Magnetic Fields at the Heart of a ULIRG: Arp220

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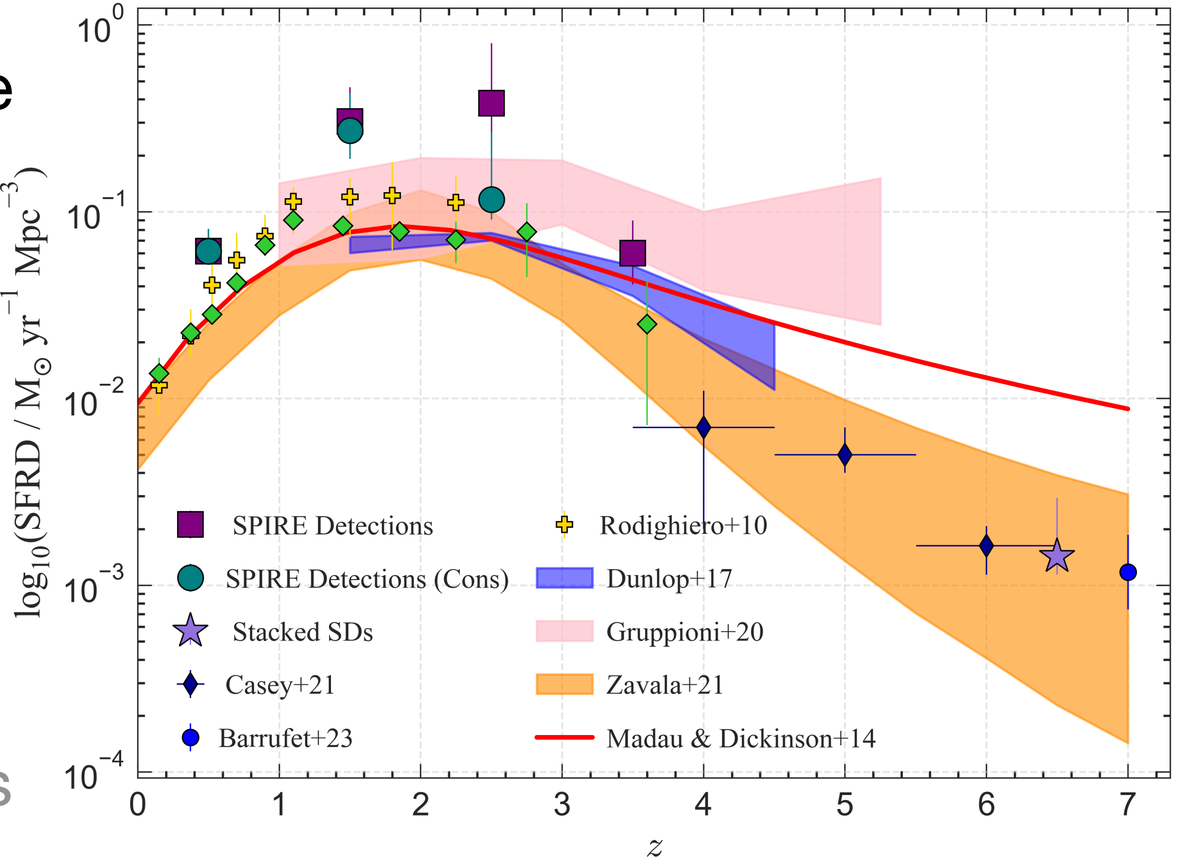
DSFGs

- Dusty star forming galaxies are the sites of the most rapid star formation in the universe 100 to >1000 Msun per year
- May dominate the SFRD of the universe at some redshifts
- Most of their energy (>95%) emerges in the FIR not optical/UV
- Local DSFGs - ULIRGs - are galaxy mergers



Parmar et al. in prep

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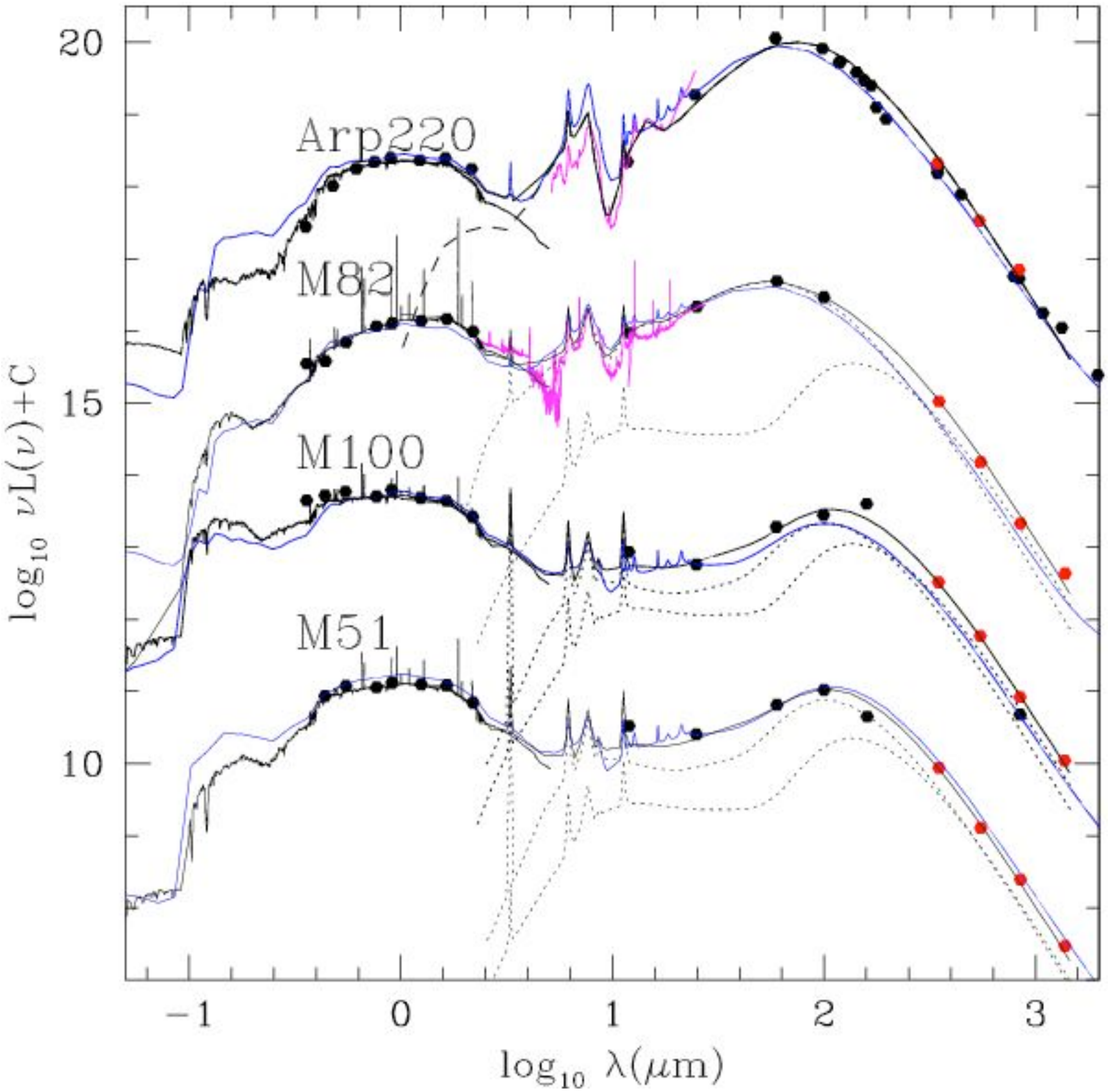
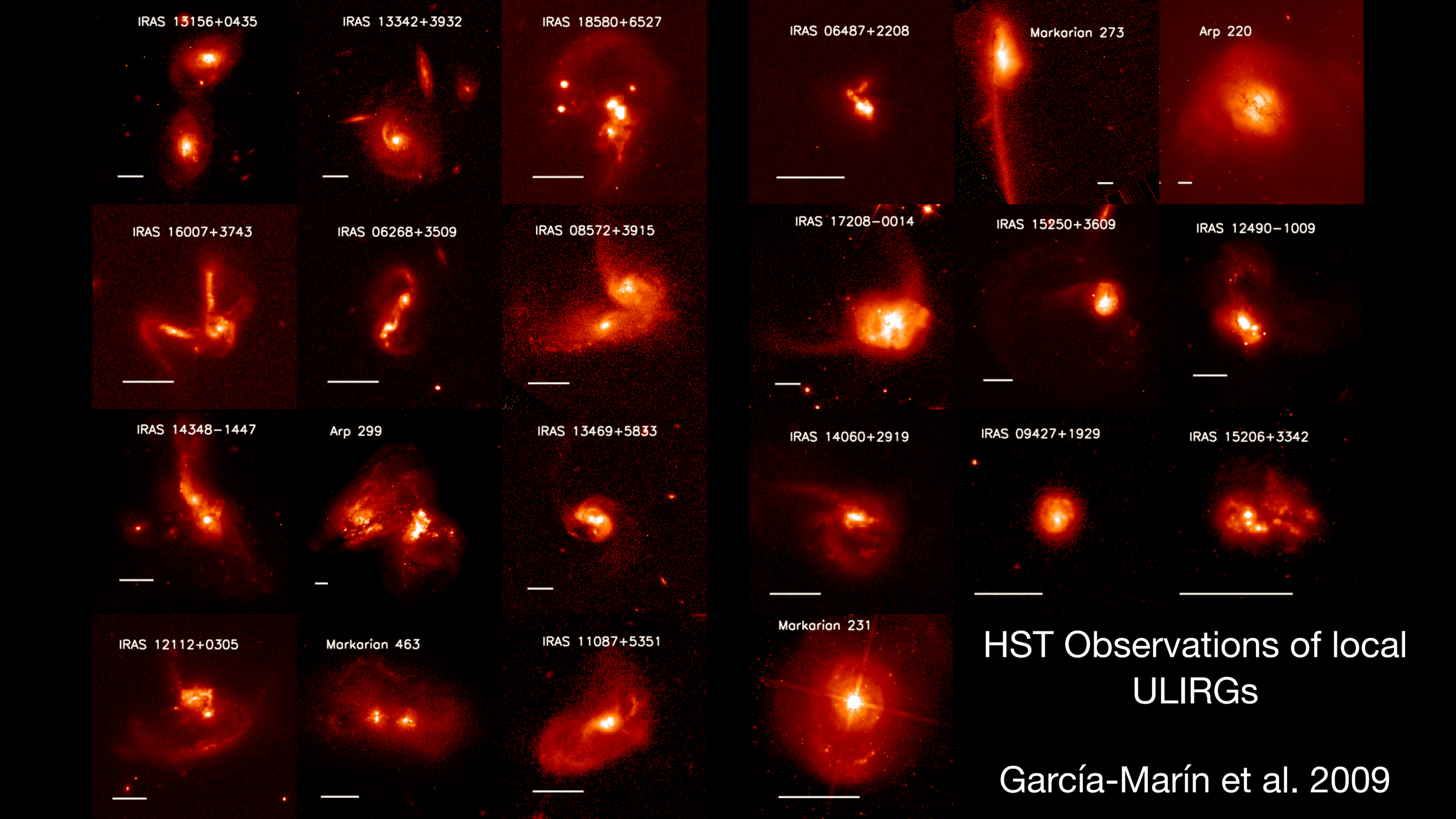




