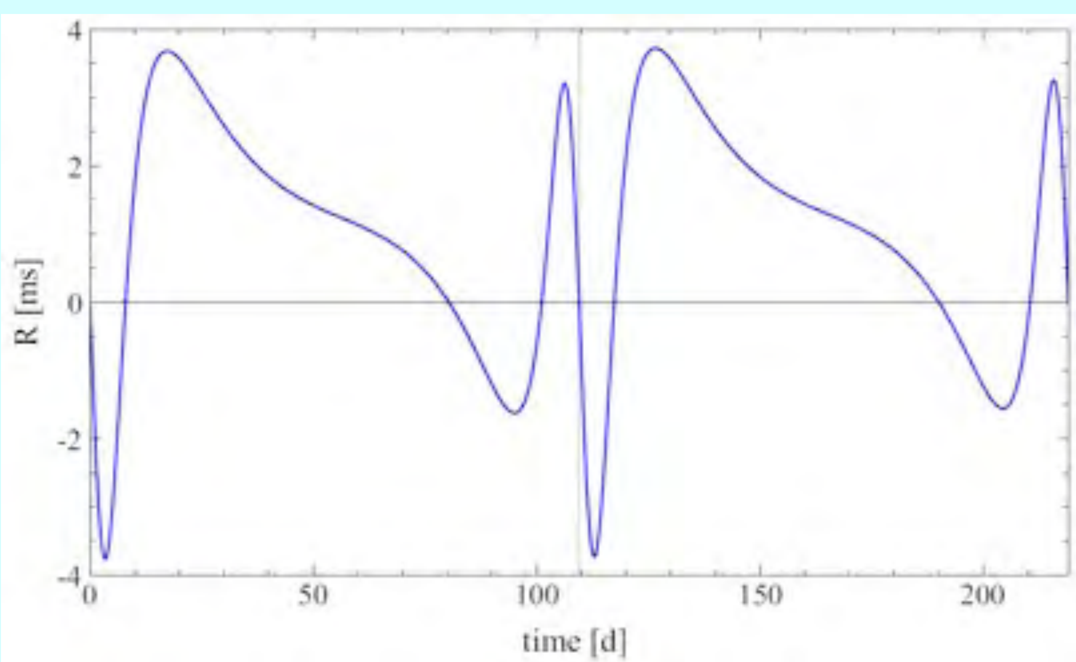
(Barker & O'Connell, 1975)

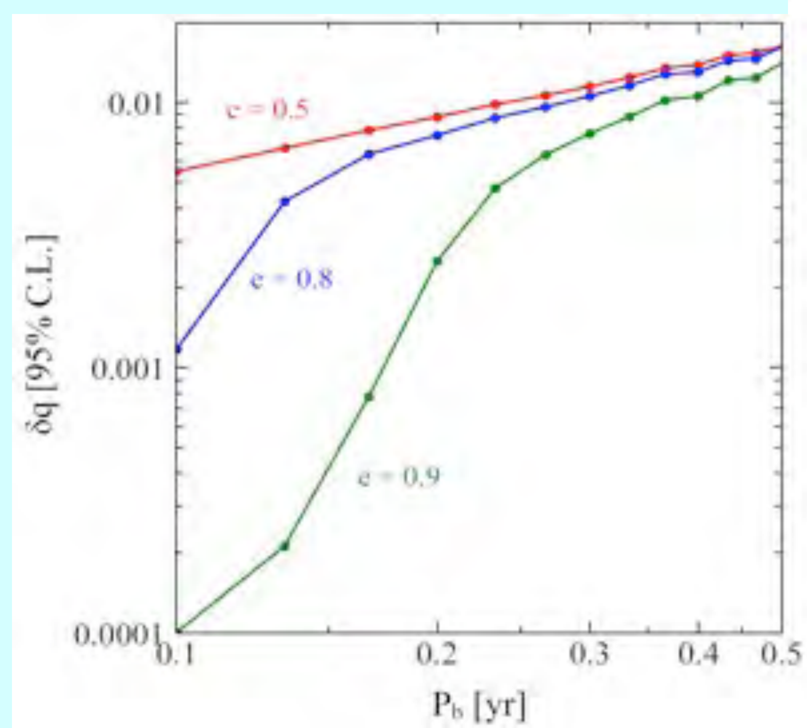


χ	e	$P_{\rm b}$ (yr)	θ_S (°)	$\hat{\sigma}$
0.2	0.1	0.3	20°	4.7% ($\ddot{x}_{\rm s}$)
			70°	NM
		0.1	20°	0.36% ($\ddot{x}_{\rm s}$)
			70°	0.92% ($\ddot{\omega}_{\rm s}$)
	0.9	0.3	20°	0.07% ($\ddot{x}_{\rm s}$)
			70°	0.18% ($\ddot{x}_{\rm s}$)
		0.1	20°	<0.01% ($\ddot{x}_{\rm s}$)
			70°	<0.01% ($\ddot{\omega}_{\rm s}$)
1.0	0.1	0.3	20°	0.14% ($\ddot{x}_{\rm s}$)
			70°	1.1% ($\ddot{x}_{\rm s}$)
		0.1	20°	0.01% ($\ddot{x}_{\rm s}$)
			70°	0.04% ($\ddot{\omega}_{\rm s}$)
	0.9	0.3	20°	<0.01% ($\ddot{x}_{\rm s}$)
			70°	0.01% ($\ddot{x}_{\rm s}$)
		0.1	20°	<0.01% ($\ddot{x}_{\rm s}$)
			70°	<0.01% ($\ddot{\omega}_{\rm s}$)

(Liu, 2011, PhD thesis)

- The quadrupole moment contribution will cause a periodic perturbation of the pulsar orbit, which can be modelled in pulsar timing and used to determine the Sgr A* quadrupole.



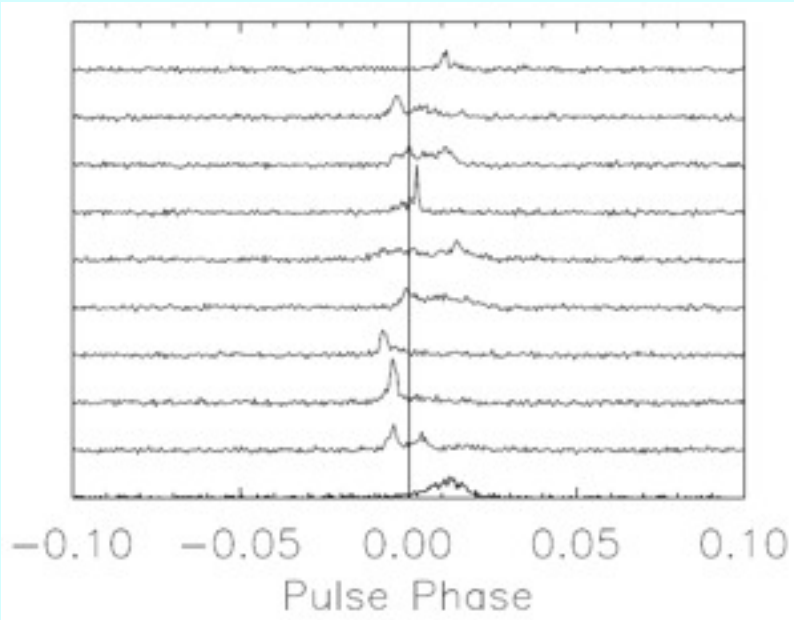


5-year SKA pulsar timing of 0.1 ms precision may achieve a test of the no-hair theorem with ~1%!

(Liu et al. 2011, submitted)

Pulse phase jitter and its influence

Phenomenon of pulse phase jitter and its measurement on J0437-4715 (Jenet et al. 1998, ApJ; Liu et al. 2011 submitted):



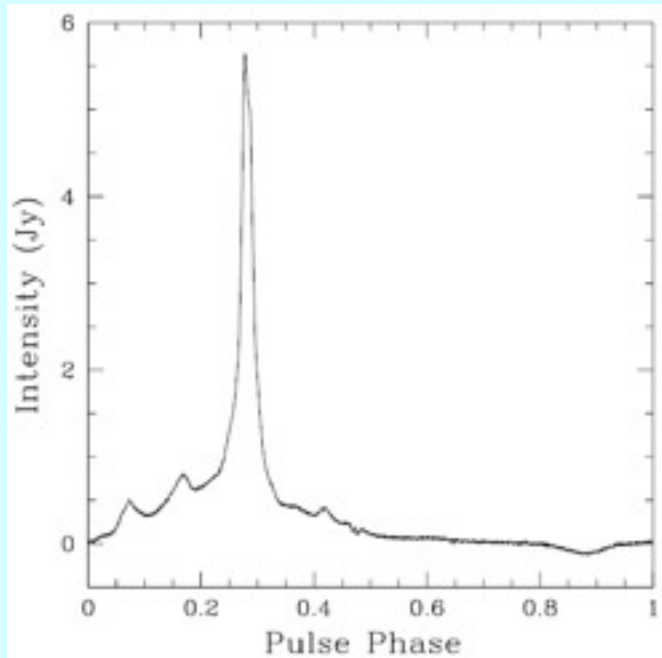


Table 3. Results of jitter parameter f_J measurements and K-S tests of all PSR J0437−4715 datasets from two 48-MHz sub-bands. The parameters f and $\mathcal{P}$ represent the central frequency and the p-value of K-S test, respectively.

Dataset (MJD)	f (MHz)	f_J	$\mathcal{P}$
53576	1341	0.067 ± 0.004	0.89
	1450	0.067 ± 0.004	0.93
53621	1341	0.067 ± 0.004	0.98
	1405	0.066 ± 0.004	0.62
53964	1341	0.066 ± 0.004	0.88
	1405	0.065 ± 0.004	0.92
54095	1341	0.069 ± 0.006	0.90
	1405	0.073 ± 0.006	0.92
54222	1341	0.069 ± 0.007	0.52
	1405	0.067 ± 0.007	0.77
54226	1341	0.068 ± 0.005	0.20
	1405	0.066 ± 0.006	0.64

Influence of pulse phase jitter on TOA precision (Cordes & Shannon 2010):

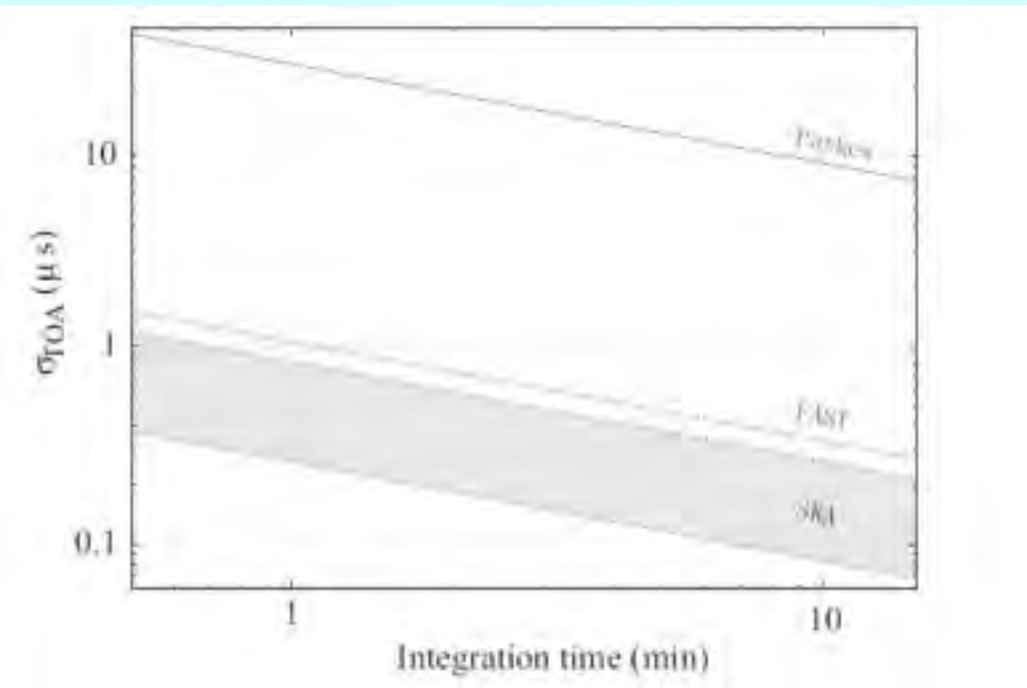


Figure 12. Expected MSP TOA precision versus integration time for different instruments. Only radiometer noise and pulse jitter are accounted for as influences on the measurement precision.

$$\sigma^2_{\rm total} = \sigma^2_{\rm rn} + \sigma^2_{\rm J} + \sigma^2_{\rm scint} + \sigma^2_0,$$

MSP (3.0 mJy at 1.4 GHz, 5.0 ms, 5% pulse width)

+

SKA (10-min integrations, 50 MHz bandwidth)

