Pulsar processing with LEAP, APERTIF & SKA

Joeri van Leeuwen

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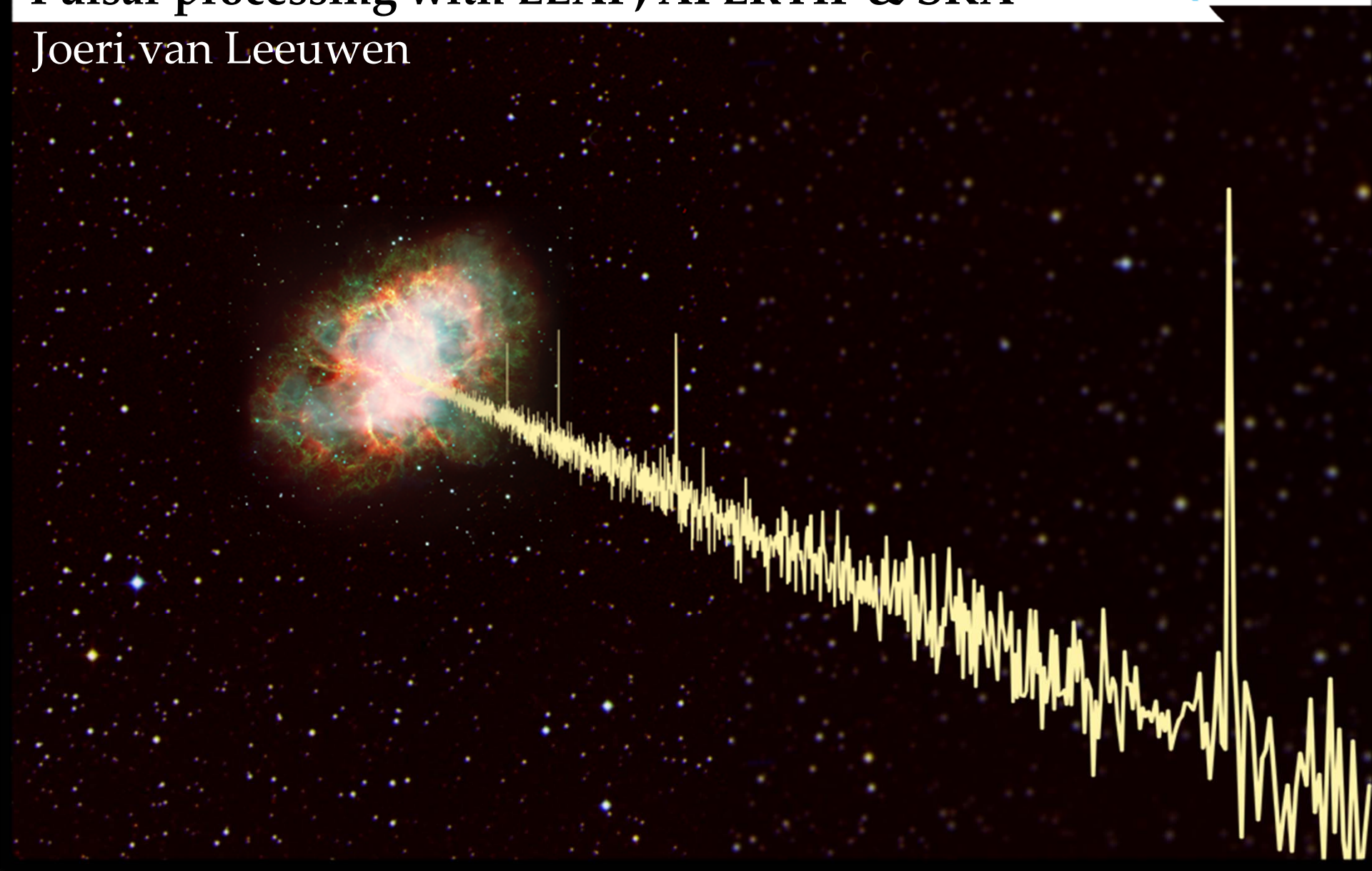

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Introduction / overview

Pulsars
with
2011: LEAP
2013: APERTIF
2018: SKA

Conclusion:
From 0-D through 1-D to 2-D telescopes

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Pulsars

Remnants of massive stars

Extremely compact and energetic

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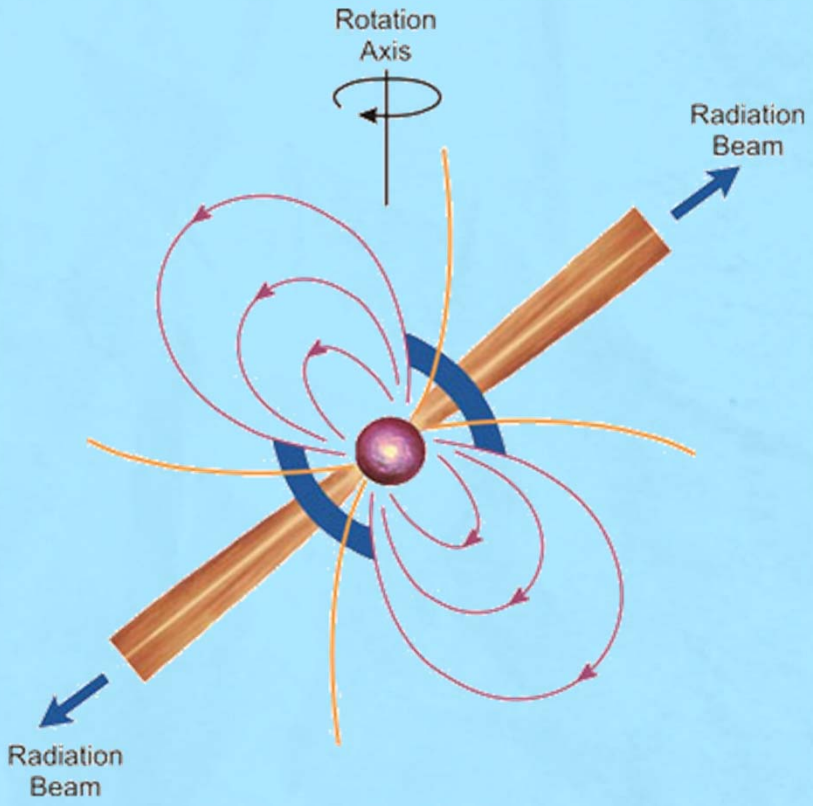
Pulsars

