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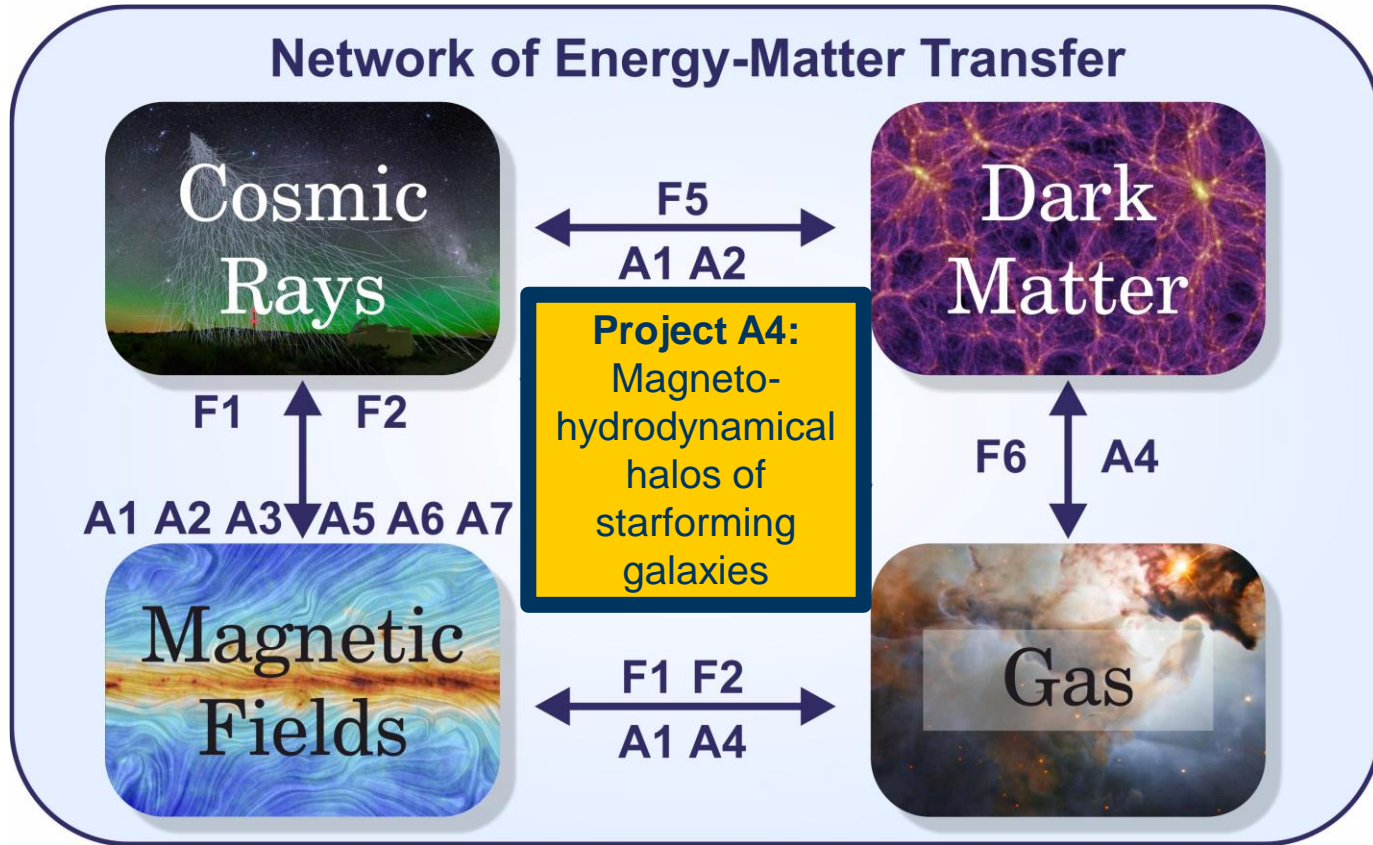
# TRACING GALACTIC MAGNETIC FIELDS AND COSMIC RAYS WITH SYNCHROTRON EMISSION | PROJECT A4

Michael Stein | SFB1491 General Assembly | 07.11.2023, Dortmund



Astronomisches Institut  
RUHR-UNIVERSITÄT BOCHUM

# Network of Energy-Matter Transfer



# Why Radio Continuum Data?

- Total synchrotron emission → Total magnetic field strength ( $\mathbf{B}_{\text{tot}} \propto I_{\text{tot}}$ )
- Polarised synchrotron emission → Regular magnetic field ( $\mathbf{B}_{\text{reg}} \propto I_{\text{pol}}$ )
- 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

