Subarcsecond imaging of nearby galaxies using international LOFAR baselines

Eskil Varenius
Chalmers University of Technology
Onsala Space Observatory

Supervisors: J. Conway, S. Aalto, I. Martí-Vidal

+ Long baseline working group

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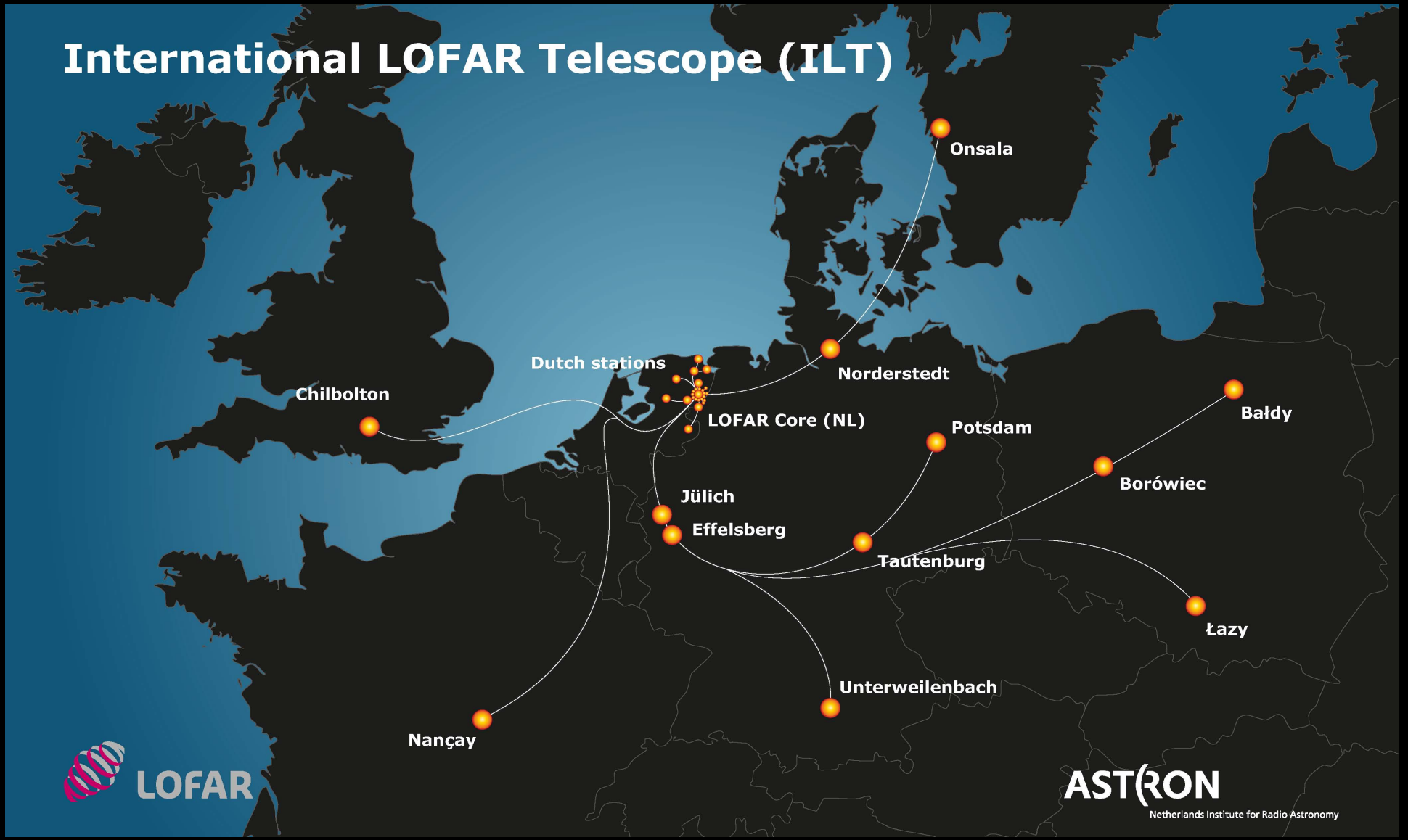
Outline

- Why International LOFAR baselines?
- Nearby galaxies
  - M 82: A record in resolution and sensitivity
  - Arp 220: Extended emission and outflows.
  - (Also NGC 3079 and Arp 299: Ask me if interested)
- Summary

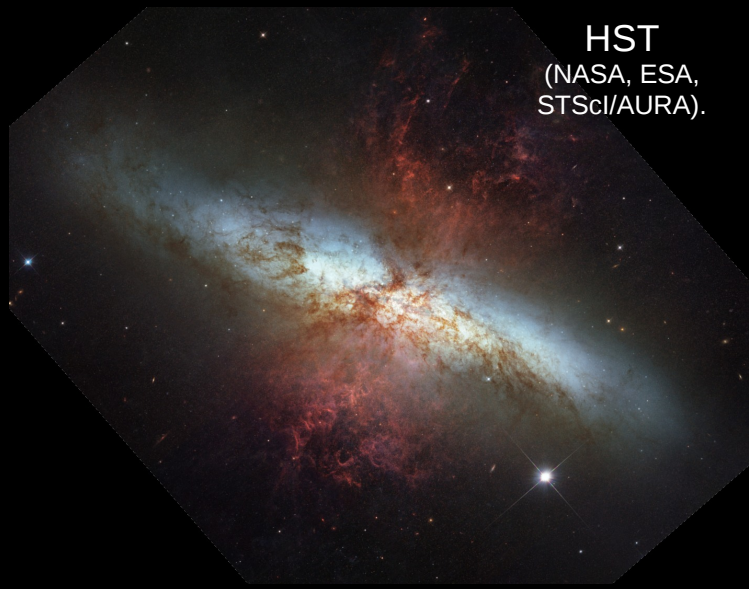
Why international baselines?



- High resolution: 2m / 1000km ≈ 0.4"
- “Simpler” calibration using small fields (data size, interference)

International baseline imaging: M 82 at 150 MHz

Why?



