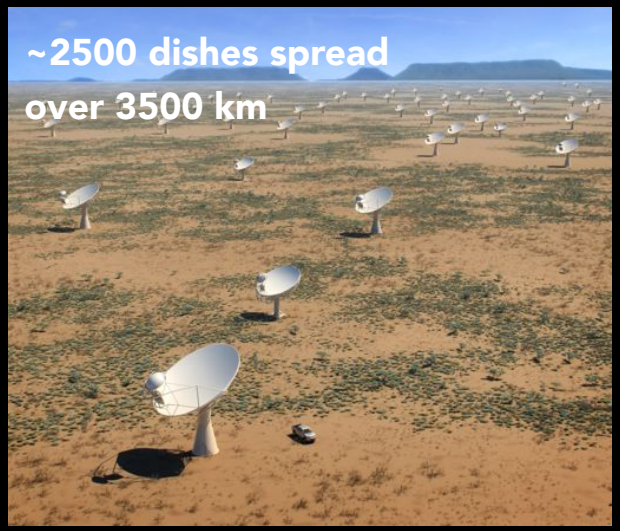
SKA AND PRECURSORS

S. CORBEL (UNIV. P. DIDEROT & CEA SACLAY/AIM & OBS. PARIS/USN)

OUTLINE

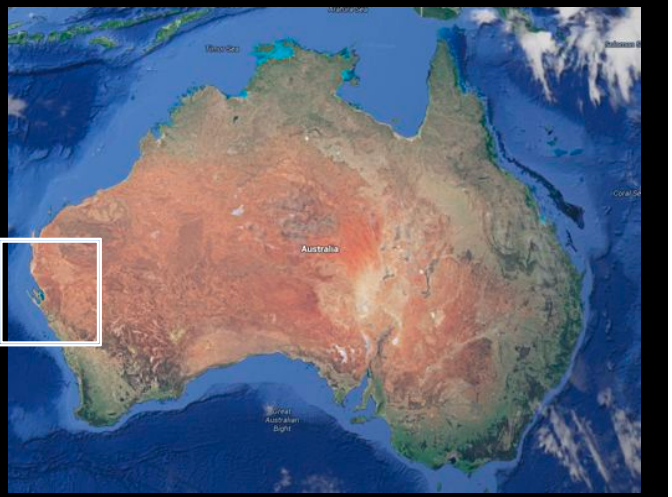
- SKA and precursors: telescopes and capabilities.
- France and the SKA : get involved now !
- PNHE science with SKA and precursors: some examples.
- Conclusions.

THE SQUARE KILOMETER ARRAY (SKA)



The SKA:

- 2 sites, 2 telescopes, 1 observatory
- ~1 km^2 collecting area
- 50 MHz - 25 GHz
- Resolution down to 10 mas+VLBI
- Phase 1 : 2018-2023
- Phase 2 : 2025-2033



SKA HQ: JODRELL BANK OBS., UK

SKA1 MID - the SKA's mid-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.

SKA SQUARE KILOMETRE ARRAY

Location: South Africa

Frequency range: **350 MHz** to **14 GHz**

~200 dishes (including 64 MeerKAT dishes)

Total collecting area: **33,000m²**

or **126 tennis courts**

Maximum distance between dishes: **150km**

Total raw data output:

2 terabytes per second

62 exabytes per year

Enough to fill **340,000** average laptops with content **every day**

Compared to the JVLA, the current best similar instrument in the world:

4x the resolution

5x more sensitive

60x the survey speed

SKA1 LOW - the SKA's low-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.

SKA SQUARE KILOMETRE ARRAY

Location: Australia

Frequency range: **50 MHz** to **350 MHz**

~130,000 antennas spread between **500 stations**

Total collecting area: **0.4km²**

Maximum distance between stations: **65km**

Total raw data output:

157 terabytes per second

4.9 zettabytes per year

Enough to fill up **35,000 DVDs** every second

5x the estimated global internet traffic in 2015 (source: Cisco)

Compared to LOFAR Netherlands, the current best similar instrument in the world:

25% better resolution

8x more sensitive

135x the survey speed

SKA PRECURSORS: MEERKAT

- Location: South Africa
- Max Baseline : 8 km
- Frequency coverage: 0.5-10 GHz
- 64 antennas (13.5 m)
- Fully operational in 2017 (partially in 2016)

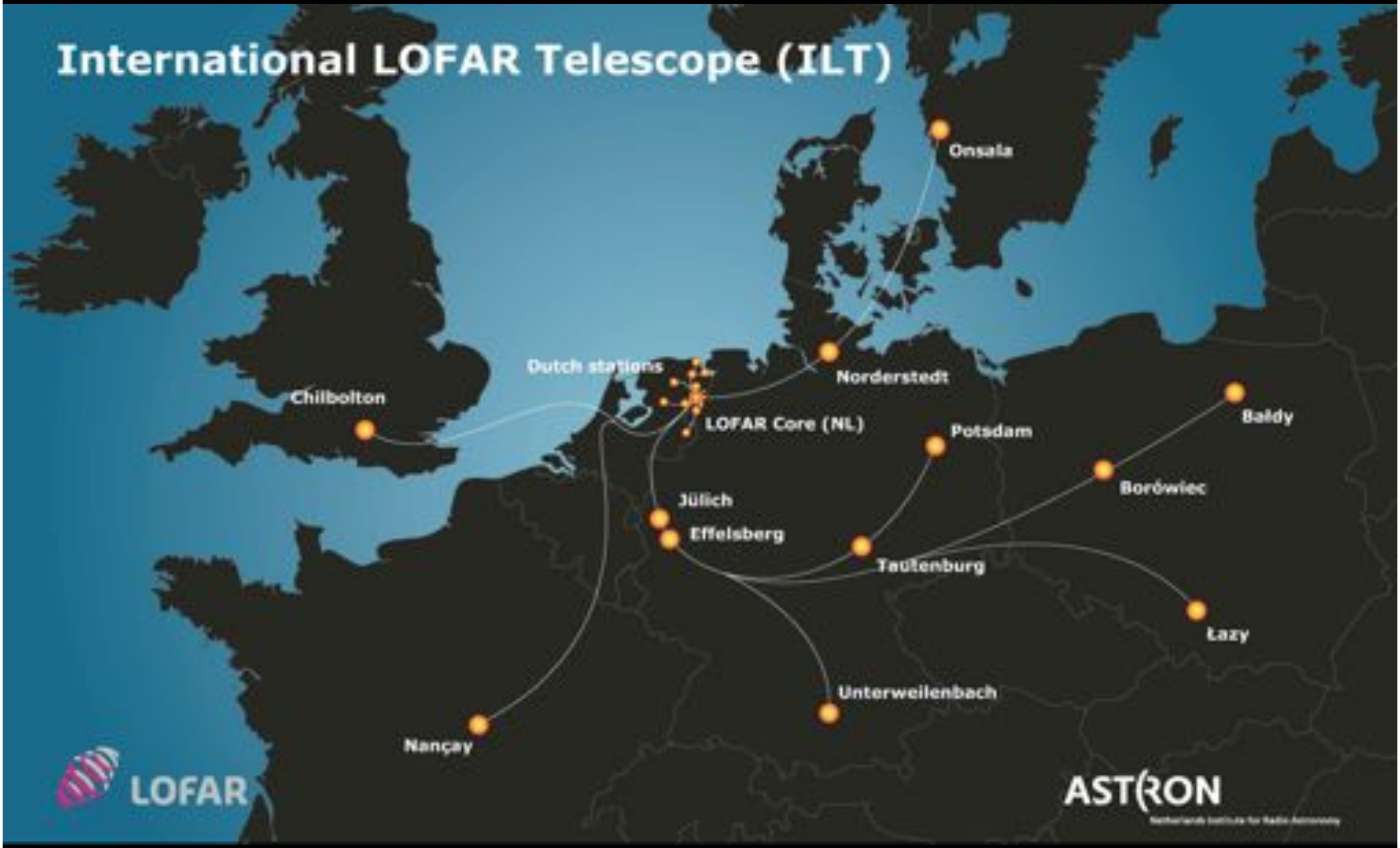
SKA PRECURSORS: ASKAP

- Location: Australia
- Max Baseline : 6 km
- Frequency coverage: 0.7-1.8 GHz
- 36 antennas (12 m) with PAF (30° FOV)
- Fully operational in 2017 (partially since 2015)

