Low Frequency Array
(LOFAR)

Masaya Kuniyoshi
(MPI→NAOJ)

On behalf of the LOFAR collaboration

Acknowledgements

Many slides used in this talk were taken from lofar workshop, 7-11 April 2014, Amsterdam, The Netherlands

http://www.astron.nl/lofarscience2014/programme_LSW.php

https://www.astro.ru.nl/lopes/

http://www.utwente.nl/ctit/research/phd/meet/phd/seyed_kasra_garakoui/

http://www.media.inaf.it/2014/04/09/una-nuova-antenna-per-lofar/

James Anderson (AIP), ESSEA, Bonn, 2010 Sep 28

Whrer is LOFAR?

the Netherlands : 48

Germany : 5(6)

England :1

France : 1

Sweden : 1

Poland : (3)

Onsala

Chilbolton

Potsdam

Jülich

Effelsberg

Tautenburg

Nançay

Unterweilenbach

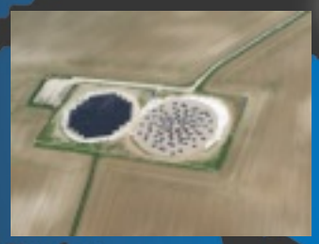
The LOFAR stations

Cosmic Magnetism
Cosmic Rays
Epoch of Reionization
Extragalactic Surveys
Solar Physics
Transients

Onsala

Potsdam

Chilbolton



Jülich

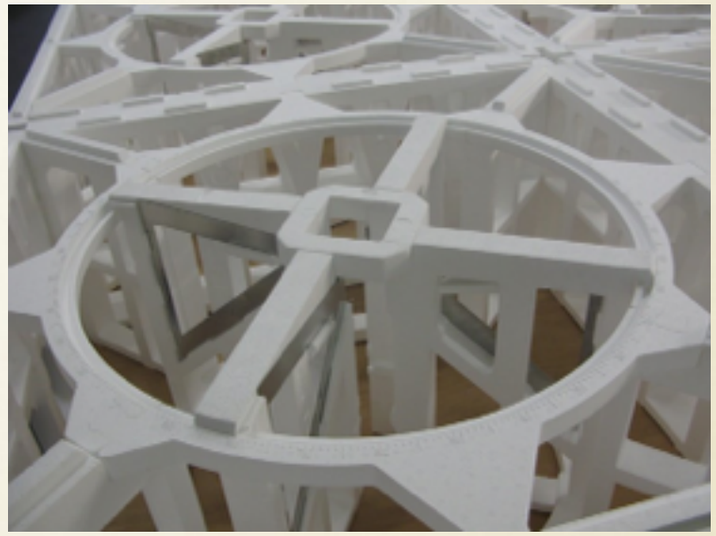
Effelsberg

Tautenburg

Nançay

Unterweilenbach

LOFAR Dipoles

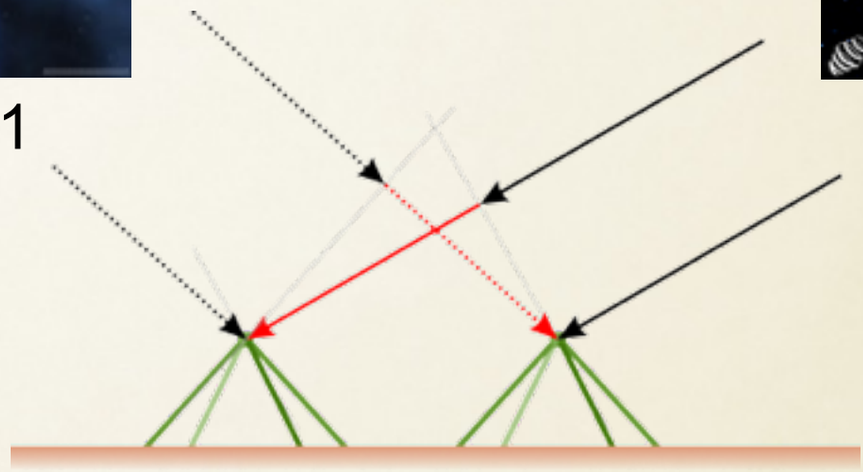


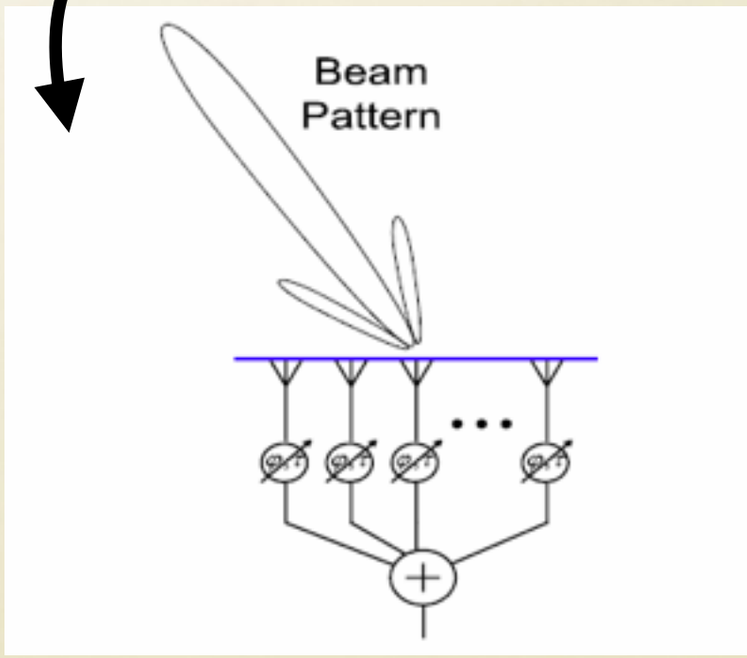
LBA dipoles (10-90 MHz) HBA dipoles (110-240 MHz)

Beamforming

target 1

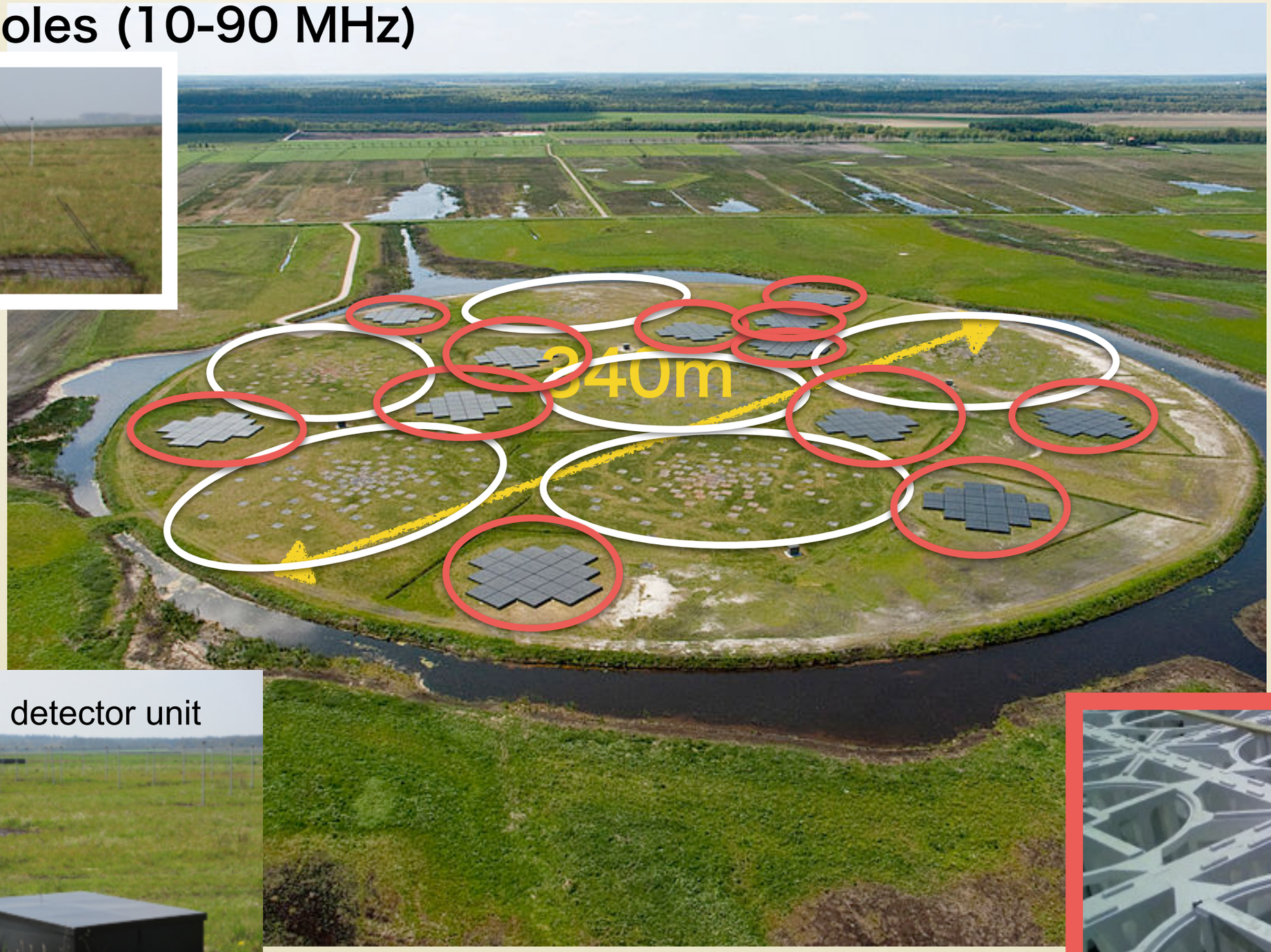
target 2





LOFAR Superterp

LBA dipoles (10-90 MHz)



