ADVANCED RADIO ASTRONOMY IN EUROPE

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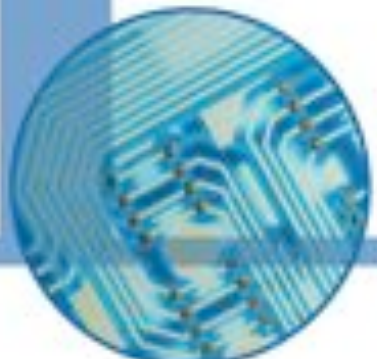


ILIAS Annual meeting
Chambery, France, 26 February 2007

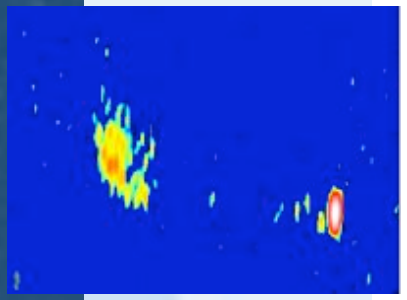
Radio Astronomy:

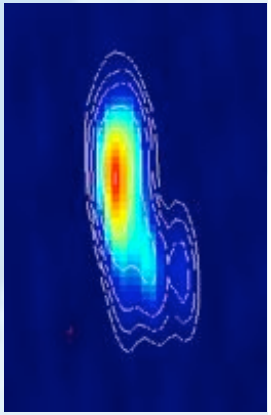
- Born on 5 May 1933
  - Karl Jansky, Bell Lab
  - 1 Jy = 10^{-26} W/(m^{2}Hz)

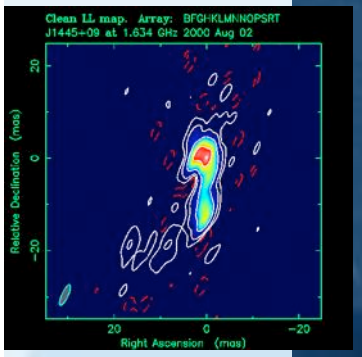
- The first non-visual window in the Universe (uv-, IR, X-ray, Gamma-ray and non-EM were to follow)

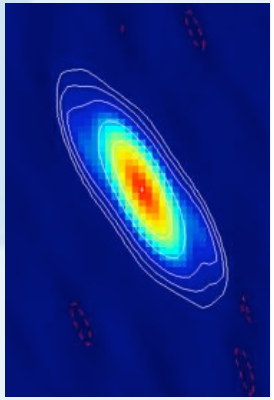
- Offers the deepest and sharpest view at the Universe

