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SFB1491

TRACING GALACTIC MAGNETIC FIELDS AND COSMIC RAYS WITH SYNCHROTRON EMISSION

Michael Stein | LOFAR Family Meeting 2023 | 16.06.2023, Olsztyn

AIRUB

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RUHR-UNIVERSITÄT BOCHUM

LOFAR Magnetism Key Science Project (MKSP)

Probing the magnetised Universe using the Low-Frequency Array (LOFAR): a cutting-edge digital radio telescope

The Circumgalactic Medium (CGM)

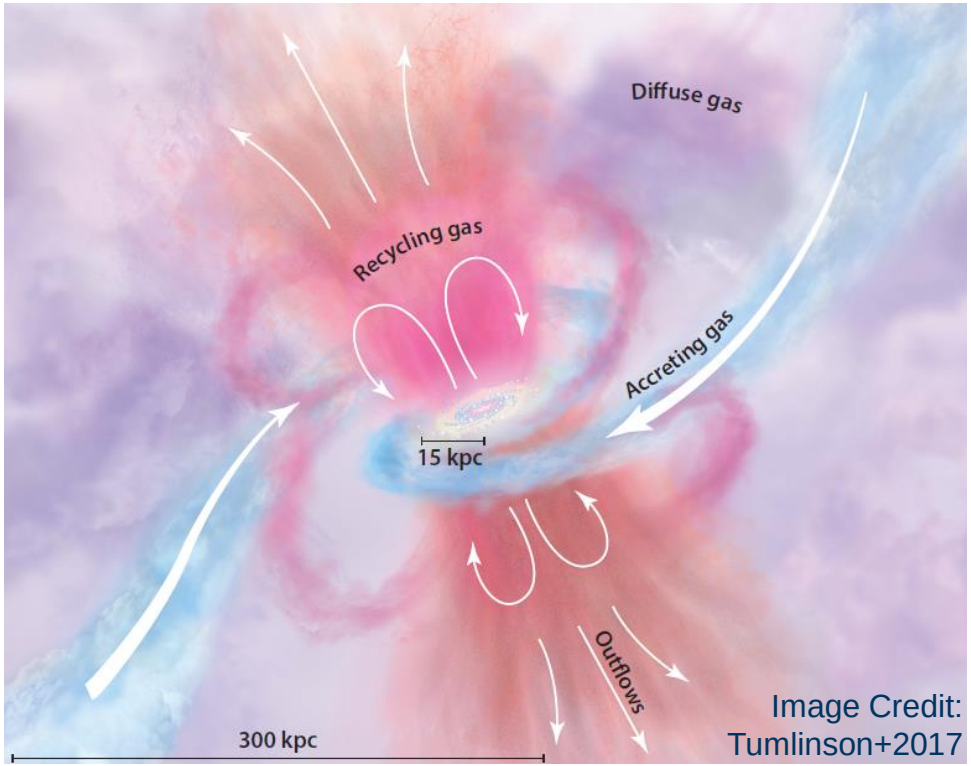
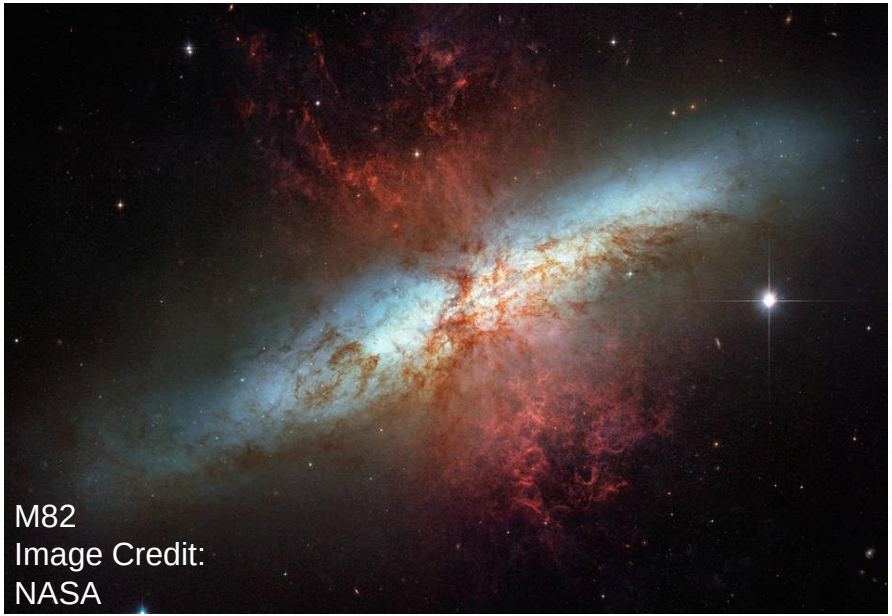