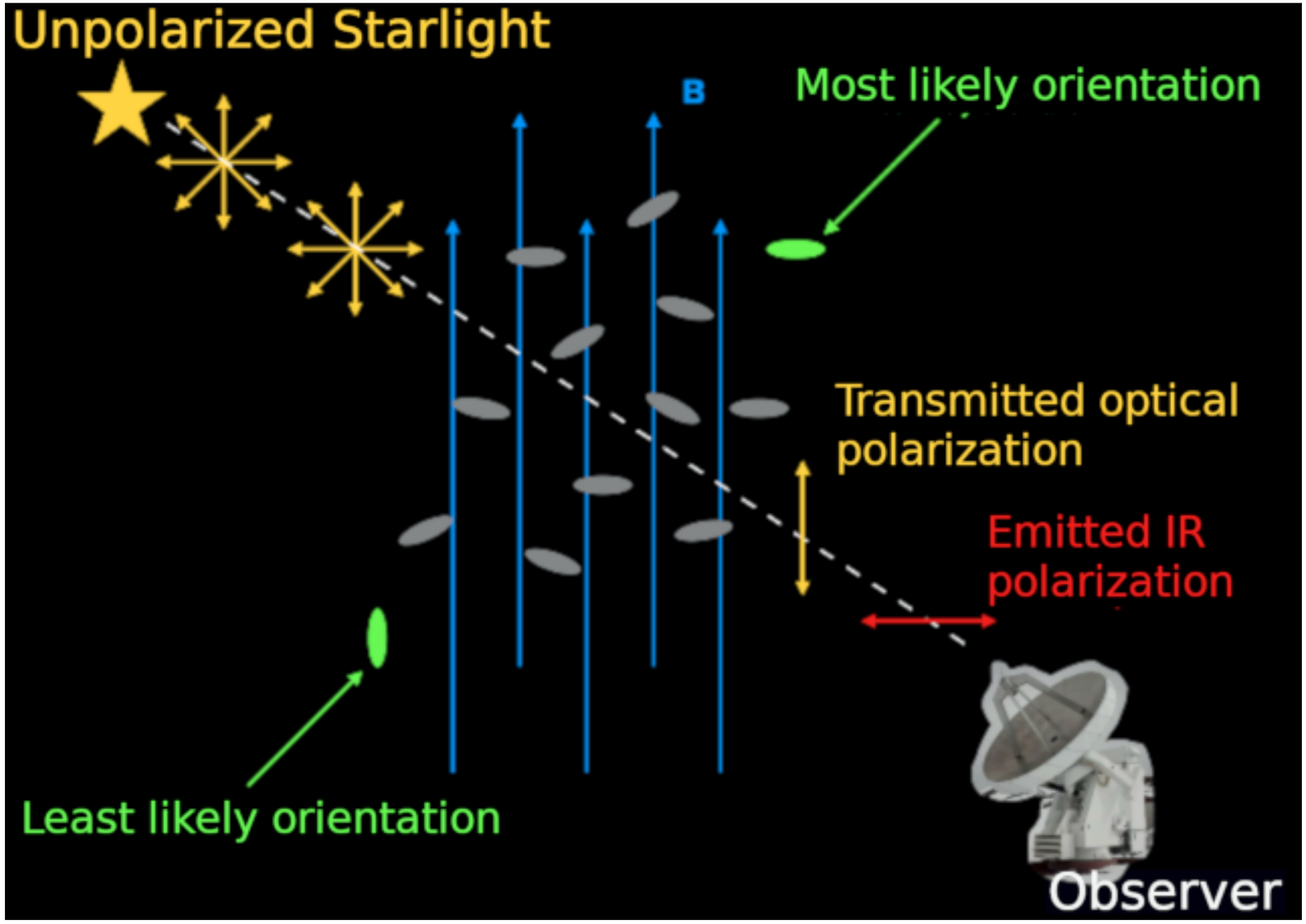
HST Observations of local ULIRGs

García-Marín et al. 2009

Magnetic Fields in Galaxies

- Ubiquitous feature of the ISM but poorly studied in far-IR in nearby galaxies due to lack of facilities (eg. closure of SOFIA)
- Different structures seen in radio and dust polarization
- On large scales magnetic fields follow spiral structure
- Can be affected by outflows from starbursts or AGN
- Now detected out to very high redshift in strongly lensed systems