The synchrotron extragalactic sky





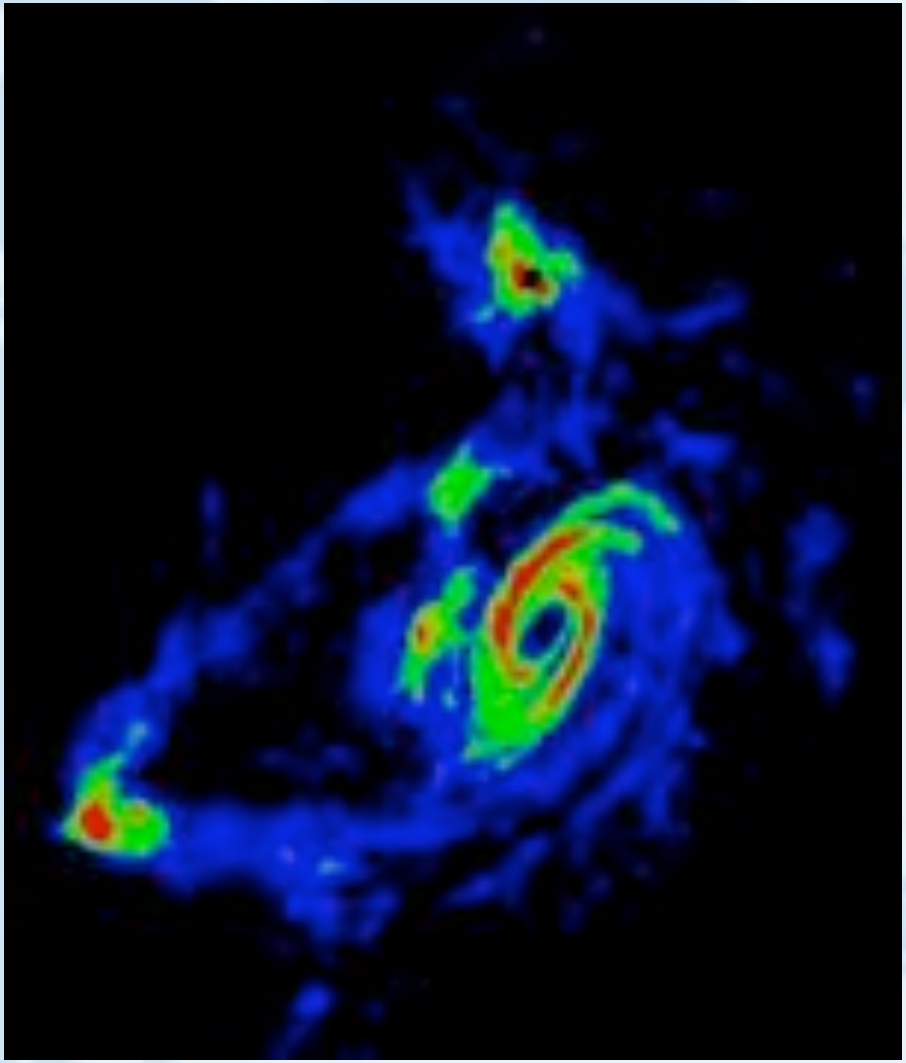




The sky of Hydrogen

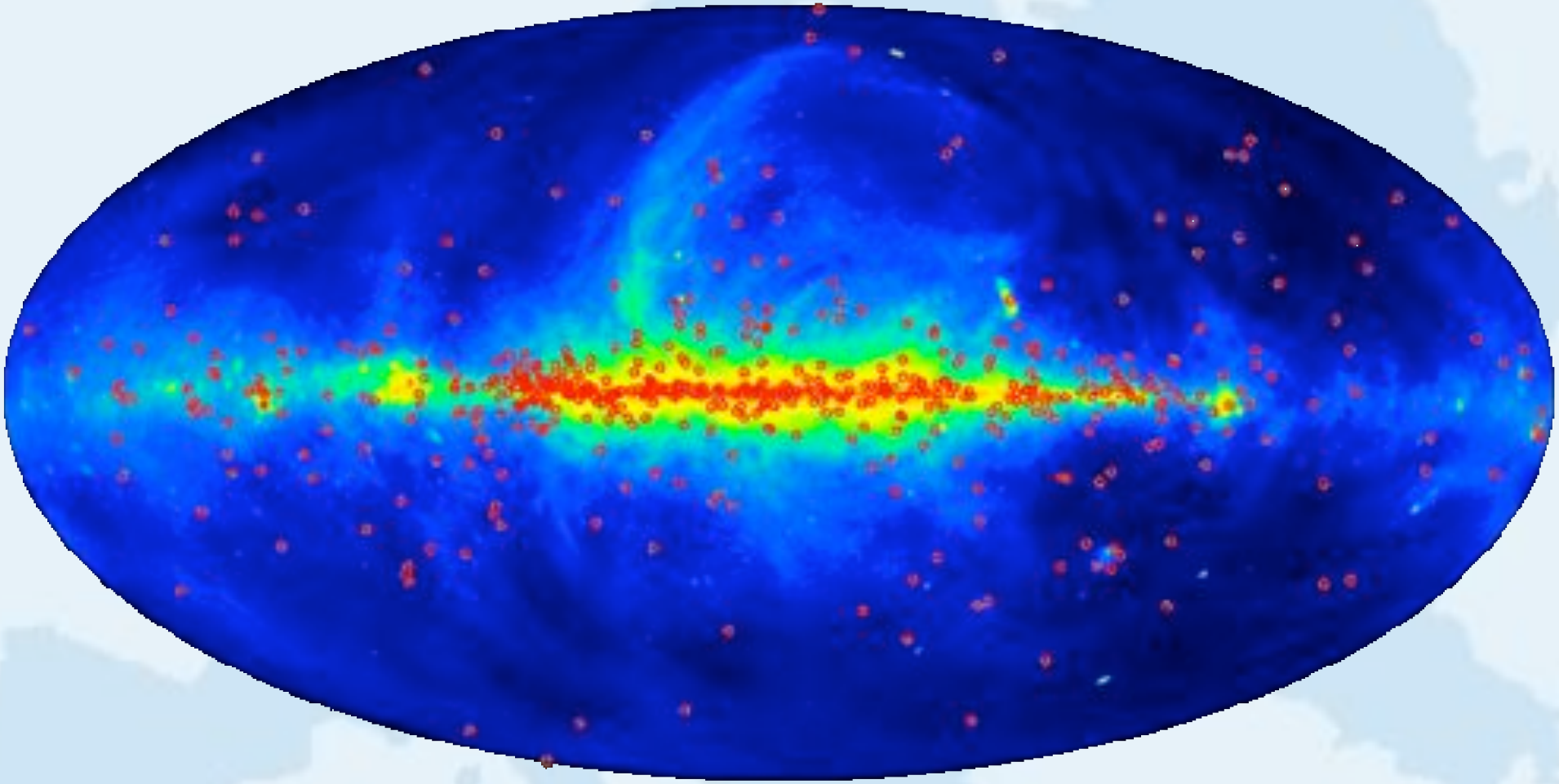
A Universe of stars

A Universe of hydrogen gas



A very different view – (but HI 21 cm signal is weak!)

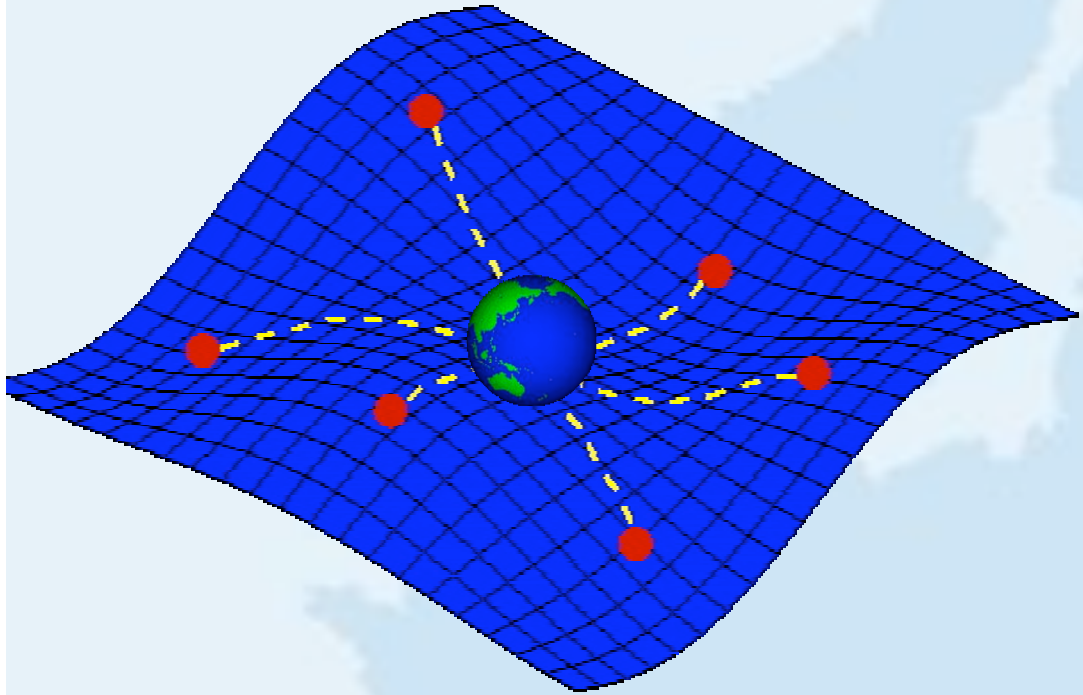
Pulsars – rotating neutron stars

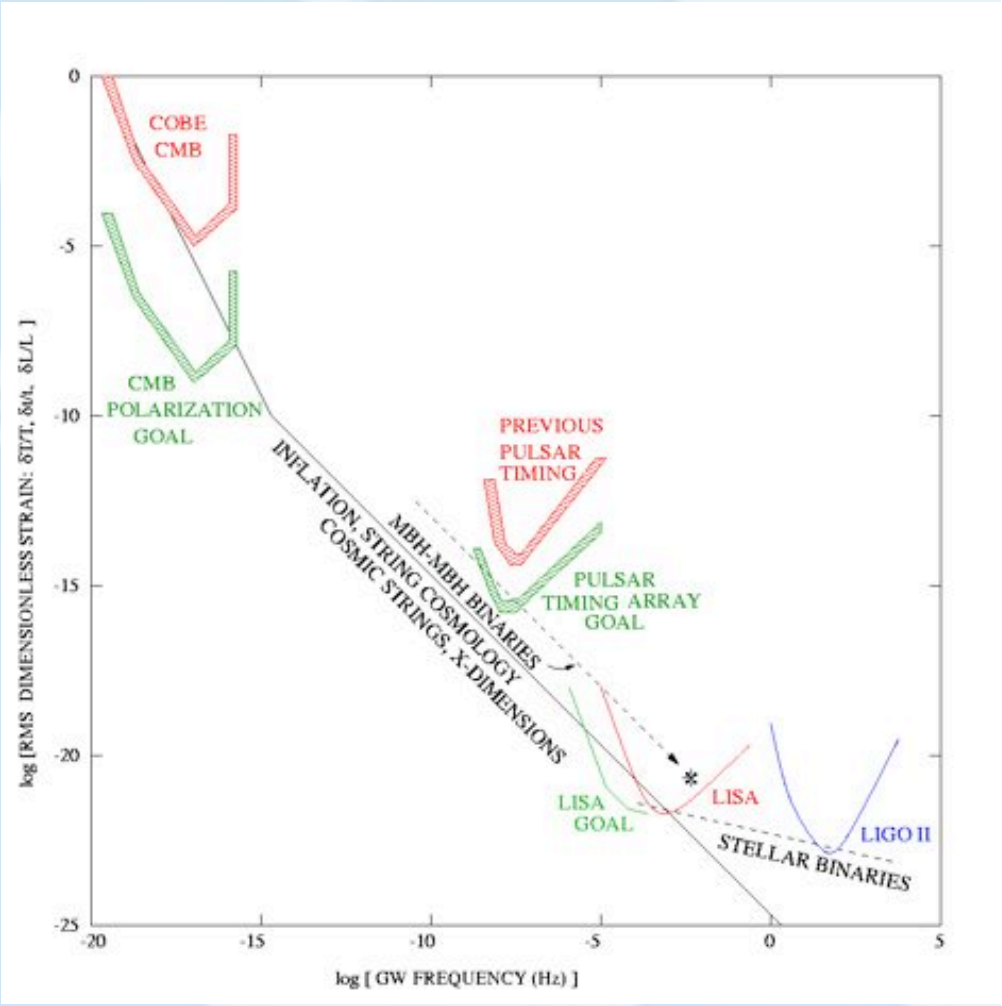


Born in the Galactic plane and then move away
(physics of initial “kick” not understood)