A particle detector unit

HBA dipoles (110-240 MHz)

HBA Beamforming (110-240MHz)

HBA tile beam
(4x4 HBA antennae)

HBA station beam

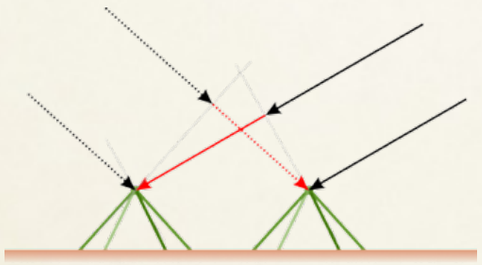
HBA station
combined beam

B. W. Stappers et al. A&A 2011

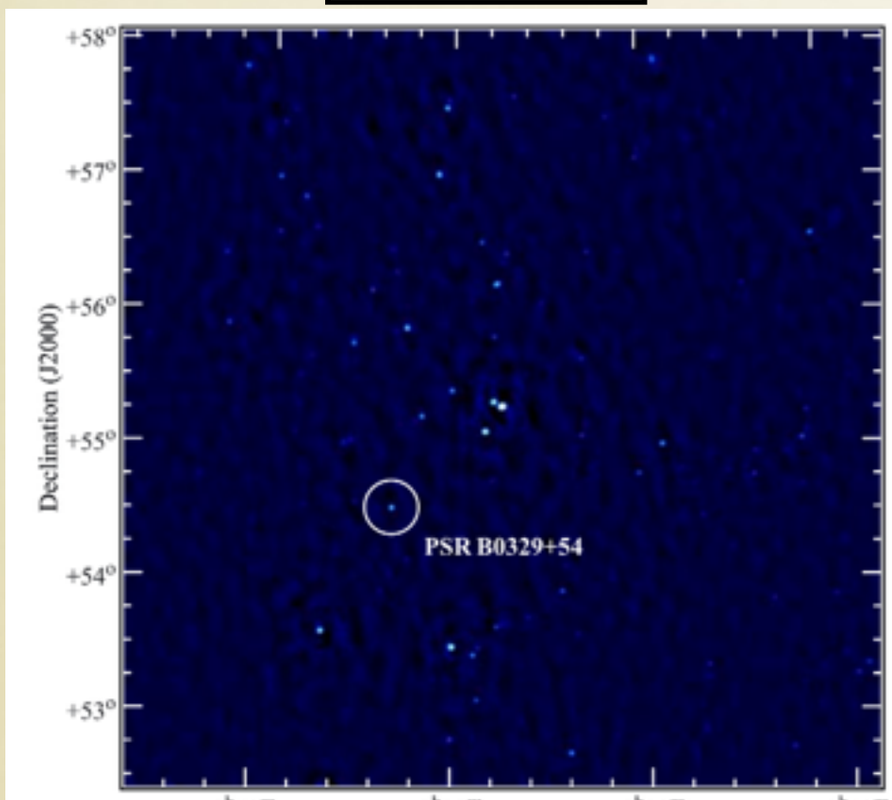
Simultaneous Observations

target 1

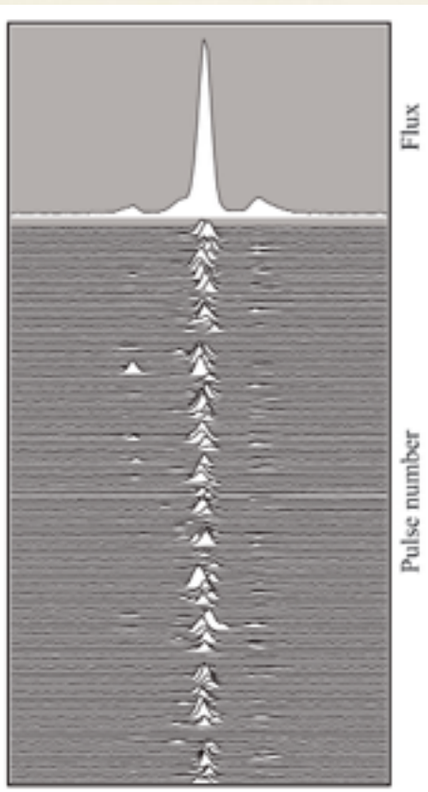
target 2



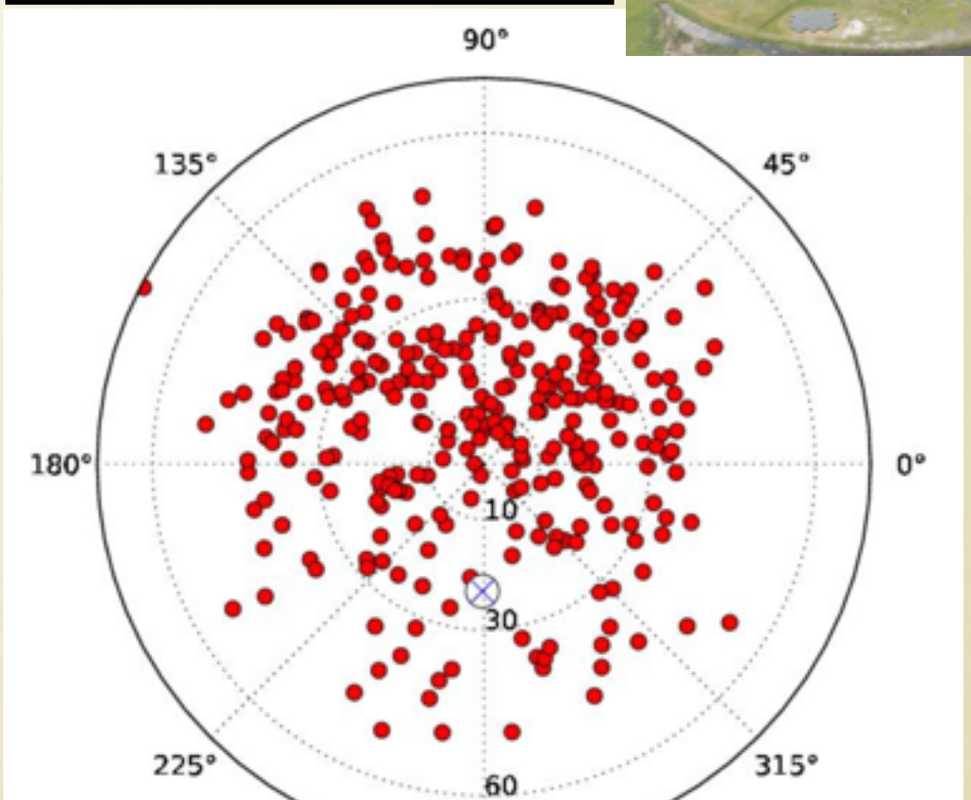
1. imaging



2. timing



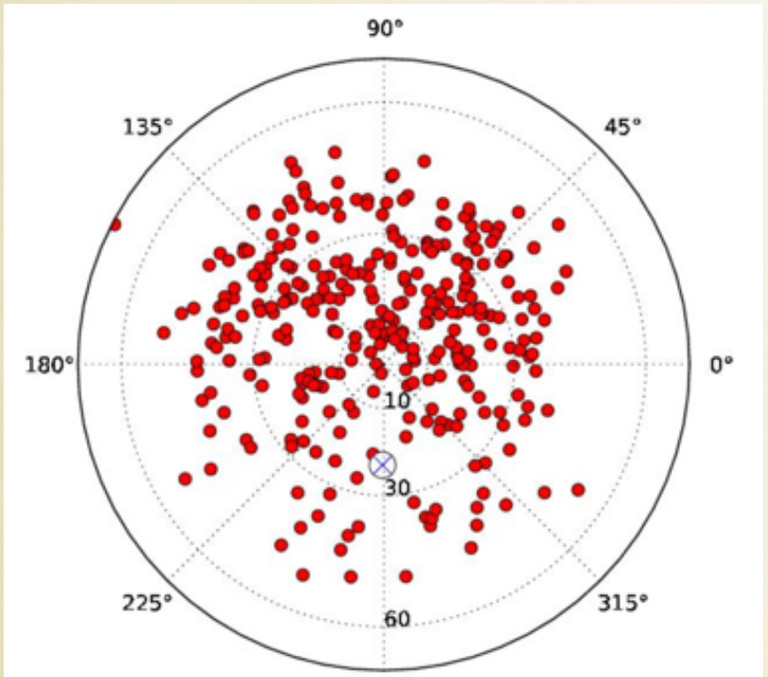
3. cosmic-ray events



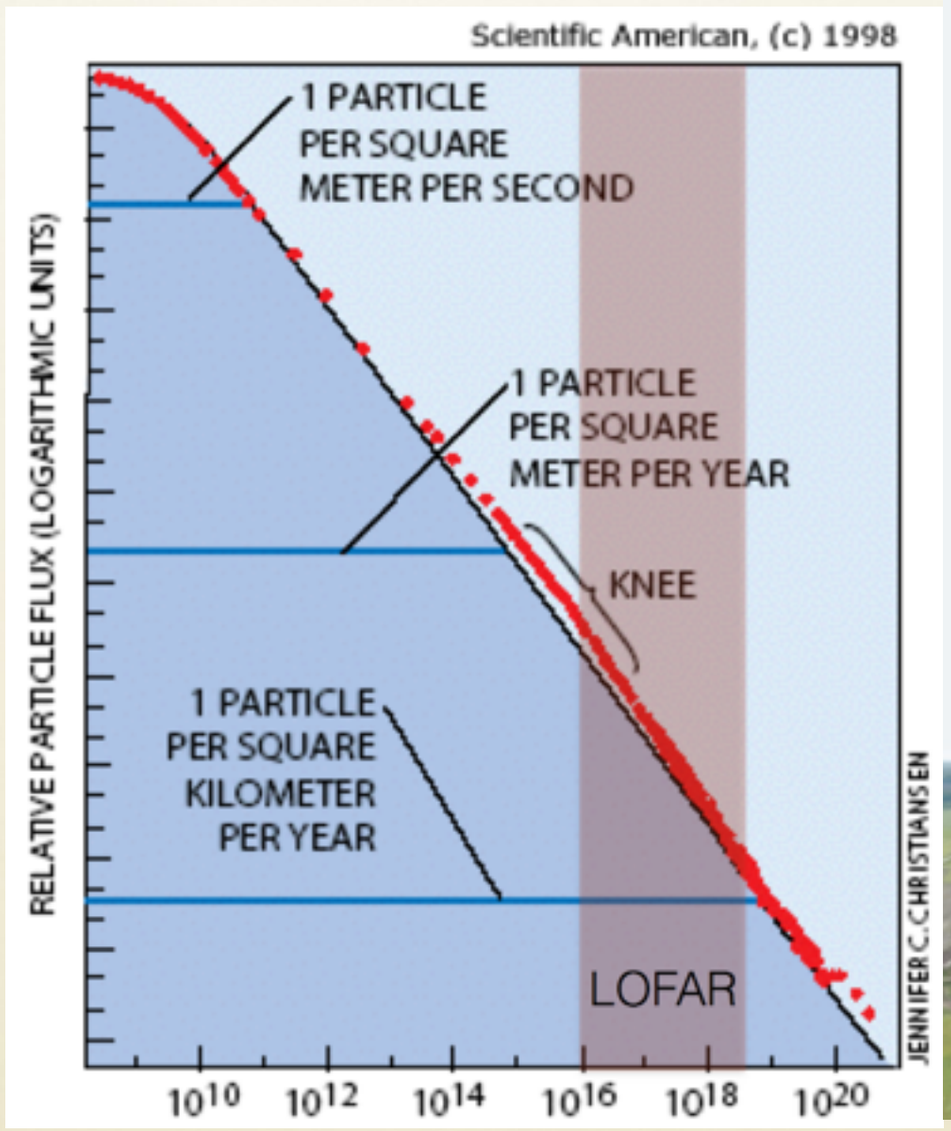
B. W. Stappers et al. A&A 2011

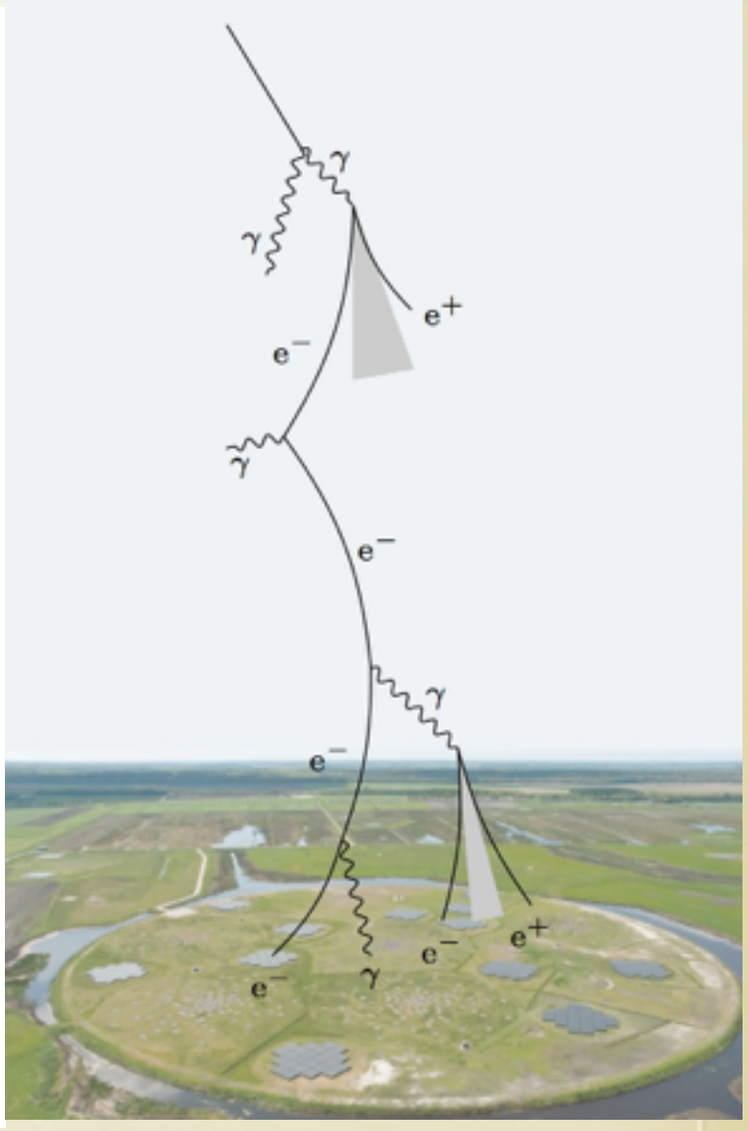
P. Schellart at al. A&A 2013

Cosmic rays with LOFAR



In the first ~2 years of observing, 405 cosmic-ray events in the energy range of 10^{16} –10^{18} eV have been detected in the band from 30–80 MHz

