February 3, 2021

HAWC+ Far-Infrared Observations of the Magnetic Field Geometry in M51 and NGC 891.

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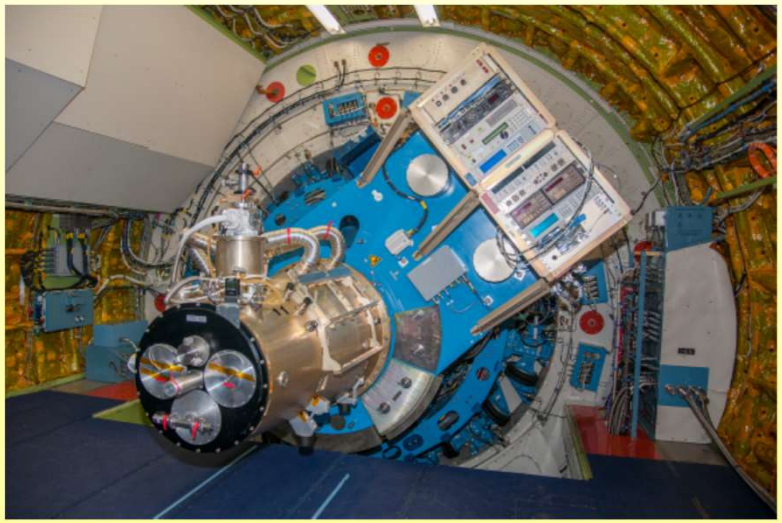
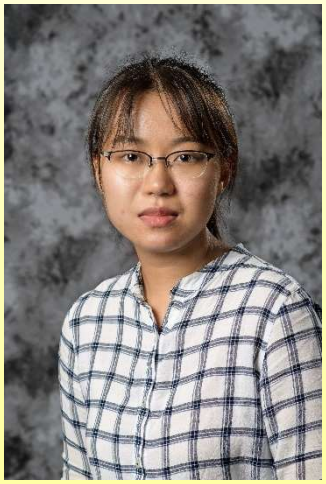
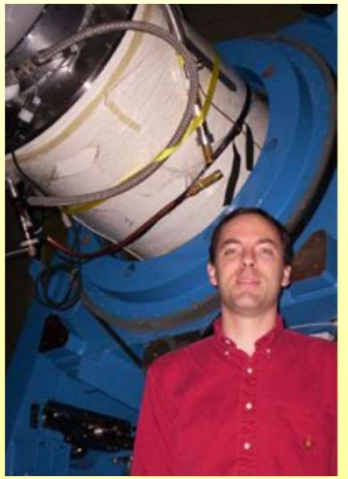
(HAWC+ Science Team)



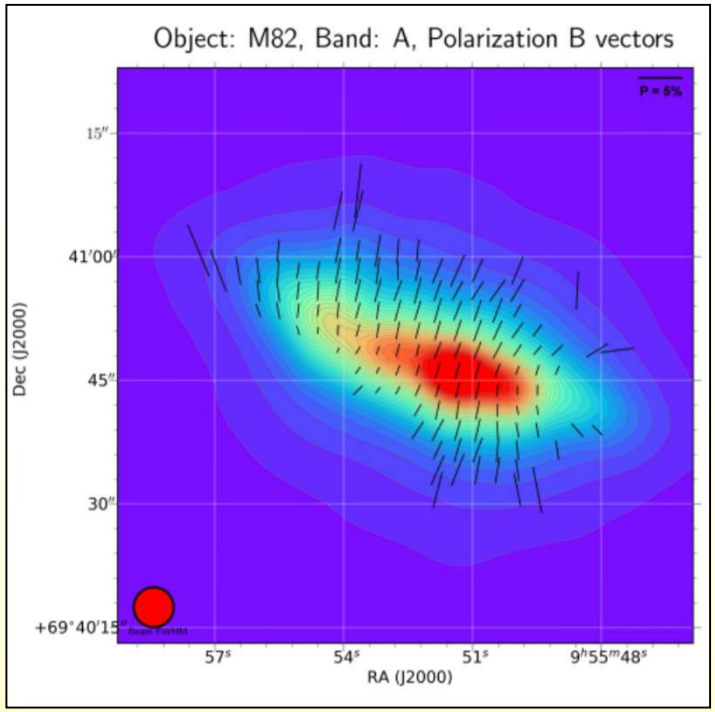
HAWC+

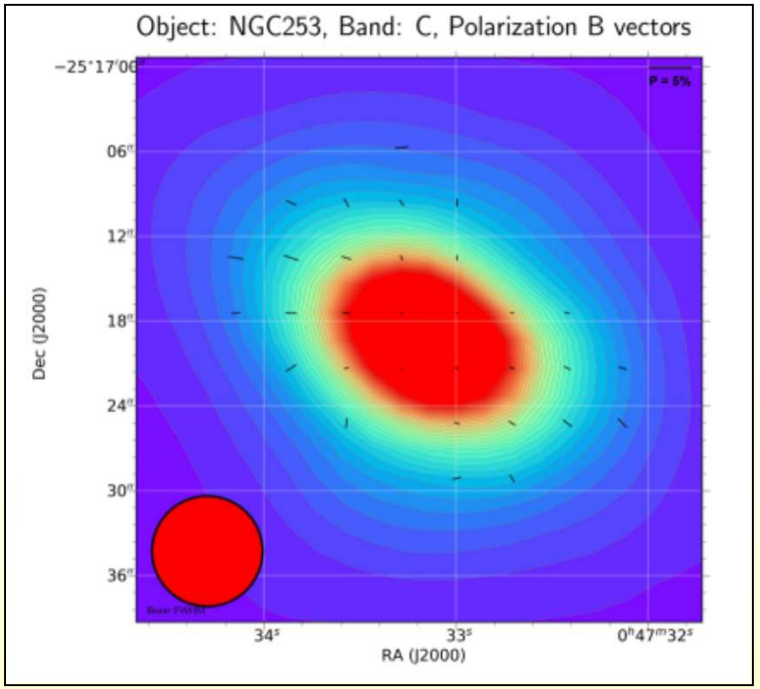


Jin-Ah Kim

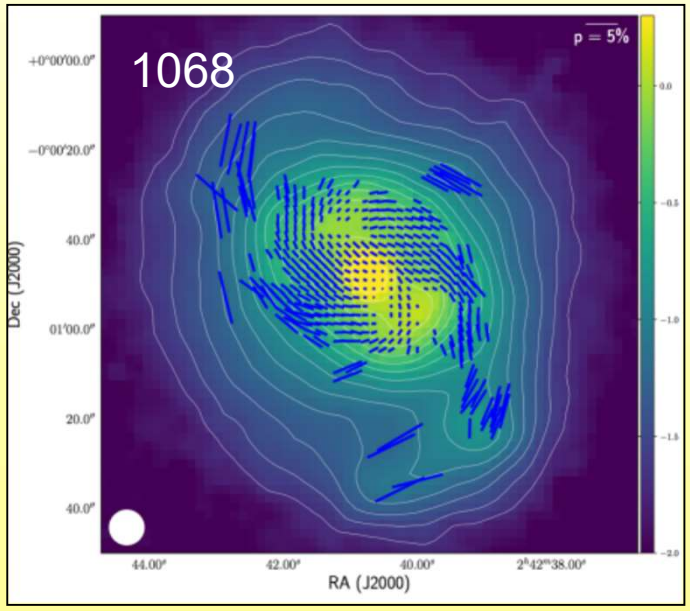


Darren Dowell




Jones et al.





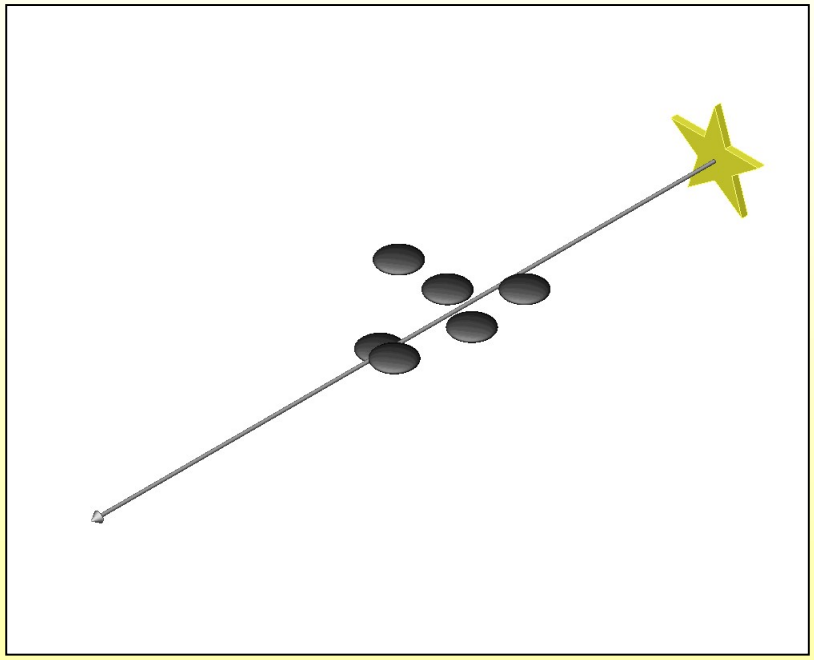
Lopez-Rodriguez et al.