Cosmological Gravitational Wave Background

Timing a net of msec pulsars



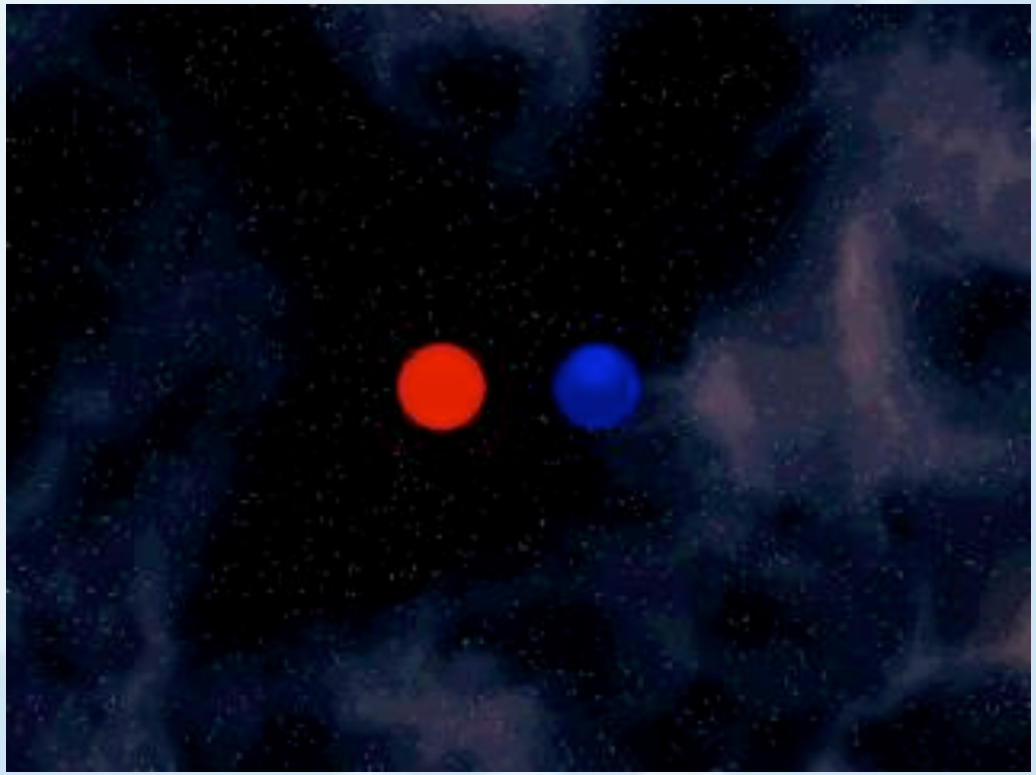


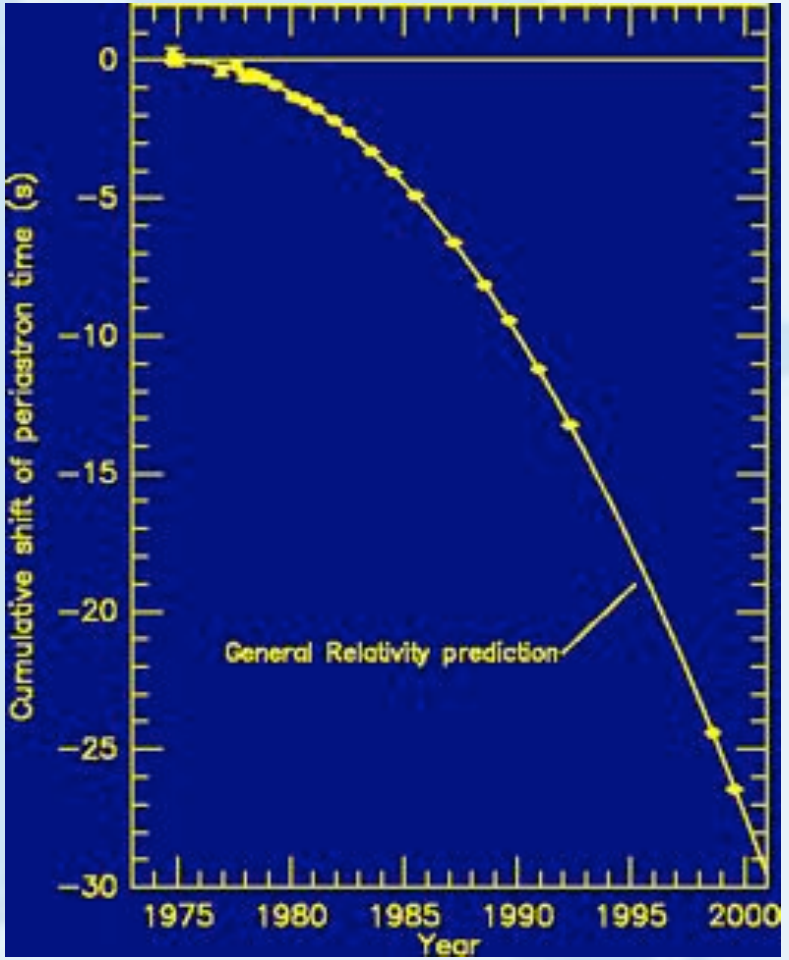
With SKA's timing precision look for spatial pattern in timing residuals!

- **Pulsars=arms of huge gravitational wave detector**
- **Complementary to LIGO and LISA**

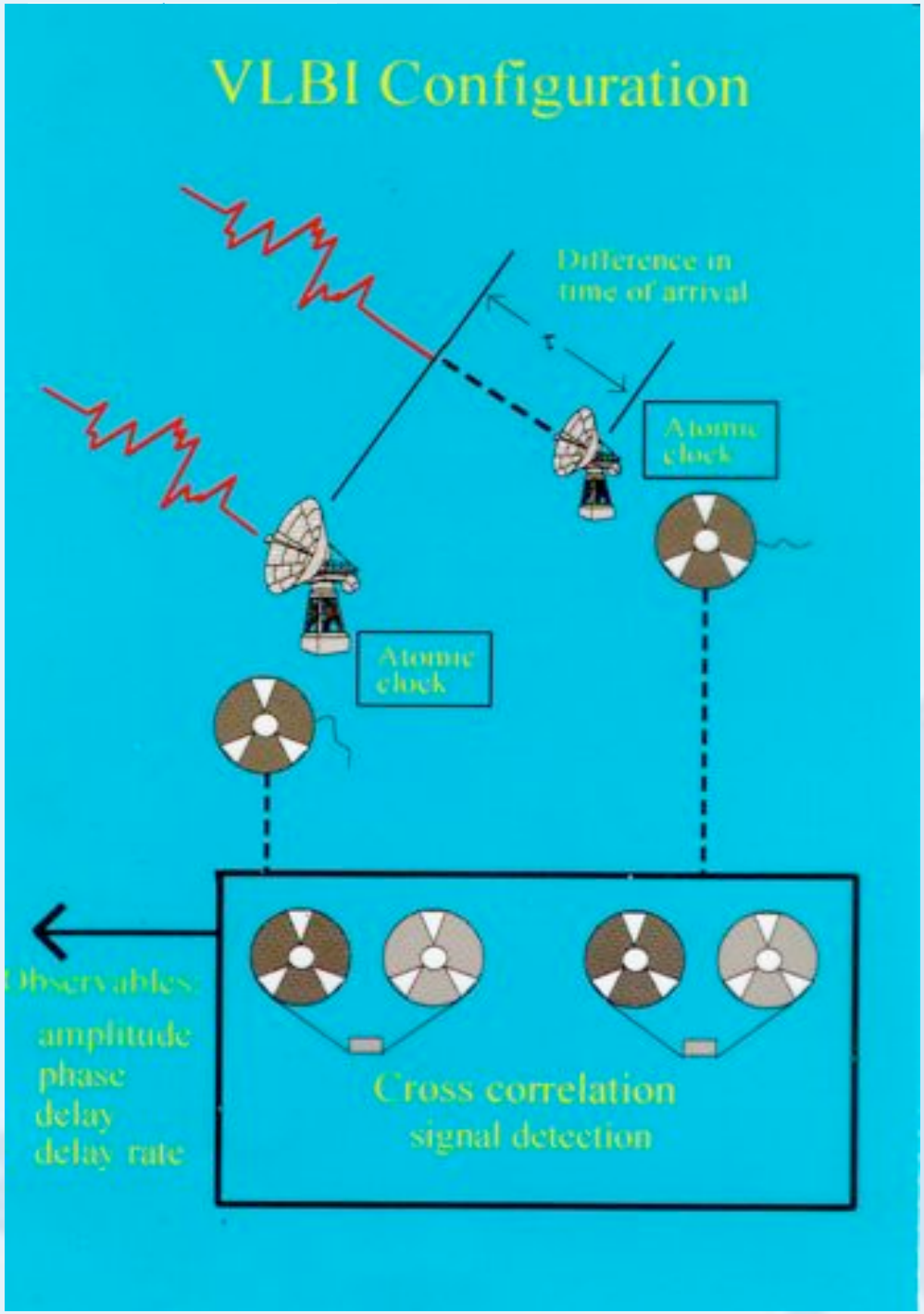
Unique Laboratories for General Relativity

