近傍活動銀河のB-BOP/SPICA遠赤外線連続光偏光観測

中西康一郎(国立天文台), SPICA サイエンス検討会近傍銀河・銀河系班
江草芙実, 左近樹, 本原顕太郎(東京大), 金子紘之, 馬場淳一(国立天文台),
稲見華恵(広島大), 渡邉祥正(日本大), 竹内努, 田村陽一(名古屋大学)

Outline

- Observation of FIR continuum in outflow
  toward starburst/AGN (including halo) with B-BOP
- aims
  - Detection of magnetic field embedded with outflow
  - Complementary to other observations (e.g. velocity structure via line emission)
- impacts
  - Origin of magnetic field in galactic discs and intergalactic region
  - Placing constraints on mechanism of outflow
  - Taking the initiative before Origins Space Telescope

“Probing the cold magnetized Universe with SPICA-POL (B-BOP)”

André+ 2019

section 6: Magnetic fields in galaxies

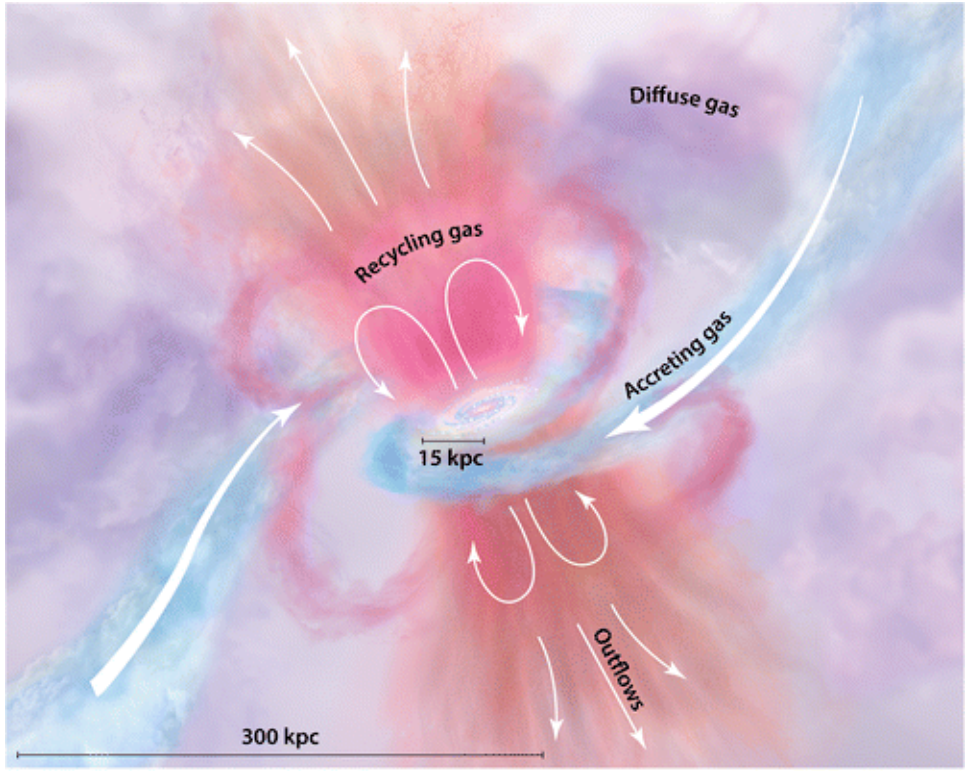
- Importance of magnetic field on extragalaxies (discs)
  - (explosive)star formation, acceleration of CR…
- Previous works mainly observed Synchrotron (cm regime)
- Observation of dust emission (FIR, submillimetre) is rare
- B-BOP
  - On-source 2 hours-> whole area of a galaxy (fig. 10)
  - Examination of galactic dynamo models, magnetic field in a dwarf galaxy, polarization mechanism of U/LIRGs and AGN, etc…
- **Few comments on outflow**

  →this study

Why galactic wind and outflow?