Remnants of massive stars

Extremely compact and energetic

Strong beamed magnetic field



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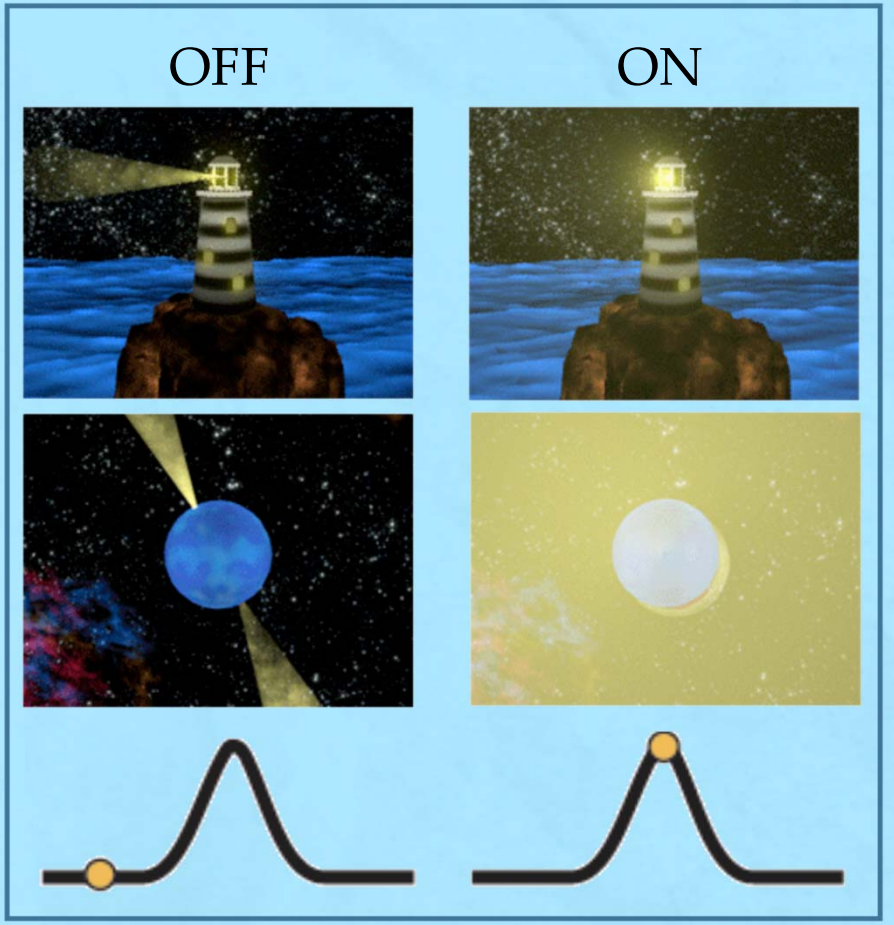
Pulsars

Cosmic lighthouses

Stability rivals atomic clocks



R. Ferdman

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LEAP --

The ``Large European Array for Pulsars''
(PI: M. Kramer, B. Stappers)

Goal: the direct detection of gravitational waves

Rowe/CSIRO

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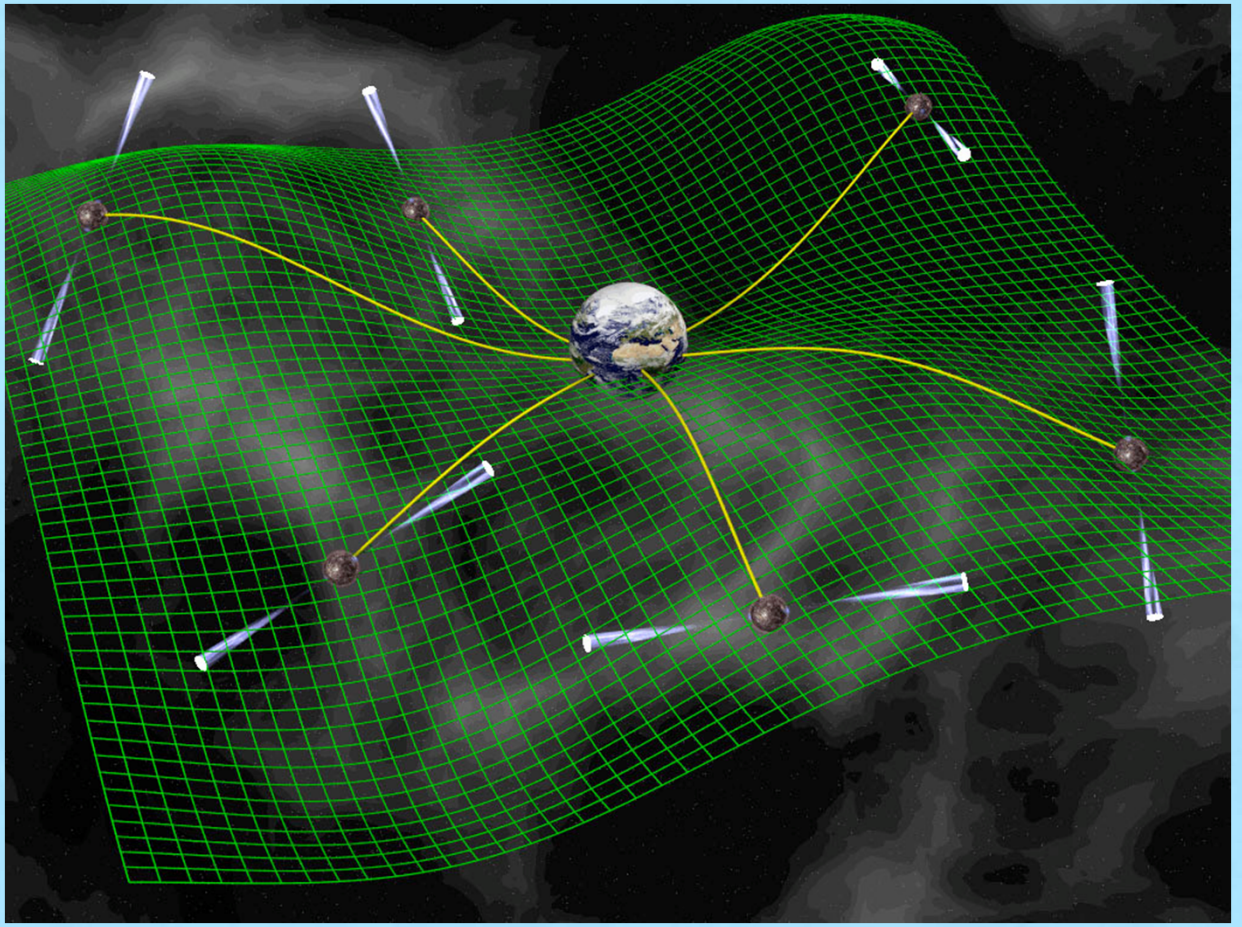
LEAP --