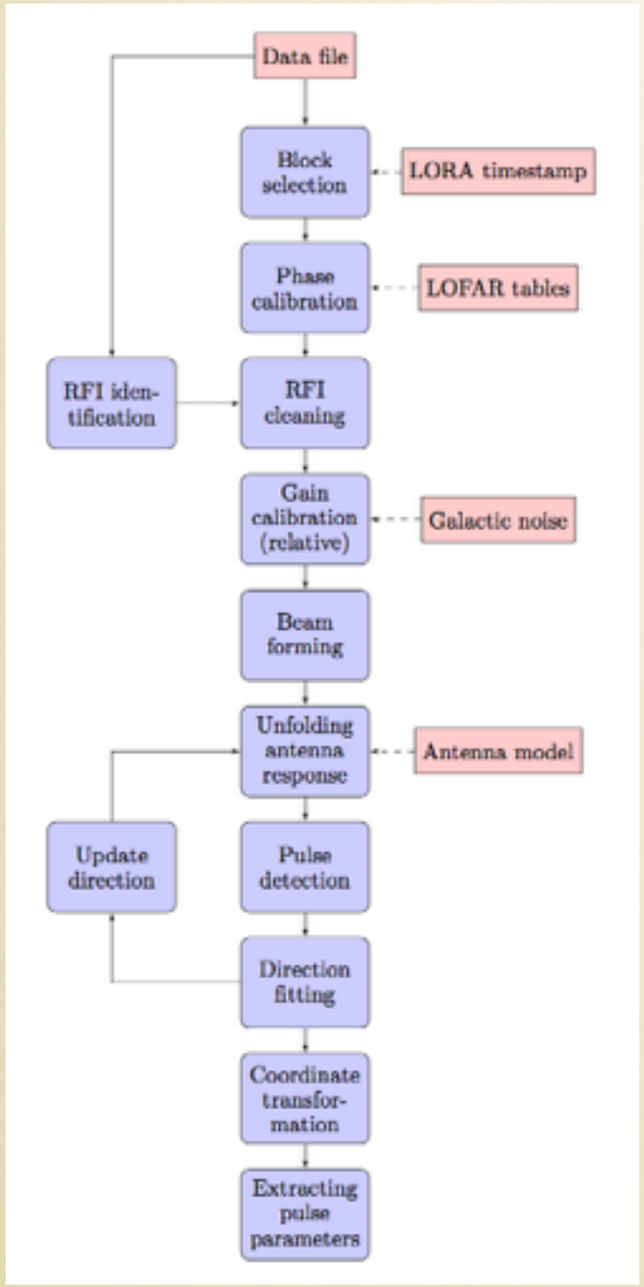


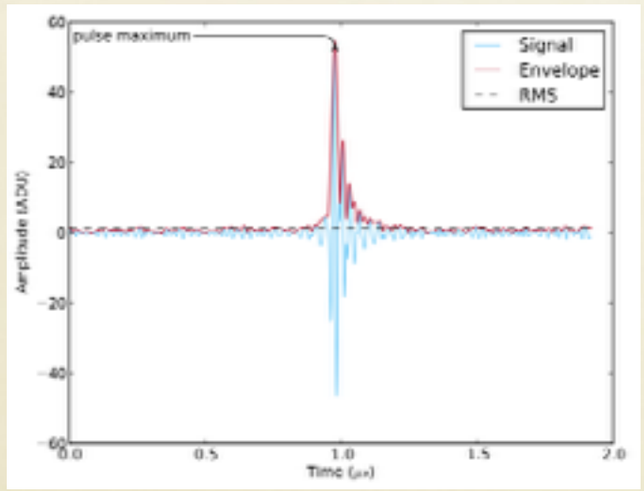


Already in the 1960s it was proven that cosmic ray-induced air showers emit nanosecond duration pulses with significant power in the MHz radio frequency range (Jelley et al. 1965; Allan & Jones 1966),

P.Schellart at al. 2013 (Radboud University Nijmegen)