- Triggered by galaxy activities (starburst/AGN)
- Roles in galaxy evolution
  - Ejection of baryon

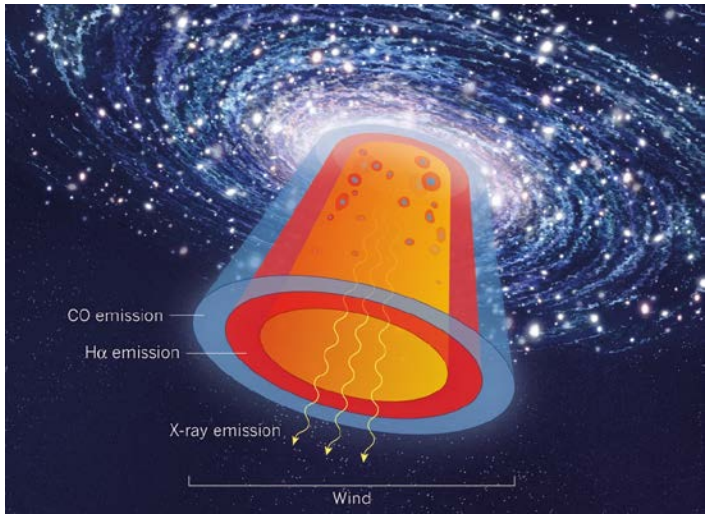
    →suppress activities, pollute IGM
  - Necessary for reproduce present-day galaxy stellar mass function



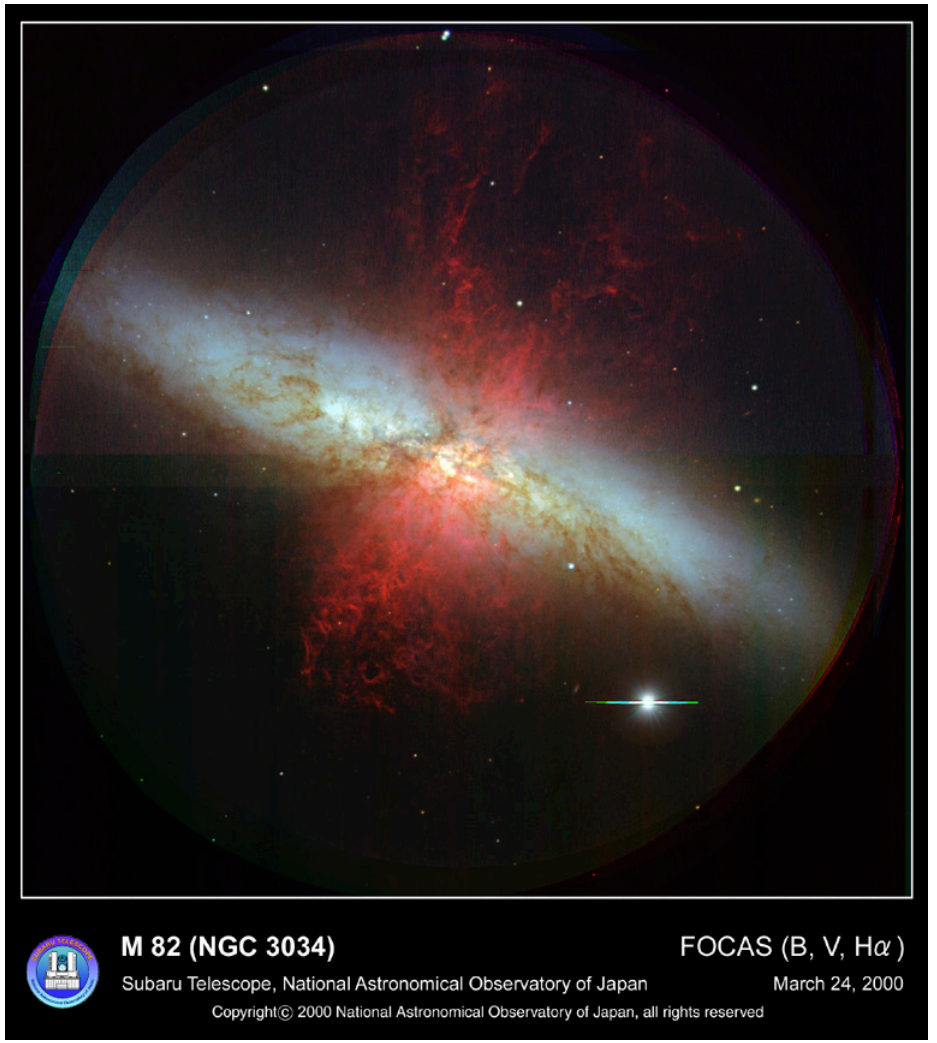
Tumlinson+ 2017 ARAA

Why galactic wind and outflow?