Monitor
the sky:



D. Champion

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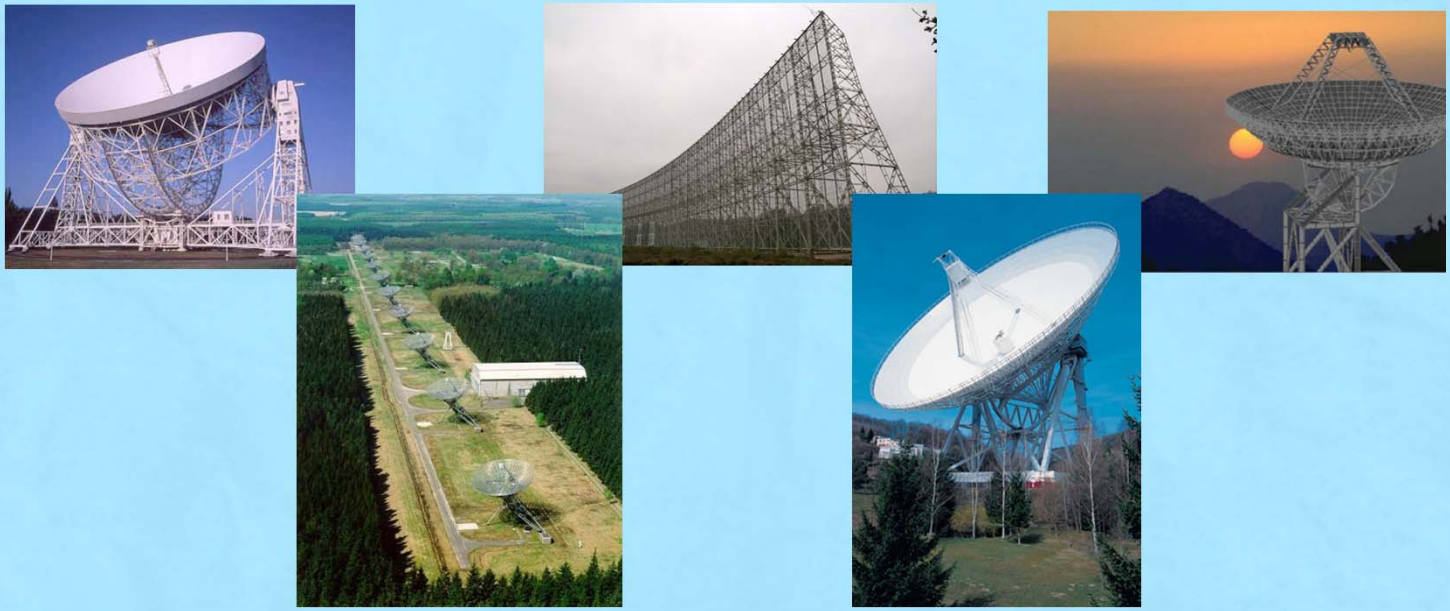
LEAP --