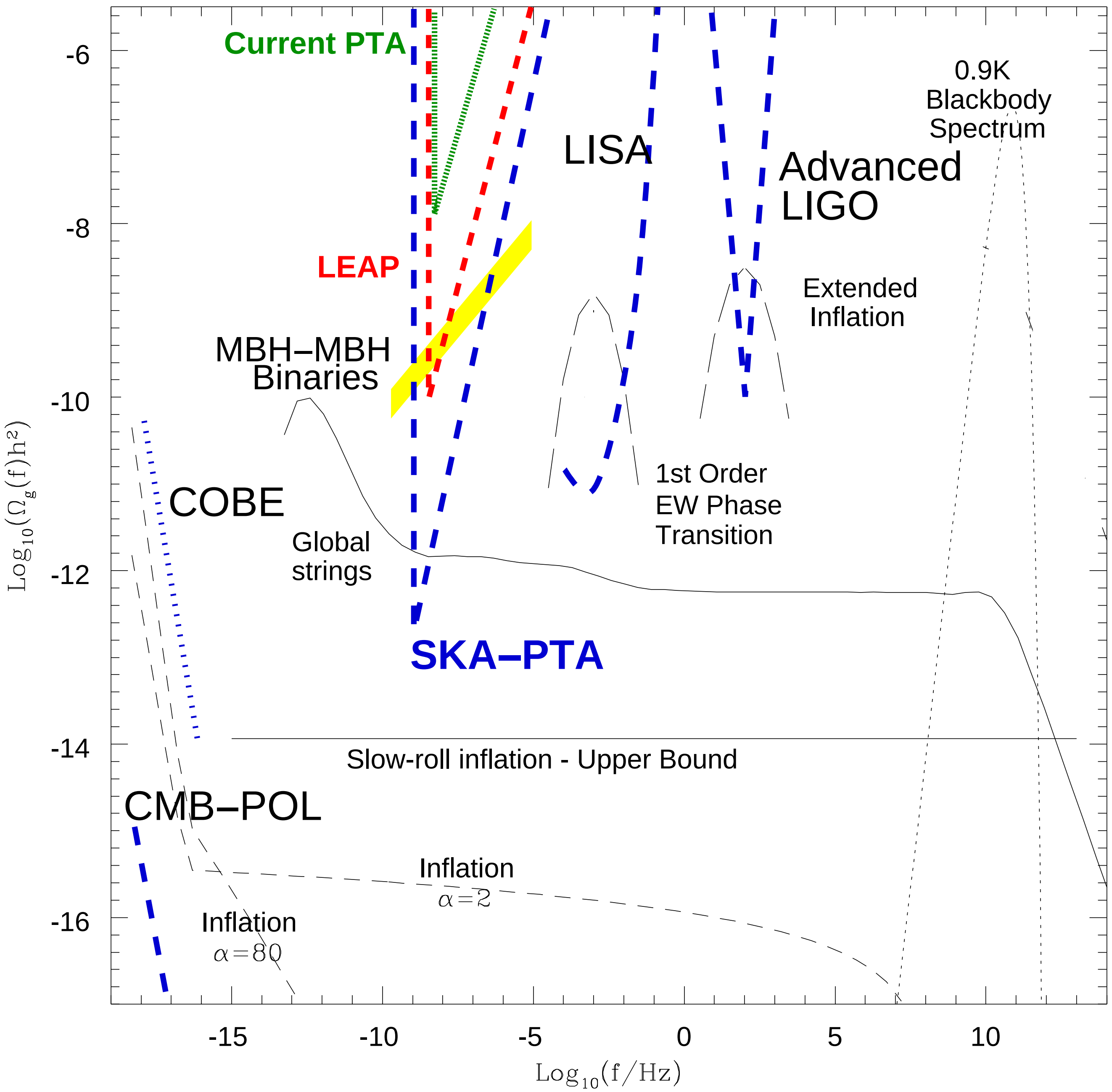
=

TOA precision of 80-230 ns (Liu et al. 2011, MNRAS)

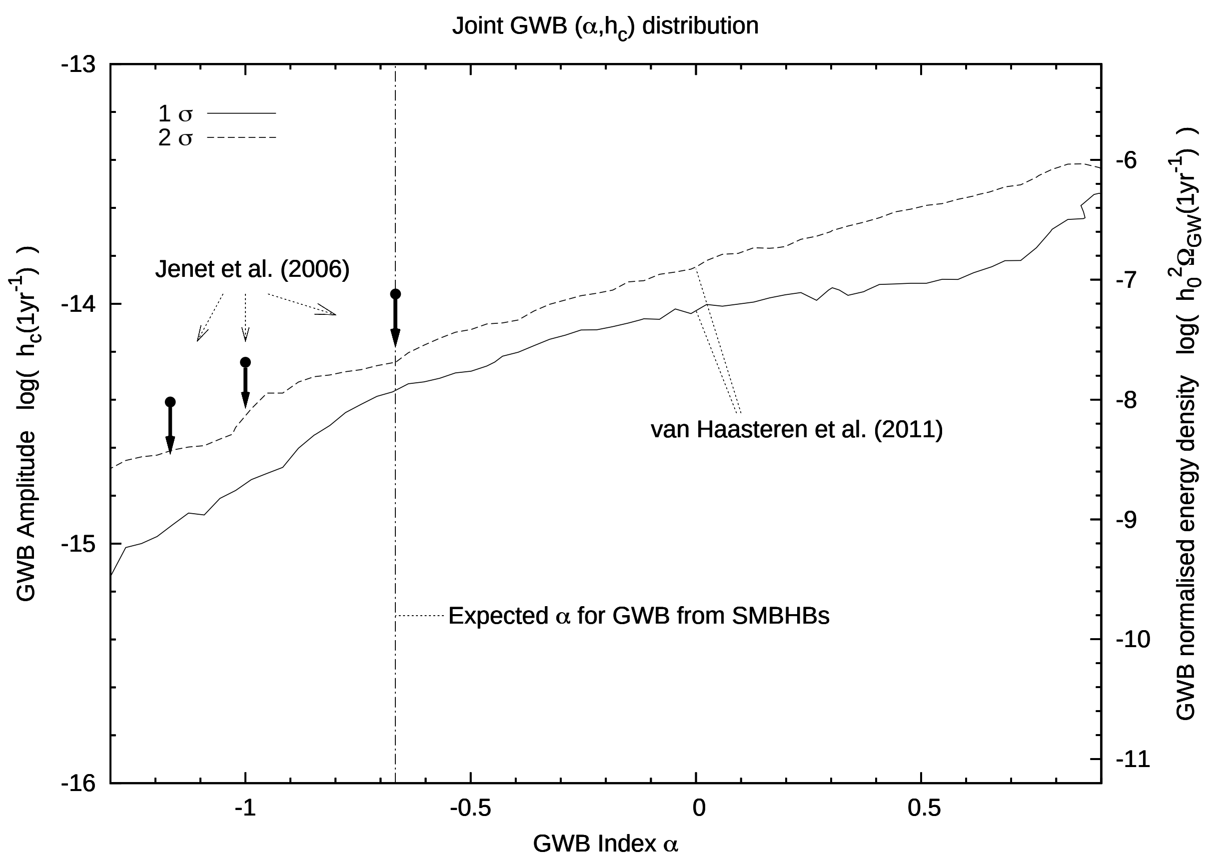
What is required for a PTA?

- Often quoted parameters are a detection are:
  - 20 - 25 Millisecond Pulsars
  - Timed to a precision of <100 ns
  - For a period of > 5 years
- Some deviations about that and different weighting
  - More MSPs will definitely be useful!
- Need to have longer baselines, better timing (10 ns) to:
  - Study spectral shape in detail
  - Limit mass of graviton
  - Study polarisation, etc....

nanoHertz GWs - Pulsars



$$h_c(f) = A(f/\mathrm{yr}^{-1})^{\alpha}$$

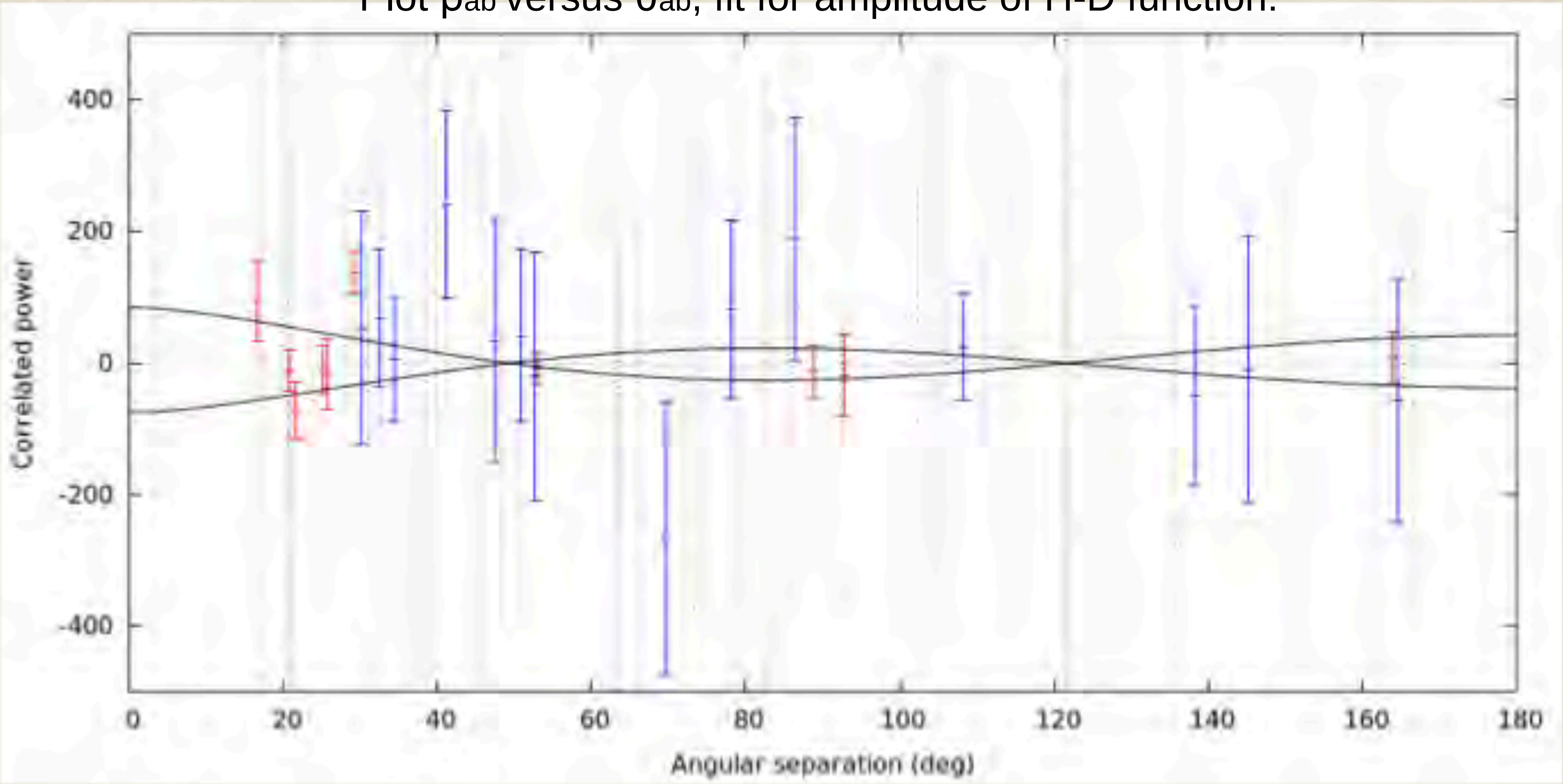


For the case α = –2/3, which is expected if the GWB is produced by supermassive black- hole binaries, we obtain a 95% confidence upper limit on A of 6 × 10^{-15}, which is 1.8 times lower than the 95% confidence GWB limit obtained by the Parkes PTA in 2006.

van Haasteren et al 2011

5-year NANOGrav GW cross-correlation analysis

Plot ρ_{ab} versus θ_{ab}, fit for amplitude of H-D function:



Y-axis values are A^2 times 10^{30} (i.e., relative to a $h_c(yr^{-1}) = 10^{-15}$ spectrum)

Computed using methods from Demorest (2007):

Assumes/optimized for -2/3 power law GW spectrum.

Current work: Inject/characterize simulated GW signals.

Similar limit to that set by the EPTA but still finalising

Demorest et al 2011

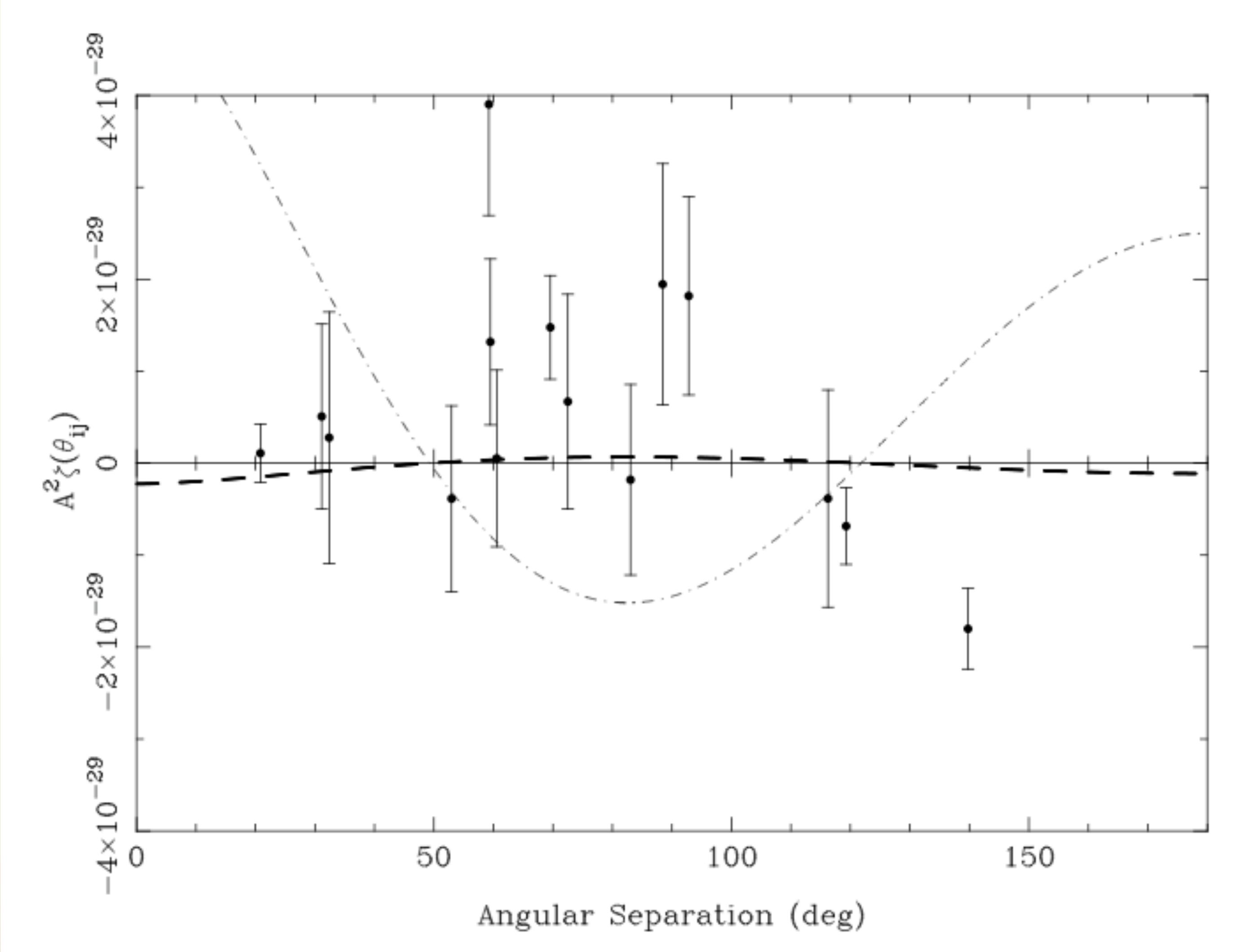
PPTA

- Verbiest et al. Parkes + Kapsi et al. Arecibo data sets analysed
- 20 pulsars with data spans of up to 23 yr (most 12 – 14 yr s)
- Overlapping data spans for each pulsar-pair analysed

