HIGH ANGULAR RESOLUTION OBSERVATIONS OF AME

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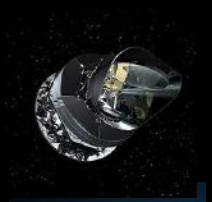
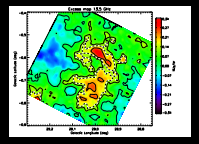
OVERVIEW

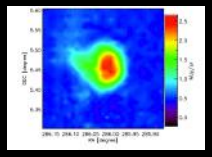


- High angular resolution: Planck did great but we now need to study the physics within selected regions

- Activity started in 2011 with 64-m Parkes radio-telescope targeting two Galactic regions



- RCW175 H II region shows clear AME: we will show maps, SED, and polarization (Battistelli et al. 2015)



- 3C396 SNR shows no evidence of AME: maps, SED and spectral index map will be shown (Cruciani et al. 2016)

- Future prospects: keep on working with giant radio-telescopes. Parkes, GBT, Effelsberg and SRT

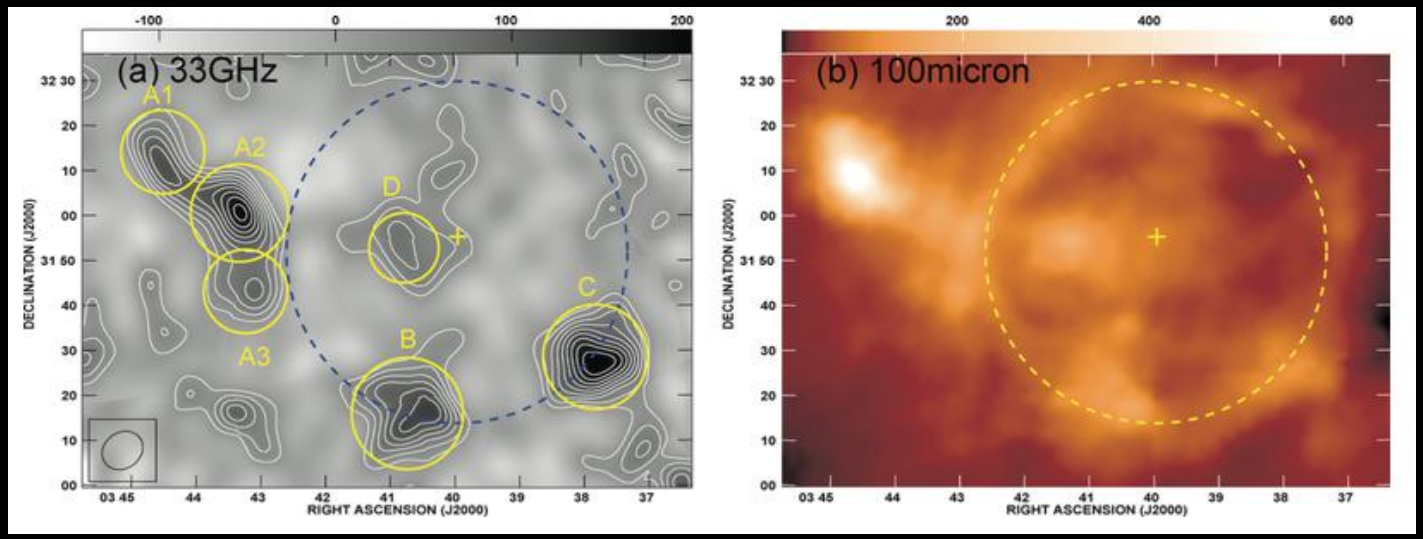
- SRT: early science call just closed

- We proposed, and got accepted, to observe the whole Andromeda in the microwaves

HIGH ANGULAR RESOLUTION OBSERVATIONS

- Is the emission diffuse or compact?

  VSA (FWHM=7') detected only 10% of the emission seen by WMAP Perseus (Tibbs et al. 2010)



Tibbs et al. (2011)

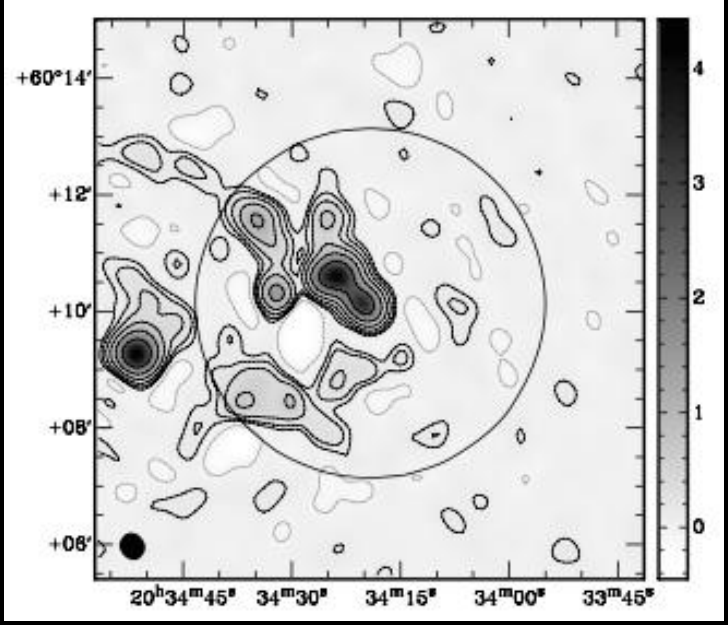
- Distinguish different components inside individual regions (HII regions, dark clouds) and isolate the AME agent

  Is the AME in W44 coming from the SNR or from surrounding HII regions (Génova-Santos et al. 2016)

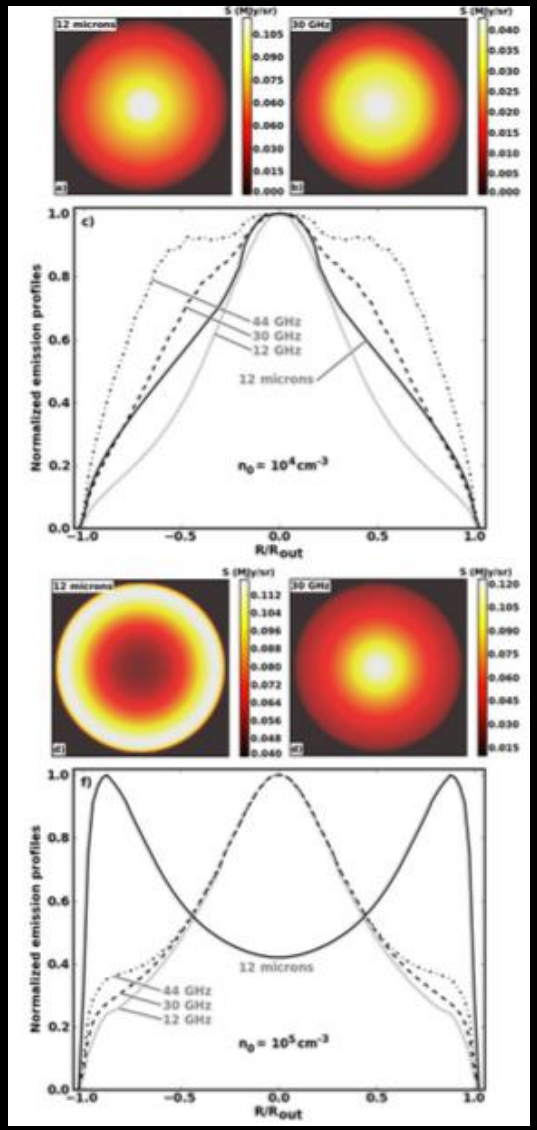
HIGH ANGULAR RESOLUTION OBSERVATIONS

- Study the interplay between different environments (MC, WIM, PDR, etc)
- Microwave-IR cross-correlations

  Ysard et al. (2011) suggested that at high-angular resolutions there could be anti-correlation in dense environments (Tibbs et al. 2015)
- Target extra-galactic AME detections



NGC6946 with AMI (Scaife et al. 2010)



Ysard et al. (2011)

HIGH ANGULAR RESOLUTION OBSERVATIONS

- Single-dish:

- Or interferometers?:

- Interferometers are able to reach much finer angular resolutions, but loose large angular scales
- Large single-dishes might be better (Battistelli et al. 2012, Harper et al. 2015)

PARKES 64-m OBSERVATIONS

- We used the Australian CSIRO's 64-m for continuum observations of two Galactic regions and their surroundings (~30 x 30 arcmin)
- Orthogonal RA and Dec scans
- Fourier space algorithm to make maps and reduce 1/f (Carretti et al. 2010)
- Polarization observations on 1-dim scan through the center of the source (instrumental spurious polarization <0.3%)

CSIRO's Parkes radio telescope. Credit: David McClenaghan, CSIRO

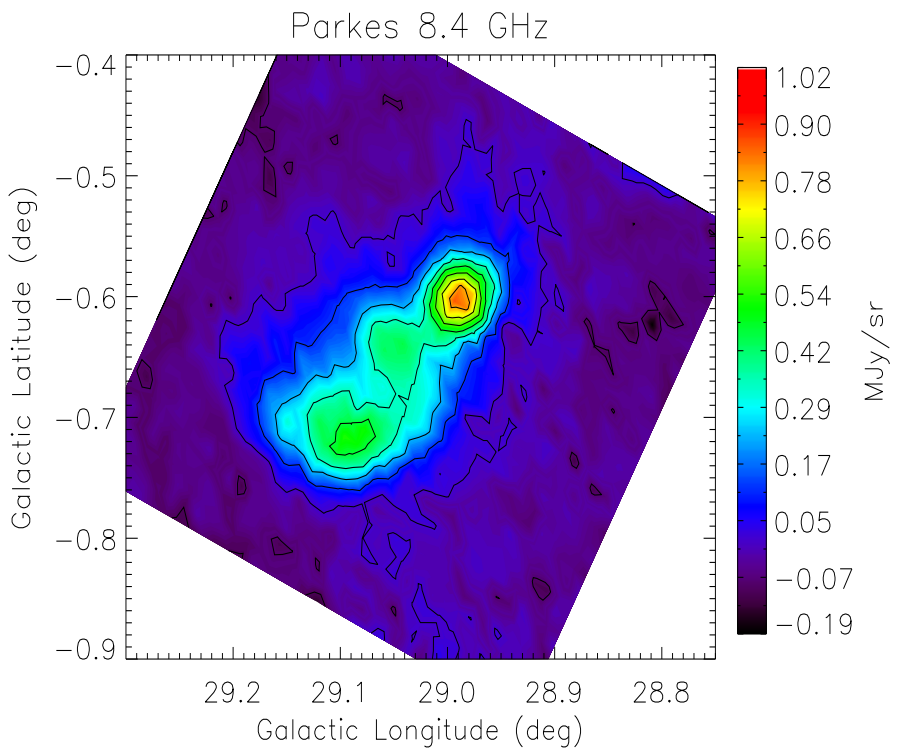
Receiver	Frequency	FWHM	Sensitivity	Polarization
MARS	8.4 GHz	2.4'	22mJy/beam*	-
Ku	13.5 GHz	1.7'	18mJy/beam*	-
13mm	18.6 GHz	1.2'	30mJy/beam	-
13mm	21.5 GHz	1.1'	5mJy/beam*	0.2mJy/beam

**dominated by the sky fluctuation*

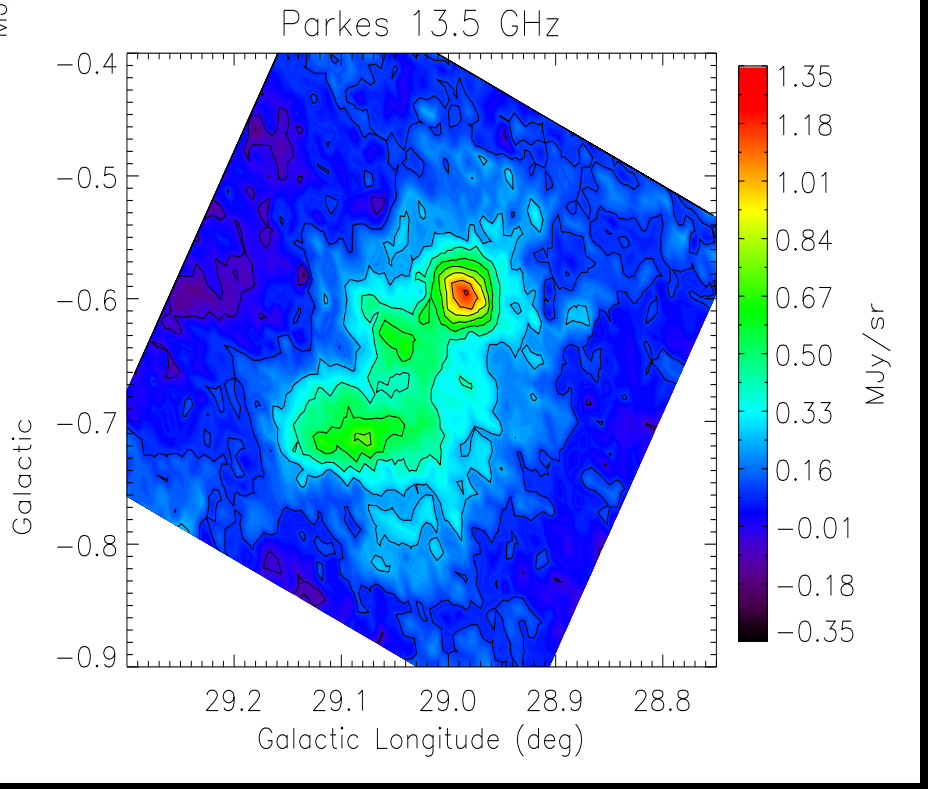
RCW175

New Radio Observations of Anomalous Microwave Emission in the HII region RCW175. Battistelli et al. 2015, ApJ, 801, 111

RCW175 MAPS



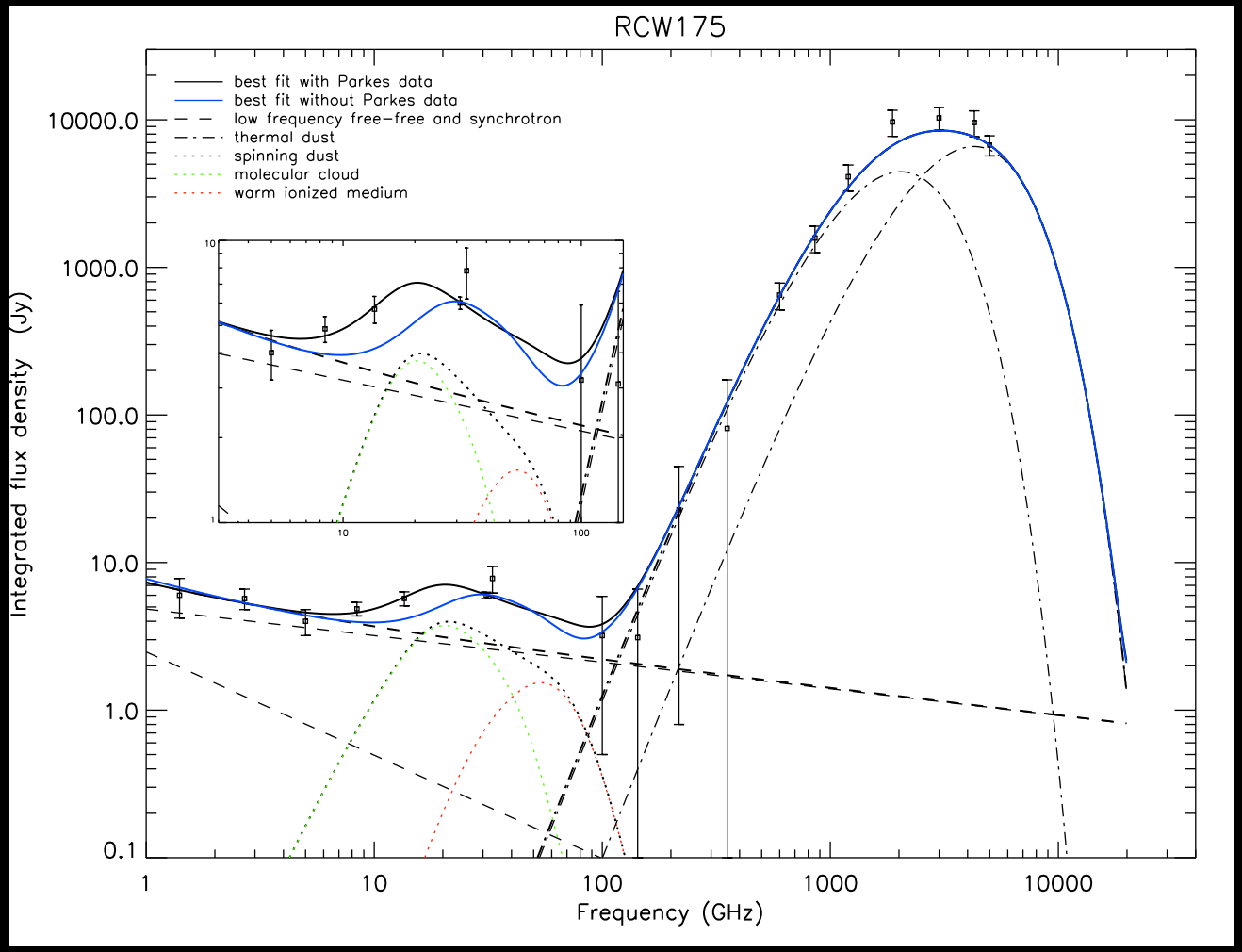
- Deeply studied by CBI (Dickinson et al. 2009) and Tibbs et al. 2012
- At least two regions were found in the microwaves