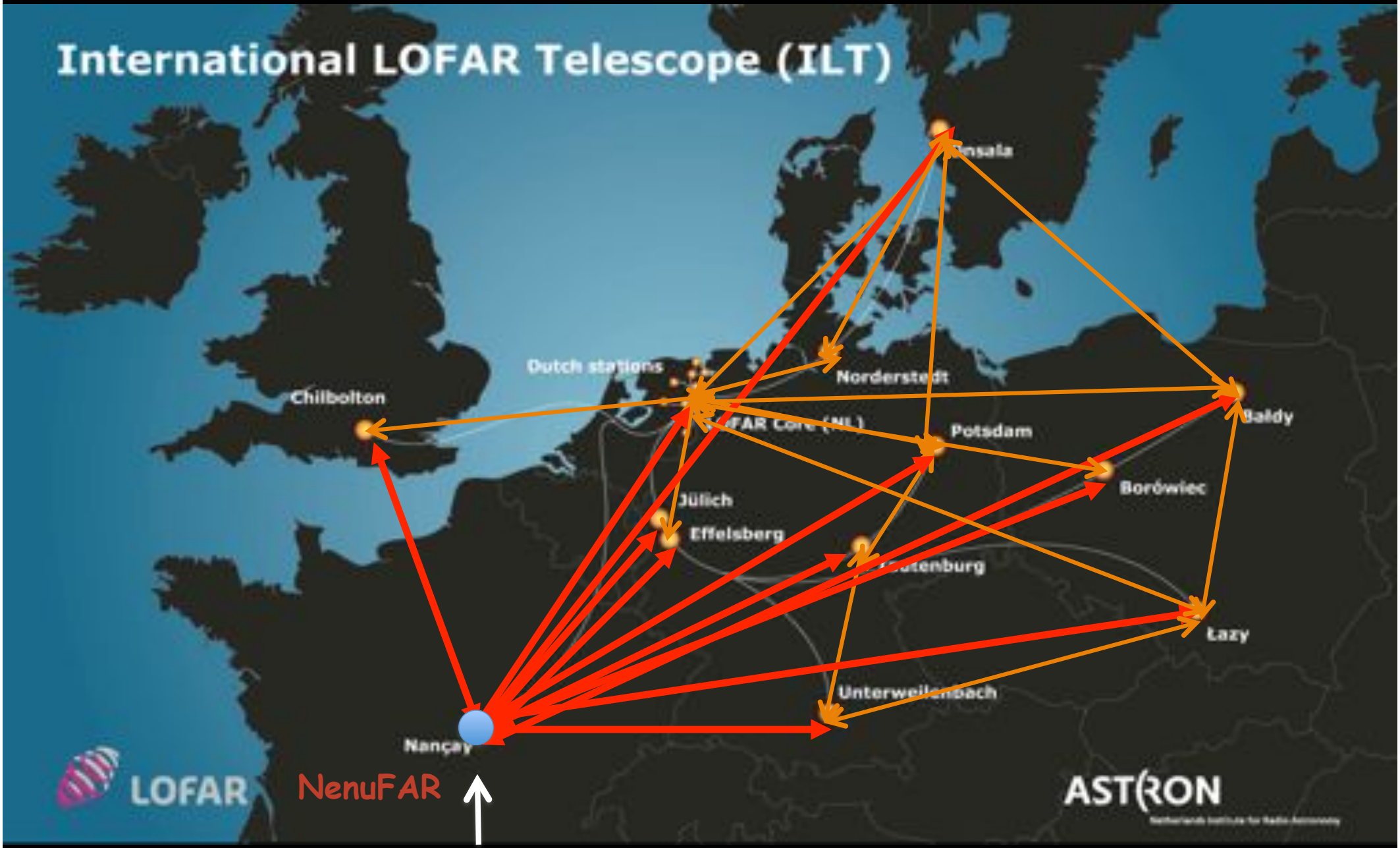
NENUFAR

2015 Nov 5

NENUFAR


International LOFAR Telescope (ILT)
Onsala
Dutch stations
Norderstedt
Chilbolton
LOFAR Core (NL)
Potsdam
Baldy
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Unterweilenbach
Nançay
LOFAR
ASTRON