# Telescopes?



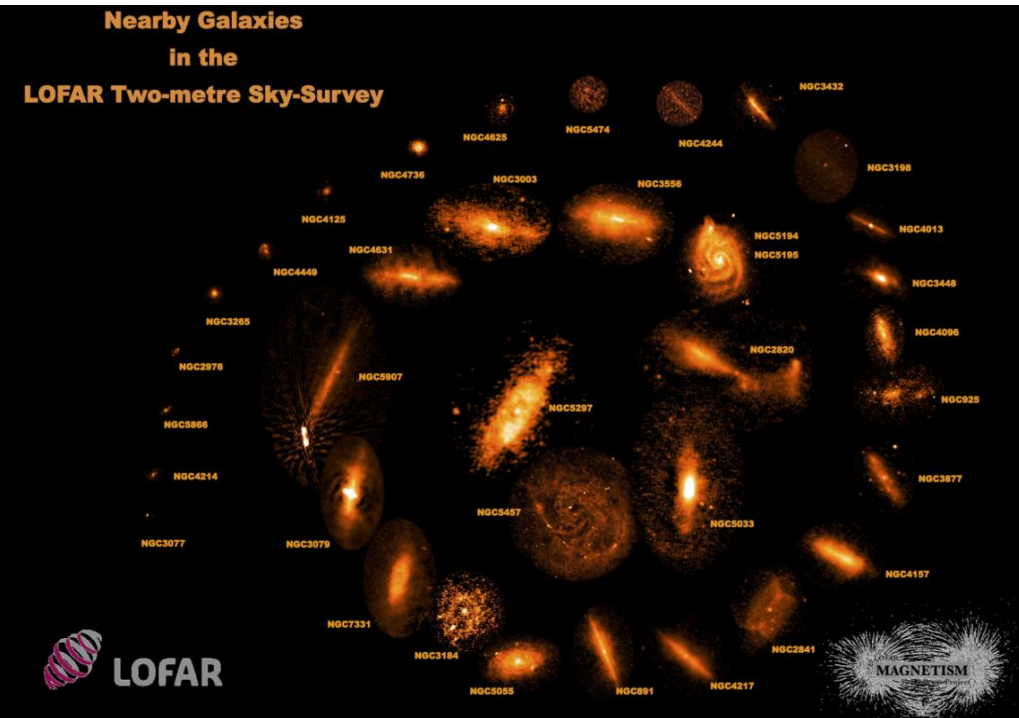
Low Frequency Array (LOFAR)



Very Large Array (VLA)

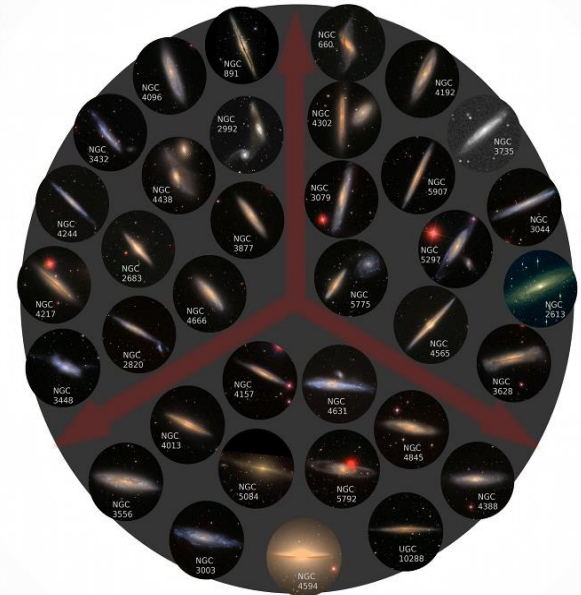


# LoTSS & VLA L-Band (CHANG-ES)



**CHANG-ES  
Continuum  
HALOs in  
Nearby  
Galaxies  
- an  
EVLA  
Survey**

**EVLA  
Expanded  
Very  
Large  
Array**



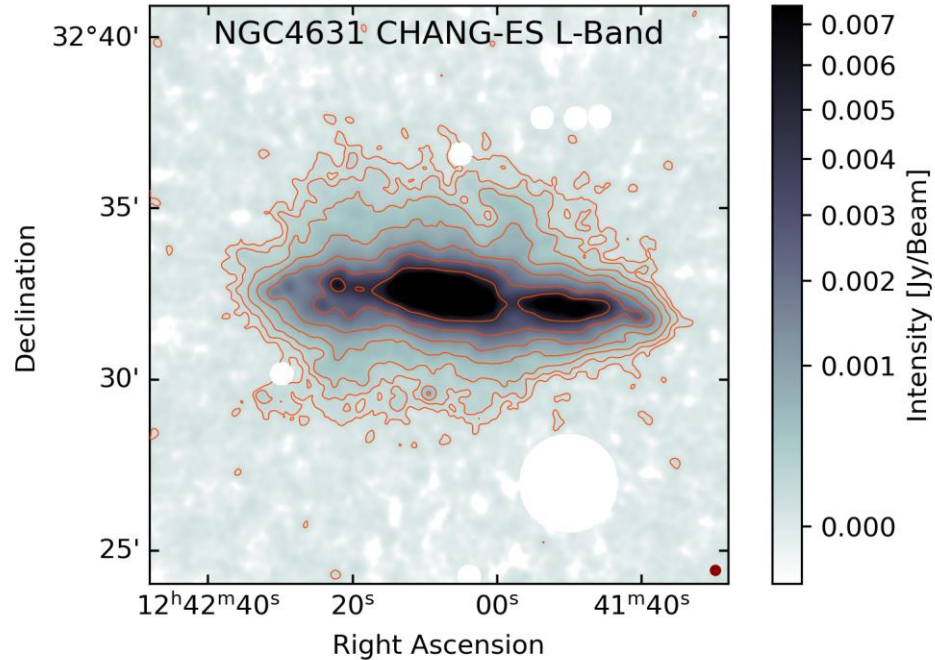
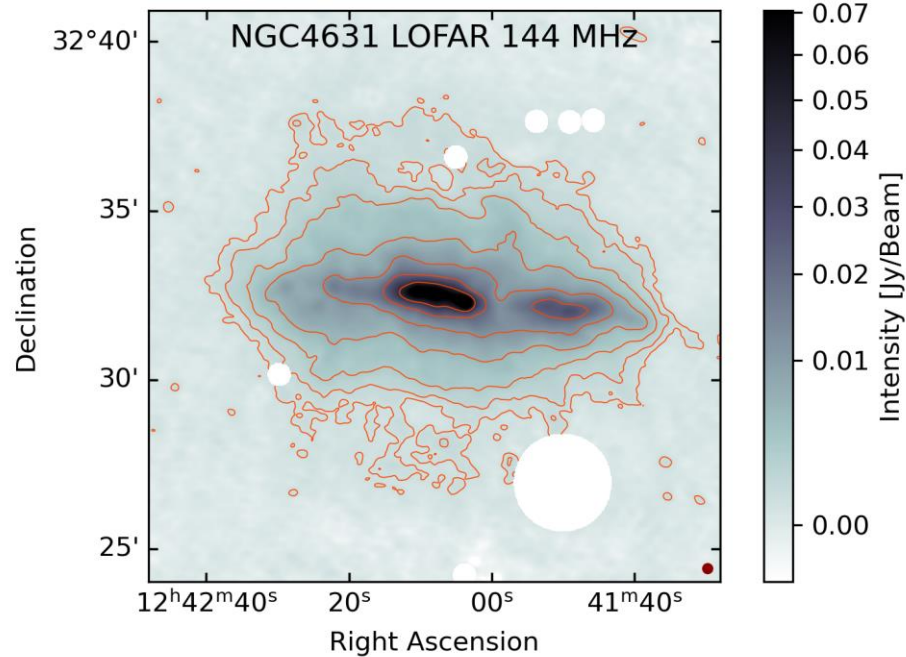
Optical Image credit: SDSS, DSS, CFHT Hawaiian Sky, ESOVIMOS, CTIO AstroDon.