- We clearly see the brighter and unresolved G29.0-0.6, and resolve G29.1-0.6/0.7 into two regions
- Similar structure seen in the 1.4GHz NVSS data (Condon et al. 1998)

RCW175 SED

- Integrated emission from 12' radius (background 12'-17')
- Used ancillary data at radio frequencies (GBT, Effelsberg) and in the IR (Planck, Hershel, IRAS, Spitzer) as well as CBI+VSA
- Radio: free-free dominated with sub-dominant synchrotron emission
- Microwave: we confirm the AME with a lower peak frequency
- Although highly model dependent, two components needed to explain the SED:
  - WIM: n_H=26.3/cm^3
  - MC: n_H=150/cm^3, T_{gas}=100K



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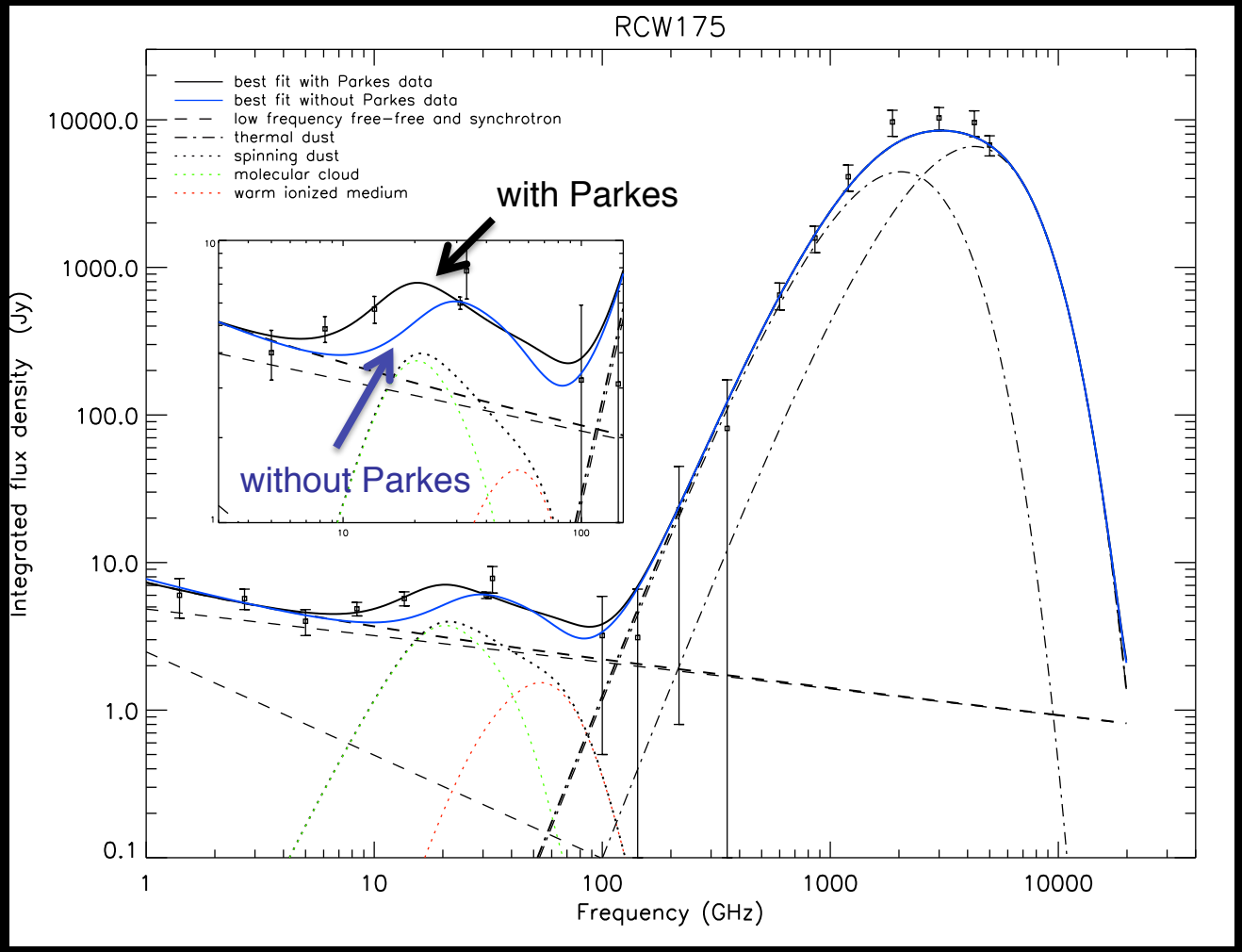
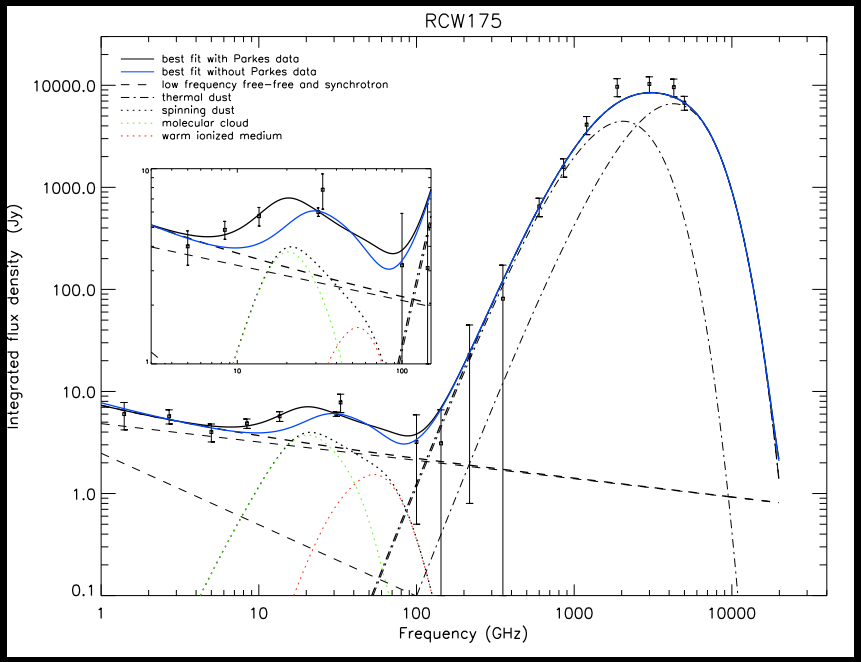
- Parkes data change the fit!