- Observed by wide variety of gas and grain
  - Emitter: neutral gas (hot and cold), ionized gas(hot), dust, PAH…
  - Wavelength: gamma ray, X ray～optical, IR～sub-mm, mm, cm

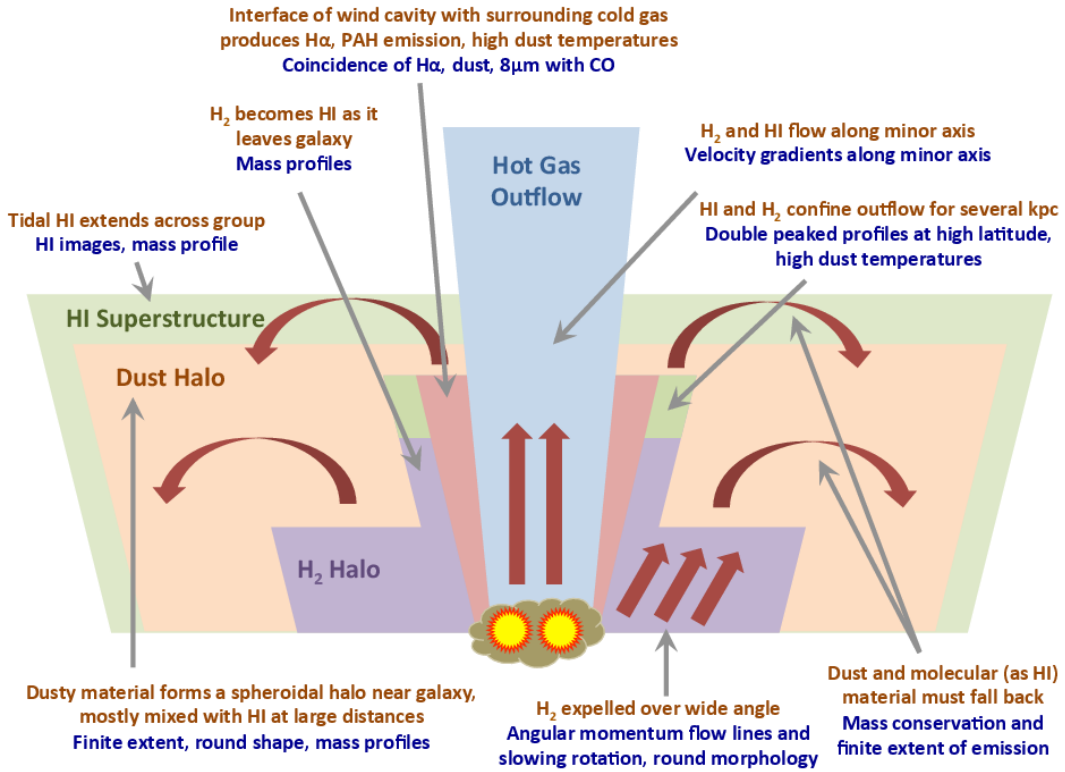


←a schematic view of conical structure in outflow driven by starburst (Westmoquette 2013, Nat.)