Image Credit: Tumlinson+2017

Observation



M82
Image Credit:
NASA

Simulation

Image Credit:
Schneider+2020

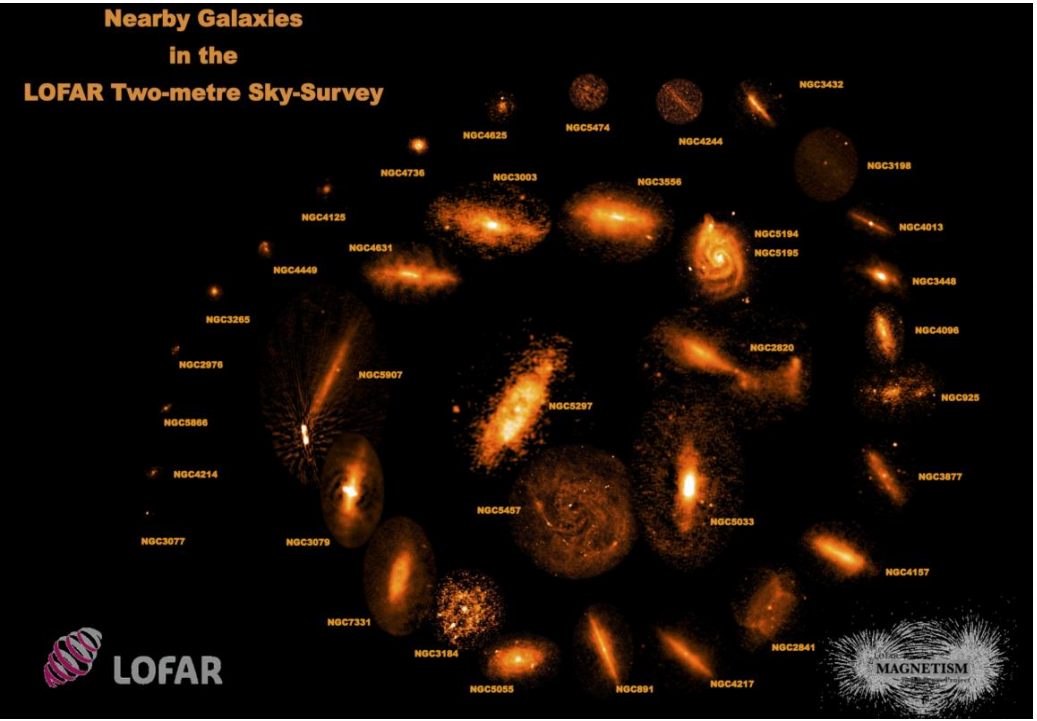
Why Radio Continuum Data?

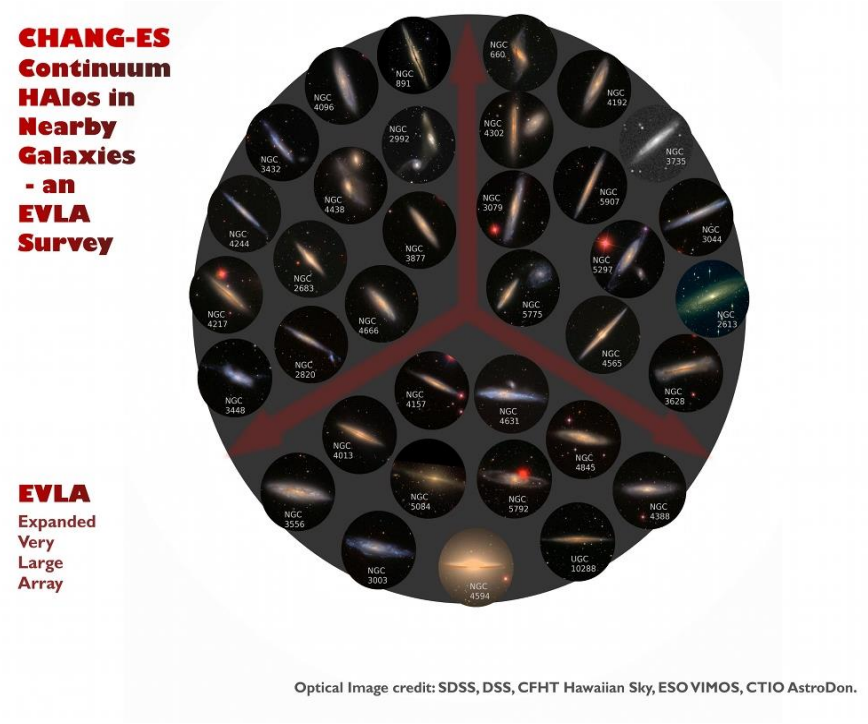
- Total synchrotron emission → Total magnetic field strength ($\mathbf{B_{tot} \propto I_{tot}}$)
- Polarised synchrotron emission → Regular magnetic field ($\mathbf{B_{reg} \propto I_{pol}}$)
- Electric vector position angle (EVPA) → Magnetic field structure orthogonal to the line of sight ($\mathbf{B_{\perp}}$)
- Faraday rotation analysis → Magnetic field structure parallel to the line of sight ($\mathbf{B_{\parallel}}$)
- Non-thermal spectral index → Age of Cosmic Rays (CRs) and CR transport mechanism

Stein+2023

Cosmic Ray Transport in Edge-On Galaxies

LoTSS & VLA L-Band (CHANG-ES)