RCW175 SED and AME MAP



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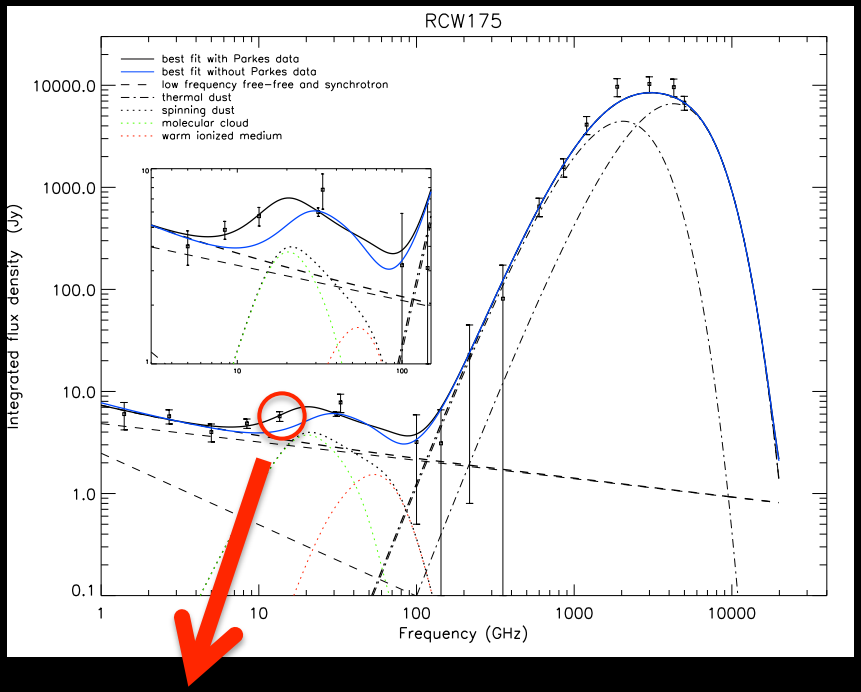

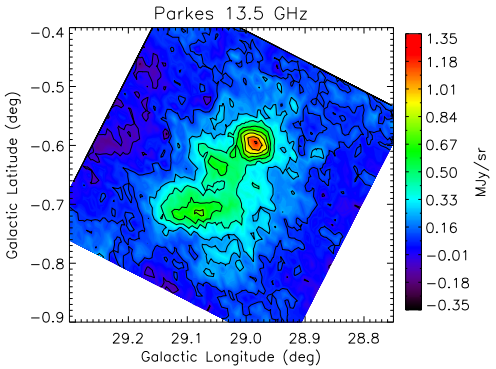

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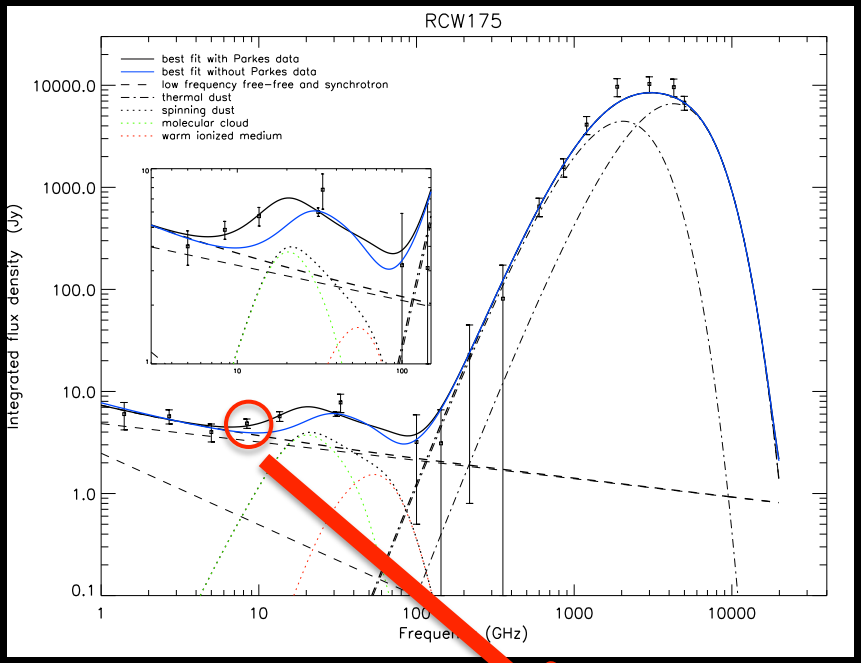

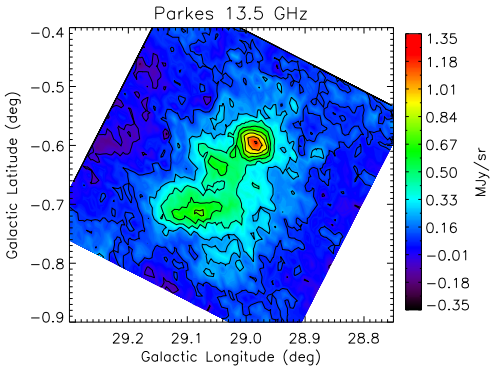

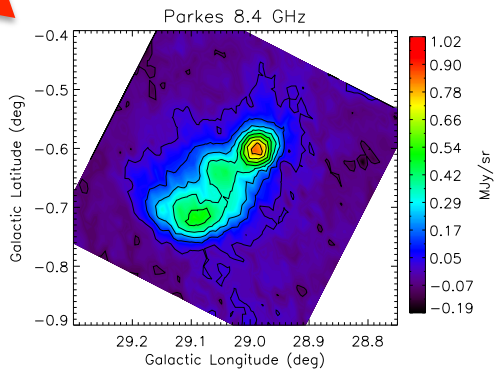

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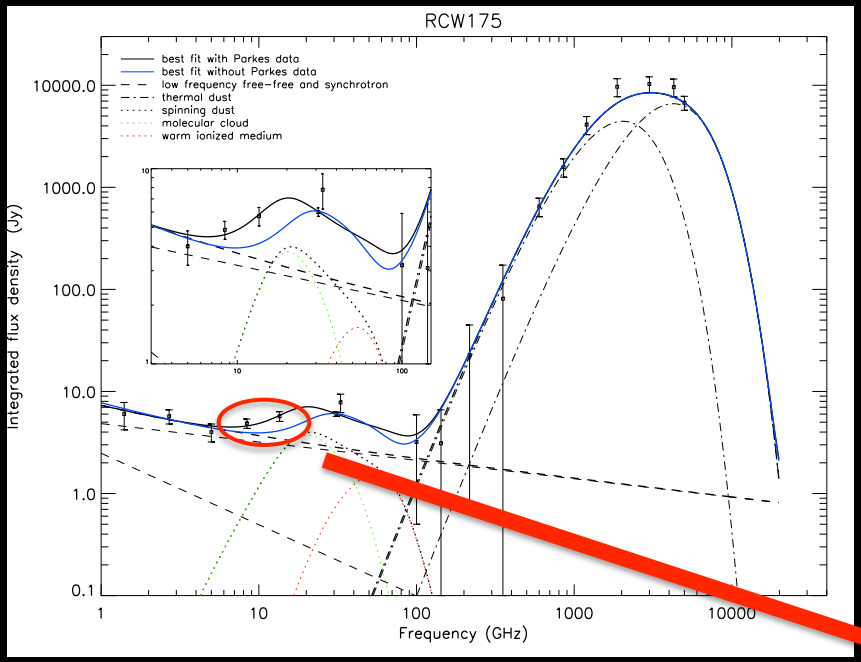