[Stein+2023](#)

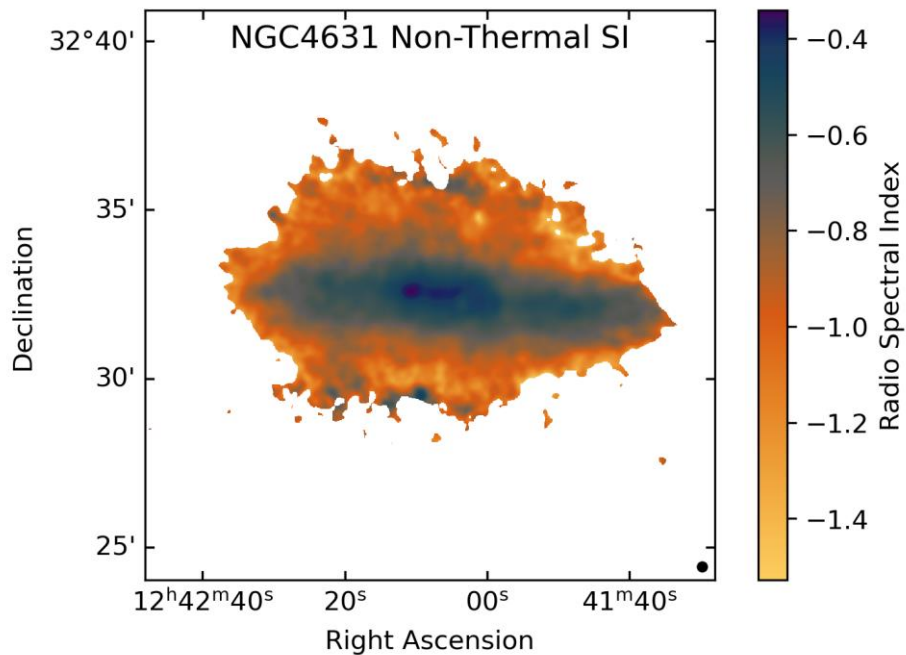
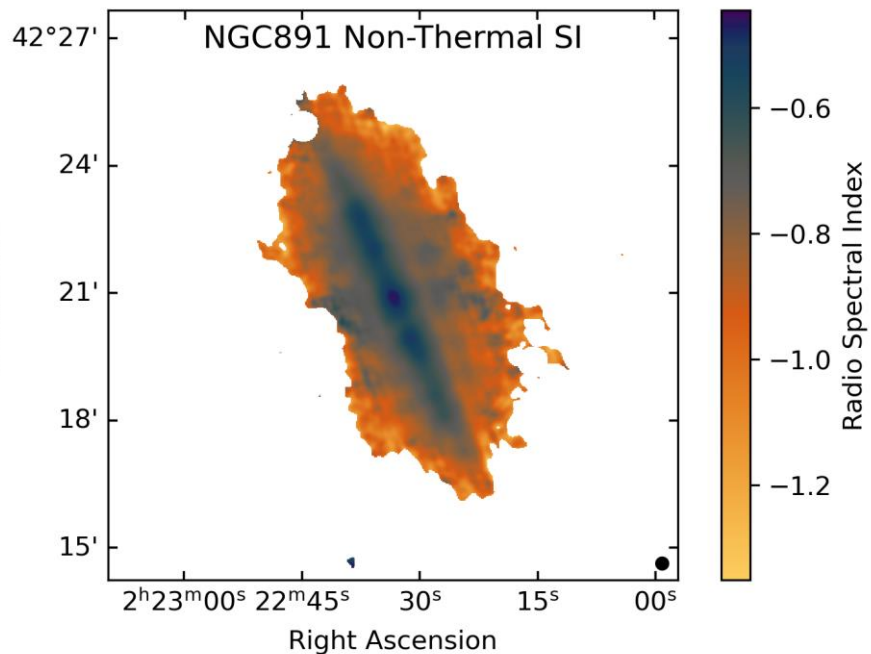


