LOFAR, E-LOFAR & VLBI

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ASTRON
Leiden & Swinburne

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Outline

- LOFAR - project status
- E-LOFAR - what does the "E" stand for ?
- Related developments in VLBI:
  - (deep, wide-field) VLBI surveys,
  - the obscured accretion history of the Universe.

LOFAR in a nutshell

- 40 stations distributed across Netherlands
- > 8 stations located in other European lands
- Unexplored freq. range of 30-230 MHz
- Wide field-of view - 8 independent beams
- Millisecond time resolution
- Data buffering - capture and replay the sky!

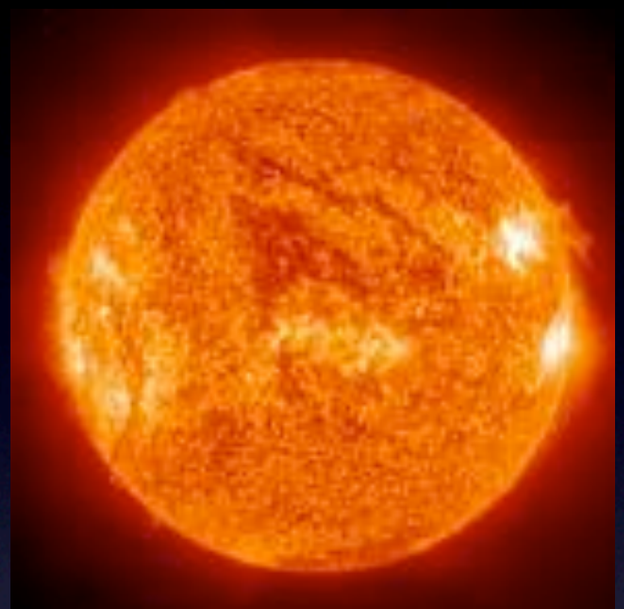
LOFAR Performance

Freq (MHz)	λ (m)	Dipole Eff. Area (m^2)	St. Eff. Area (m^2)	T_{sys} (K)	ΔS_{20} (mJy)	ΔS_{18+18} (mJy)	ΔS_{25+25} (mJy)
15	20	27.0 – 118	1296 - 5675	623373	781 - 178	429 - 97.9	308 - 70.2
30	10	27.0 – 33.3	1296 - 1600	47309	59.3 - 48.0	32.6 - 26.2	23.4 - 18.9
45	6.7	14.8	710.8	9706	22.2	12.2	8.73
60	5.0	8.33	399.8	4277	17.4	9.53	6.84
75	4.0	5.33	255.8	4573	29.0	15.9	11.4
120	2.5	1.56	1198	776	1.04	0.574	0.412
150	2.0	1.33	1021	525	0.825	0.455	0.327
180	1.7	0.93	714.2	417	0.943	0.522	0.374
210	1.4	0.68	522.2	347	1.07	0.589	0.423
240	1.3	0.52	399.4	294	1.18	0.654	0.469

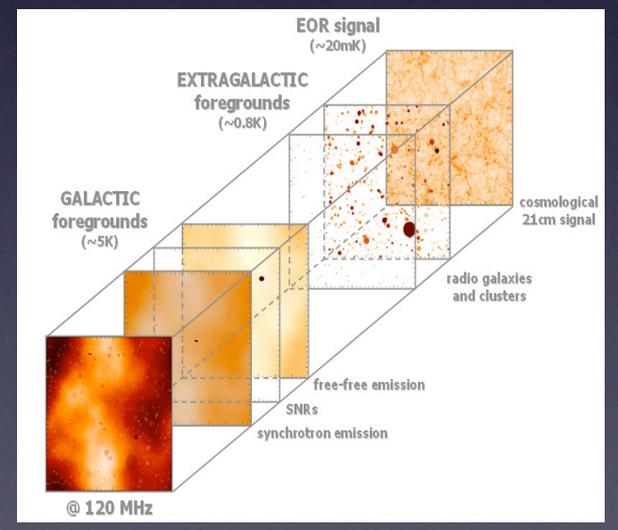
- 1 hr integration time
- 3.57 MHz eff. BW
- noise increase due to weighting: factor 1.3

With M. Pandey-Pommier

LOFAR Science Case

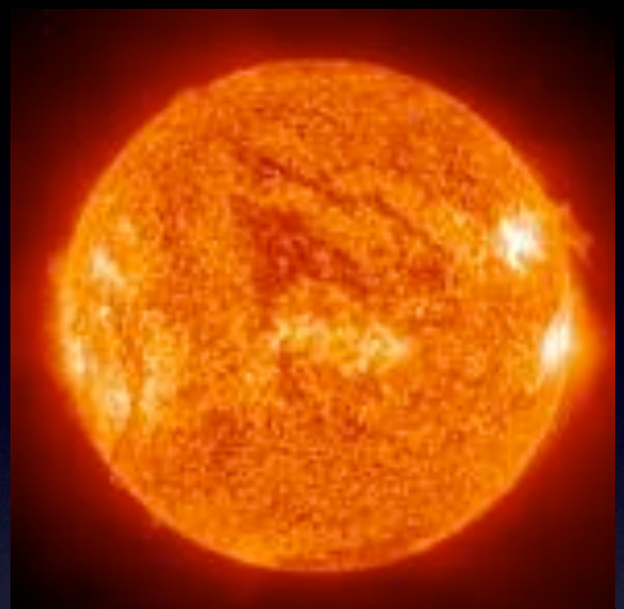


Solar System



Epoch of reionisation

LOFAR Science Case



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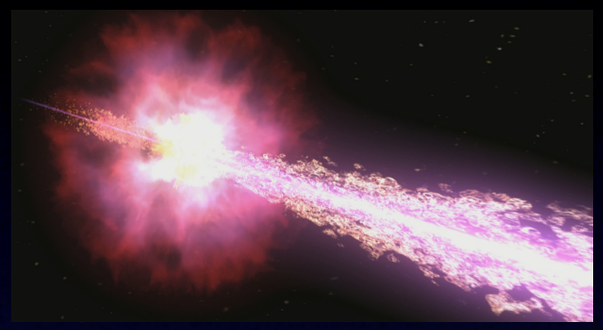
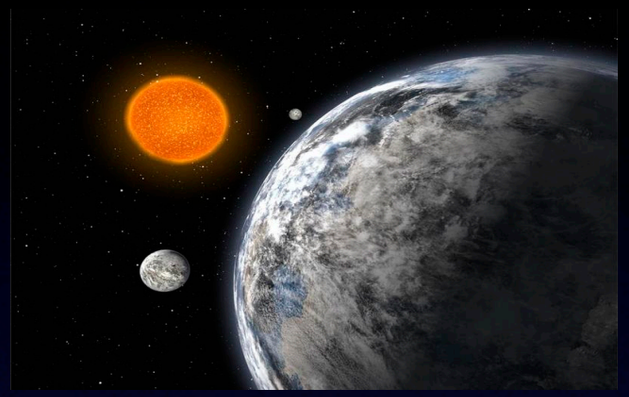
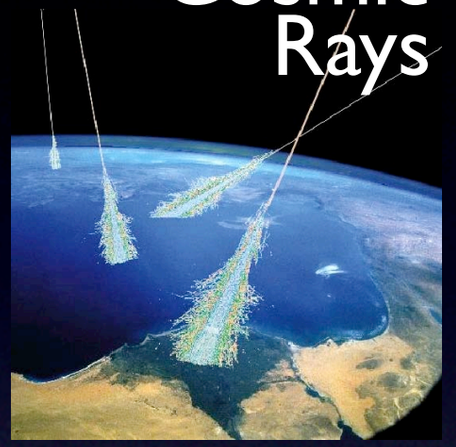
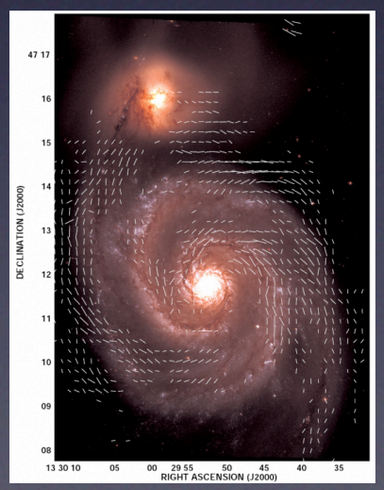