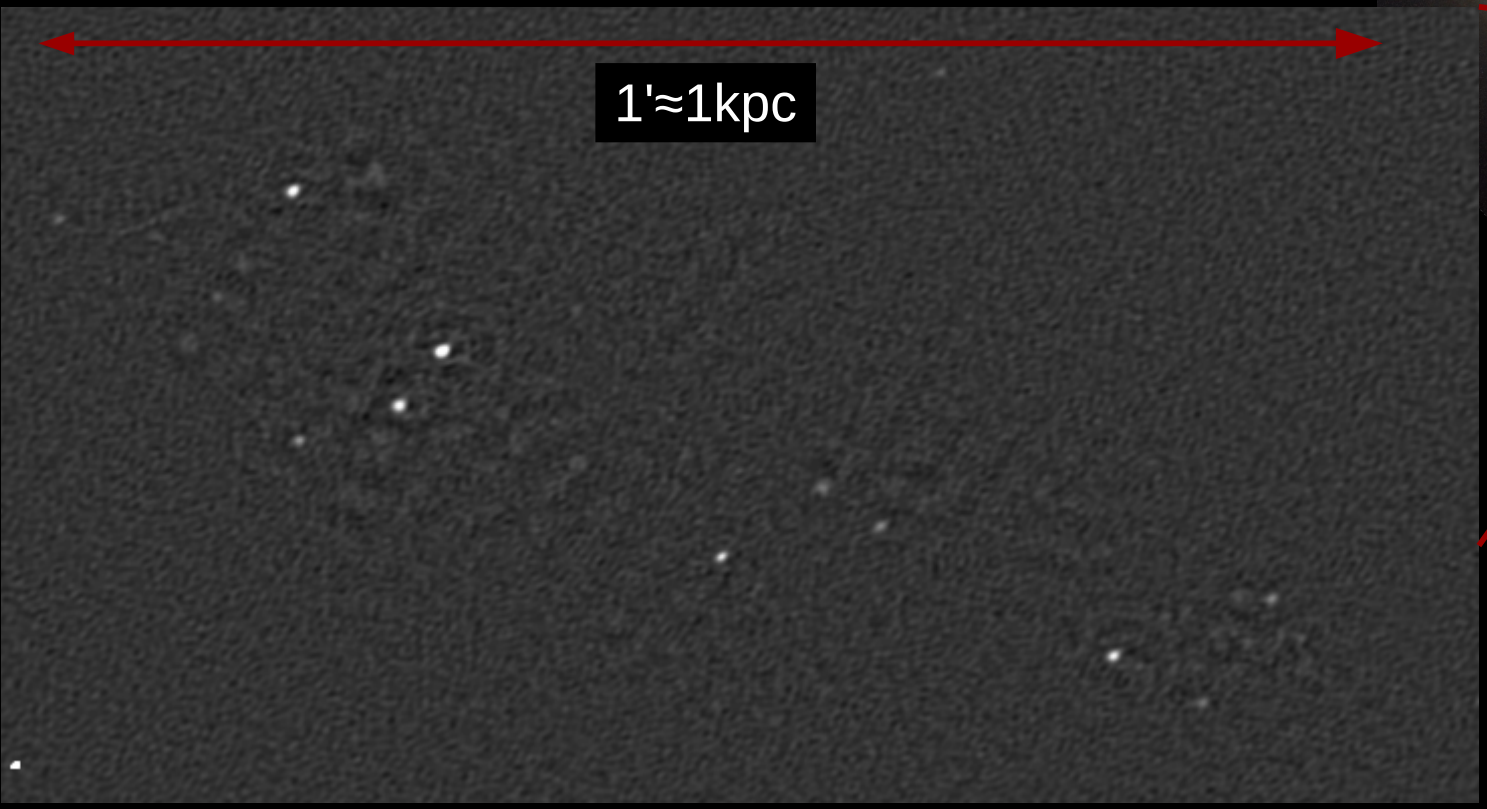
HST
(NASA, ESA, STScI/AURA).

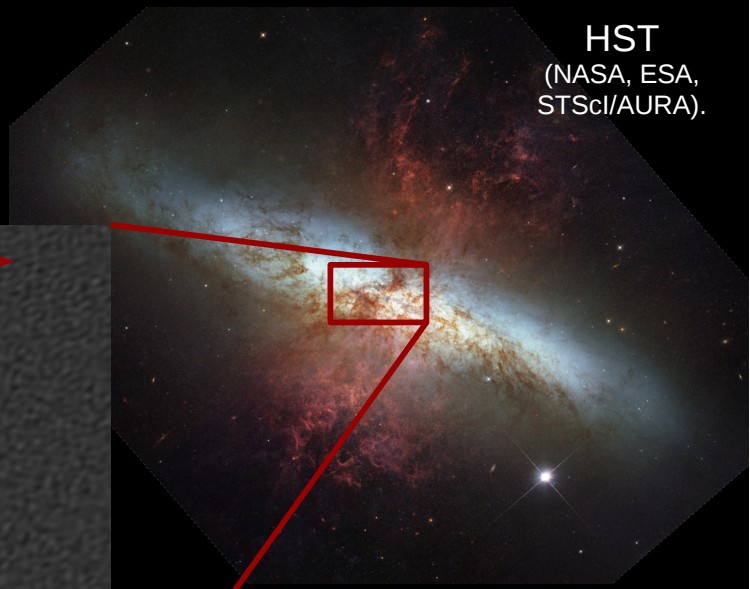
- Study star formation: nearby starburst.
- With SNRs < 1": Need Int. LOFAR baselines.
- Well studied: Good first target.

International baseline imaging: M 82 at 150 MHz

LC0_026: 16 MHz bandwidth, 16 hours.

Resolution 0.3'', rms noise 0.15 mJy/beam.





Results:

- Detect 16 objects (7 new)

Varenius et al. (2015), A&A.

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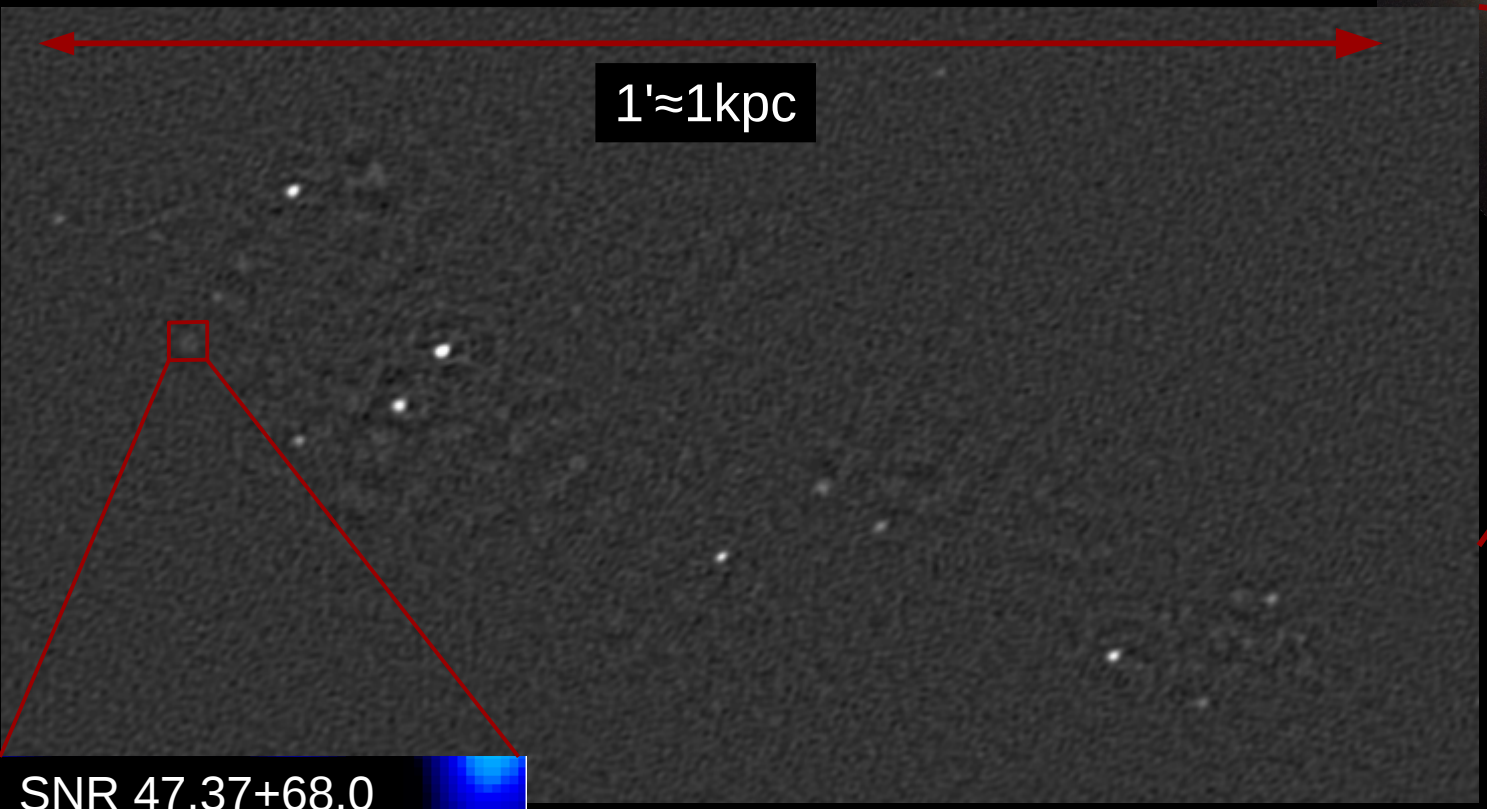