# Cosmic Ray Transport in Edge-On Galaxies

# Radio Continuum | NGC 4631

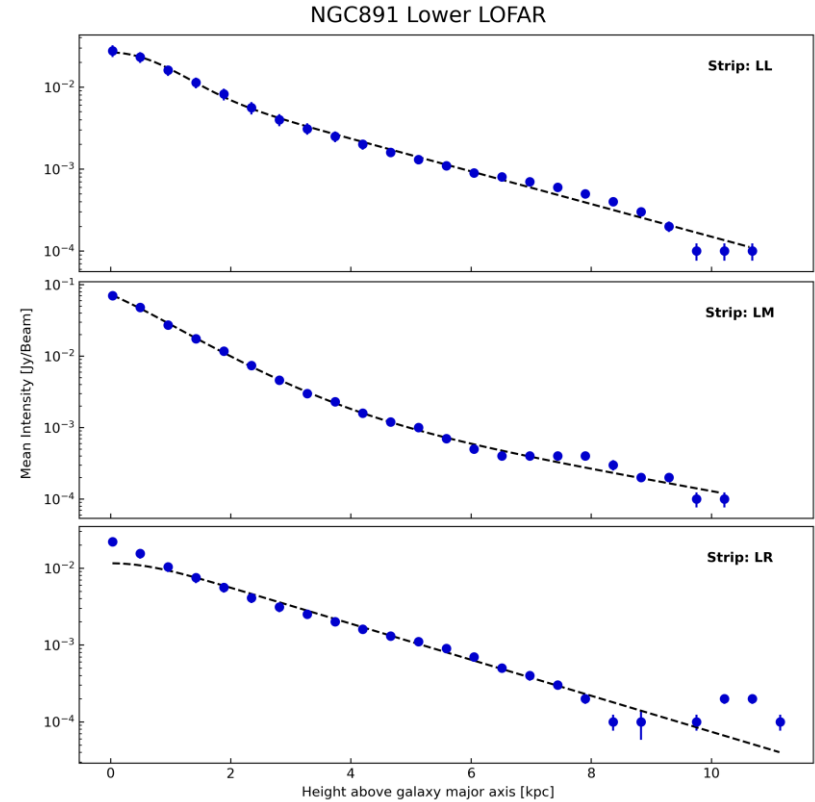
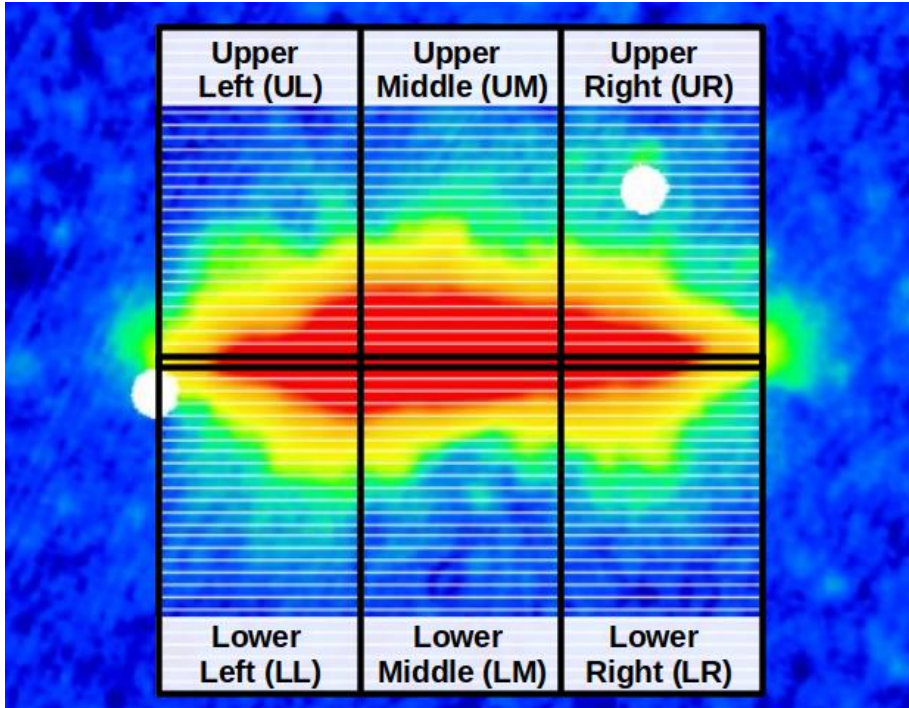