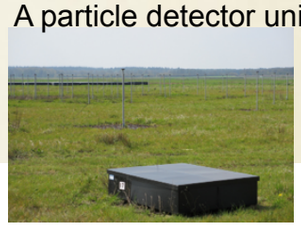
Radio emission from air showers

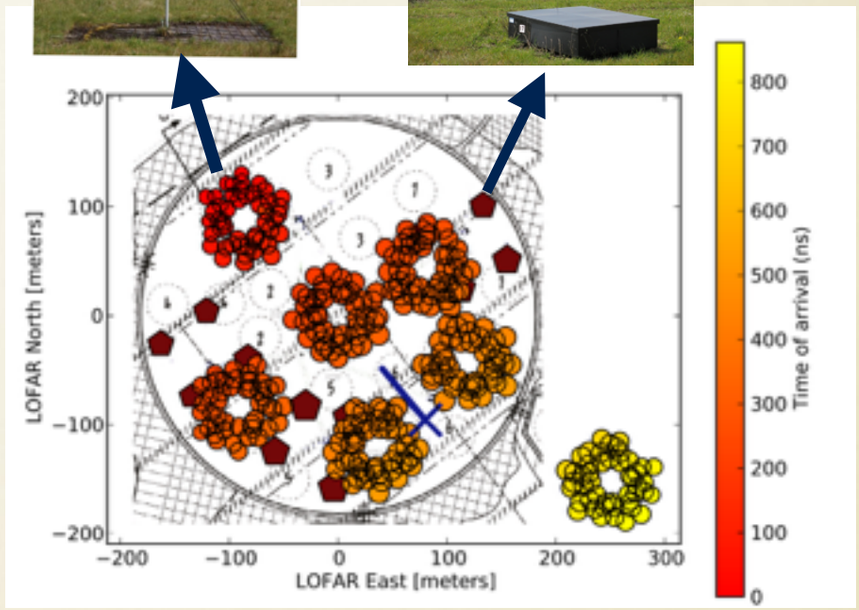


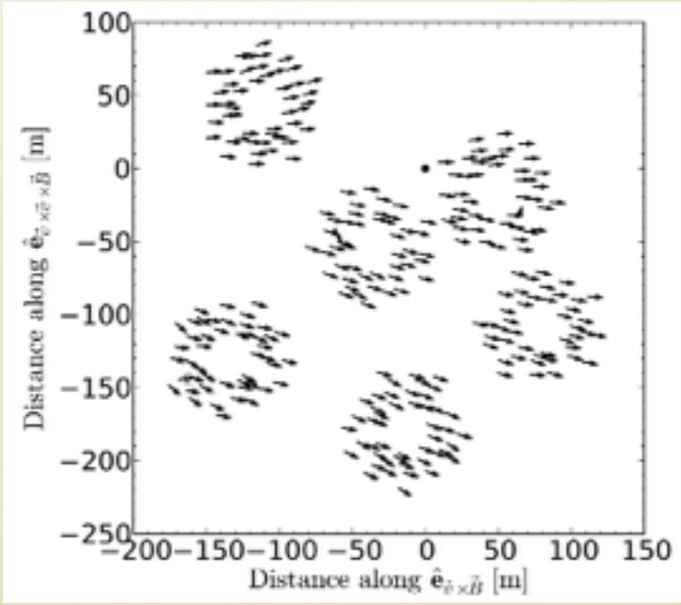


LBA dipoles

A particle detector unit

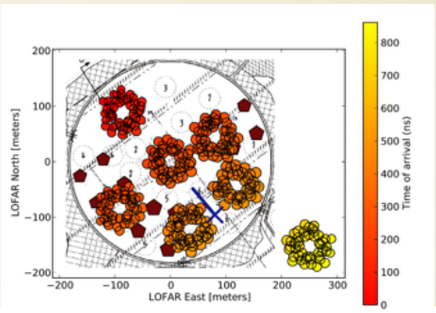




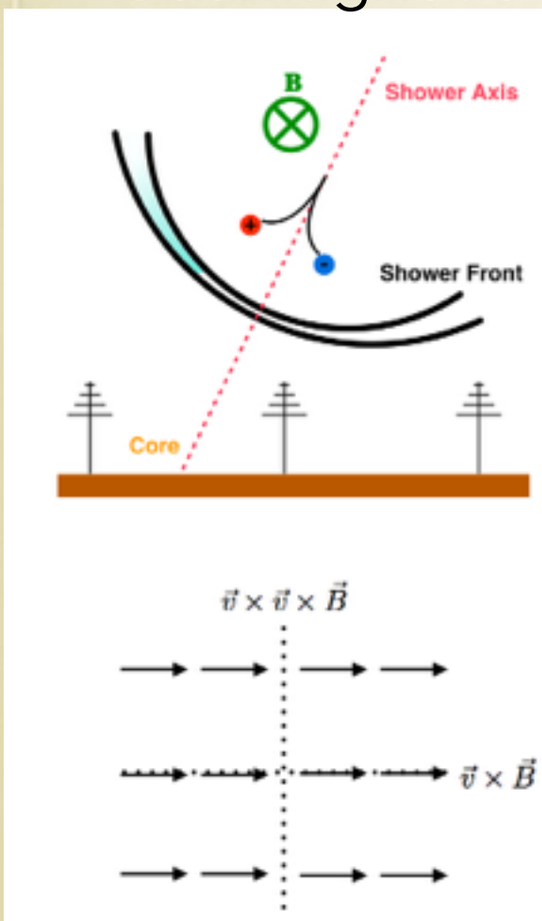


P. Schellart at al. A&A 2013

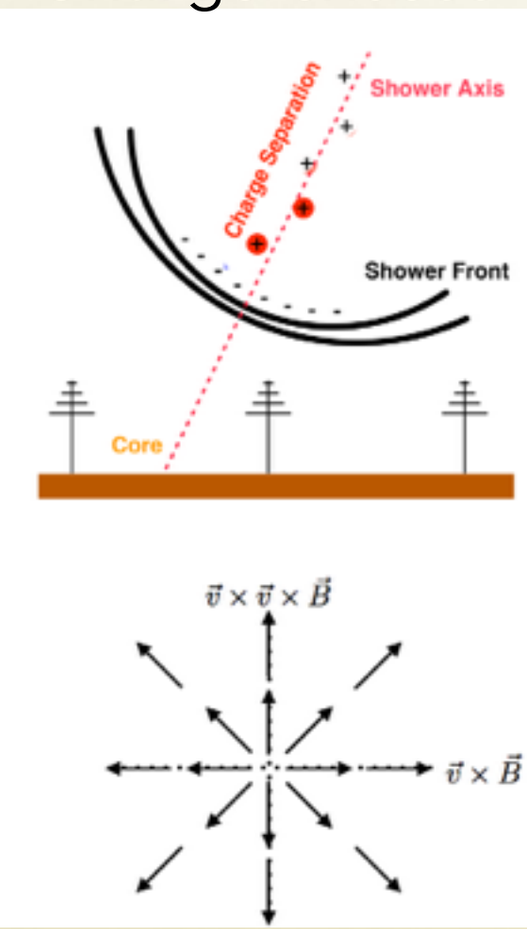
Radio emission from air showers



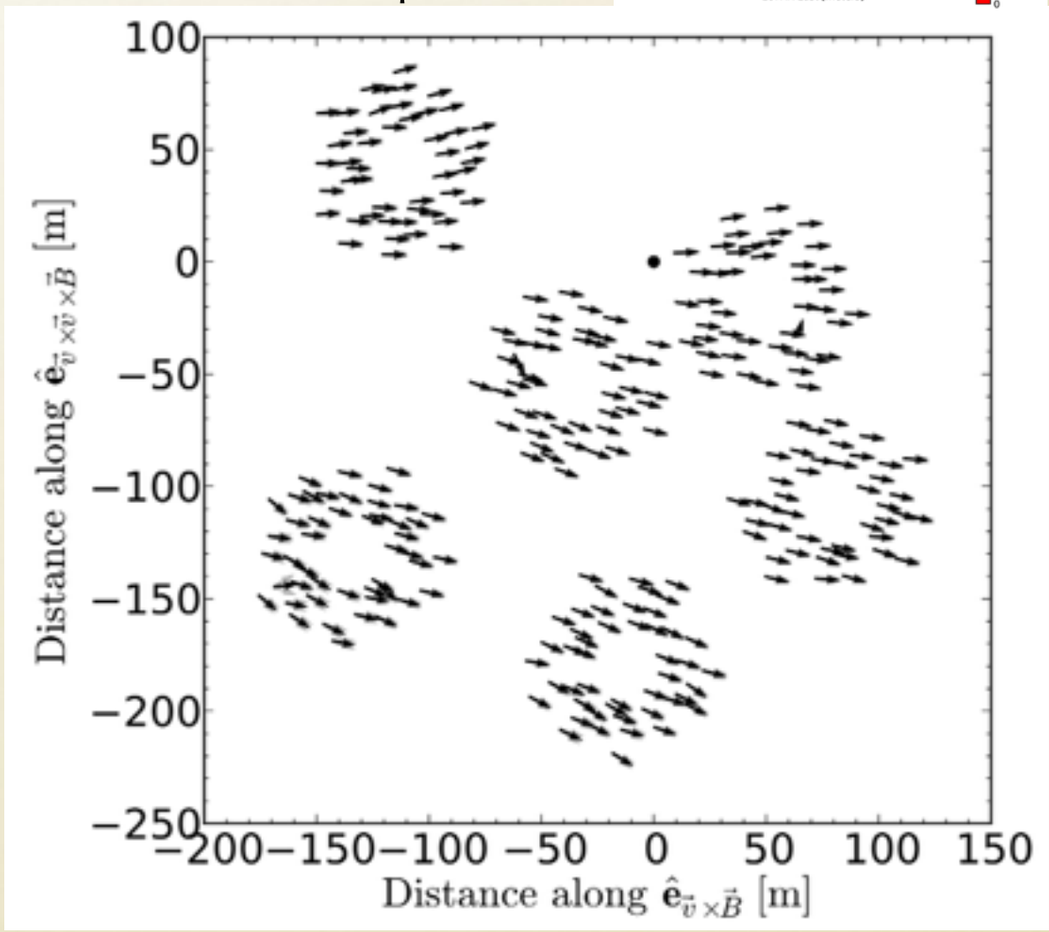
Geomagnetic



Charge-excess



Polarization pattern



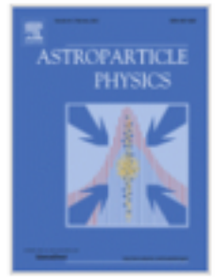
Pim Schellart (Radboud University Nijmegen)

Radio emission from air showers

ELSEVIER

Astroparticle Physics

Volume 61, February 2015, Pages 22–31



The shape of the radio wavefront of extensive air showers as measured with LOFAR

