Magnetisation of the Universe - the case of the irregular galaxy NGC4449

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MKSP and SKSP NG WG





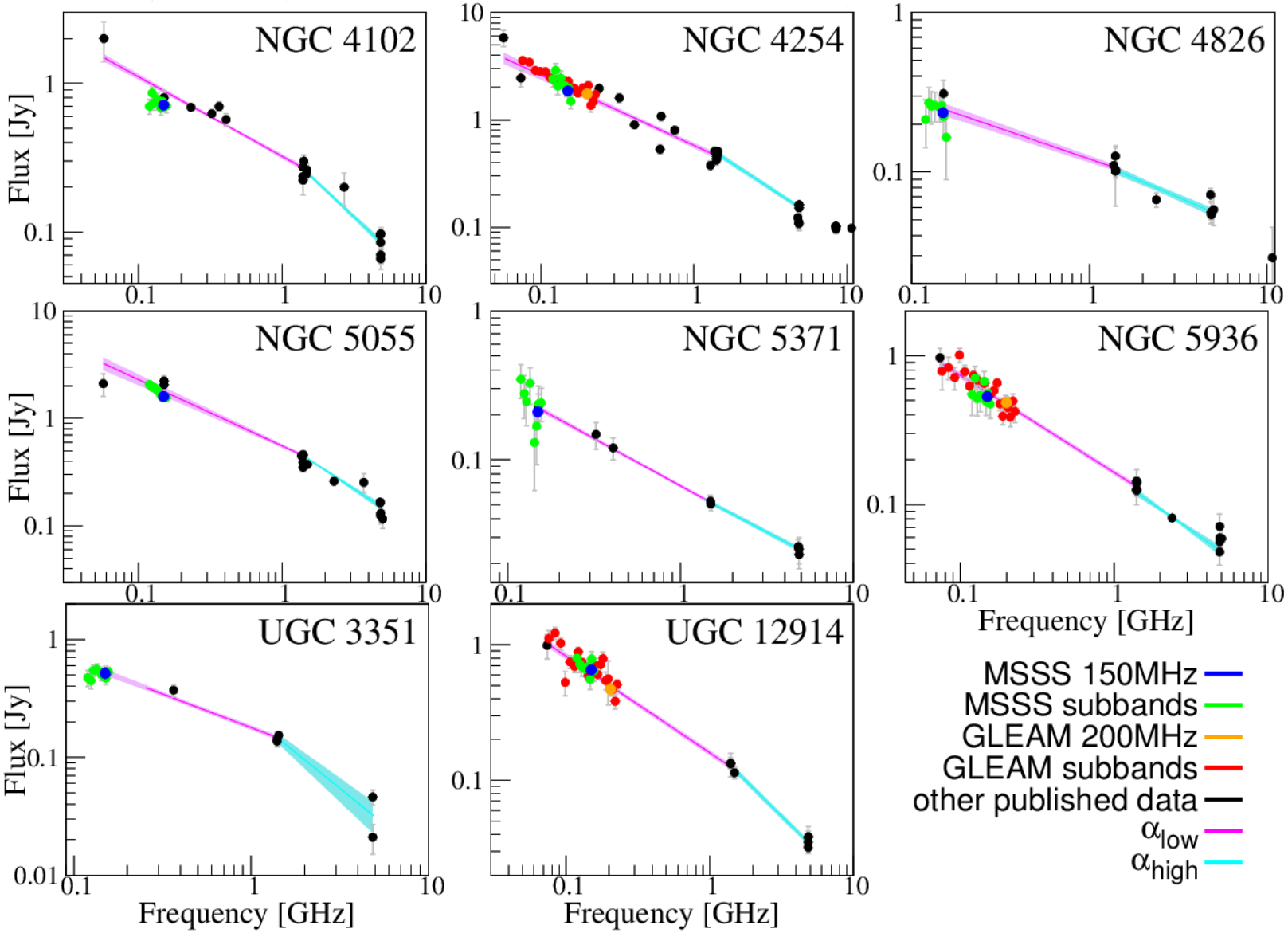
Outline

- Spectra of local galaxies
- Unusual case of a nearby starbursting irregular galaxy NGC4449
- Probing distant galaxies in GOODS-N field (250 observing hours with LOFAR HBA, Cosmic Magnetism KSP)





Spectra of local galaxies



LOFAR MSSS: Flattening low-frequency radio continuum spectra of nearby galaxies,Chyży et al. 2018, AA, 619, A36

Studies of absorption effects

LOFAR MSSS (Heald et al. 2015)

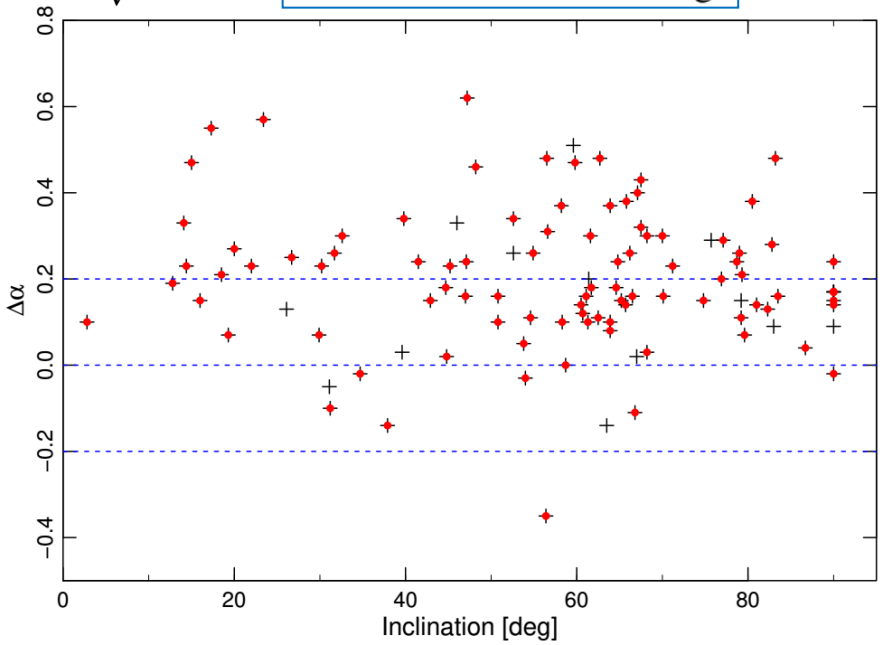
106 galaxies suitable for analysis

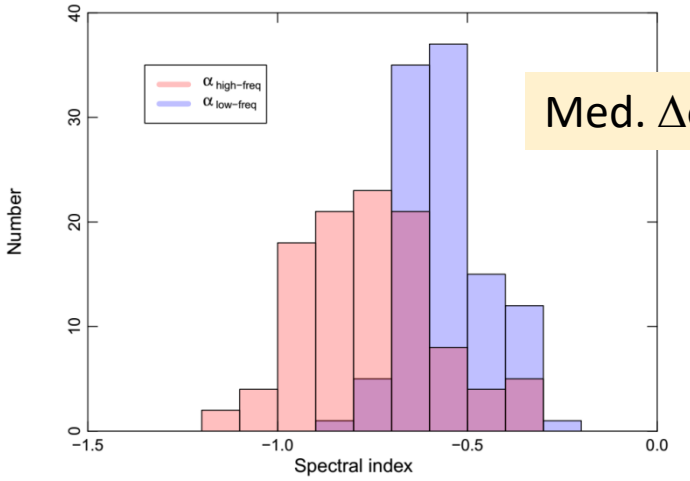
from Yun, Reddy, Condon (2001)

α_{low}: 50-1400 MHz

α_{high} : 1400-5000 MHz (avoid th. em.)

$S_\nu \propto \nu^\alpha$ $\quad \Delta\alpha = \alpha_{low} - \alpha_{high}$





Med. $\Delta\alpha$=0.20±0.02

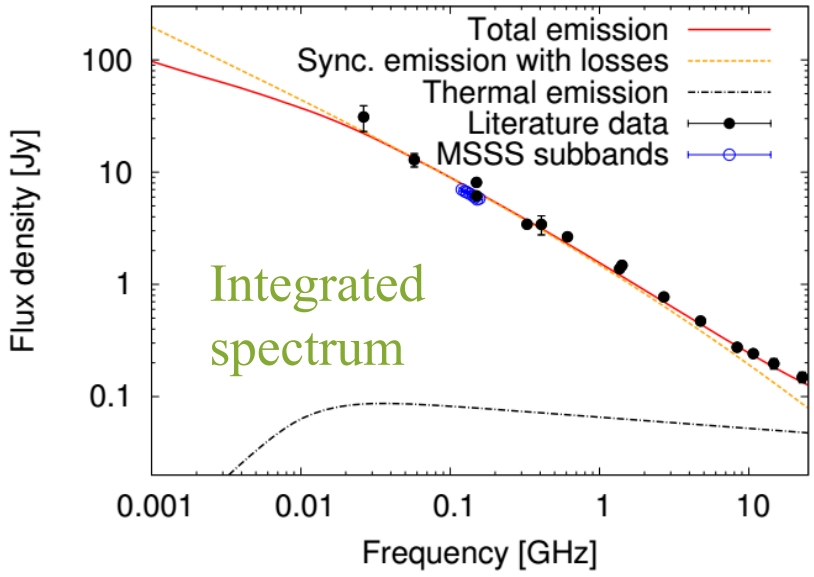
Small spectral flattening at low frequencies