# Non-Thermal Spectral Index



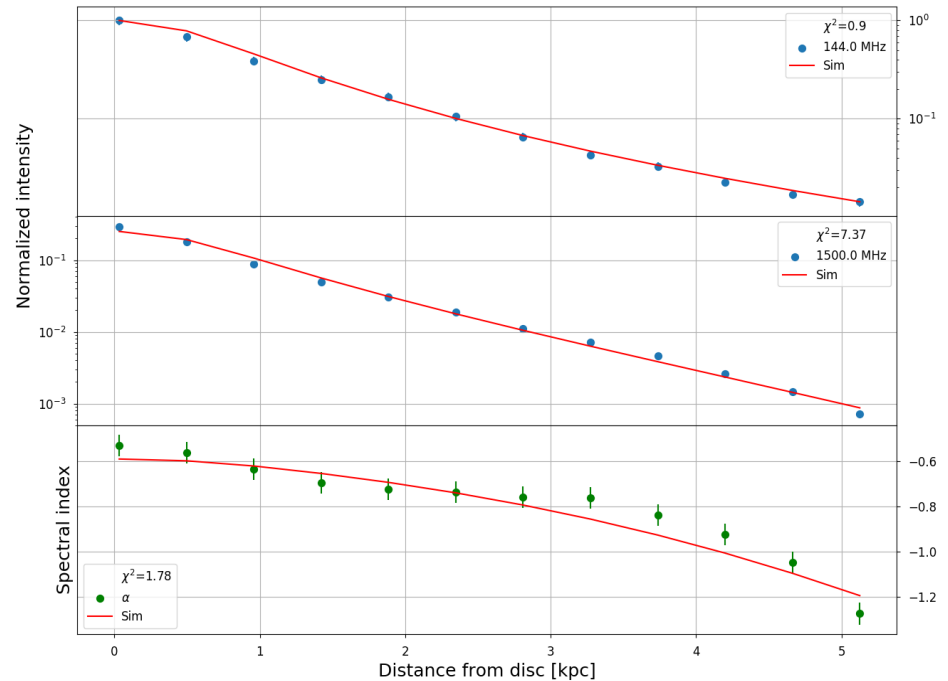


# Box Integration

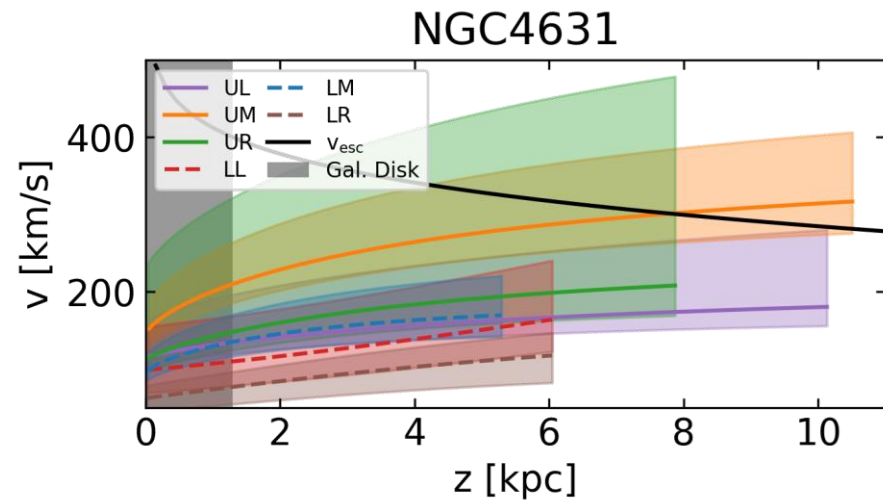
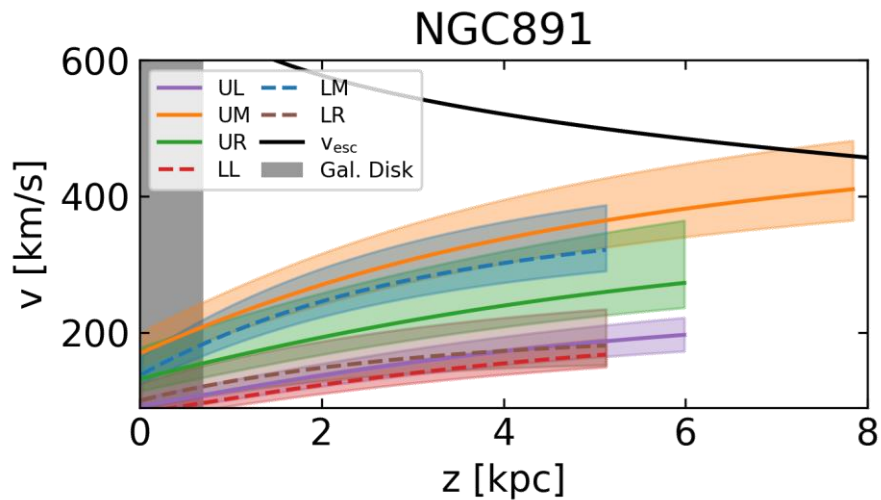


# CR Transport | SPINNAKER

- 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.