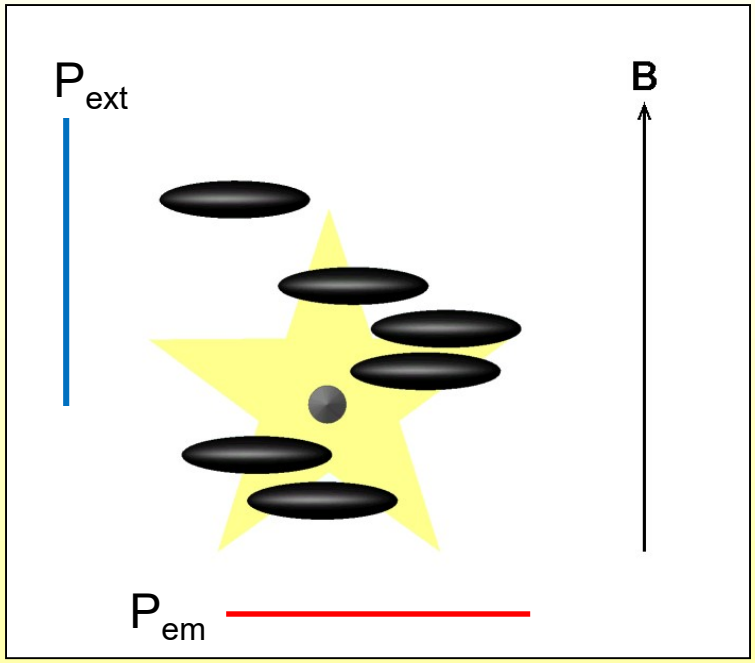
M51
D=8.5 Mpc
Beam = 560 pc

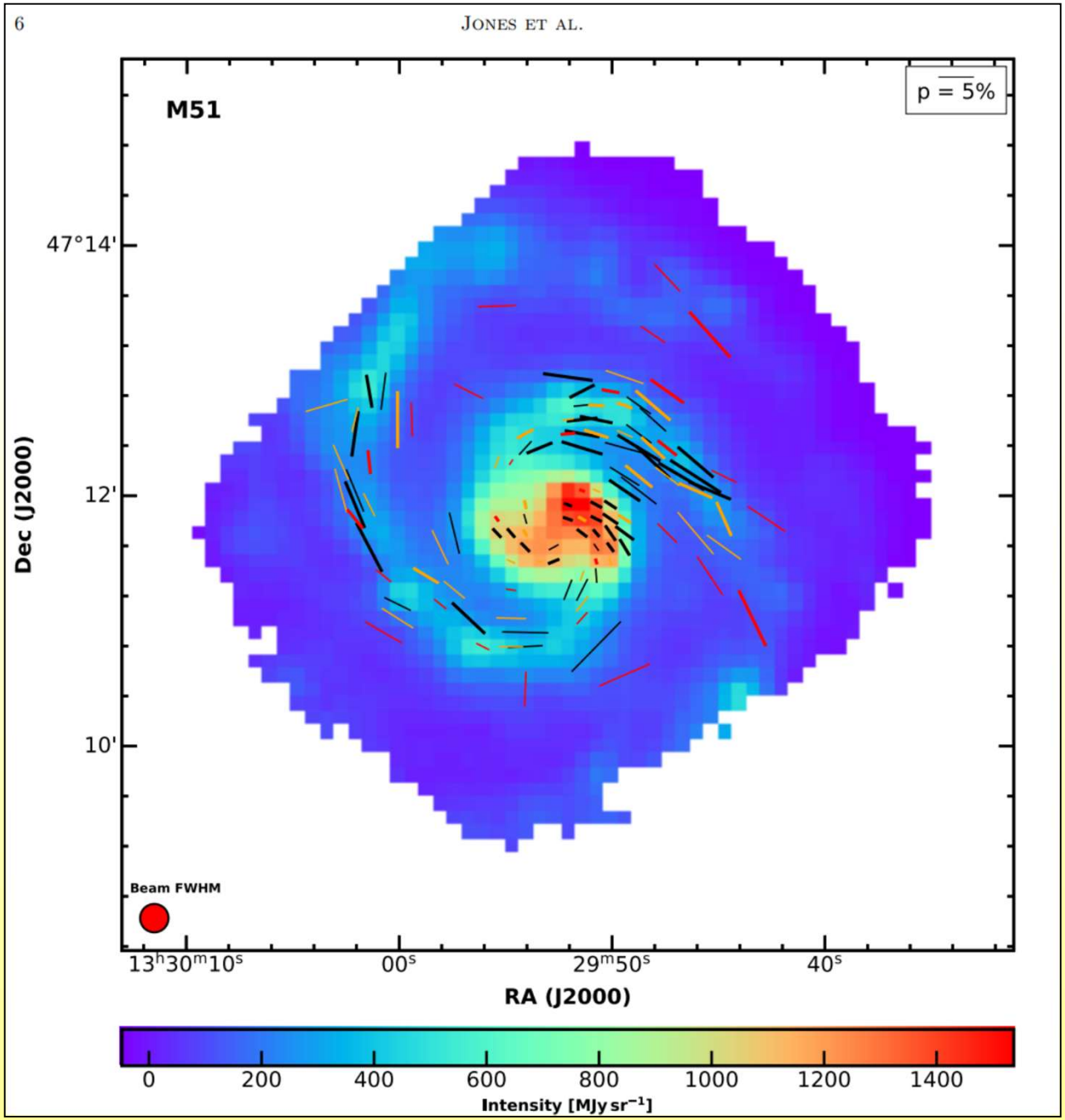
NGC 891
D=8.4 Mpc
Beam = 550 pc

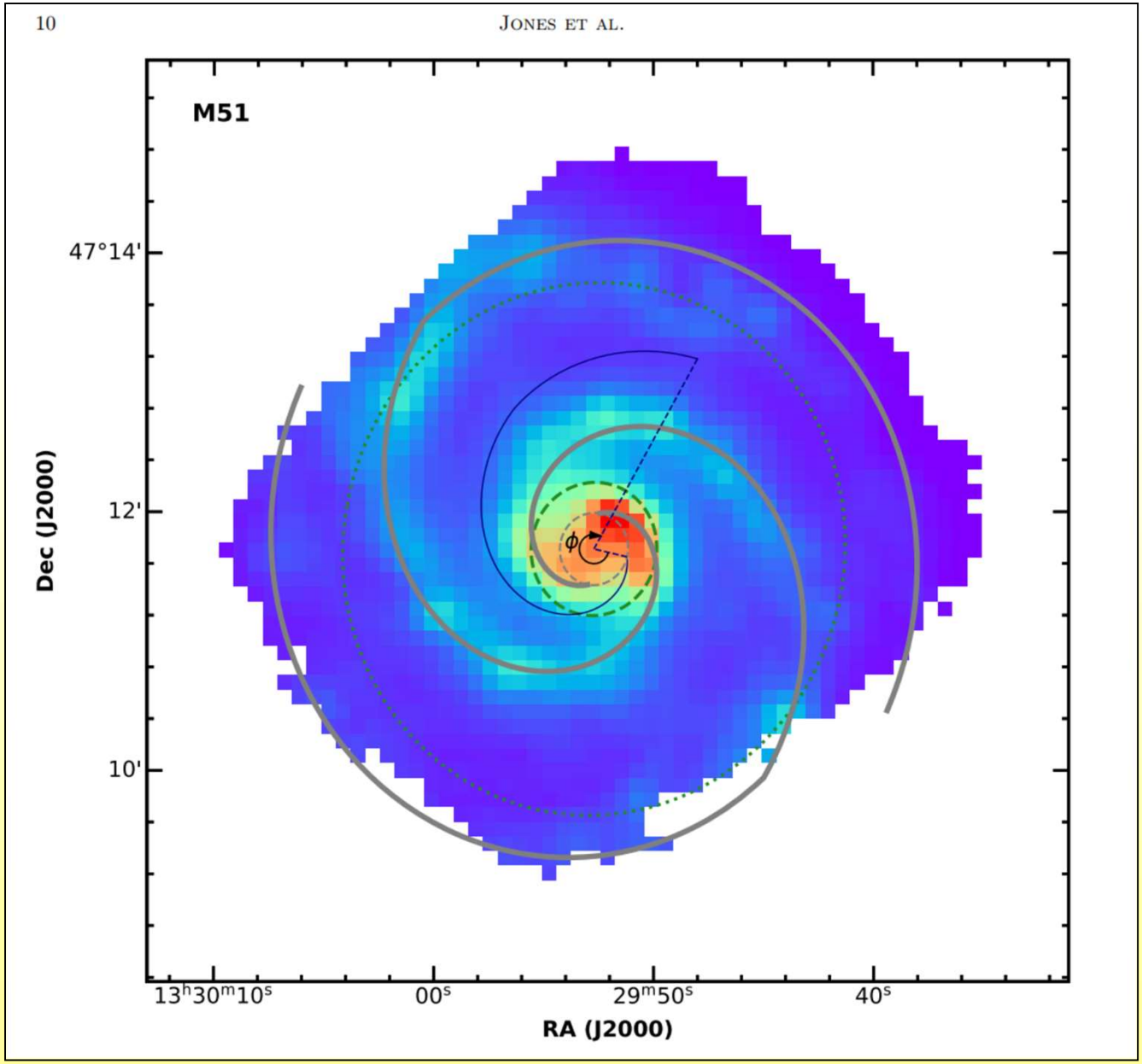
HAWC+ polarimetry has far outperformed our expectations