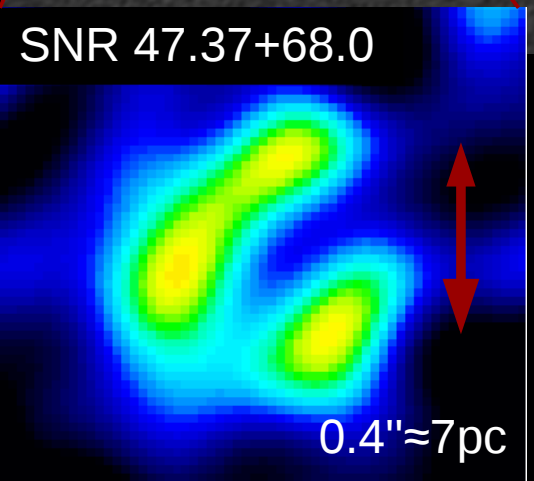

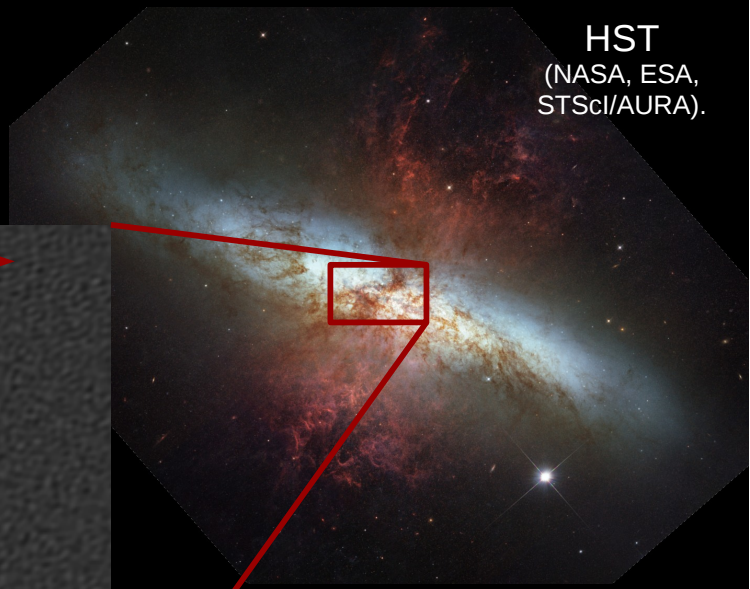

Results:

- Detect 16 objects (7 new)
- Resolve SNR shells

Varenius et al. (2015), A&A.

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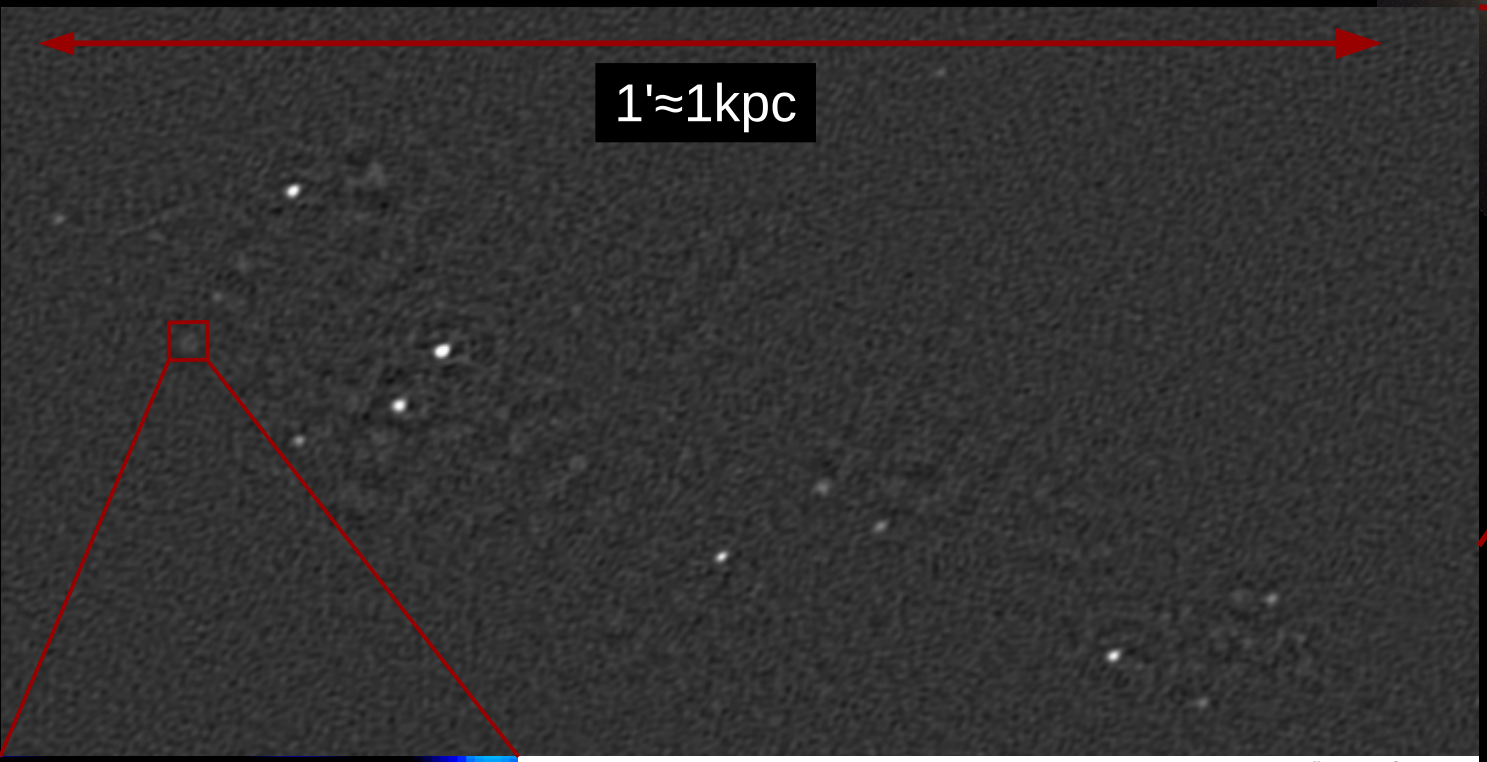
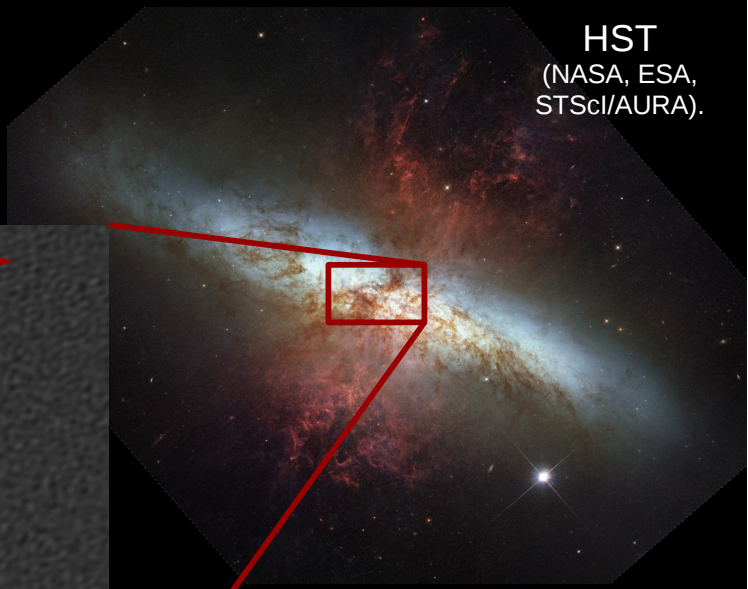
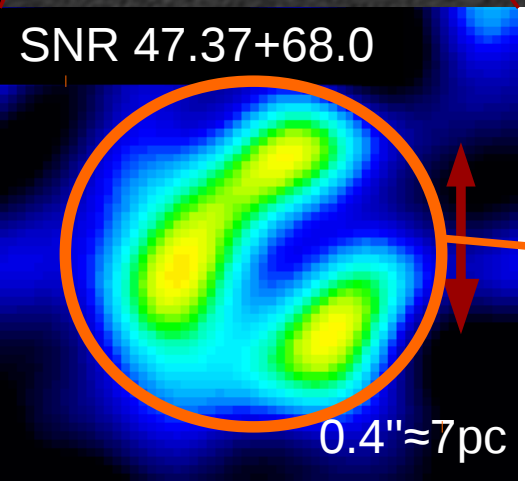
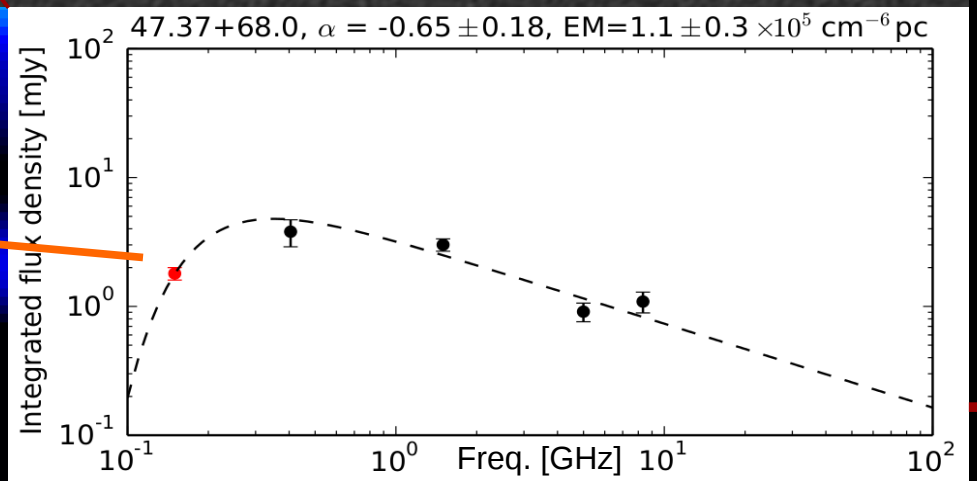