A. Corstanje[a, 1], P. Schellart[a], A. Nelles[a, c], S. Buitink[a], J.E. Enriquez[a], H. Falcke[a, b, c, d], W. Frieswijk[b], J.R. Hörandel[a, c], M. Krause[a], J.P. Rachen[a], O. Scholten[e], S. ter Veen[a], S. Thoudam[a], T.N.G. Trinh[e], M. van den Akker[a], A. Alexov[f], J. Anderson[g], I.M. Avruch[h, i], M.E. Bell[j], M.J. Bentum[b], G. Bernardi[k], P. Best[l], A. Bonafede[m], F. Breitling[g], J. Broderick[n], M. Brüggen[m], H.R. Butcher[o], B. Ciardi[p], F. de Gasperin[m], E. de Geus[b, q], M. de Vos[b], S. Duscha[b], J. Eislöffel[r], D. Engels[s], R.A. Fallows[b], C. Ferrari[t], M.A. Garrett[b, u], J. Grießmeier[v, w],

LOFAR MSSS

Multifrequency Snapshot Sky Survey

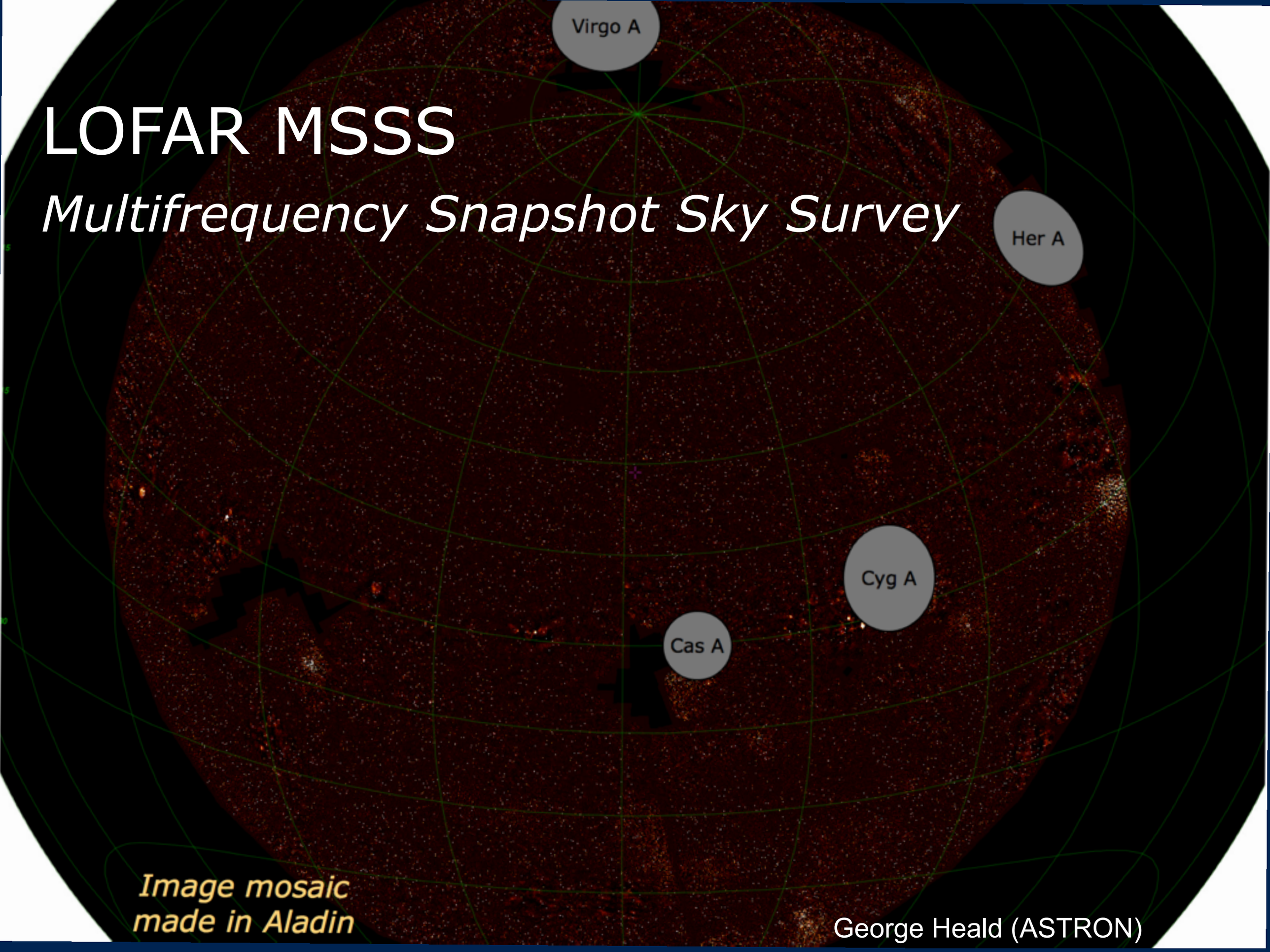
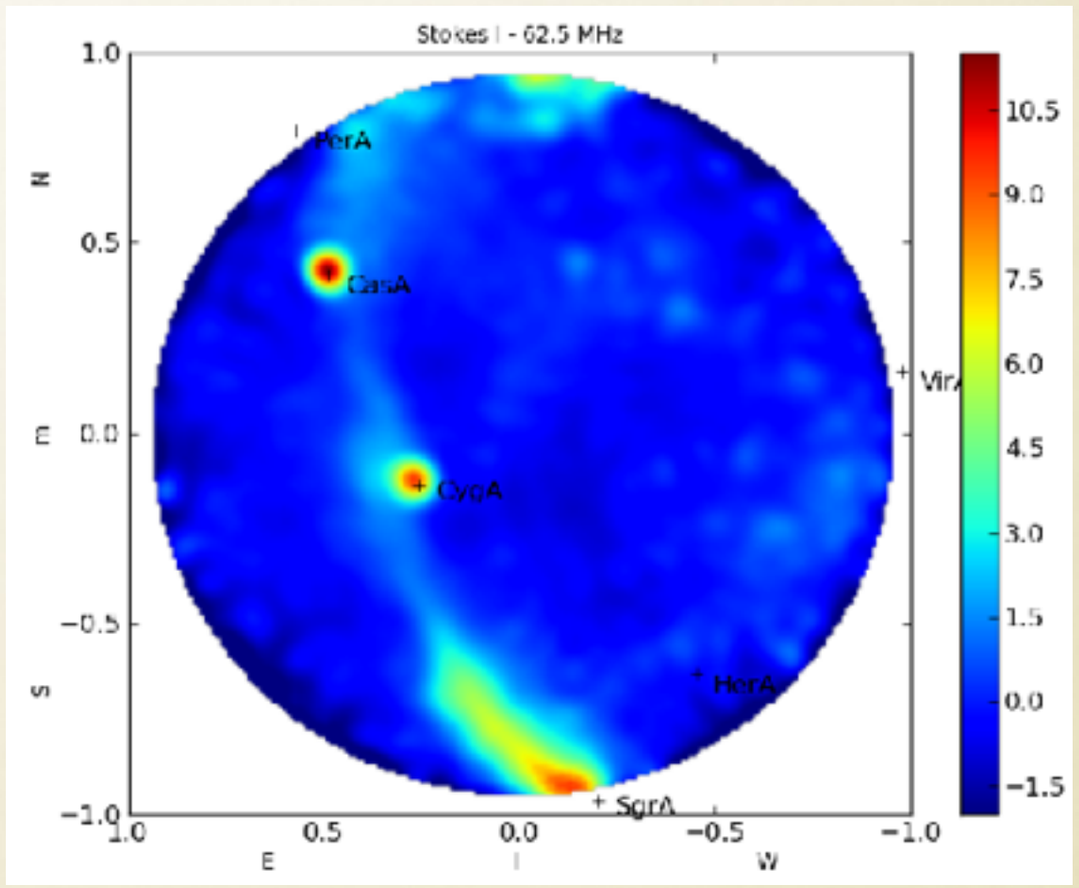