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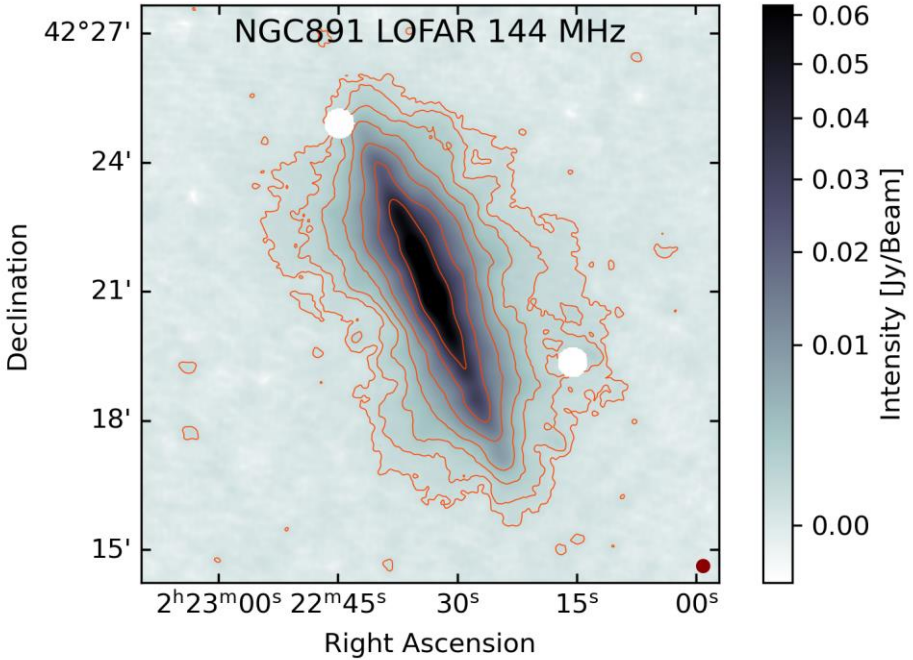
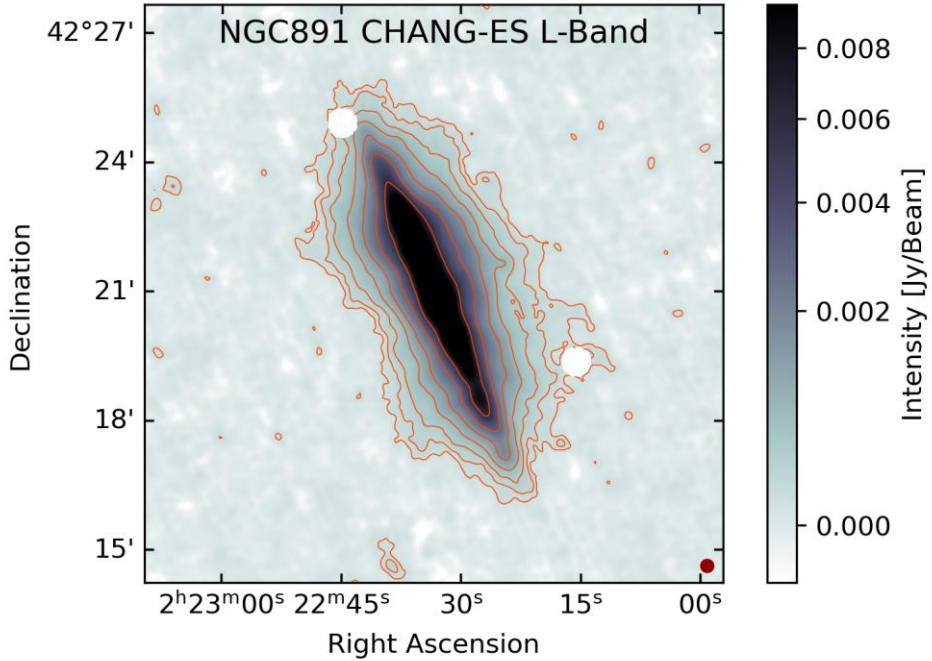
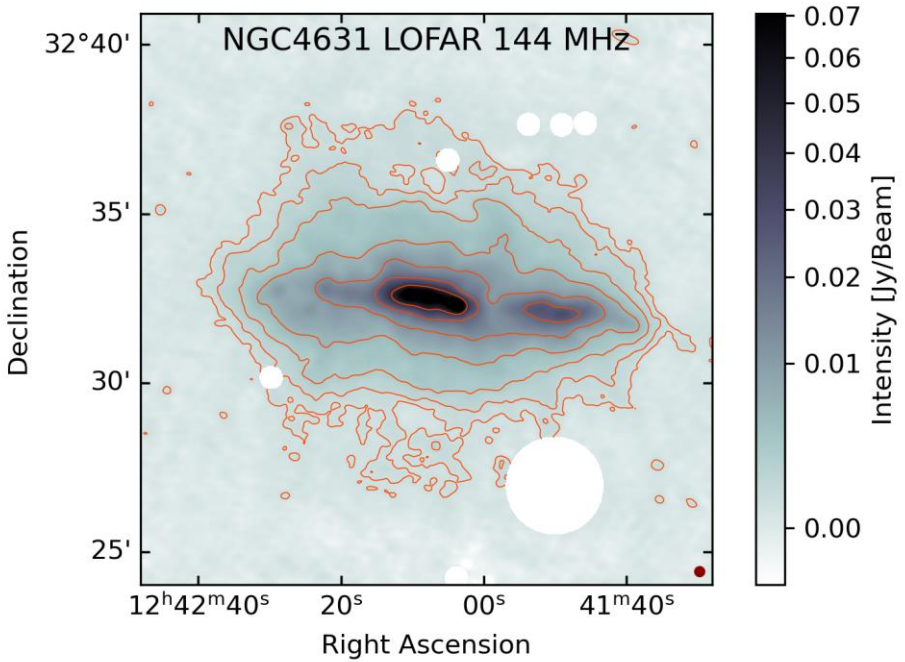
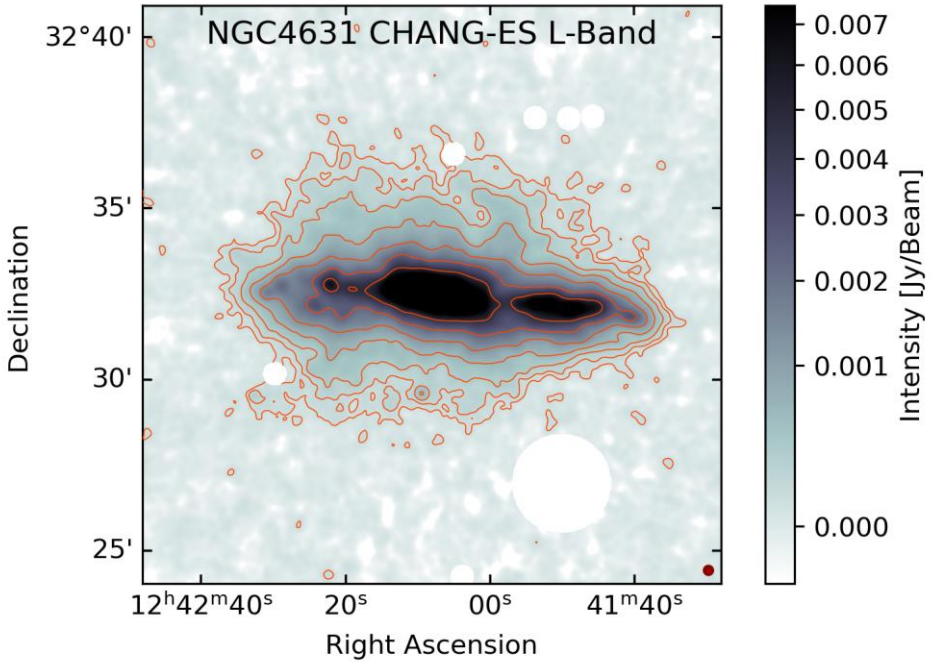
Radio Continuum | NGC891