NENUFAR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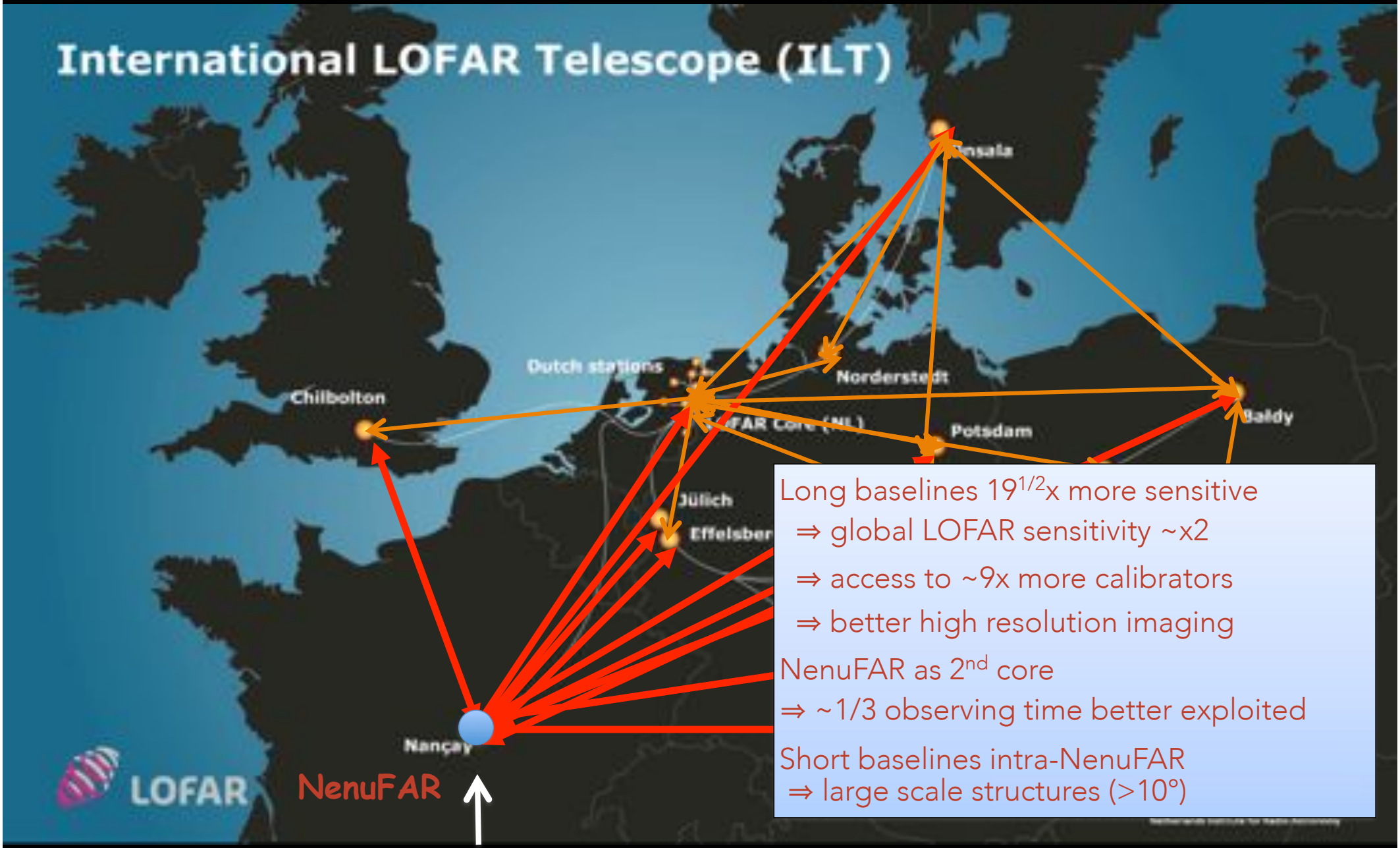
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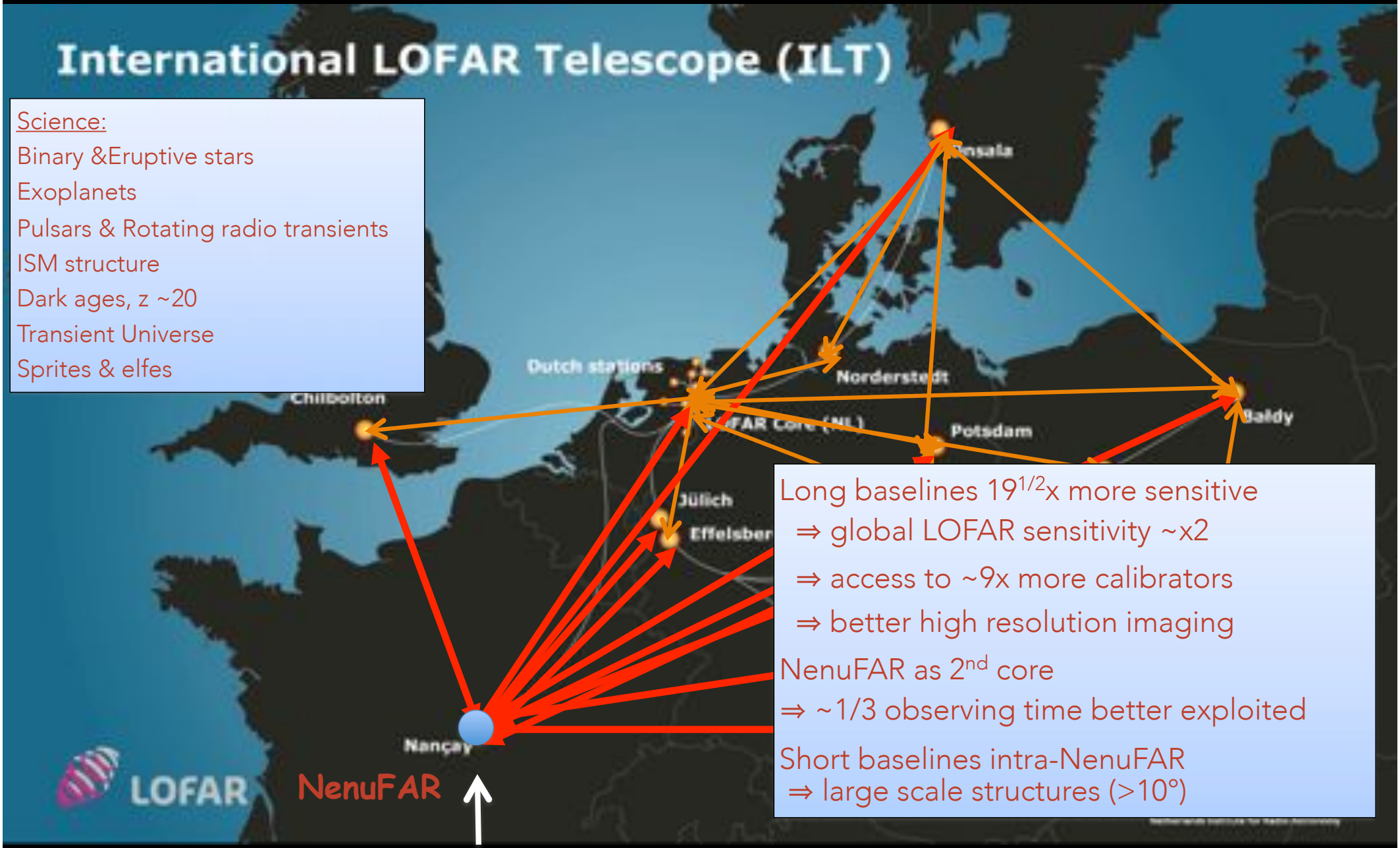
LOFAR
NenuFAR
Long baselines 19^1/2x more sensitive
⇒ global LOFAR sensitivity ~x2
⇒ access to ~9x more calibrators
⇒ better high resolution imaging
NenuFAR as 2nd core
⇒ ~1/3 observing time better exploited
Short baselines intra-NenuFAR
⇒ large scale structures (>10°)