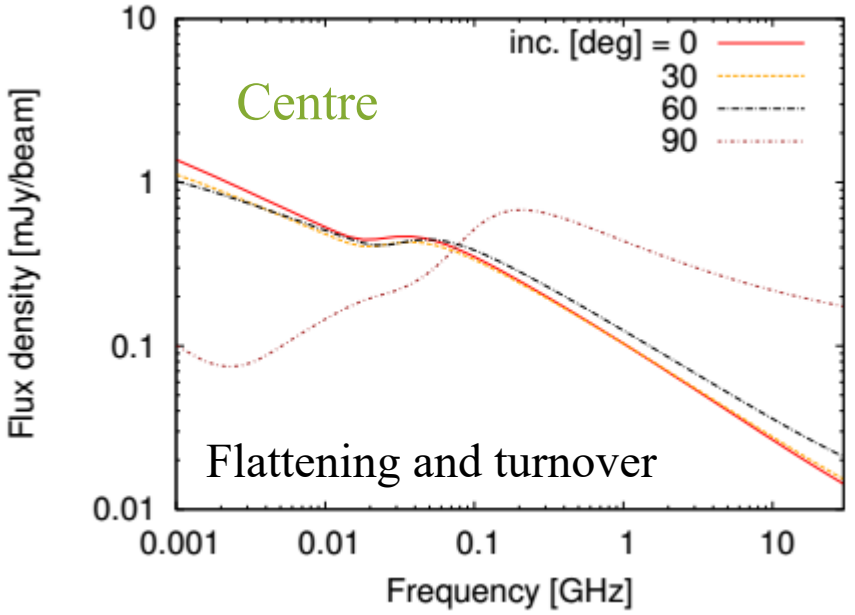
$\Delta\alpha$ - inclination plot contradics the previous claim:

~~F. Israel and M. Mahoney 1990: increasing free-free absorption of synchrotron emission with increasing galaxy tilt (57 MHz)~~

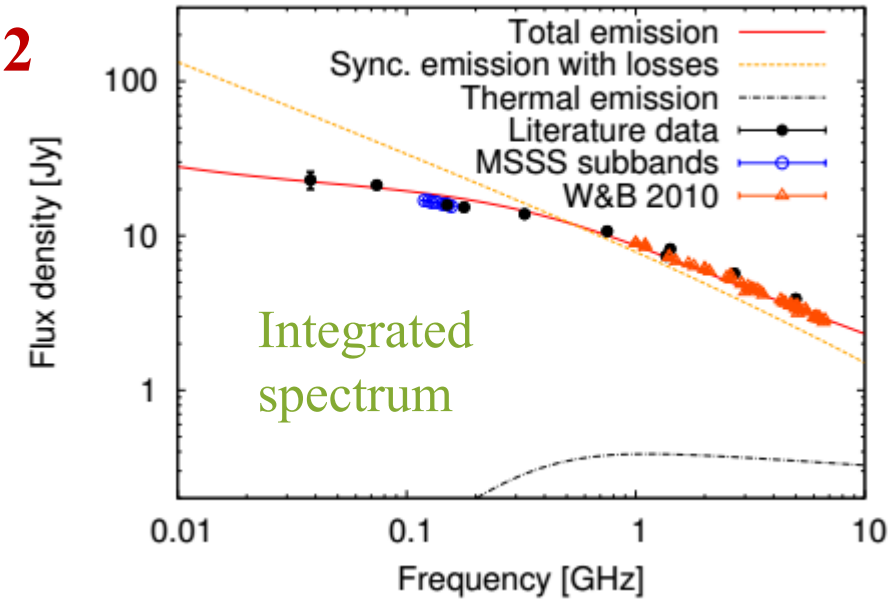
M51 and M82 3D modelled global and local spectra

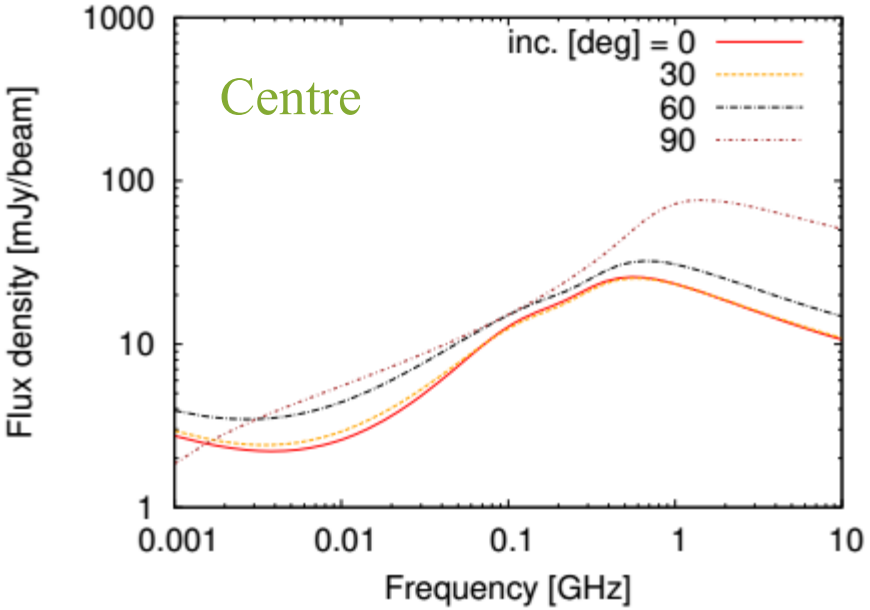
M51





M82





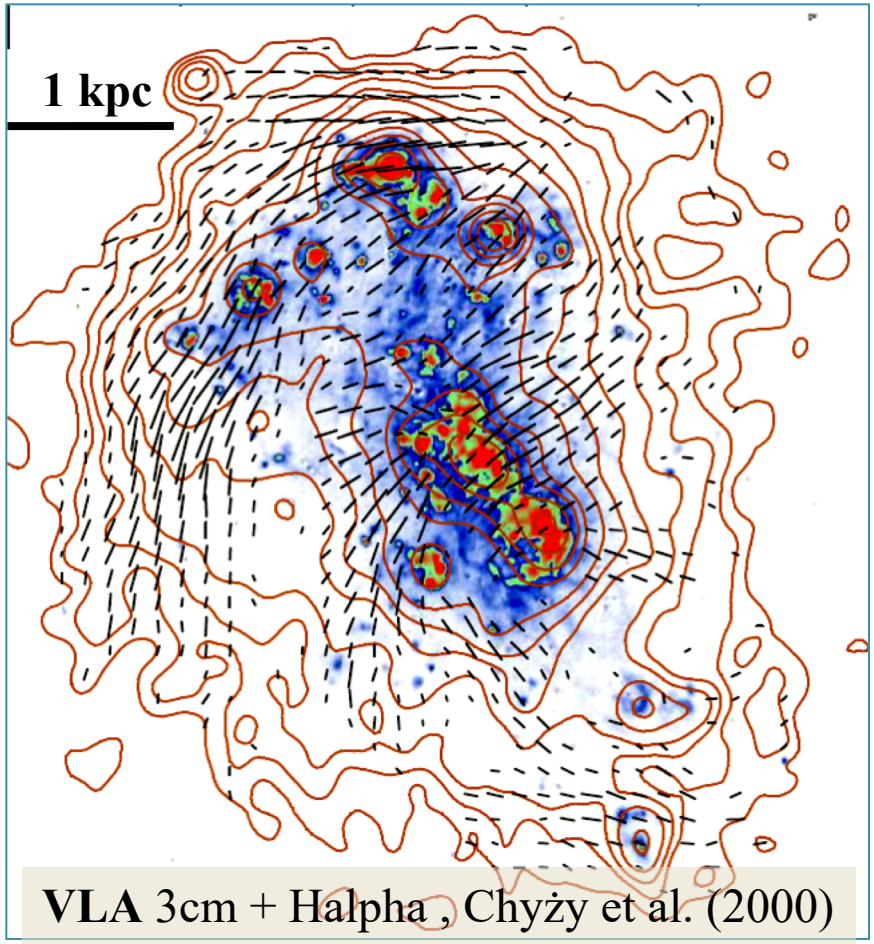
Case of the starbursting irregular NGC4449

Magnetisation of IGM with outflows from primordial **low-mass** galaxies (Kronberg et al. 1999, Bertone 2006):