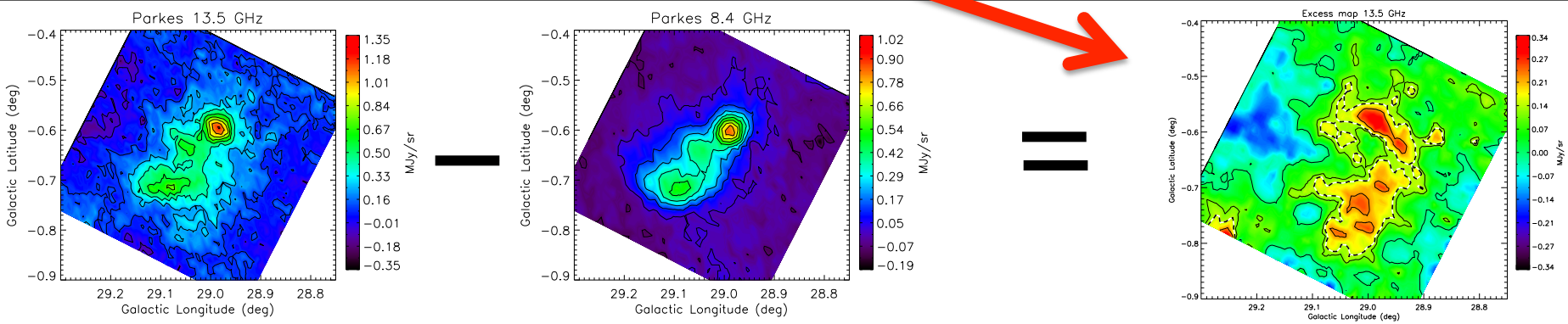

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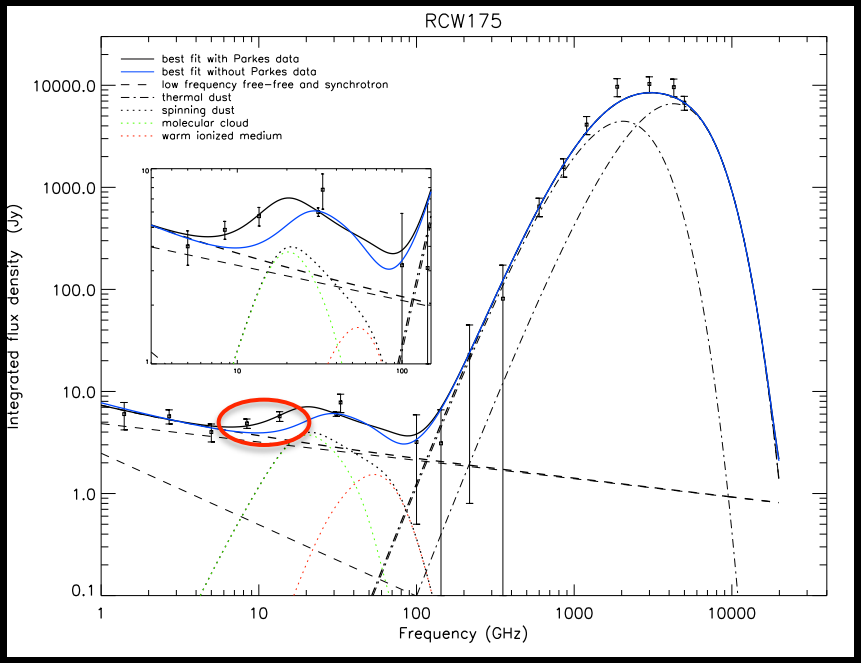
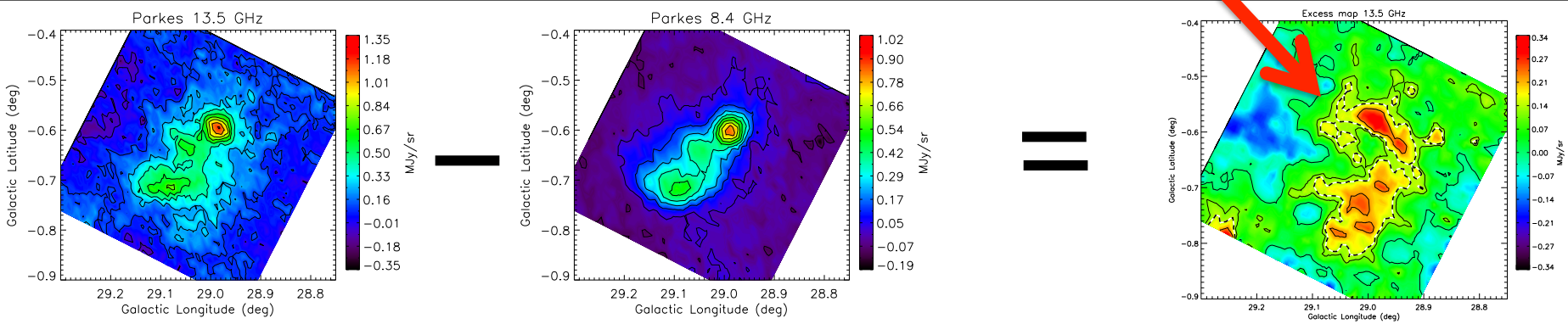


- From two (self-consistent) sensitive maps made in identical ways
- We apply a simple component separation extrapolating the 8.4GHz map at higher frequencies to extract the AME map at 13.5GHz
- Result: a concentrated emission in G29.0-0.6 is evident as well as some diffuse emission



RCW175 MW - IR CORRELATION

- Detailed IR- MW correlation has been carried out

- We correlated Parkes 13.5GHz with:

- SPIRE 500μm
- SPIRE 350μm
- SPIRE 250μm
- PACS 160μm
- PACS 70μm
- SPITZER 24μm

As well as with the Dustem derived parameters (Tibbs et al. 2012)

- Y_{VSG}
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- This to track:
  - Big Grains emission
  - Very Small Grains emission
  - PAH abundance
  - Big Grains replenishment
  - Excitation radiation field
  - Hydrogen column density

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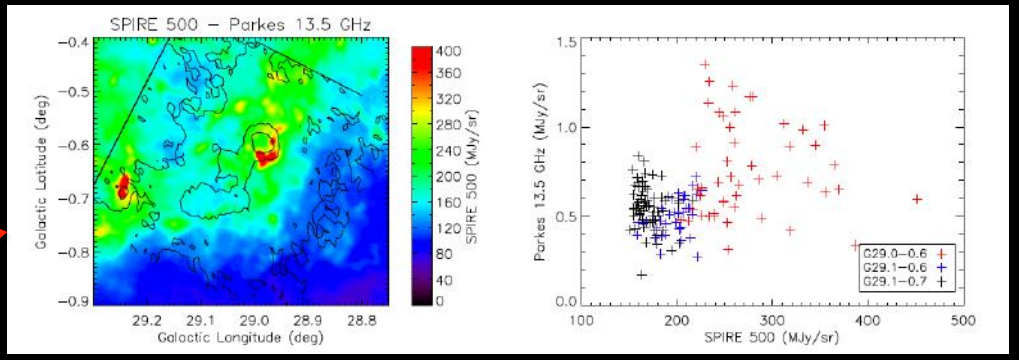

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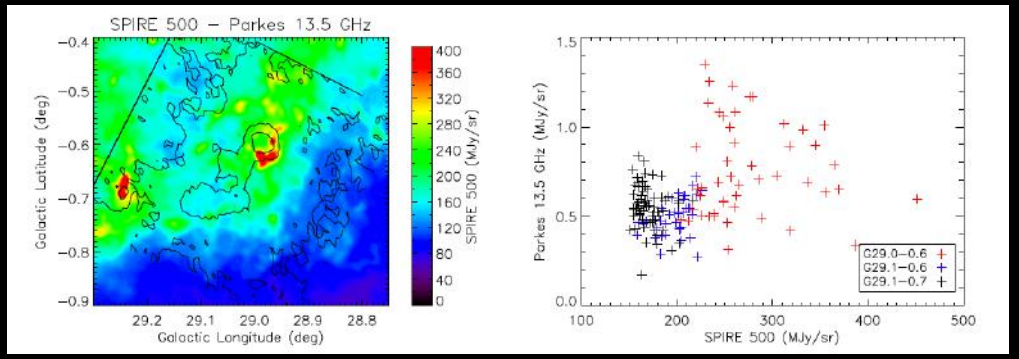