NENUFAR


International LOFAR Telescope (ILT)
Science:
Binary &Eruptive stars
Exoplanets
Pulsars & Rotating radio transients
ISM structure
Dark ages, z ~20
Transient Universe
Sprites & elfes
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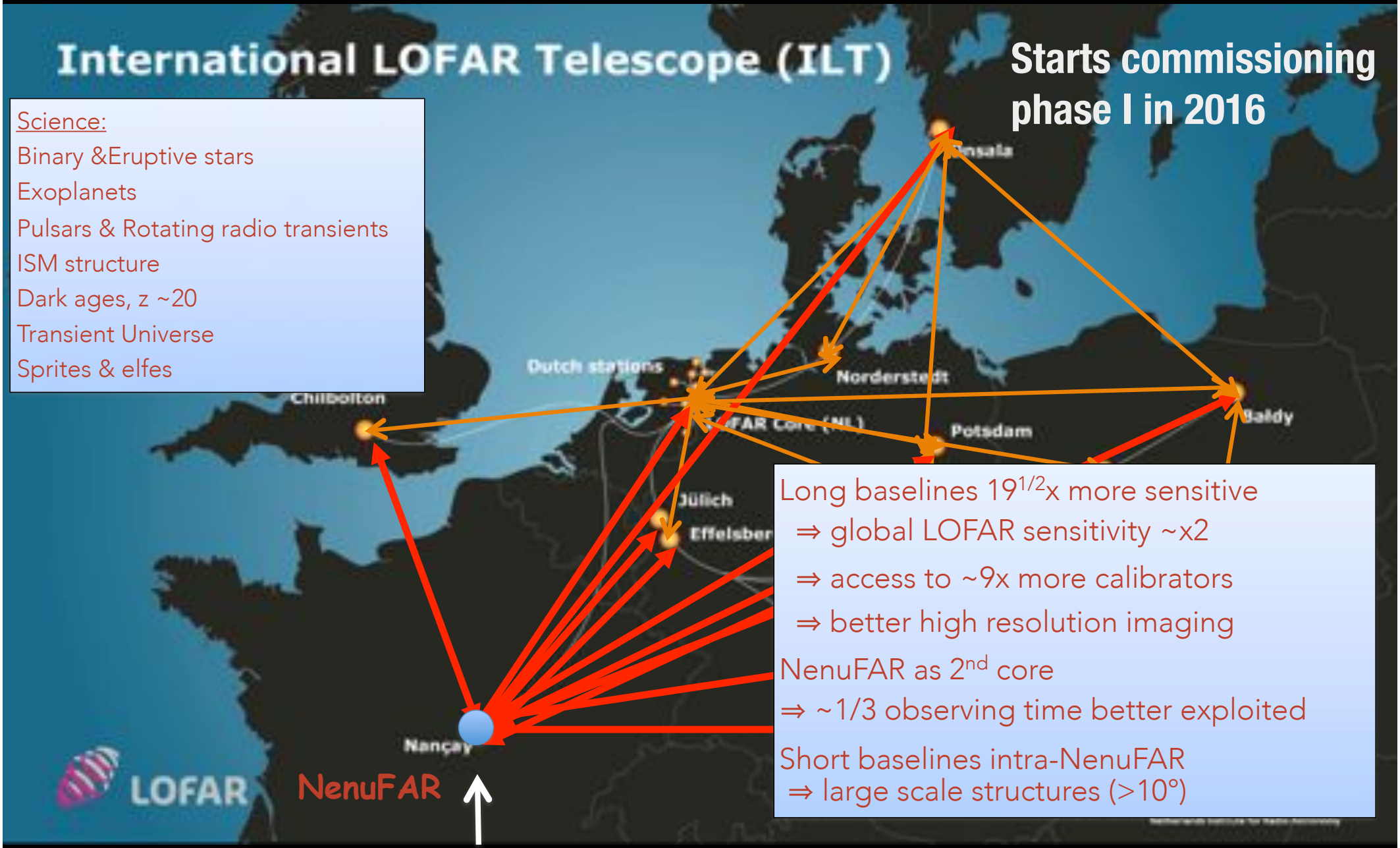
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Starts commissioning phase I in 2016
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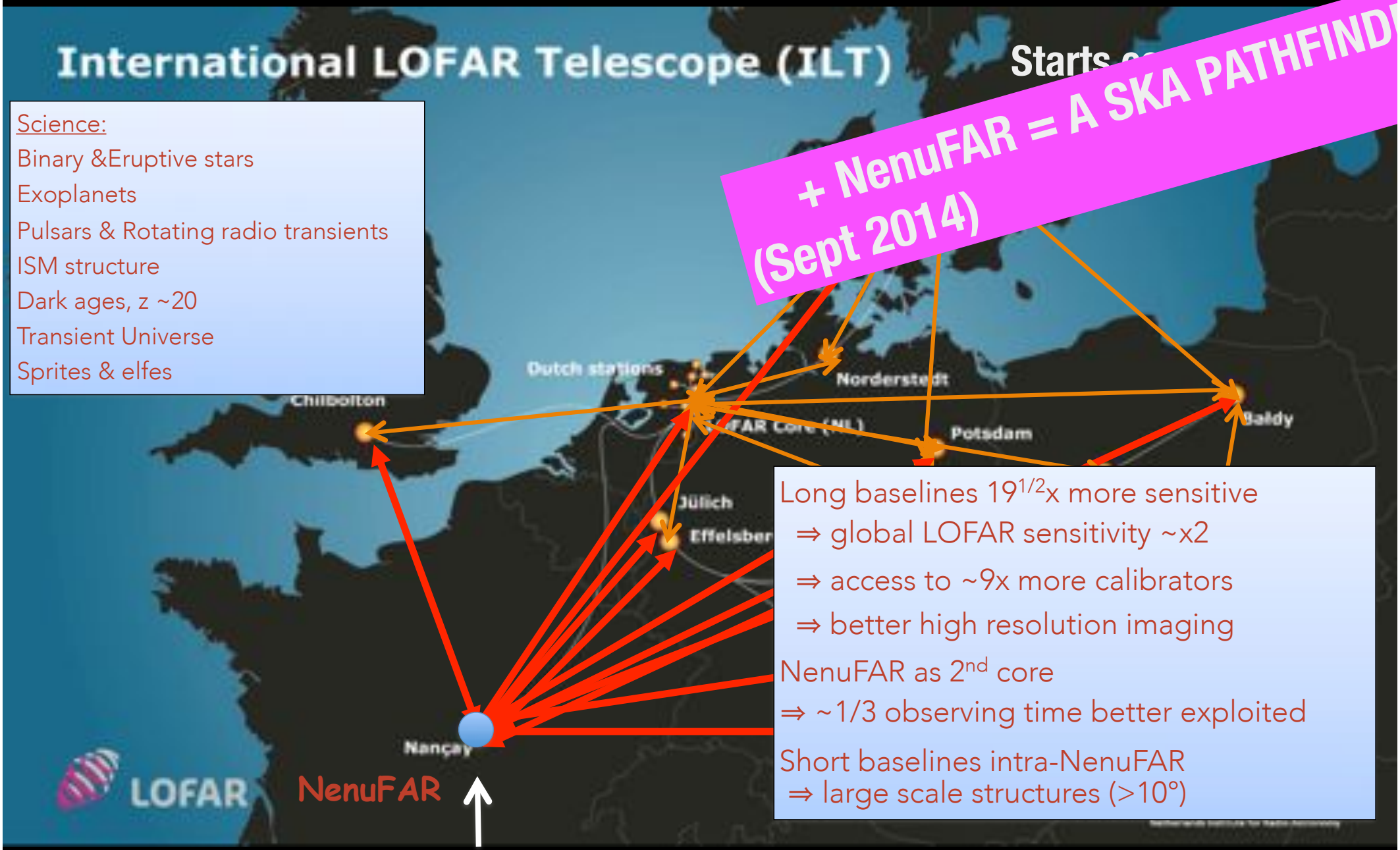
International LOFAR Telescope (ILT)
Starts
+ NenuFAR = A SKA PATHFIND
(Sept 2014)
Science:
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SCIENCE WITH MEERKAT

- 2010: Call for large (> 1000 hr) survey projects (70% allocated). Good contribution from the French community.
- + 30% for smaller PI driven proposals (of which 5% will be DDT).
- **MeerKAT Workshop** in 2016: 25 to 27 May in Stellenbosh (South Africa). The large programs will need to be updated (technical specifications, science evolution, …).
- Priority 1 programmes:
  - **Radio pulsar timing** (PI: M. Bailes): Testing Einstein's theory of gravity and gravitational radiation - Investigating the physics of enigmatic neutron stars through observations of pulsars.
  - LADUMA (Looking at the Distant Universe with the MeerKAT Array) - An ultra-deep survey of neutral hydrogen gas in the early universe. PI: Blyth, Holverda, Baker.

SCIENCE WITH MEERKAT

- Priority 2 programs, e.g :
- **TRAPUM** (Transients and Pulsars with MeerKAT) - Searching for, and investigating new and exotic pulsars. PI: Steppers, Kramer
- **ThunderKAT** (The Hunt for Dynamic and Explosive Radio Transients with MeerKAT) - e.g. gamma ray bursts, novae and supernovae, plus new types of transient radio sources. PI: Woudt, Fender (with e.g. Corbel, Daigne, Vergani…)
- + all programs related to radiogalaxies, galaxy formation, VLBI, …