Transient sky

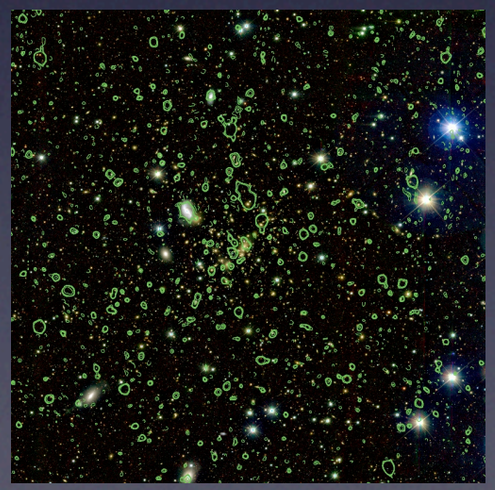


SETI/Exoplanets

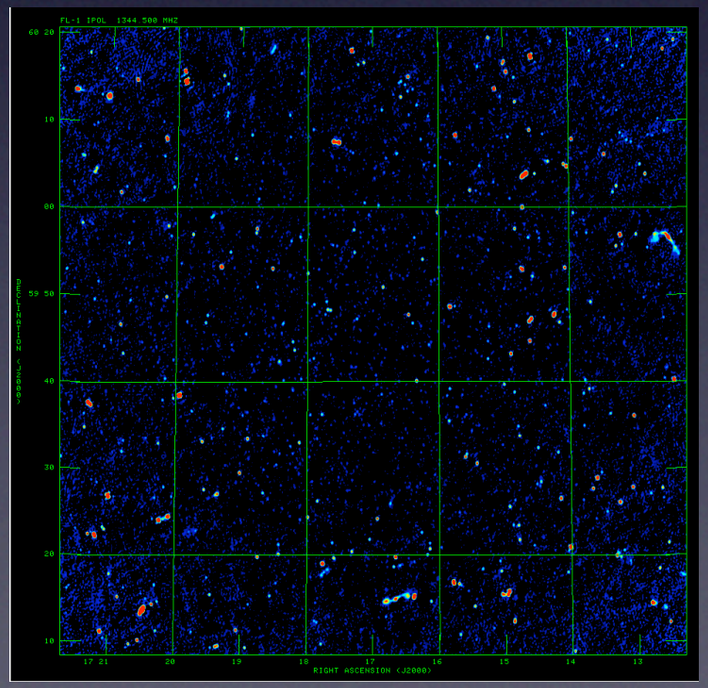




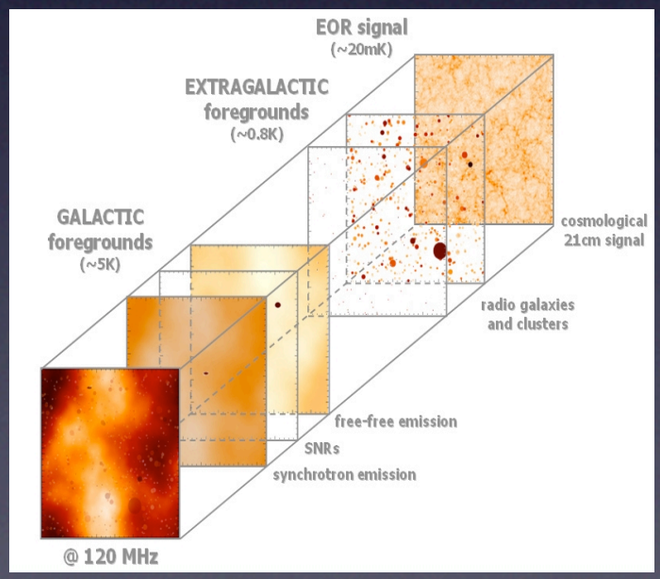
Cosmic Magnetism



LSS + Lensing



Deep Surveys



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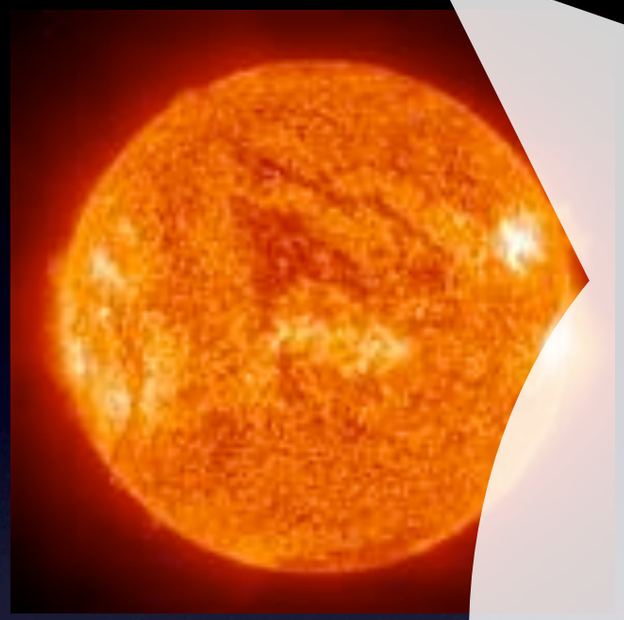

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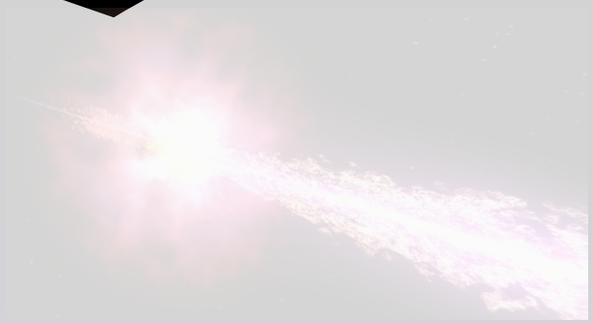

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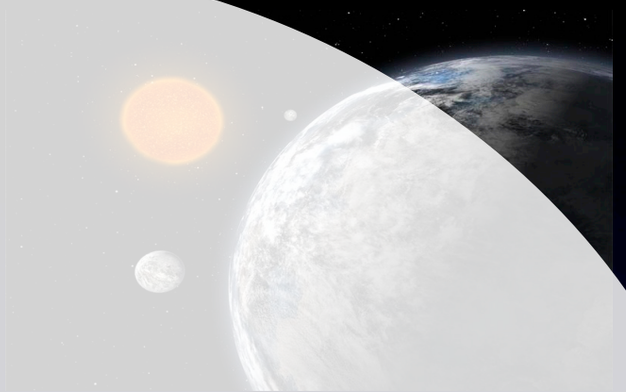

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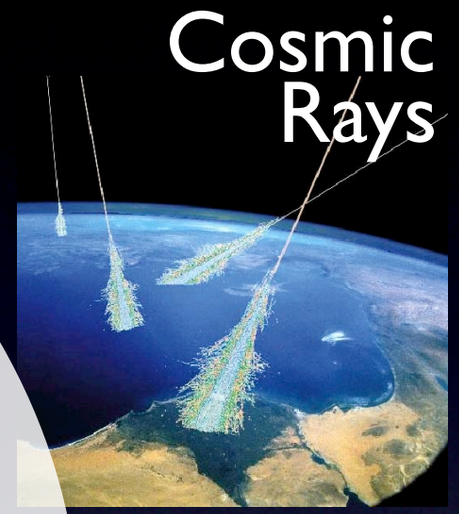
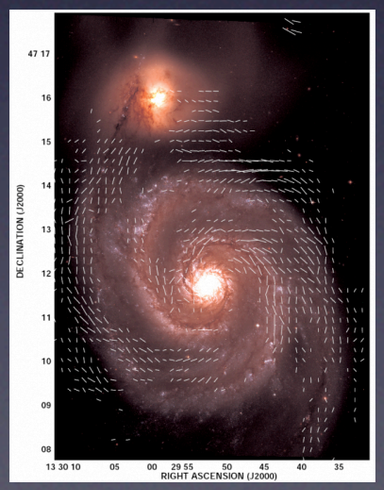


Cosmic Rays

CALL FOR PROPOSALS - END OF YEAR!



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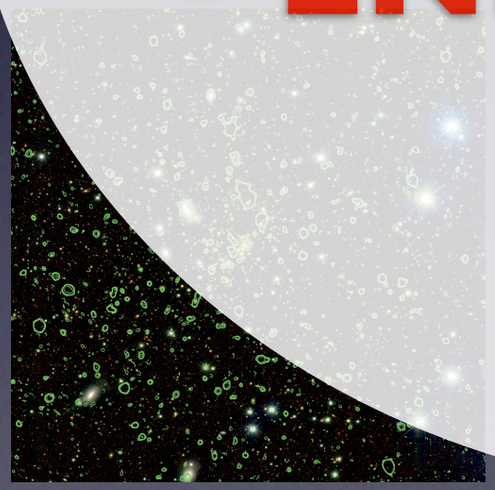

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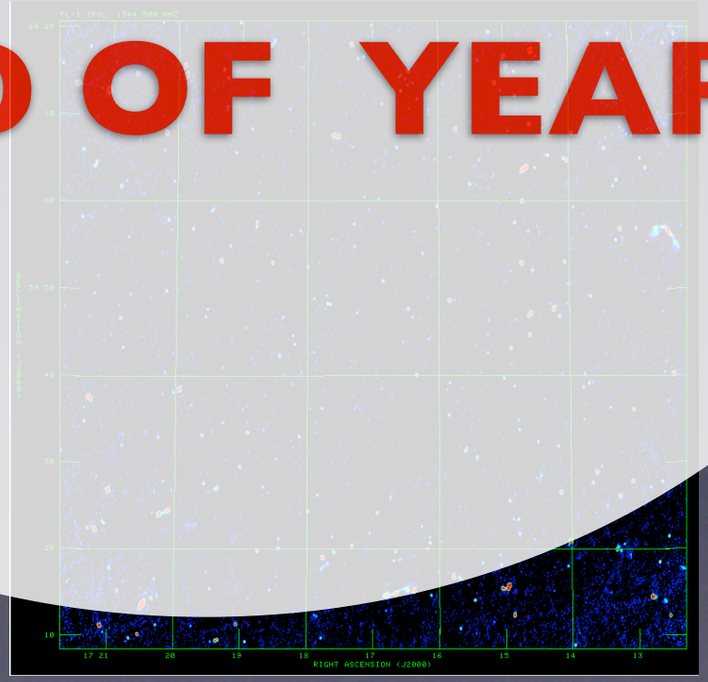