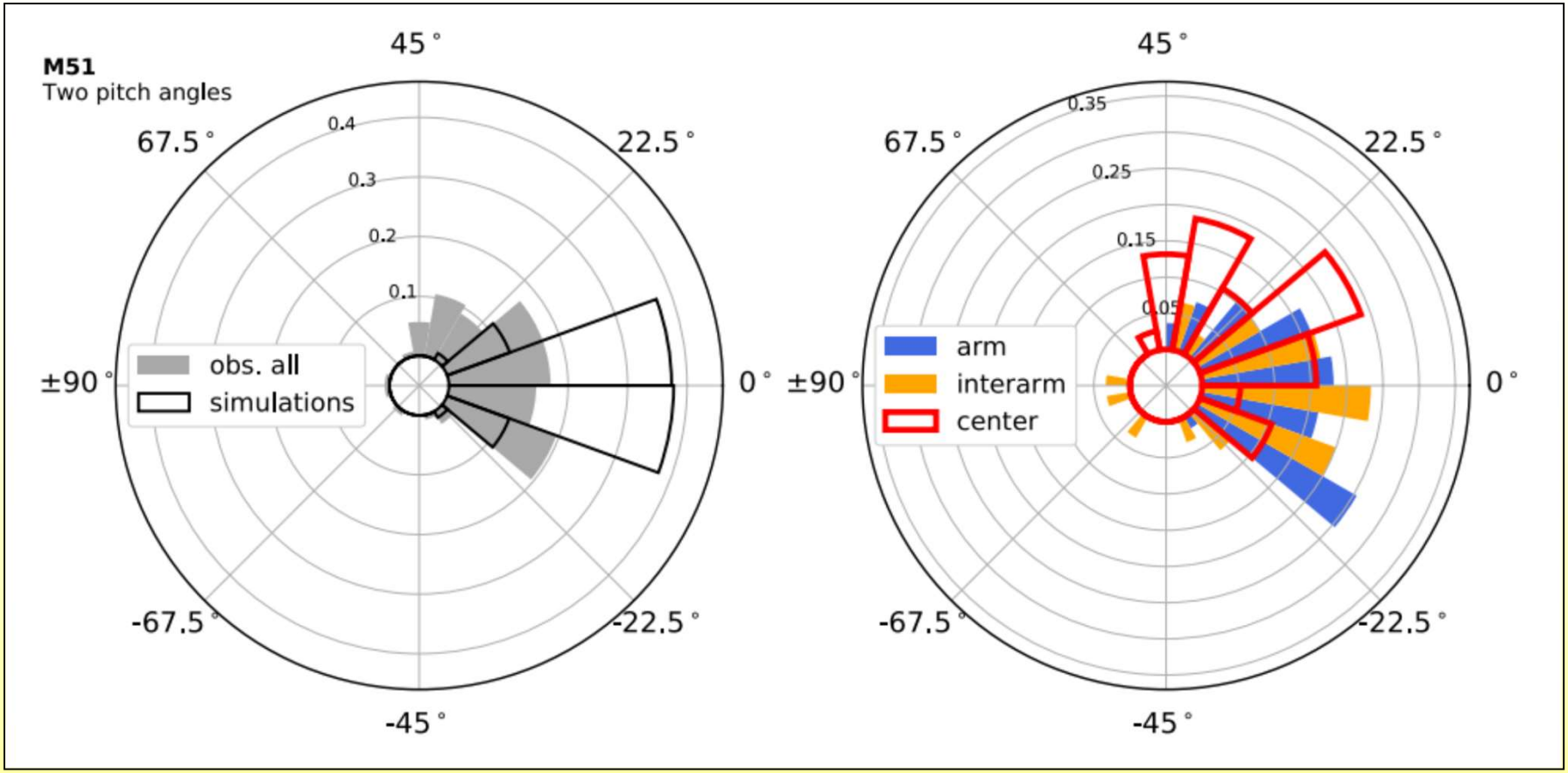
# Interstellar Polarization






6
JONES ET AL.
M51
p = 5%
47°14'
12'
10'
Dec (J2000)
Beam FWHM
13h30m10s
00s
29m50s
40s
RA (J2000)
0
200
400
600
800
1000
1200
1400
Intensity [MJy sr−1]


10
JONES ET AL.
M51
47°14'
12'
10'
Dec (J2000)
13h30m10s
00s
29m50s
40s
RA (J2000)
ϕ




Arm, interarm, center – Pineda et al. 2018

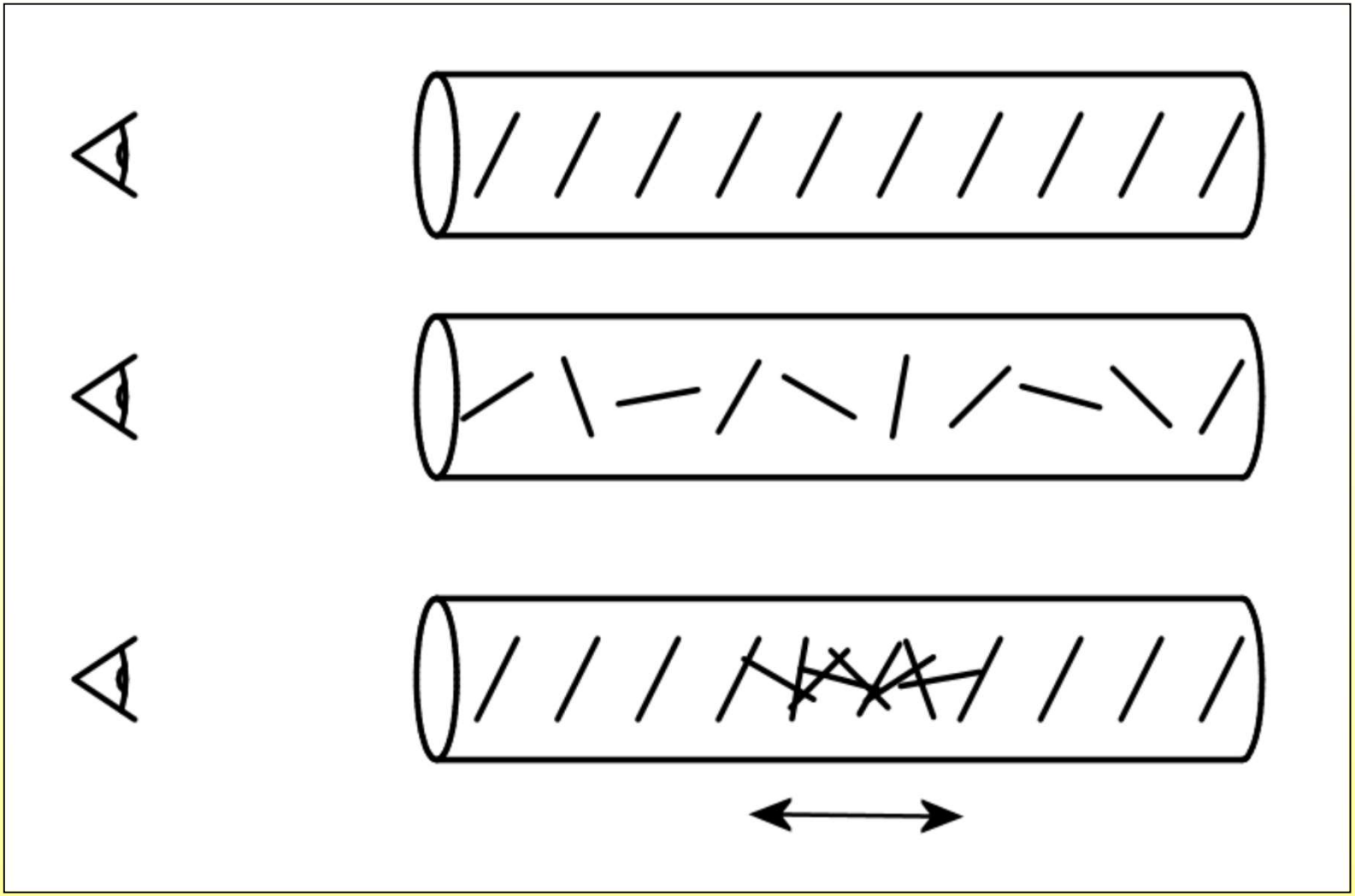
# Polarization vs. Optical Depth (Column Density)

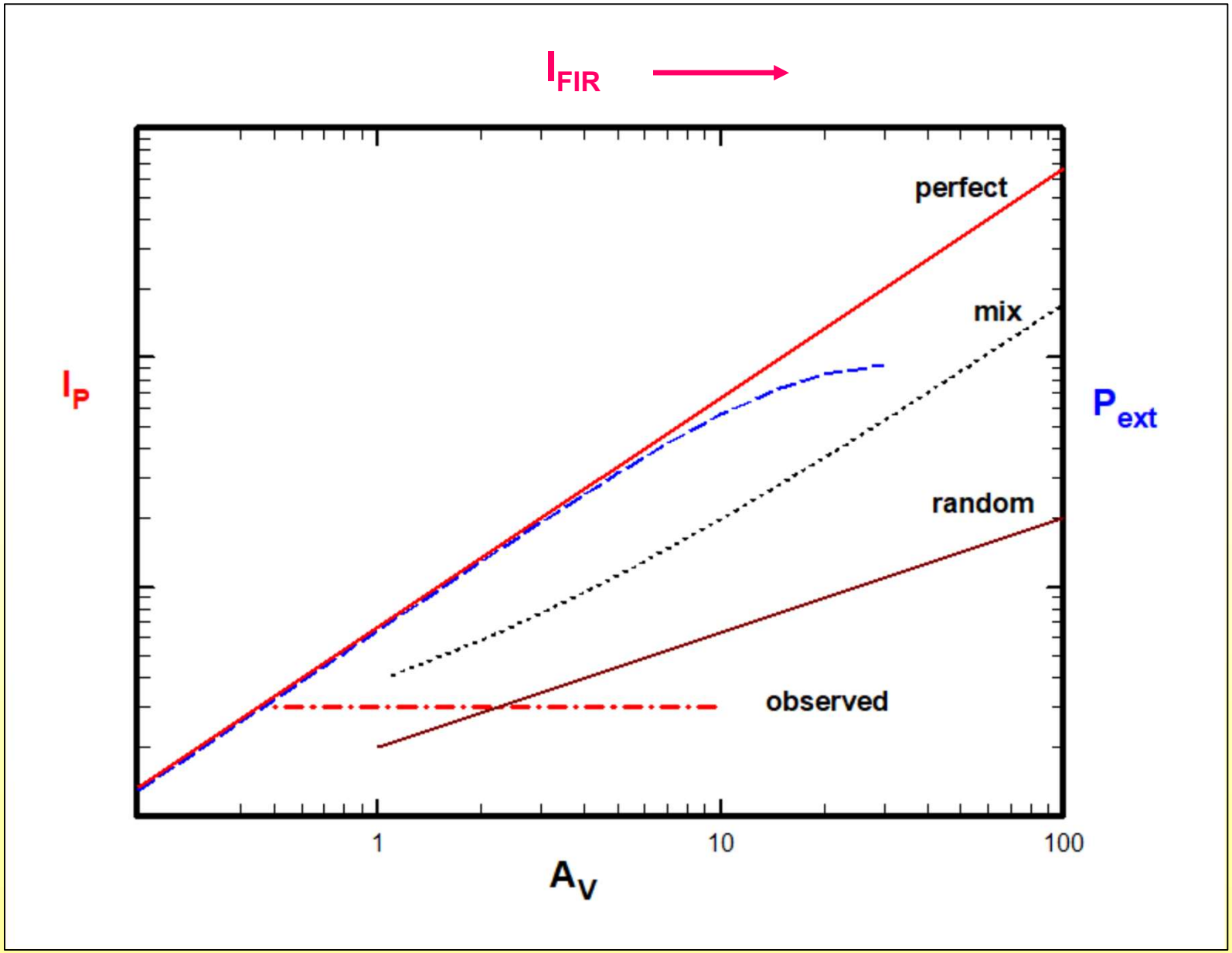
$$P_{ext} = \mathrm{Tanh}(\tau_P) \sim \tau_P$$
$$I_P = \tau_P B \propto P_{ext}$$