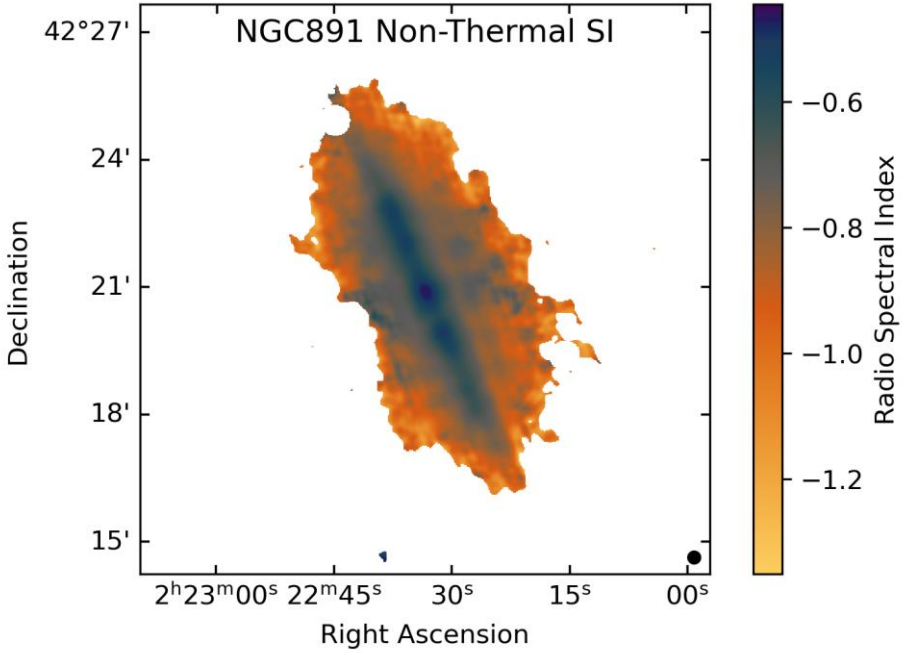


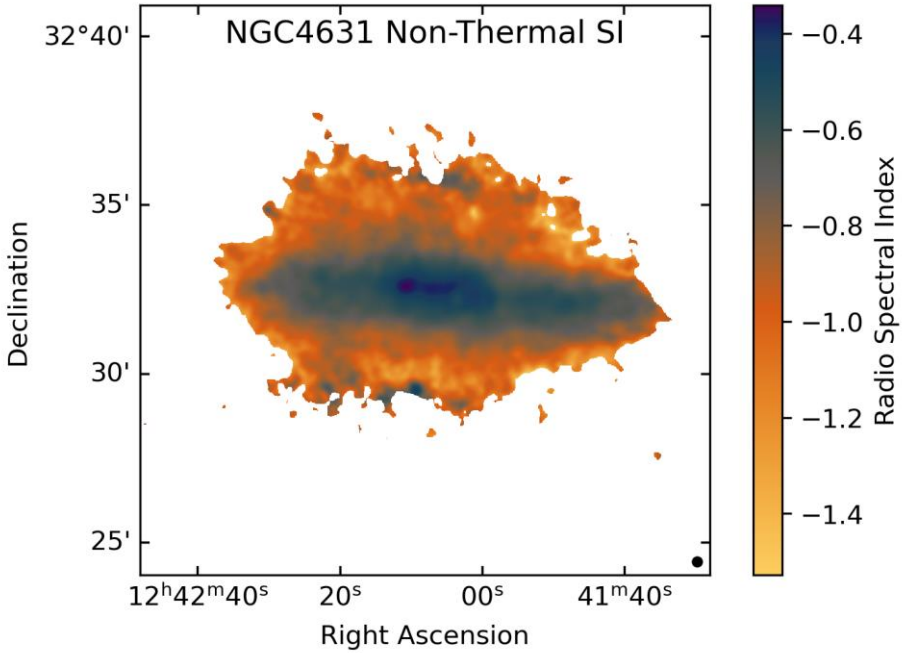
Radio Continuum | NGC4631



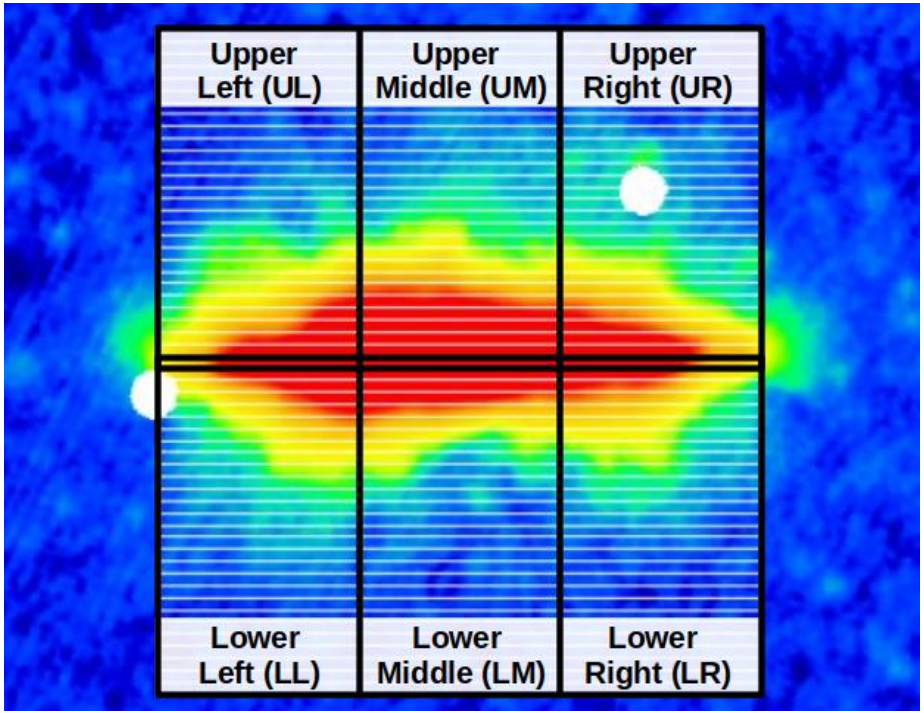


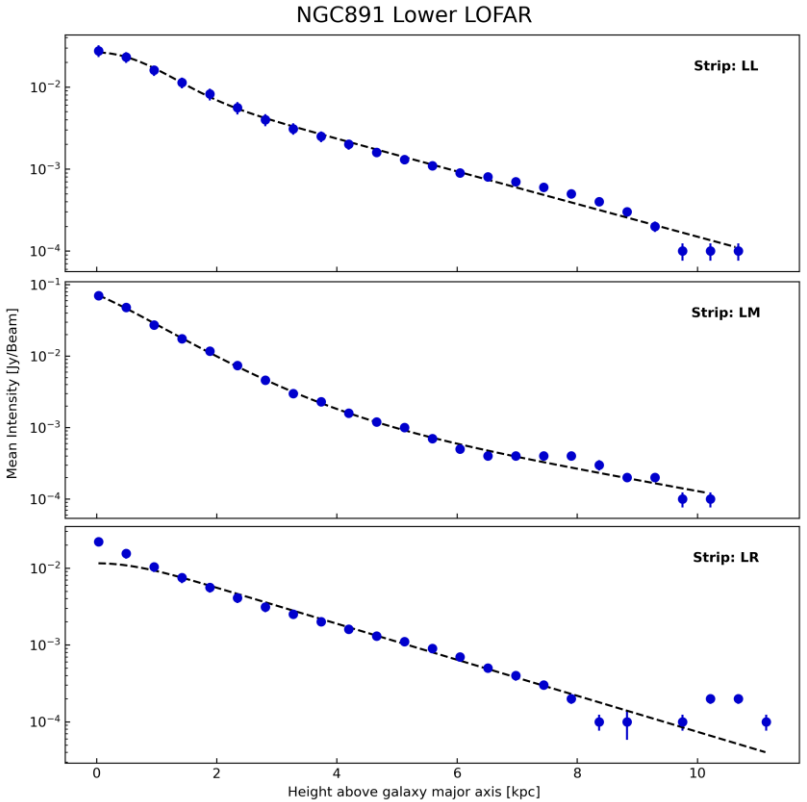
Non-Thermal Spectral Index