For GWB from SMBHB a = -2/3

$h_c = A\,(f/f_{1yr})^{\alpha}$

- Correlation amplitude estimated in Fourier domain using weighted average of spectral components
- Effect of timing fits calibrated by injecting GW signals into data (Jumps are bad!)
- Weighted fit of HD curve fitted to resulting amplitudes
- Best-fit value for $A^2 = -4.5 \times 10^{-30}$ BUT
- Consistent with no GW at 76% confidence
- Need IPTA, longer data spans!
- Method not optimal for setting a limit on GW amplitude



(Yardley et al. 2011)

How TO Improve?

Currently happening:

- Discover/add more pulsars (>100 MSPs in last 2 years!)
- Better instrumentation - everywhere

  e.g. Increased BW, coherent dedispersion

  EPTA limit based on predominantly old data

- Improved data analysis (more GW signals; ISM, polarisation)
- Collaborating! --- International Pulsar Timing Array.

Near future:

- Increase observing time on current telescopes.
- Receiver upgrades -- very wide bandwidths (300 - 3000 MHz)
- LOFAR -- ISM analysis / pulse shape variations.

More collecting area (larger telescopes).

- short term: LEAP
- medium term: SKA pathfinders
- longer term: SKA_1 and then SKA

Lots of new work on transients…

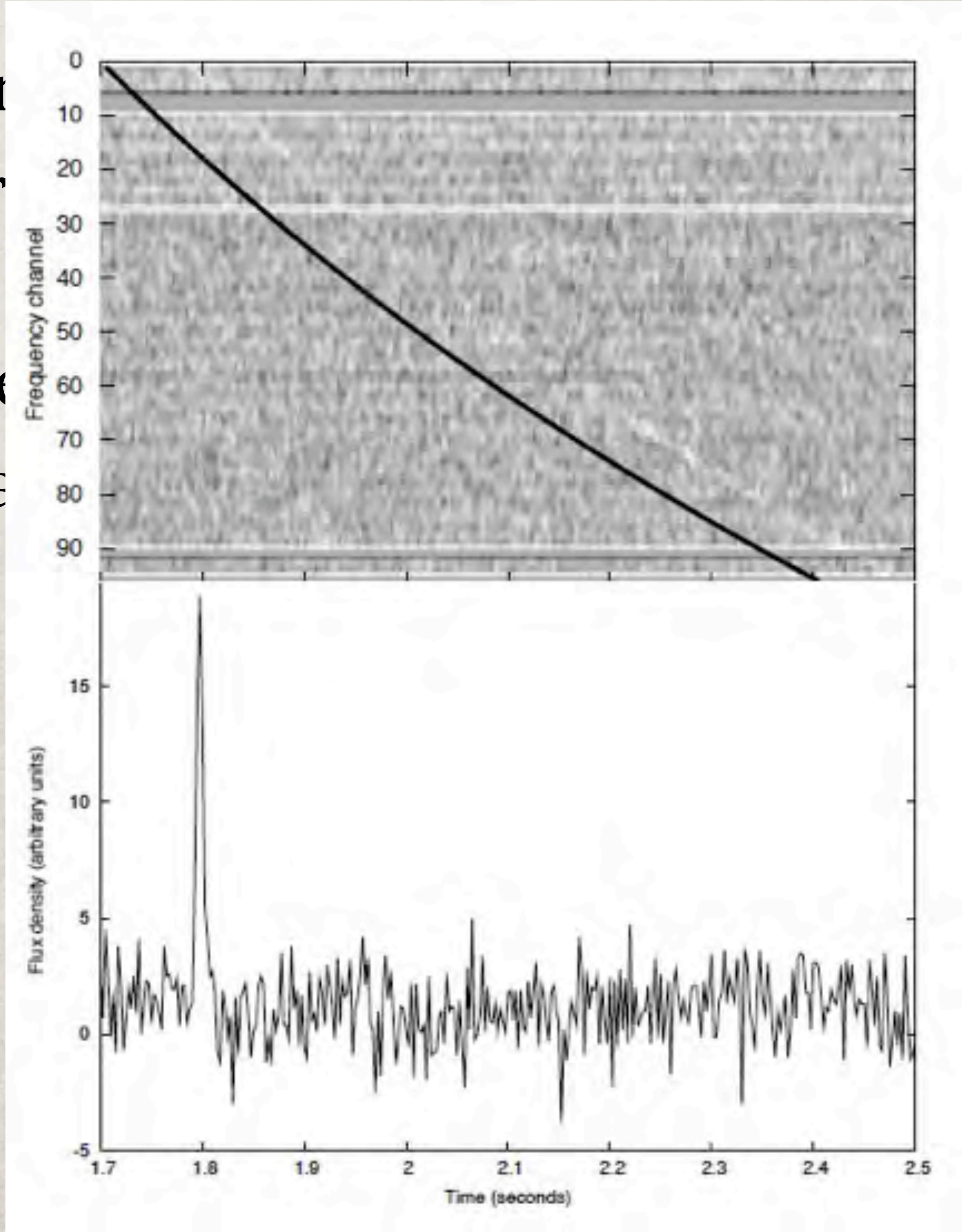
- Multimoment radio transient detection - Spitler et al 2011
- The chirpolator and the chimageator - Bannister and Cornwall 2011
- Real-time, fast radio transient searches with GPU de-dispersion - Magro et al 2011
- Searching for Fast Radio Transients with SKA Phase 1 - Clarke & Colgate 2011
- Detection Rates for Surveys for Fast Transients with Next Generation Radio Arrays - Macquart 2011
- Observing pulsars and fast transients with LOFAR - Stappers et al 2011
- The Allen Telescope Array Fly′s Eye Survey for Fast Radio Transients - Siemion et al 2011
- ++++++ (apologies if I missed anyone's recent work!).

A Second LB?

- Searched the PMPS & sear c,
  well beyond the Galaxy for

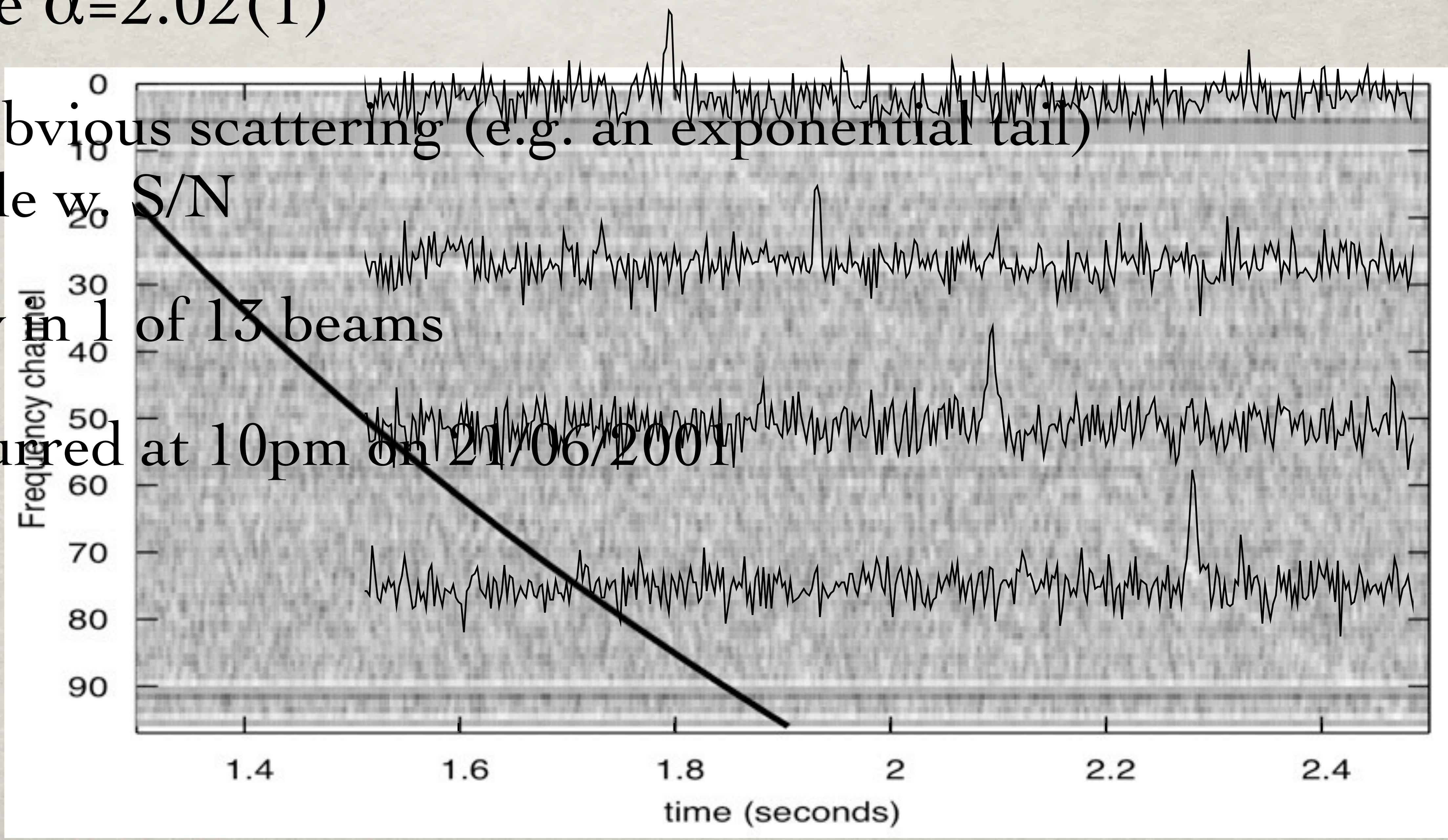
- 19 new discoveries (single e
  -> one in particular is also a
  -> a second LB?

- DM = 745 cm^{-3}pc
  W = 7 ms
  gl = 25.4^{o}, gb = -4.0^{o}
  DM$_{extra}$ = 222 cm^{-3}pc



A Second LB?

- Time delay has freq. dependence of $f^{-\alpha}$ where α=2.02(1)
  - No obvious scattering (e.g. an exponential tail) visible w. S/N
  - Only in 1 of 13 beams
  - Occurred at 10pm on 21/06/2001

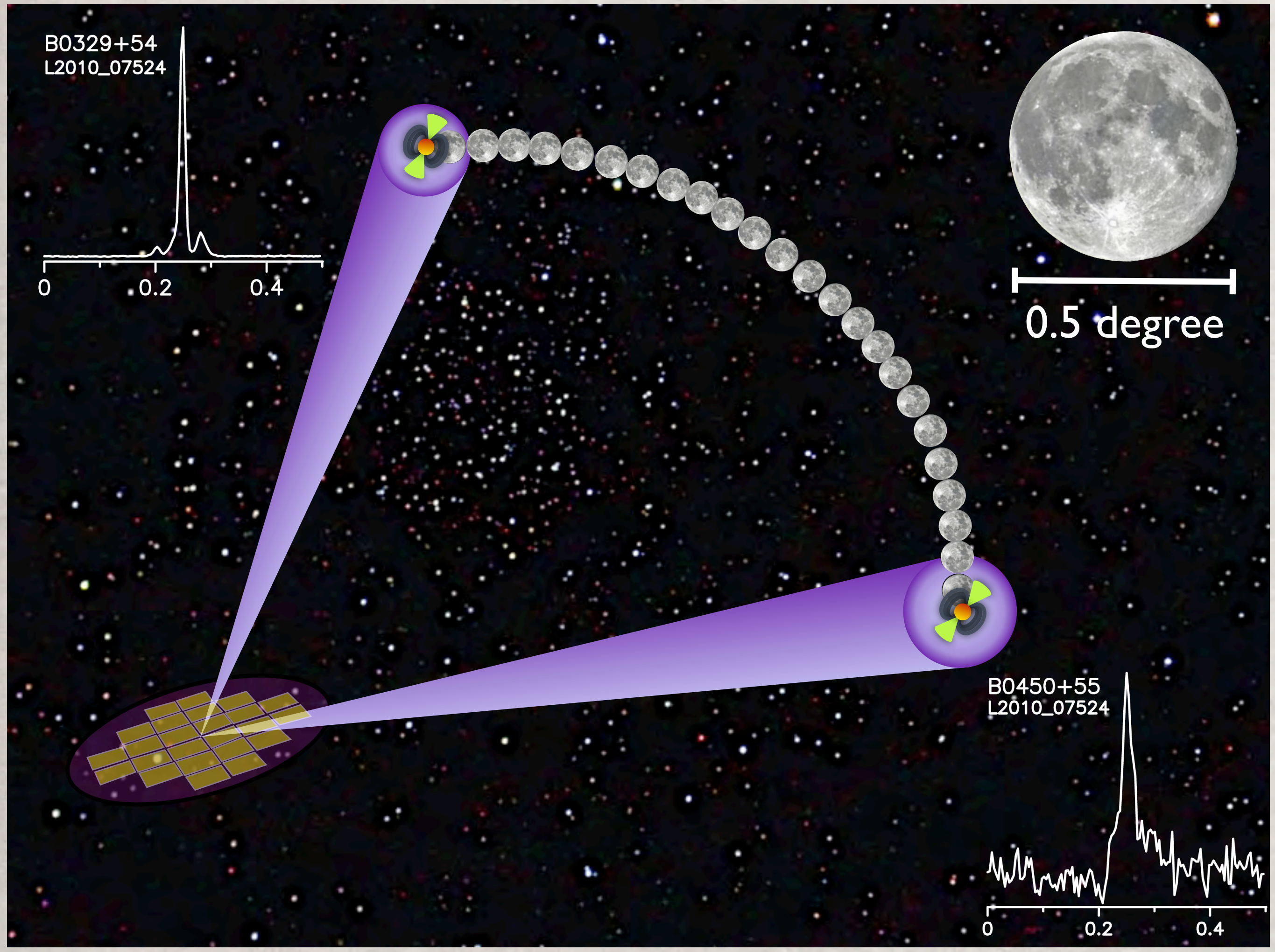


How to proceed?