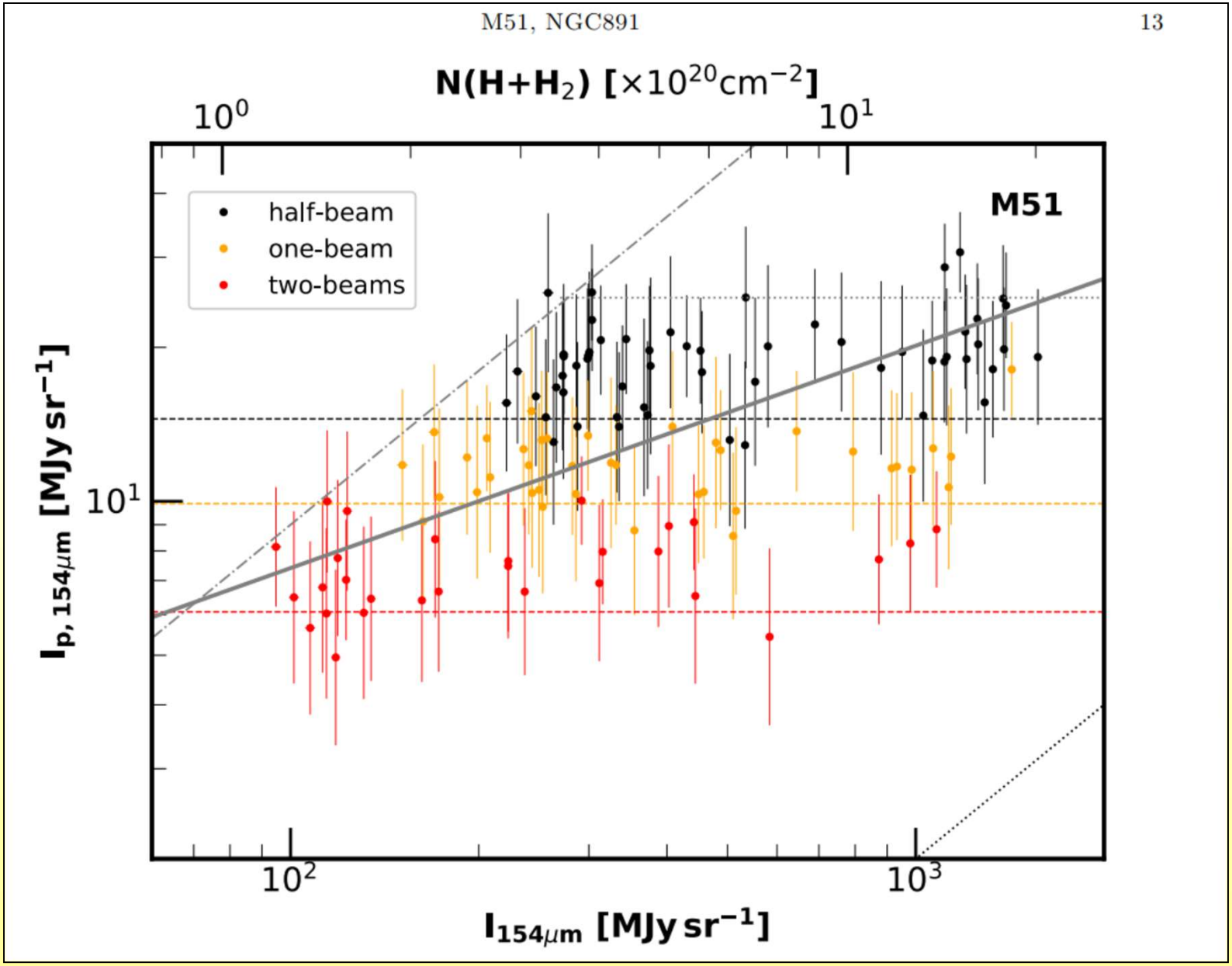
$$I_P = \sqrt{Q^2 + U^2}$$

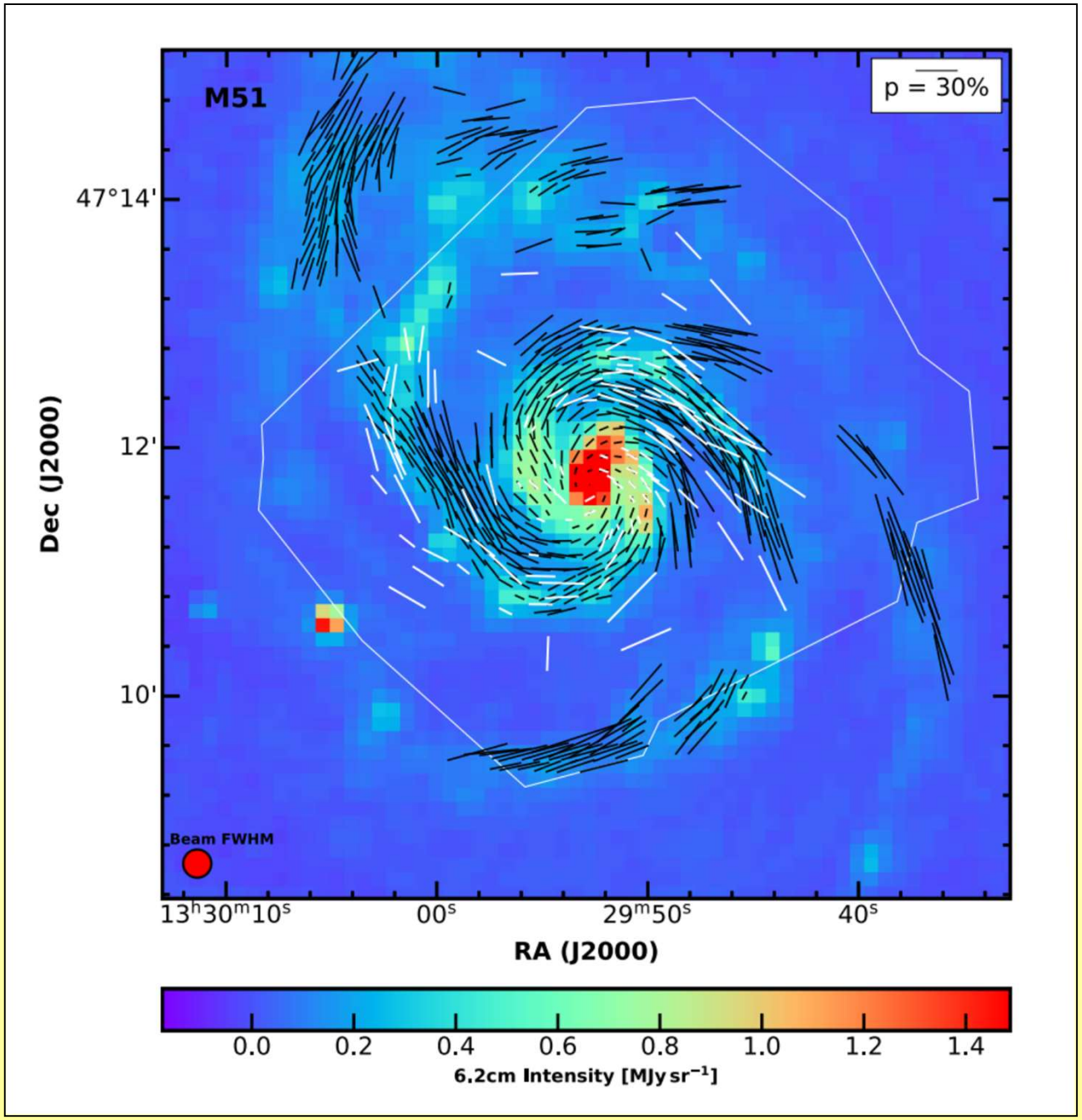
Jones & Whittet 2015

# Consider three different lines of sight




$I_{FIR}$
perfect
mix
random
observed
$I_P$
$P_{ext}$
1
10
100
$A_V$


N(H+H2) [×10^20 cm^-2]
10^0
10^1
half-beam
one-beam
two-beams
M51
Ip, 154μm [MJy sr^-1]
10^1
10^2
10^3
I154μm [MJy sr^-1]

