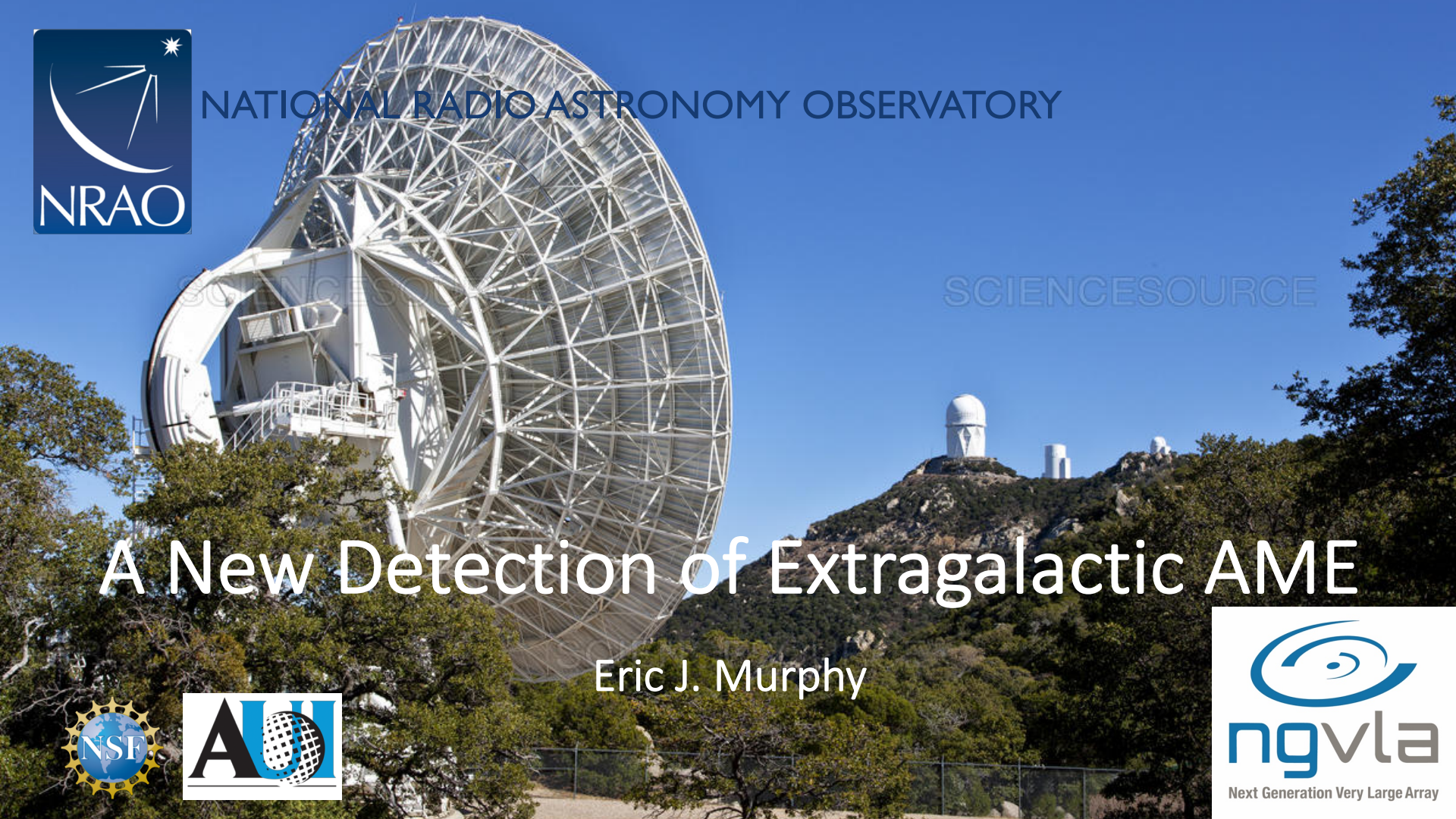
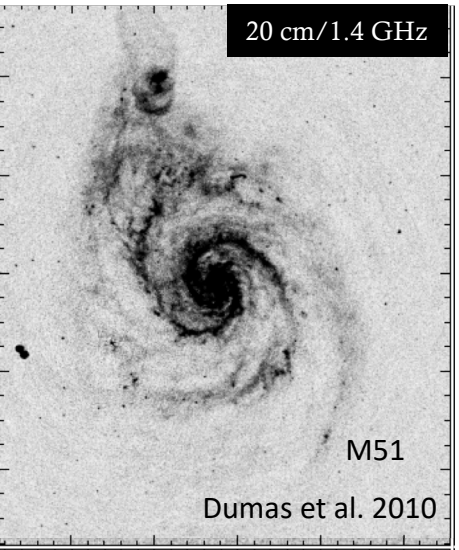