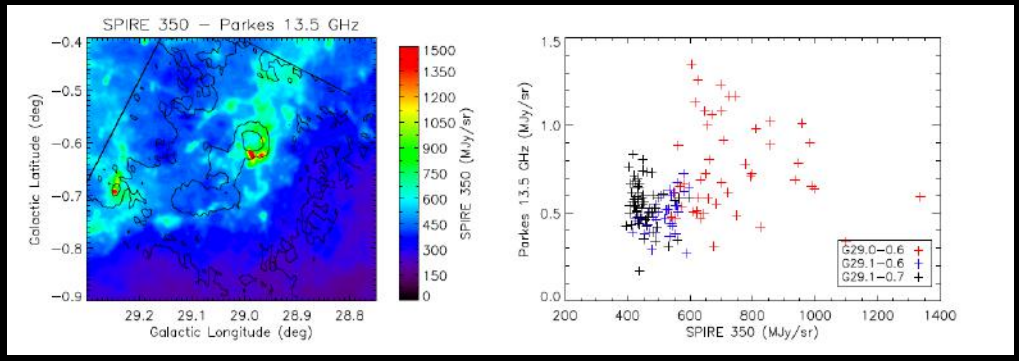

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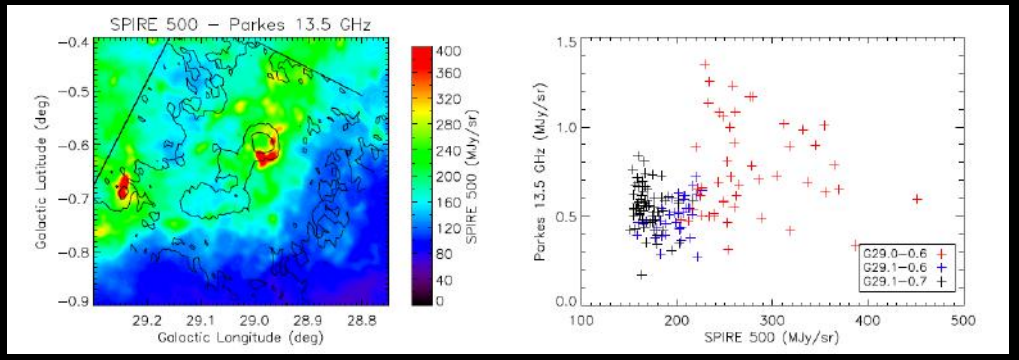

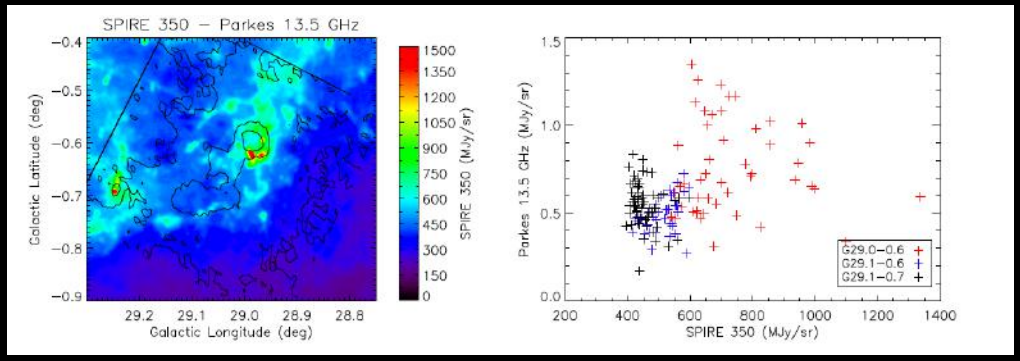

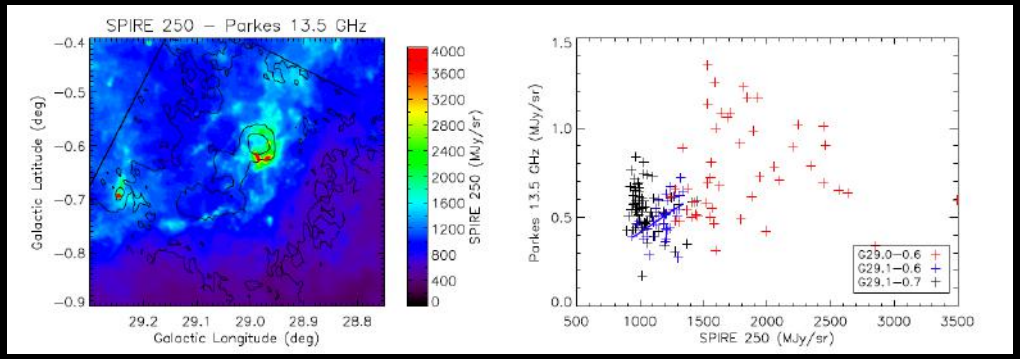

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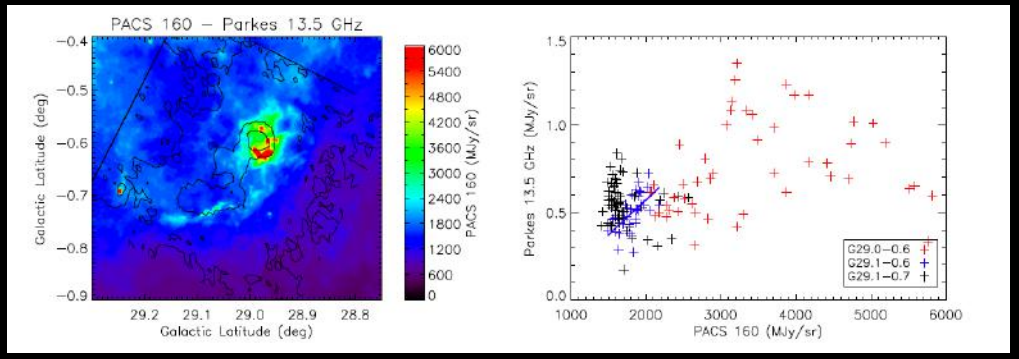

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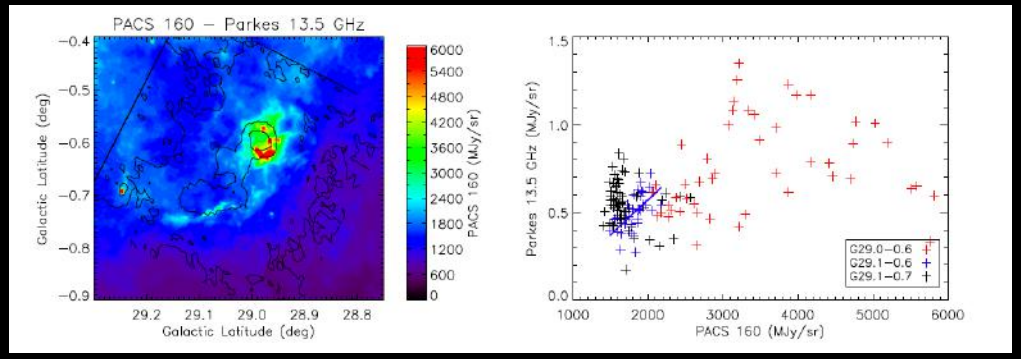