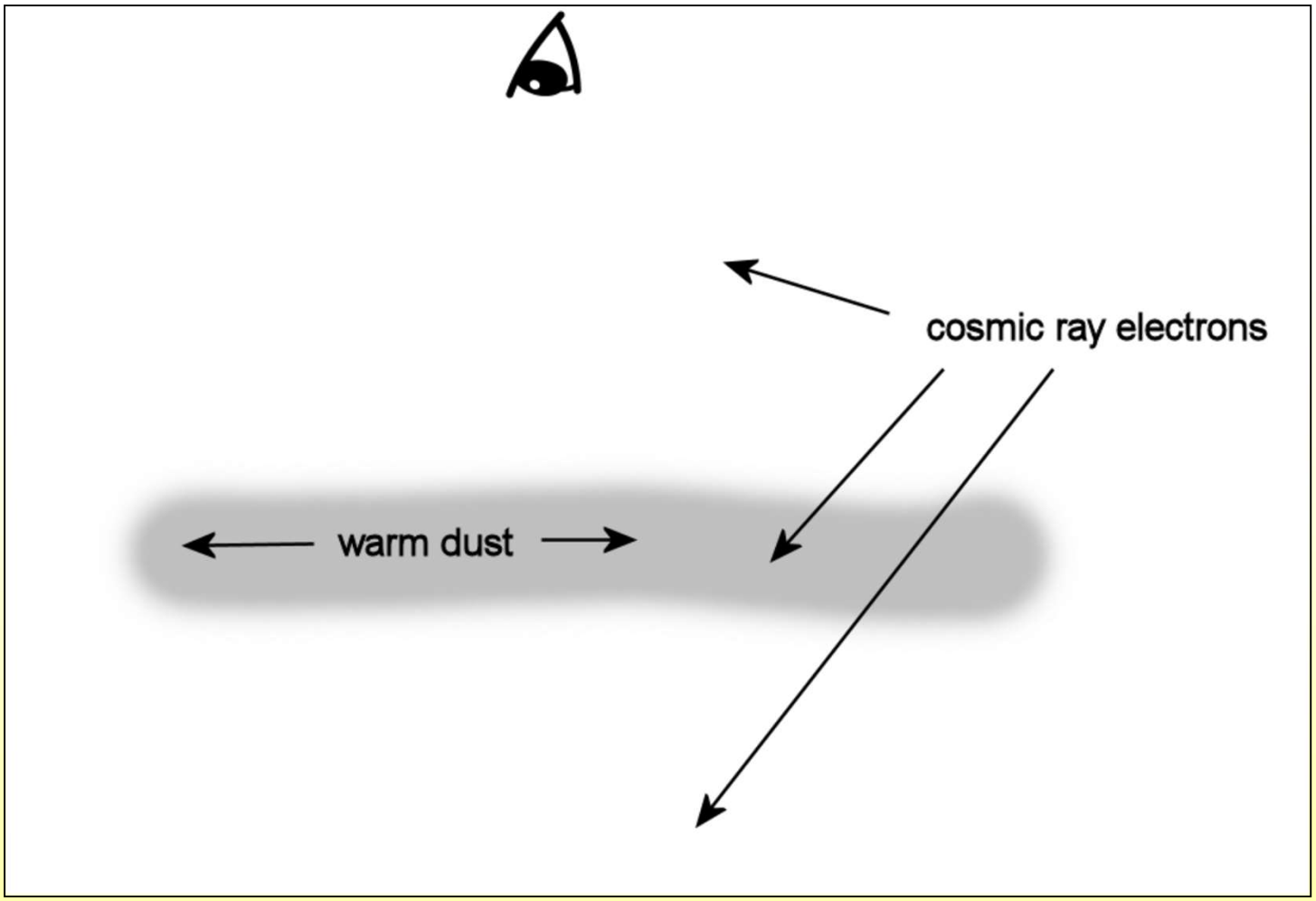



Radio Comparison

Black = 6.2 cm

Fletcher et al. 2011

White = FIR




**FIR and Radio polarimetry sample different regions**

**FIR fractional polarization depends on**:
Geometry
Grain alignment
Grain size and composition
Independent of magnetic field strength

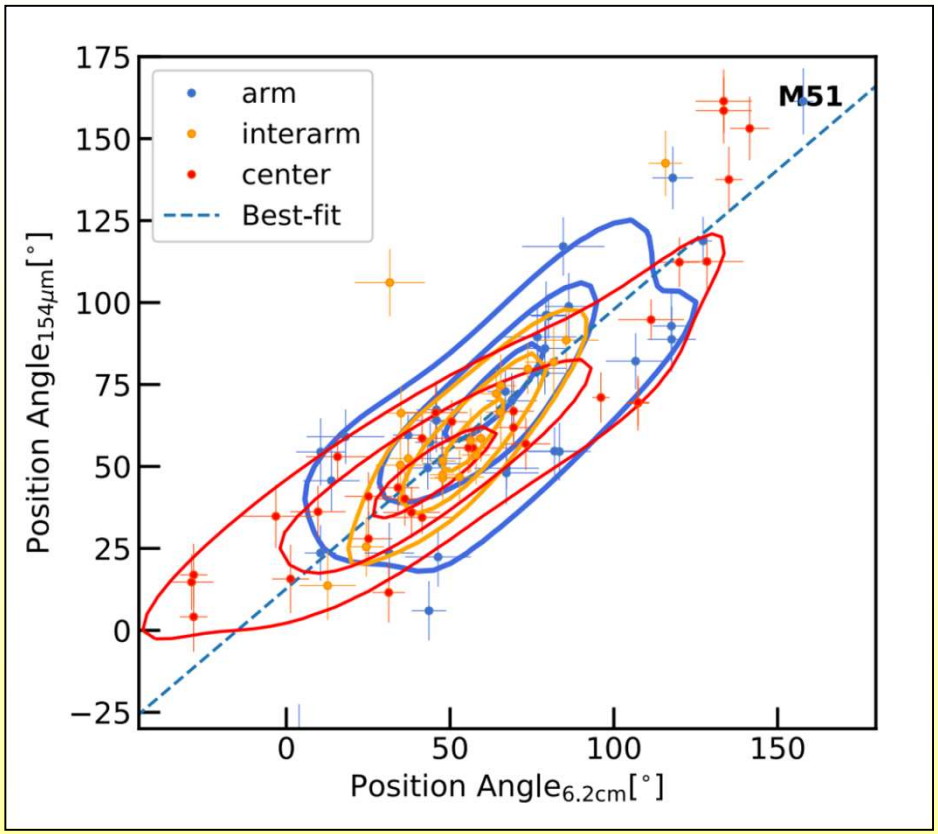
**FIR polarized intensity depends on:**
Geometry
Grain alignment
Grain size and composition
Grain column density and temperature
Independent of magnetic field strength