Results:

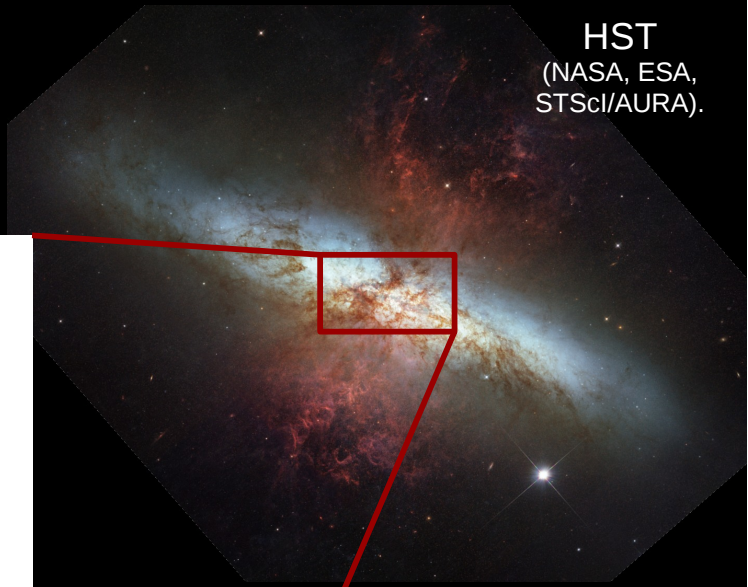
- Detect 16 objects (7 new)
- Resolve SNR shells
- Probe ISM structure through low-freq turnovers in SNR spectra.

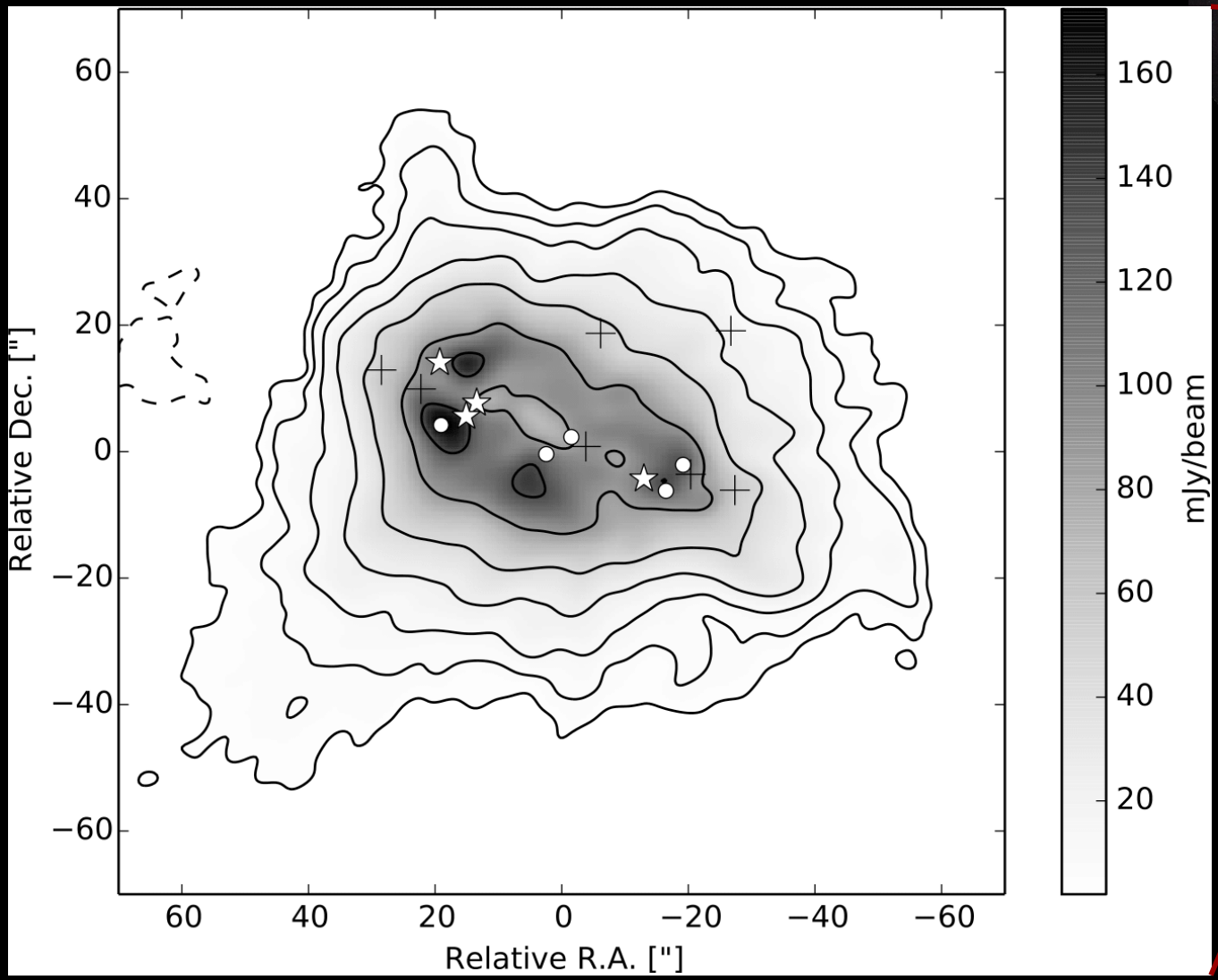
Varenius et al. (2015), A&A.

Int. cal. but also remote baseline imaging!

LC0_026: 16 MHz bandwidth, 16 hours.