SCIENCE WITH MEERKAT

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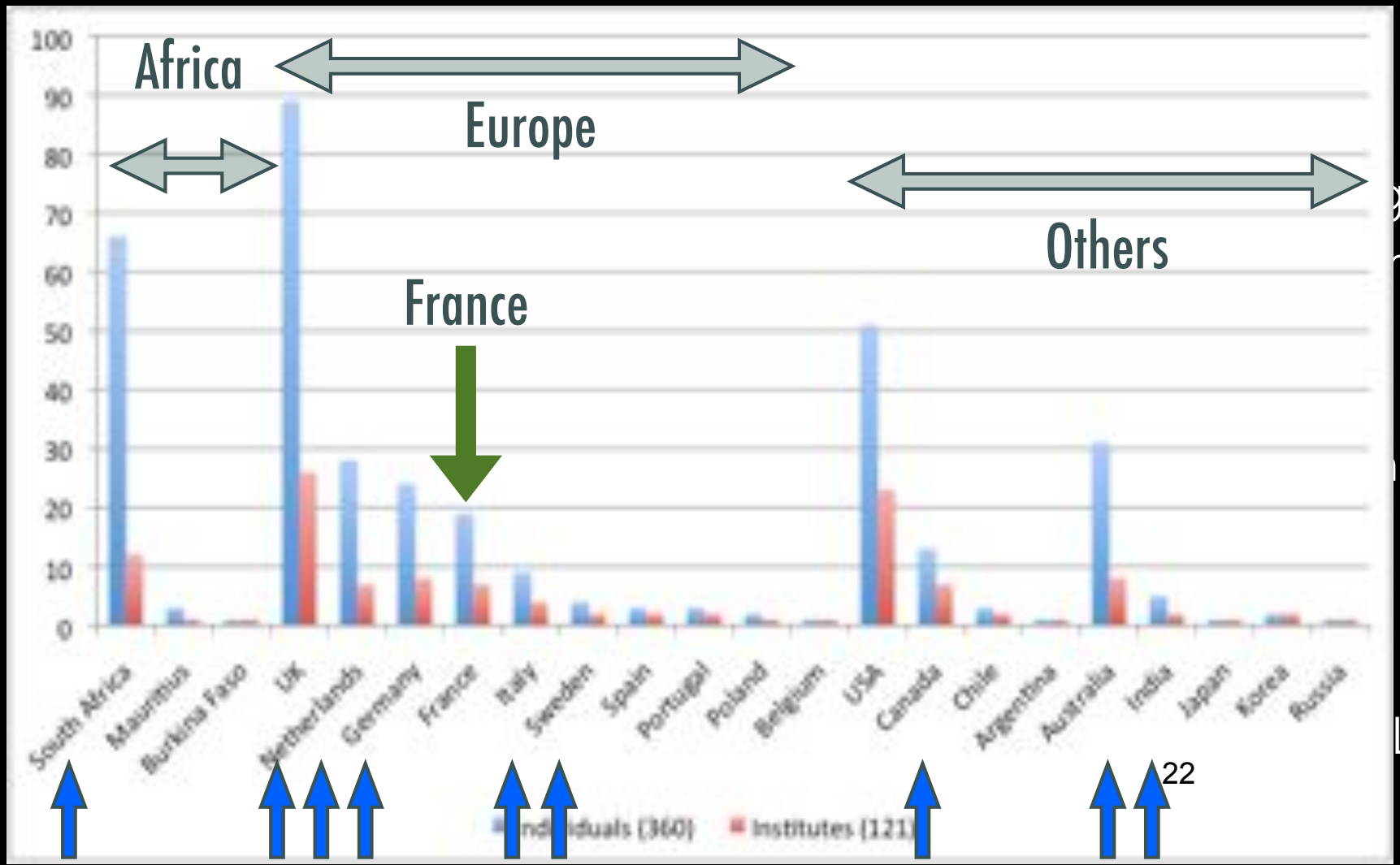
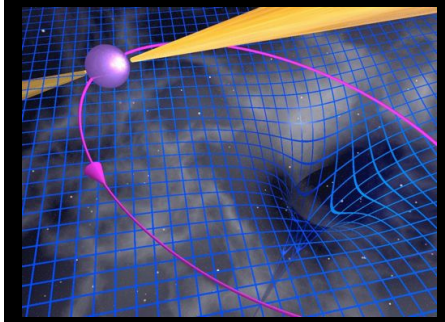


SCIENCE WITH ASKAP

- During ASKAP's first five years of operation at least 75% of its time will be used for large Survey Science (>1500 hr).
- Selection of ten projects in 2009:
  - An ASKAP Survey for Variables and Slow Transients (**VAST**). PI : Murphy, Chatterjee
  - The Commensal Real-time ASKAP Fast Transients survey (**CRAFT**). PI : Hall
  - Compact Objects with ASKAP: Surveys and Timing (**COAST**). PI: Stairs
  - + VLBI, magnetism, galaxies, …
- **ASKAP 2016**: The future of radio astronomy surveys. June 6 to 10 in Sydney.

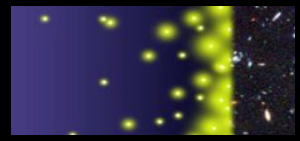
FRANCE : SKA MAP

- ~30 French scientists involved in the 11 SKA **science working groups :** Transients, Fundamental physics with pulsars, Cosmic Rays (in formation)
- 21 French scientists involved in 31 out of the 125 chapters of the **new SKA science book** (lead 5 chapters).
- 110 participants in the 2014 **SKA/LOFAR radio days** organized by AS SKA-LOFAR
- ~13 FTE per year in **technological developments** for SKA (USN, Bordeaux, …)
- **INSU 2014 prospective** : more than 23 ~scientific FTE/year working on SKA in France ! More today. P0: SKA board.
- Global community that could potentially be interested by SKA > 200-250 persons (most of them are currently not radio-astronomers).

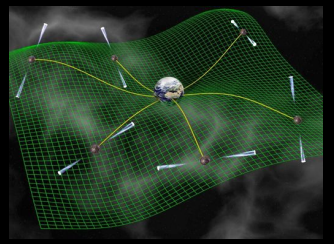


SKA SCIENCE INTERESTS IN FRANCE (AND **PNHE**)

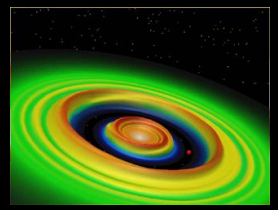
- HI for mapping the evolution of the Universe : towards 1 billion of galaxies in HI! (AIM, IAS, IAP, LAL, Marseille, Obs Paris, Nice, Obs Strasbourg,…)

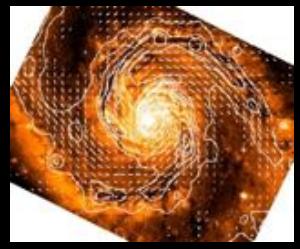


- **Fundamental physics with Pulsars** and **gravitational waves** (Orléans, APC, AIM, …)
- **Transients**: searching for the known, the known unknown and the unknown unknown ! (AIM, IPAG, Obs Paris, IRAP, OCA, Strasbourg, …)

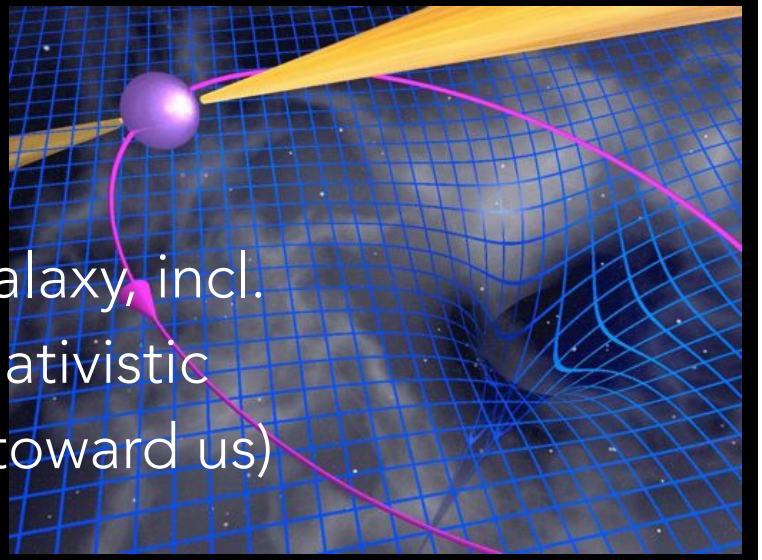


- Cosmic **magnetism** (Toulouse, Obs P., ..)
- Planet, the Sun, stars and interactions (Bordeaux, Grenoble, Obs. Paris, …)
- **Synergies**: ALMA, Euclid, JWST, **SVOM**, **CTA**, … (all institutes in France)
- **Astrometry** (Bordeaux) and much more …