**Synchrotron fractional polarization depends on:**
Geometry
Independent of magnetic field strength

**Synchrotron polarized intensity depends on:**
Geometry
Cosmic ray electron density
Magnetic field strength

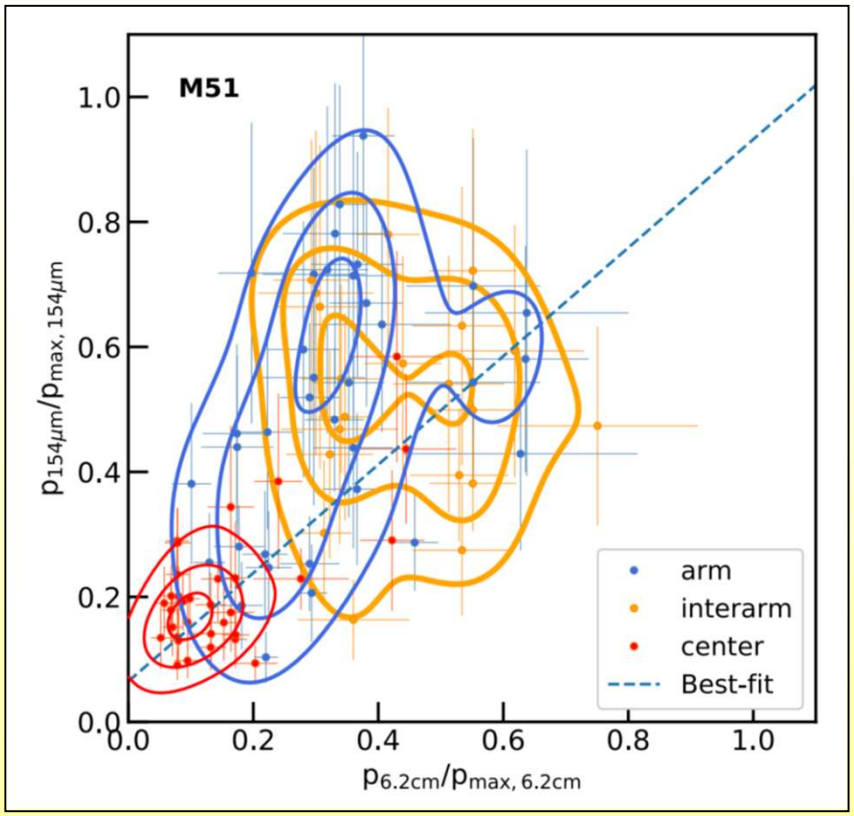
# Radio Comparison

Position Angle



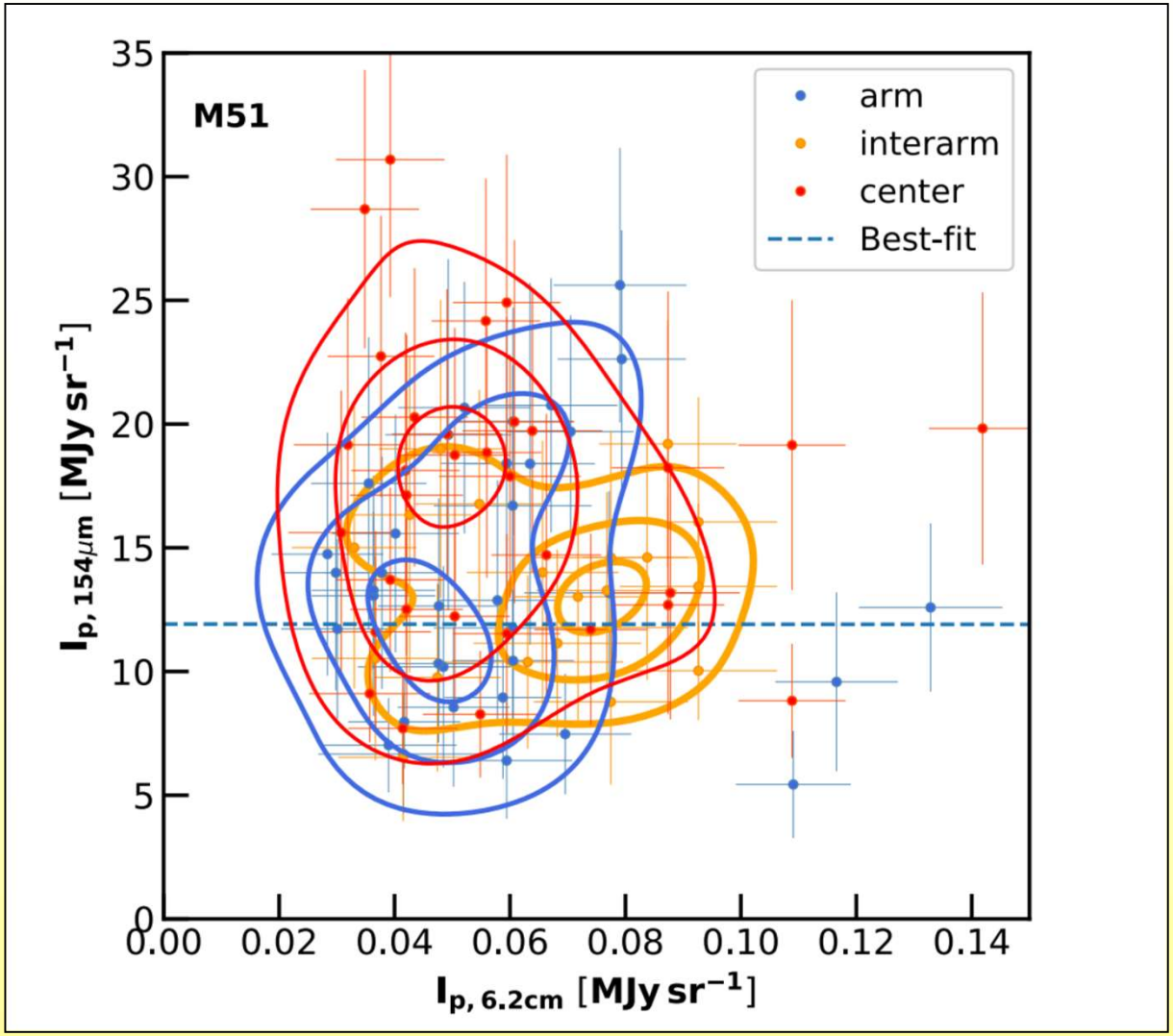

Strong Correlation

Fractional Polarization

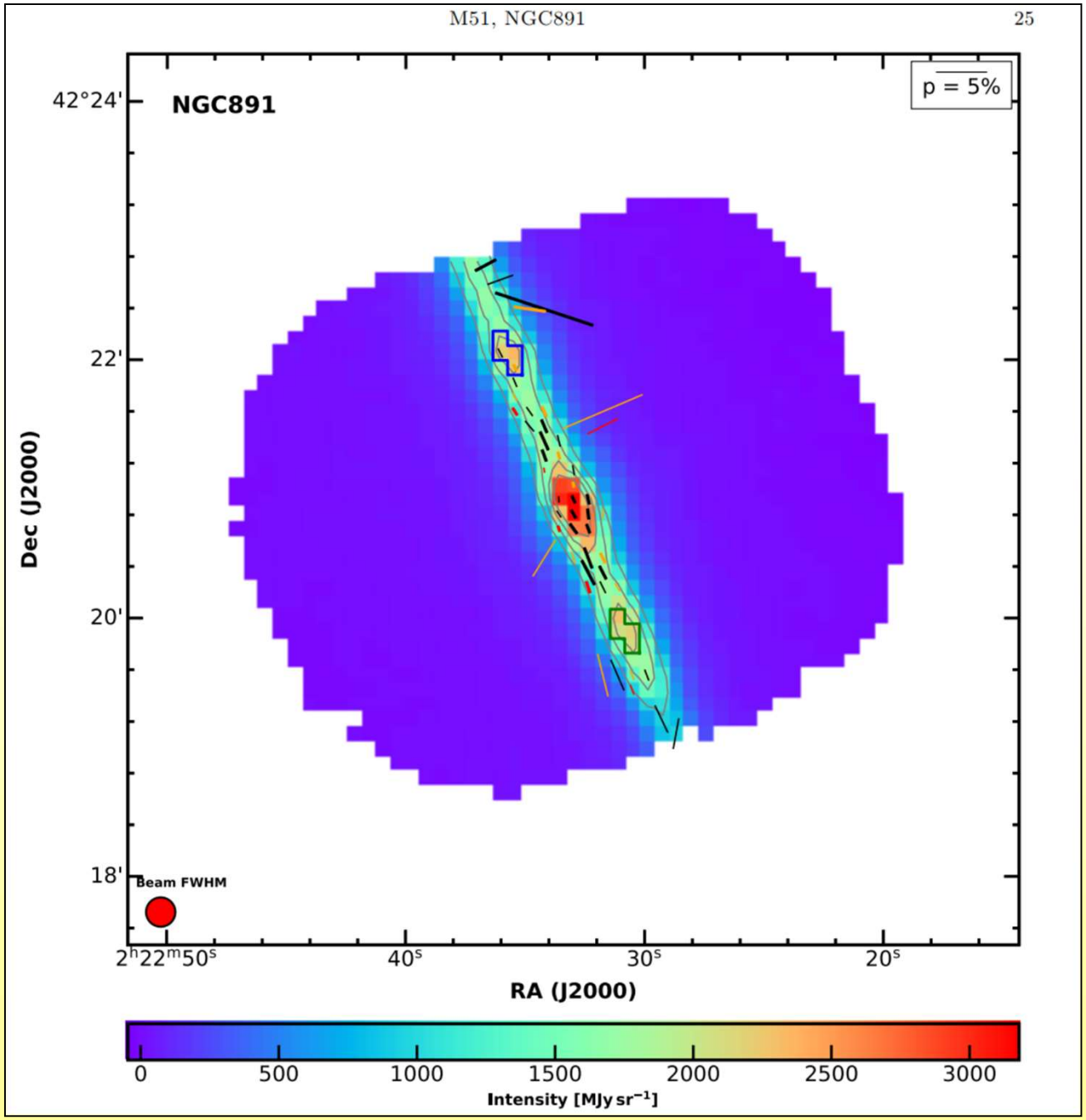


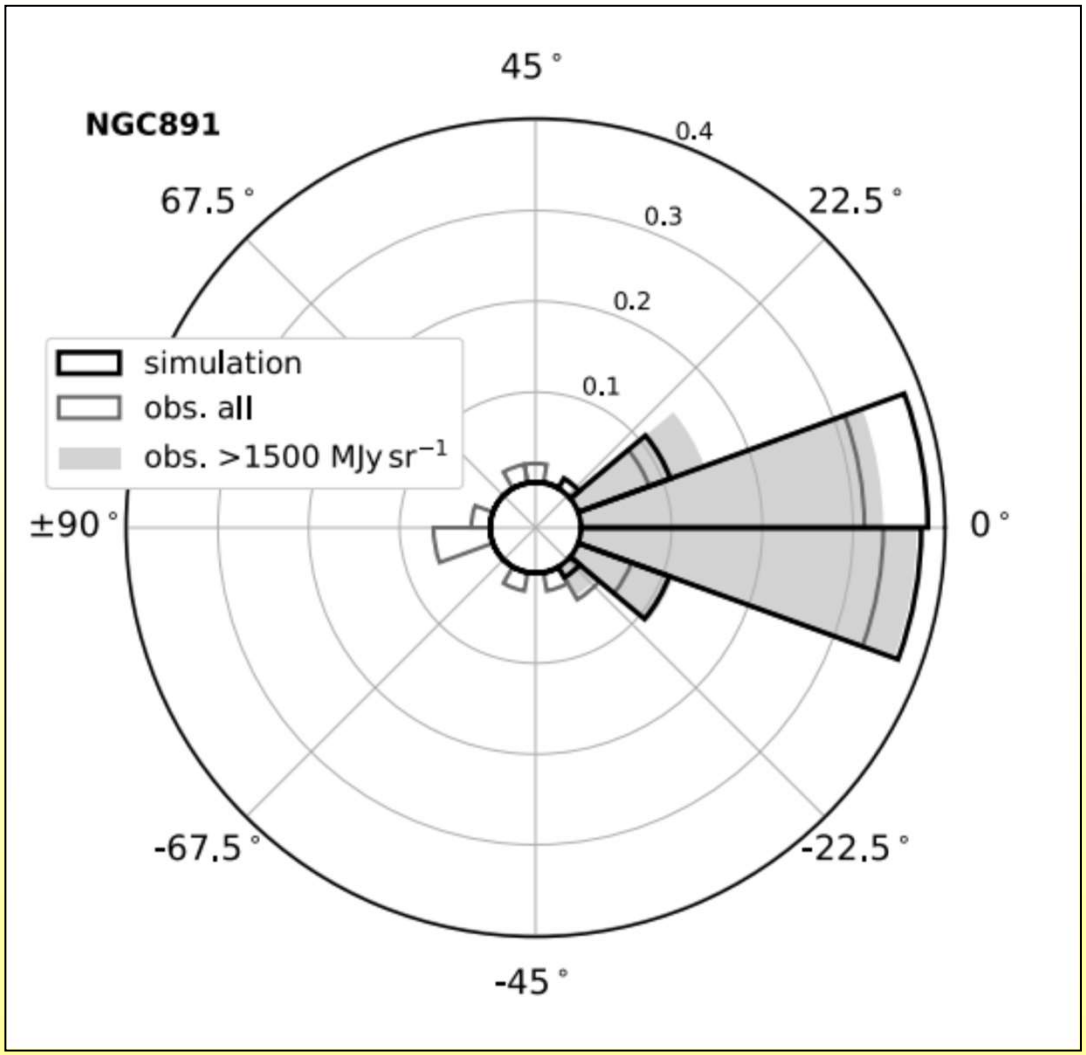