e.g. timing of B1913+16:





- Orbit shrinks every day by 1 cm!
- Confirmation of gravitational waves!



Radio interferometry

⇐ telescopes in different locations (countries, continents)

⇐ data relayed or recorded on tape and transported to a central facility

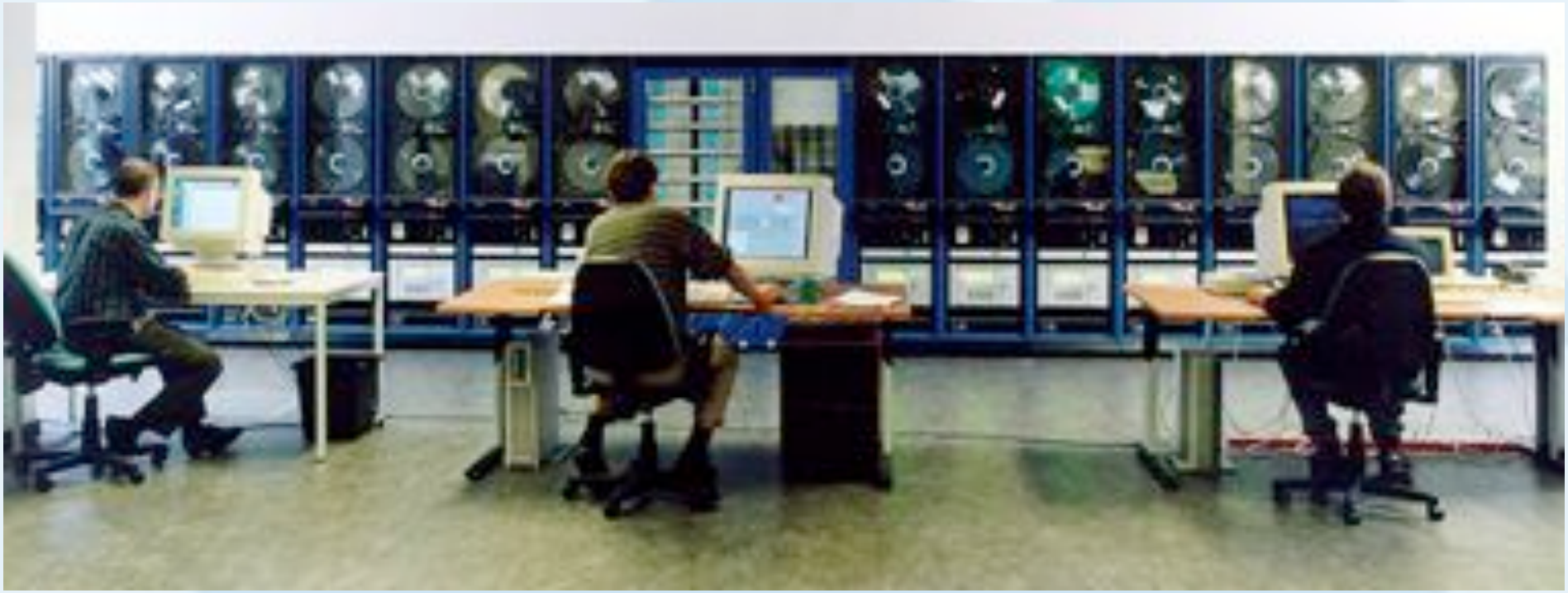
⇐ data processed ("correlated")

Data rate: ~1 Gbps per RT;

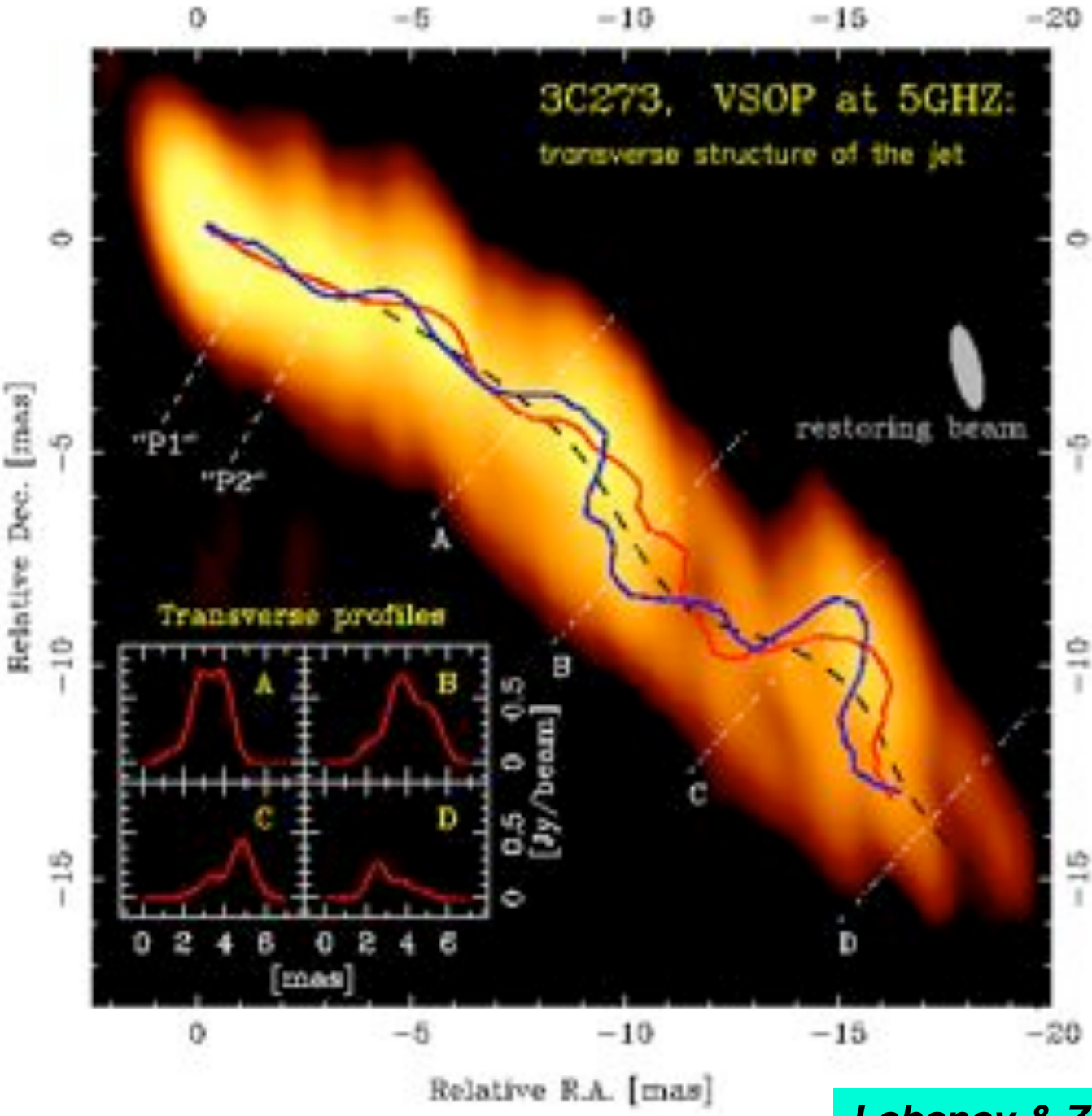
Total: ~ 1-100 TB per exp.