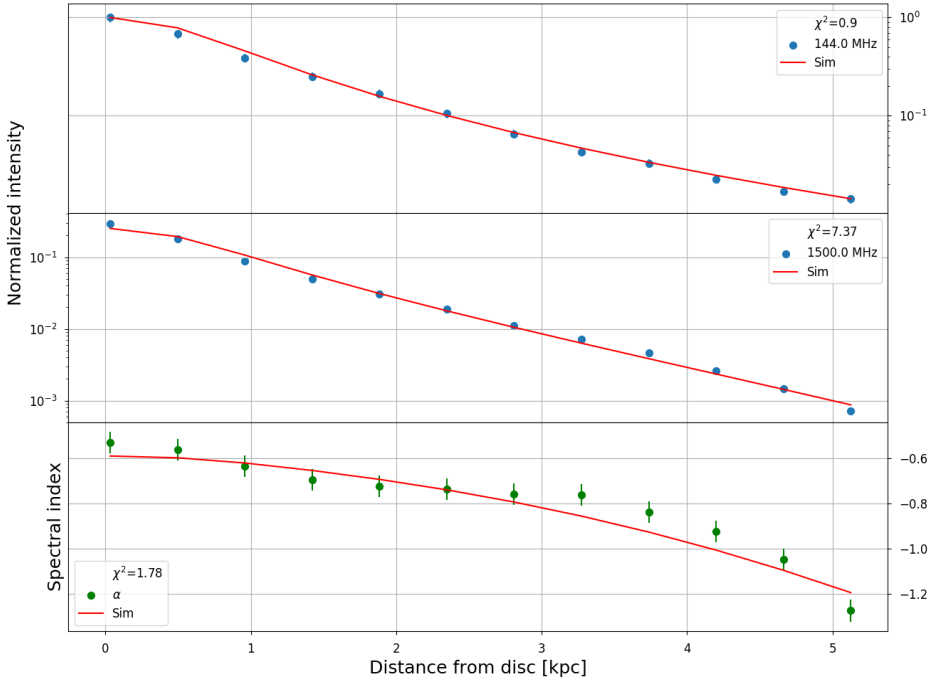
Box Integration



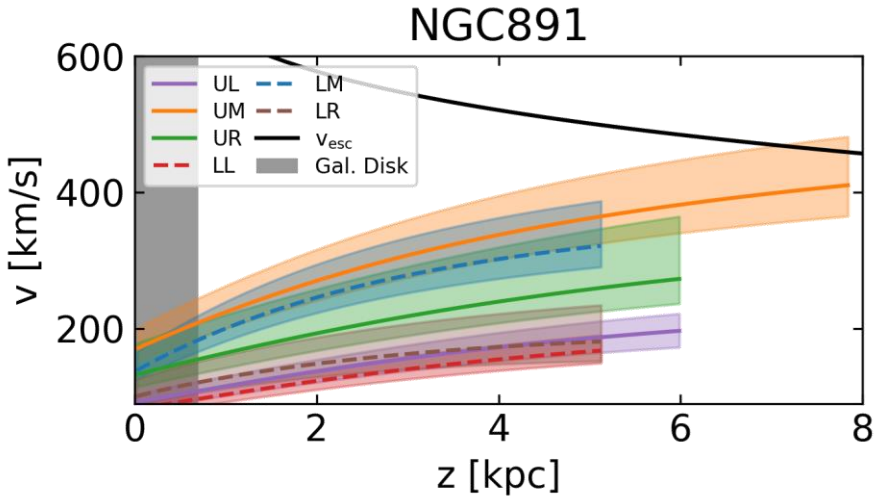


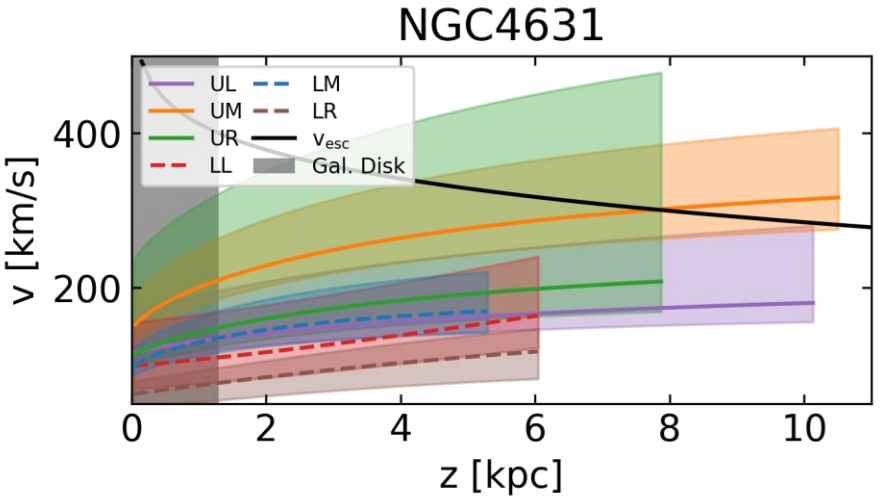
CR Transport | SPINNAKER

- Fitting two intensity profiles and one spectral index profile simultaneously.
- Distinction of Diffusion and Advection.
- Derive wind velocities and magnetic field strength profiles for advection models (Heald+2022).
- Critical point:
  Transition from sub- to supersonic wind speeds.