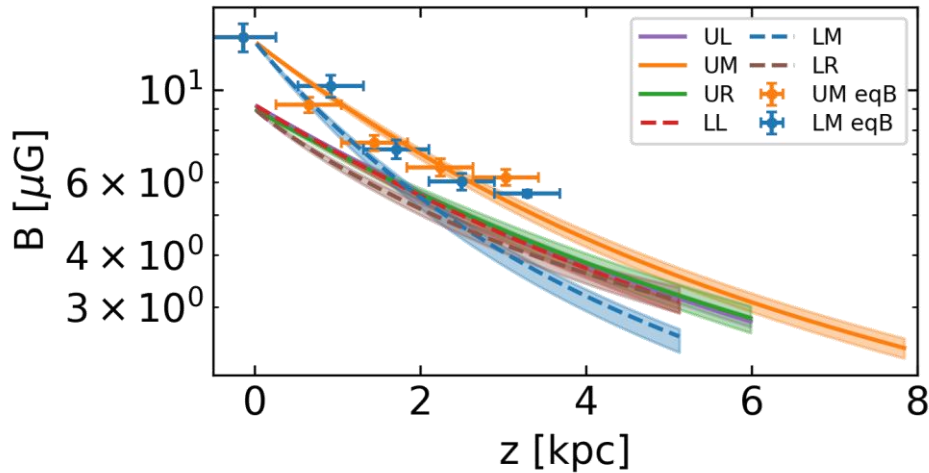


# CR Transport | Wind Profiles

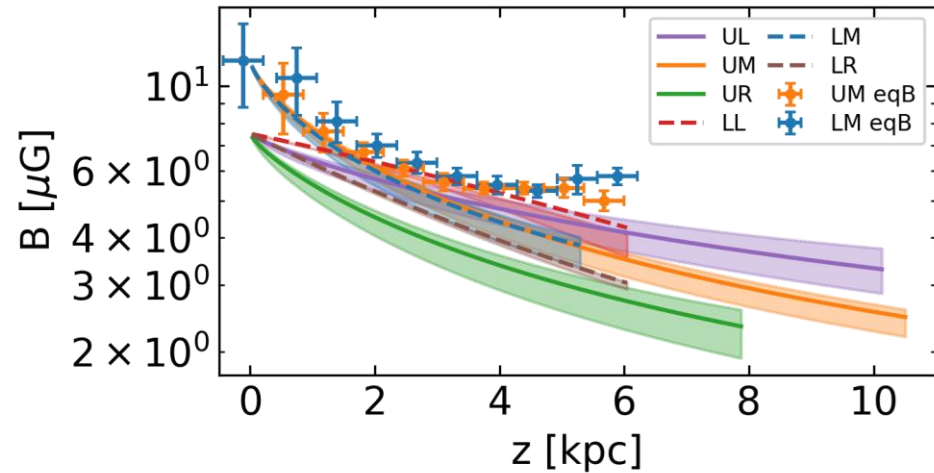


# CR Transport | Magnetic Field Strength Profiles

NGC891



NGC4631



- 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

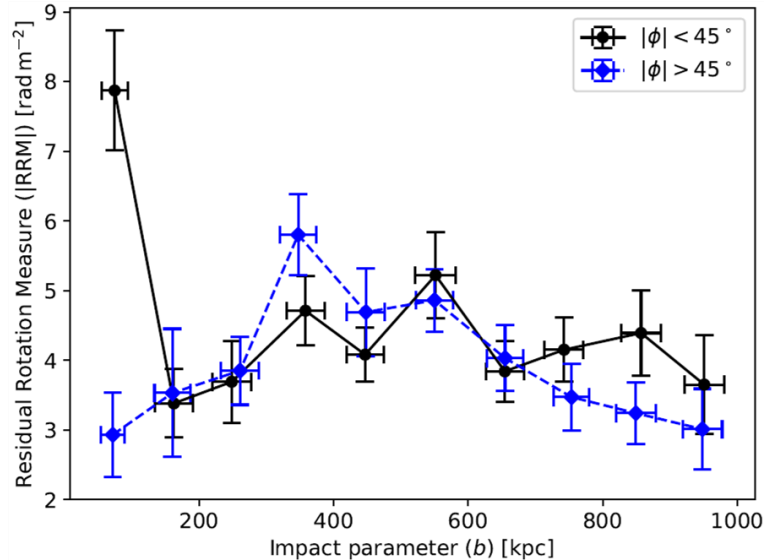
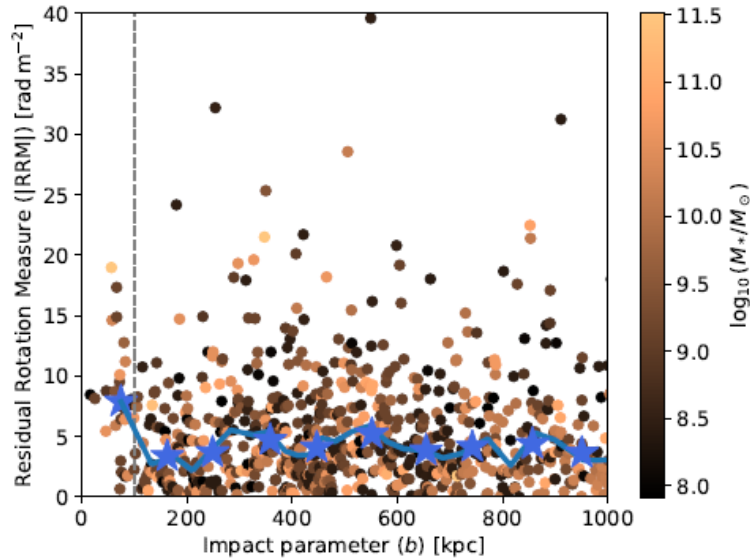


# Magnetic Field in the CGM

- 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.
- NGC 4244: 4 sources within 100 kpc, 12 sources within 200 kpc



# 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)

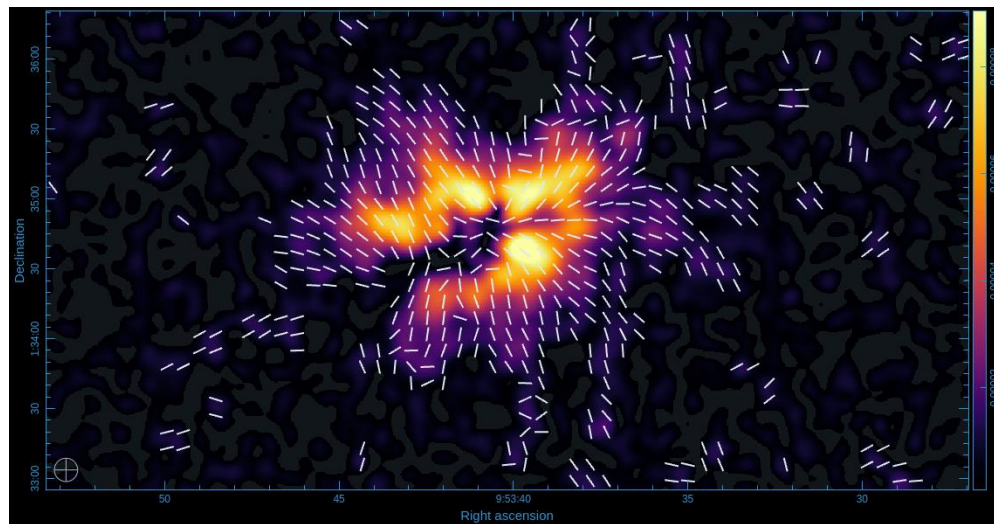


NGC 4217 (Image Credi: Y. Stein (CDS), NRAO, SDSS, KPNO 0.9m, J. English (U. Manitoba), R.-J. Dettmar and A. Miskolczi (Ruhr U.), R.J. Rand (U.N.M.), and J. Irwin (Queen's U.))