The European VLBI Network

EVN data processor at JIVE (the Netherlands)



Arguably, the fastest computer in the world, BUT …



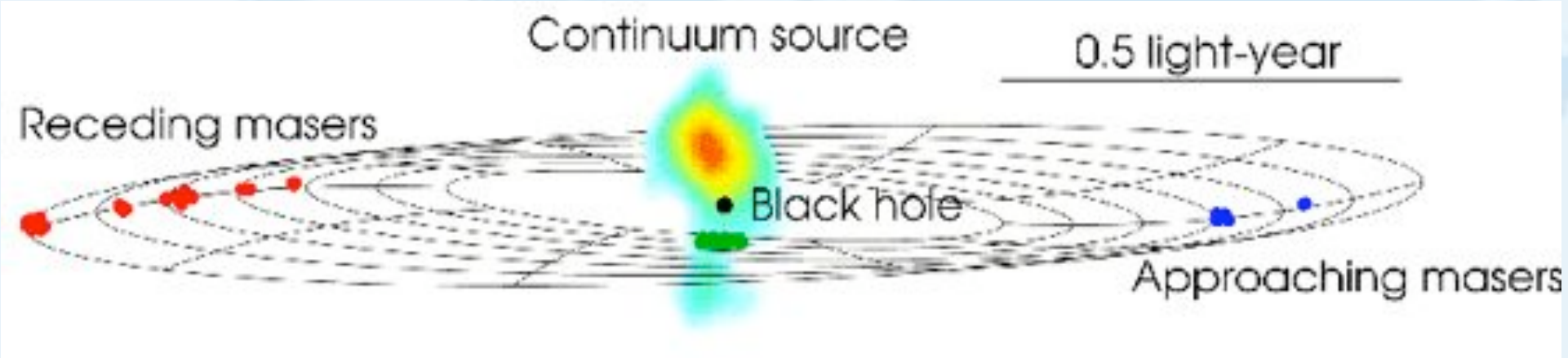
3C273: the classical VLBI target

Lobanov & Zensus, 2000

NGC4258: the most convincing case for a super-massive black hole

(Miyoshi et al. 1995, Nat 373, 127; Herrnstein et al. 1998, ApJ 497, L69)

Rotating gas near the centre of the galaxy NGC4258, as traced by VLBI observations of the water vapor maser line at 22 GHz (1.35 cm)



Doppler measurements → **Radial velocities**

VLBI measurements → **(Angular) radii**

$$V^2 / R \longrightarrow 3.6\times10^7 M_{\text{sun}} \text{ within } R = 0.13 \text{ pc}$$

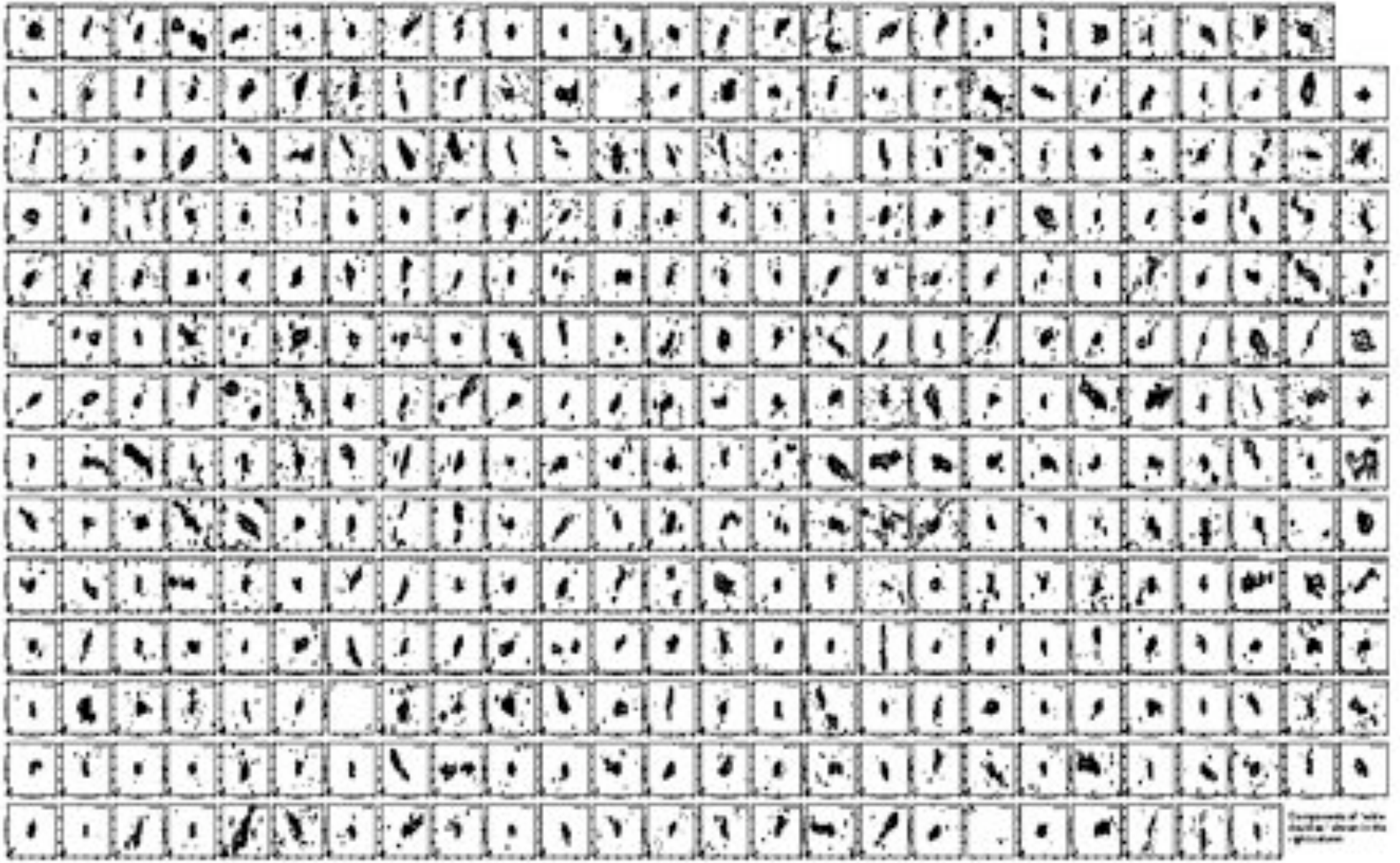
VSOP/VLBA Pre-launch Survey of Extragalactic Radio Sources at 5 GHz (VLBApls)

E.B.Fomalont [1], S.Frey [2], Z.Paragi [2], L.I.Gurvits [3], W.K.Scott [4], A.R.Taylor [4], P.G.Edwards [5], H.Hirabayashi [5]

[1] National Radio Astronomy Observatory, Charlottesville, VA, USA
[2] FOMI Satellite Geodetic Observatory, Penc, Hungary
[3] Joint Institute for VLBI in Europe, Dwingeloo, The Netherlands
[4] University of Calgary, Alberta, Canada
[5] Institute of Space and Astronautical Science, Sagamihara, Japan

Observed 05-06 June 1996. Axes marked in milliarcseconds.