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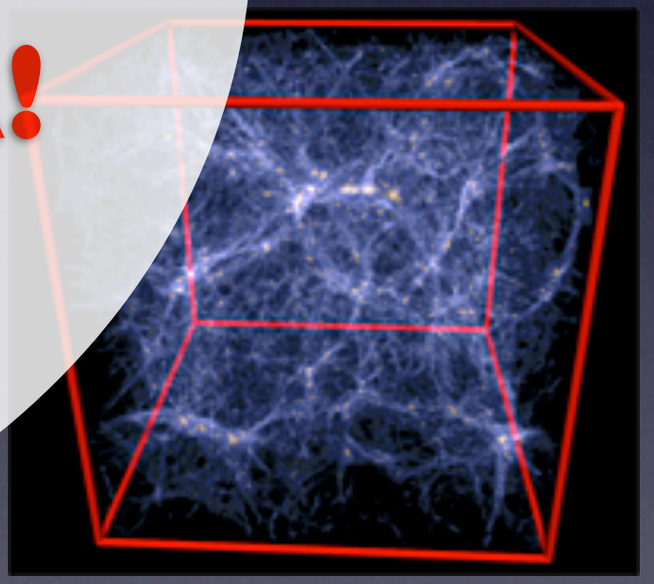
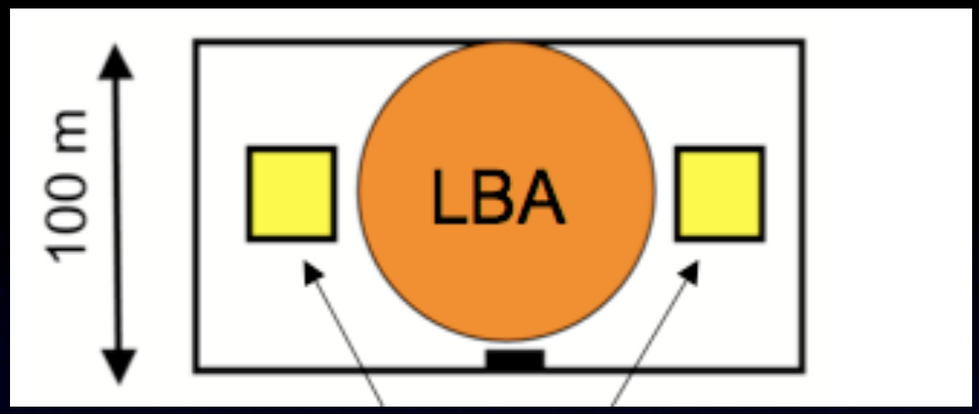


Epoch of reionisation

LOFAR status - last 12 months

Descope!



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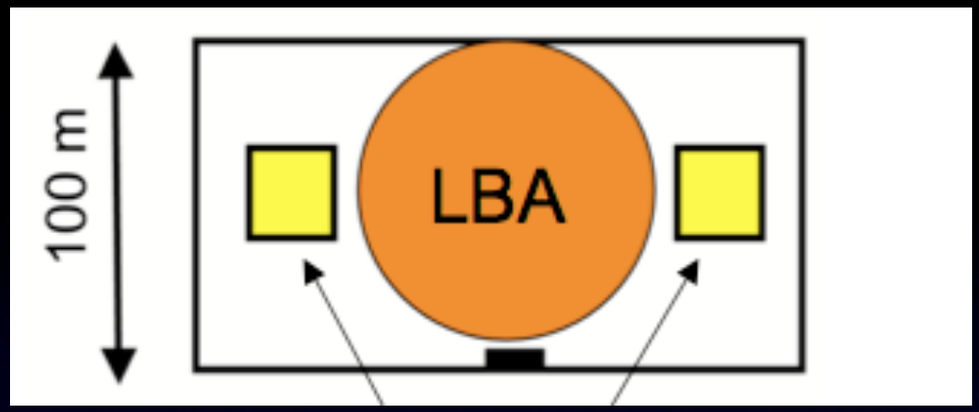