Molecular gas and dust in outflow

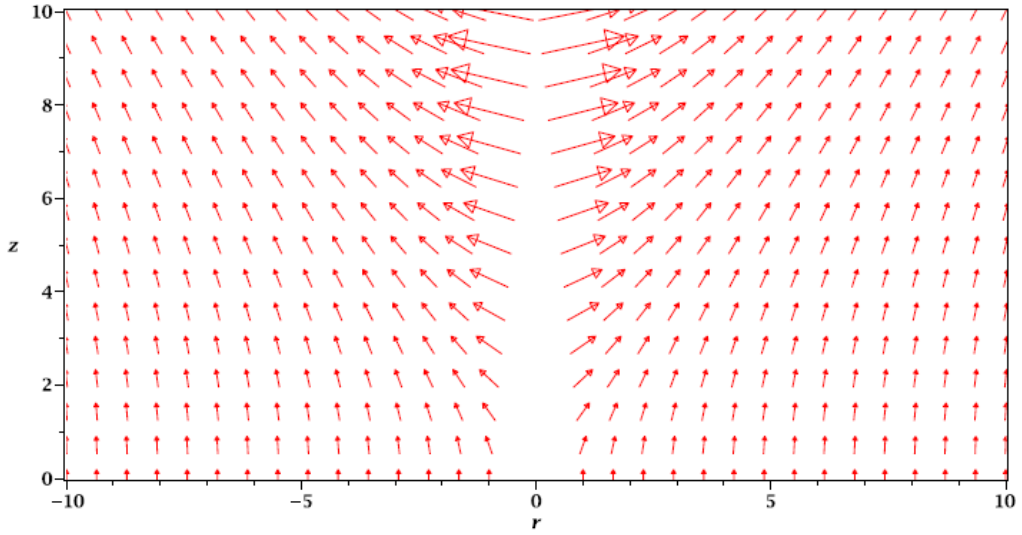
- Observations of cold ISM (molecular gas/dus) in outflow have been reported
- Open question: if the cold ISM clouds are entrained from galactic plane, can they survive all the way?
- Magnetic field in outflow may play a role (e.g. McCourt et al. 2015; see also Cottle et al. 2020)



Leroy et al. 2015, ApJ, 814, 83

Magnetic field embedded with outflow

- A role on driving outflow
- Control gas/dust dynamics at a boundary region of disc and halo (e.g. Henriksen & Irwin 2016)
- Connect galactic and intergalactic magnetic field (e.g. Bernet, Miniati, & Lilly 2013) contribute a formation of intergalactic magnetic field

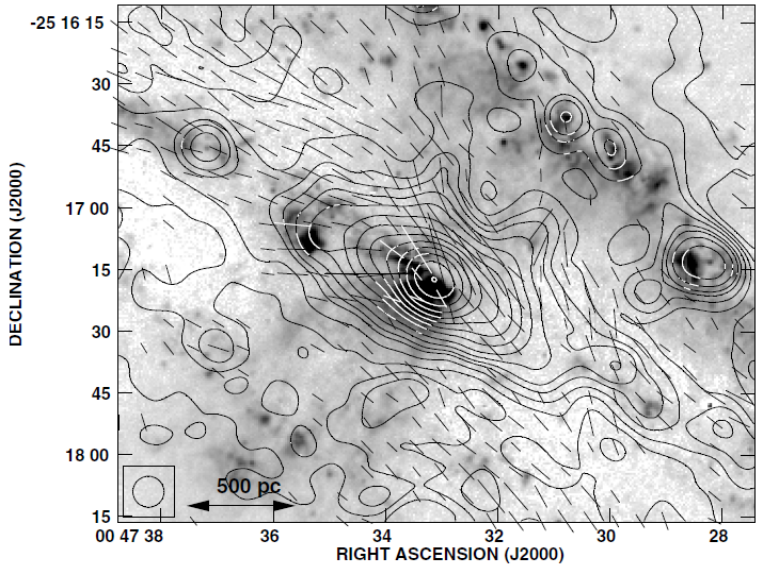


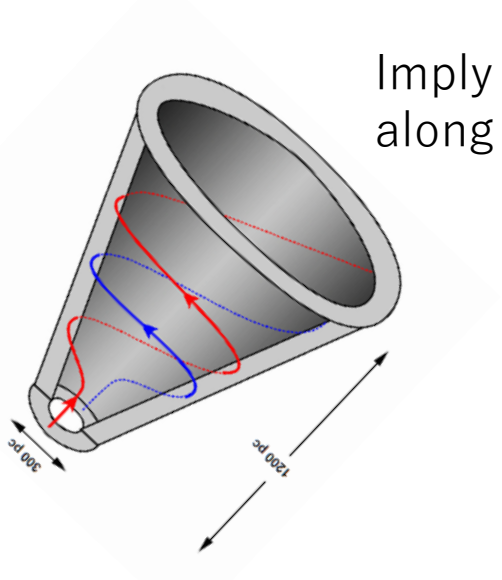
Example of analytical model
(Henriksen & Irwin 2016; unit of kpc)
Magnetic structure at halo

Observation of magnetic field in outflow (cm wavelength)