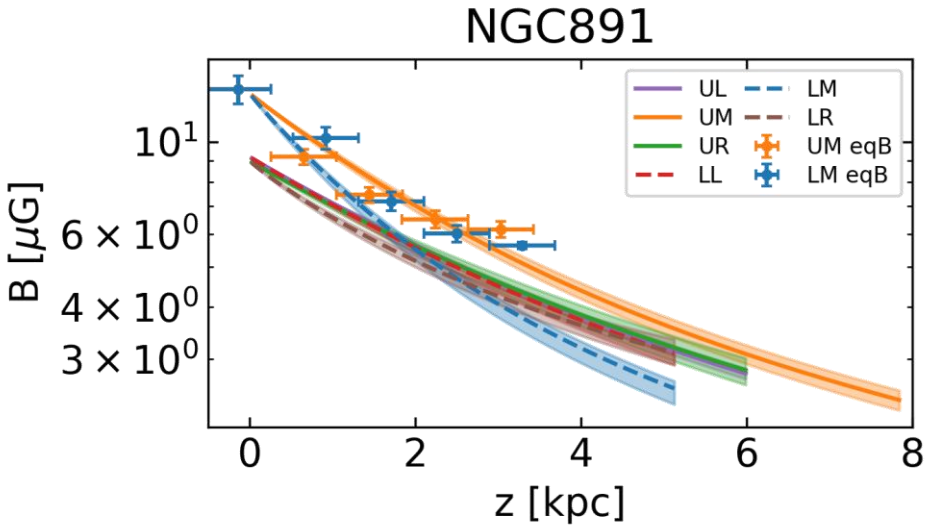


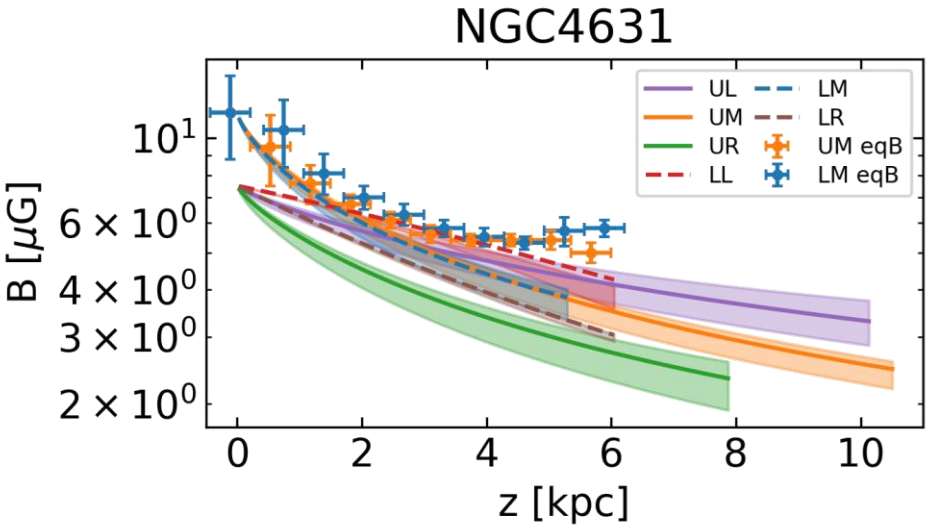
CR Transport | Wind Profiles





CR Transport | Magnetic Field Strength Profiles





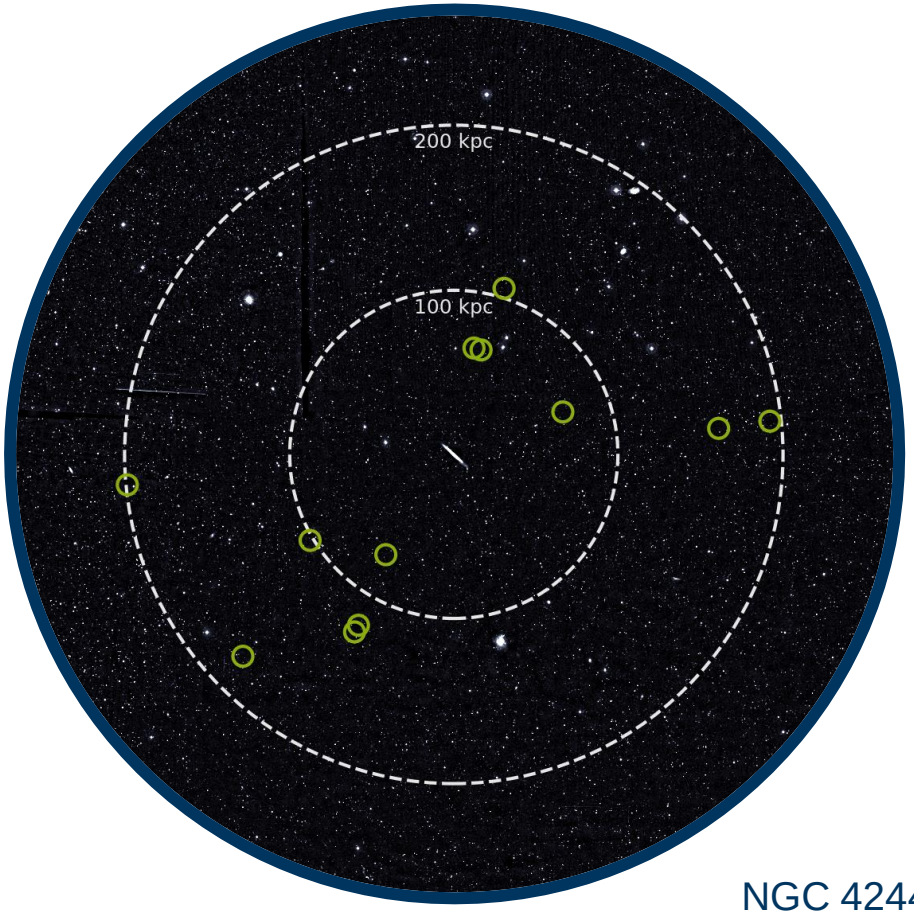
- Equipartition estimates of the magnetic field:
  based on Beck&Krause+2005 (Proton-Electron Ratio K_0=100)