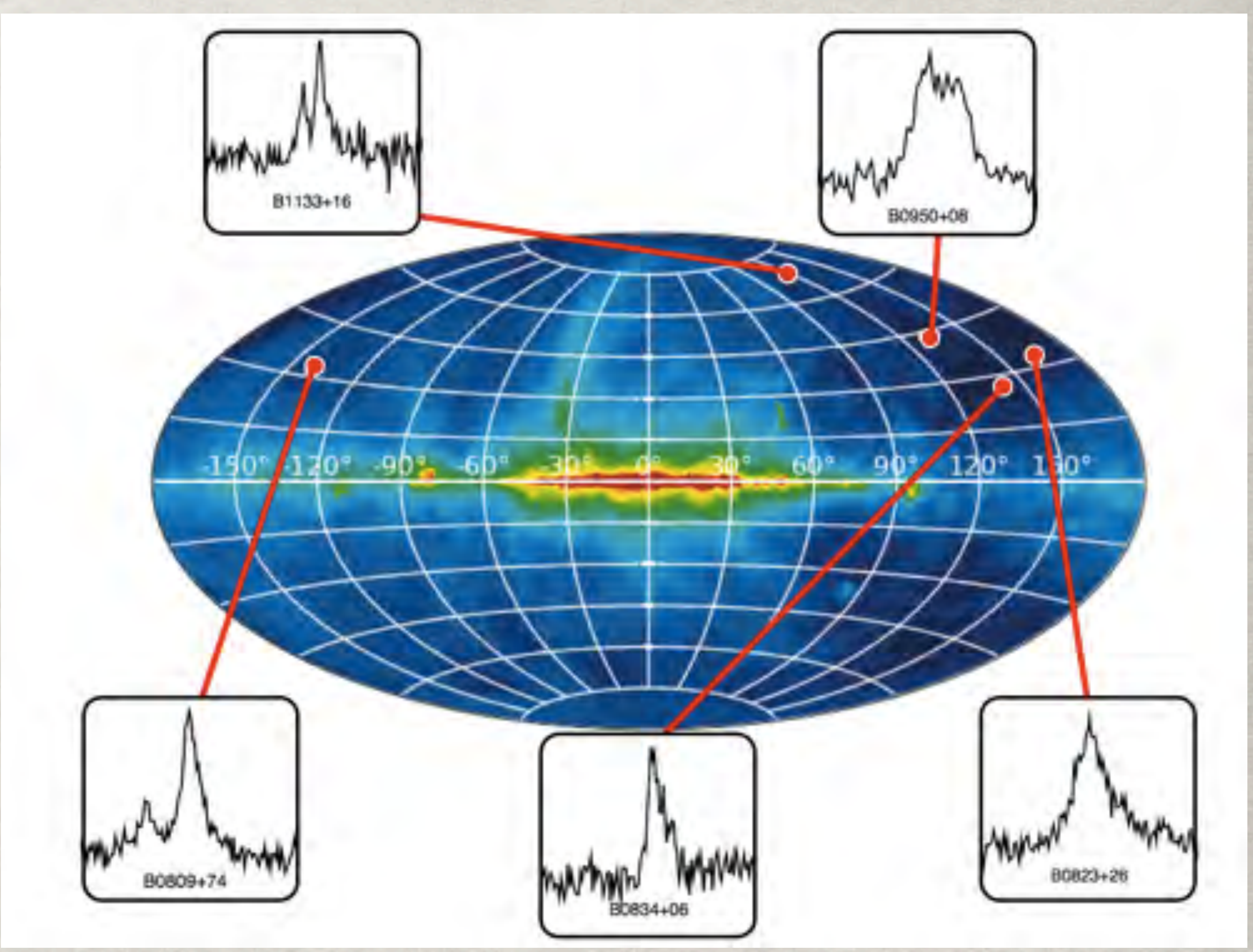
- Make sure they don't repeat (done for both known burts) --> extreme in any sense.
- Find many more to understand the Luminosity distribution ---> Requires wide area survey capabilities.
- This should be possible with next generation telescopes.
- Try and find them in real time and then do multi-wavelength follow up including GWs as some source classes should generate GWs.

WIDE FOV & MULTI-BEAMING

HBA



LBA



Hessels, Hassall, Stappers & PWG

Beam-formed modes ...there are many possible.

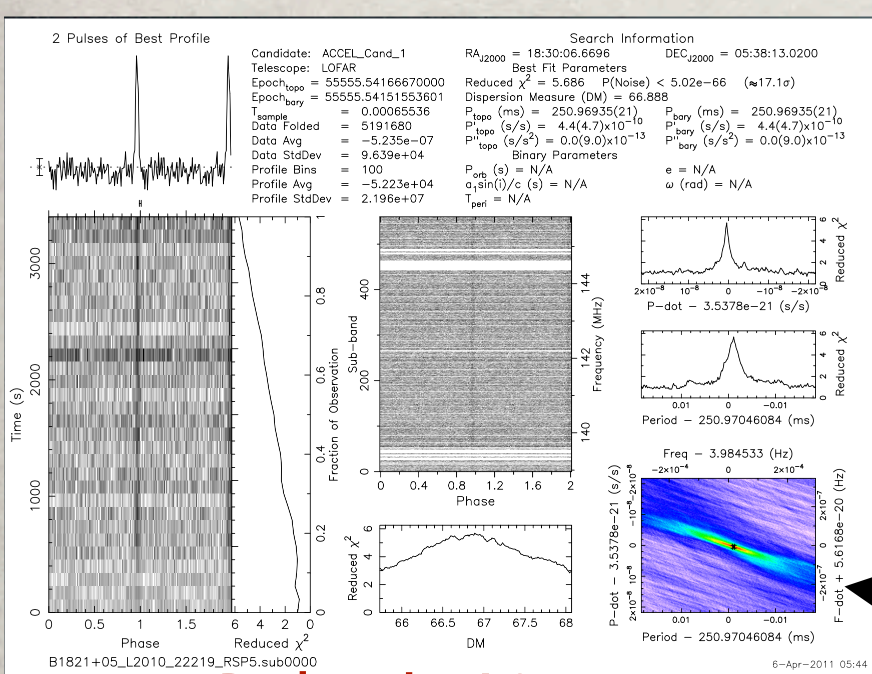
Mode	Description	Data Rate	FoV (sq. deg.)	Res. (deg.)	Sens. (norm.)
Incoherent (par. imaging)	Stations added without proper phase correction.	2-250 GB/hr	2.5	2	6.0
Tied-array	Stations add[illegible] prop[illegible]	[illegible]	[illegible]	0.03	36.0
Single Station	For p[illegible] tim[illegible] s[illegible] requ[illegible]	[illegible]B/hr	12.5	2	1.0
Superstation	Interesting balance of sensitivity and FoV.	Up to 23TB/hr	9.0	0.2	12.0
Fly's Eye	Maximize total FoV for bright transient survey.	Up to 8TB/hr	450	2	1.0

Flexible to match different science goals!

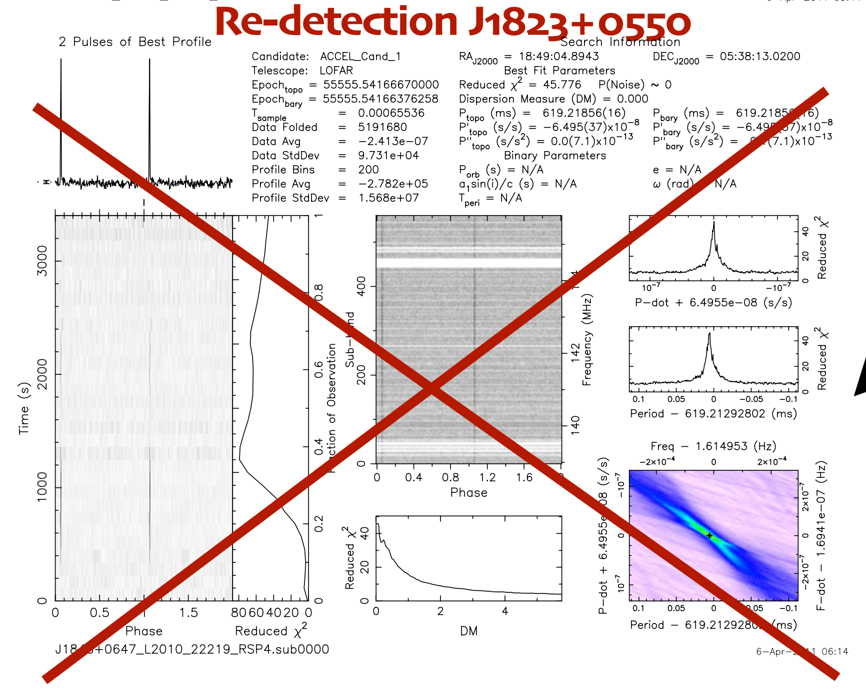
LOFAR Pilot Pulsar Survey (LPPS)

Coenen & PWG

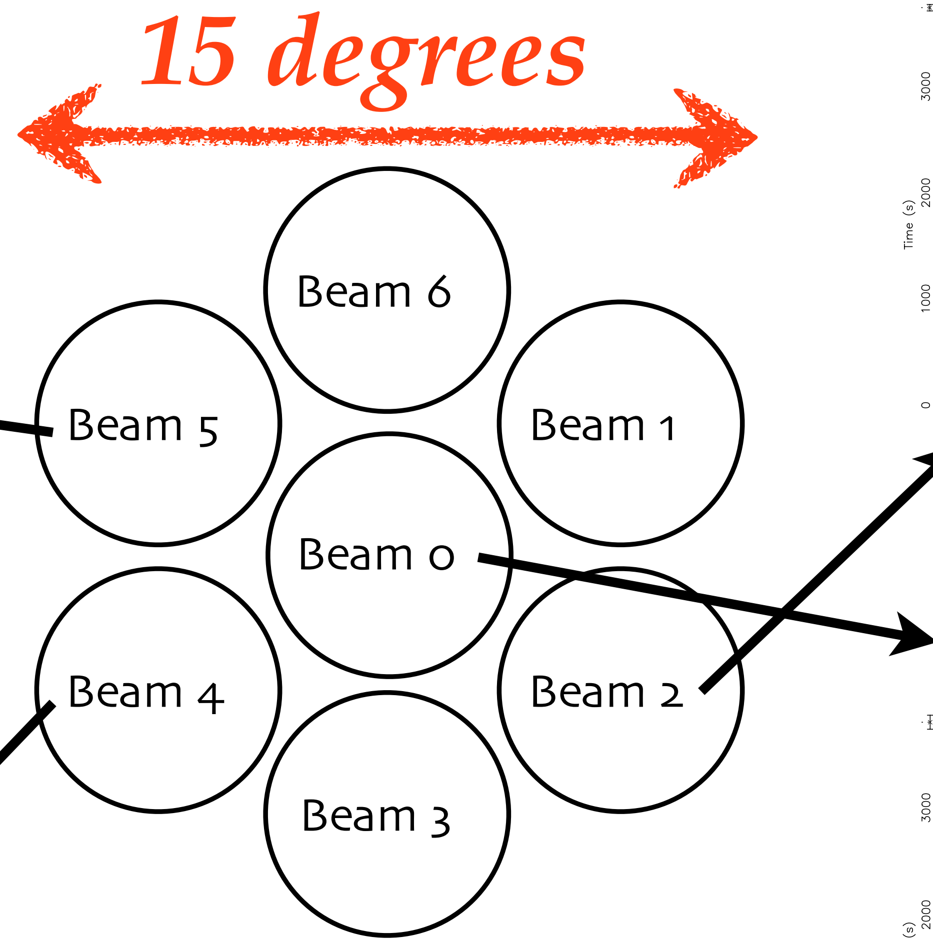
All sky survey with 7 HBA Station Beams summed incoherently