Combining 5 large European telescopes:
Results in ~200m equivalent dish



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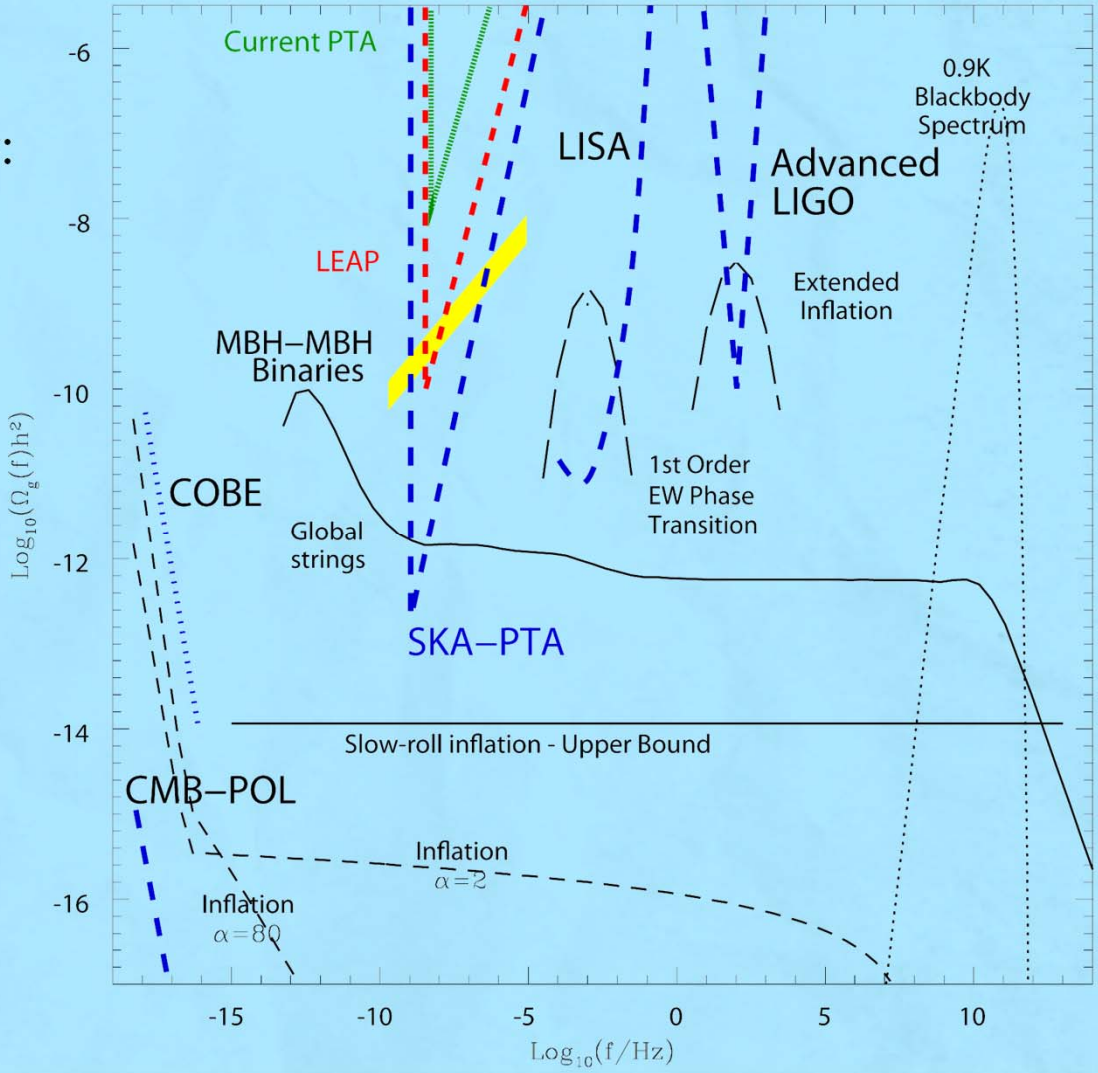
LEAP --

Gravitational wave sensitivity:

Assuming:
20 pulsars
100 ns precision
5-10 years



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LEAP --

ERC funded project

Providing

- 100-MHz baseband writing at all telescopes
  - Based on ROACH boards
  - (Higher bandwidth needed than VLBI backends provide)
- Person power for implementation and science

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LEAP --

Status:

Back ends currently in place in 4 out of 5 telescopes

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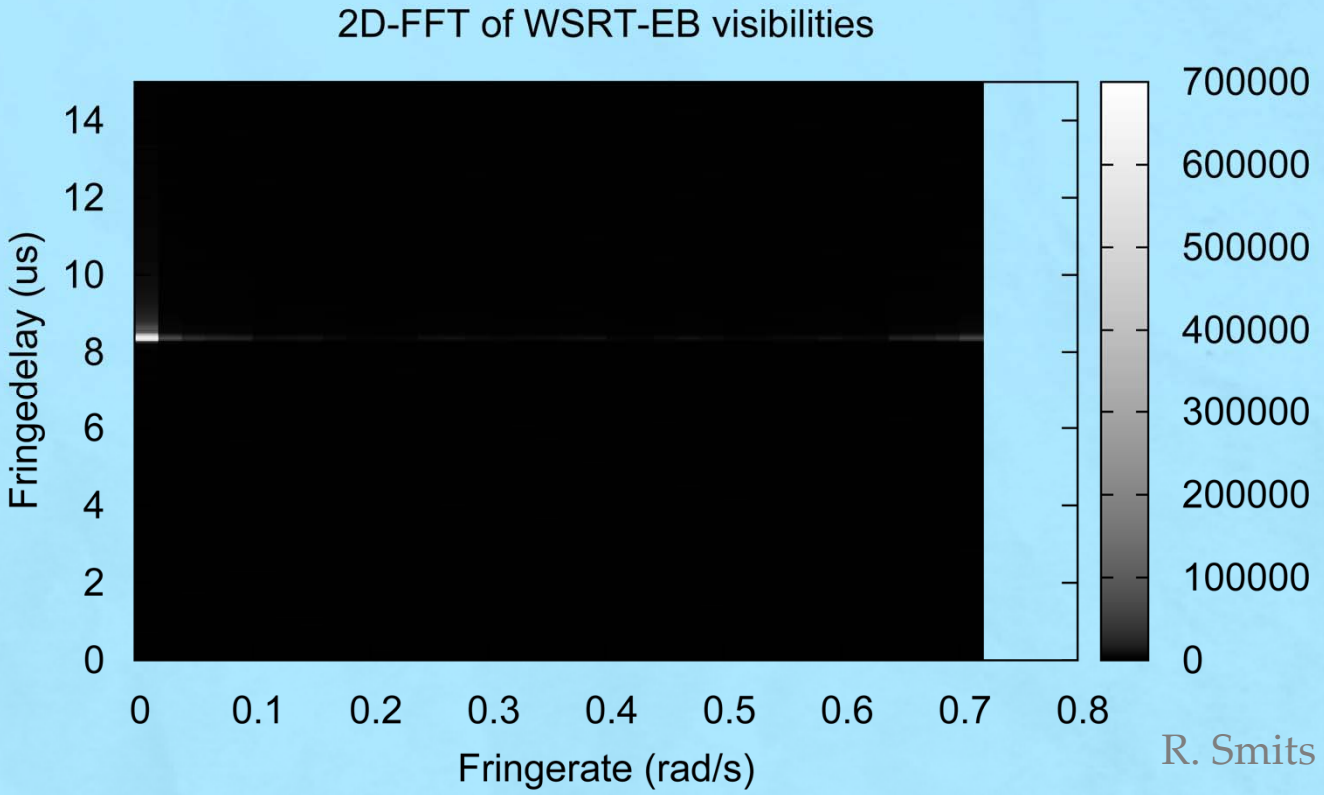
LEAP --