- large number of galaxies
- shallow gravitational potential

NGC4449 - **nearby irregular 5x smaller, 8x less massive than the MW**

A search of a LARGE synchrotron envelope due to galactic wind

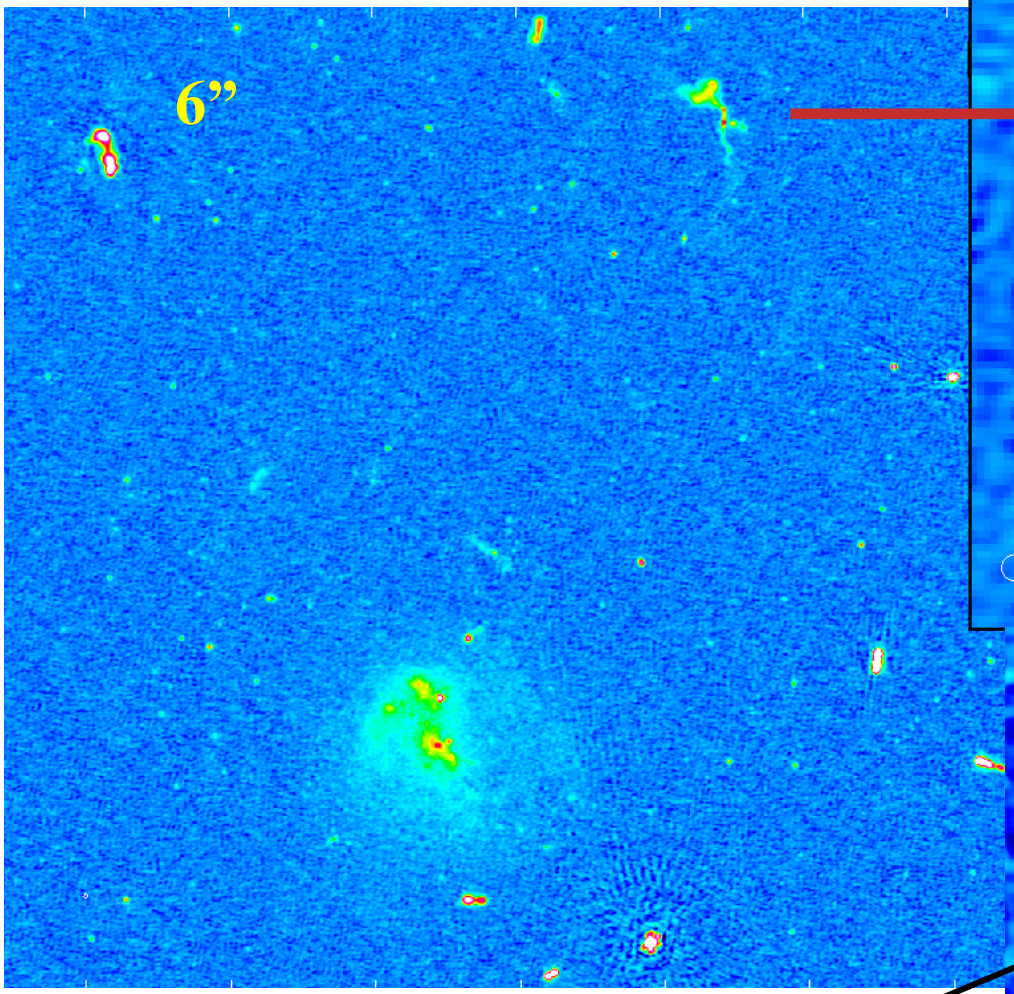


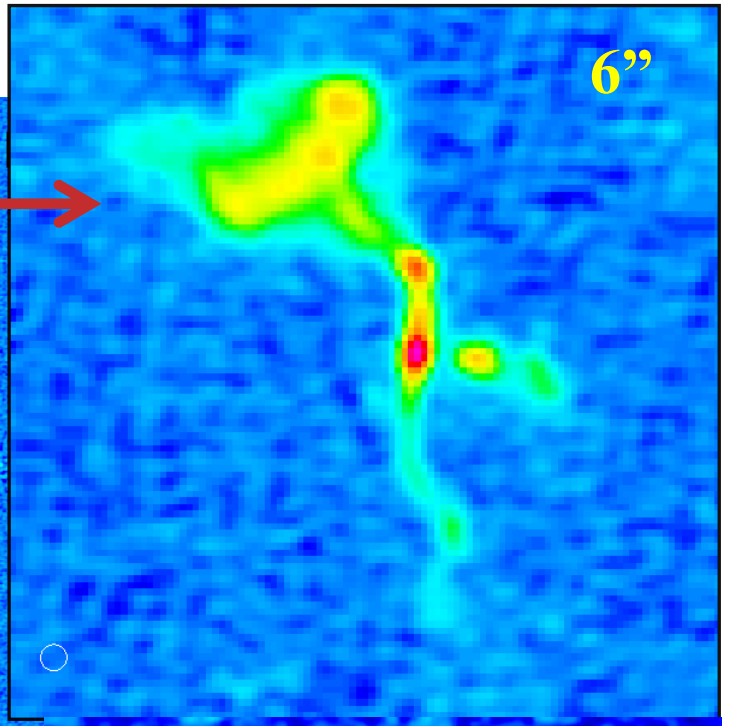
VLA 3cm + Halpha , Chyży et al. (2000)

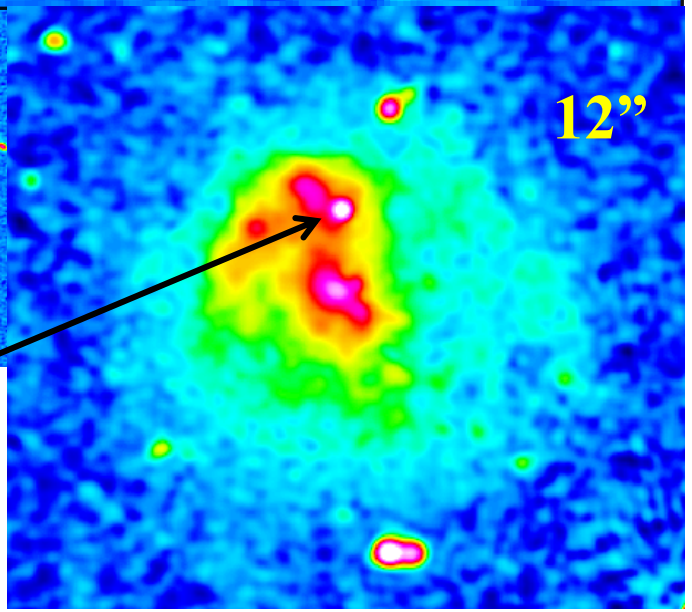
LOFAR project: Krzysztof Chyzy, Julia Piotrowska, Sarrvesh S. Sridhar, Uli Klein, Rainer Beck, Wojciech Jurusik, Dominik Bomans, Anna Scaife, Roberto Francesco Pizzo, Annalisa Bonafede, Joern Geisbuesch, Cathy Horellou, Keitaro Takahashi, Ralf-Juergen Dettmar, Andreas Horneffer, Shinsuke Ideguchi, Amrita Purkayastha, Andrew Fletcher,

LOFAR HBA observations of NGC4449

LoTSS DR2 image (thanks to Tim & Cyril et al.)