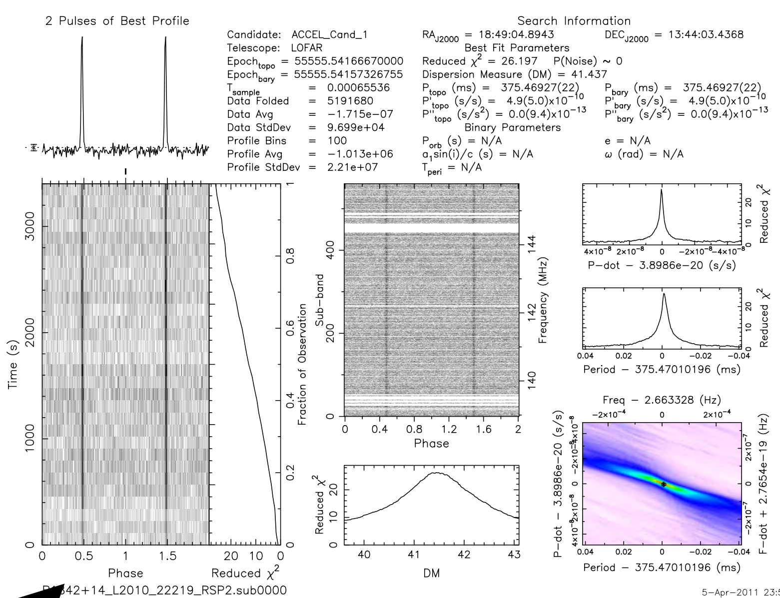
Re-detection J1823+0550



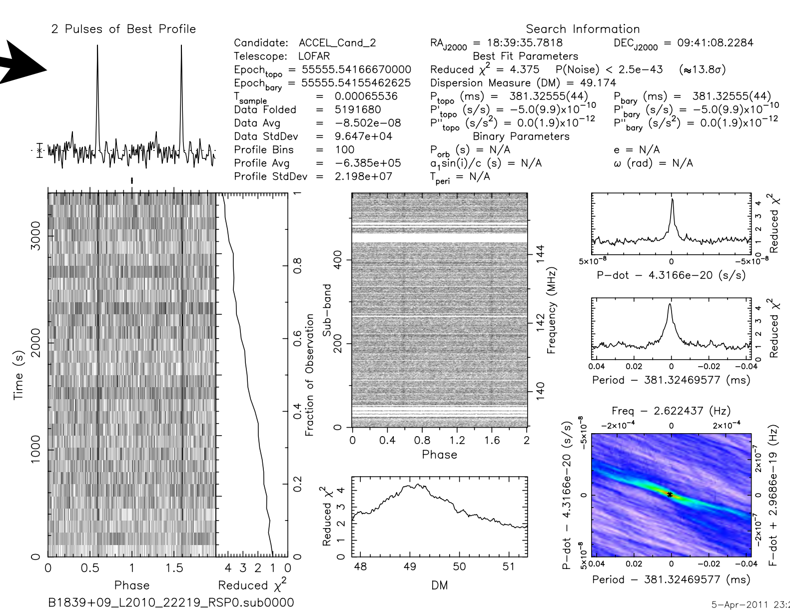
RFI (DM = 0 cm-3 pc)



LPPS pointings contains 7 beams



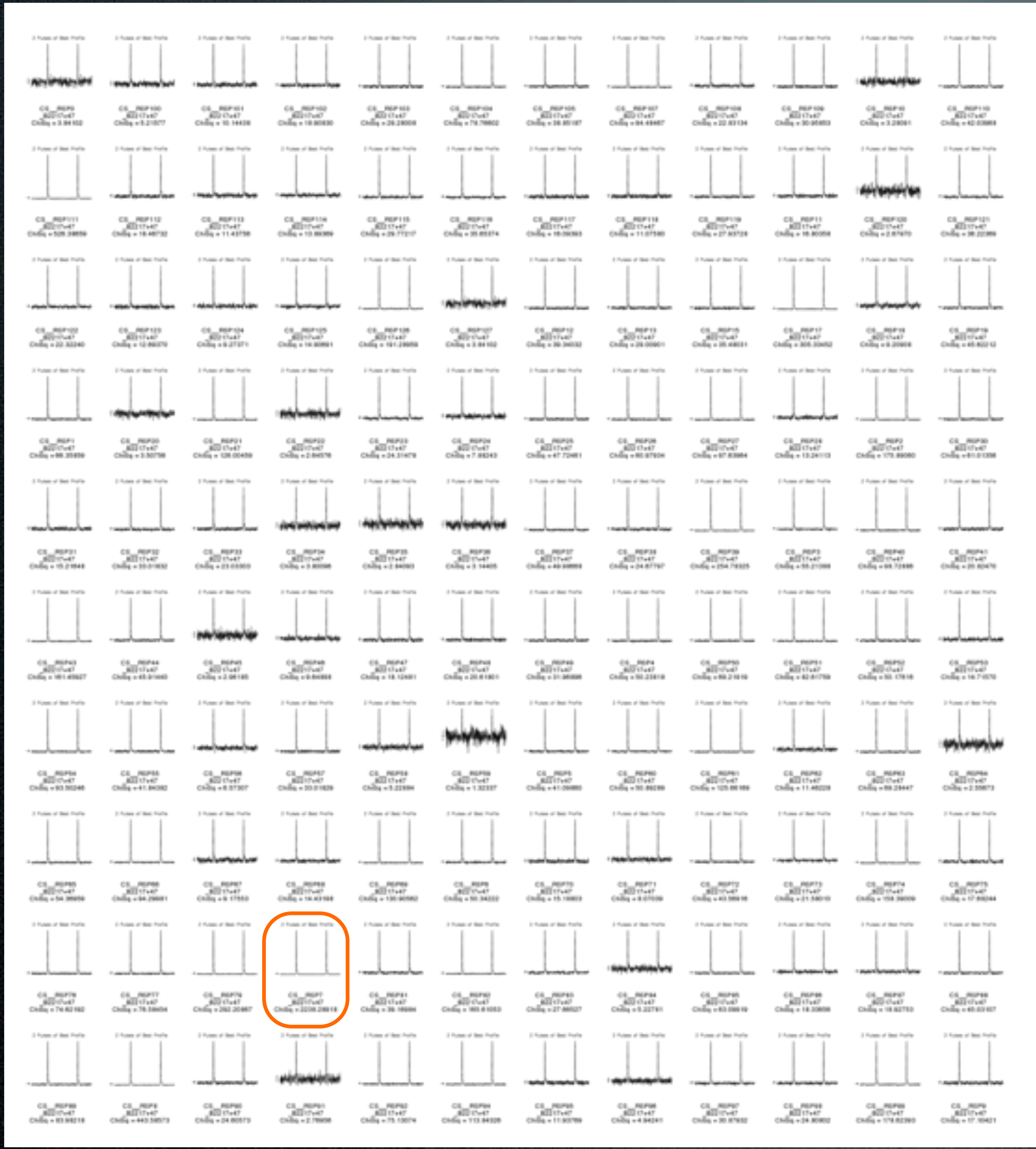
Re-detection J1844+1454



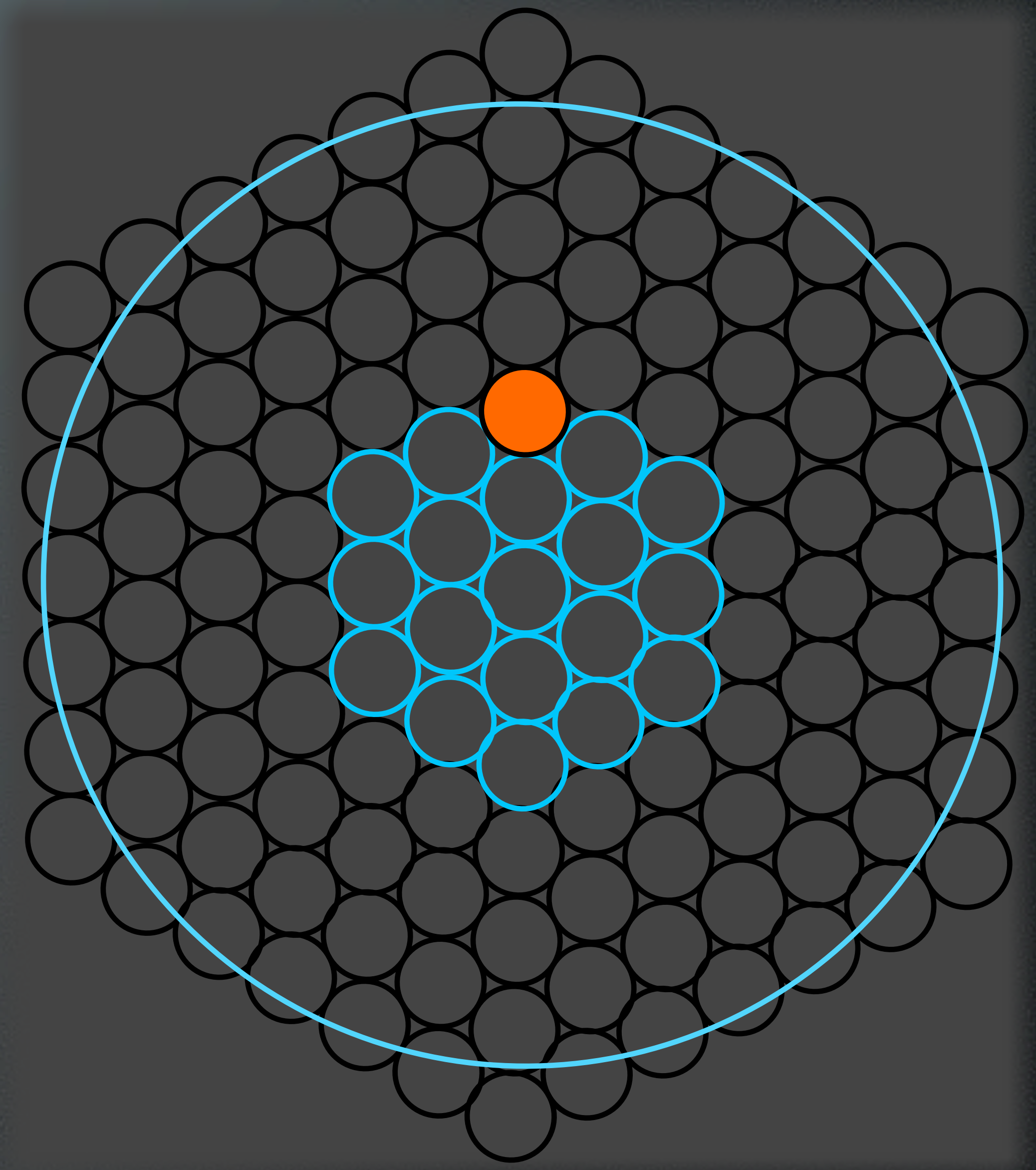
Re-detection J1841+0912

~400 7-beam pointings > -35 deg DEC

LOFAR 127-beam Tied-Array!!



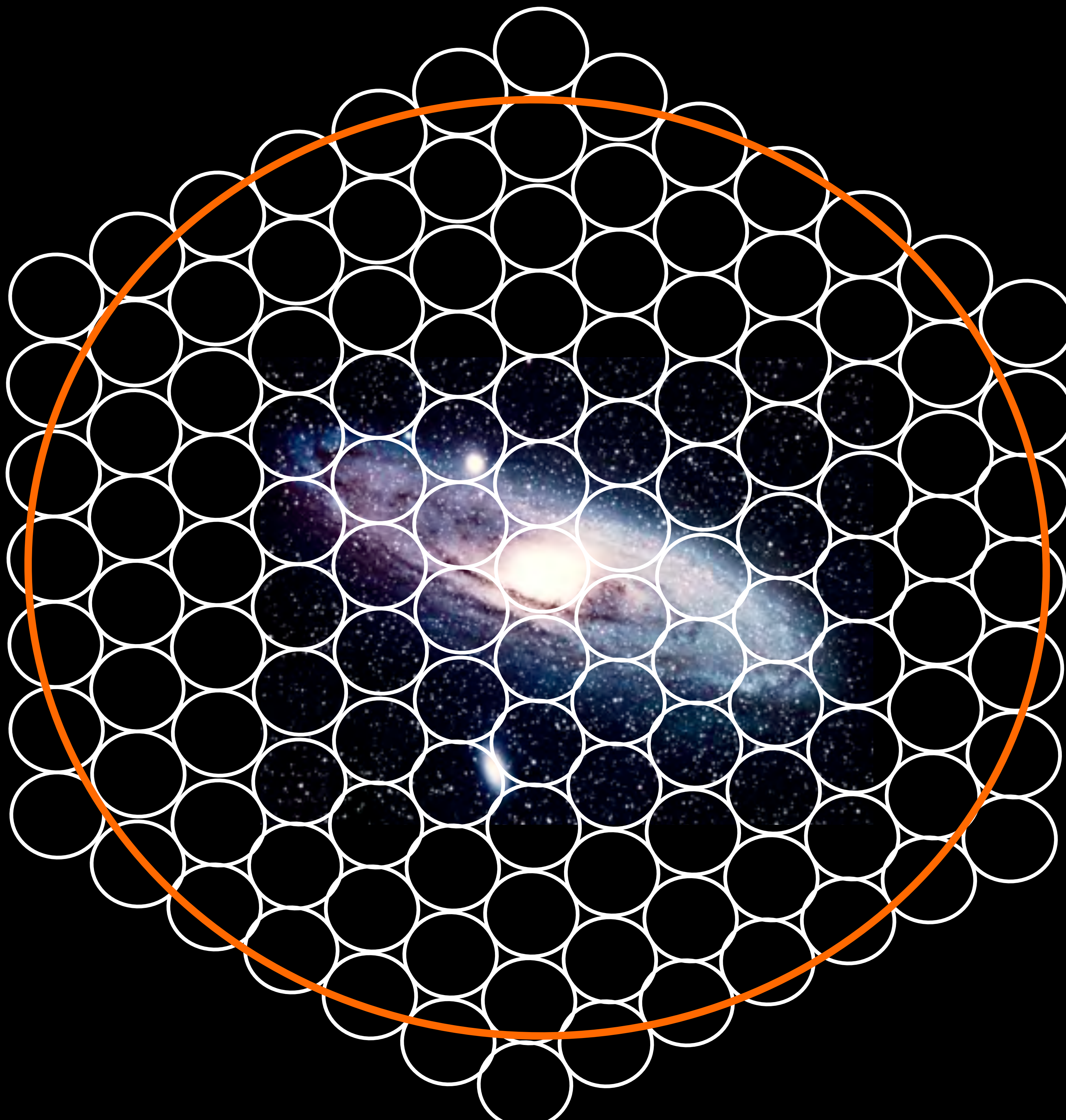
Shifted 1 deg south



Pulsar is 10x brighter in the correct beam (beam 7)!