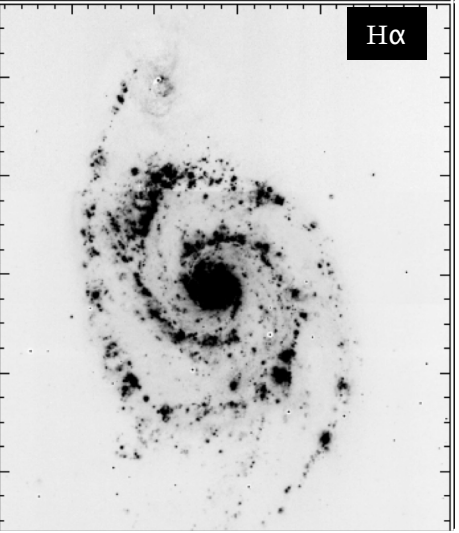
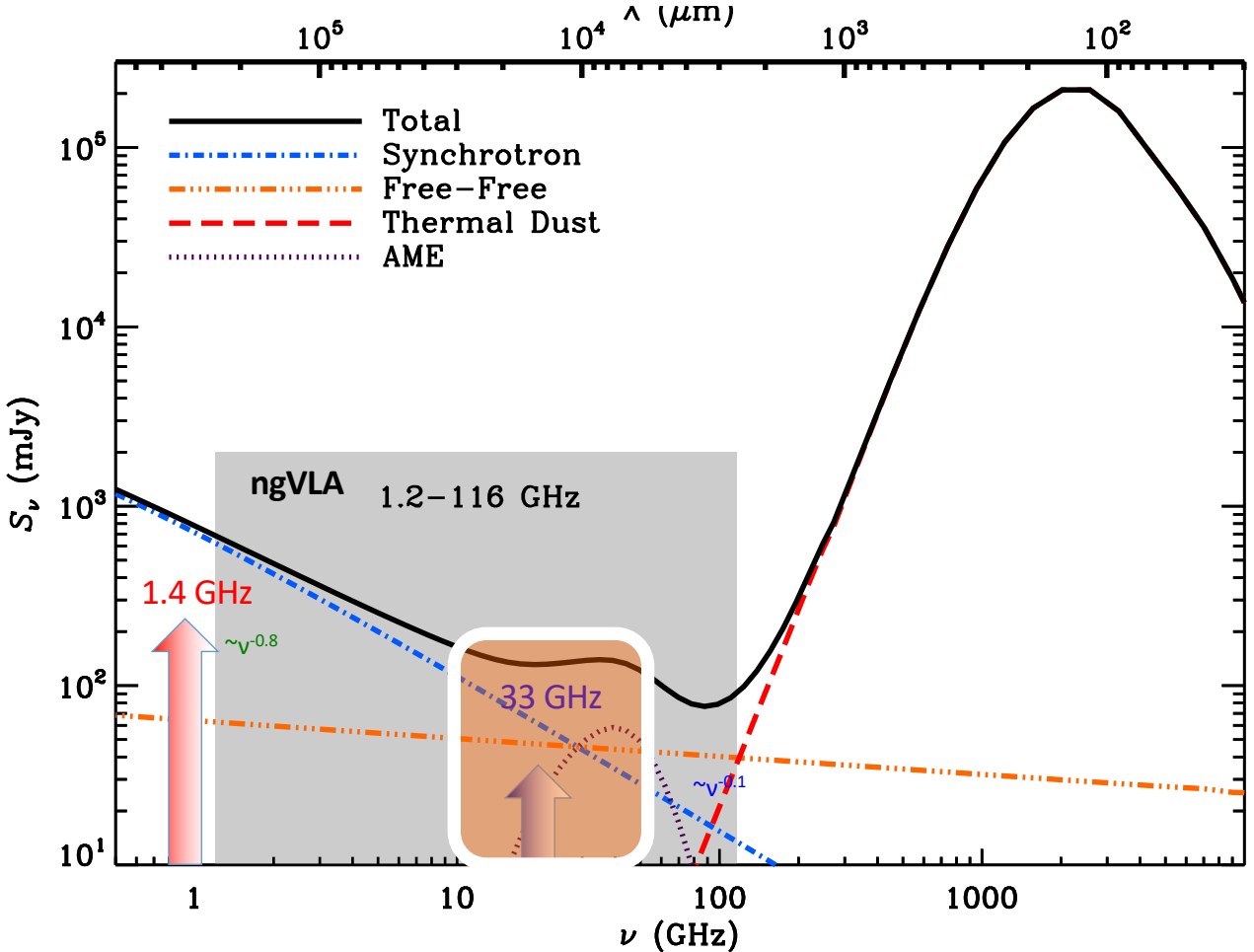