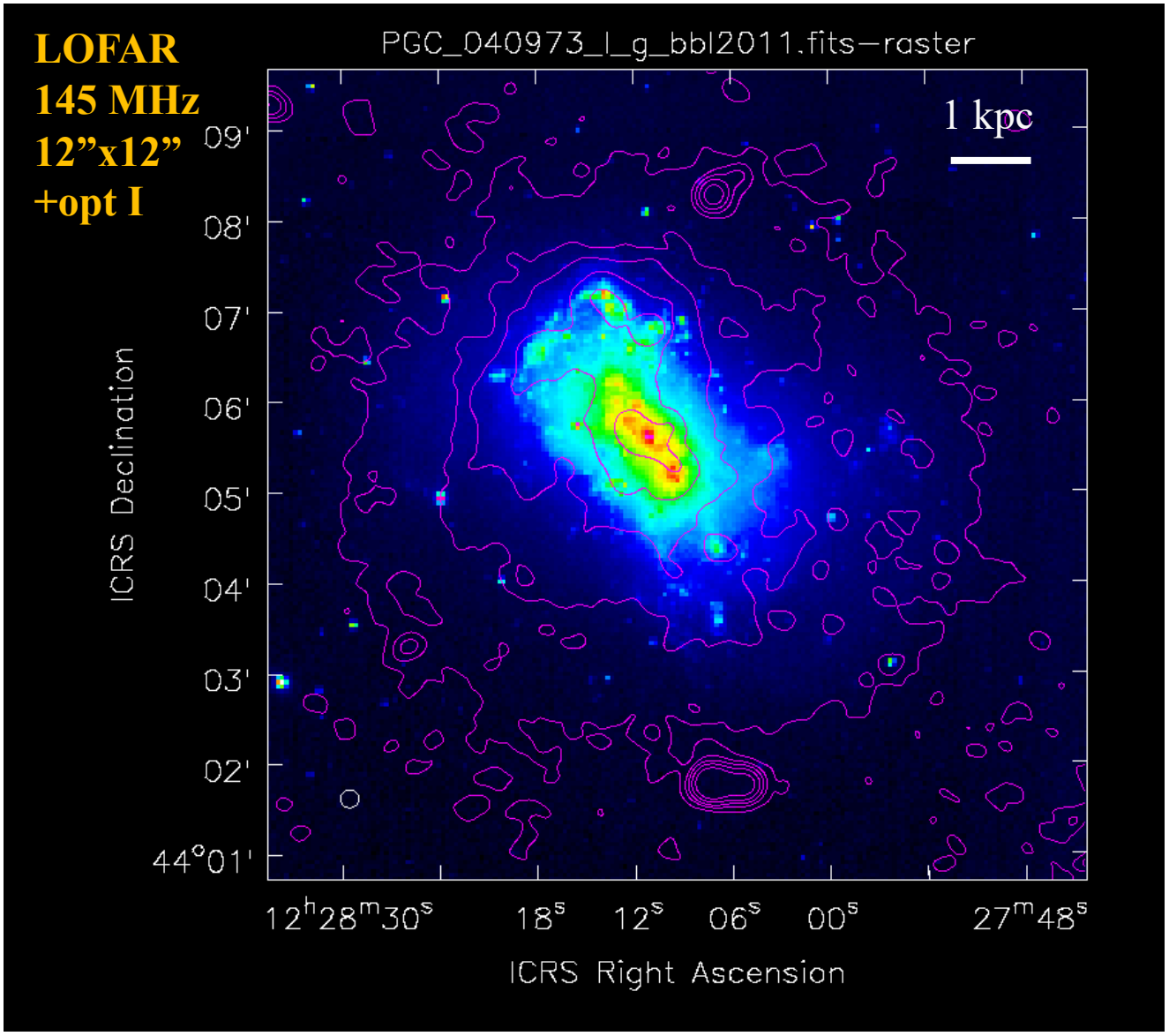


SNR – 25x as lum. as Cas A (Kirshner 1980)





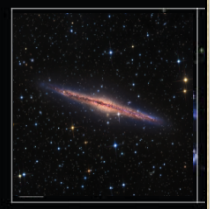
Synchrotron envelope of NGC4449



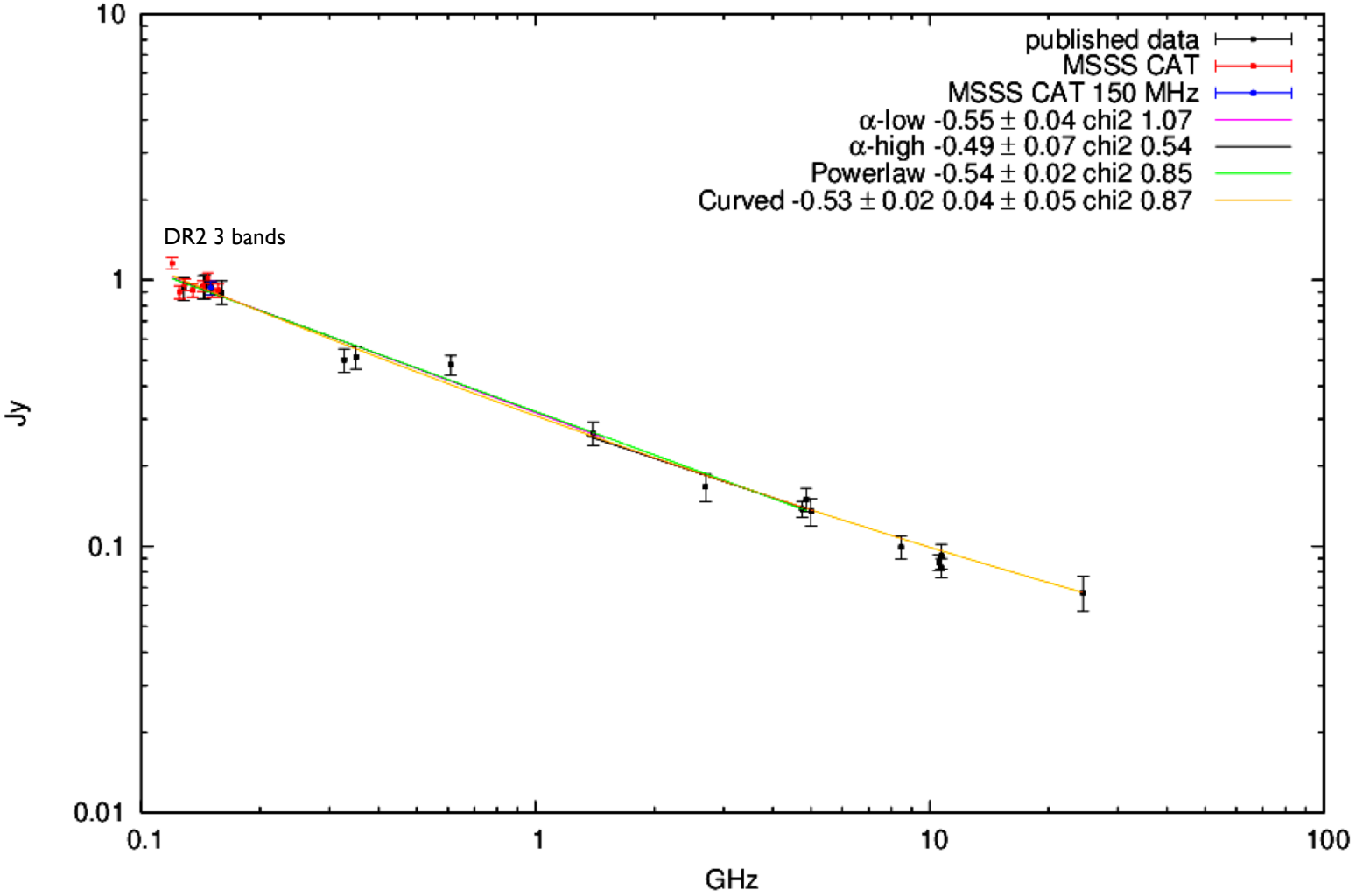
- Symmetric envelope of irregular galaxy!