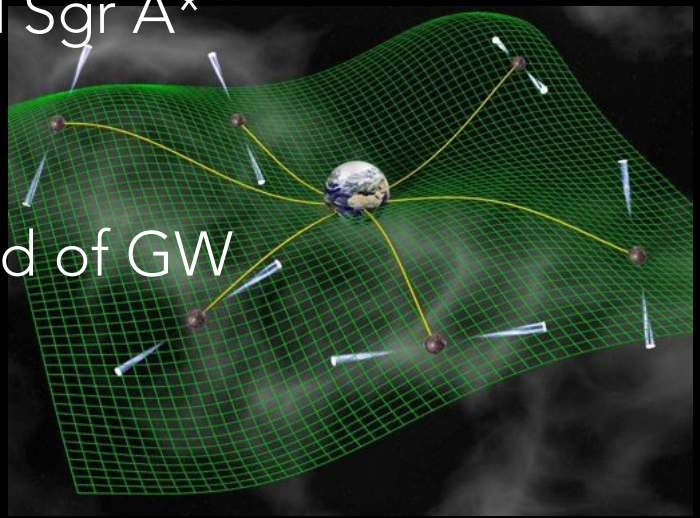




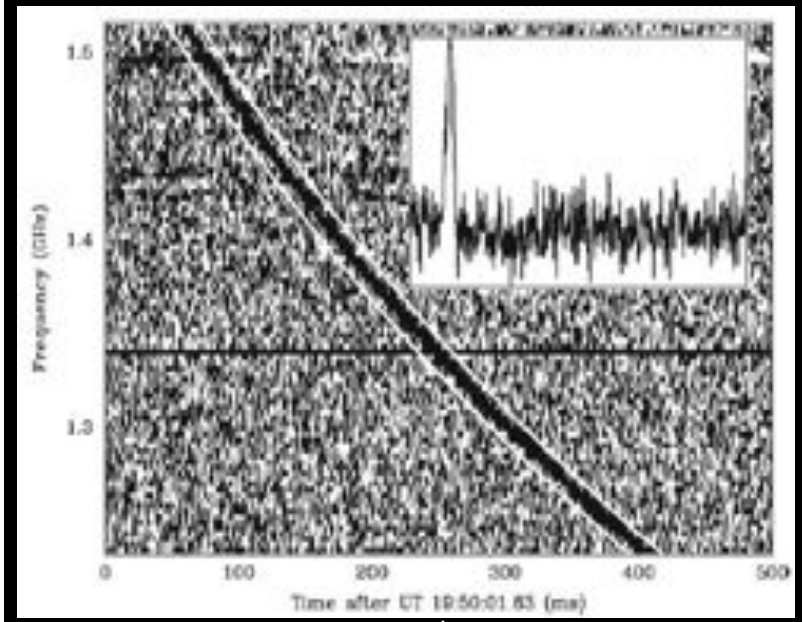
PULSARS



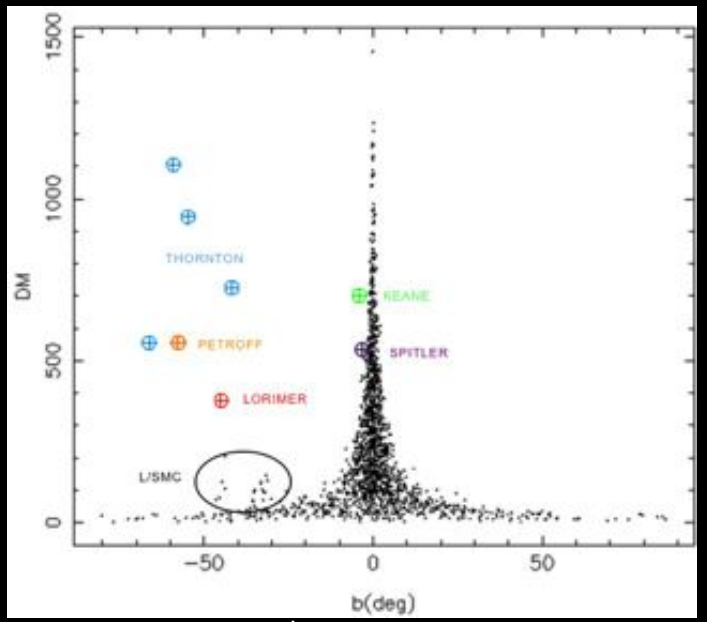
- SKA will detect up to 20 000 pulsars in the Galaxy, incl. 1 000 ms pulsar, incl. at least 100 compact relativistic binaries (almost all the population beamed toward us)
- Probing relativistic binaries: Equivalence principle, Strong-field tests of gravity
- Full sample is certain to include the «holy grail» : Black hole - neutron star binaries? ms pulsar around Sgr A* (massif black hole)
- Pulsars Timing Arrays: a stochastic background of GW emission