NRAO
NATIONAL RADIO ASTRONOMY OBSERVATORY
SCIENCESOURCE
A New Detection of Extragalactic AME
Eric J. Murphy
NSF
AUI
ngvla
Next Generation Very Large Array



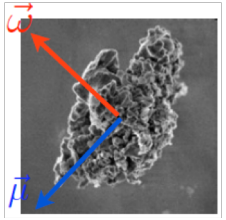


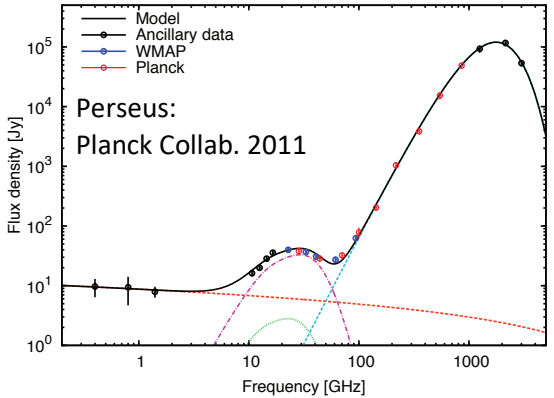
Radio-to-FIR Spectrum of a Galaxy

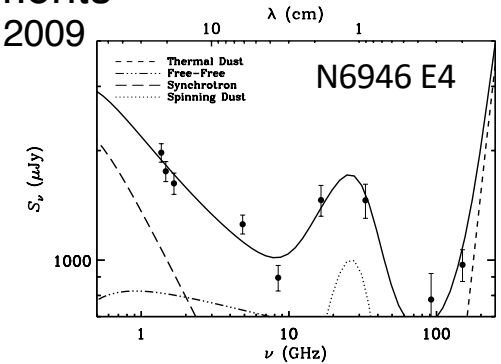


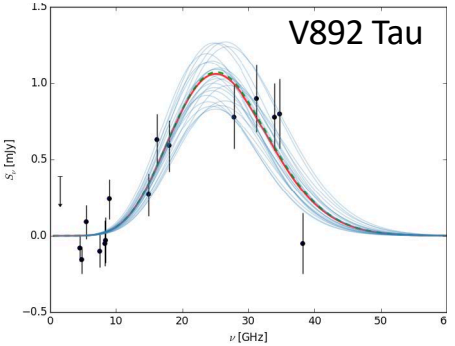
AME over the last 20 years

- First detected in 1996 as an excess CMB component
  - Kogut et al. 1996; Leitch et al. 1997
- Thought to arise from “spinning” dust
  - Erickson 1957; Draine & Lazarian 1998
- Detected in a range of Galactic environments
  - E.g., Finkbeiner et al. 2002; Dickinson et al. 2009
- First extragalactic detection
  - Murphy et al. 2010
- Detected in 3 proto-planetary disks
  - Greaves et al. 2018
- *Status: Carrier and ISM conditions that drive AME still completely unknown*

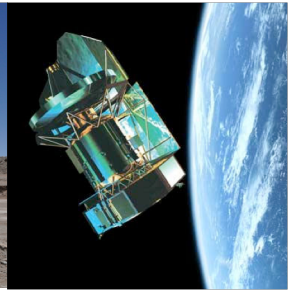


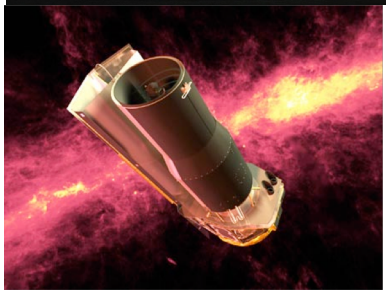






ngvla
Next Generation Very Large Array





The Star Formation in Radio Survey (SFRS)

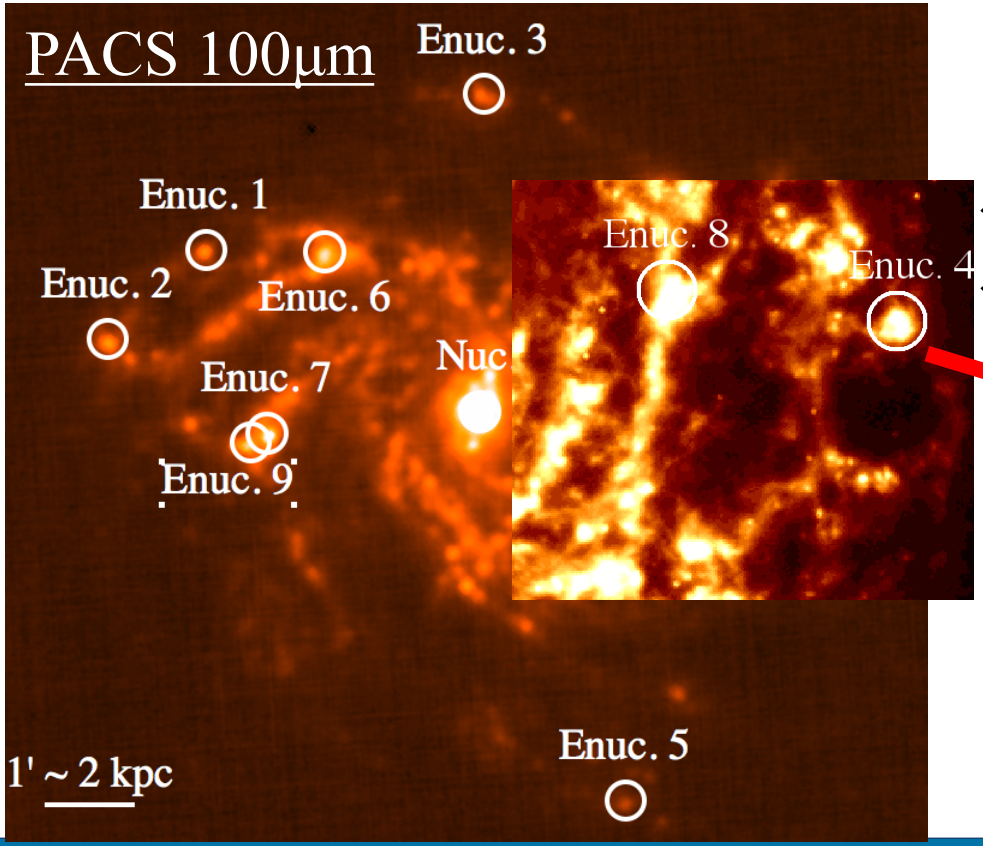
Studying the Astrophysics of Star Formation in Nearby Galaxies