Dust Polarization to Magnetic Fields



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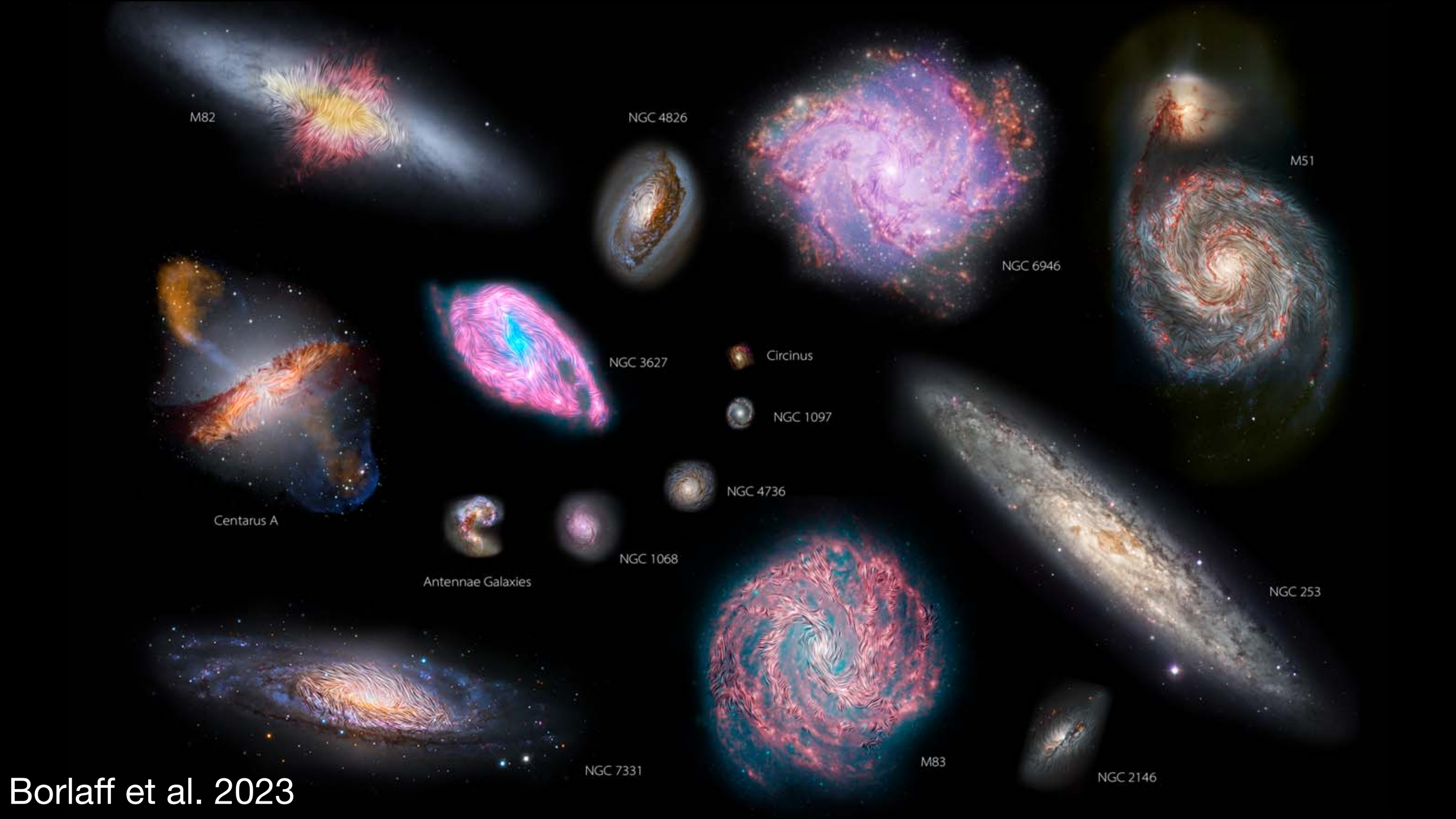