Heesen+2023

Magnetic Fields in the CGM of Nearby Galaxies

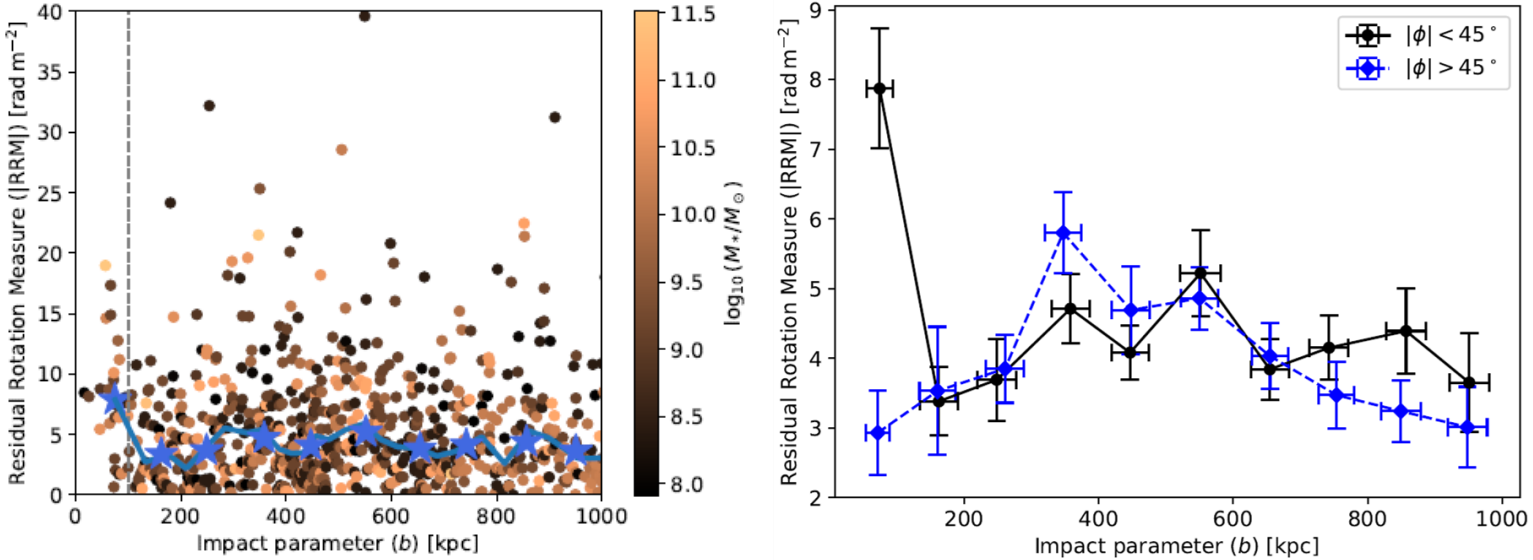
Magnetic Field in the CGM

- Statistical sightline analysis of polarized LOFAR sources
- **Background Sample:** 2461 RM sources from LOFAR (O'Sullivan et al. 2023), with sightlines close to nearby galaxies.
- **Foreground Sample:** Magnitude selected Palomar sample, 183 galaxies overlap with the background sample.
- NGC4244: 4 sources within 100 kpc, 12 sources within 200 kpc



NGC 4244

Magnetic Field in the CGM



- Excess of residual RMs (RRM, after correction for the Galactic foreground) for edge on galaxies and sightlines close to the minor axis.
- RRMs point to a magnetic field in the CGM of a few tenths of a micro gauss.

Magnetic Field Structure in galactic Halos (in progress)

NGC 5775 (Image Credit: NRAO, NASA, ESA, Hubble; Processing: Jayanne English (U. Manitoba))

NGC 4217 (Image Credi: Y. Stein (CDS), NRAO, SDSS, KPNO 0.9m, J. English (U. Manitoba), R.-J. Dettmar and A. Miskolczi (Ruhr U.), R.J. Rand (U.N.M.), and J. Irwin (Queen's U.).)

Summary

- Synchrotron emission is great to examine magnetic fields and CR transport in galactic halos.
- LOFAR is key to trace the oldest CR electrons in galactic halos.
- CR advection transport modelled in: NGC891 and NGC4631 (there is more in the paper).
- Wind velocities are likely to reach the escape velocity of the halo (truncated at 30kpc).
- RRM studies seem to be very promising to further constrain the magnetic field in the CGM.

CR Transport | Central vs. Outer Strips