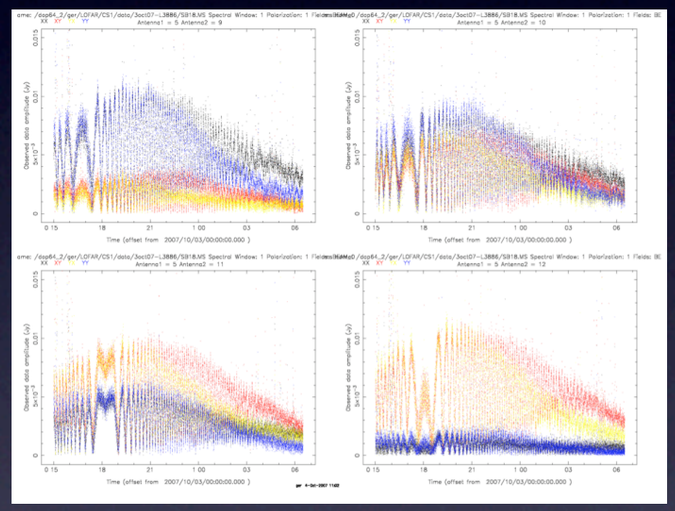

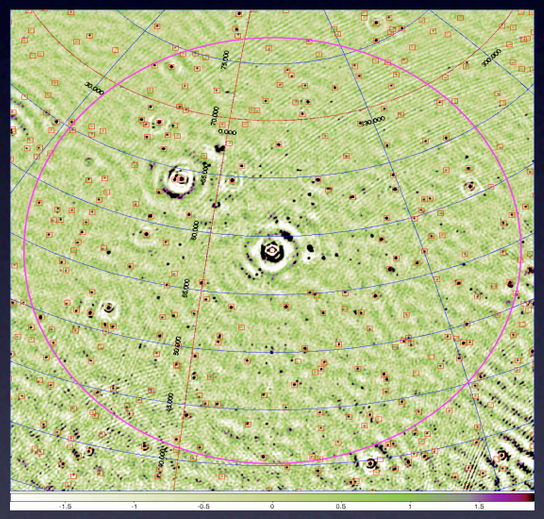

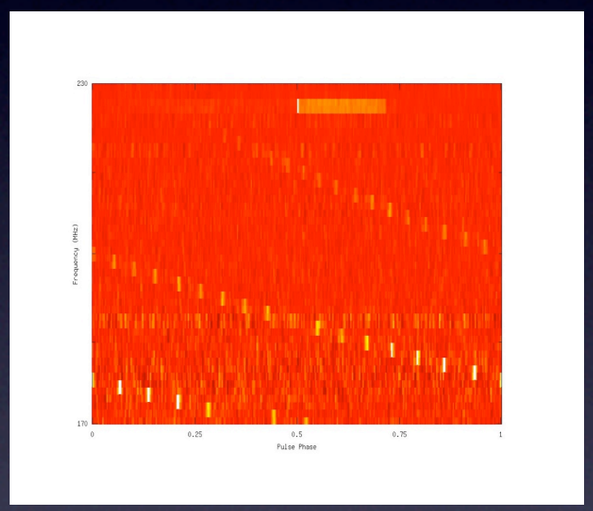

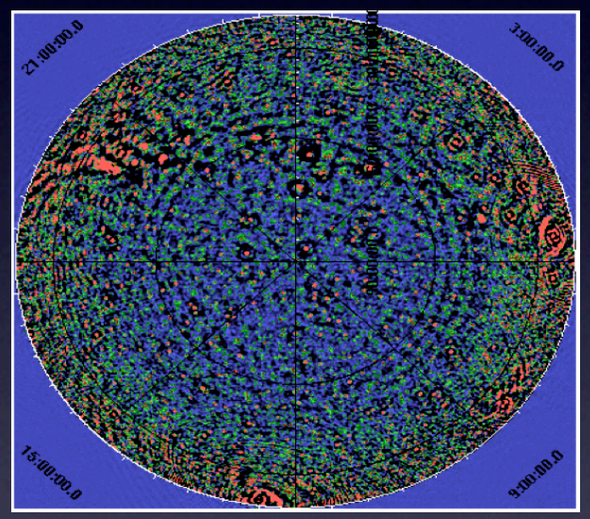

Site Preparation

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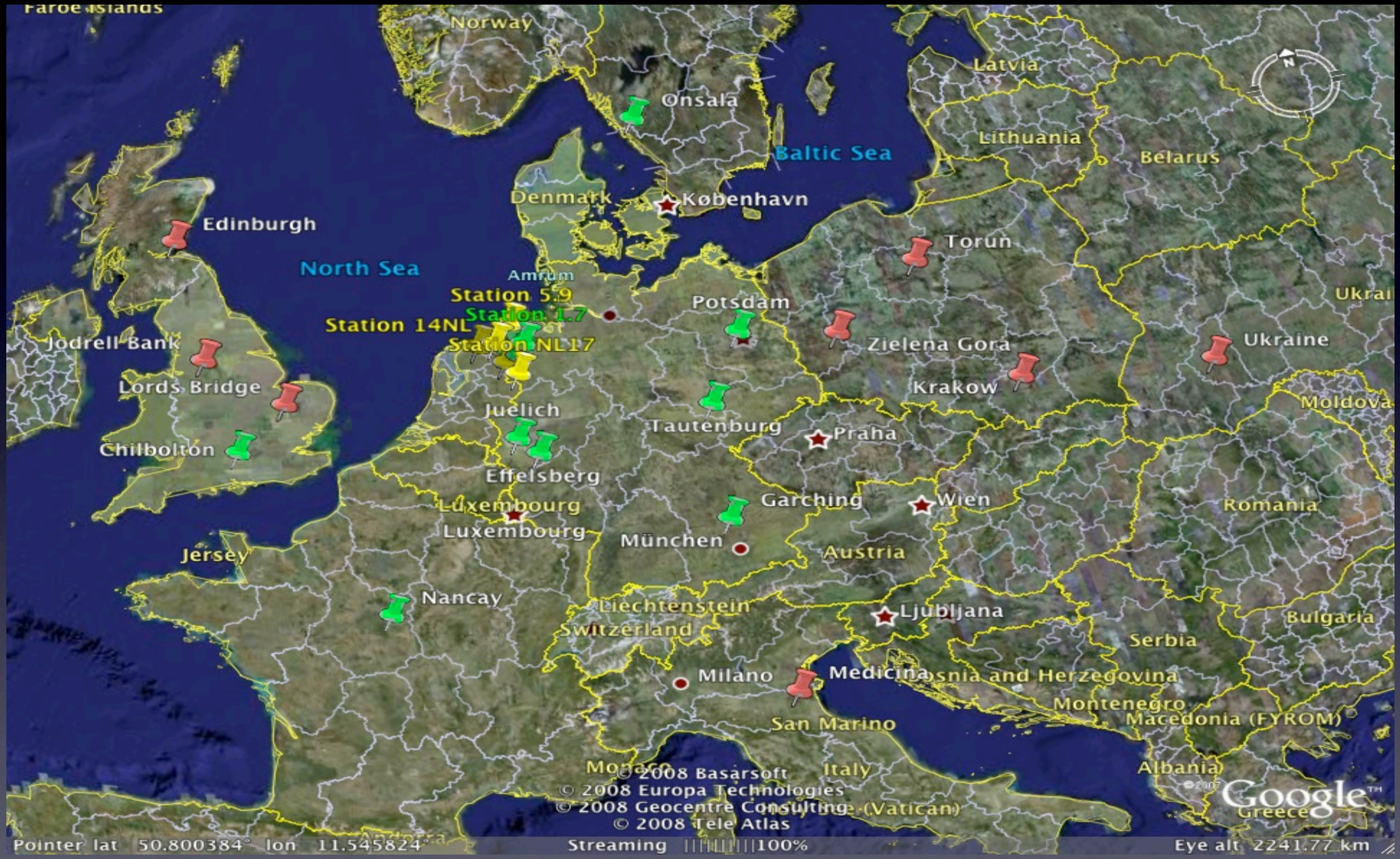
E-LOFAR:

★ **E**xpansion of LOFAR across **E**urope:

European Station	Baseline Length	Country	Status
Effelsberg	260 km	Germany-1	Funded - LBA
Garching	600 km	Germany-2	Funded - contract
Potsdam	400 km	Germany-3	Funded - contract
Tautenburg	400 km	Germany-4	Funded - contract
Julichh++	220 km	Germany-5-8	not yet funded
Nancay	750 km	France-1	Funded
Onsala	600 km	Sweden-1	Funded
UK	400 - 1000 km	UK-1-4	UK-1 funded
Italy	1000 km	IT-1	not yet funded
Ukraine	1200 km	Ukraine-1	not yet funded
Poland	600-950 km	Poland-1-3	not yet funded

???

★ **E**xpansion of LOFAR across **E**urope:



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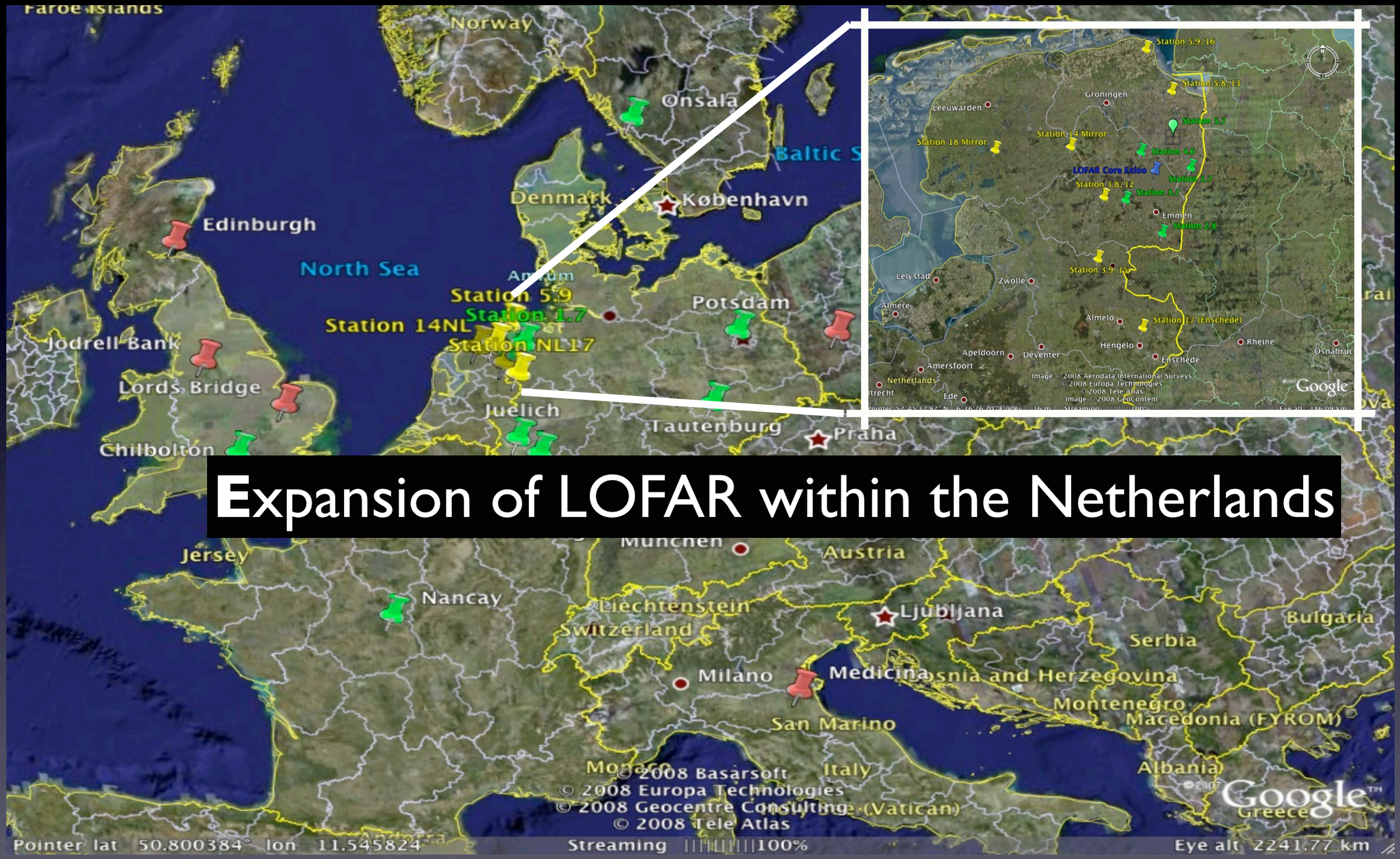
NWO

★ **E**xpansion of LOFAR across **E**urope:



Expansion of LOFAR within the Netherlands

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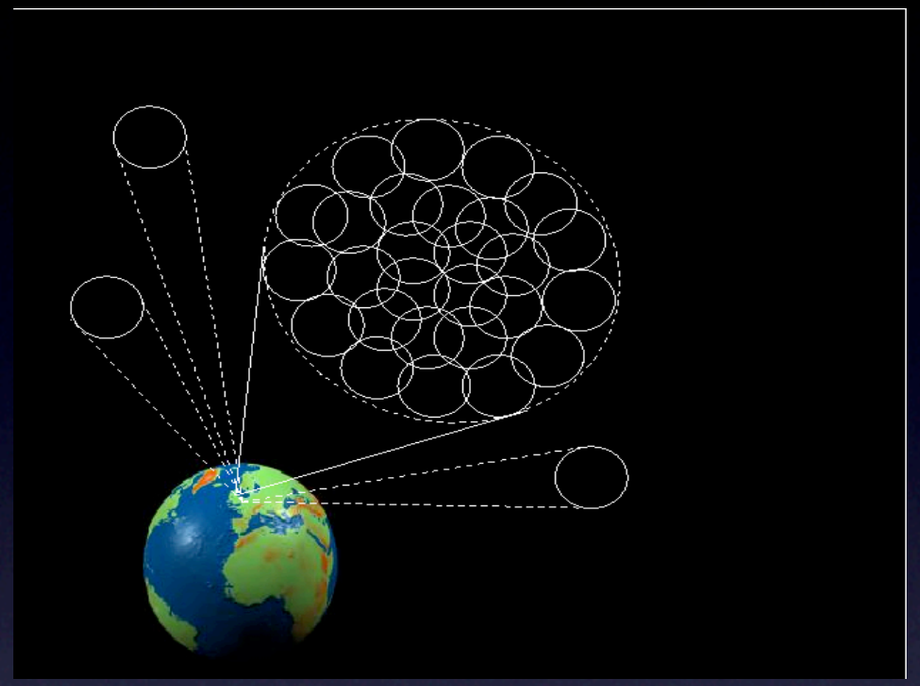
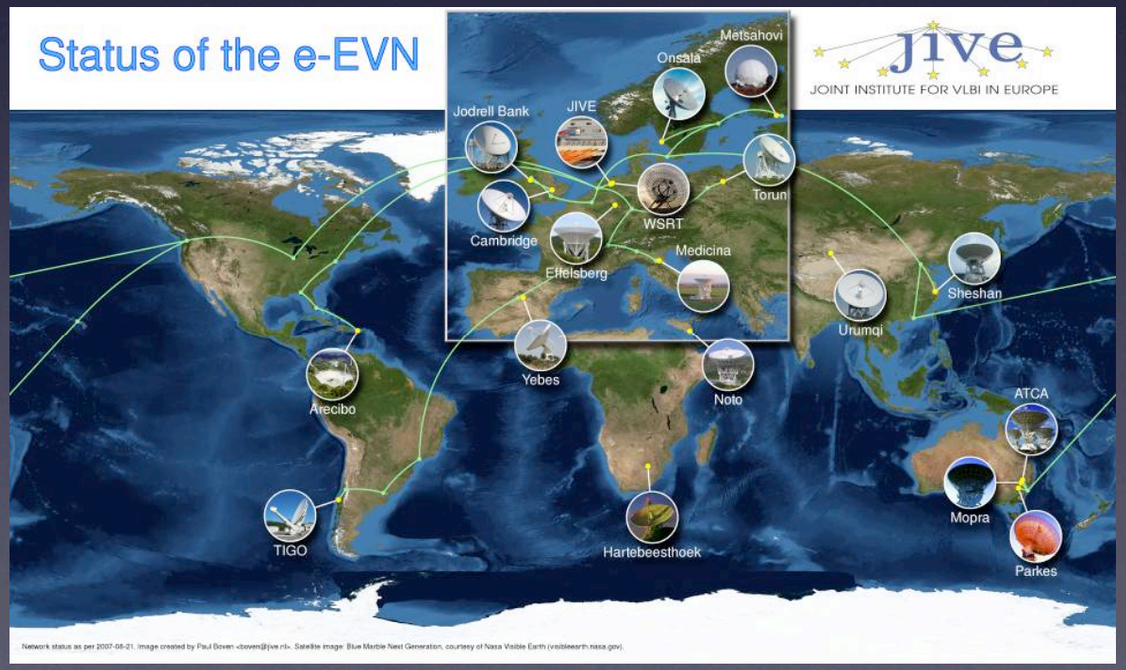
NWO

LOFAR - synergy with VLBI

- Transients and e-VLBI - obvious!

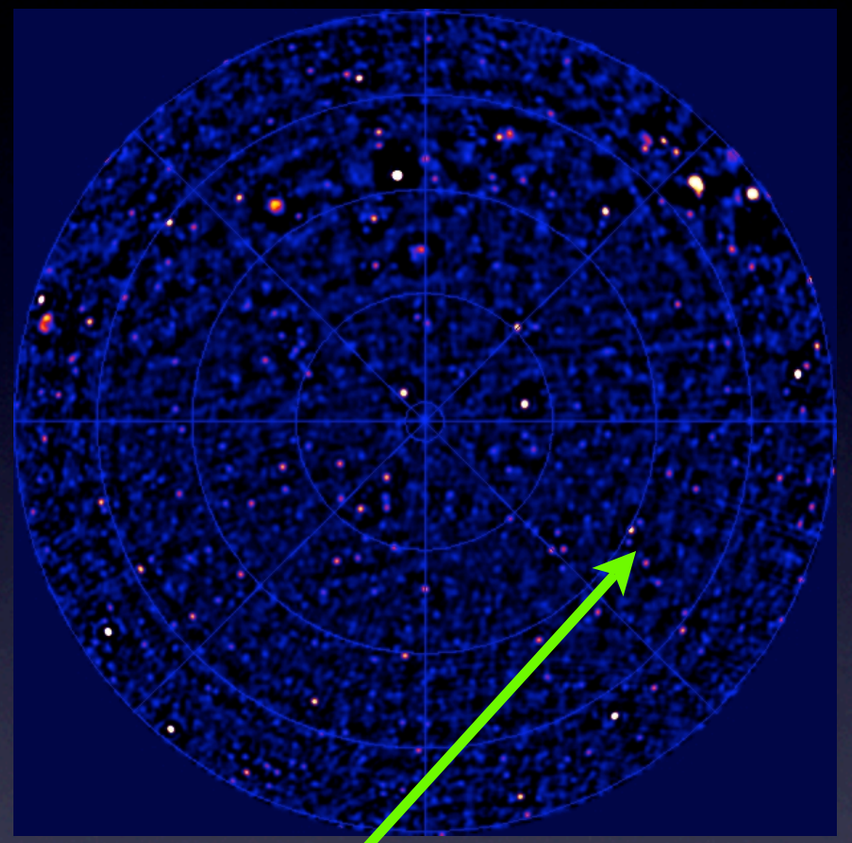


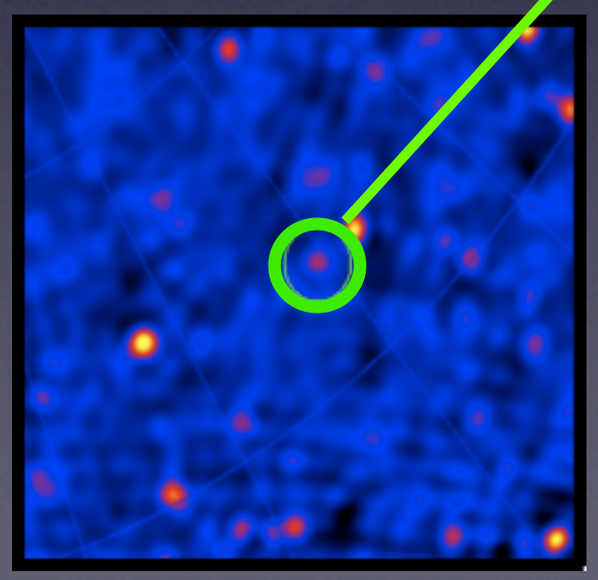


- Global LOFAR obvious next step!?

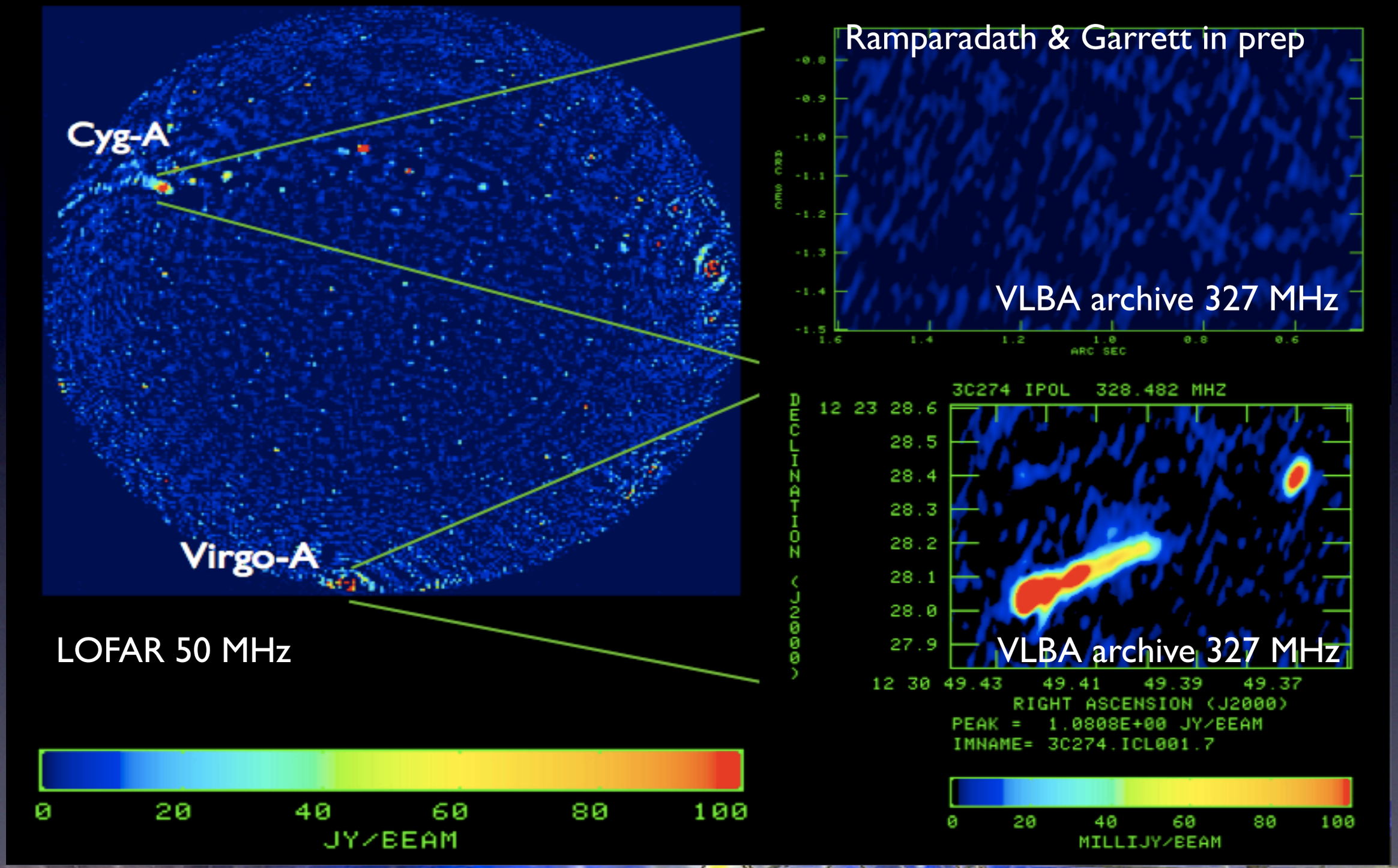
LOFAR - synergy with VLBI

- Deep, wide-field VLBI surveys:
  - calibrators for LOFAR (& RadioAstron),
  - characterising the low-frequency/high resolution sky,
  - (obscured) accretion... across cosmic time.