Status:

Back ends currently in place in 4 out of 5 telescopes

First DiFX (software correlator) fringes fit, 8 May 2011



R. Smits

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LEAP --

Status:

- Back ends currently in place in 4 out of 5 telescopes
- First DiFX fringes fit, 8 May 2011
- Tied-array beam forming being added to DiFX

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APERTIF --

Enlarge field of view of WSRT w/ array of densely packed Vivaldi receptors and *fully sample* focal plane

To be installed 2012; operational 2013

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APERTIF --

Apertif	WSRT
• 121 elements (dual pol)	1 (x2)
• 37 beams on the sky	1
• Range ν: 1000 – 1750 MHz	117 – 8650 MHz
• *T*sys 50 K	30 K
• Aperture efficiency 75%	55%
• Bandwidth 300 MHz	160 MHz
• 16384 channels	1024 channels
• 12 dishes	14 dishes

Survey speed increases by factor 30.

Data rate increases

120x (front-end) = 400 GB/s

75x (beamformed) = 250 GB/s

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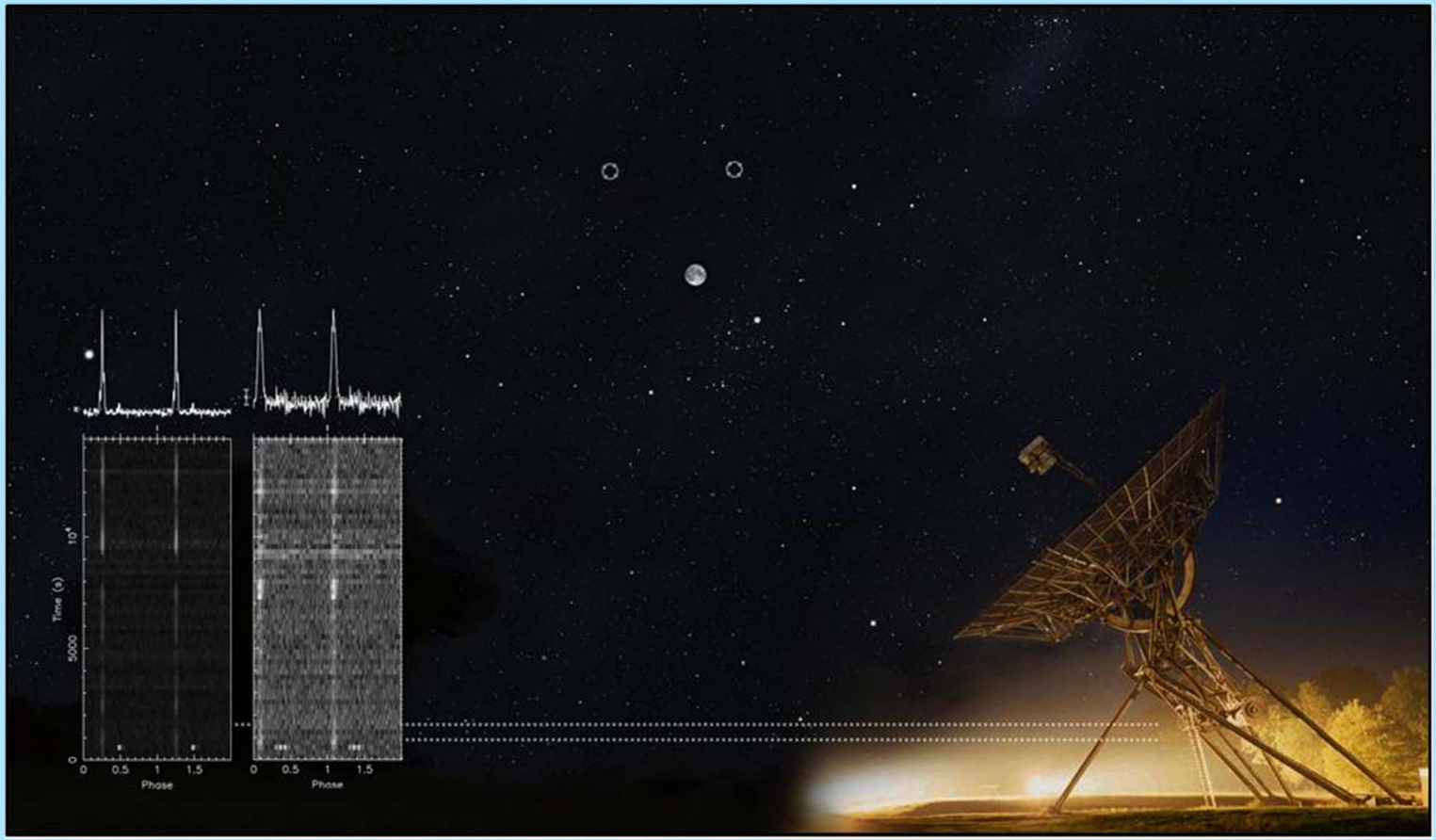
APERTIF --

First (test) system on single dish, works as planned:



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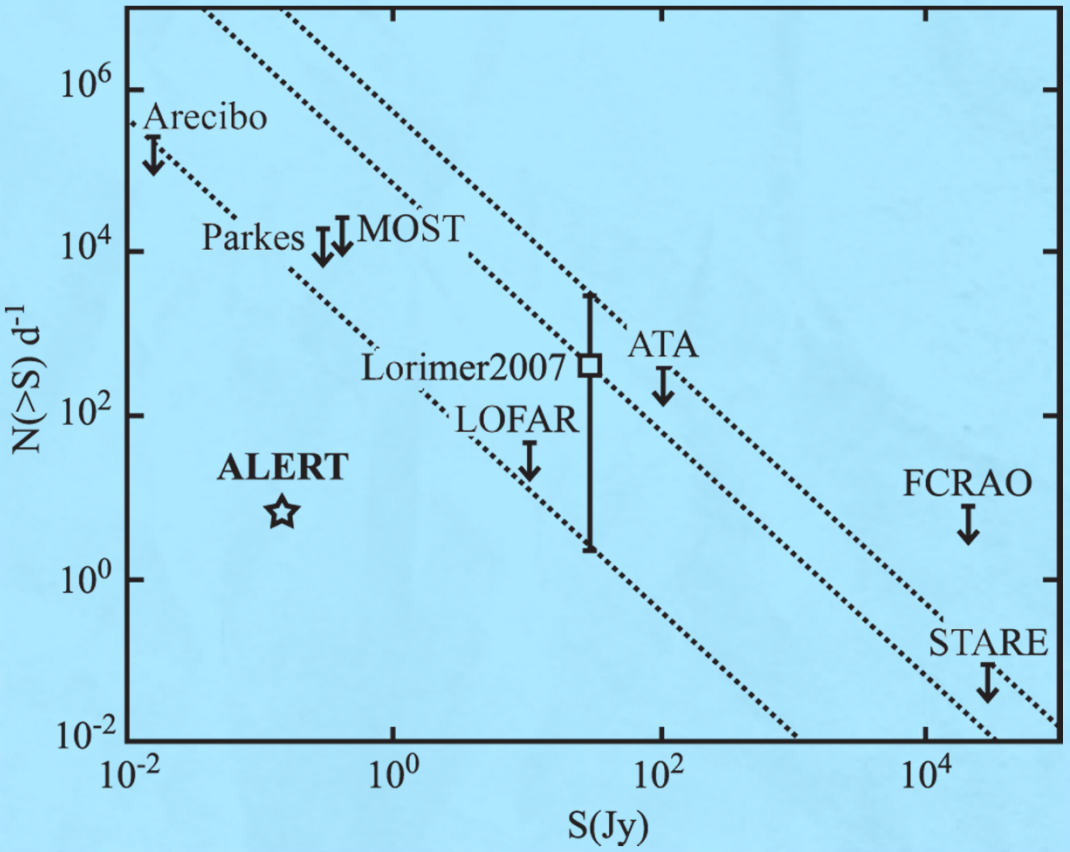
APERTIF --

ALERT (PI: vL) -- The APERTIF legacy exploration of the fast radio transient sky



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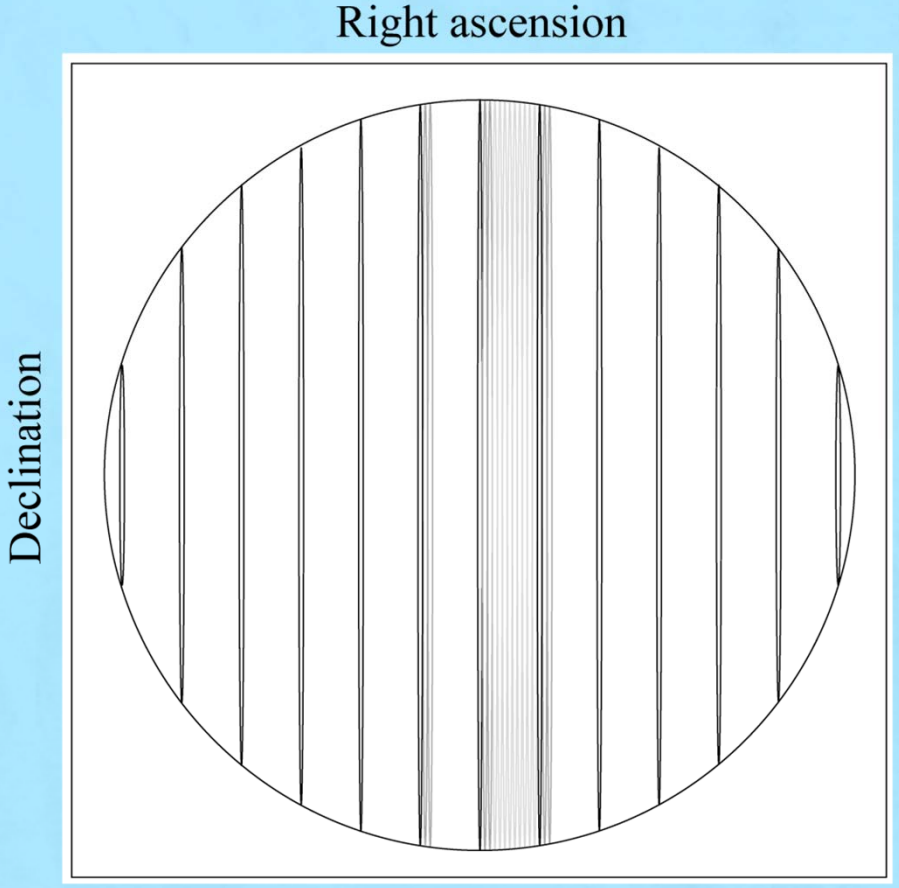
APERTIF --

ALERT needs full element-Field-of-View in tied-array beams.

WSRT is a 1-D (linear),
and regular, array.
~16 beams (x 37 FoVs)

Advantage over 2-D
snapshot arrays,
e.g. SKA, LOFAR
~10,000 beams



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APERTIF --

Full FoV tied-array beamforming.