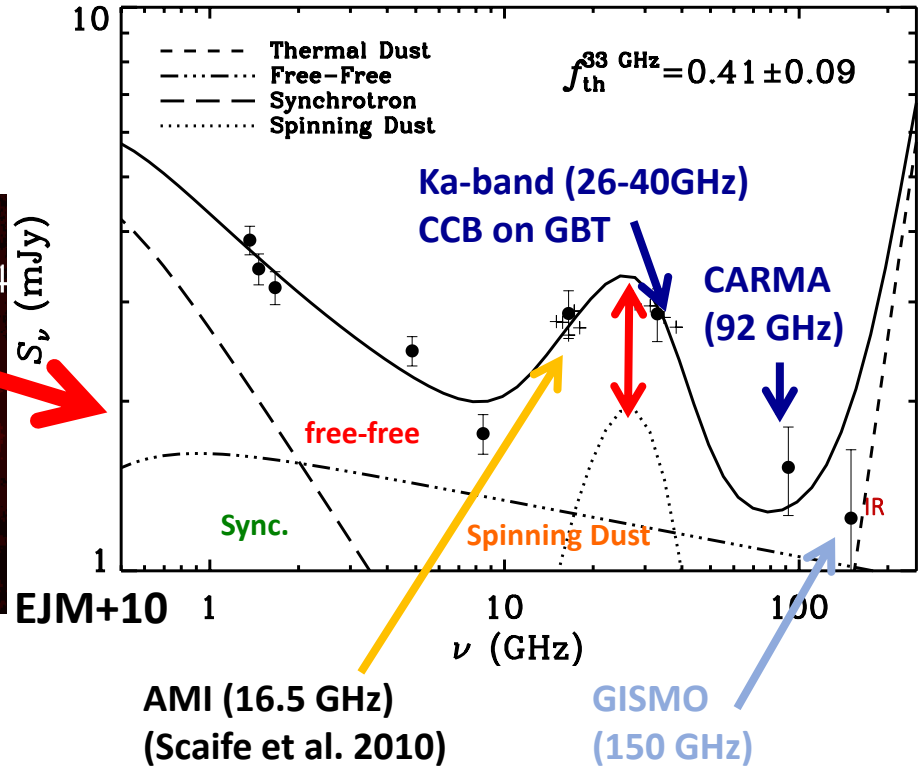
- **Sample Derived From: SINGS/KINGFISH/GOALS**
  - 3.6 – 500μm imaging of 61+ nearby galaxies borne from SINGS sample
  - IRS/PACS spec-mapping for 118 Nucs (56) + enucs (62)
  - Additional ~68 LIRGs/ULIRGs from GOALS (Barcos, **Evans**, Leroy, **Linden**, **EJM**)

See Evans talk & Linden Poster

- **SFRS: GBT/JVLA/ATCA/ALMA**
  - GBT: Ka-band for >~100 SINGS/KINGFISH SF regions (EJM+11,12)
  - JVLA: S-, Ku-, and Ka-band for >~112 SINGS/KINGFISH SF regions (EJM+18a,b) + 88 local (U)LIRGs
  - ALMA: for dense gas tracers (e.g., HCN, HNC, CS) for resolved SF Law work (EJM+15)

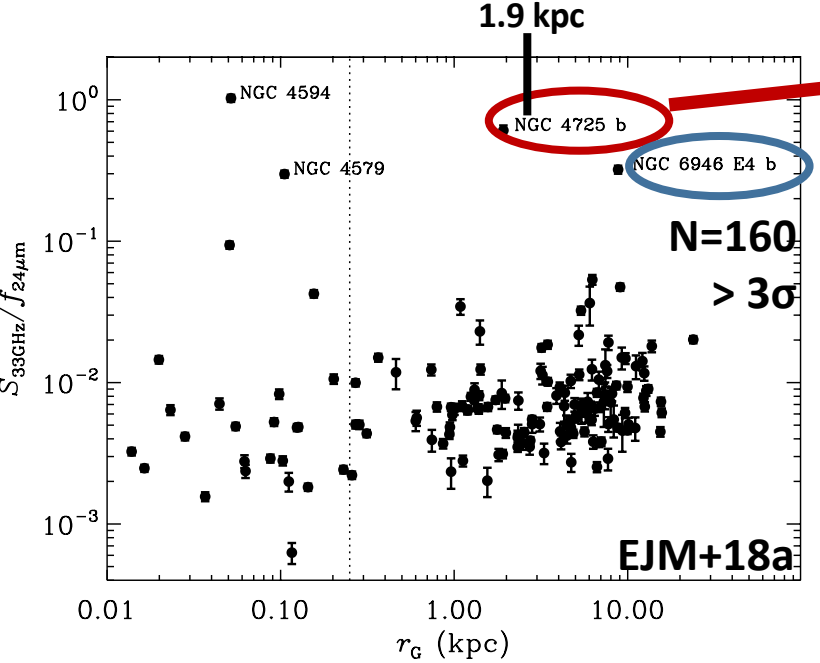
The Pilot: NGC 6946 – The First Detection of Extragalactic AME