Resolution 4", image noise 0.27 mJy/beam.



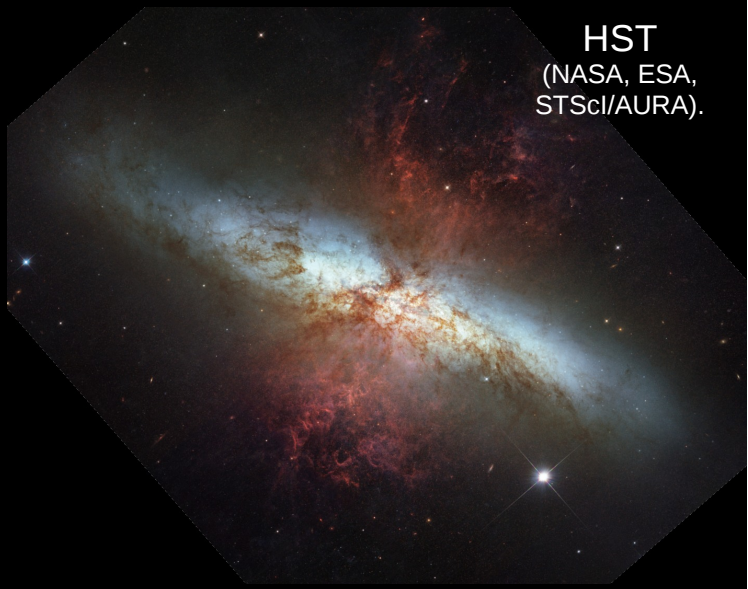


+ = new
* = Turn-over
o = Power-law

Lowest contours at (-10, 10) σ.

Varenius et al. (2015), A&A.

Key results from M 82



HST
(NASA, ESA, STScI/AURA).

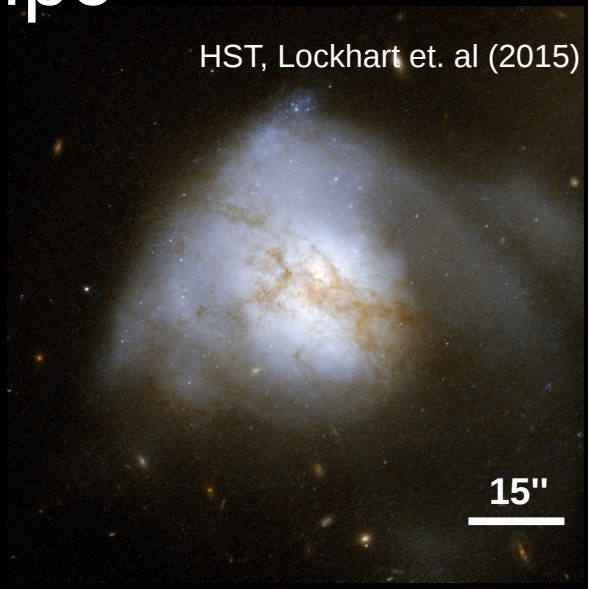
- Subarcsecond imaging works!

- Free-free absorption is non-uniform in M82.

- M82 brightest above and below the disk

  -> Majort part of 150 MHz emission from halo/outflow.

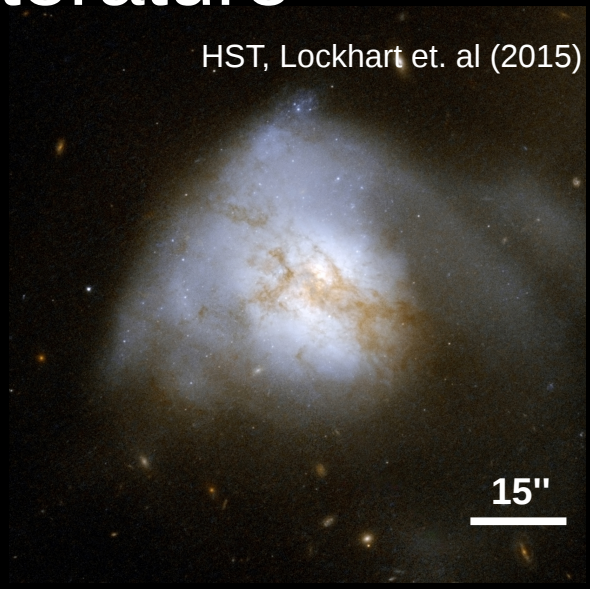
The ULIRG Arp 220 at 77 Mpc

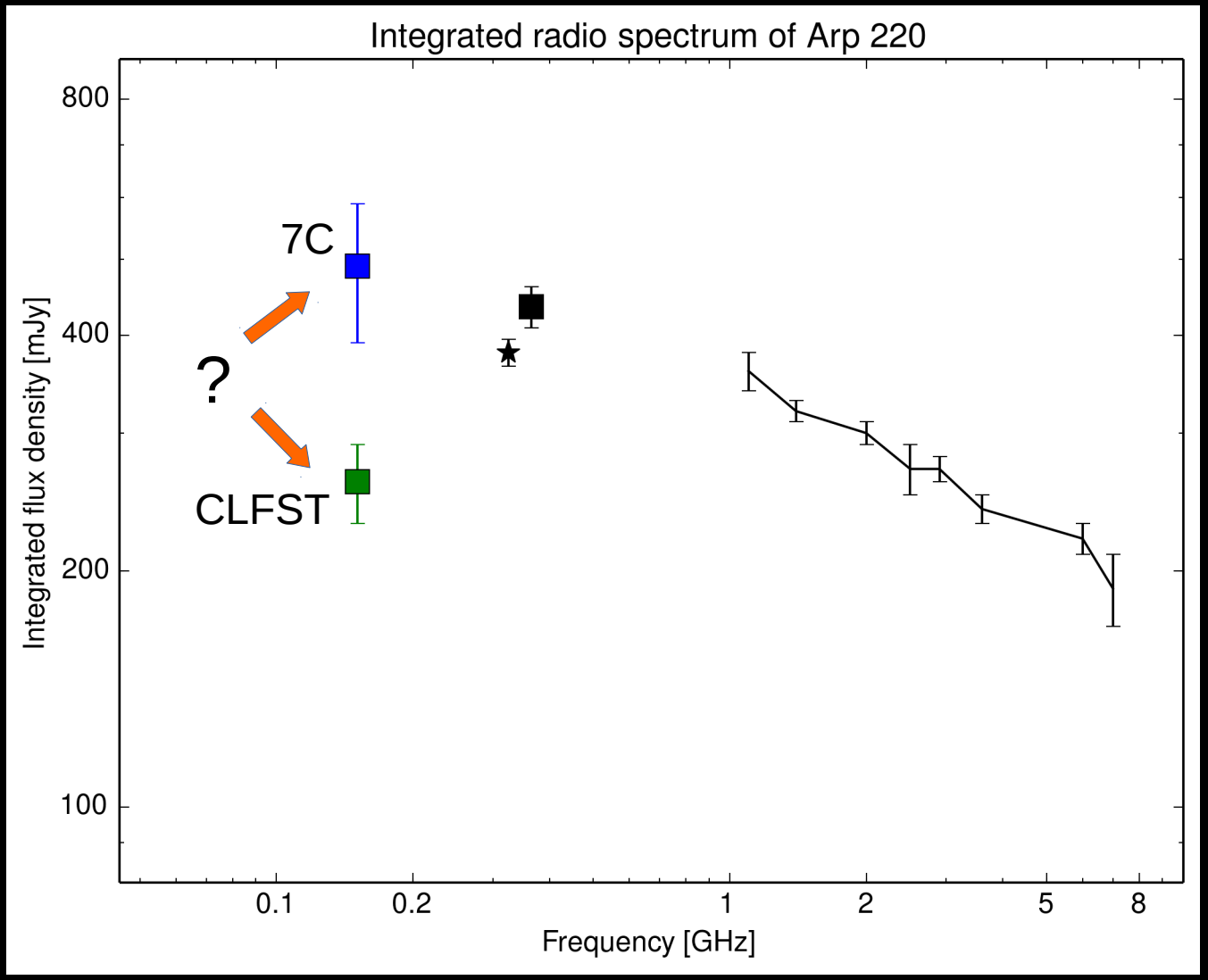


Why?