Credit: Alexov & Hessels

Andromeda



Credit: Hessels

Motivation II
Transients science is the canary in the coal mine of SKA system design

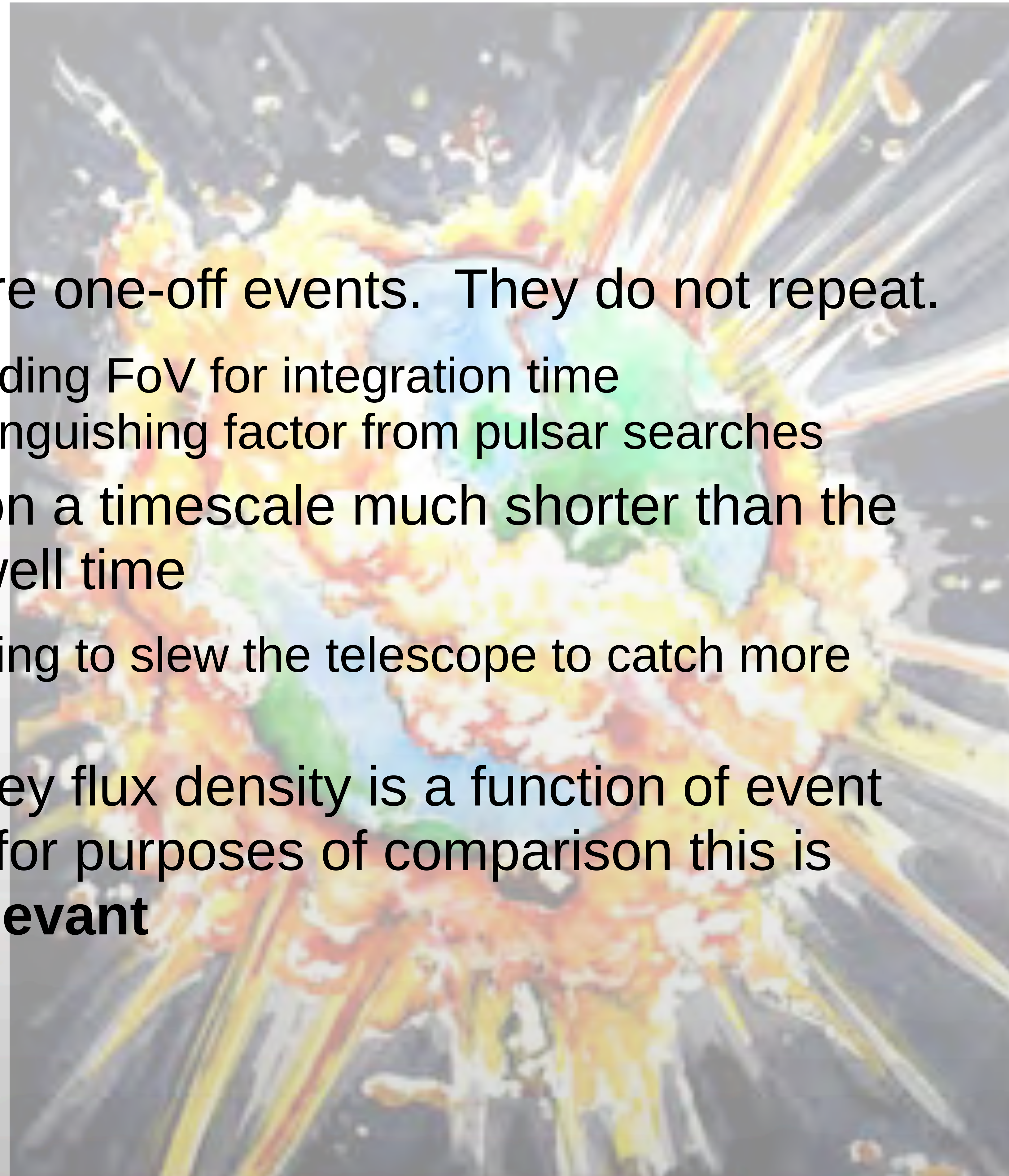
- Given an underlying event rate, luminosity function, sensitivity and FoV
  - how many events should we expect to detect?
  - what is their distance distribution? - what DMs?
- What configuration yields the most detections?
- Influence SKA architecture and observing strategies

What matters most?

- Field of view
- Sensitivity
- Temporal Resolution
- Buffer
  - refine position and DM
  - post processing
  - VERIFICATION

Key Points

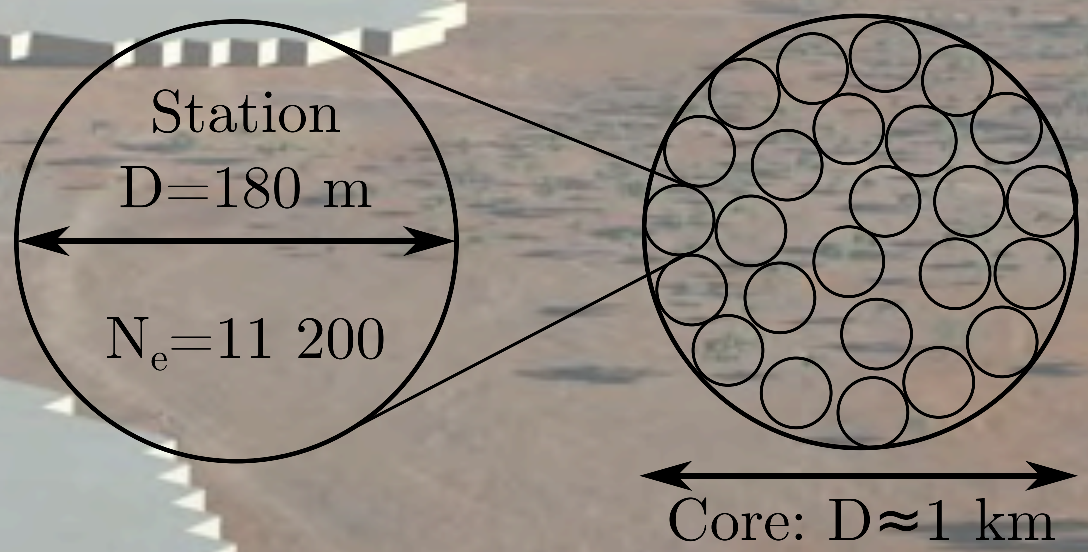
- Transients are one-off events. They do not repeat.
  - No point trading FoV for integration time
  - Crucial distinguishing factor from pulsar searches
- They occur on a timescale much shorter than the telescope dwell time
  - No point trying to slew the telescope to catch more events
- Limiting survey flux density is a function of event duration but for purposes of comparison this is (mainly) **irrelevant**



Maximising bang for buck

see Colegate & Clarke, PASA 2011

- We consider the AA-lo layout of Memo 130 (Dewdney et al. 2010)
- Diameter 180 m, 50 stations, 11200 elems/station
  - 25 stations at (r <0.5 km)
  - 10 stations (0.5 < r < 2.5 km)
  - 15 stations (2.5 < r < 100 km)
- 70 - 450 MHz
- Dense-sparse transition at 115 MHz
- T_{sys} = 150K + T_{sky} --- T_{sky}=60 $\lambda^{2.55}$ K



Sub-Conclusions

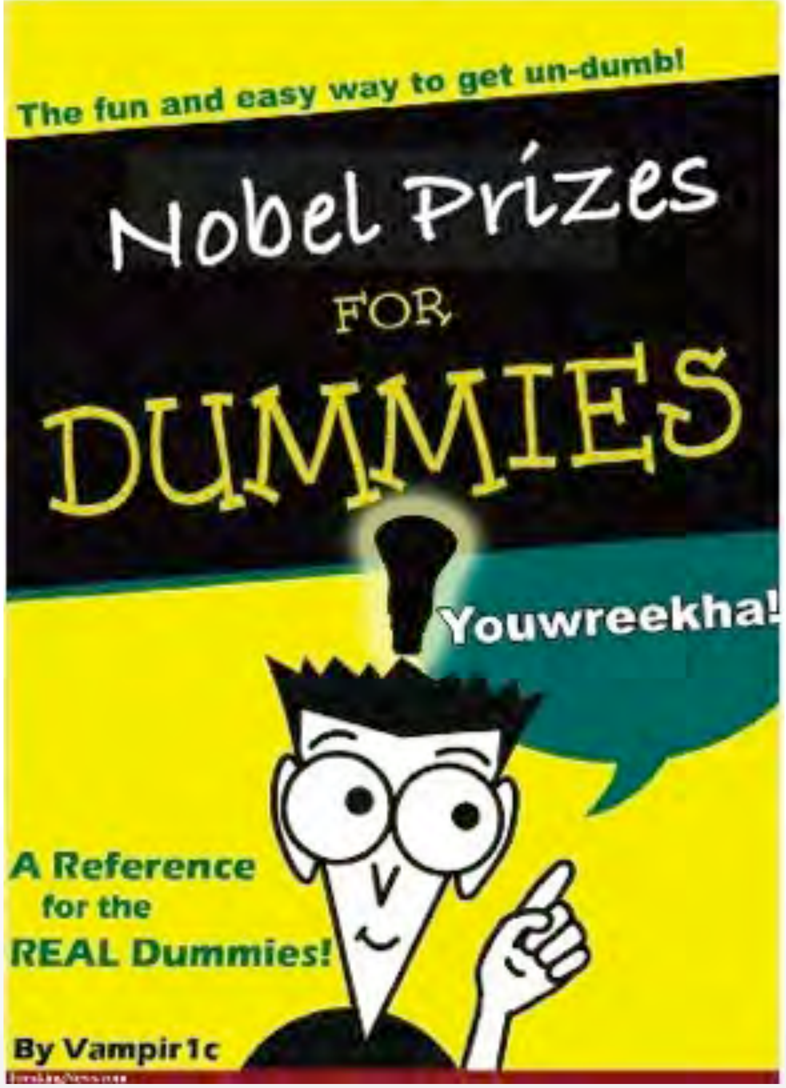
- Detection rate scales as $\Omega S_0^{-3/2+\delta}$ where $\delta=0$ for an extragalactic survey and any sensitivity-limited survey in which temporal broadening is unimportant
  – In the Galaxy, both interstellar scattering and the finite extent of the Galaxy force $0 \le \delta \le 3/2$
- If the event rate is constant over the sky, a fly's-eye survey detects $N^{1/4}$ more events than a collimated incoherent survey
- If there are large variations in the event rate as a function of sky position, conduct a collimated incoherent survey on the high event rate region instead of a fly's-eye survey over both high and low event rate regions when

$$f^{\delta/2-3/4} > 1 + \frac{1-f}{\eta f} \qquad f = \Omega_1 / N\Omega_t$$

  – N f is the ratio of the solid angle covered by the high event rate region (angle Ω_1) to the array element FoV, and $\eta > 1$ is the ratio of the high to the low event rate per solid angle.