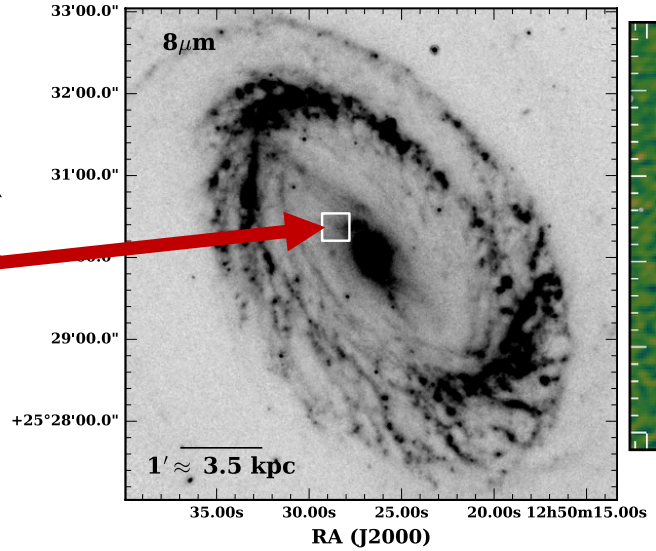


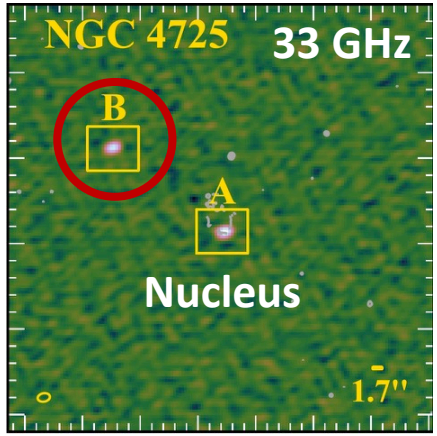


See Hensley, EJM, & Staugun (2015) for latest modeling

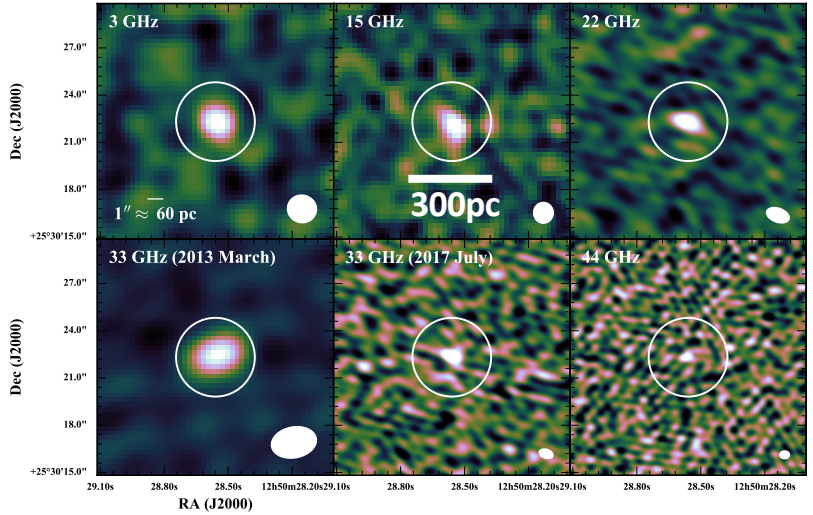
A new detection of AME: NGC 4725 B







EJM+18b



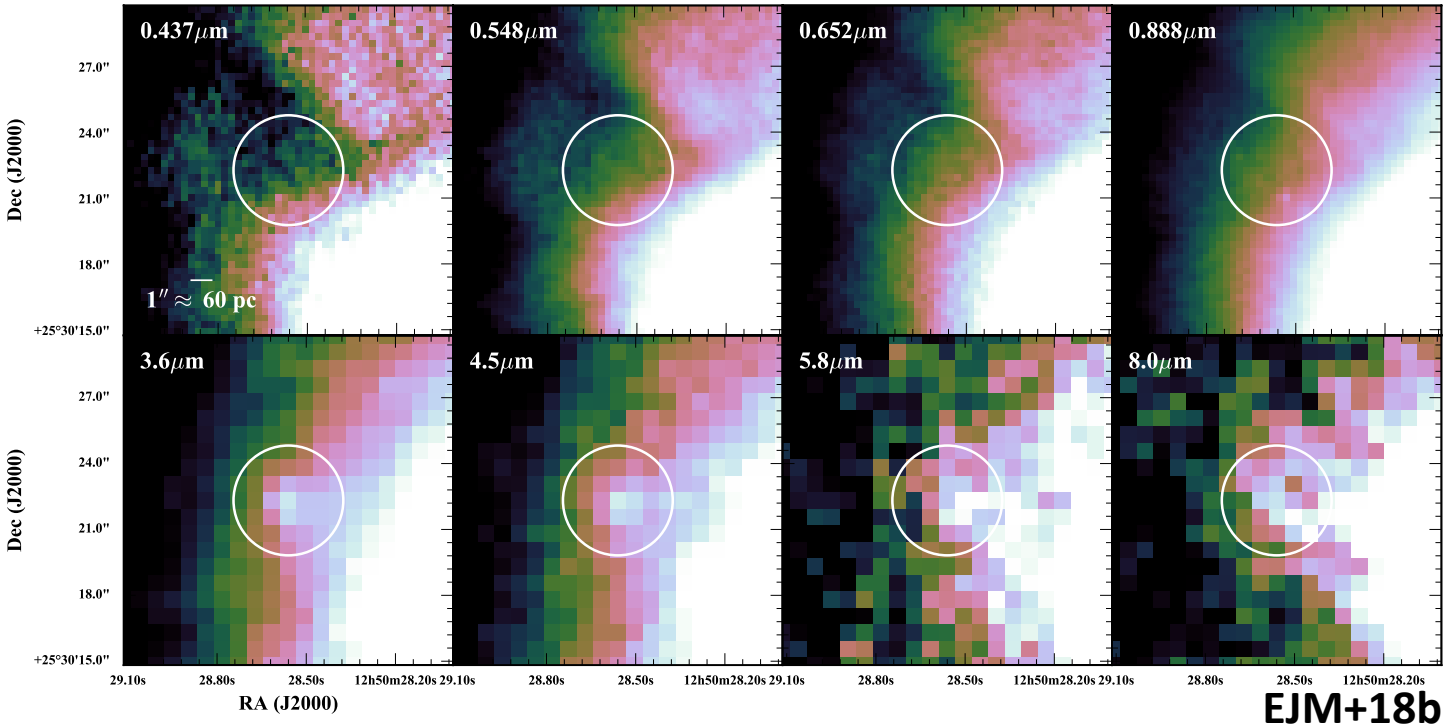
Radio Observations

ν (GHz)	3	15	22	33	44
Date Obs.	11/13	11/14	7/17	3/13, 7/17	7/17

A new detection – NGC 4725 B (optically invisible)