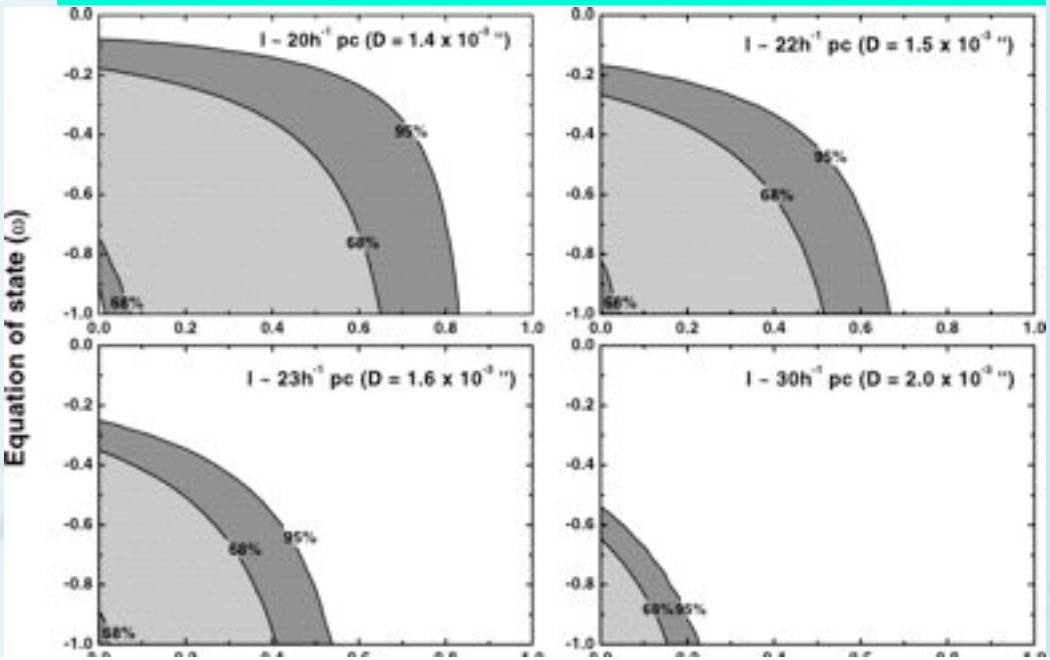
Astrophysical Journal Supplement, 2000



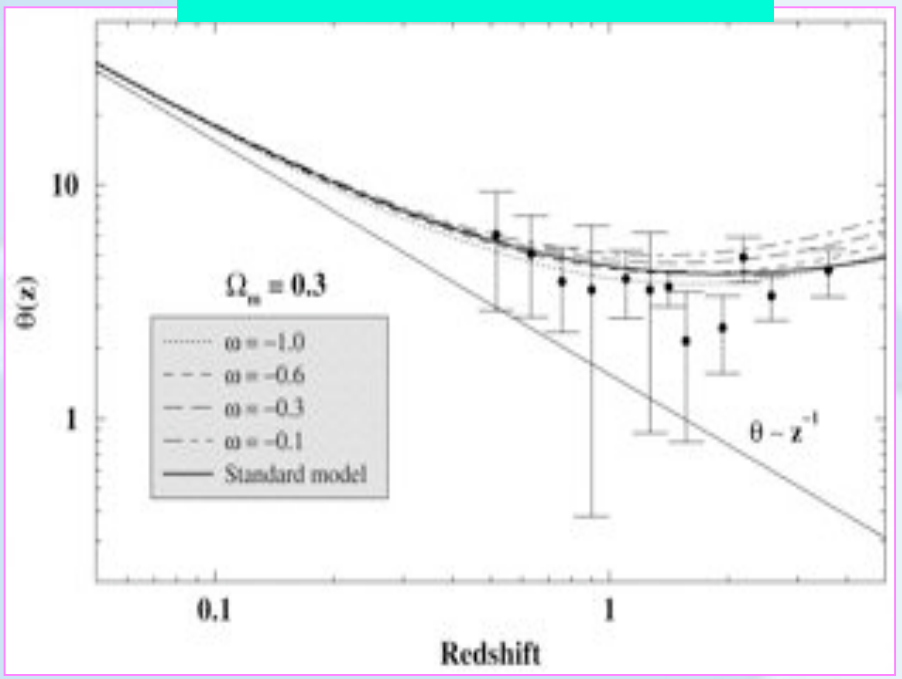
Pre-WMAP hints on the dark energy dominance

- **FRW model driven by non-relativistic matter and a smooth "dark energy" component $p_x = \_\_\_ x$**
- **Best fit:**

$$\Omega_m \le 0.62, \quad \omega \le -0.2, \quad lh = 20 \text{ pc}$$
$$\Omega_m \le 0.17, \quad \omega \le -0.65, \quad lh = 20 \text{ pc}$$



Lima & Alcaniz 2002



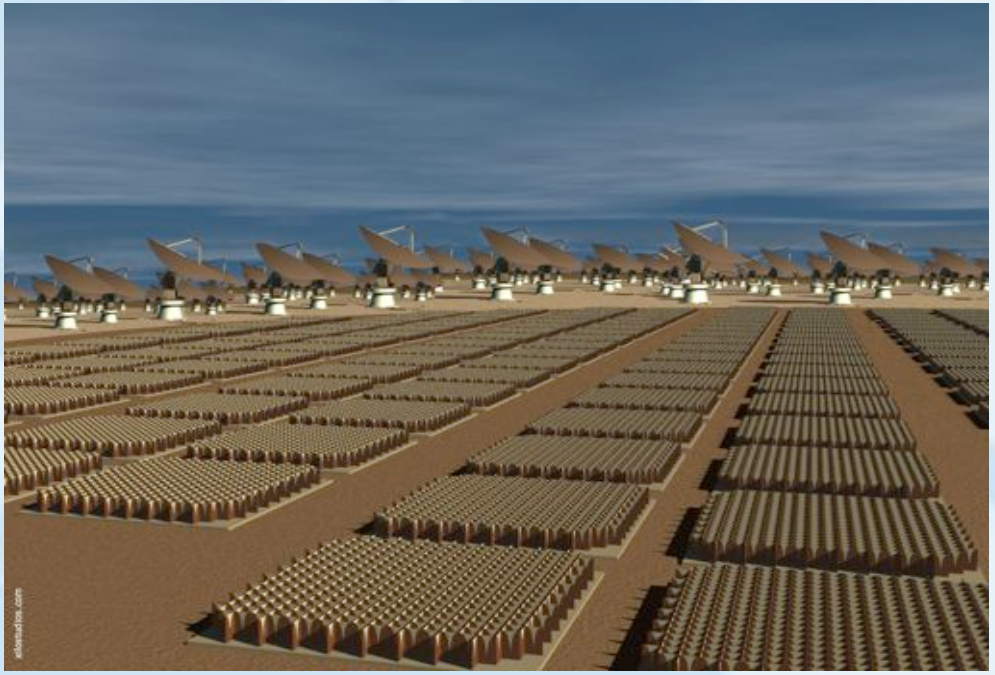
Conventional flat _CDM model (_ = -1) with _m=0.2 is the best fit.