Borlaff et al. 2023

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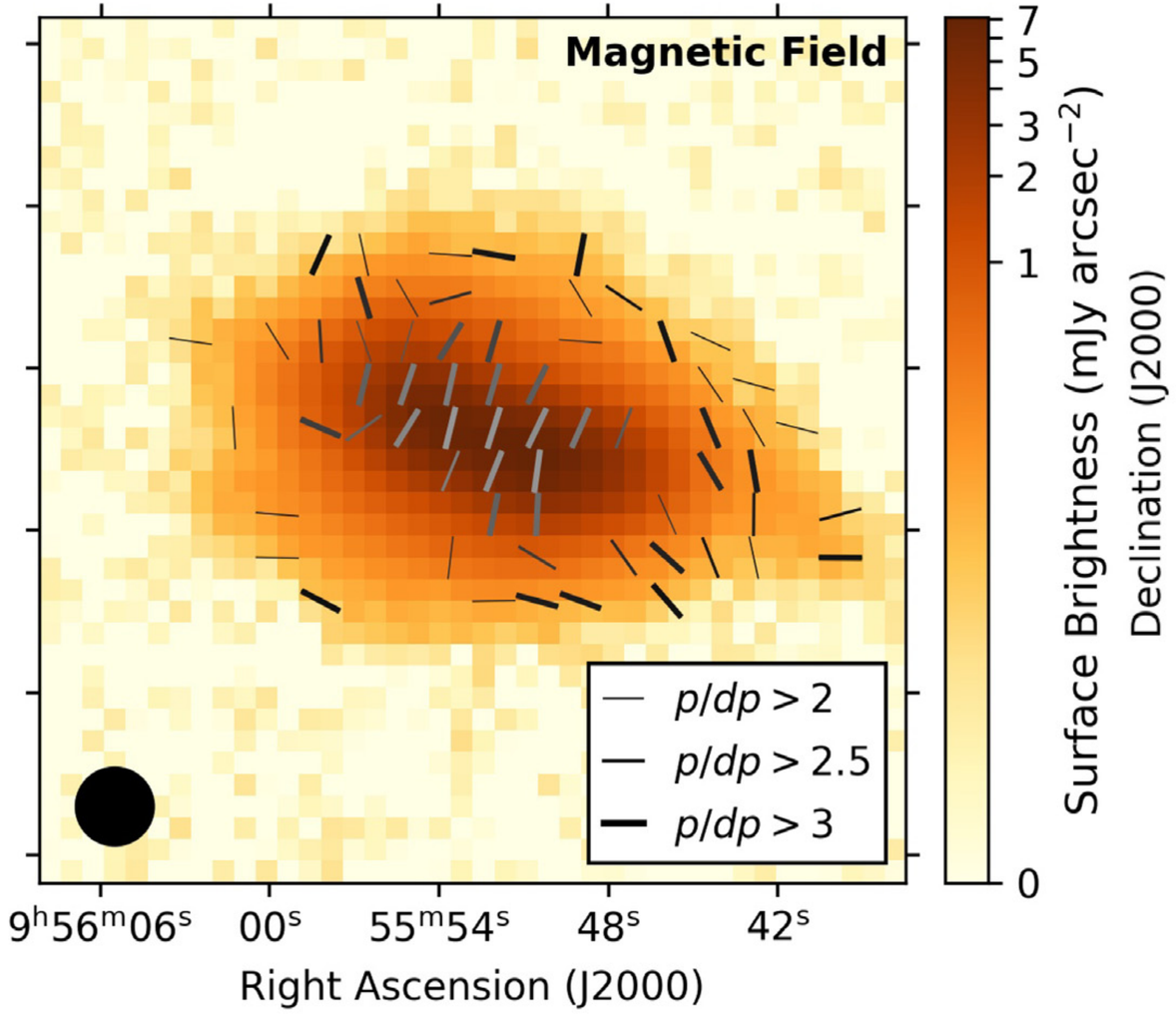
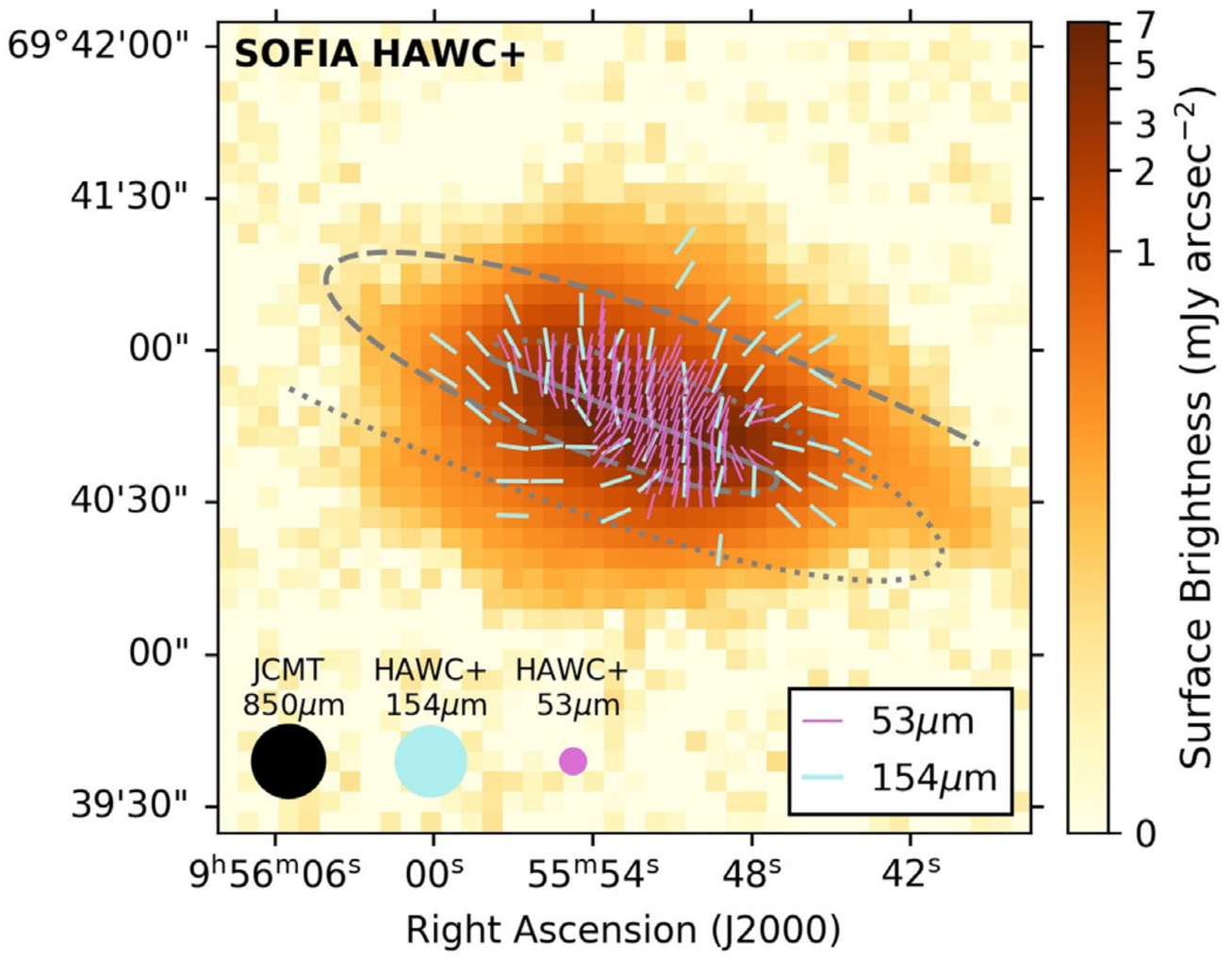
NOAJ