- Extreme environment (ULIRG: $L_{IR}>10^{12}L_{sun}$)
- Merger with two nuclei 1'' apart
- Starburst: ~230 M_{sun} per year

Integrated flux of Arp 220 from literature

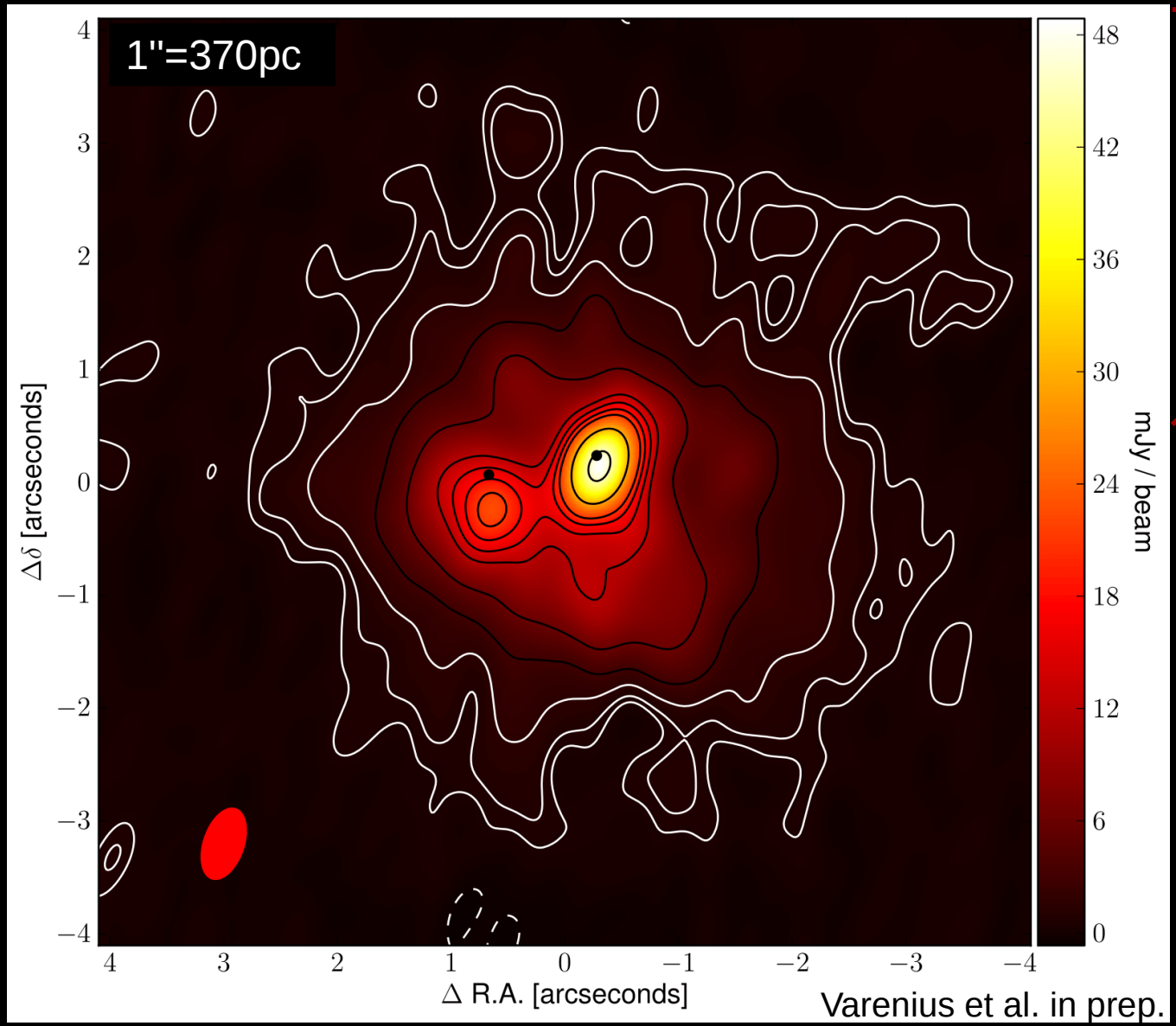


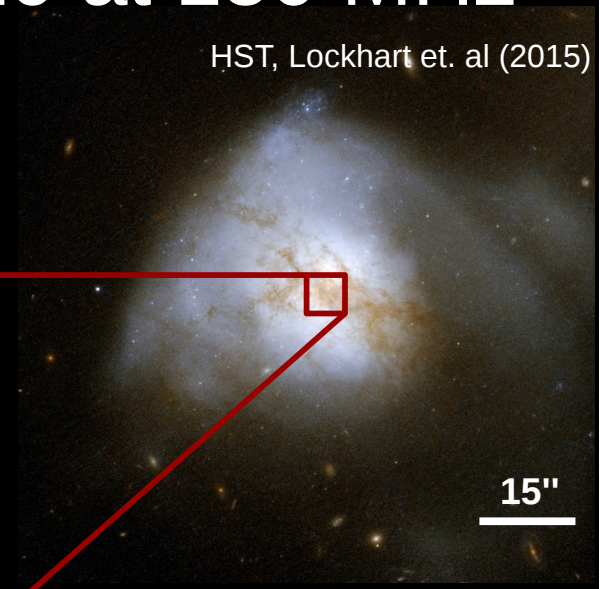


International baseline imaging: Arp 220 at 150 MHz

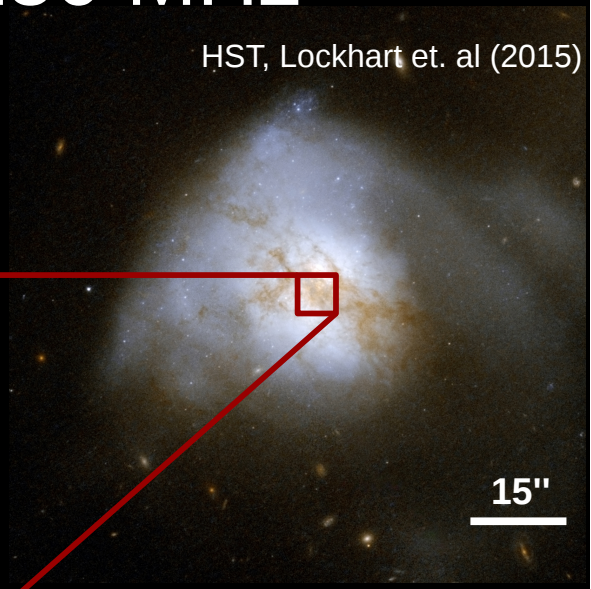
LC2_042: 48 MHz bandwidth, 6 hours.