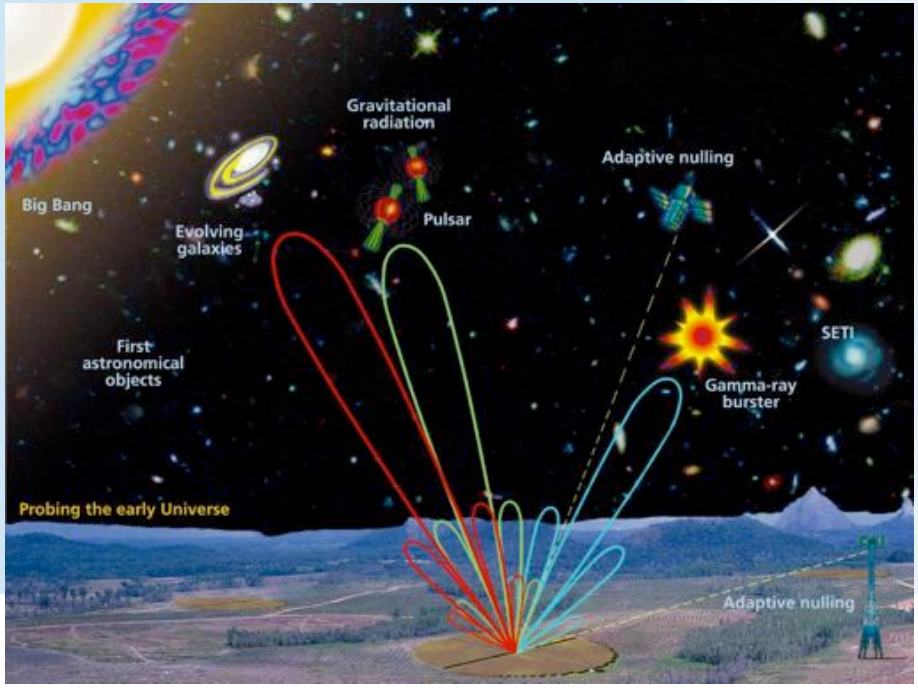
Better statistics –

– more data needed!

SKA; the radio telescope of the XXI century

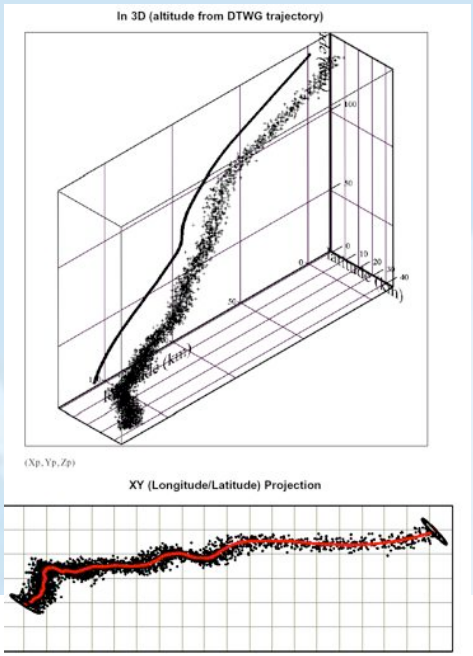
- 100-fold increase in sensitivity
- Test-bed for new technologies and their applications beyond astronomy
- Natural bridge (in frequency domain) between LOFAR and ALMA
- Global project; to be constructed by 2020





Recent European radio astronomy news

- Next Generation VLBI correlator: pre-design study underway
- eVLBI EC FP6 project EXPReS funded; kick-off in 2006
- EC FP6 SKA Design Study commenced in 2005
- VLBI tracking of Huygens Titan Probe (Jan 2005), SMART-1 (May-Sep 2006)
- Active preparation for EC FP7 underway



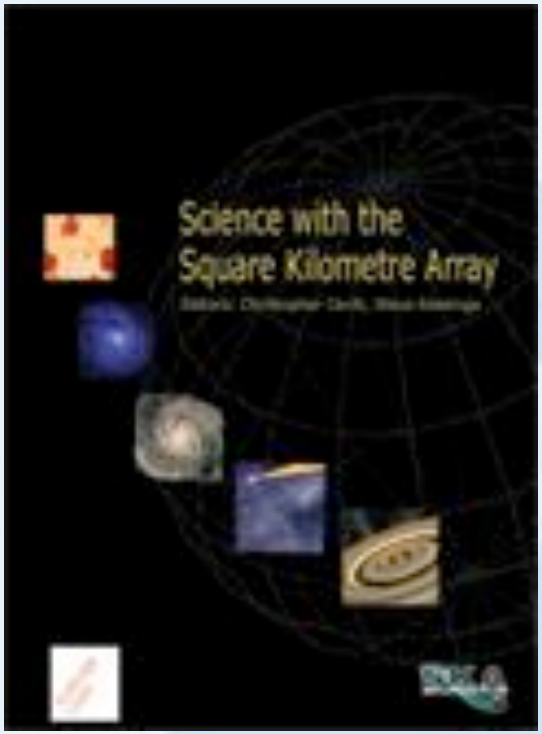
FP6 RadioNet at a glance

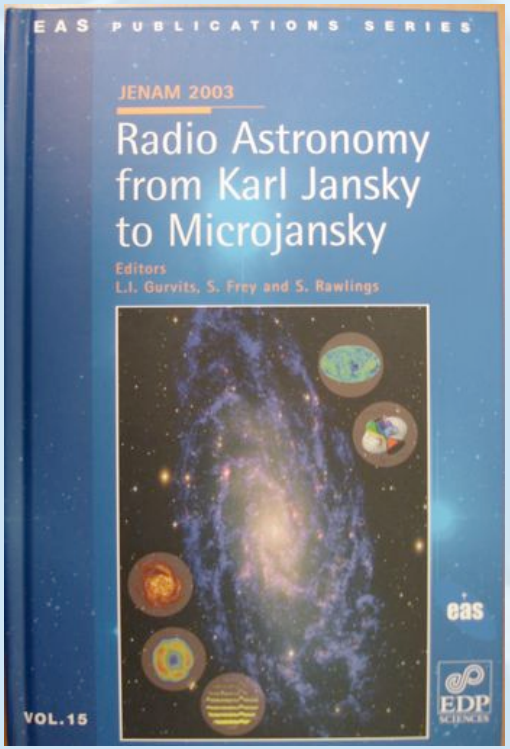
- Building-up on the strong European heritage in RA; descends from the 30-yr-old European VLBI Network
- Unifies the majority of RA institutes in Europe – 24 total
- Keeps RA developments on the edge-cutting level
- Total EC contribution 12.4 M€
- Provides synergy between various radio astronomy related technological developments, in particular:
  - FP6 SKA Design Study;
  - FP6 EXPReS (e-VLBI, Info Society DG)
- Participates in the public outreach activities

FP6 RadioNet at a glance (cntd)