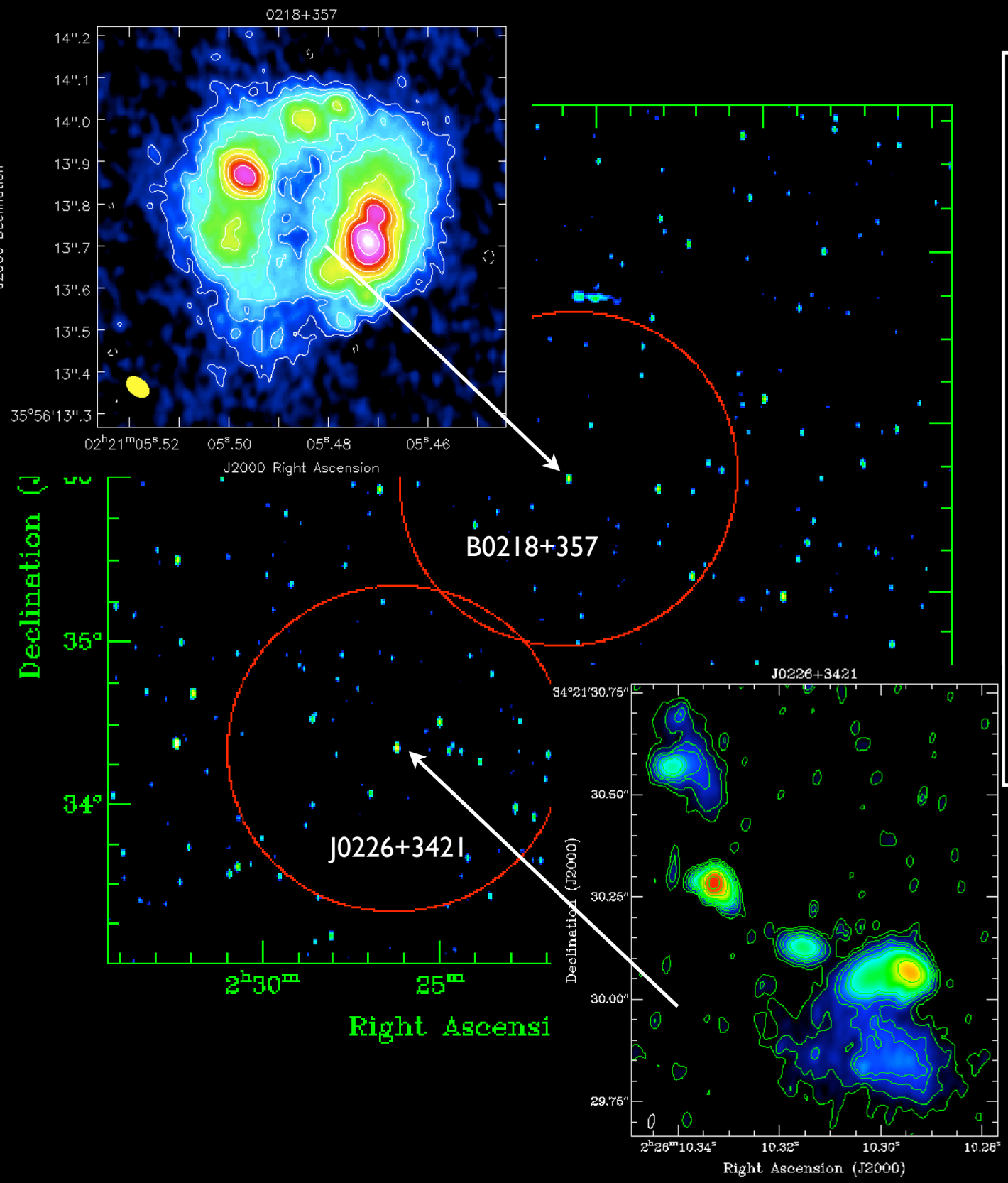


- **Characterising low-v sky at high resolution:**



Wide-field, Low Frequency VLBI 327 MHz Surveys

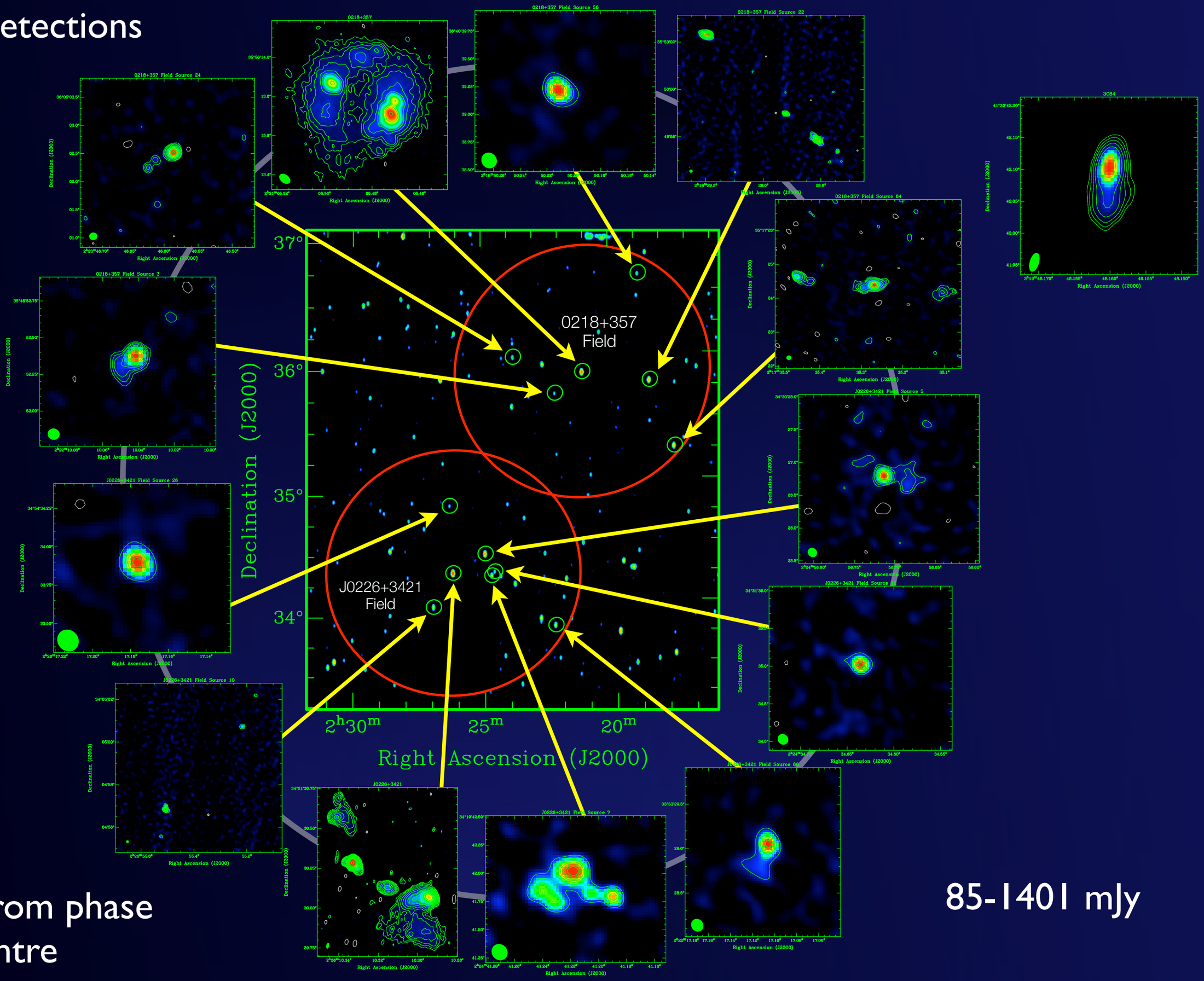
- Lenc et al. 2008



- VLBA + Jodrell Bank + WSRT @ 327 MHz
- Keep data in unaveraged form to prevent smearing effects and taper data as necessary
- Map-out small regions of sky around potential target sources (drawn from WENNS catalogue)
- Use "in-beam" self-calibration of well detected sources to calibrate surrounding and much fainter sources in the rest of the field-of-view

- Choose "goldilocks" calibrators sources:
  - Not too bright & not too faint
  - At least one should be interesting in its own right, in order to secure observing time (Wucknitz et al.)!