Image mosaic made in Aladin

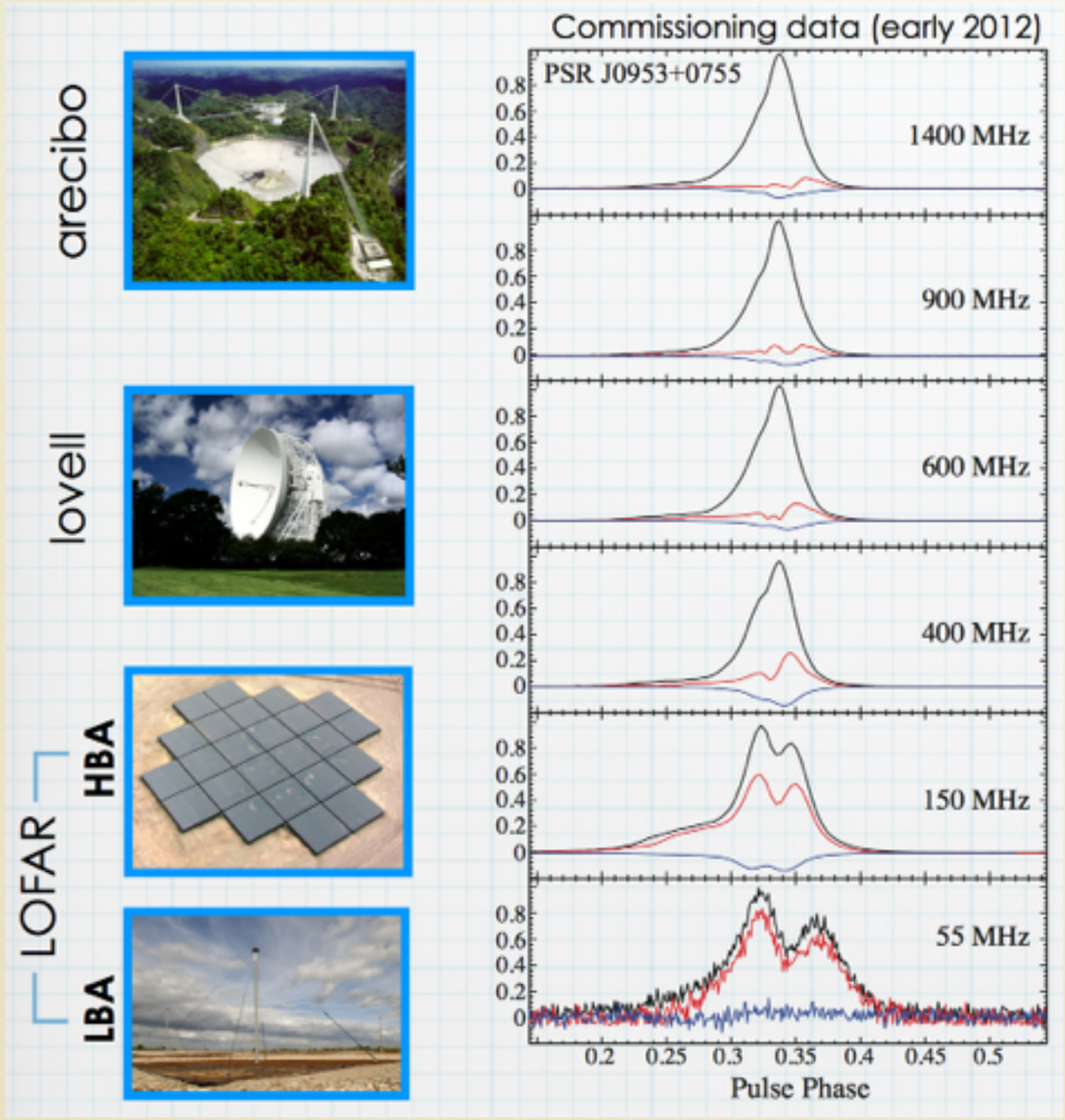
George Heald (ASTRON)

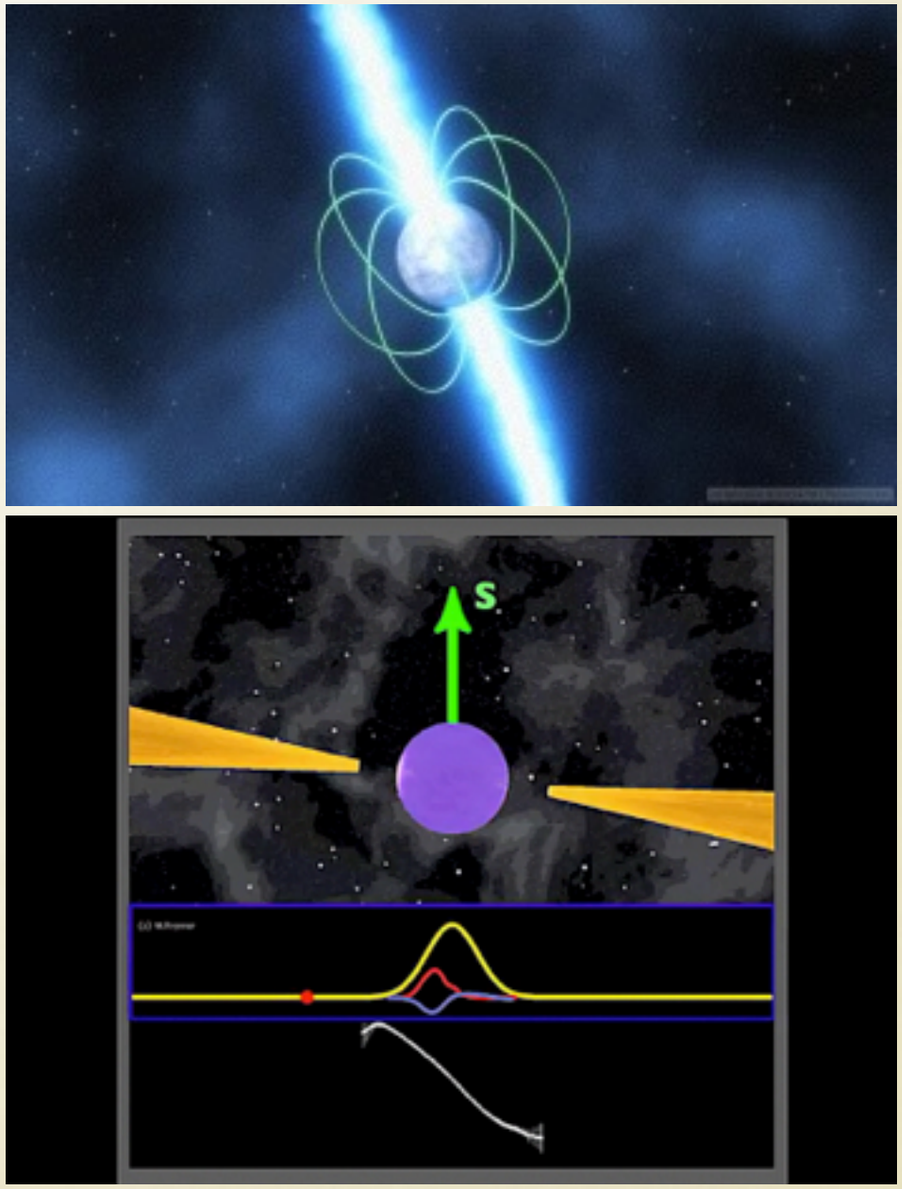
Single station mode
All sky monitoring



Jana Ko¨hler and James Anderson (MPIfR)