- Three JRA's:
  - PHAROS: Aperture and focal array developments;
  - AMSTAR: mm radio astronomy LNA's and other instruments;
  - ALBUS: Advanced Long Baseline User Software
- Eight TNA facilities
- Eight Networks
- Governed by the Board (25 members, incl reps of sister I3's, ILIAS and OPTICON as at large members)
- Considers SKA as the focus of future developments (and collaborates closely with FP6 SKA Design Study)
- Stays in contact with AstroNet, OPTICON, ILIAS and EuroPlaNet on strategic planning issues

Recent publications





Science with the Square Kilometre Array
eds: C. Carilli, S. Rawlings,
New Astronomy Reviews,
Vol. 48, Elsevier, 2004
(see SKA booth, 2nd floor)

Radio Astronomy from Karl Jansky to Microjansky
eds: L/I/ Gurvits, S. Frey, S. Rawlings
EAS Publ. Series, Vol. 15,
EDP Sciences, 2005
(see Astronomy and Astrophysics booth, 2nd floor)

More info on RadioNet : www.radionet-eu.org

RadioNet beyond FP6

- The strategy must be science-driven.
- Exploit new and strategic instruments owned and operated by Europe, e.g. e-MERLIN, e-EVN, PdB, upgraded single-dishes, LOFAR, ALMA and SKA
- Enunciate clear goal for the inclusion of a particular R&D area
- Ensure that we educate and train the next generation of astronomers and engineers:
  - Foster the leaders of the next decade.
- Think strategically and on European-scale, not nationally:
  - Relevant for RadioNet and also for new/upgraded infrastructure call

Decision-making

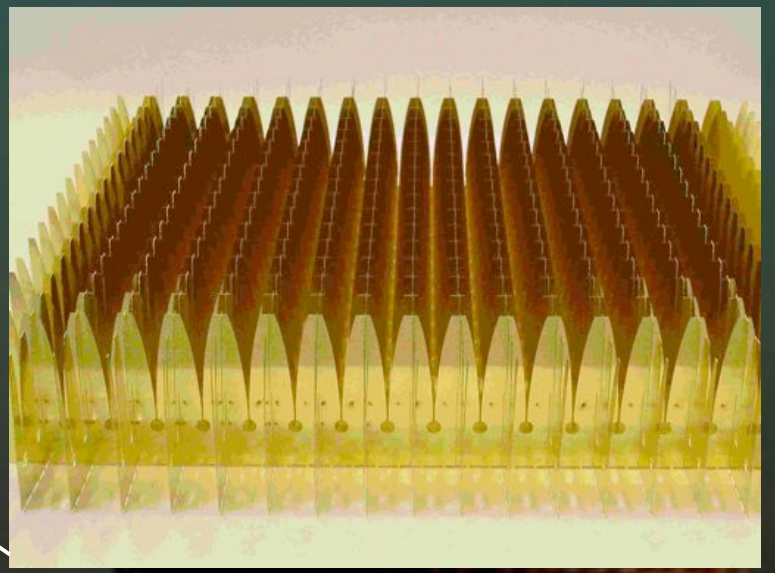
- Developing the decision-making process
  - TNA facilities must be world-class, relatively rare and offer a unique capability; they must have, or be able to demonstrate, a substantial European user base.
  - JRAs ideas to be developed further must fit within the strategic framework, they must have both a degree of relevance to existing facilities and can/should also demonstrate a role within future facilities.
  - NAs: Networking ideas should fit within the strategic framework of RadioNet.
- Should suggest areas of common interest for merging of ideas within RadioNet; possible interactions with other I3s?'

RadioNet beyond FP6: JRA's

- JRAs – 5/6 major areas have emerged
  - Focal Plane A\arrays (PHAROS+)
  - Very large format FPAs at mm/submm wavelengths and new methodologies at THz frequencies (AMSTAR+)
  - (User) software development (ALBUS+)
  - Digital systems: next generation VLBI correlator, pulsar timing, RFI monitoring/mitigation, SKA clock distribution, etc.
  - High-frequency and space science VLBI, astronomy from the Moon (prototyping)
  - SKA-related ideas (low power antennas, optical processing)

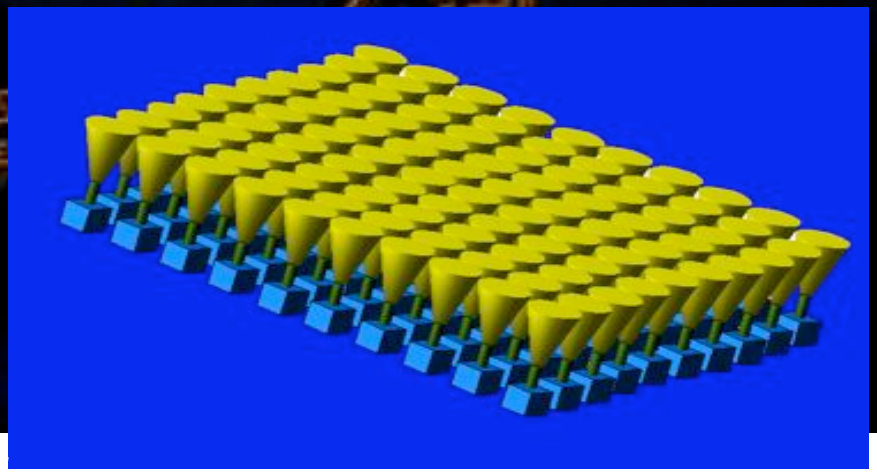
Focal Plane Arrays are science multipliers

Low-frequency (1.4-5 GHz) beam-forming arrays to maximise the potential of the EVN



• Mid-frequency (30-120 GHz) horn arrays to maximise the potential of large single dishes in Europe (e.g. Yebes, Effelsberg, SRT etc)

• High frequency (100-1000 GHz) horn arrays to maximise the potential of high-altitude single dishes in the era of ALMA



Networks

- Good case for continuing and expanding some, but not all, existing NAs:
  - Management
  - Synergy
  - Science Workshops
  - Engineering Forum
  - ALMA Forum
  - Spectrum monitoring

Networks

- See case for over-arching science workshop activity:
  - Coordinates workshops in different areas : general science themes, mm/sub-mm-related themes (separate in FP6); pulsar meetings; Suggestion on panchromatic workshops supporting SKA science case.

- See case for activity running schools & maybe science personnel exchanges:
  - m/dm/cm/mm/submm interferometry schools
  - Single-dish schools
  - YERAC
  - Solar physics schools
  - Spectrum management Schools
  - Training in best engineering practice

Networks

- Geonet – link geodesy to European astronomy activities
- LOFAR across Europe: planning, RFI, long-baseline calibration strategies…
- SKA non-astronomy applications
- QASP for E. European antennas
- Space VLBI – preparation for VSOP-2. Will now happen, so important we organise ourselves.
- ESKAC
- Policy / Industrial links

TNAs

- Define selection process – follow FP6 criteria?
  - Strong case for major existing facilities (but all should be re-examined)
  - Several major new instruments coming on-line soon – LOFAR, Yebes, SRT
  - Other large facilities : NRT, GMVA
  - Smaller, more focused facilities : INAF 32’ms, APEX (Swedish time), Nancay radioheliograph, AMI/VSA

Inter-I3 Issues

- Can we define a strategy?
  - Prime – support of existing strategic facilities based on science goals. What are these goals? How do we define? Each facility has different but complementary science goals e.g. LOFAR vs PdB
  - Secondary – keep an eye on the future: SKA, ALMA, multi-waveband single-dish survey machines
  - How strong should SKA theme be within networking activities? They provide an avenue to support future facilities, I believe should be strong focus
- How do we strengthen links with other I3s and projects?
  - Inter-I3 JRA (e.g. Space Sci applications, with EuroPlaNet)
  - Joint ILIAS-RadioNet Science workshop on “dark” topics?

More on RadioNet

www.radionet-eu.org