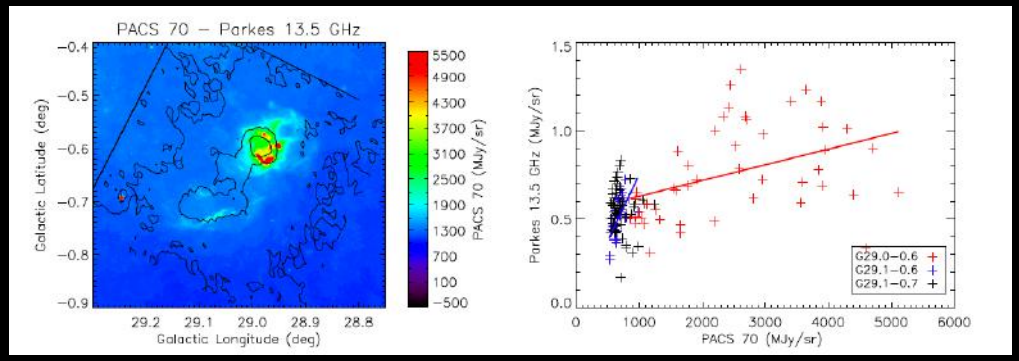

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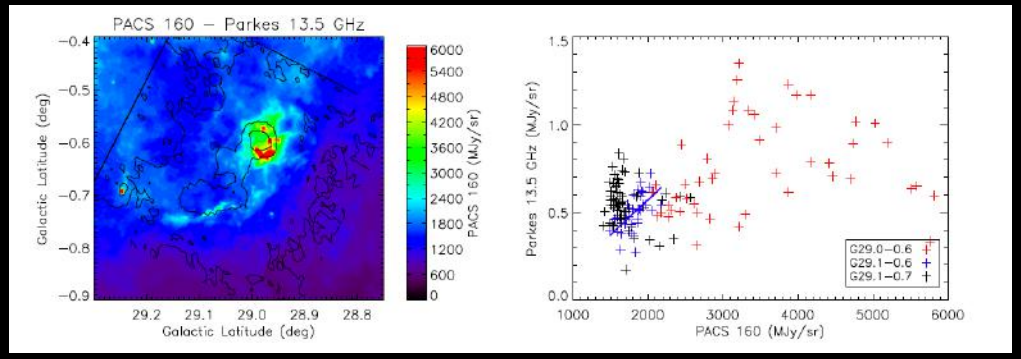

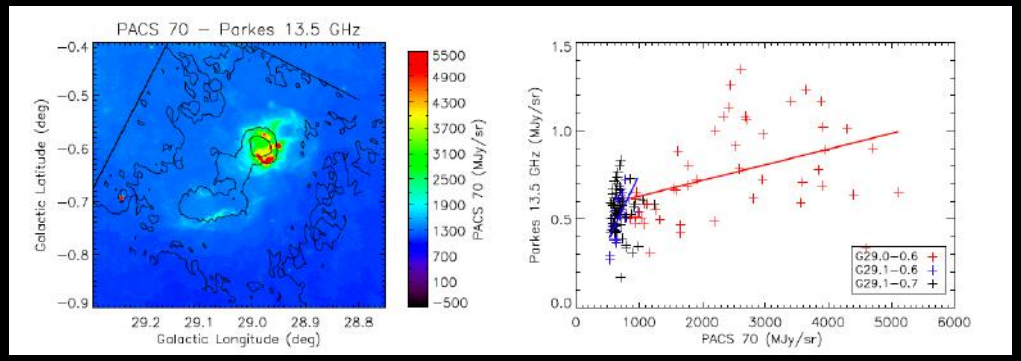

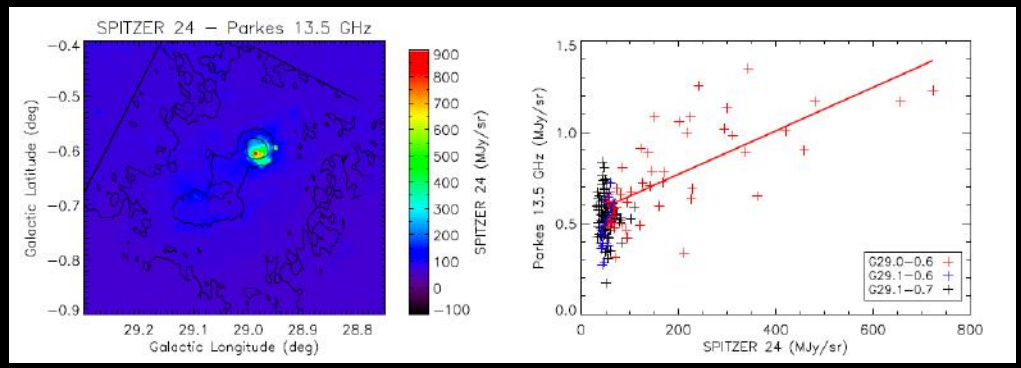

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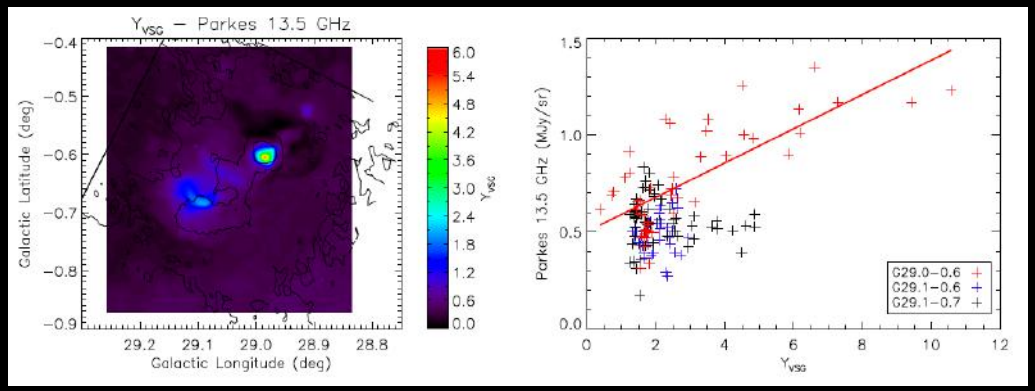

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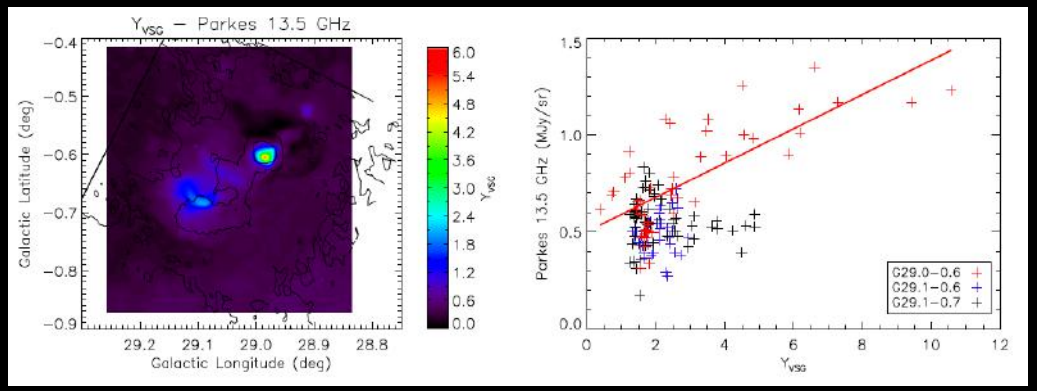

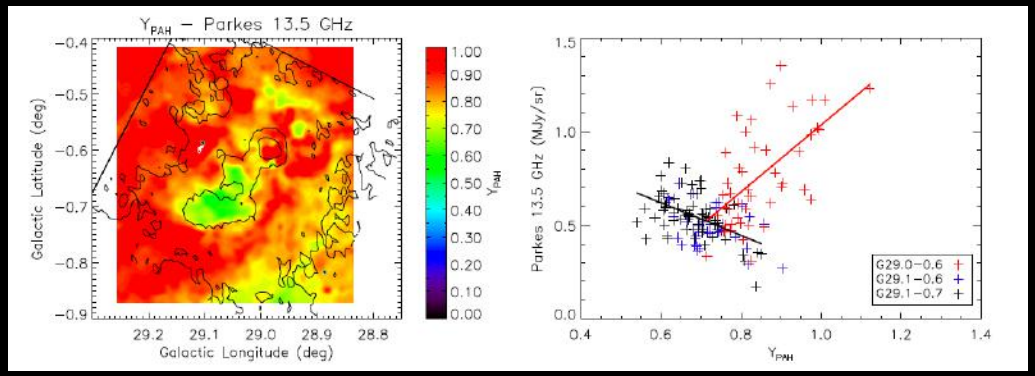

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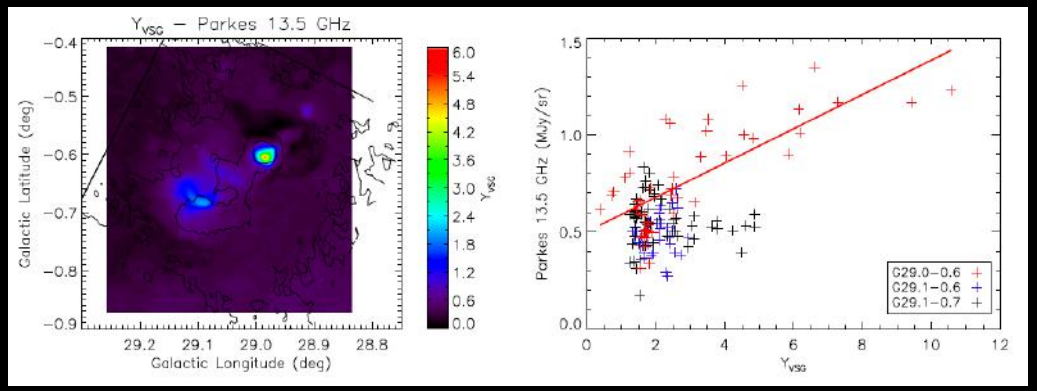