Optical (*BVRI*)

Mid-IR *Spitzer*



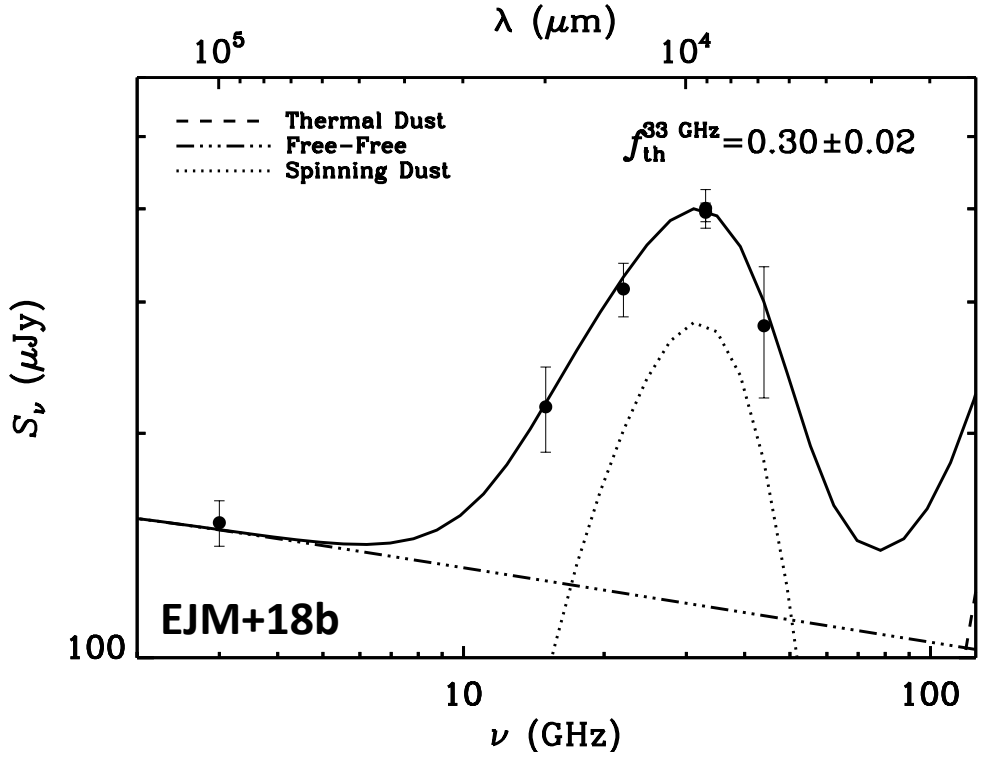
EJM+18b

A new detection – NGC 4725 B

- Similar 33GHz thermal fraction and AME luminosity as N6946E4
- No obvious optical or non-thermal component
- Mid-IR counterpart (hot dust/small grains)
- Unlikely background given what (little) is known (Murphy & Chary 2018).

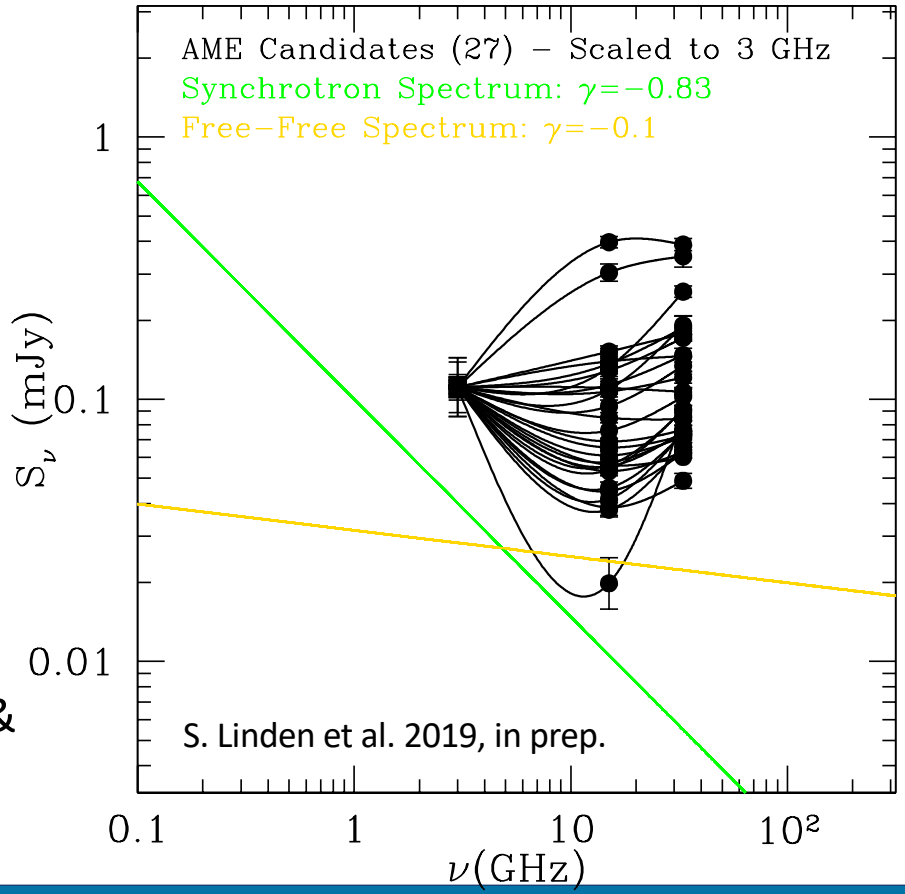
- ***Highly enshrouded, nascent star-forming region (<3 Myr).***

- Implications for observed AME?
  - ***Smallest grains not yet destroyed by SNe?***



New Extragalactic AME Candidates

- 29 AME Candidates
  - ≈ 10 % of sources (N=291)
  - r_g > 250pc
  - $|\alpha(15,33\text{GHz}) + 0.1|/\sigma > 3$
- Potential Background Sources?
  - 16 removed by eye from all SFRS detections
  - Unlikely given n(S) (Murphy & Chary 2018)
- Proposal in to follow-up with VLA (15, 33, & 44 GHz)… ALMA (3mm) to follow.