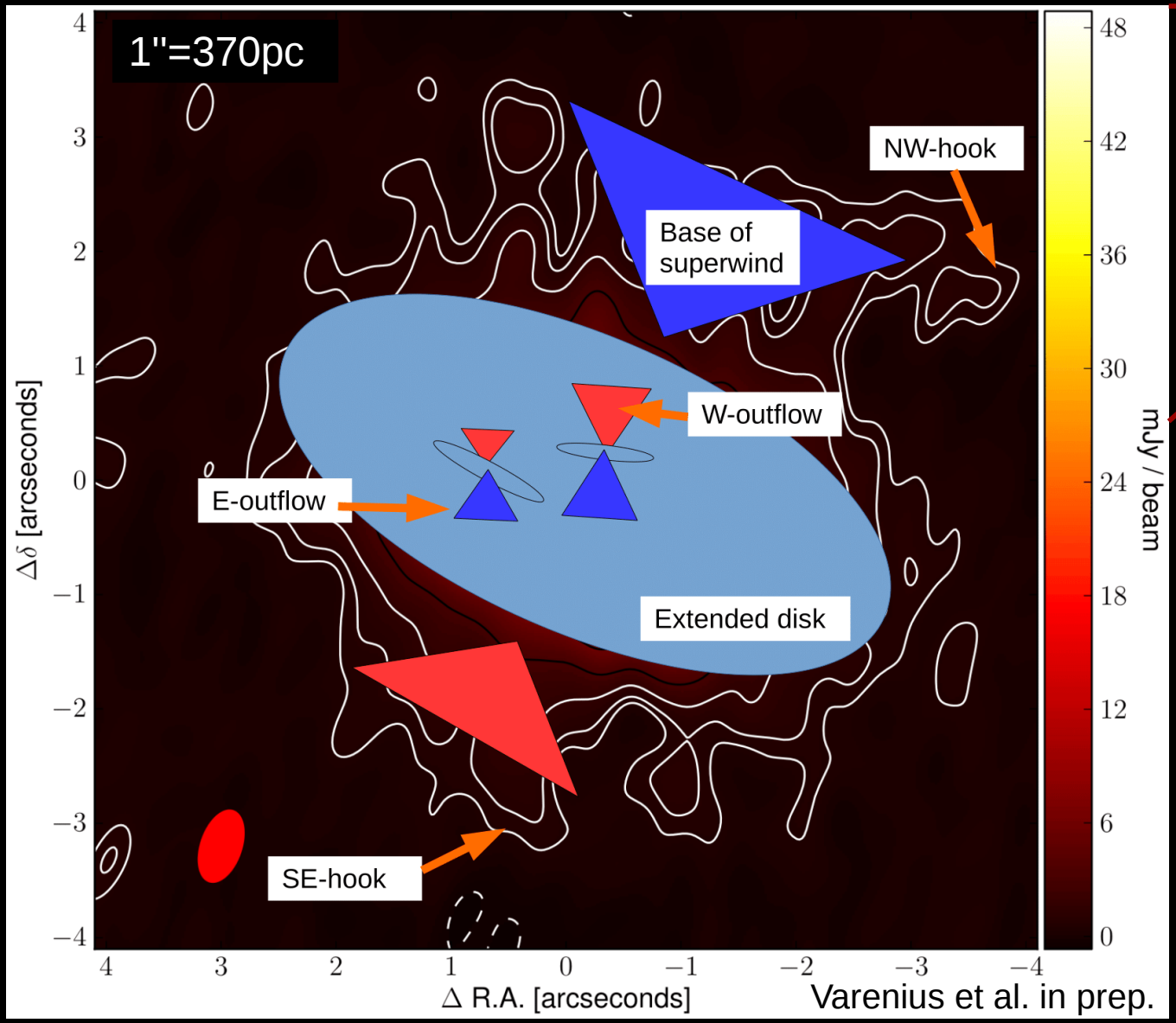
Resolution 0.65"x0.35", noise 0.15 mJy/beam.





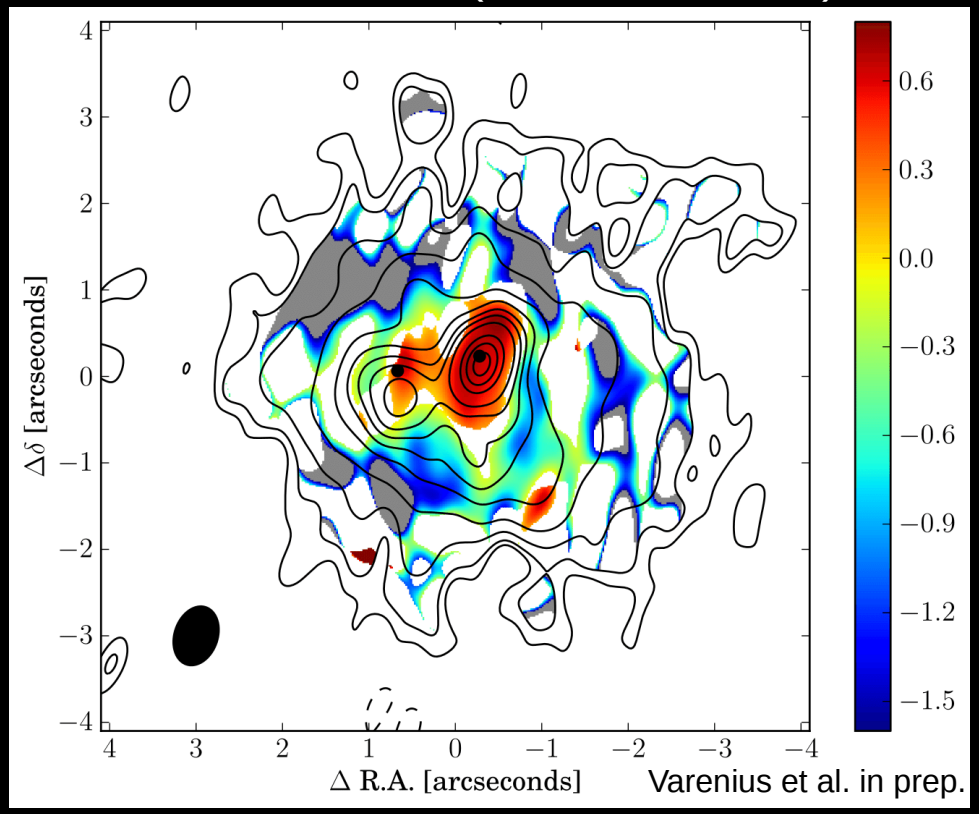
A “simple” sketch of Arp 220 at 150 MHz





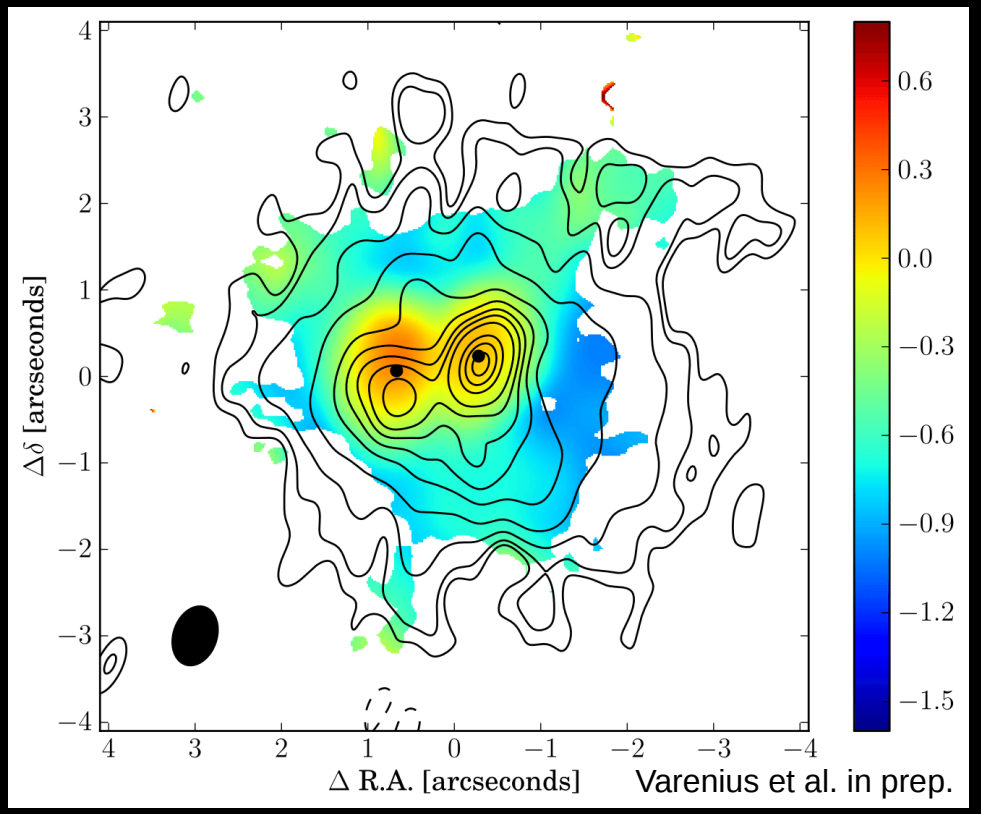
Spectral index maps of Arp 220

LOFAR in-band (127 to 174 MHz)