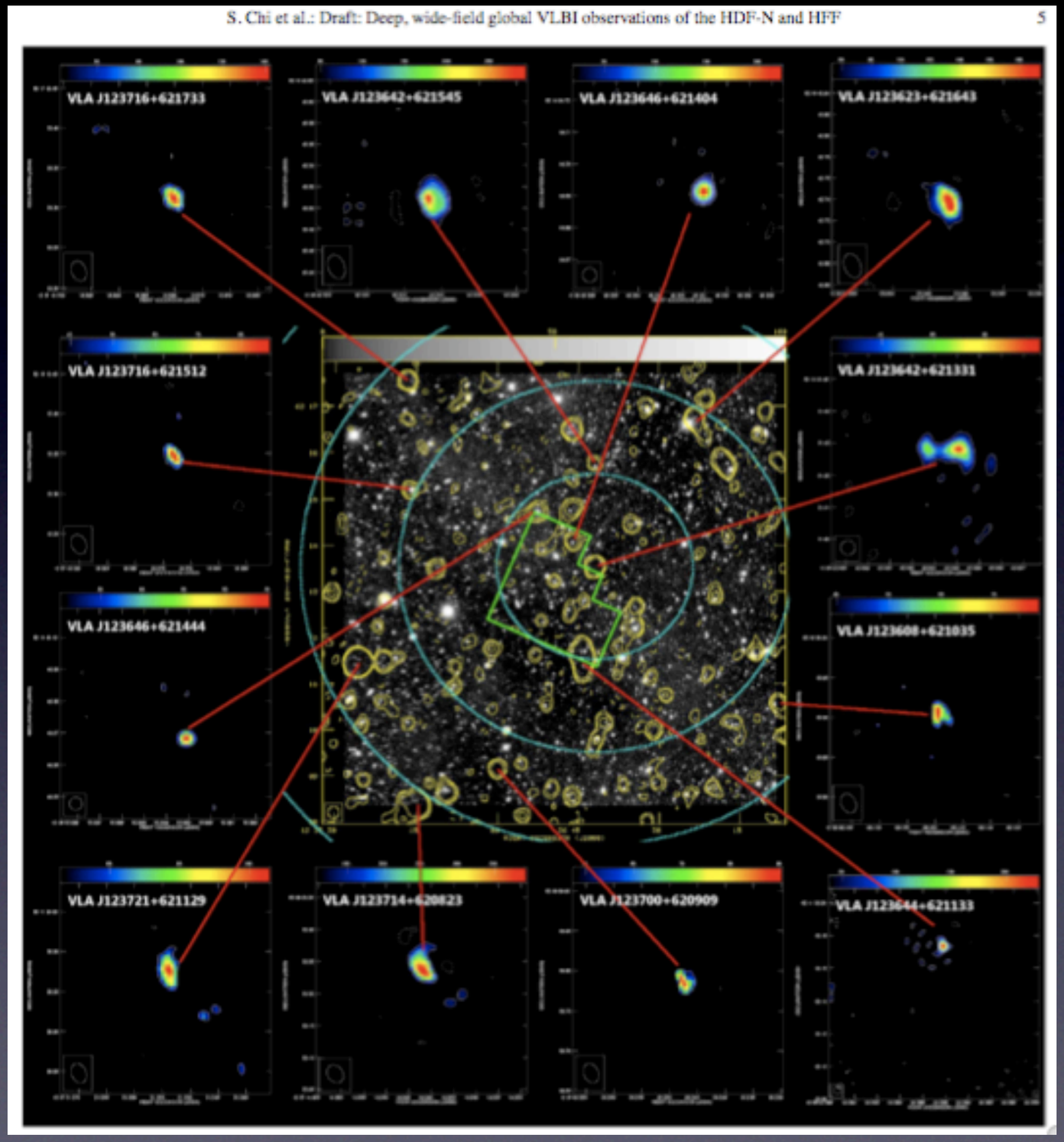
7-12σ detections

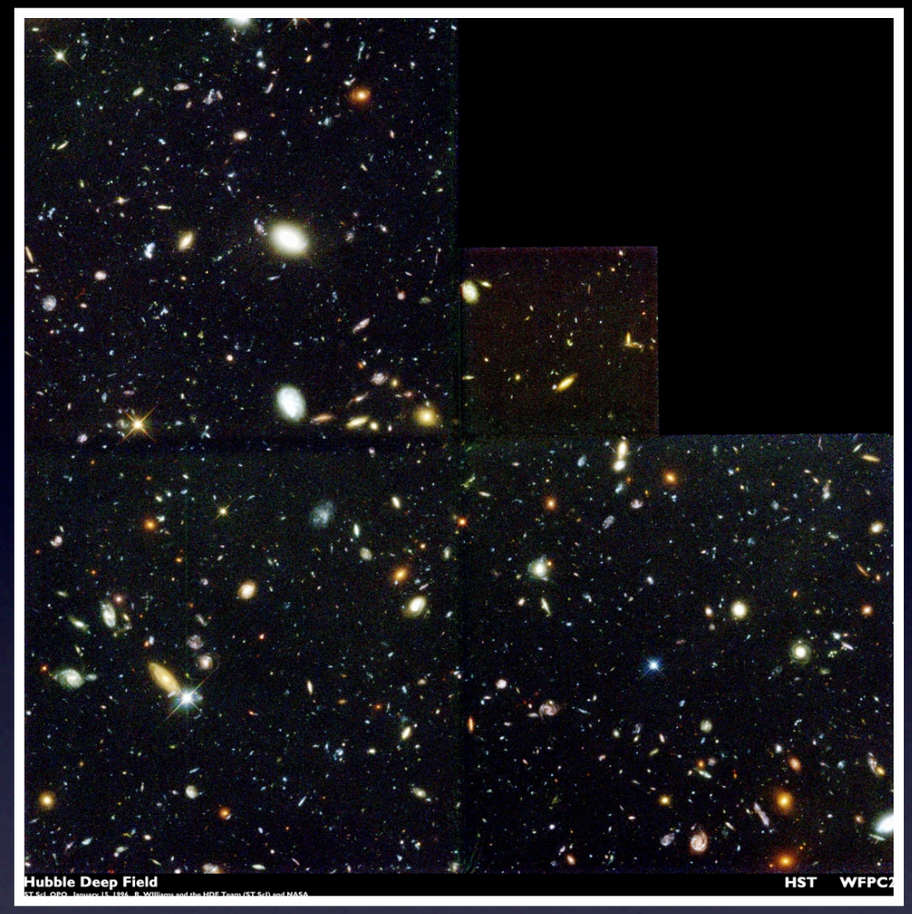


16’-58’ from phase centre

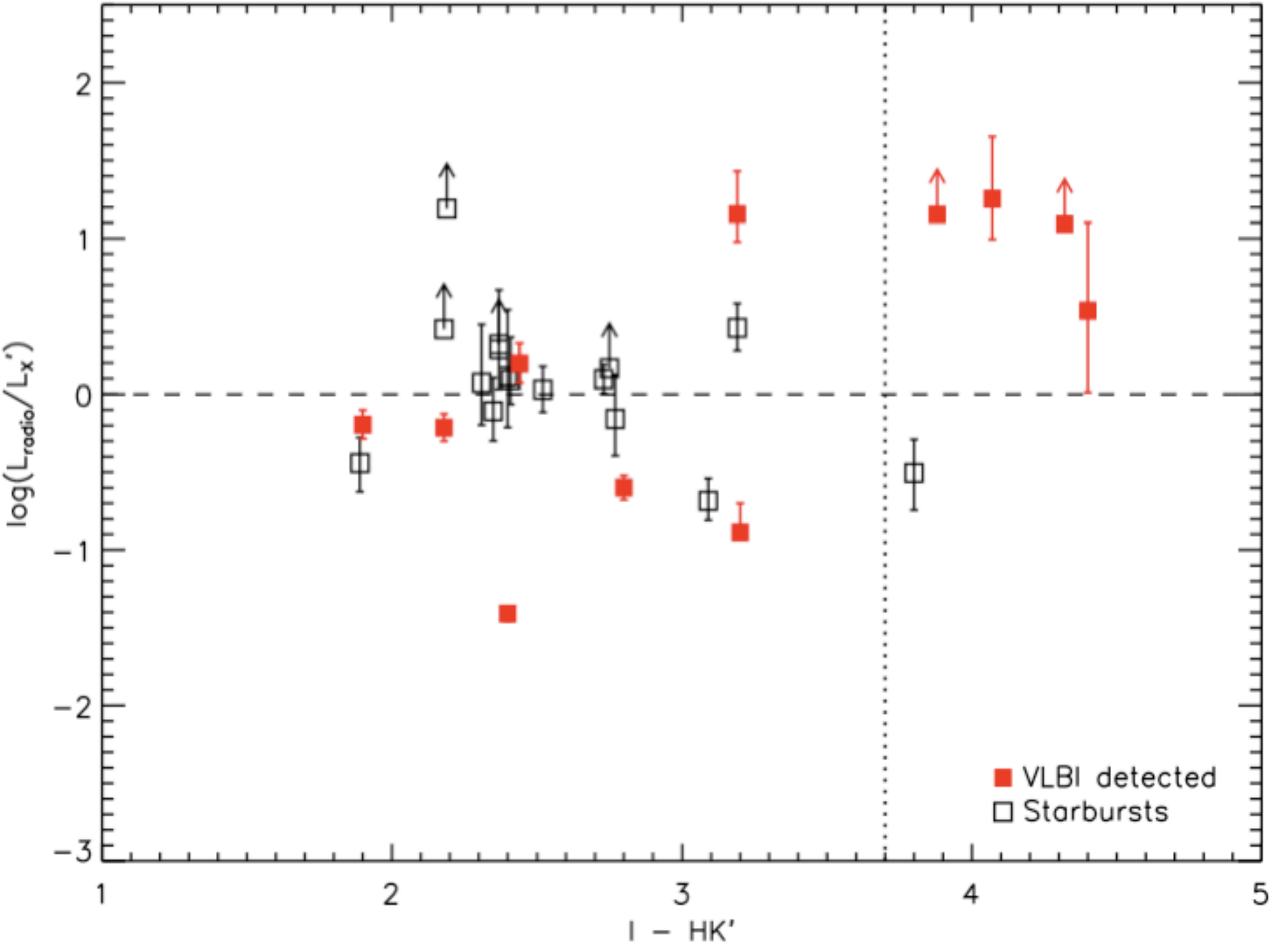
85-1401 mJy

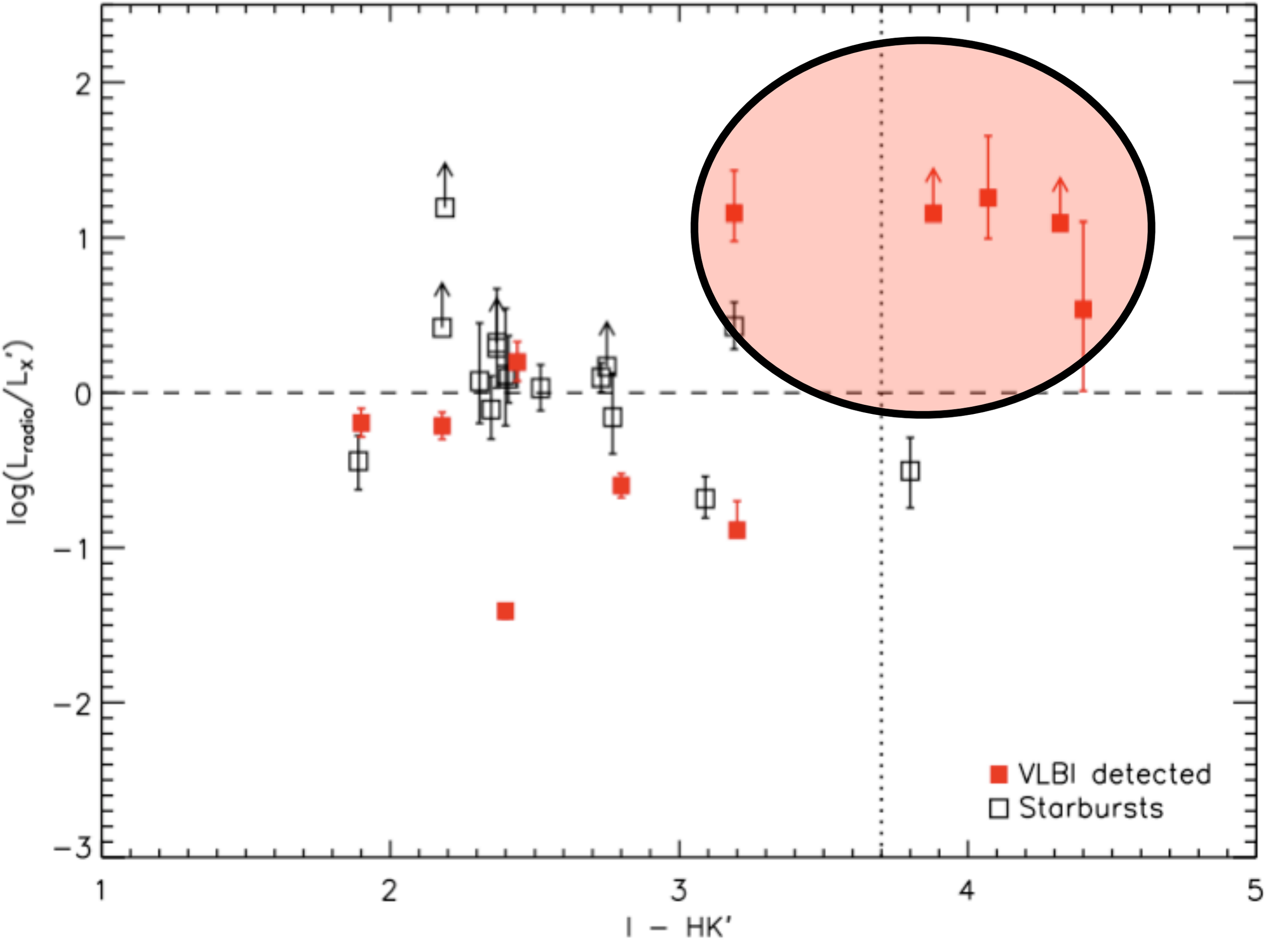
Hubble Deep Field North (Chi et al. in prep)





Global VLBI
~ 7 microJy noise


2
1
0
−1
−2
−3
log(L_radio/L_X')
1
2
3
4
5
I − HK'
VLBI detected
Starbursts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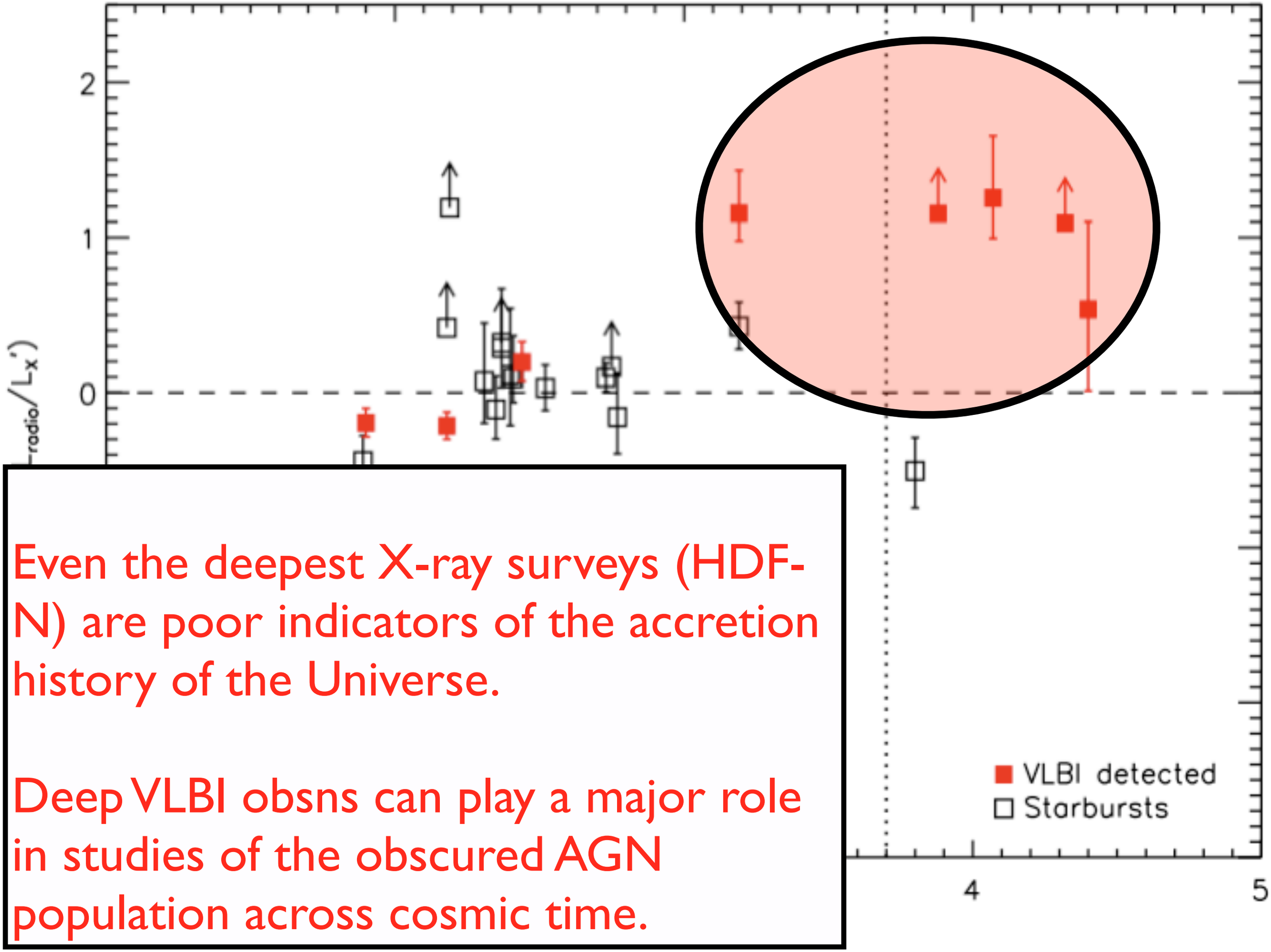
−2
−3
log(L_radio/L_X')
1
2
3
4
5
I − HK'
VLBI detected
Starbursts

Even the deepest X-ray surveys (HDF-N) are poor indicators of the accretion history of the Universe.

Deep VLBI obsns can play a major role in studies of the obscured AGN population across cosmic time.



- Potential of LOFAR is staggering:
  - from here (moon) to infinity (EOR).
- Follow progress on ASTRON JIVE Daily Image or LOFAR news exploder.
- The international baselines are an essential part of LOFAR.
- Open-skies - Individuals and small groups also important!!!!!

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- Open-skies - Individuals and small groups also important!!!!!
- **EVN users especially welcome to apply for time!**