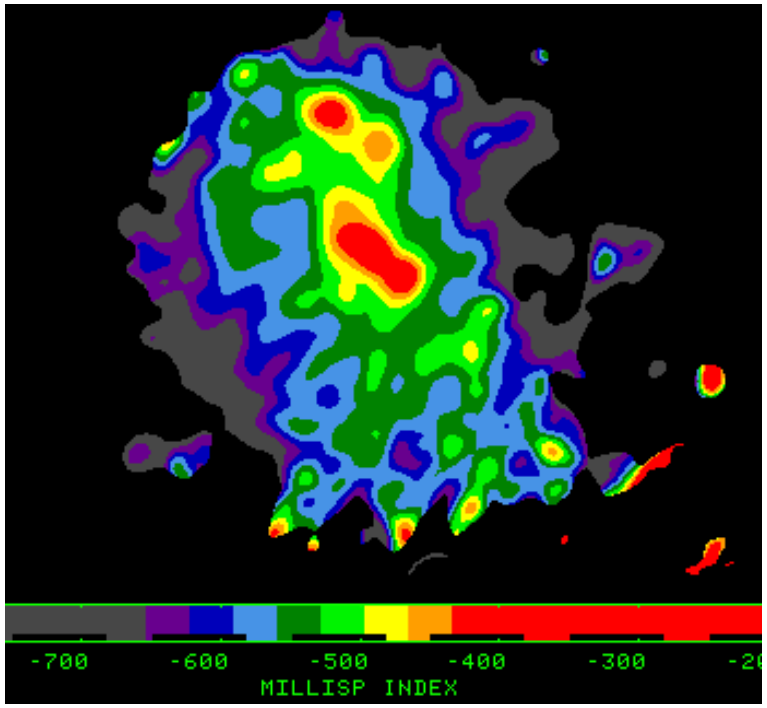


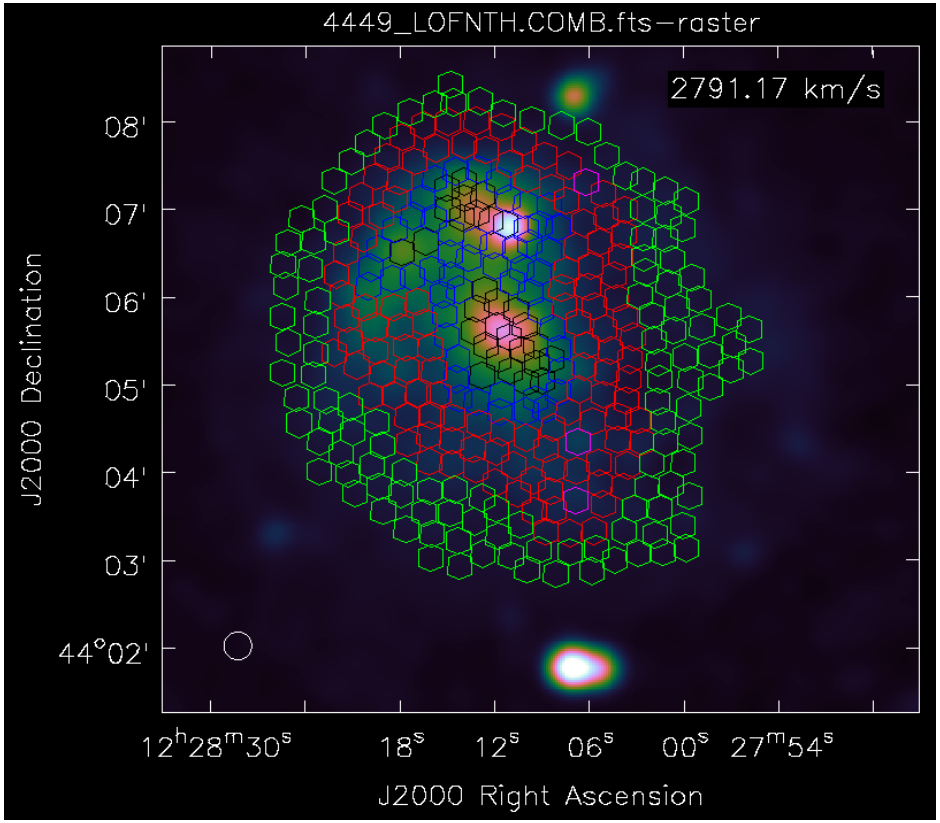
Global spectrum of NGC4449



- LOFAR DR2 and MSSS fluxes are the same within errors
- Straight and flat total spectrum (-0.55) – from a large population of SNRs

Nth α_{low} map 145-4860 MHz

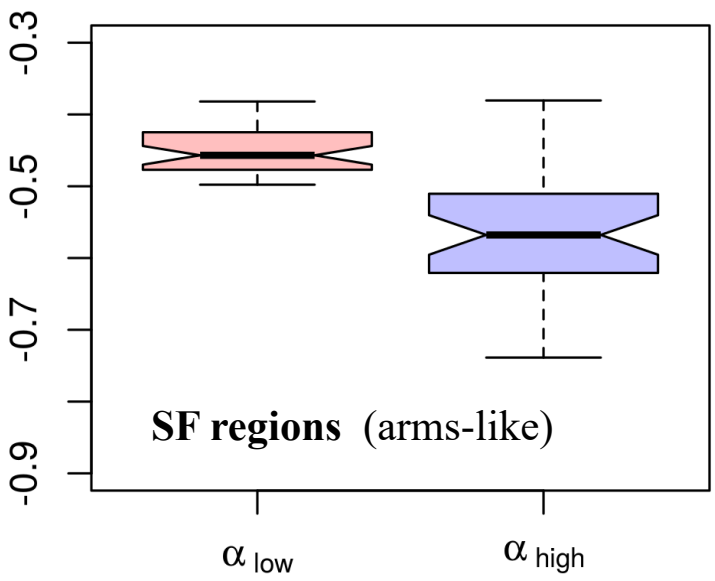


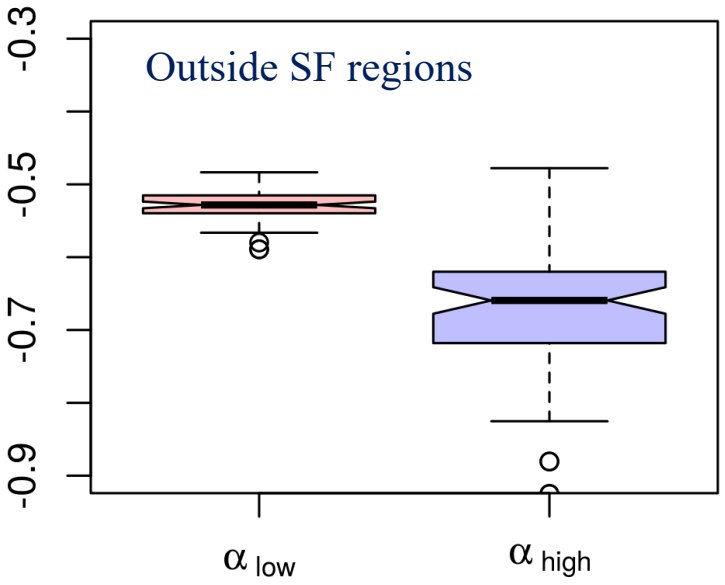


α_{low}
150-4860 MHz

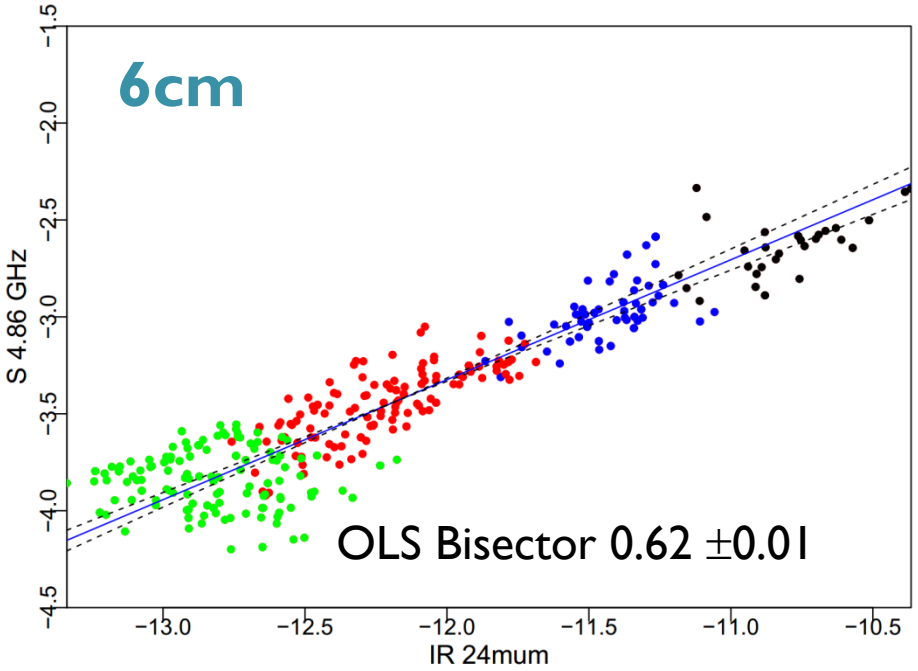
α_{high}
4860-8460 MHz

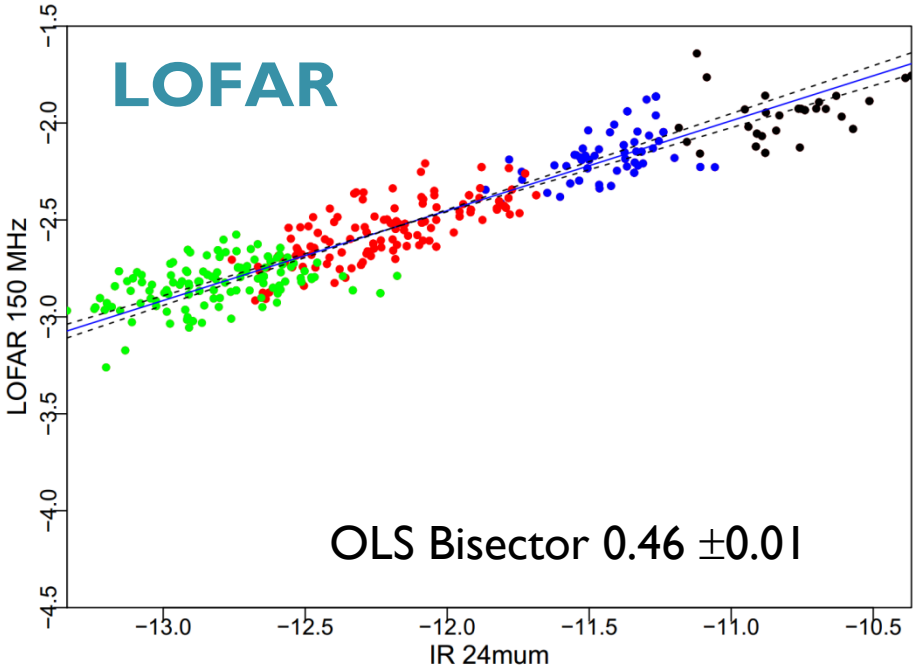
-flattening at lower freq.
- absorption or CR energy losses?