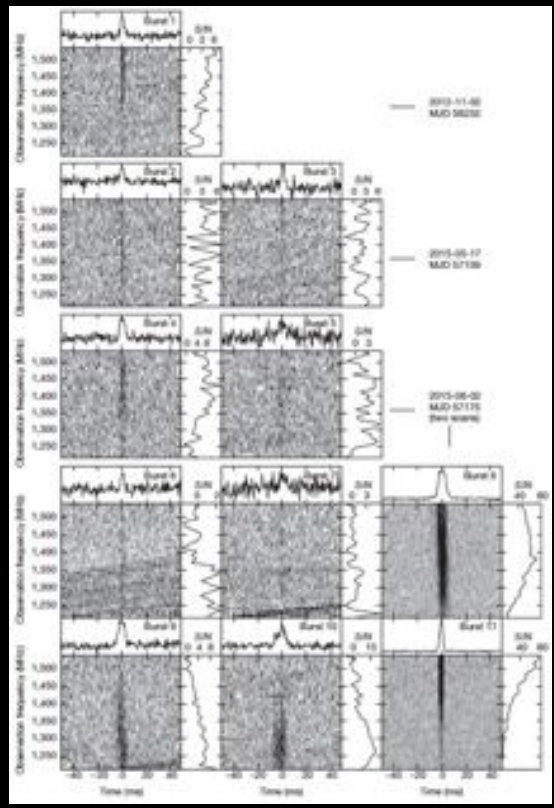
FAST TRANSIENTS: FRB



Lorimer et al. 2007



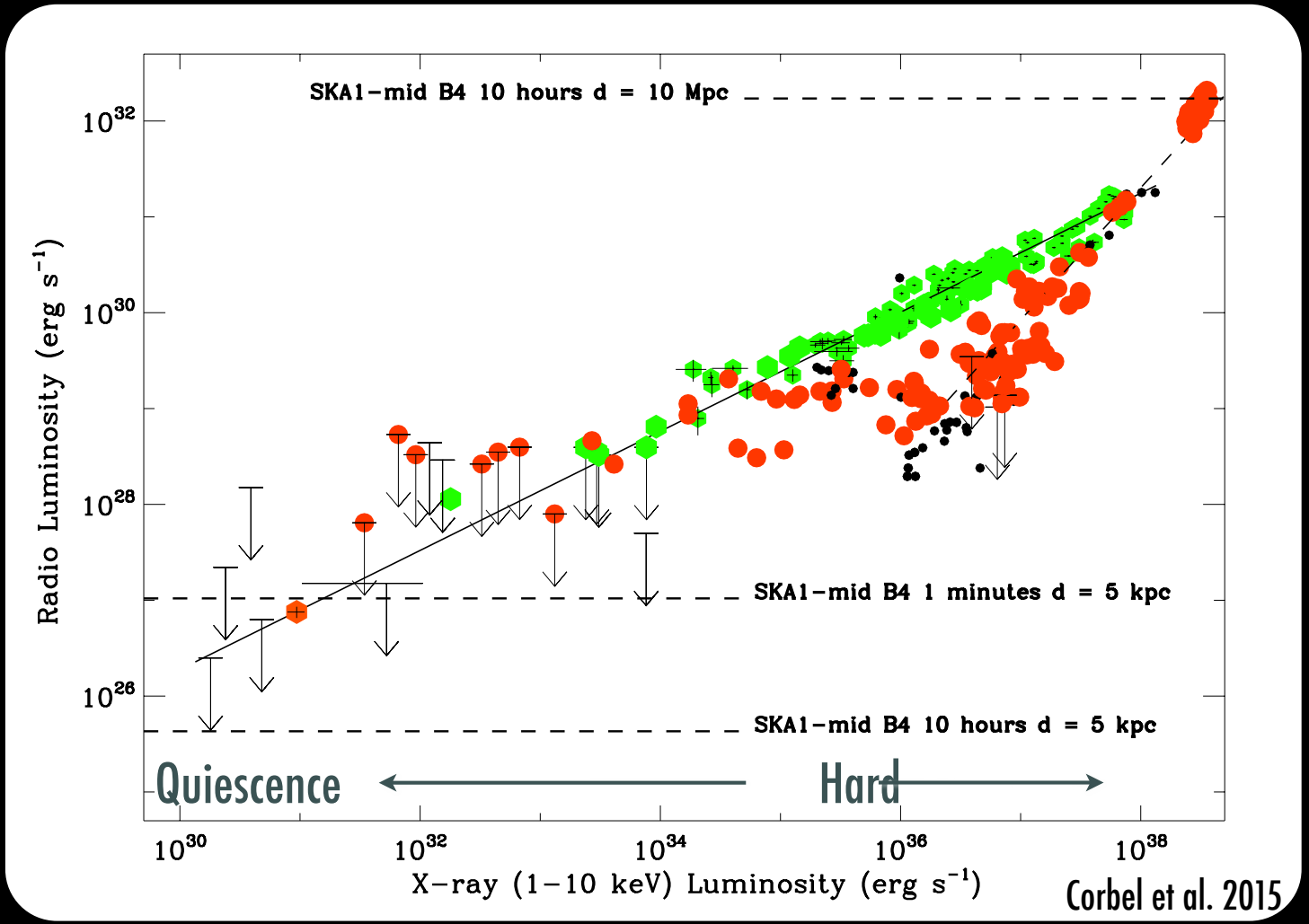
Ng et al. 2014



Spitler et al. 2016

- Discovery in 2007 —> 15 FRBs just for 2015 ! Afterglow ? Repeating bursts.
- > 50 Models (back to the GRB history ?): SN, blitzars, merging NS, magnetar, supergiant pulsar pulse, pulsar companions, …
- Important for solving the missing baryons problem !

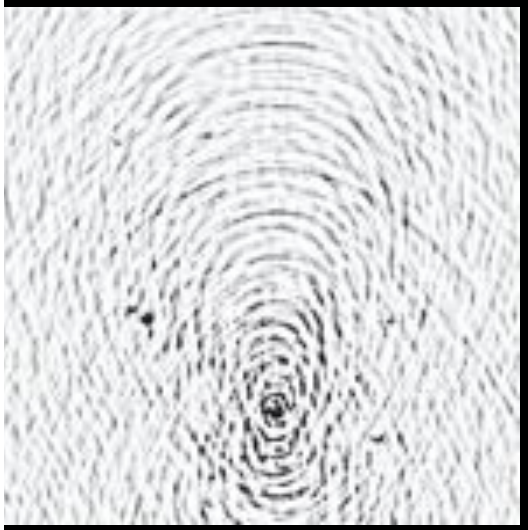
SLOW TRANSIENTS: MICROQUASARS



- **SKA**: probing **a significant fraction of the whole outburst** duration for almost all BHs in our Galaxy
- All **flaring transient BHs** accessible in the local Universe (possibly also up to Virgo @ 15 Mpc)

ALGORITHMIC DEVELOPMENTS

Tasse et al. 2013 : LOFAR imager



w term

w term + array +
element beam

- Garsden et al 2015: Compressed sensing in radioastronomy (see also Dabbech et al. 2015)
- Girard et al. 2016: Transients. Tasse et al. 2016: DDFacet. DR ~ 5 millions !

ALGORITHMIC DEVELOPMENTS

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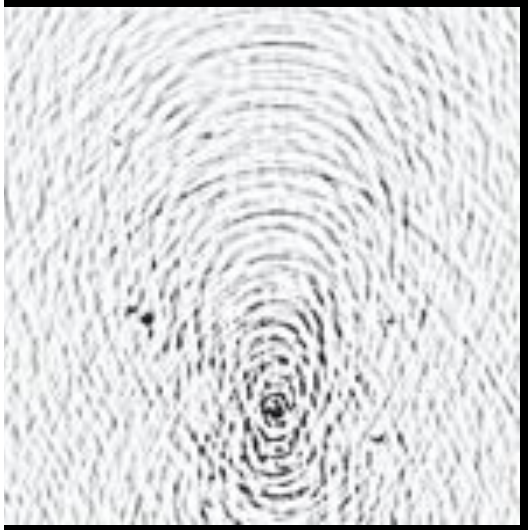

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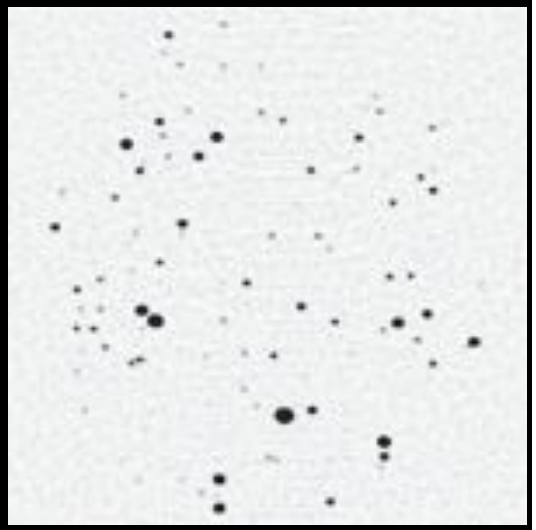
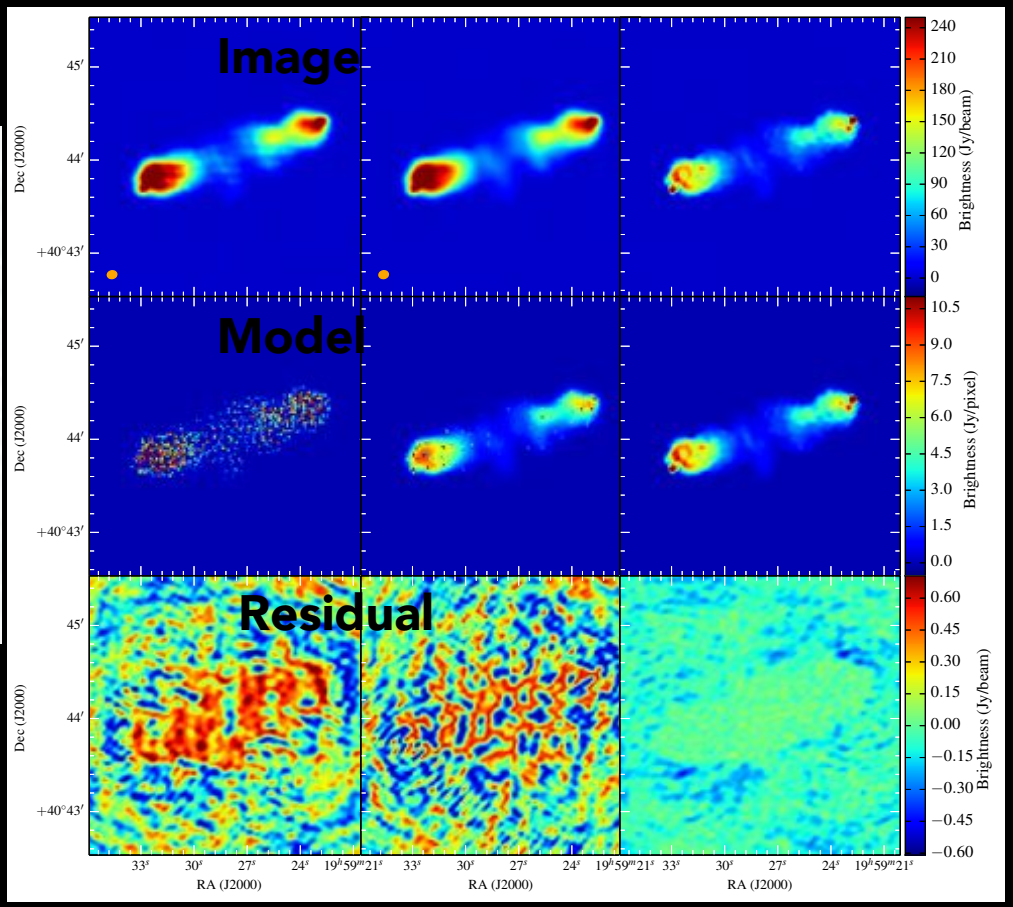