Pattle et al., 21

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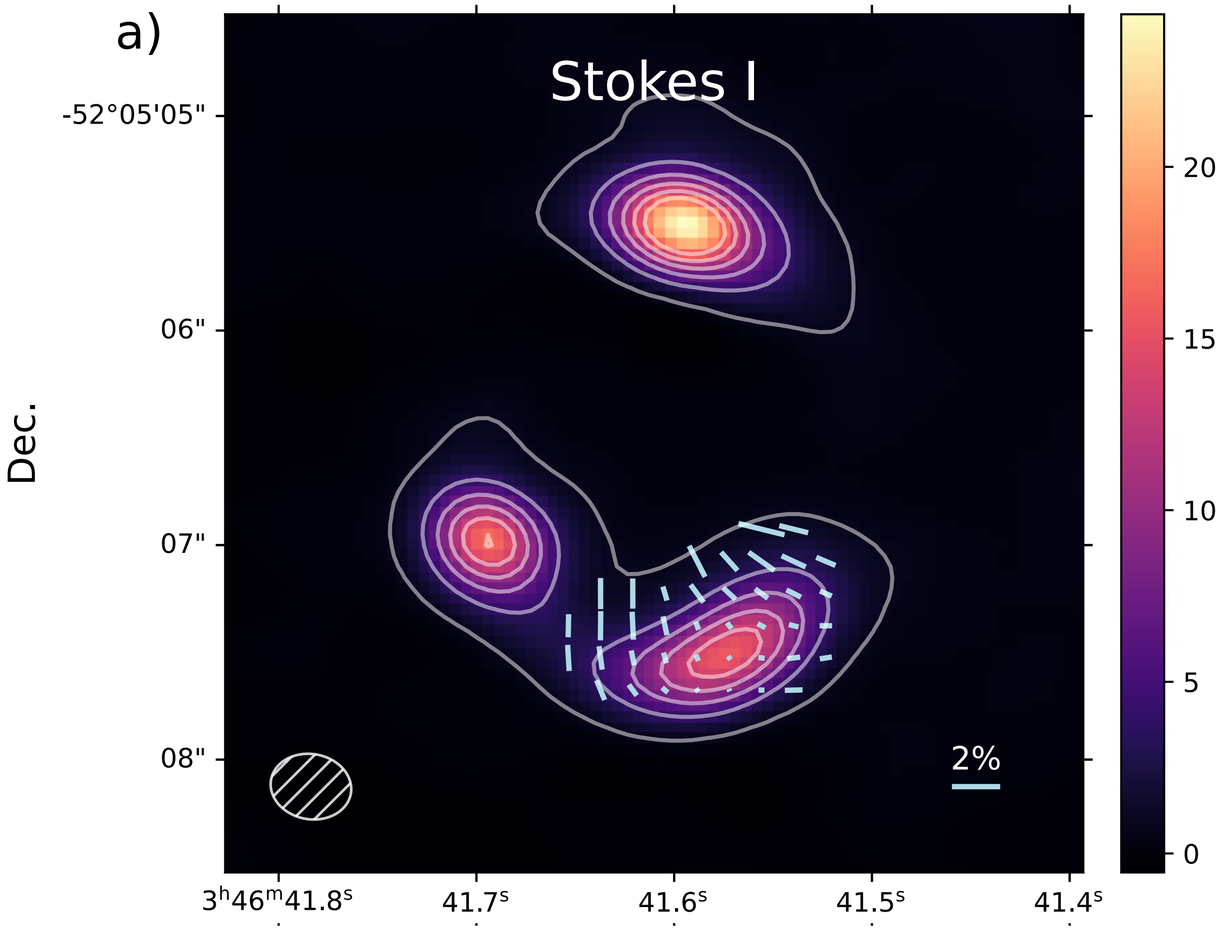
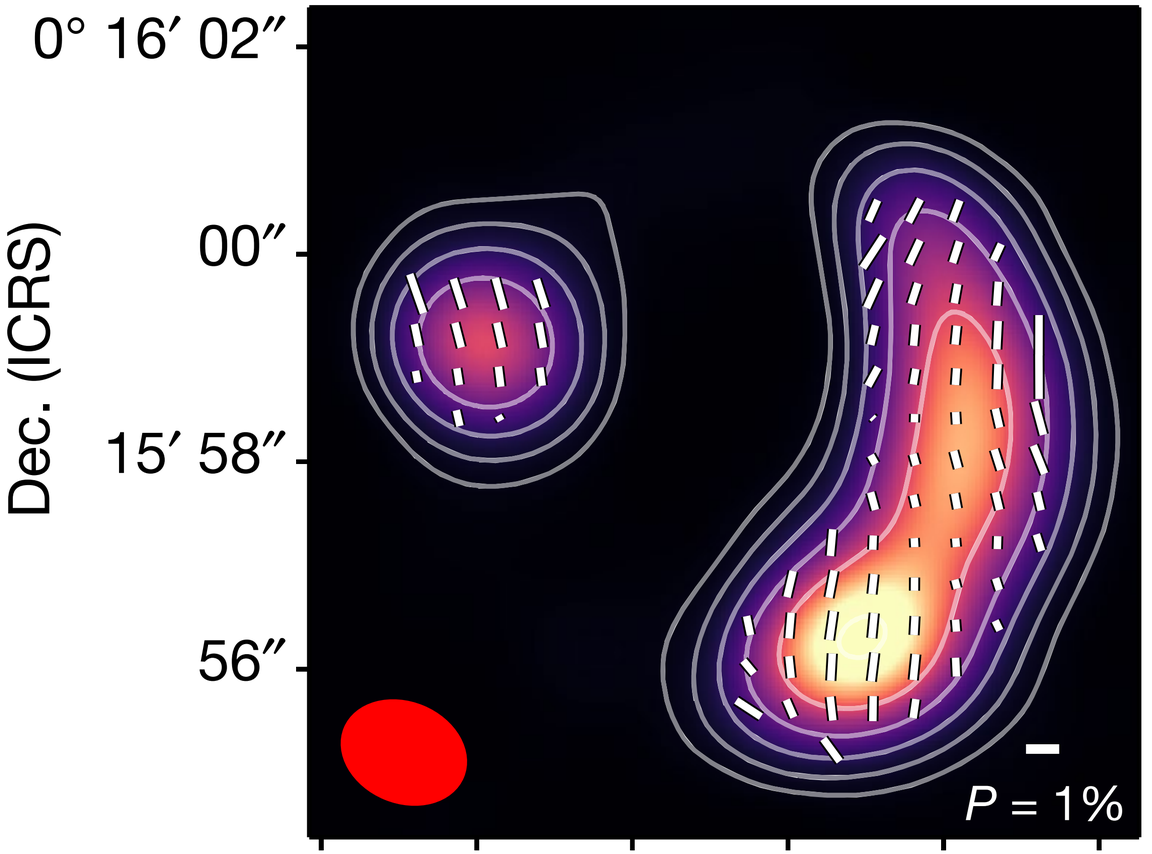


z=5.6 Chen et al., 2024



z=2.6 Geach et al., 2023

Magnetic Fields in Mergers

- Not much simulation work done on MHD (vs. HD) on galaxies or galaxy mergers

- Whittingham et al. (2023):

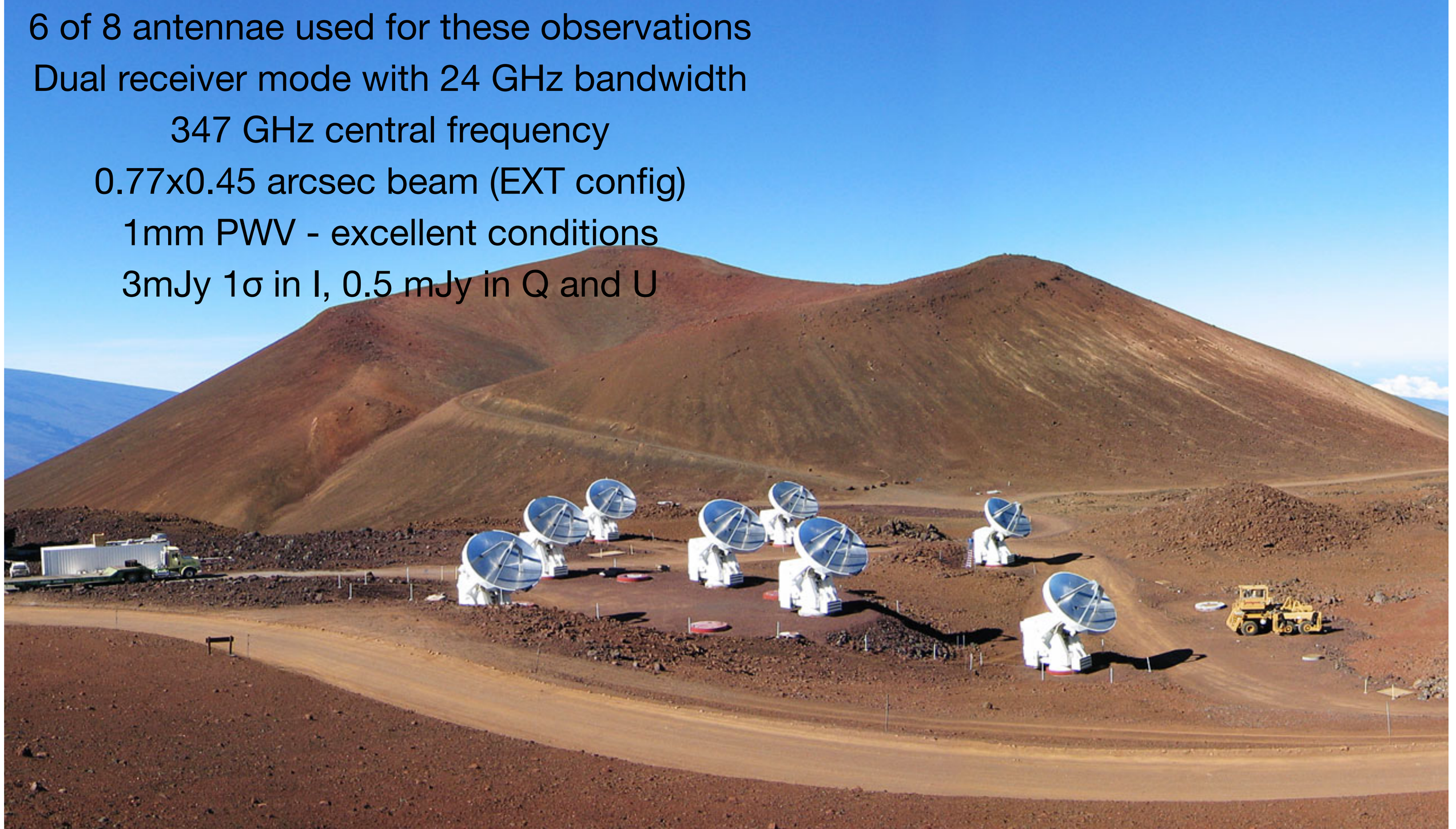
  - ‘We find that magnetic fields modify the transport of angular momentum, systematically hastening the merger progress.’