Conclusions

- Galactic surveys can be either sensitivity- or volume-limited or a combination of both
  - ISS acts as fast transients detection barrier & makes detection rate highly position dependent
- Optimization of survey strategy influences detection rate by orders of magnitude
  - Flexibility is the key to maximizing discovery
    - Tied-array sub-optimal if survey is volume-bound
    - Fly's eye yields better rate than incoherent collimated, but requires more processing
- Cannot rely on imaging end products
  - Access to raw data is the way to win Nobel prizes



Blind Detection of Giant Pulses

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{dalal.ait_allal, cedric.dumez-viou, gilles.theureau}@obs-nancay.fr
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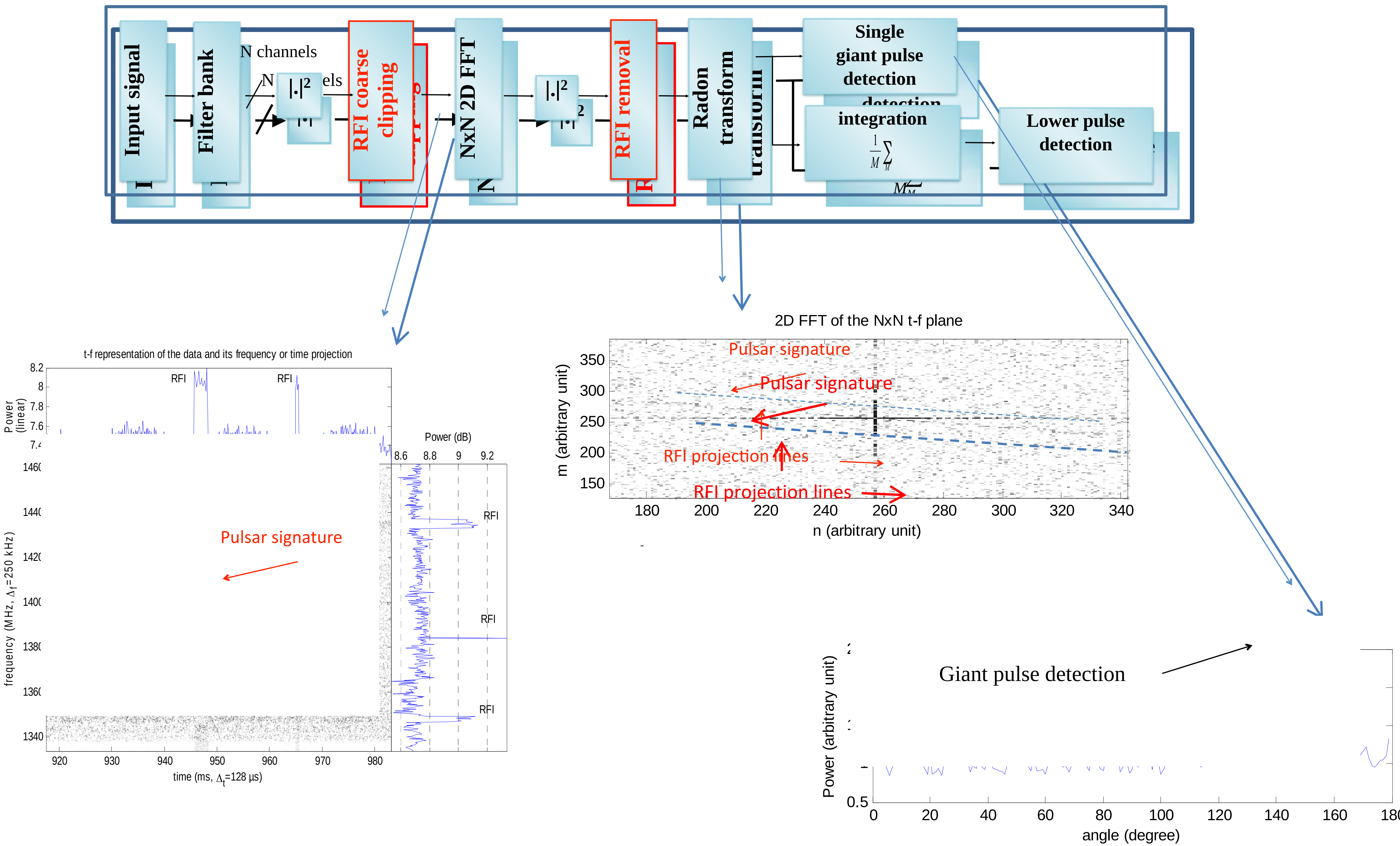
Principle



 Details in Ait-Allal & al. " Blind Detection of Giant Pulses: GPU Implementation" Comptes Rendus Physique 13 (2012)

Conclusions

Drawback :

- Less sensitive than classical de-dispersion procedures

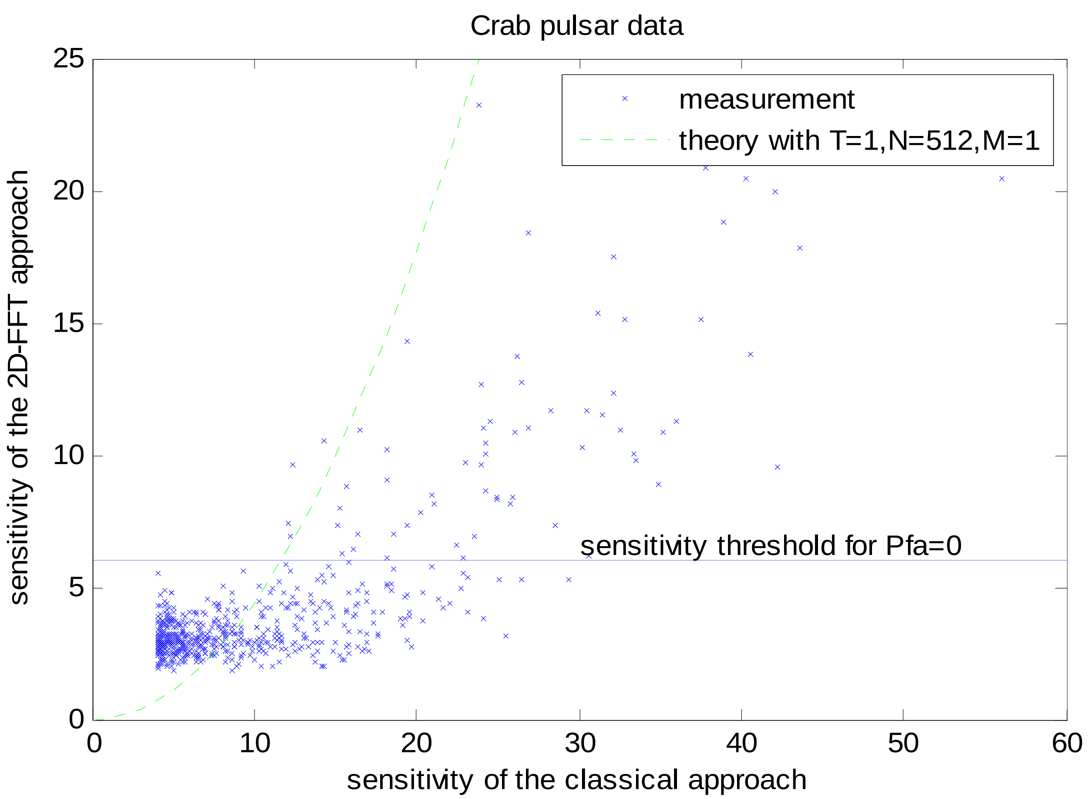
$$Sensitivity = T.SNR^{2}.\sqrt{NM}$$

SNR signal to noise ratio
T = pulse width
N X N size of the T-F plane
M number of T-F planes

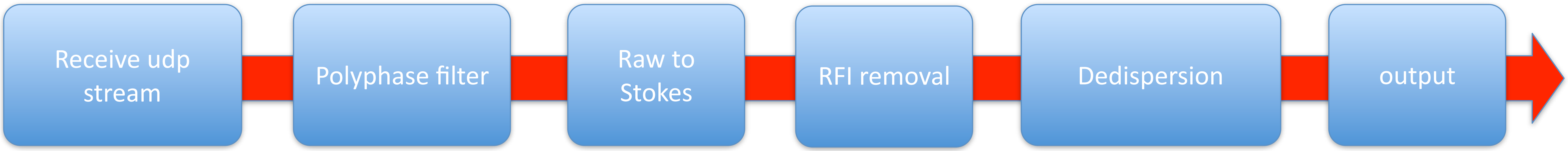
Advantages:

- simple implementation (real time)
- blind (no need to know the pulsar period nor the pulsar DM)

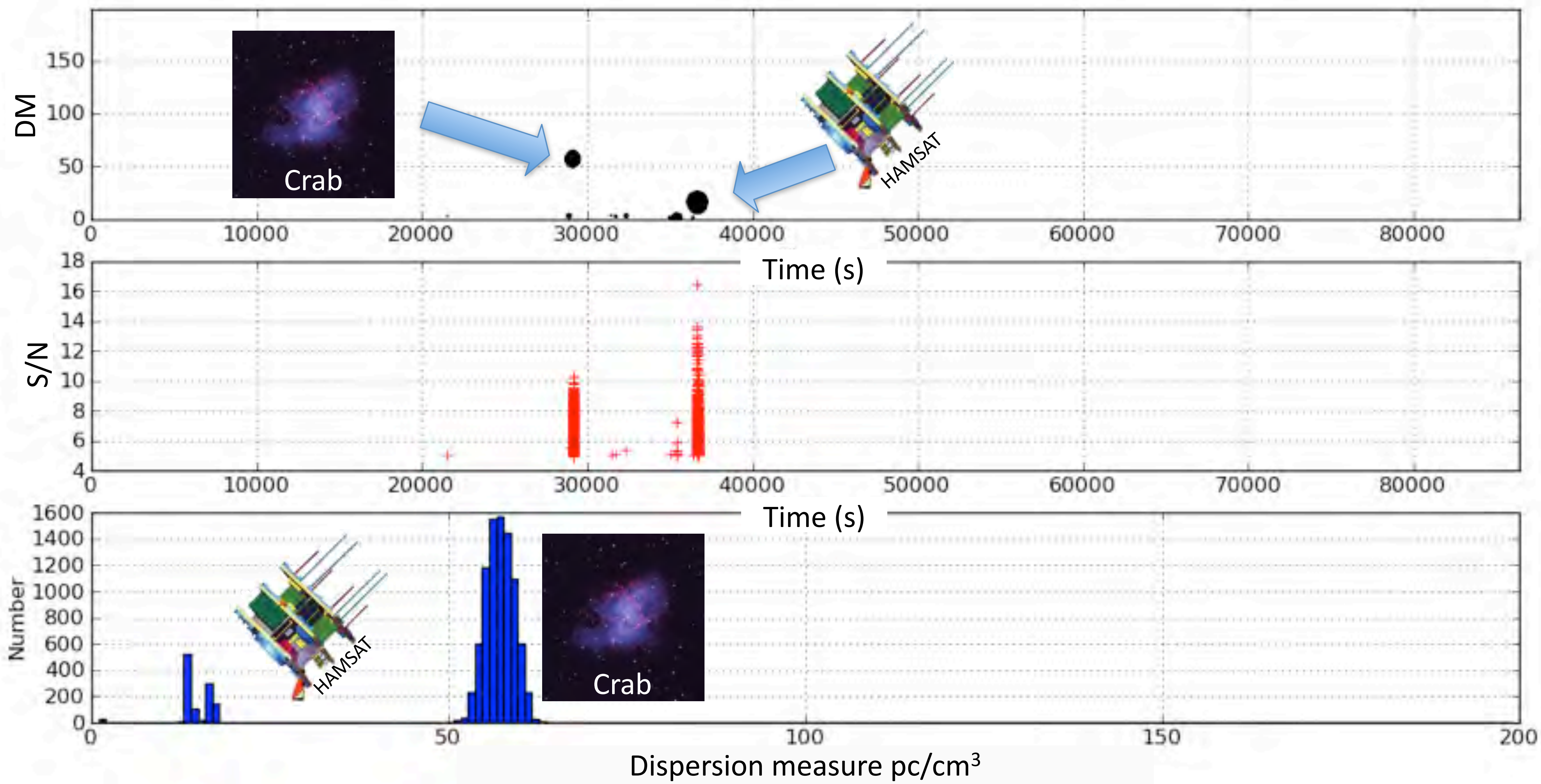
Can be use as piggy-back blind detector of strong pulses (Giant pulse, RRATS, unknow strong transients…)?



- Real-time searches for Individual Radio Pulses
- Dedispersion over 4000 DMs per beam in real time with GPUs
- Pilot survey 1: 6-8 beams tracking circumpolar targets
- Pilot survey 2: 6 beams fixed on the meridian from 8^{o} to 28^{o} dec



Pipeline diagnostic plot from Pilot survey 2 – daily summary from one of six beams

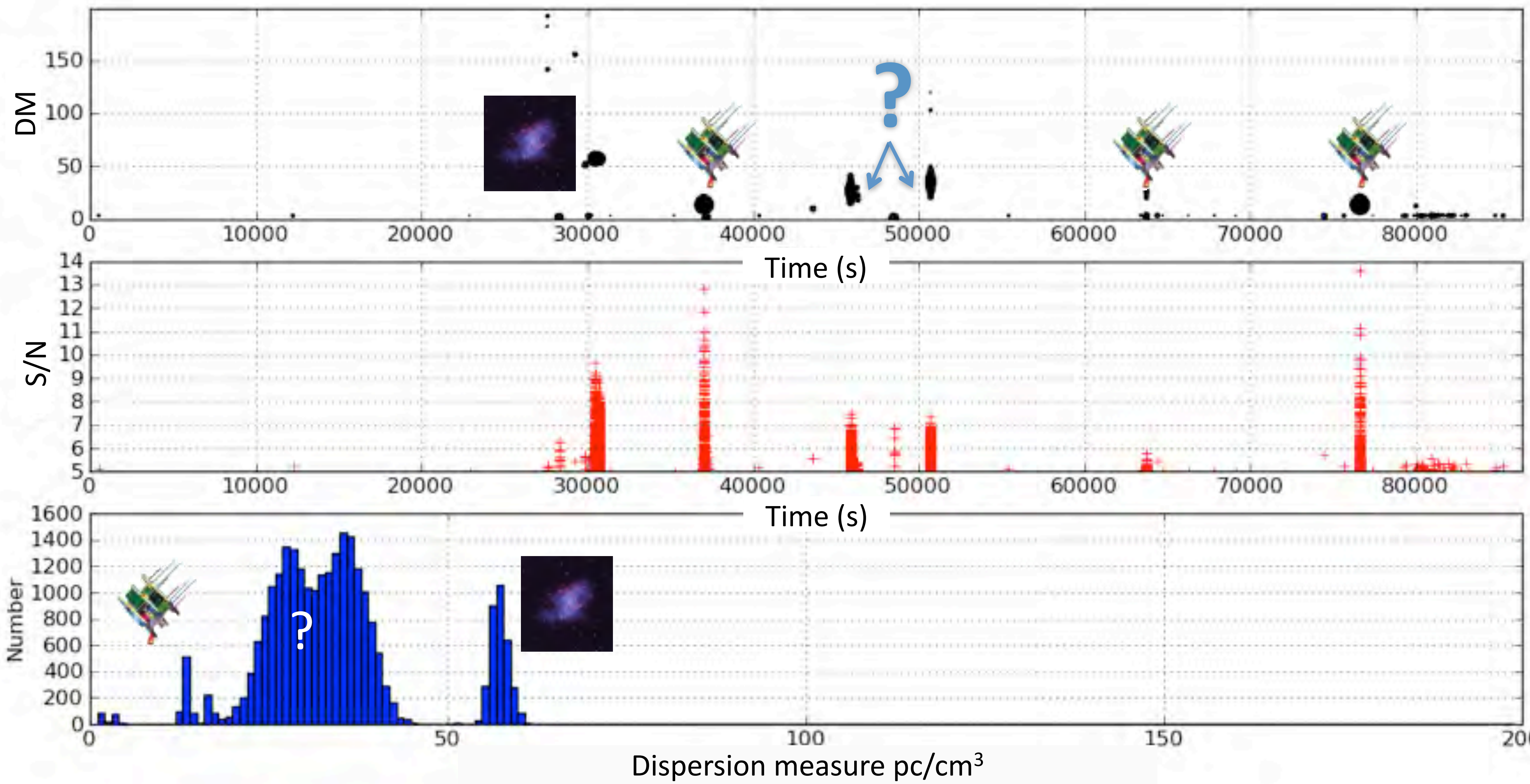


Aris Karastergiou (aris@astro.ox.ac.uk)

- Performed on 800 mbps streams
- Each node has: 12 Xeon CPU cores + 1 NVIDIA M2050 (or GTX)
- DM processing is ~10x better than real time
- RFI rejection performing well in very contaminated environment

Detecting known sources of dispersed pulses including pulsars and frequency swept radio emitters (HAMSAT).