37 x 2 x (12 x 300MB/s) = 250GB/s in and out
Telescope combining + channelization on
APERTIF Uniboard Correlator/Beamformer

Output data to be
searched for transients in real time (~100 T FLOPS)
stored for 12 hours (400TB after first decimation)

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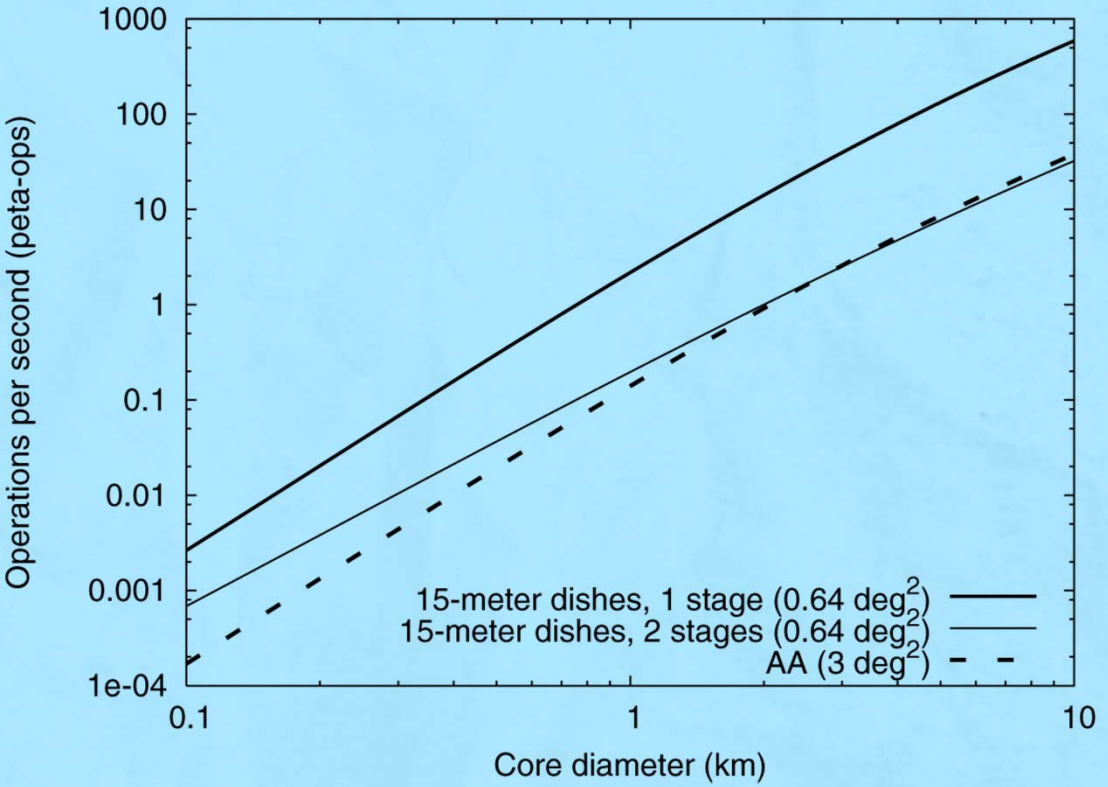
SKA --

Beam-forming entire 'element' FoV

Compact core -- maximal collecting area within ~1km

$N_{PSR} \sim \mathrm{sqrt}(FF)$



Smits et al. 2009

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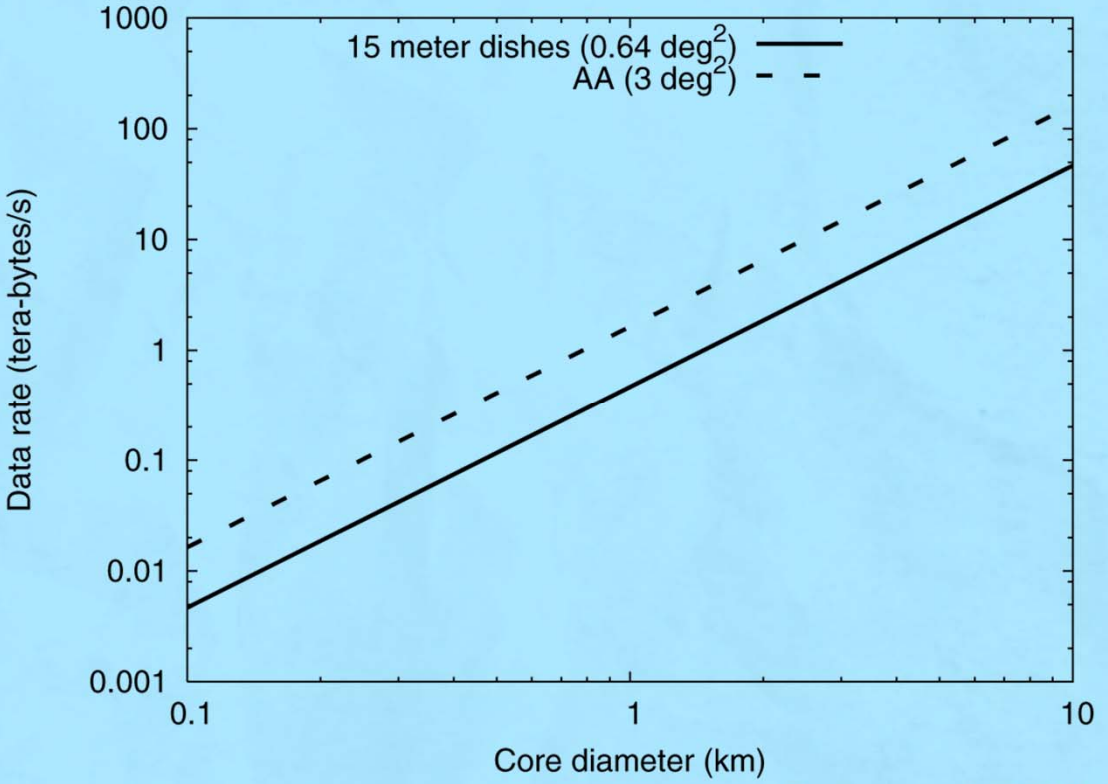