  - ‘stellar feedback is substantially less influential in MHD simulations, which allows for the later accretion of higher angular momentum gas’

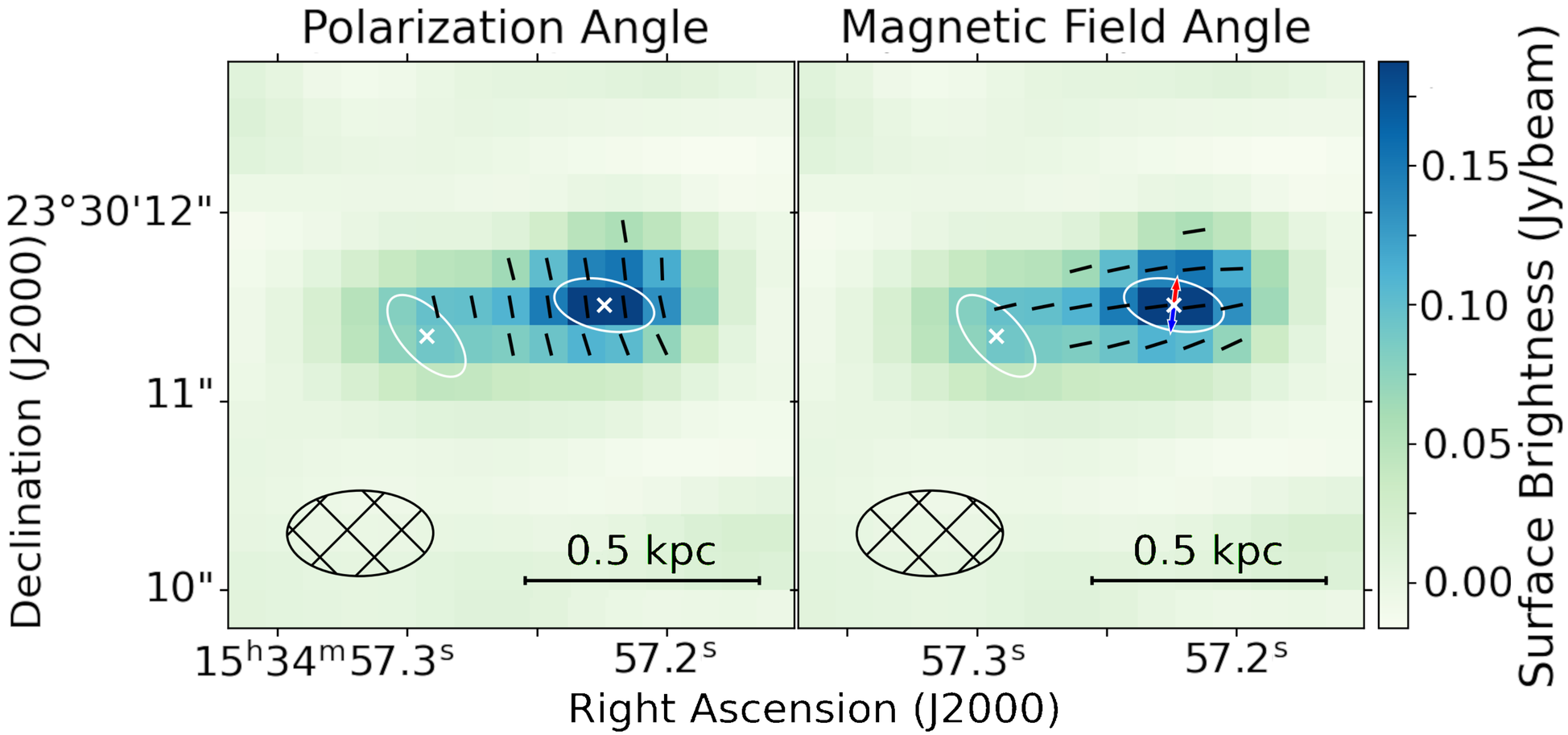
- Implies impact on both star formation in the merger - providing fuel faster & longer - and increasing SMBH growth

Magnetic Fields in Local ULIRGs

- Star formation in most local ULIRGs is dominated by their central regions
    - Late stage mergers so can look for AGN and other feedback effects leading to quenching
    - Bright & compact in the far-IR/submm
- Need interferometry for this since scales are much smaller than SOFIA can reach (or PRIMA in the future)
- Start with the nearest and brightest: Arp220
    - Turns out it’s the only ULIRG bright enough for polarization observations with the SMA


6 of 8 antennae used for these observations
Dual receiver mode with 24 GHz bandwidth
347 GHz central frequency
0.77x0.45 arcsec beam (EXT config)
1mm PWV - excellent conditions
3mJy 1σ in I, 0.5 mJy in Q and U

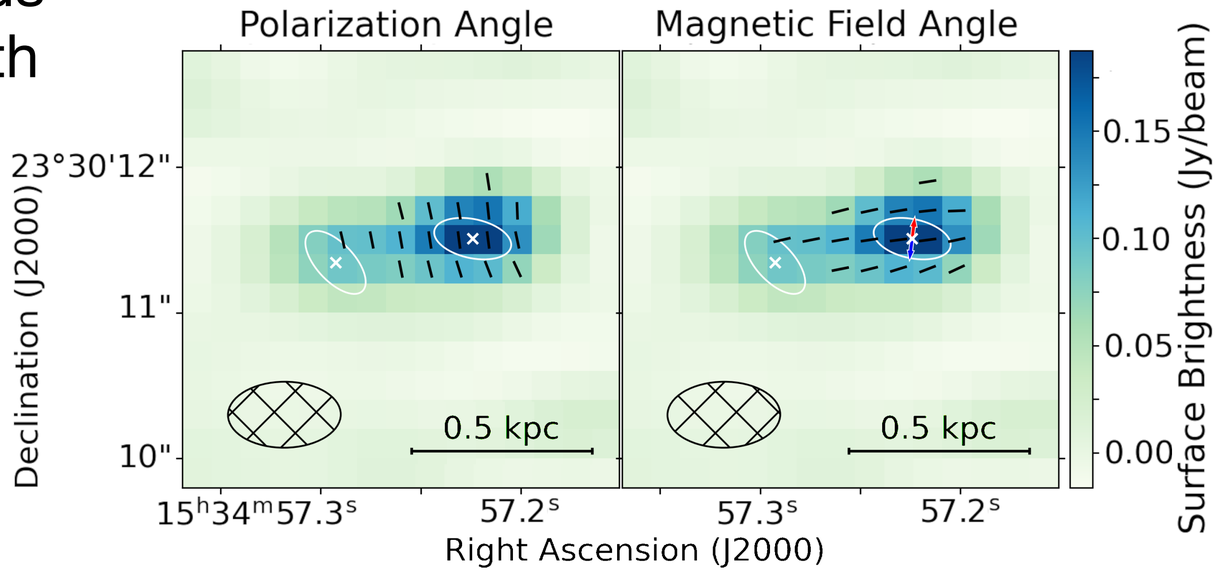
Arp 220 Polarization



Circles indicate known dust/gas disks, red/blue arrows indicate known outflow in W nucleus