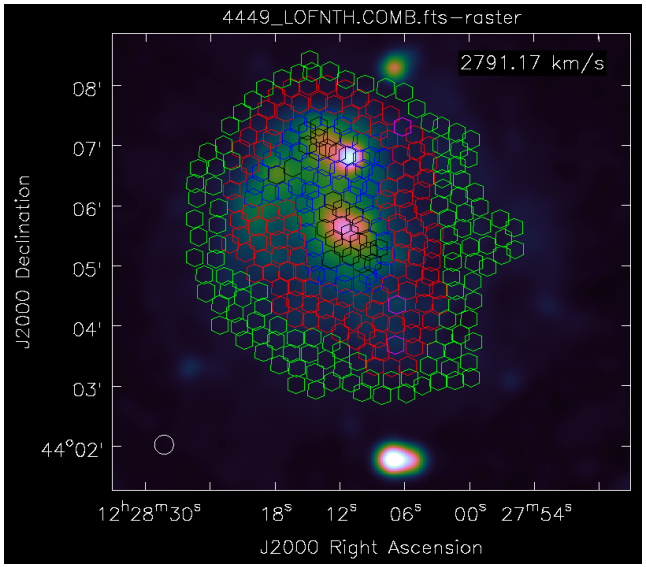


Local radio–infrared relation within NGC4449

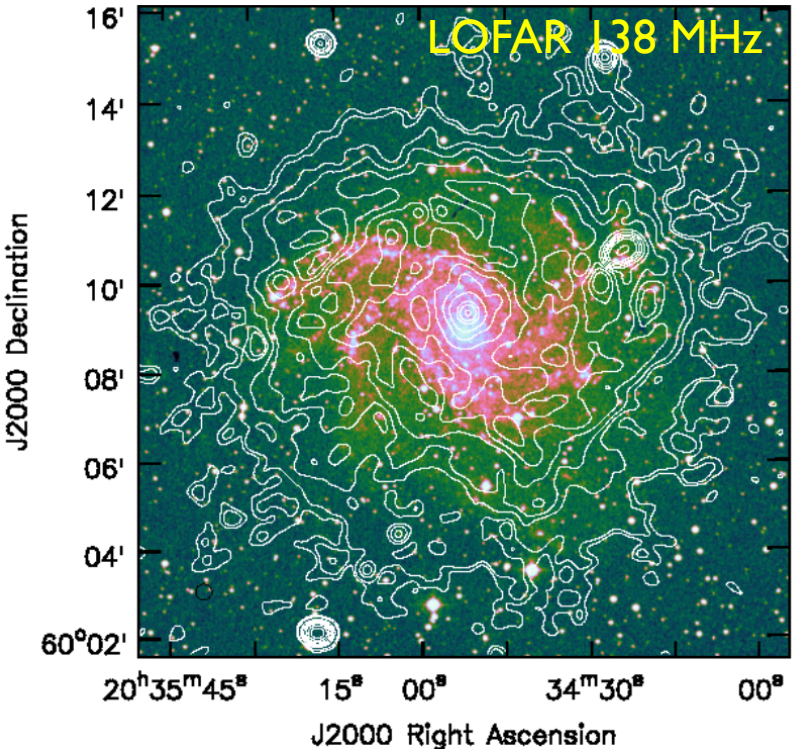




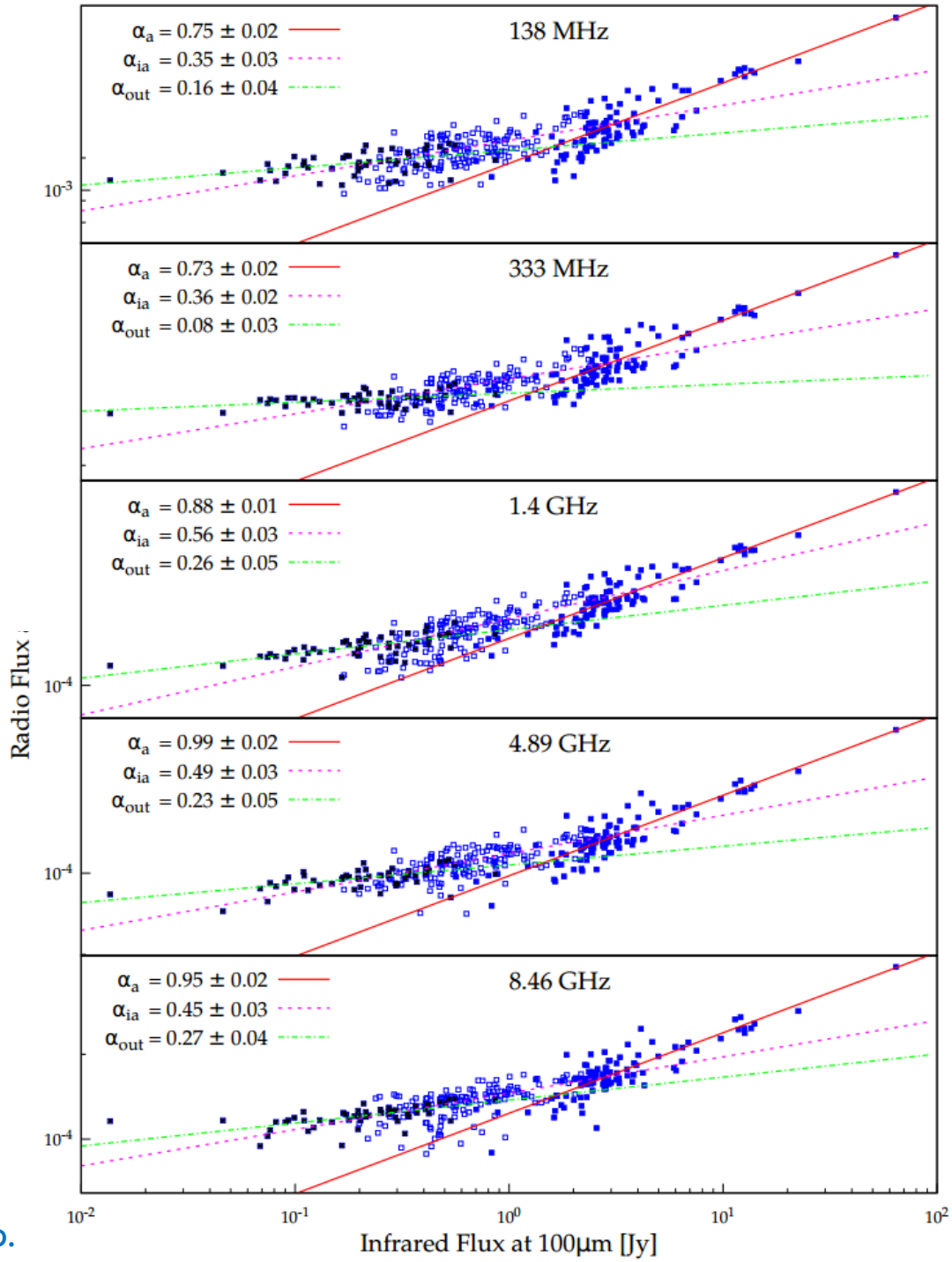
- Radio-Ir relation flatter for LOFAR
- Confirm transport of low energy CRe from SF regions (by wind/diffusion)
- But the shape is unexpected…



Radio-fir: NGC6946



- NGC6946: In arms relations are linear at high freq.
- Relations for inter-arm and outer regions are sublinear, like in all regions of NGC4449
- Strong winds makes a difference for NGC4449?



J. Piotrowska, K. Chyży, S. Sridhar et al. In prep.





GOODS-N

Great Observatories Origins Deep Survey

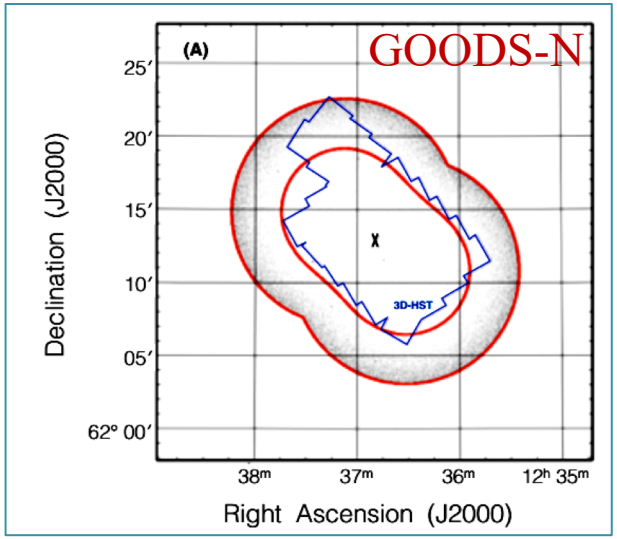
Project:

- 250 observing hours with LOFAR HBA, MKSP to probe the *μ*Jy polarized source population as a function of frequency
- Subproject – stokes I – **galaxy spectra, radio-FIR relation, B strength – compare with nearby galaxies**
- LC7012, LC9 033 120h observed (A. Scaife et al., current PI Valentina Vacca)
- Data reduction in Bochum (A. Miskolczi)
- Preliminary results from LoTSS DR2

Data:

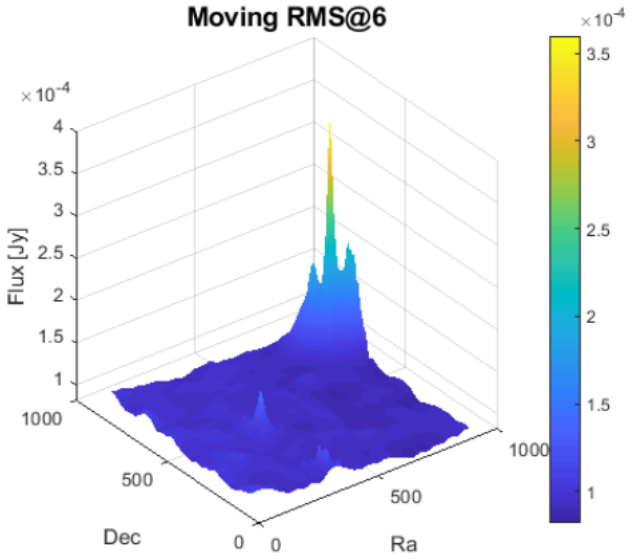
- 1.5 GHz (Owen 2018)
- 5 GHz- Gim et al. (2019)
- 10 GHz (Murphy et al. 2017)
- 150 MHz – LOFAR (DR2 data)

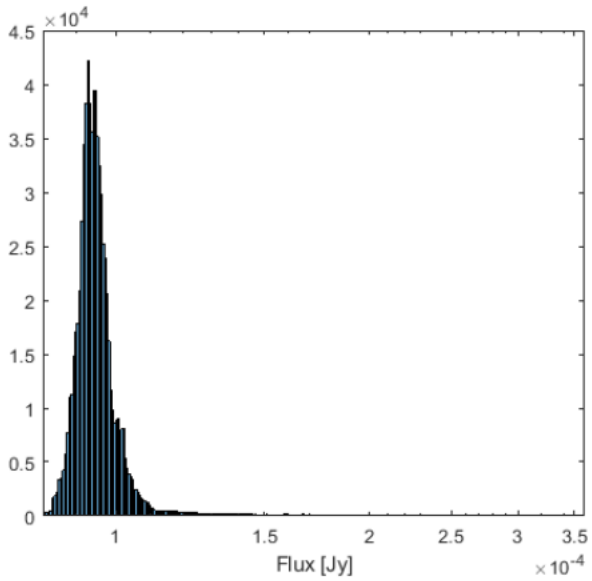
Gim et al. (2019)



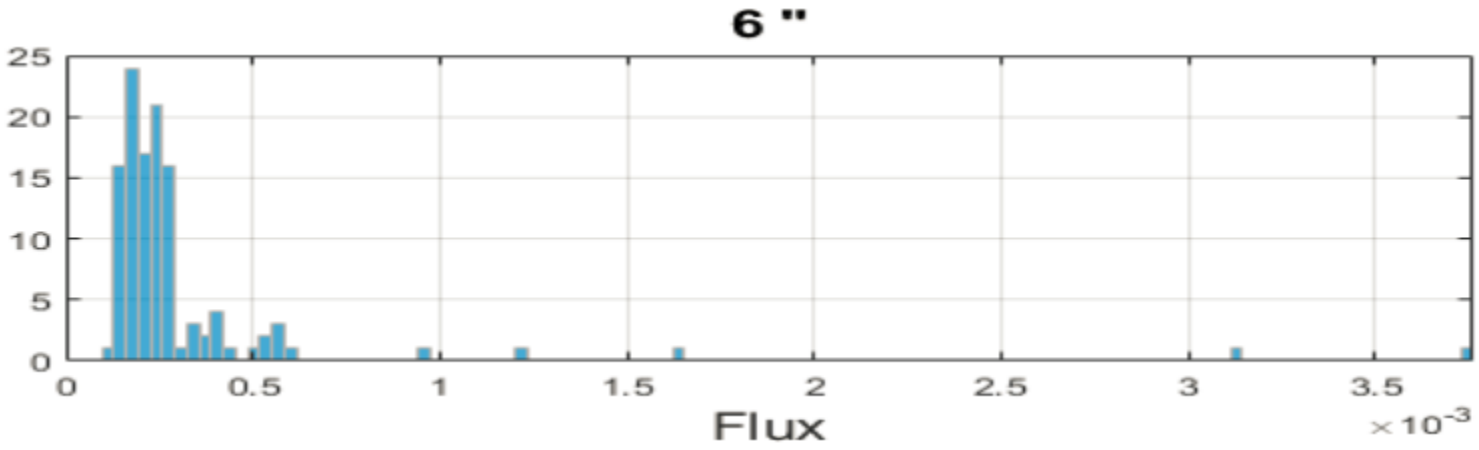
K. Chyży, M. Weżgowiec, A. Kurek, J. Piotrowska, A. Goyal, MKSP (V. Vacca et al.) in prep.