# Magnetic field structure in galactic halos

- Radio polarimetry observations of NGC 3044 with the VLA (CHANG-ES).
- Combining S- & C-band data.
- Polarised intensity overlaid, with B-Field Vectors
- NGC 3044 shows large magnetic tubes that reach into the galactic halo.
- B-Field vectors show X-shape structure.

Image Credit:  
Cook, Irwin, Stein



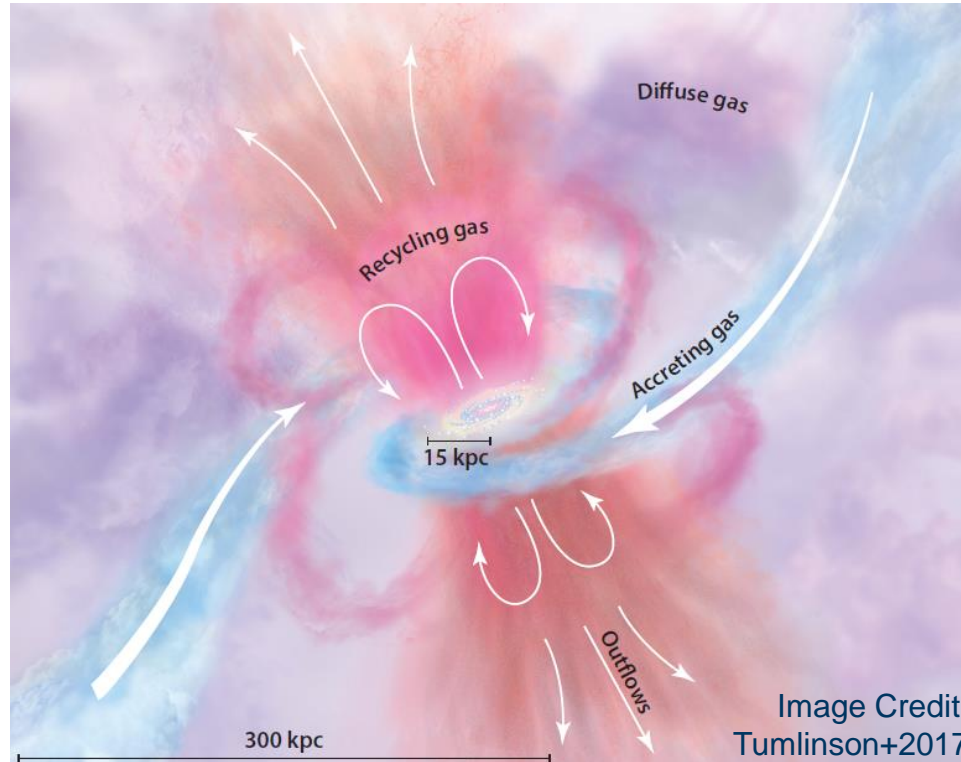


# Project A4: Observers Promises

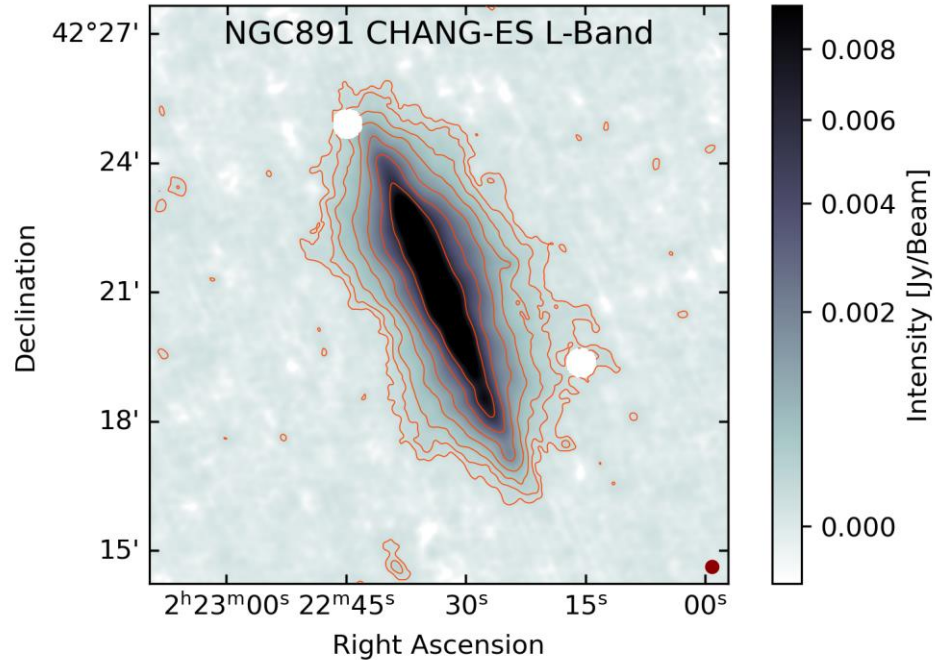
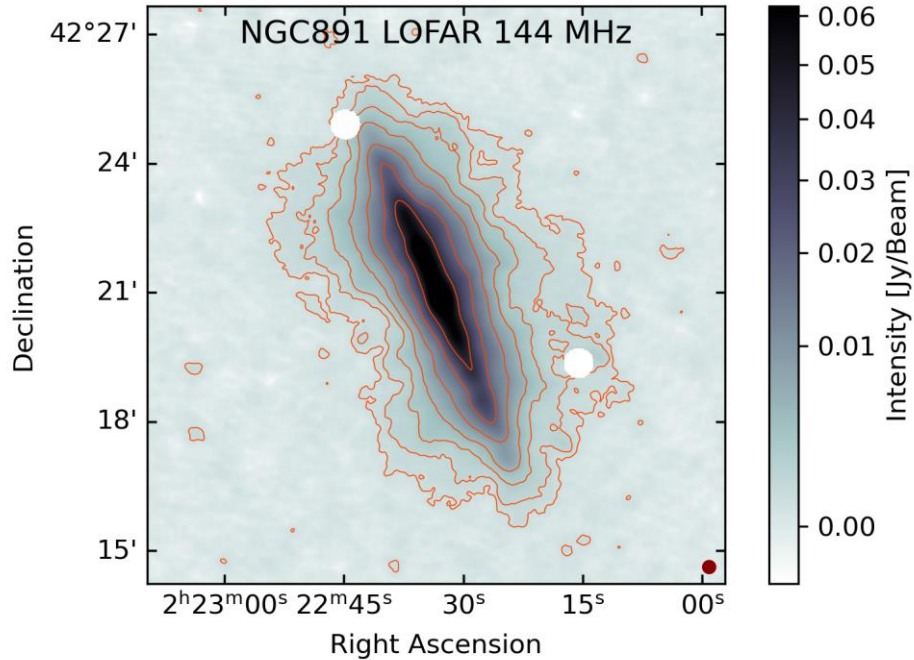