Results

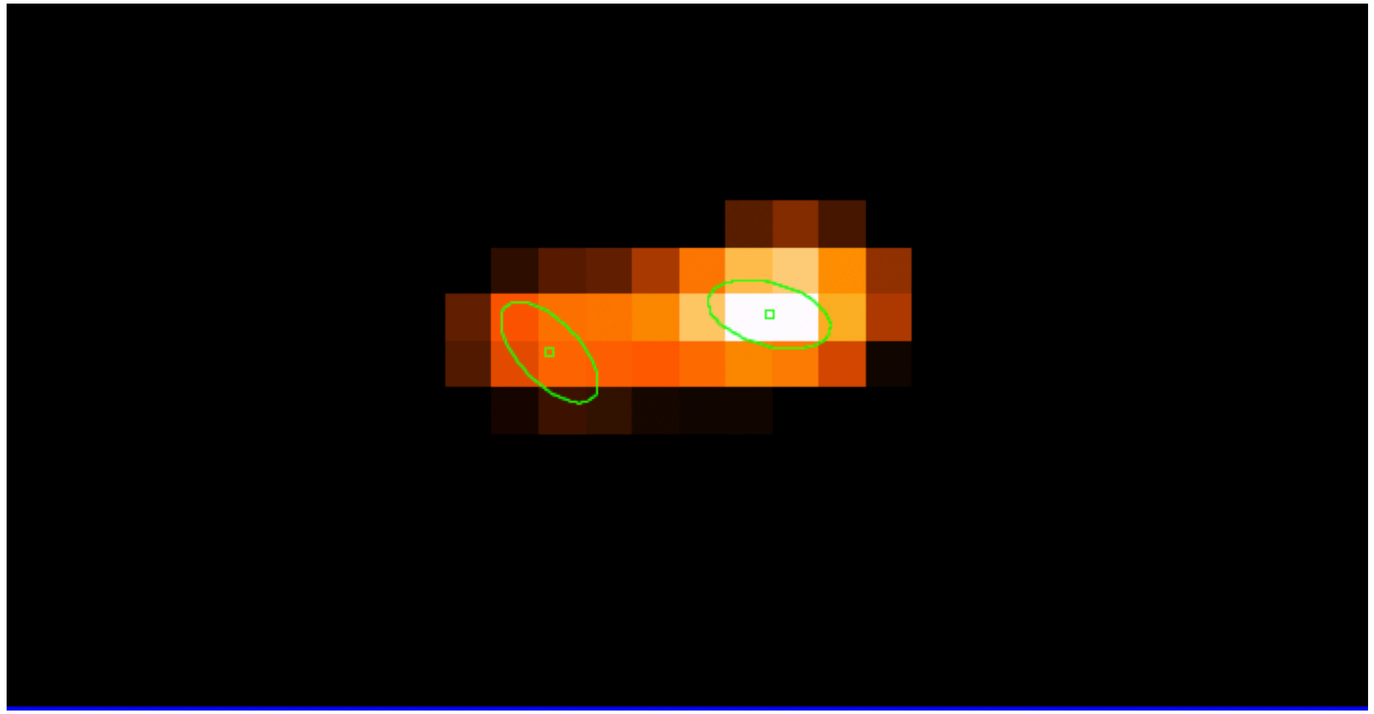
- Dust polarization and thus magnetic fields detected in brighter W nucleus at 6σ, with 2.7±0.45% polarization
- Magnetic field aligned with dust/ molecular disk
  - Slight misalignment due to interaction effects?
- No sign of young (~10^5 yr) outflow reshaping magnetic fields yet
  - Magnetic field confining outflow?



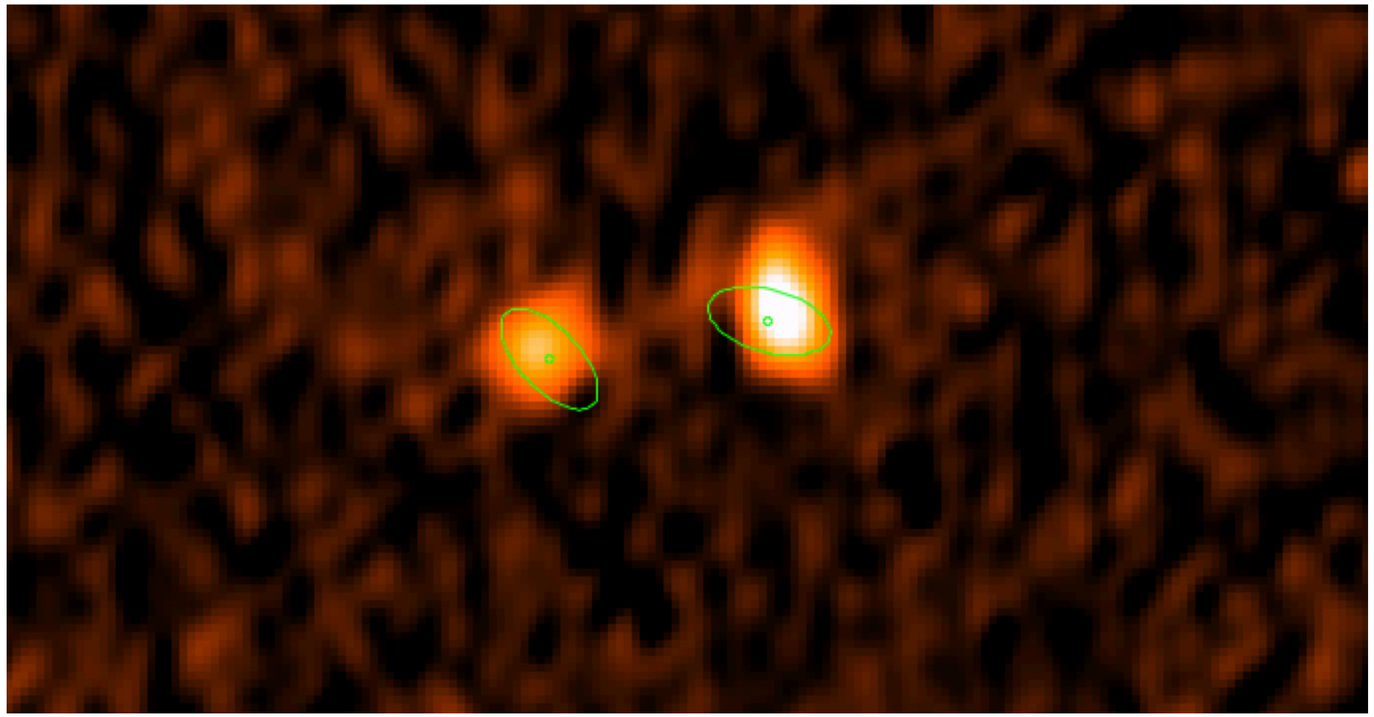
See Clements et al. 2025 for more details

Next Steps

- E nucleus ~ 1/2 as bright as W nucleus, so would not expect to detect polarization at this level (still get 2.8σ indicative result)
    - More data coming which should be able to get to sufficient depth
- Ideally need more sensitivity and resolution to see better what's going on
- Need sample of local ULIRGs to get information on population
    - Suggests need for ALMA and NOEMA: proposals submitted or in prep