GOODS-N





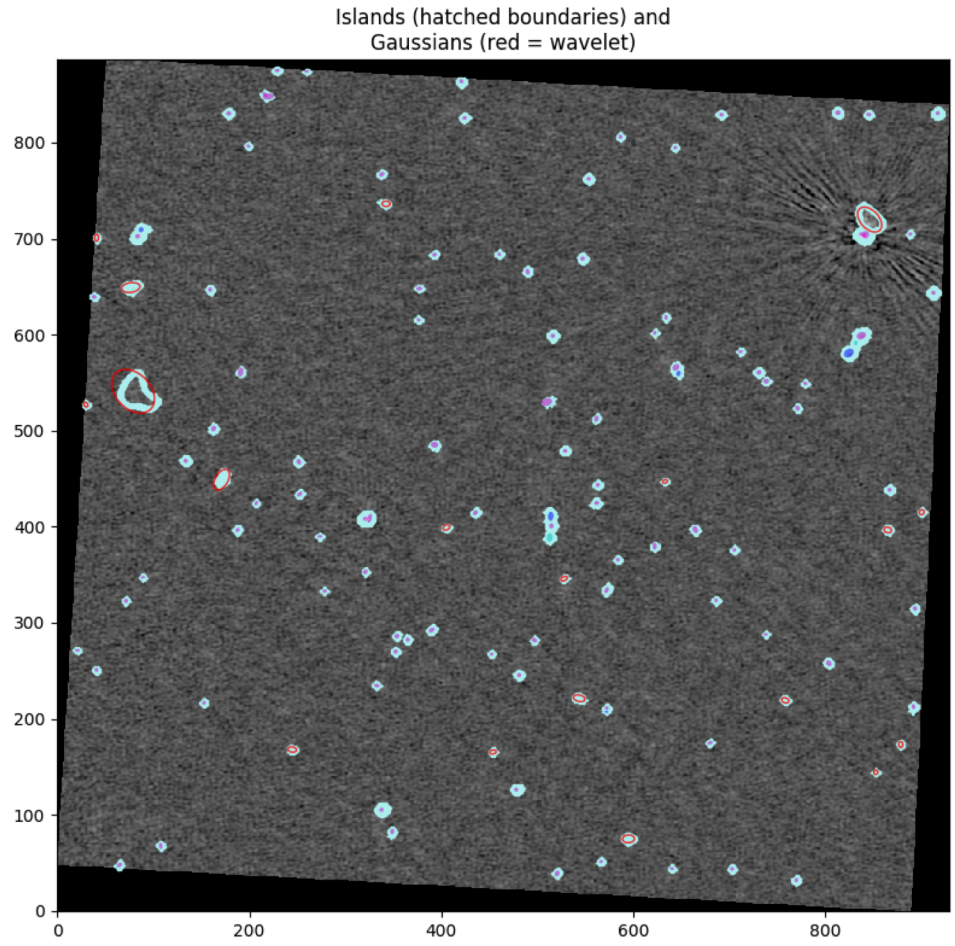
rms



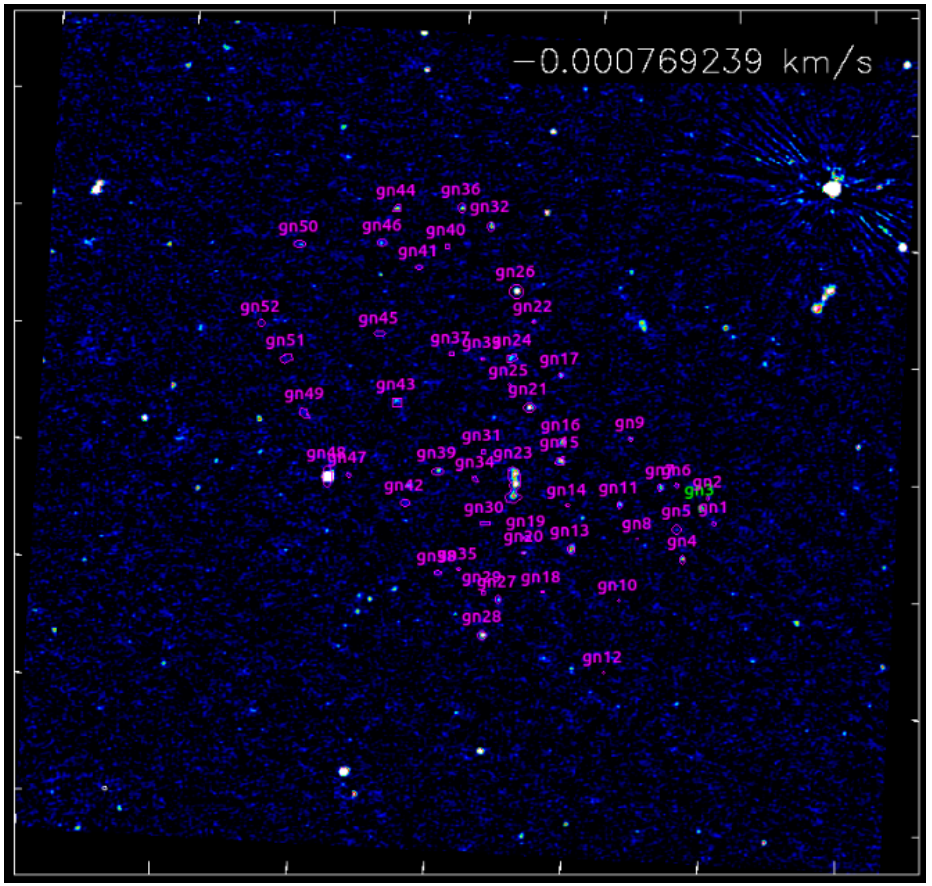
Sources
>3 sigma rms

GOODS-N flux measurements

PyBDSF

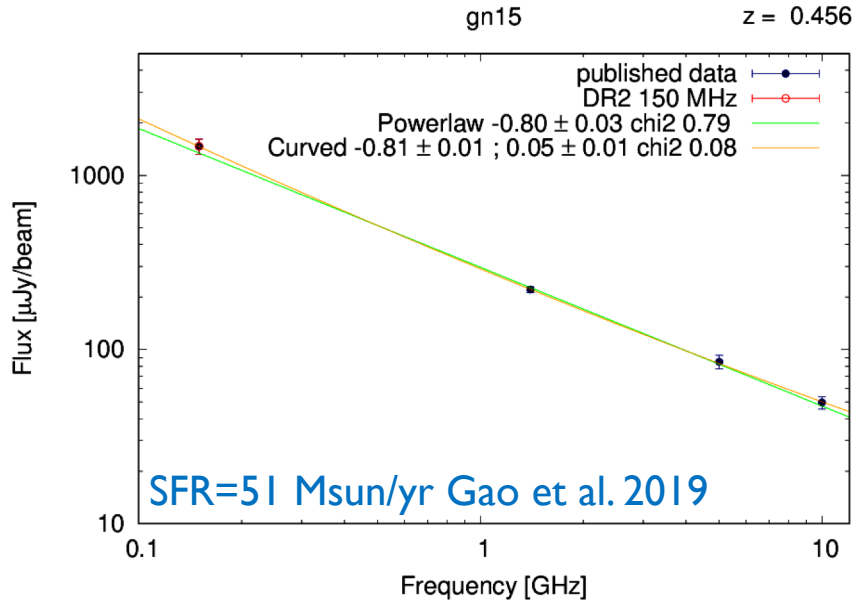


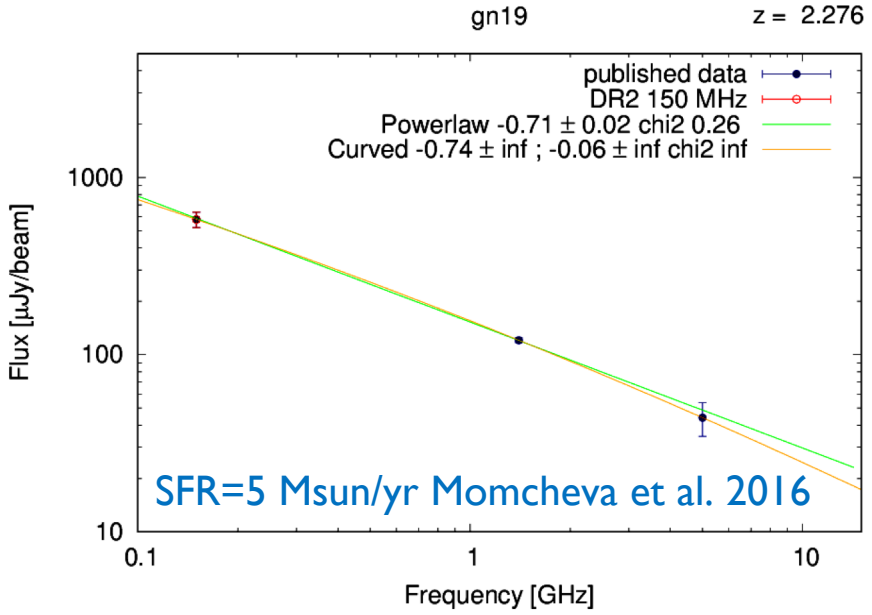
CASA regions
Gim et al. 2019, 52 sources

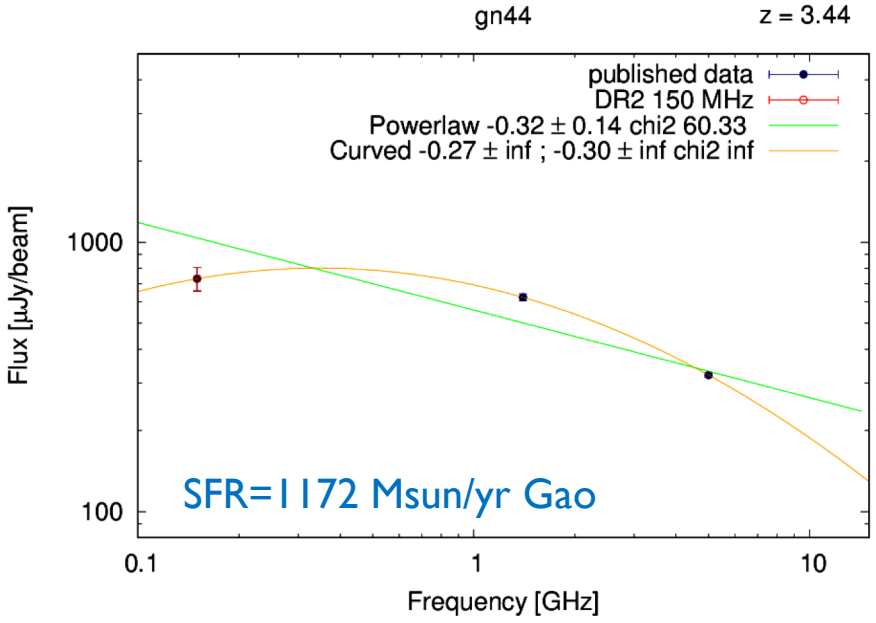


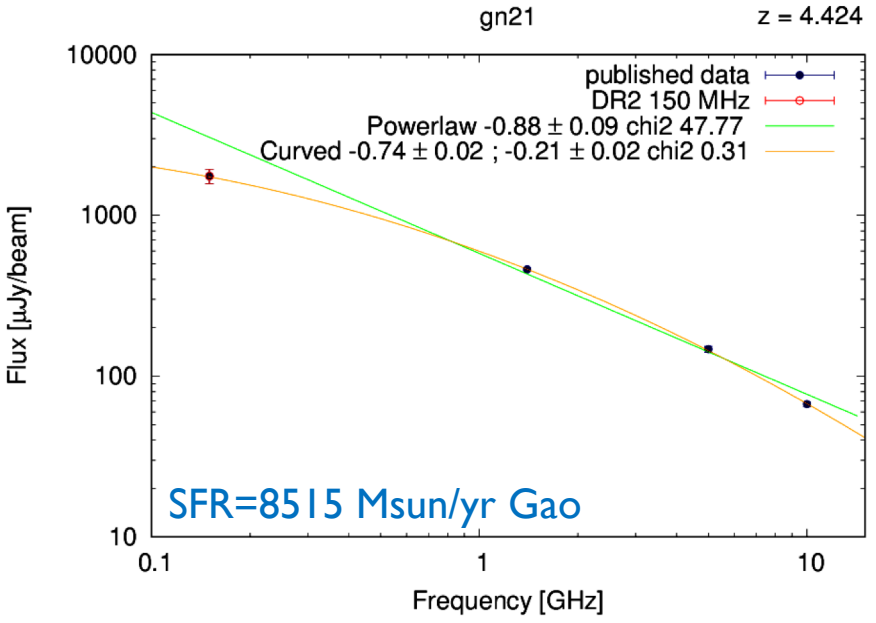
Cross-matched and verified 23 sources

GOODS-N spectra of distant SF-galaxies





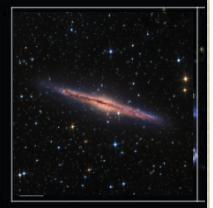




Flattening - as predicted by our 3D model (if this is absorption)







Summary

- We constructed a large MSSS sample of ~100 galaxies
- Weak spectral flattening at low freq., no relation with inclination (not strong f-f absorption)
- Stronger absorption effects predicted for high-SF (distant) galaxies
- NGC4449 reveals a synchrotron envelope – winds/diffusion
- Stright an relatively flat integrated spectrum of a starburst NGC4449 – from a population of young SNRs
- Unusual sublinear radio-fir relation for regions within NGC4449
- GOODS-N high-z galaxies show curved spectra