- Synchrotron emission from plasma
  - Covers wide area (>kpc)
  - Needs to remove Faraday rotation at low frequency (shortcoming)
  - One of main science goals of SKA/ngVLA
- Example: NGC 253 observed by VLA

  (3cm=10GHz, Hessen+ 2011, A&A 535 A79)



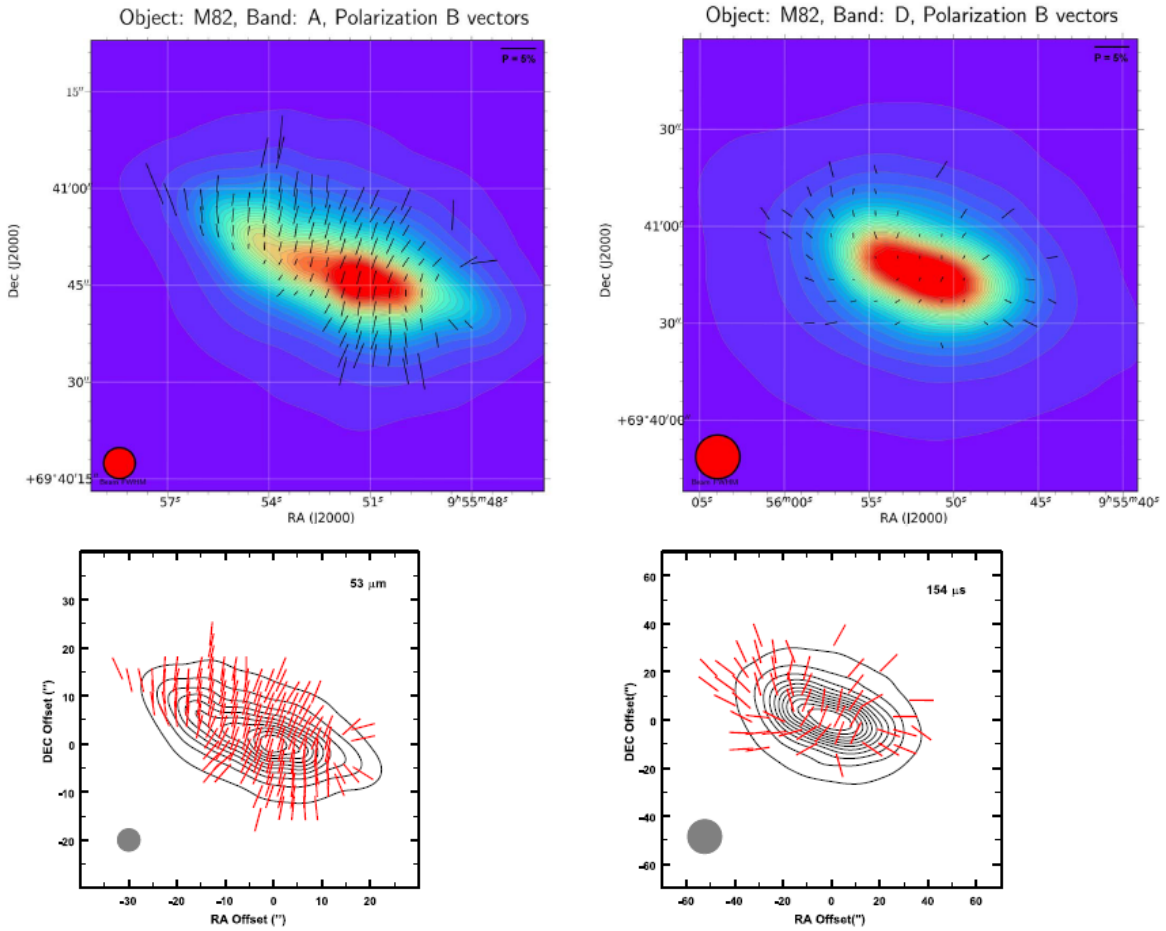


Imply magnetic structure along an outflow wall

FIR observation of magnetic structure embedded with dust in an active galaxy

Messier 82 SOFIA/HAWC+ 53/154 um

- Observations of nearby starburst M82 and NGC 253 by SOFIA/HAWC+ (Jones+ 2019 ApJL 870 L9)
  - Detect polarization perpendicular to a disc
  - polarization in outflow (kpc scale): non-detection