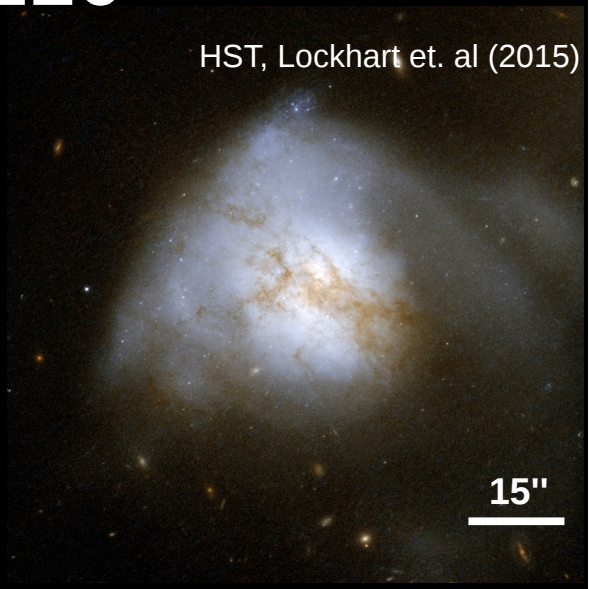
Contours: 150 MHz LOFAR
(Map from MFS-cleaning with nterms = 2 in CASA.
White: blanked when error < 0.75 α.
Grey: below color range)

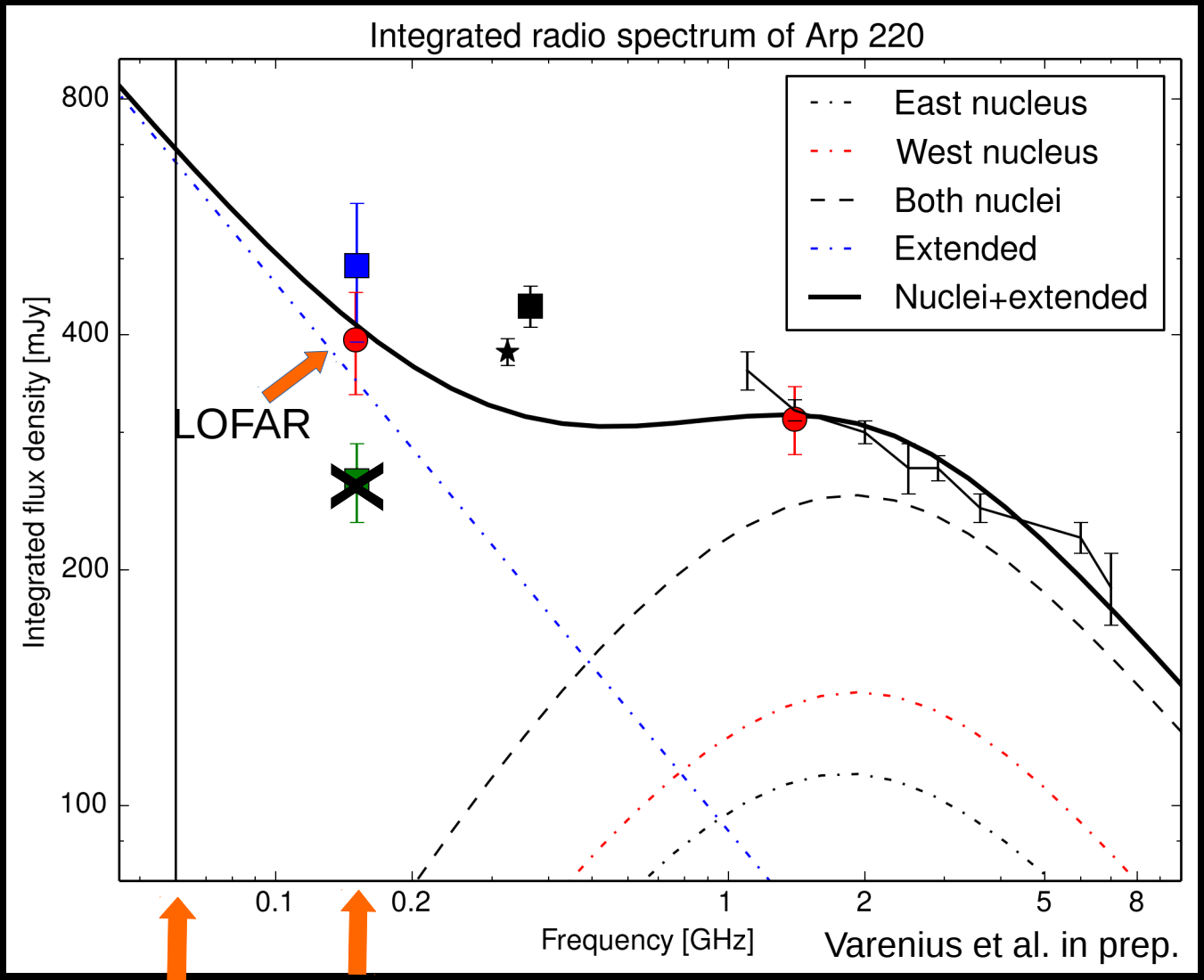
LOFAR 150 MHz to VLA 6 GHz



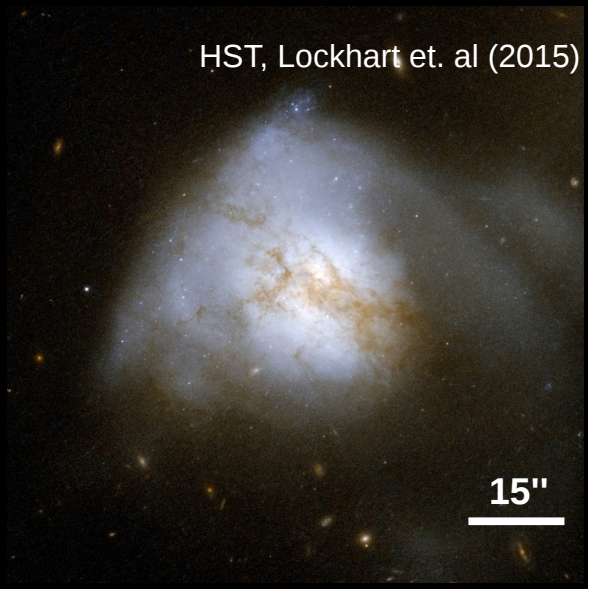
Contours: 150 MHz LOFAR
(White: blanked when 6 GHz below 5σ)

Integrated spectrum of Arp 220





Key results from Arp 220



- Extended kpc-scale radio emission.

- Severe absorption of the nuclei at MHz and GHz freq.

- Less than 20% of 150 MHz emission from main star forming regions (nuclei).
  -> Unresolved observations of ULIRGS/LIRGS at 150 MHz may not give good SFR estimates.

Summary

- Subarcsecond imaging possible at 150 MHz.
- LOFAR very good for studying free-free absorption, steep spectrum halos and outflows in nearby galaxies.
- M 82: 16 compact objects at 150 MHz, 7 new.
- Arp 220: <1% thermal emission at 1 GHz.
- Unresolved observations of ULIRGS/LIRGS at 150 MHz may not give good SFR estimates.