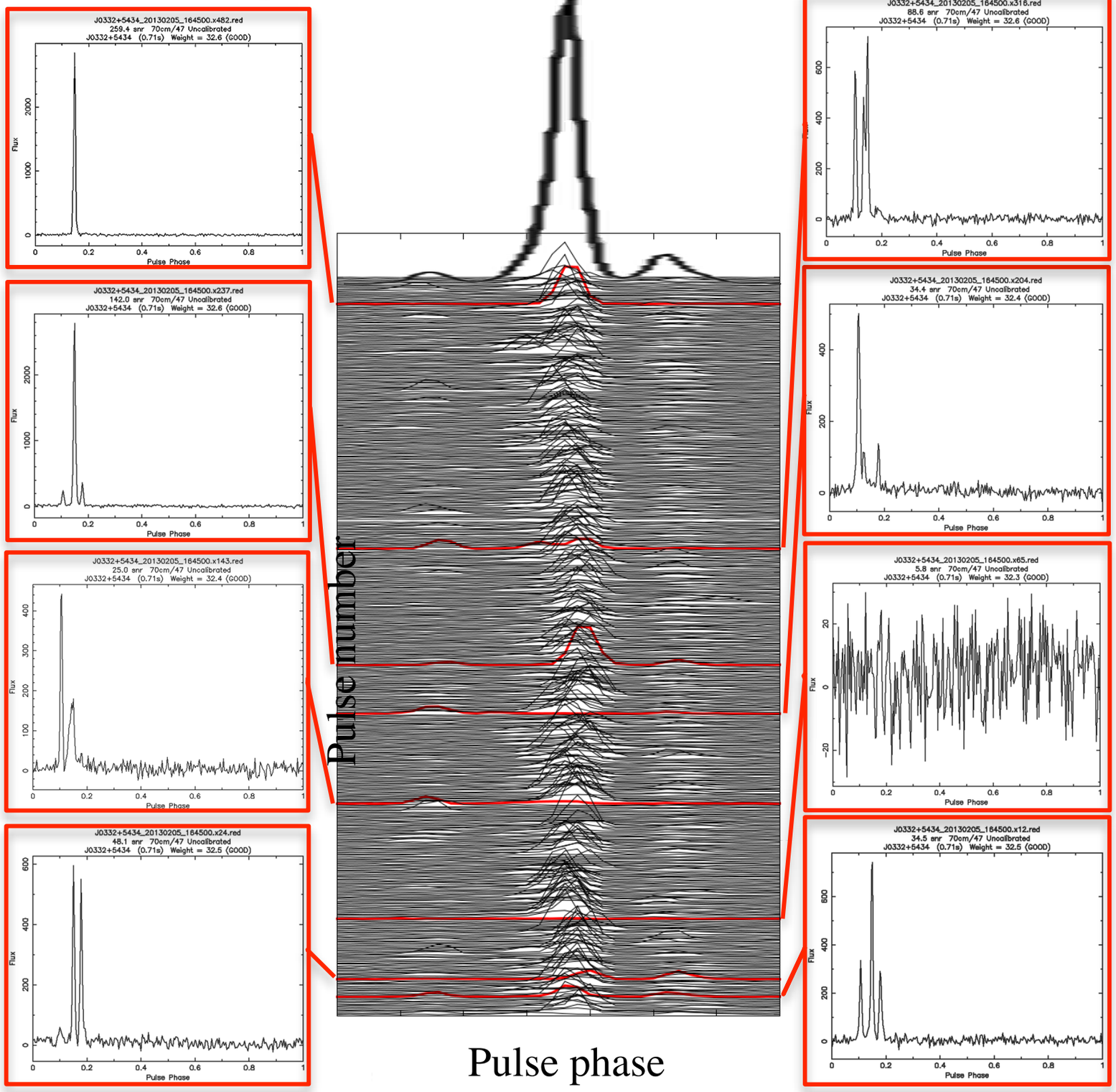
Multi-Frequency profiles

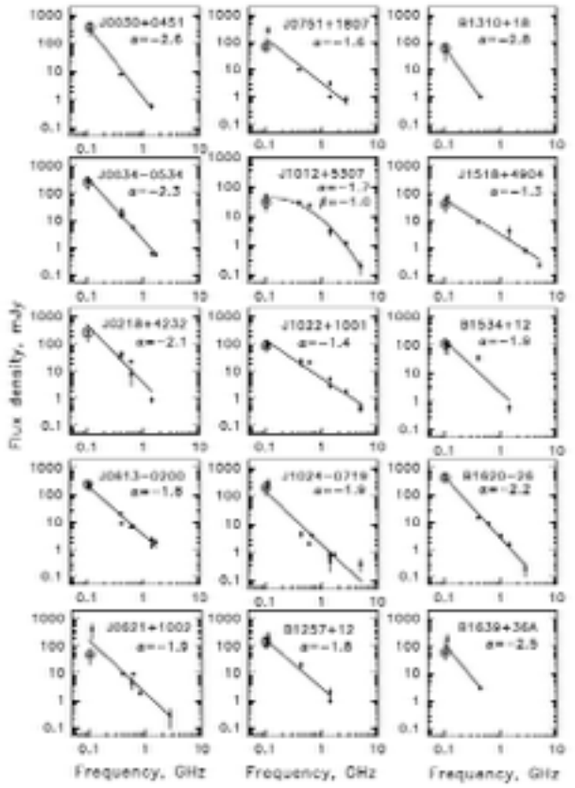




Aristeidis Noutsos (MPIfR)

Individual pulses

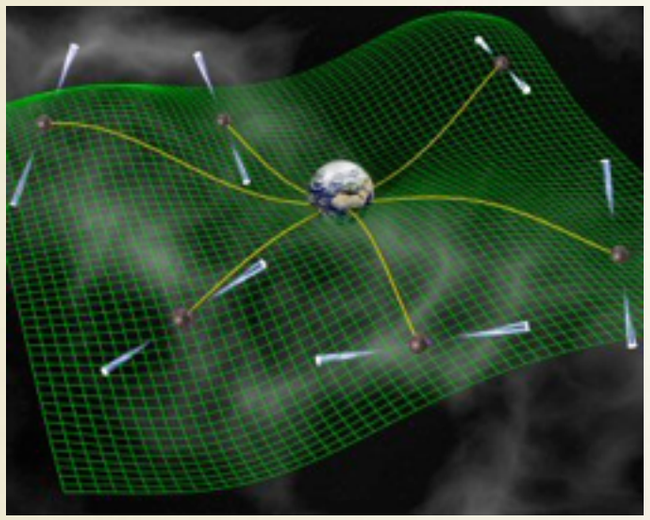




$$S_{\mathrm{mean}}(f) \propto f^{\xi} \qquad 0 \gtrsim \xi \gtrsim -4$$

- A mean value -1.4±0.1
- A rich variety structure
- A wealth of emission process
- Time-variable plasma processes create

LOFAR's Applicability to High Precision Timing

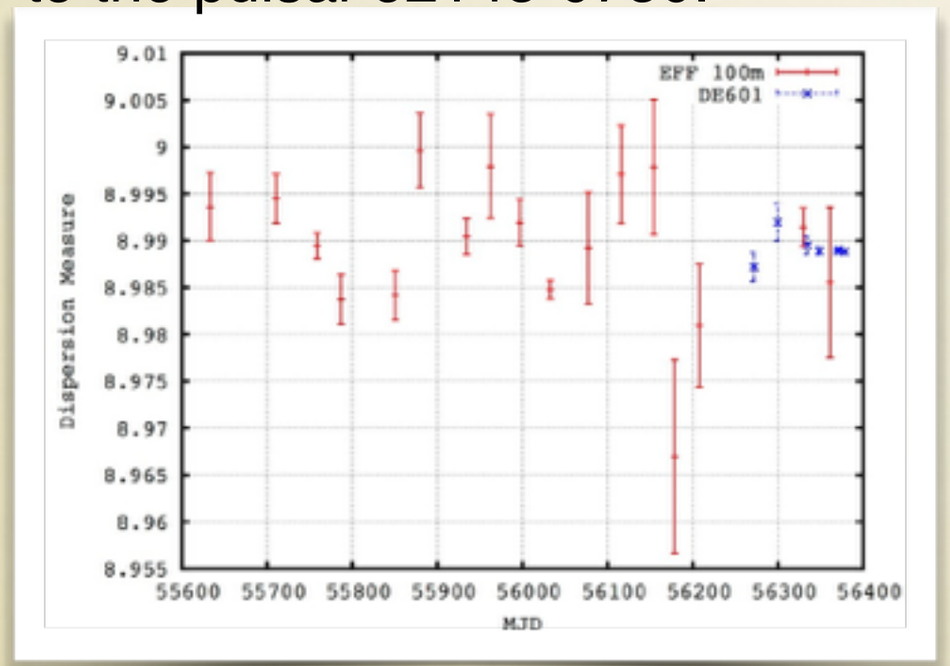


The Universe is filled with a background of gravitational waves.