SPICA B-BOP observation toward active galaxies with outflow

- B-BOP would be a powerful tool
  - High sensitivity in polarized emission (Stokes Q/U) detection:
    two orders of magnitude better than SOFIA/HAWC+
  - Useful for both nearby galaxies (< a few 10Mpc) and extended outflow
  - Farther active galaxies could be observed
- Competitive science
  - ALMA

    1) central region of nearby active galaxies (~10pc scale)

    →not very good for >kpc scale

    2) high spatial resolution & high sensitivity observations of farther (> few 10Mpc) active galaxies (100pc - kpc scale)
  - Origins Space Telescope

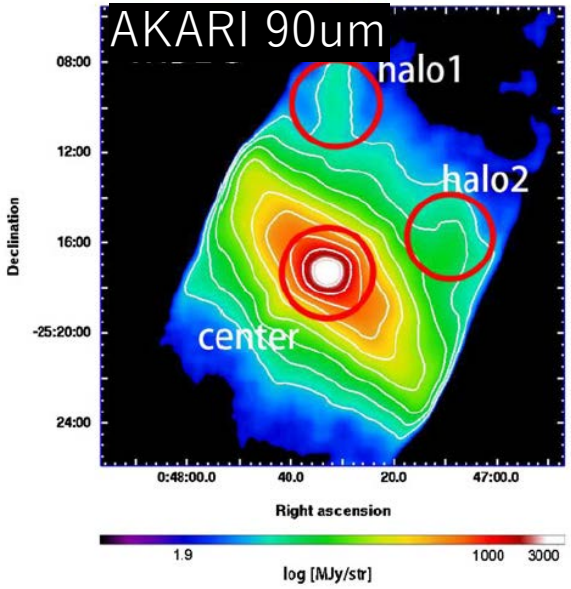
    → outflow is one of the major science themes

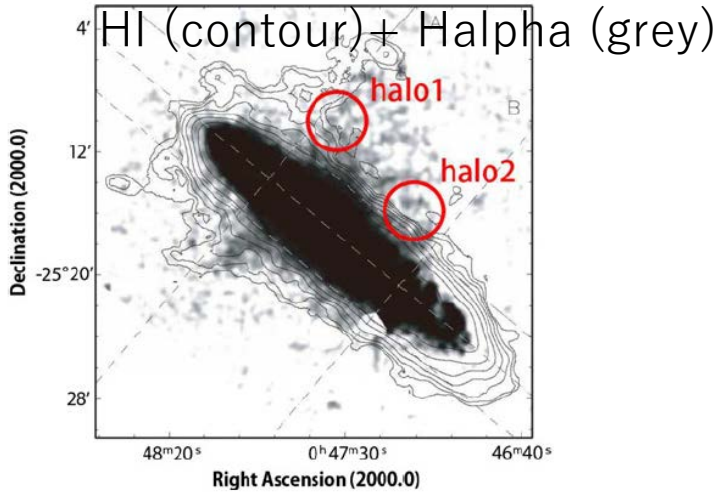
SPICA B-BOP observation toward active galaxies with outflow: Aims

- Dust distribution embedded with outflow
  - Is a multi-layer structure as M82 (Leroy+ 2015) universal?
- Does magnetic structure exist along outflow?
  - Can structure shown in Hessen+ 2011 also be found in dust?
- What is a role of magnetic field in cold ISM (dust/gas) in outflow?
  - it would help dense ISM clouds in galactic plane pushed out by outflow to survive all the way and reach to intergalactic space
- As a bi-product, it can reveal magnetic structure of a galaxy itself

Dust emission from halo in NGC 253

- Kaneda+ 2009 (ApJ, 698, L125)
  - AKARI FIS(90/140μm)
  - emission of dust origin from halo(6-9kpc from galactic centre)
  - Dust: ejected from outflow driven by starburst