w term + array + element beam



Clean MS Clean CS

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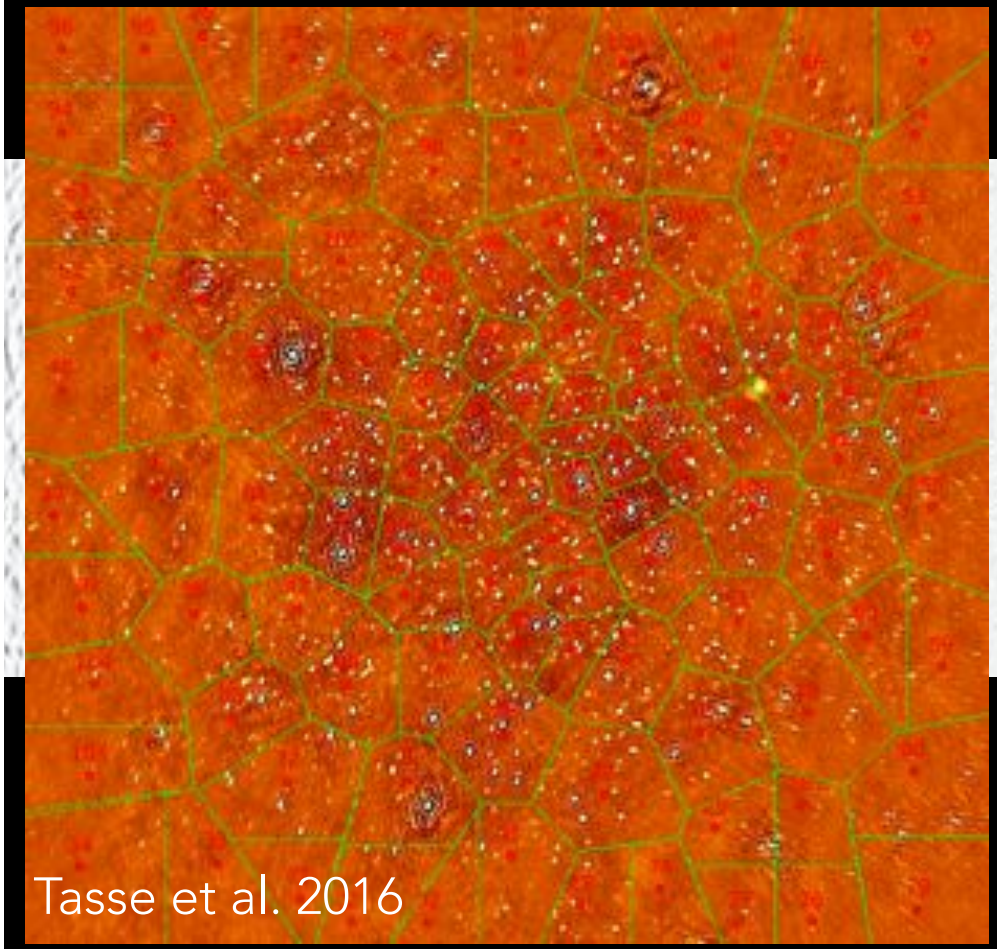

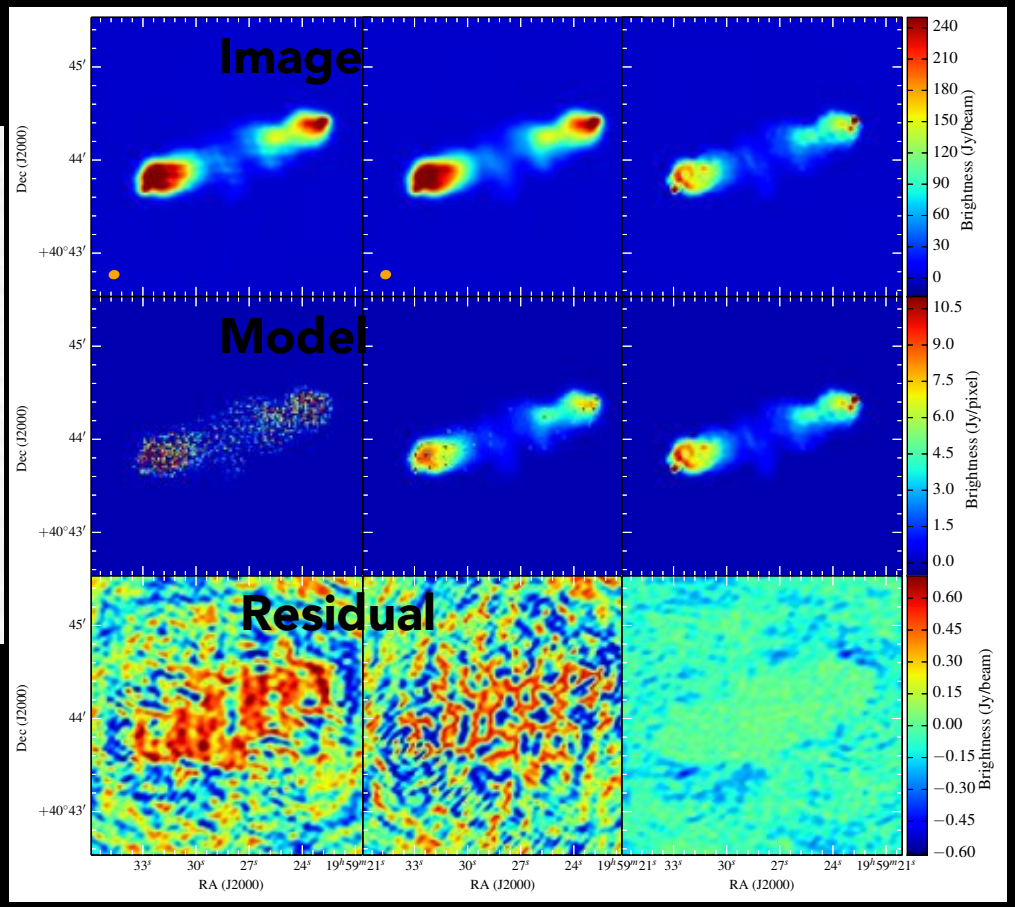

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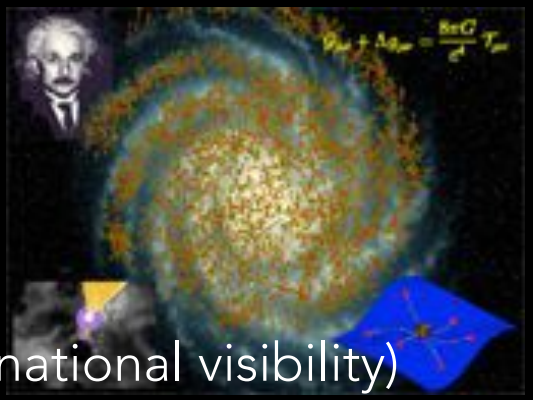
CONCLUSIONS



- Topics pertaining to PNHE (with French teams of large international visibility)
  - Sources: transients of various kinds, pulsars and GW, cosmic rays, the unknown, … commensal observing !
  - Physics: accretion, ejection, fundamental physics, GW, particles acceleration, dense matter, …
- Synergies SKA - HE experiment: duty tasks for CNAP , big data, algorithms,
- Get involved: SKA science book, working groups, KSP, …
- Workshop during SF2A organized by AS SKA-LOFAR + mailing list
- A dedicated workshop with PNHE ?
- PNPS school: « Le diagramme HR en radio »

NOBEL PRIZE GRANTED TO RADIOASTRONOMY

NOBEL PRIZE GRANTED TO RADIOASTRONOMY

The Nobel Prize in Physics 1978

"for their discovery of cosmic microwave background radiation"

Robert Woodrow Wilson

The Nobel Prize in Physics 1974

"for their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars"

Sir Martin Ryle

Antony Hewish

The Nobel Prize in Physics 1993

"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"

Russell A. Hulse

Joseph H. Taylor Jr.