- In high-precision timing, the biggest problem is variations in DM.

$$DM = \int_0^d n_e \, dl$$

Measurements of interstellar dispersion to the pulsar J2145-0750.

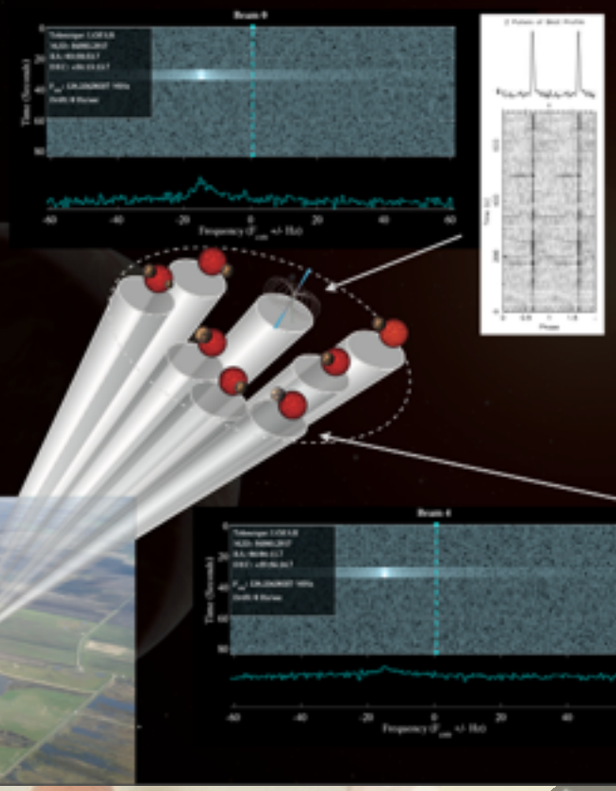


Courtesy: J.Verbiest (MPIfR)

- LOFAR works at lower frequencies, which can make these measurements much more accurately and can measure DM variations at a much more precise level.

Advanced Intelligence

Cycle 0: A Pilot Search for Advanced Civilizations Around Nearby Stars with LOFAR

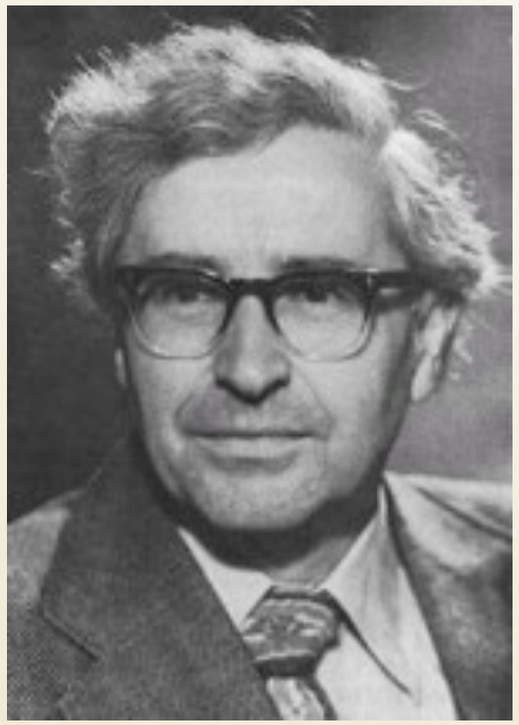


- Fields Chosen to be Coincident with a Bright Pulsar for Diagnostics
- Multibeaming: Astronomical Sources Only Appear in a Single Beam, Interference in Many Beams → Excellent RFI Rejection

Cycle 2 (pending): A Panchromatic Search for Advanced Intelligence Around Nearby Stars

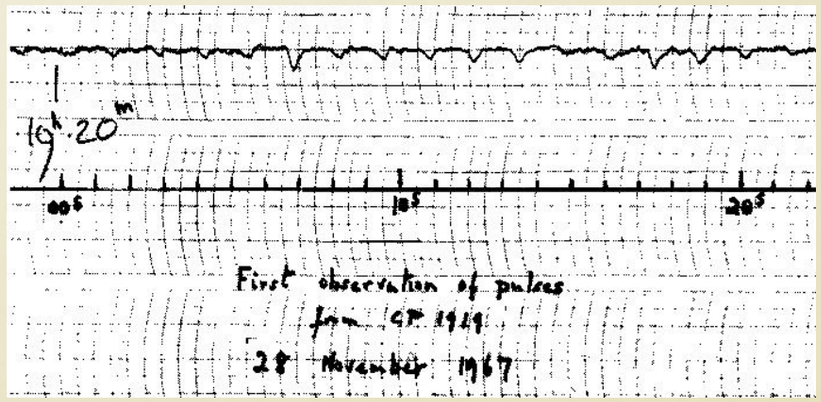
Andrew Siemion - UC Berkeley / ASTRON / Radboud

The first discovered pulsar CP1919



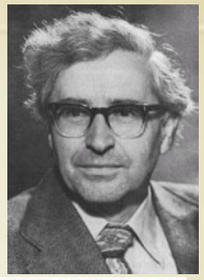
Jocelyn Bell & Antony Hewish

Nobel Prize in Physics in 1972

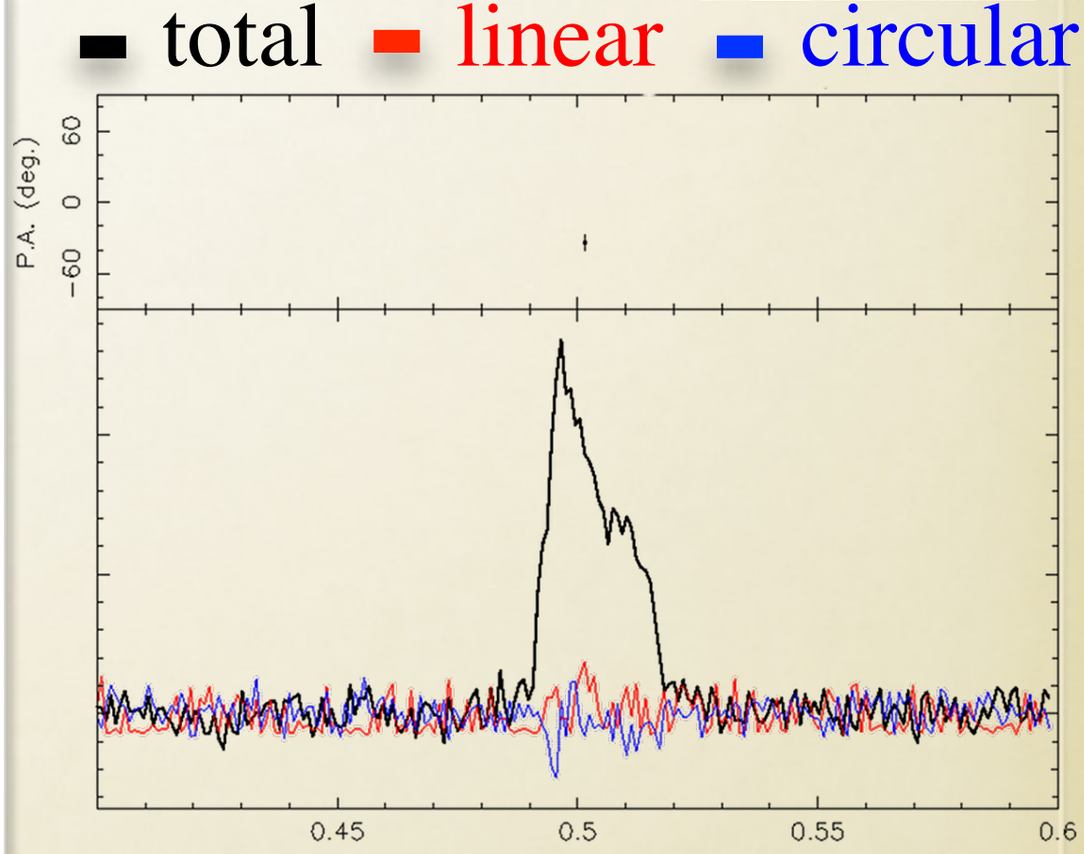


Public Outreach

(brainwashing kids into Astronomy)



2013-01-27 Düsseldorf, Germany



Our group has been involved in public outreach, organizing lectures at schools, where the general public was given a chance to perform pulsar observations with LOFAR. The young students were excited to see the profile of the first discovered pulsar CP1919, in 30 seconds of LOFAR data.

http://www.astron.nl/lofarschool2014/

End