Dust emission from halo in NGC 253

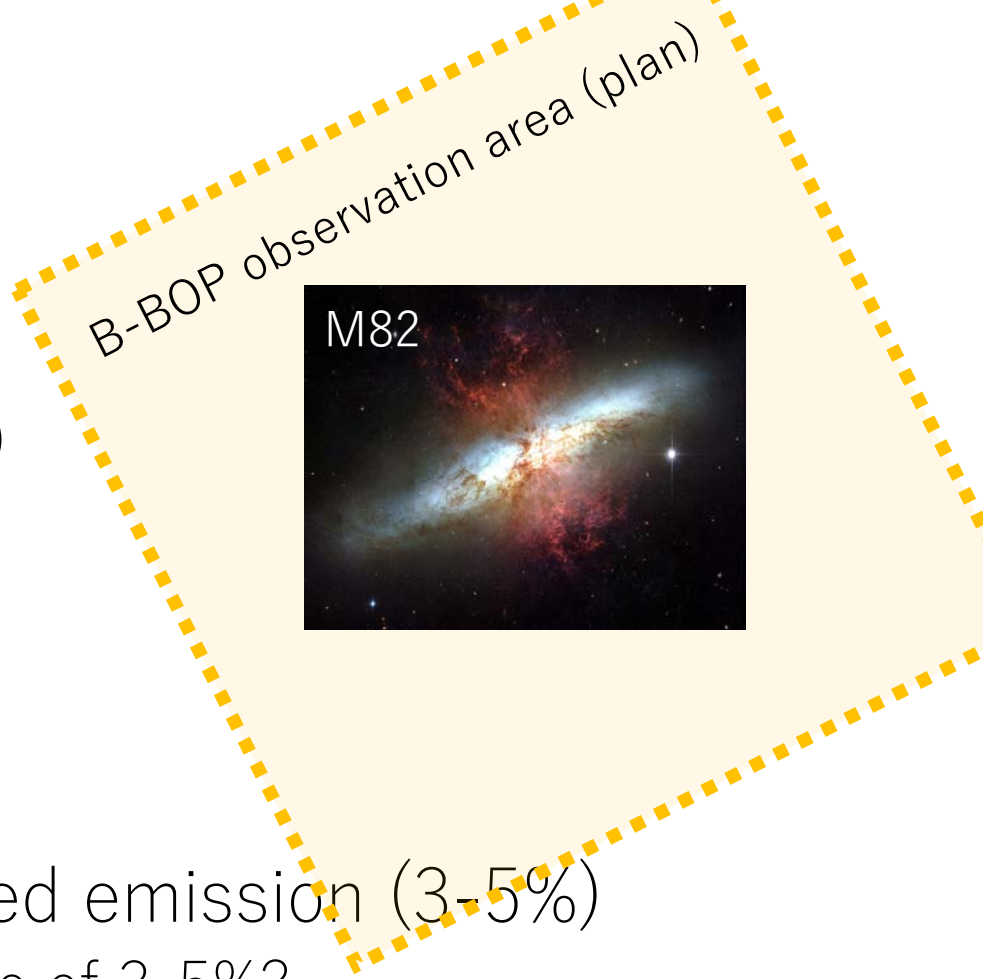
- Flux of dust emission at halo (Kaneda+ 2009)
  - two emission structures were detected
  - flux = 9.5 and 18 Jy (4' aperture), surface density = 9 and 17 MJy/sr @90um
- B-BOP (André+ 2019) Table 1

Surface brightness sensitivity 1 deg^2 5σ-10hr			
Unpol.	0.09 MJy/sr	0.045 MJy/sr	0.025 MJy/sr
5% Q, U †	2.5 MJy/sr	1.25 MJy/sr	0.7 MJy/sr
	↑	↑	↑
	100 um	200 um	350 um

  - Same sensitivity (5σ) can be reached 1hr observation (20x20 arcmin^2)
  - If dust is polarized ~5%, SPICA can easily detect the emission

Observation plan

- Nearby galaxies with outflow
  - Target candidates (having prominent outflow)
  - NGC 253, M 82, NGC 4945 (nearby galaxies)
  - NGC 891, NGC 3256, NGC 1569, NGC 2146
  - Arp 220, NGC 6240 (U/LIRGs)
- instrument: B-BOP 90μm
- Target sensitivity: 5 σ detection of polarized emission (3-5%)
  - [to be assured] can expect polarization degree of 3-5%?
- On-source time: total a few x10 hrs (closest 1-2 hrs, others >5hrs)



M82 image credit: NASA, ESA and the Hubble Heritage Team