- **Year 1:** Analysis of large scale magnetic (perpendicular to the line of sight) fields in CHANG-ES galaxies.
- **Year 2:** Analysis of the cosmic ray transport based on LOFAR and CHANG-ES data
- **Year 3:** Analysis of the magnetic field parallel to the line of sight
- **Year 4:** Analysis of the full CHANG-ES sample



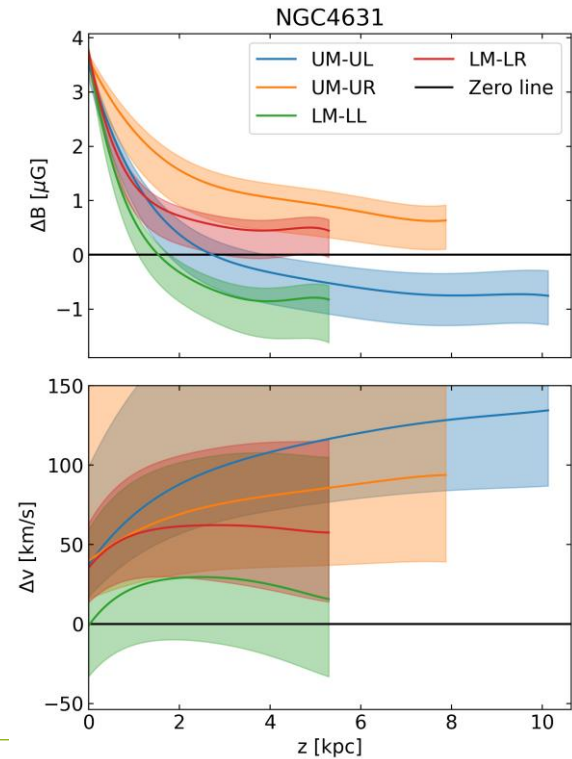
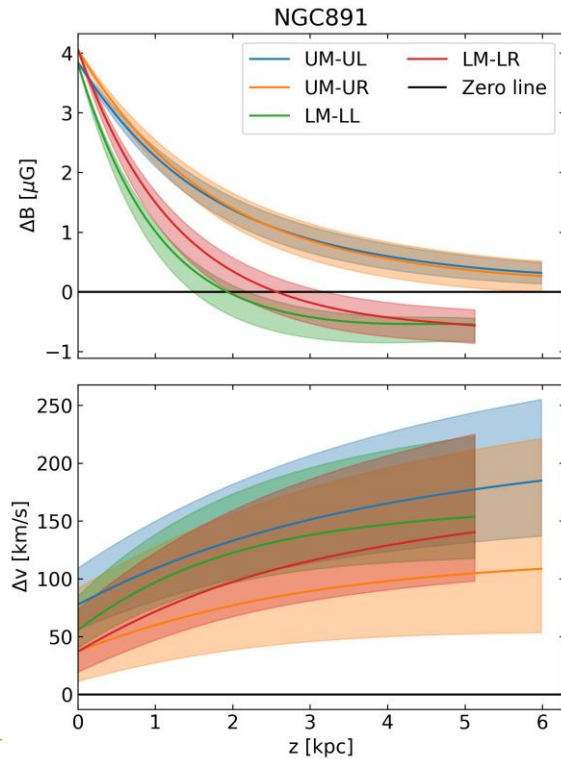
# The Circumgalactic Medium (CGM)



# Radio Continuum | NGC891



# CR Transport | Central vs. Outer Strips





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