Summary/Future Outlook

- 2/160 (~1%) sources have very large 33 GHz/24μm ratios & strong AME
- 30GHz (AME)/IR (dust) ~x2-3 larger in both N6946E4 and N4725B compared to MW values – *most favorable extreme from strong AME*?

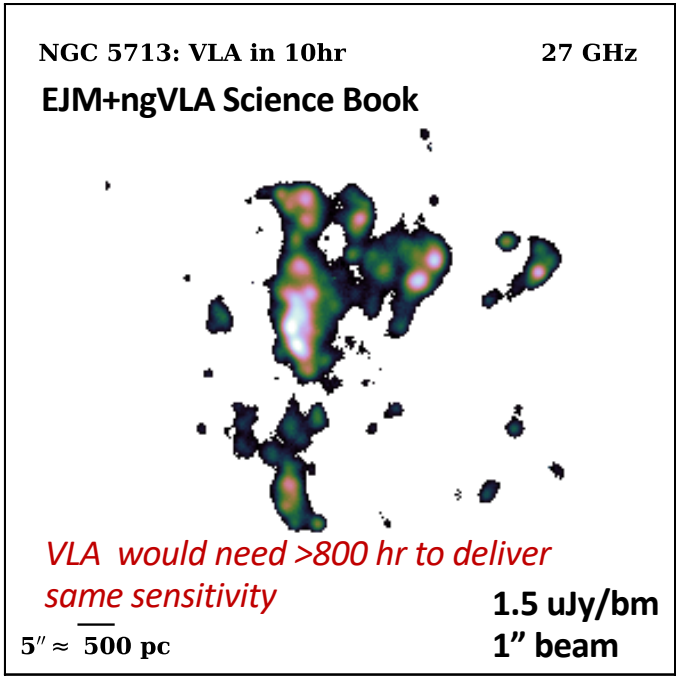
- Accepted ALMA proposal to look at 90GHz + CO emission from N4725B
- *HST* to do FUV spectroscopy to attenuation curves/grain size distributions & PAHs
- *JWST* to map 3.3/3.4 μm PAHs + nano-diamands from both sources
  - *written and ready for June 2020!*

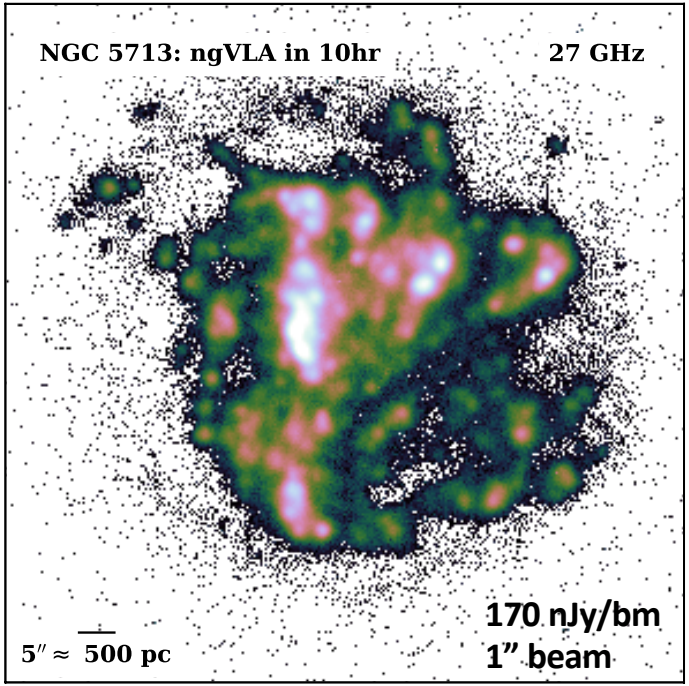
- ***Real progress requires a next-generation radio instrument (e.g., ngVLA)***
  - Currently sensitivity starved in the radio to map large areas & PP disks!
  - DS2020 WP being prepared