Modest Correlation

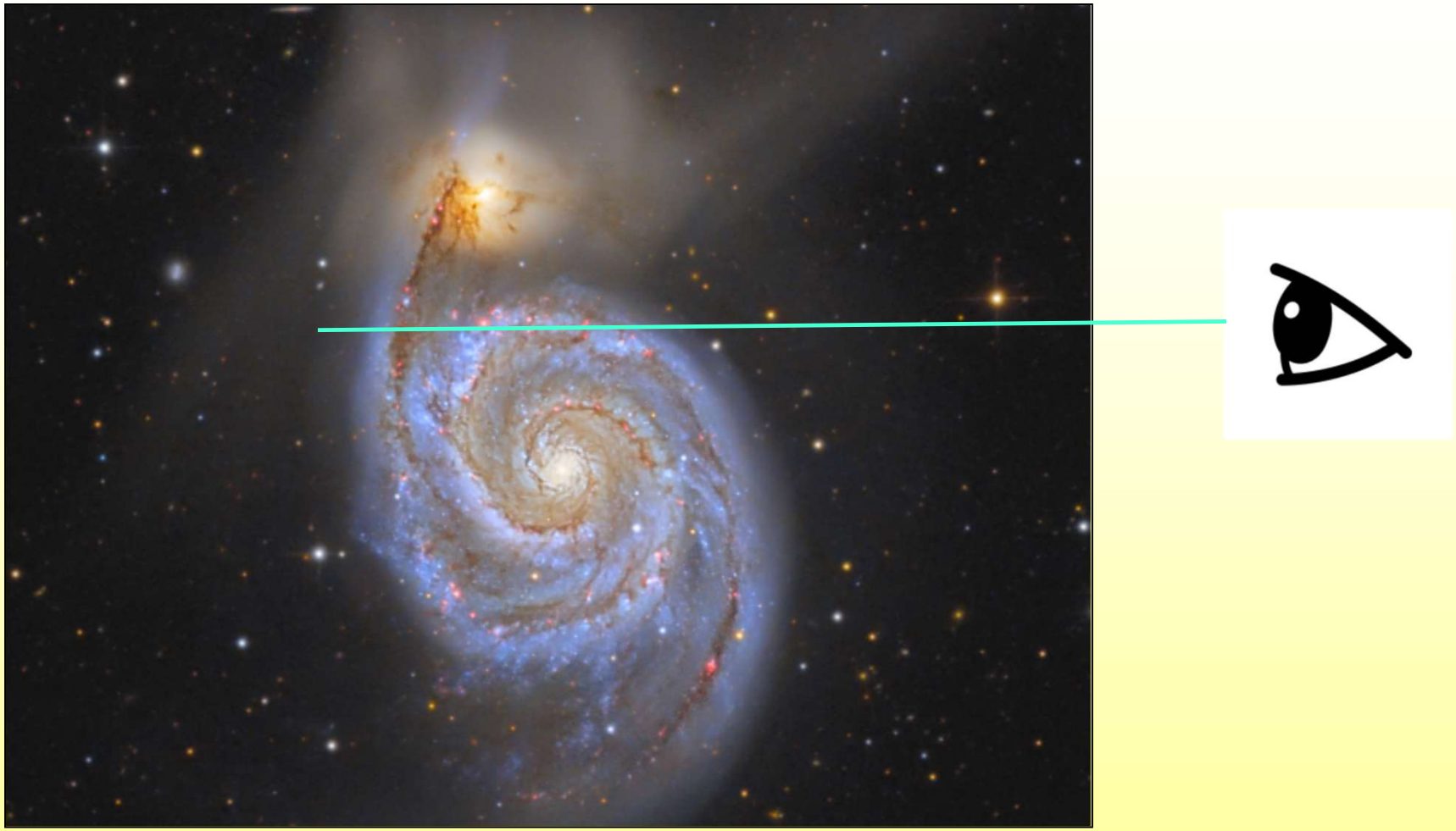
# Polarized Intensity

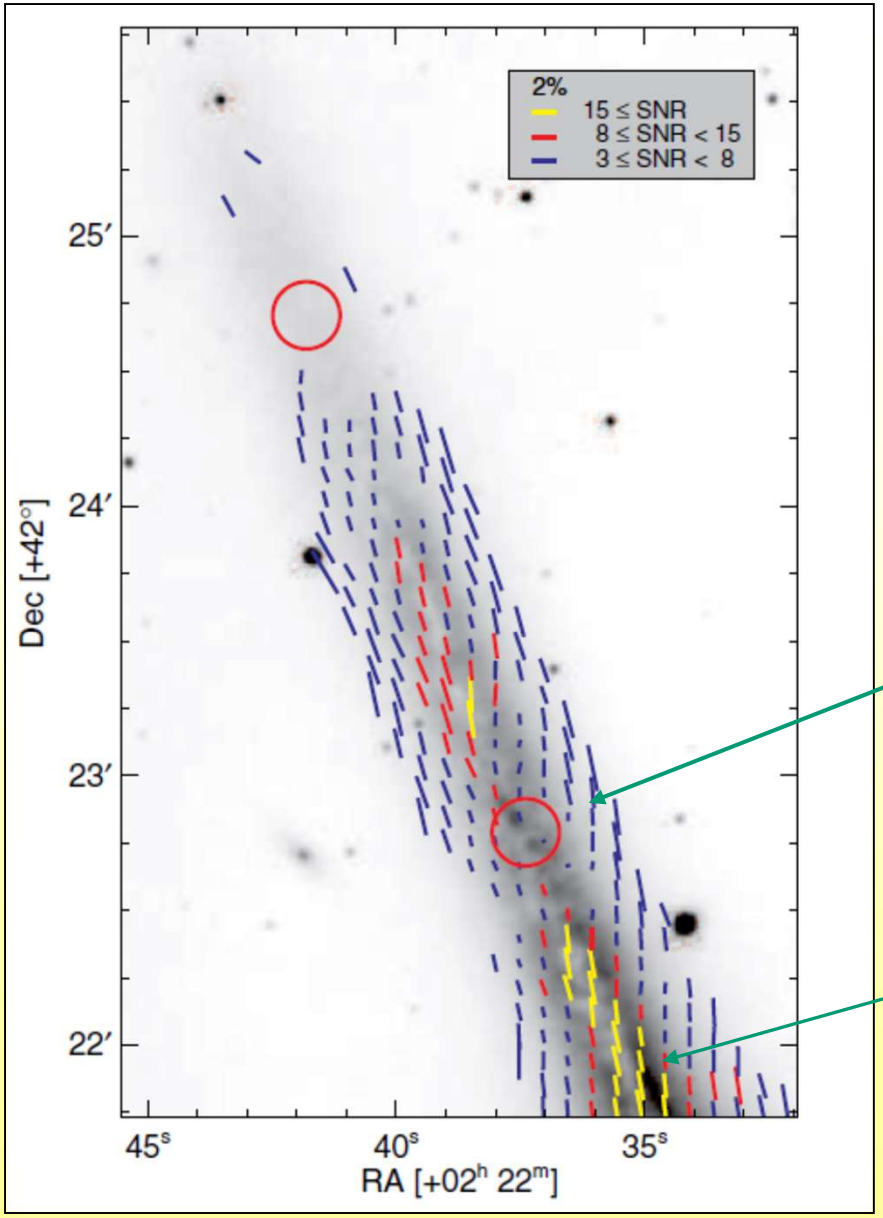



No Correlation


M51, NGC891
25
NGC891
p = 5%
42°24'
22'
20'
18'
Dec (J2000)
Beam FWHM
2h22m50s
40s
30s
20s
RA (J2000)
0
500
1000
1500
2000
2500
3000
Intensity [MJy sr−1]


NGC891
45 °
67.5 °
22.5 °
0.4
0.3
0.2
0.1
simulation
obs. all
obs. >1500 MJy sr$^{-1}$
±90 °
0 °
-67.5 °
-22.5 °
-45 °