Smits et al. 2009

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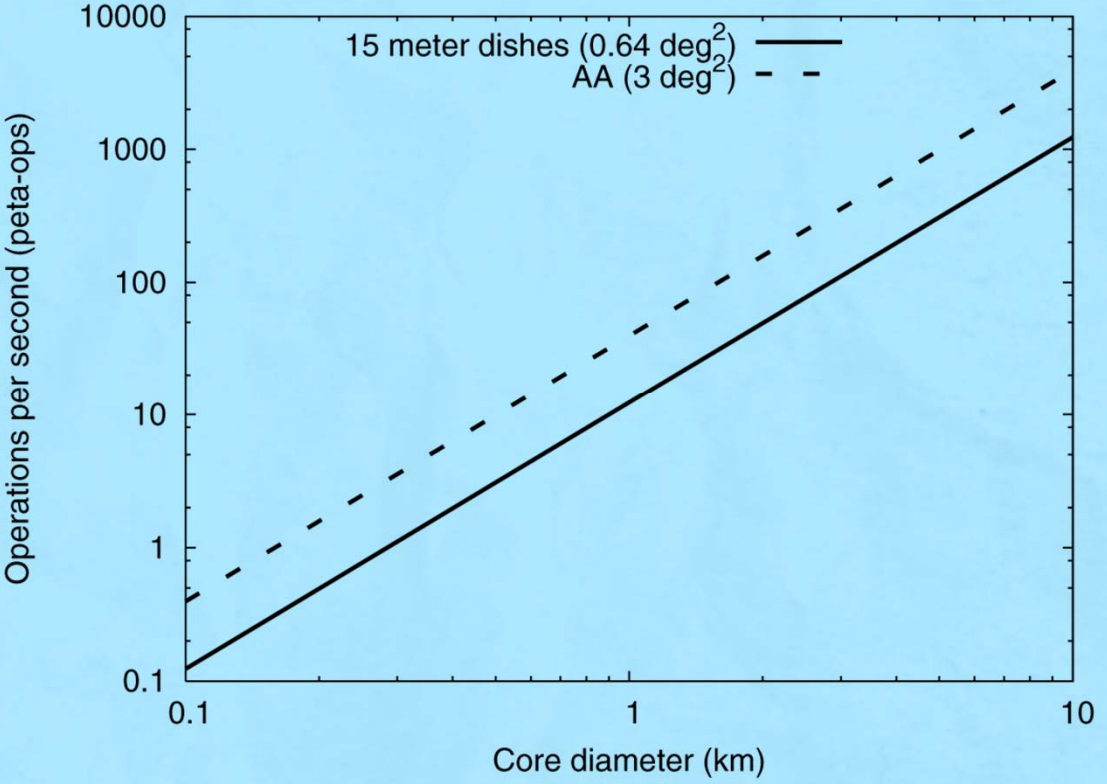
SKA --

Pulsar (high time-resolution) survey



Smits et al. 2009

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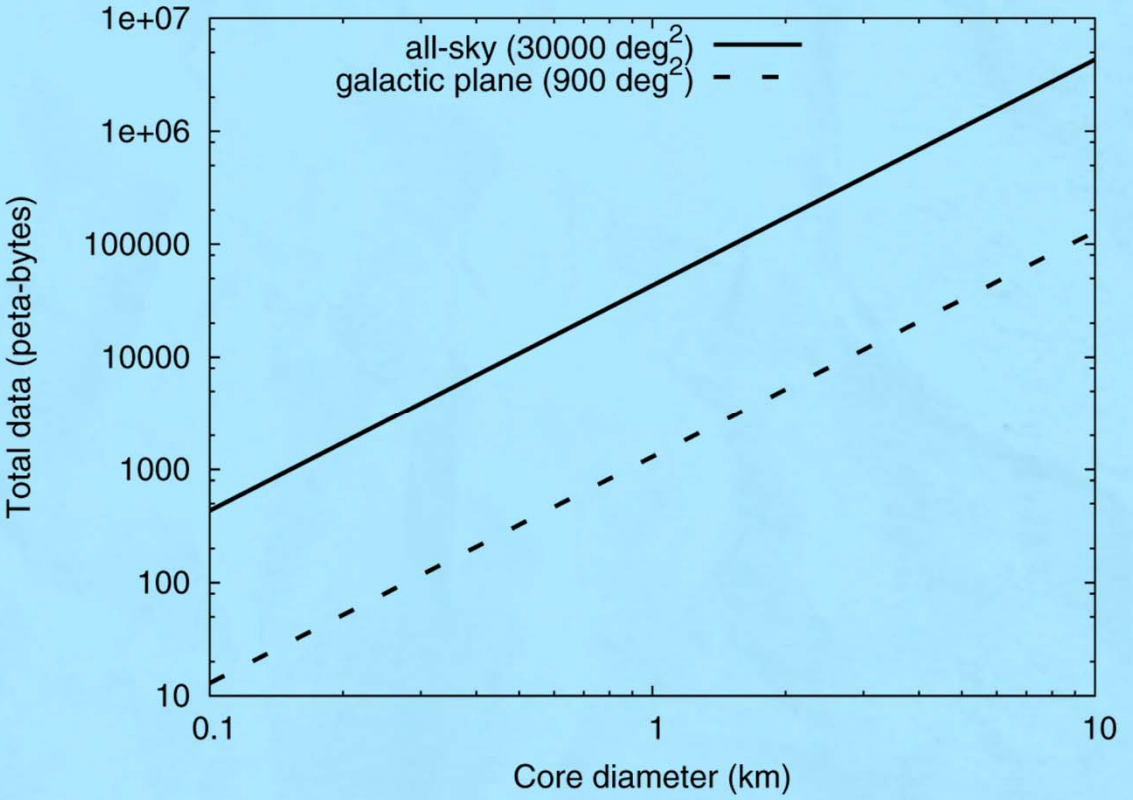

Smits et al. 2009

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Conclusions

LEAP bringing VLBI techniques to pulsar timing

APERTIF exploiting PAFs + regular array layout for surveying

SKA most compact core scenario + ~10-100 P-OPS