Prospects with the ngVLA

A transformational step in studying star formation (and AME) in Galaxies

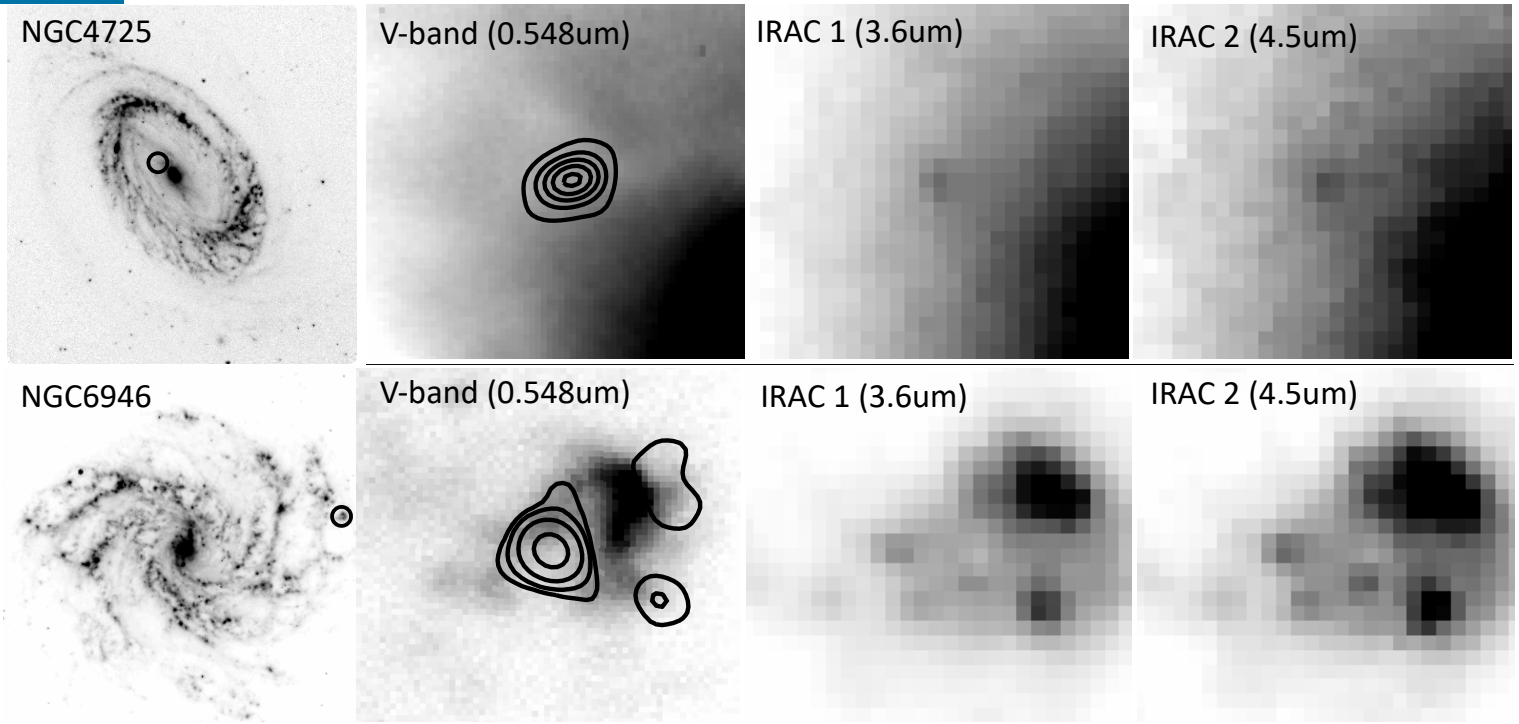
Hα –like images (sens./res.) w/out extinction, FG stars, or [NII] contamination





ngvla
Next Generation Very Large Array

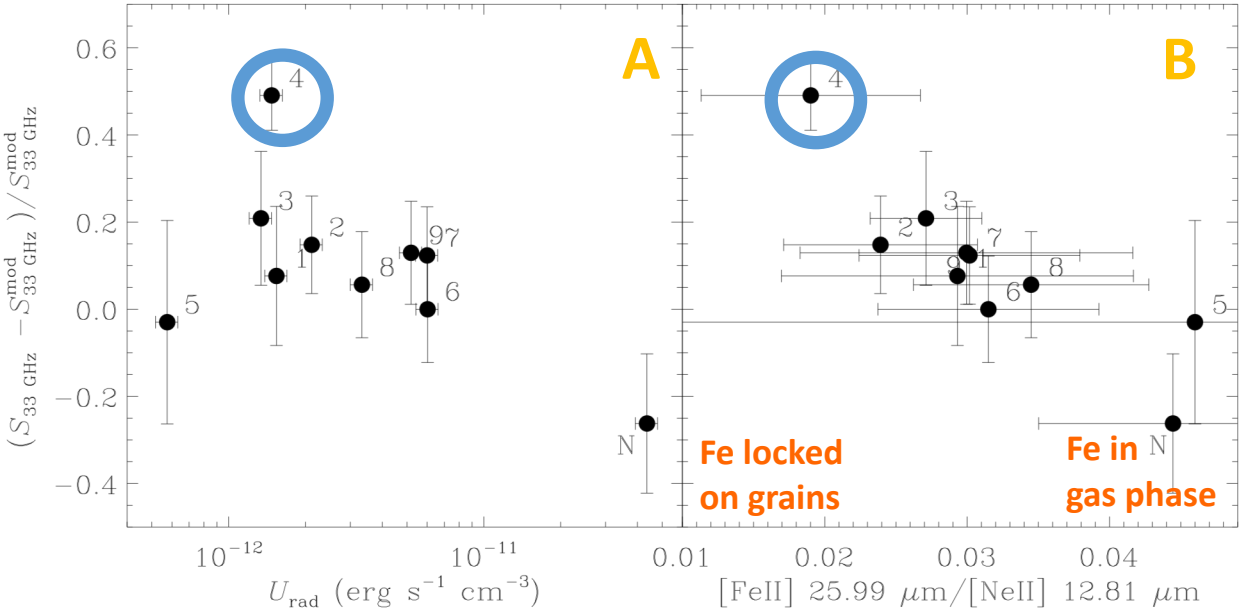
Comparison: N6946E4 & N4725B



Variations in Grain Distribution?

Importance of MIR/FIR Spectral Maps

Strength of 33 GHz AME/Excess



A. Exposed to a near-average radiation field.

B. Much less gas phase Fe^+ (IP~7.9eV) relative to Ne^+ (IP~21.9eV)

- Fe locked up on grains that have not been processed by shocks?
  - ***Abundance of small grains (a < 10 nm) present contributing to anomalous emission?***