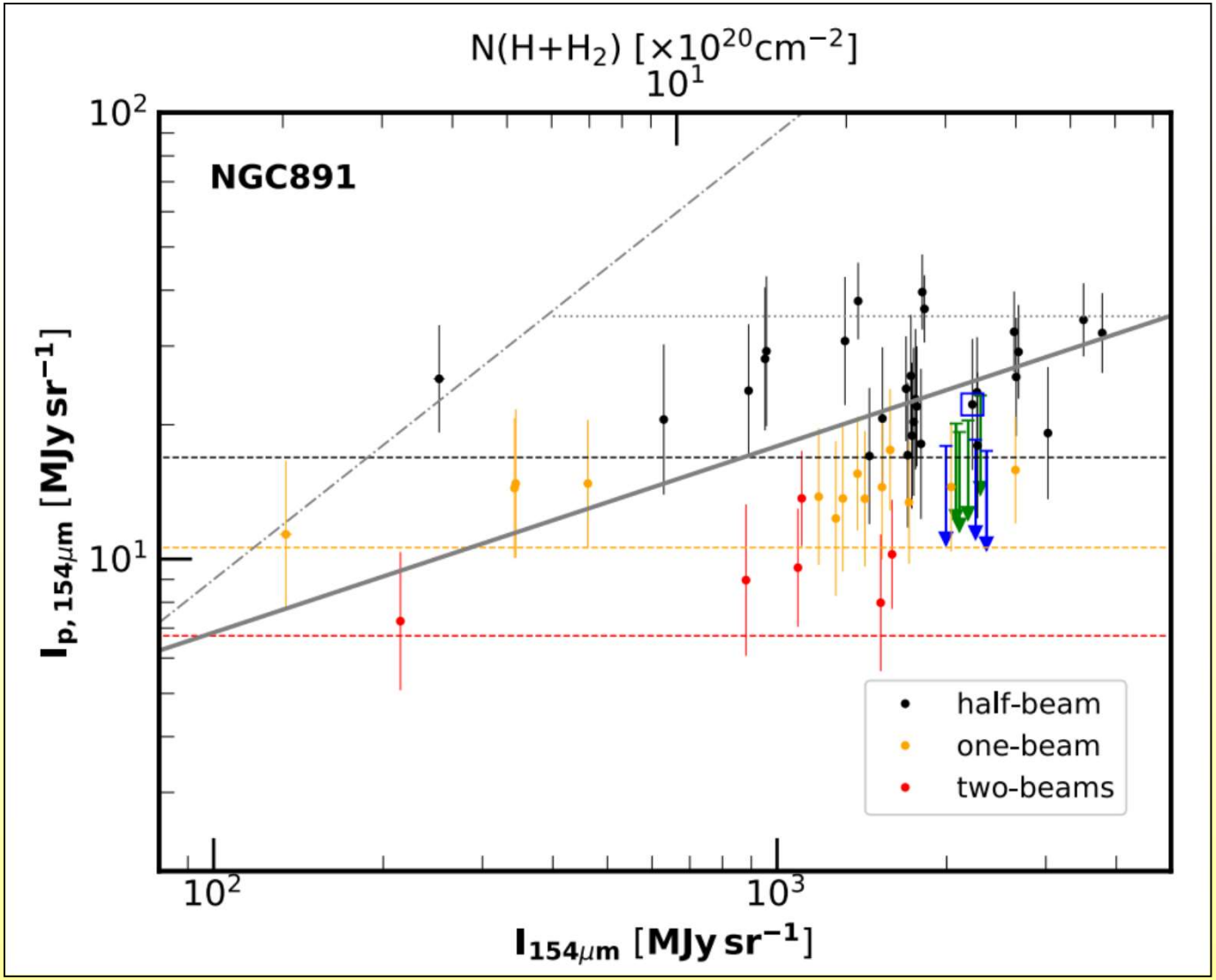


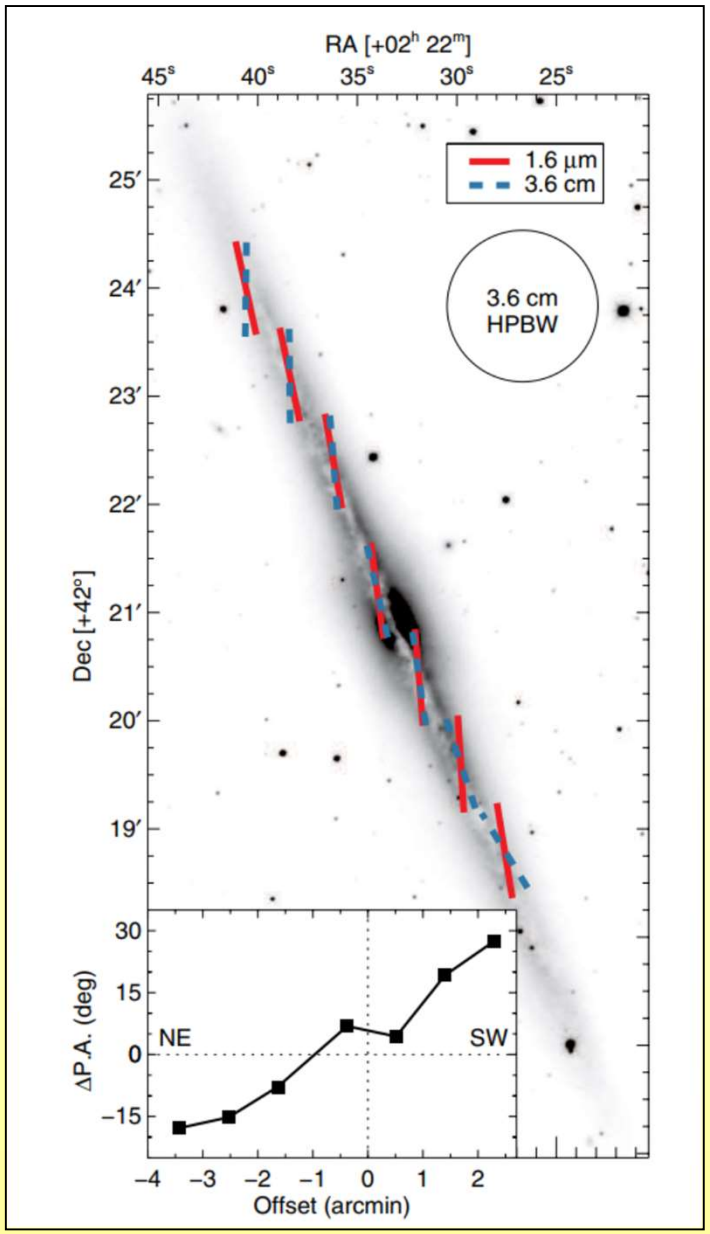

Montgomery & Clemens 2014

'Null Points'

Spiral arm?

FIR 'Null Point'

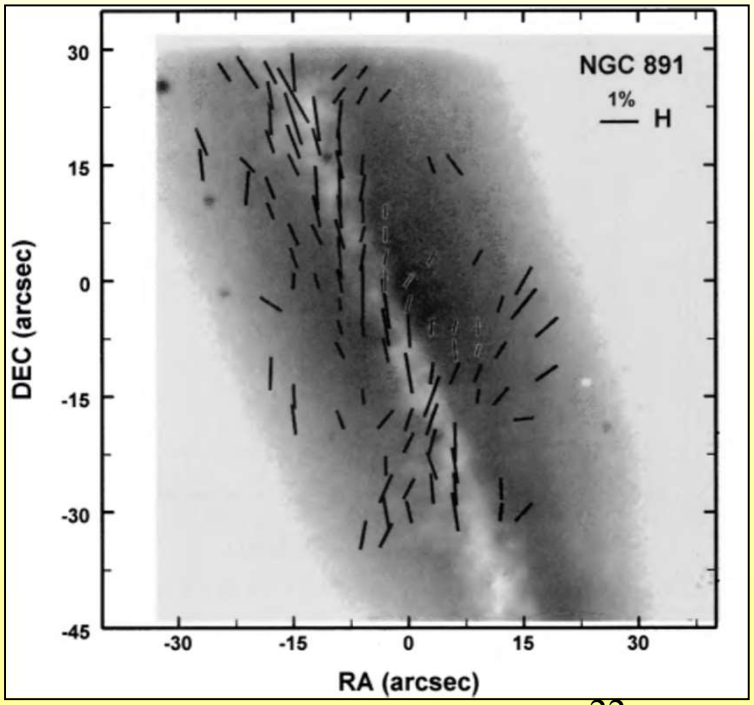

N(H+H2) [×10^20 cm^-2]
10^1
10^2
NGC891
I_p, 154μm [MJy sr^-1]
10^1
half-beam
one-beam
two-beams
10^2
10^3
I_154μm [MJy sr^-1]




NIR and Radio see a tilt in the plane. This is NOT seen in the FIR.

Montgomery & Clemens 2014

Jones 1997



# In the Pipe

Magnetic Field of the Galaxy M82, J. Guerra Aguilera, et al.

Magnetic Field in the Central Region of the Circinus Galaxy with OFIA/HAWC+, L. Grosset et al.

Dust Alignment and Magnetic Fields in the 30 Doradus Star-Forming Region, S. Coude et al.

The Magnetic Feld across the Warped Molecular Disk of Centaurus A, E. Lopez Rodriguez

The Multi-Phase Spiral Magnetic Field of M51*(A. S. Borlaff, E. Lopez Rodriguez, L. Grosset, P. M. Marcum, J. E. Beckman, A. Hughes, R. Stepanov)*

# Conclusions

M51

1. The FIR polarization vectors generally follow the spiral pattern.
2. There is excess dispersion relative to the spiral arms, and the central regions show a more ‘open’ spiral pattern.
3. The FIR and the Radio synchrotron polarimetry show a strong agreement in geometry, a moderate correlation in fractional polarization, but no correlation in polarized intensity.
4. The polarized intensity saturates at modest column depths, suggesting regions of disorder with very short scale lengths.

N891

1. The FIR polarization vectors in the disk are strongly aligned with the disk major axis.
2. Two regions of low polarization suggest we are looking down spiral features.
3. The 15º tilt with respect to the disk seen at NIR and Radio wavelengths are not seen in the FIR.
4. There is evidence for vertical magnetic fields seen in dust emission off the disk into the halo.

# Future Work

**Awarded priority 2 time for more observations of M51.**

1. Study the inter-arm region.
2. Measure the field geometry in the bridge to M51b.
3. Study the field in the 'inside' arm shocks (Jorge).

**Awarded priority 1 time for more observations of NGC 891.**

1. Explore the vertical field geometry.
2. Look for spiral arm features seen in the NIR.
3. Compare with models that generate magnetic fields.