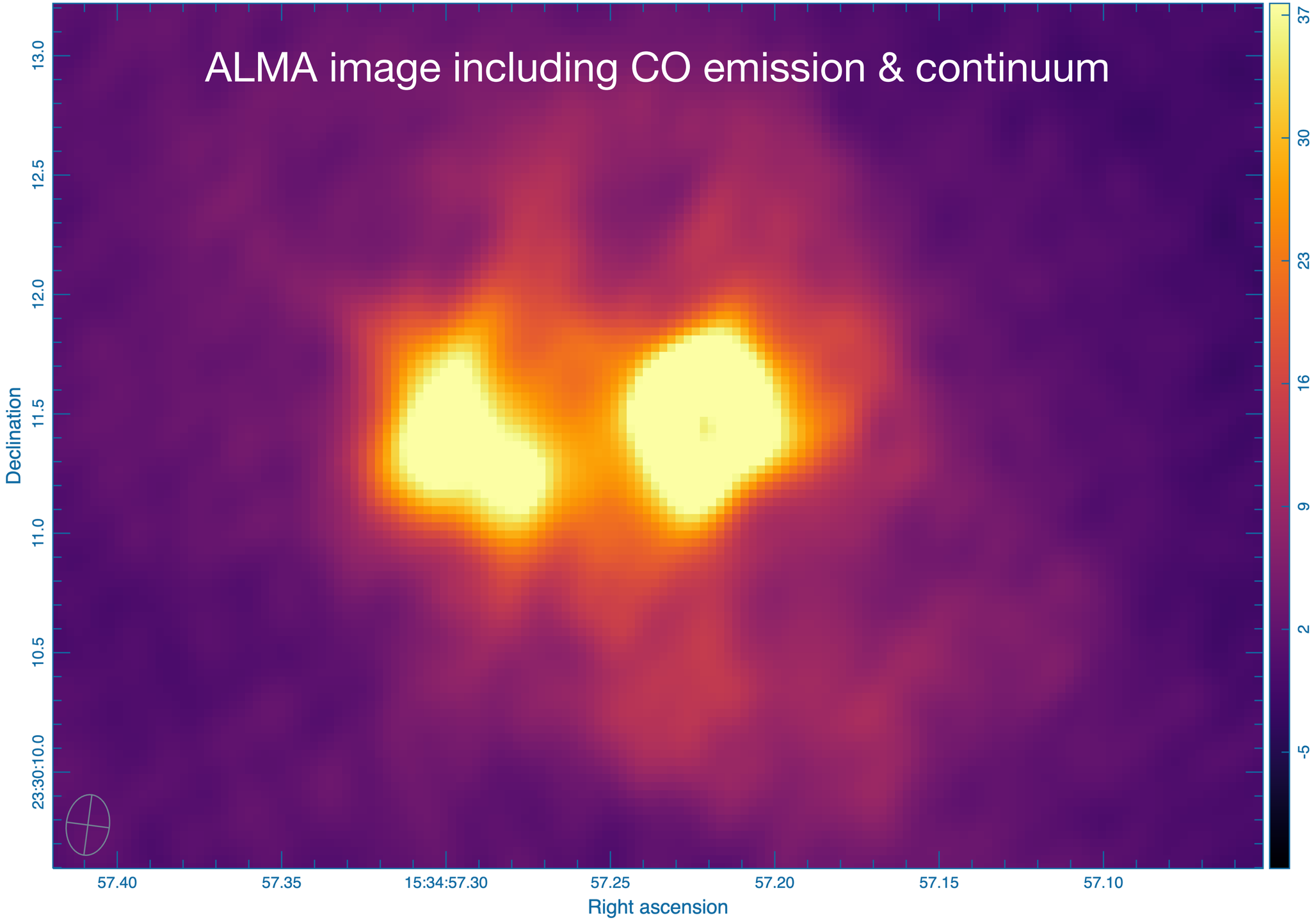


Our SMA intensity image



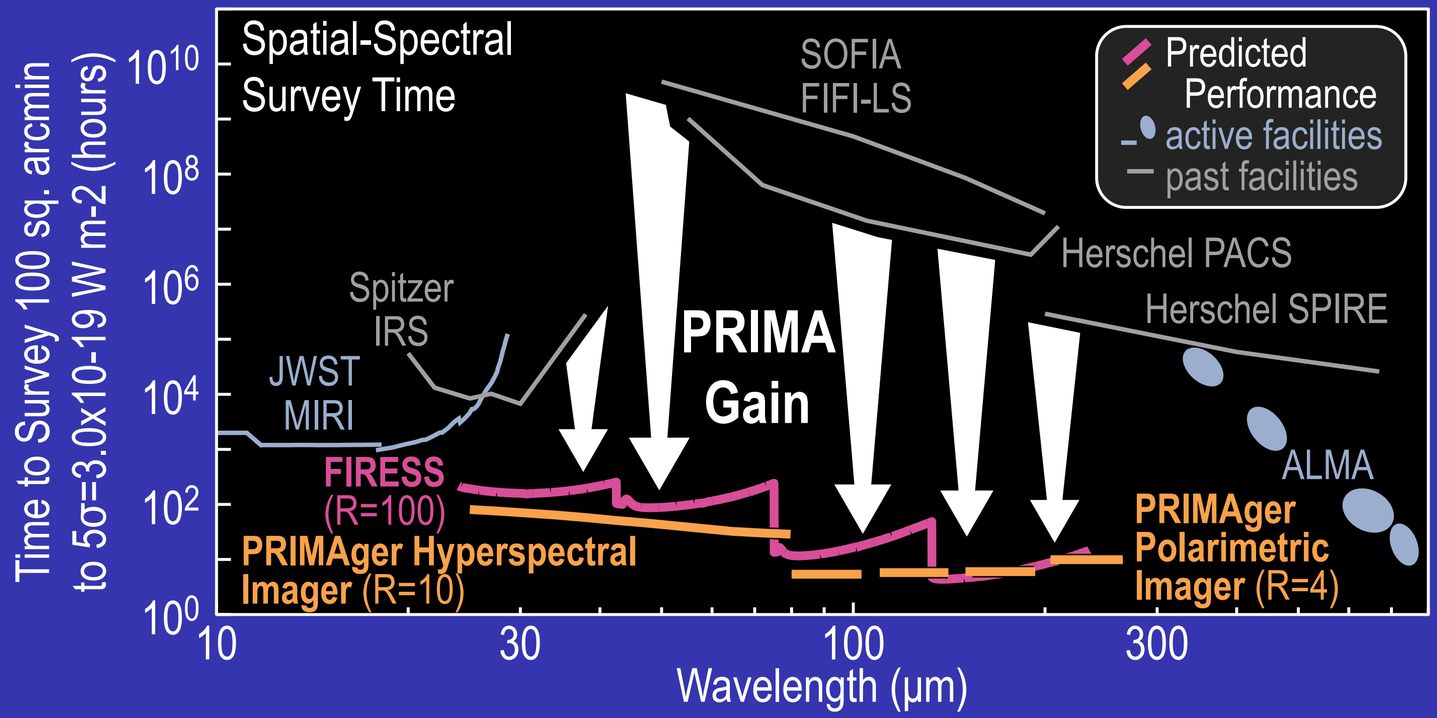
Archival ALMA intensity image at same freq (Scoville PI)

Archival polarization data exist for Arp220 but are not yet public


ALMA image including CO emission & continuum
Declination
13.0
12.5
12.0
11.5
11.0
10.5
23:30:10.0
57.40
57.35
15:34:57.30
57.25
57.20
57.15
57.10
Right ascension
37
30
23
16
9
2
-5

GENERAL OBSERVER SCIENCE

PRIMA's 3-5 orders of magnitude gain in spectral mapping speed unlocks science discovery space between JWST and ALMA. With 75% of observing time dedicated to GO science, PRIMA can obtain spectra of hundreds more protoplanetary disks, young stars, and distant galaxies than Herschel. See the PRIMA GO Science Book (https://arxiv.org/abs/2310.20572) for cases already identified by the community.



PRIMA Website
prima.ipac.caltech.edu

Conclusions

- Magnetic fields potentially important in mergers and starbursts
- Dust polarization studies with mm/submm interferometers now possible
- SMA observations have detected dust polarization in Arp220
- New window on the forces that control the brightest far-IR sources in the local universe