Anticoincidence experiments with Effelsberg + Nancay will reveal nature of enigmatic detections

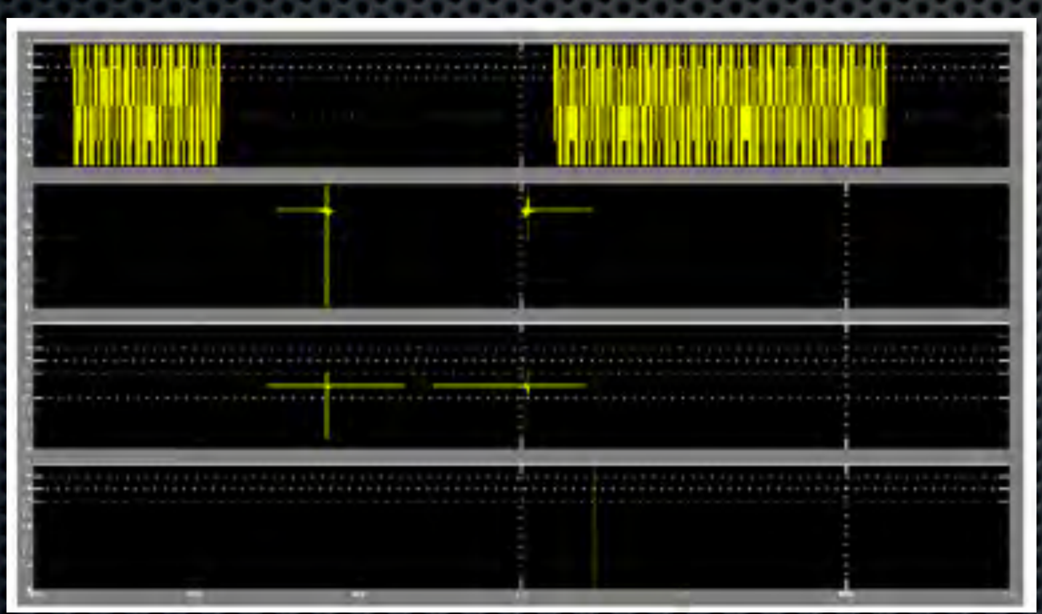


Aris Karastergiou (aris@astro.ox.ac.uk)

Uniboard: Pulsars

- Working on giving the pulsar flavour to the board
  - Coherent Dedipsersion
  - Folding
  - Incoherent dedipsersion of multiple DMs
  - Searching (partial/full)
- Will be tightly linked with the RFI modules
- Will be modular so may be linked to beamformed modes being developed by other partners.

Figure 9: Large FFT computation



Coherent Dedipsersion

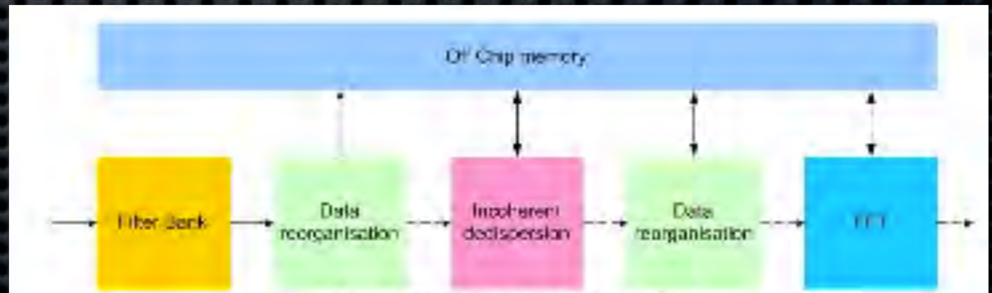


Figure 24: Pulsar searching system

Ahmedsaid, Shenton, Ferdman, Stappers

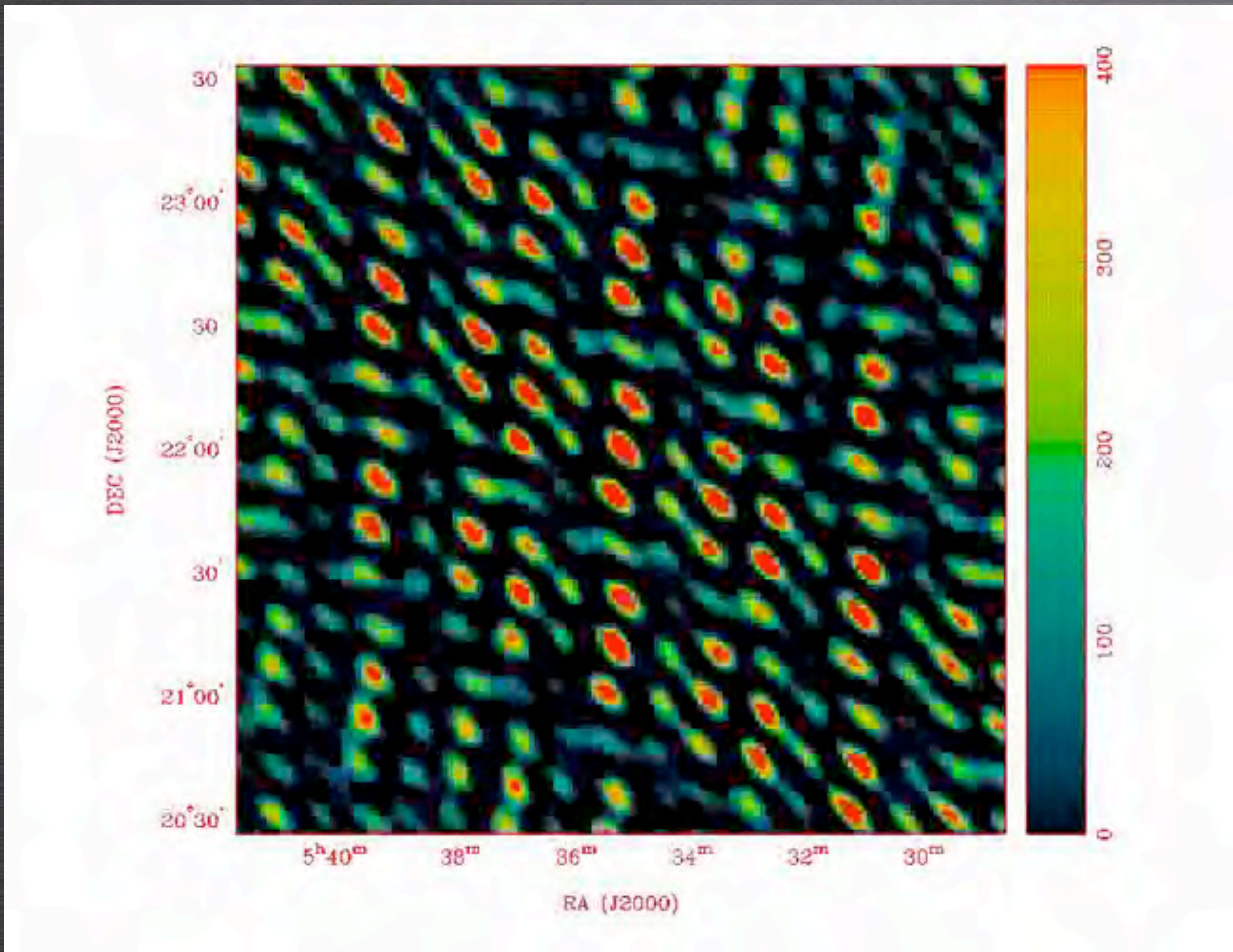
"Fast Imaging"

- Correlators synthesize thousands of beams!

- Interferometers can:
  - Localize events
  - reject Interference
  - calibrate easily

- Conceptually simple, Technically challenging

Imaging a Pulse



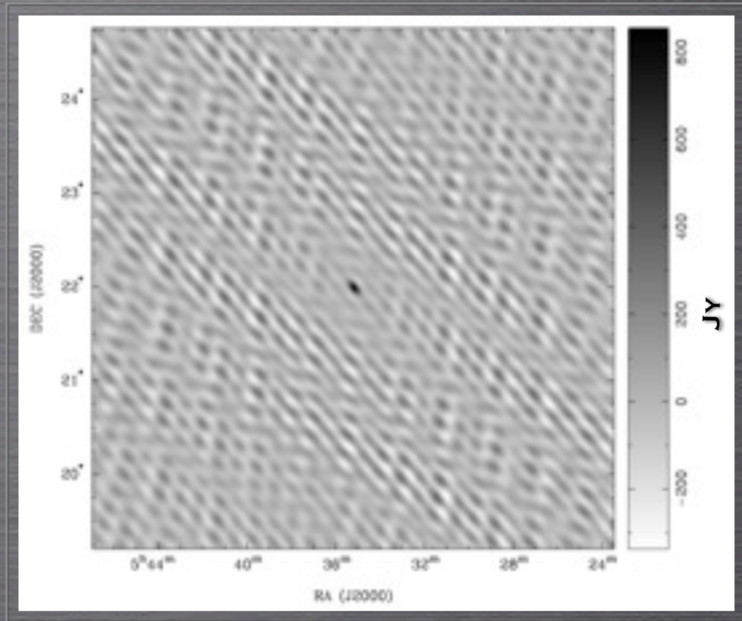
Movie of Crab Pulse (1/40th true time)

- Pocket Correlator at ATA (8 ants, 1 ms)
- Visibilities allow Coherent background subtraction
- Used to constrain pulse rate in M31 (Law et al. 2011)

Also recently trialled on KAT-7 on VELA

New Dimension, New Algorithms

Imaging



$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Model Fitting

Statistical

$$V_i = I\, e^{-j2\pi(u_i l + v_i m + \phi_i)}$$

SKA Phase 1 -- WP2

GR/GW Through timing dishes / Survey and efficient timing of slow pulsars with AAlow

Freq (GHz)	BW (MHz)	l,b lim (deg)	#PSR	#MSP	T_surv (days)	Data (exa)	#ops (peta)
1.4	500	all sky	6400	700	2000	17000	4.3
1.4	500	45, 5	3000	190	50	500	4.3
1.4	500	90, 10	5200	450	200	2000	4.3
0.4 [1]	100	all sky	8000	1300	250	9000	16.6
0.4 [3]	100	all sky	13300	2400	250	9000	16.6
0.4 [1]	100	90, 10	6000	700	25	1000	16.6
0.4 [3]	100	90, 10	10700	1400	25	1000	16.6

[1,2,3] corresponds to Aeff of 25000, 50000, 75000

Simulations of all sky-survey at 400 MHz (100 MHz BW) and Galactic plane survey (|l|<90, |b|<10) at 1.4 GHz (500 MHz BW) combined:

Type	#PSR	#MSP
[1]	9300	1400
[2]	12000	2000
[3]	14000	2500

[1,2,3] corresponds to Aeff of 25000, 50000, 75000

Smits, Stappers, Kramer, Karastergiou

Phase 1 Survey Use Case

- One of the key goals of the SKA in both phase 1 and 2 will be to perform an all sky survey for new pulsars, especially MSPs, and fast radio transients.
- In Phase 1 there ***might*** be two different frequency ranges and technologies.
    - AAs for < 450 MHz and Dishes around L-band
- Our simulations show that the AAs can perform an all-sky survey most efficiently
- For the plane the dishes allow us to reach deeper, but presently survey speed too slow for all sky

NON-IMAGING PROCESSING USE CASES

Document number WP2-040.030.010-TD-002
Revision .... A
Author .... B.Stappers
Date 2010-09-06
Status .... Draft

Area to be surveyed	36,000 square degrees
Survey Duration	200 days
Integration/Pointing	600 s
Number of Stations	35
Diameter of Stations	180 m
Size of Core	5,000 m
Central Frequency	400 MHz
Bandwidth	50-100 MHz
Sampling Time	64 us

Conclusion

- Lots of development going on in both hardware, software, simulation and technique development going.
- The (fast) transient case is growing rapidly and is being implemented at many precursors
- We are honing the requirements for SKA Phase 1 which definitely includes a strong case for the upper half of SKA-low (searching) and the dishes for follow up work.
- Aperture Arrays in the mid-range are ideal for searching and lower precision timing in the full SKA
- We should not consider the f-word as being a swear word never to be spoken, it must be at least discussed.
- It is absolutely vital to continue and improve the dialogue with the engineering communities.
- There is much more going on than I can possibly summarise here....
- No chance to mention ASKAP (COAST, VAST, CRAFT) nor MeerKAT (Timing, TRAPUM, Thunderkat)
- It highlights the vibrancy of the pulsar and transient community.