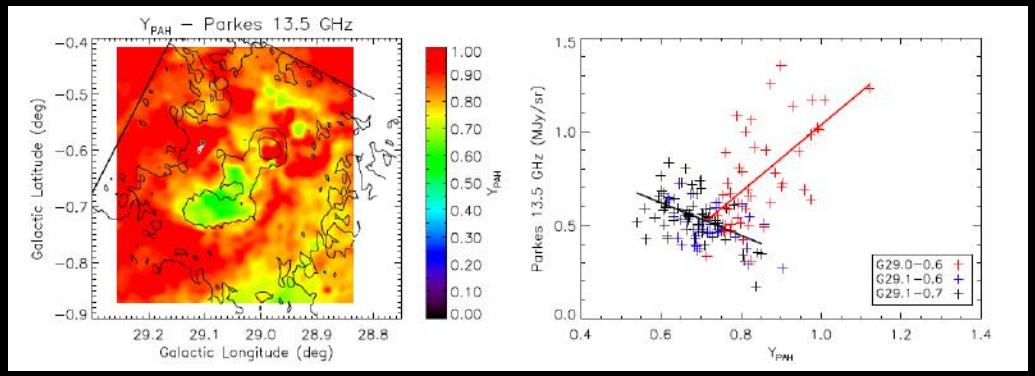

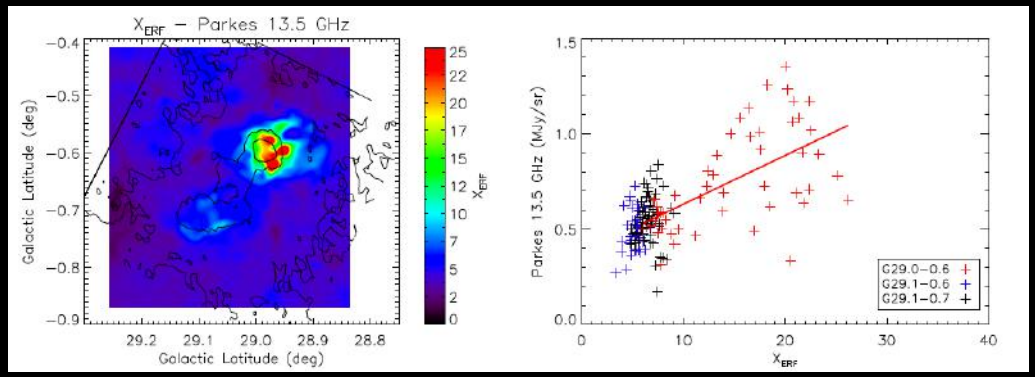

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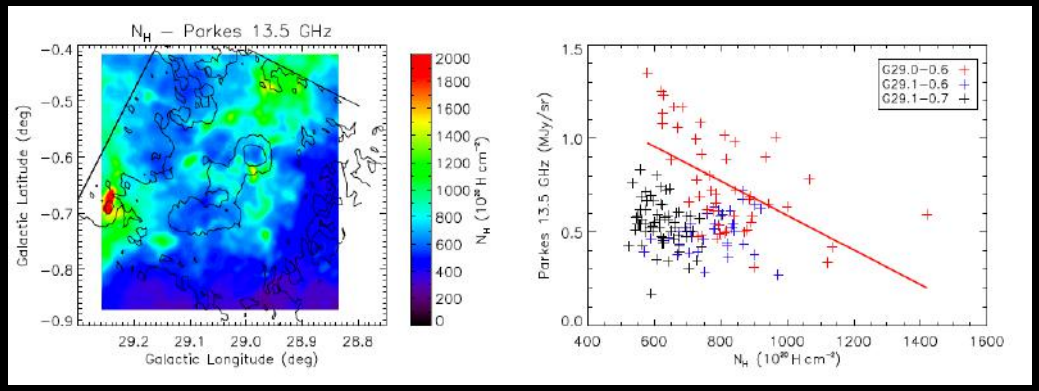

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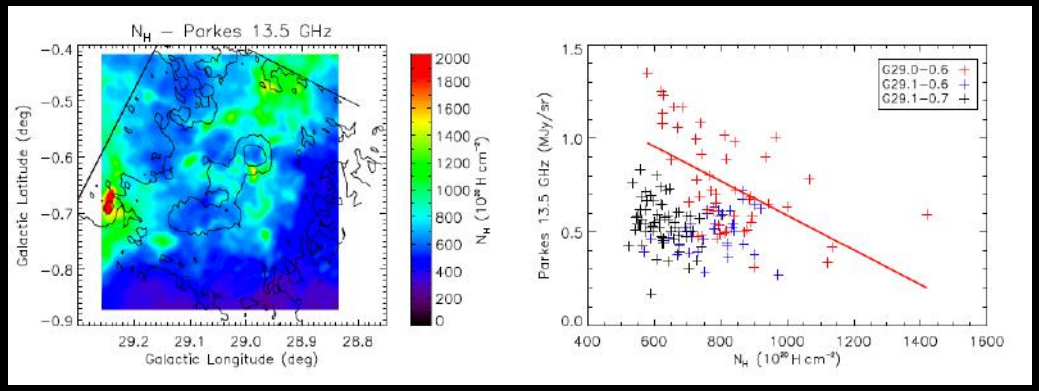
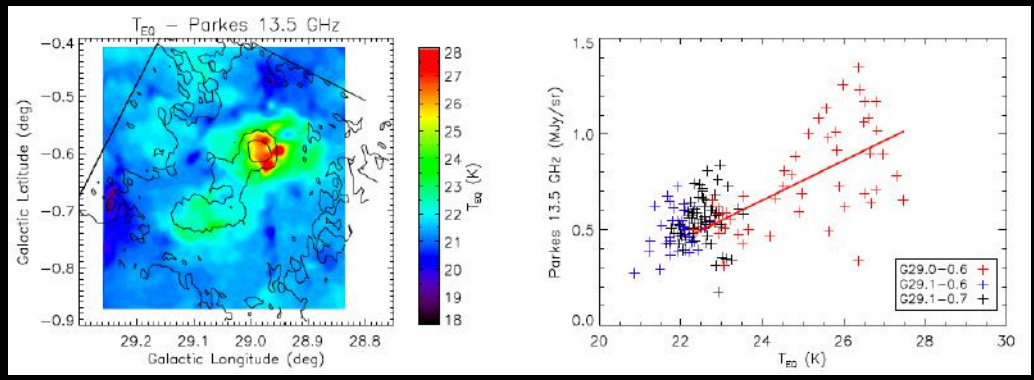
- SPIRE 350μm
- SPIRE 250μm
- PACS 160μm
- PACS 70μm
- SPITZER 24μm

As well as with the Dustem derived parameters (Tibbs et al. 2012)

- Y_{VSG}
- Y_{PAH}
- X_{ERF}
- N_H
- T_{EQ}





RCW175 MW - IR CORRELATION

- Detailed IR- MW correlation has been carried out

- We correlated Parkes 13.5GHz with:

- SPIRE 500μm
- SPIRE 350μm
- SPIRE 250μm
- PACS 160μm
- PACS 70μm
- SPITZER 24μm

As well as with the Dustem derived parameters (Tibbs et al. 2012)

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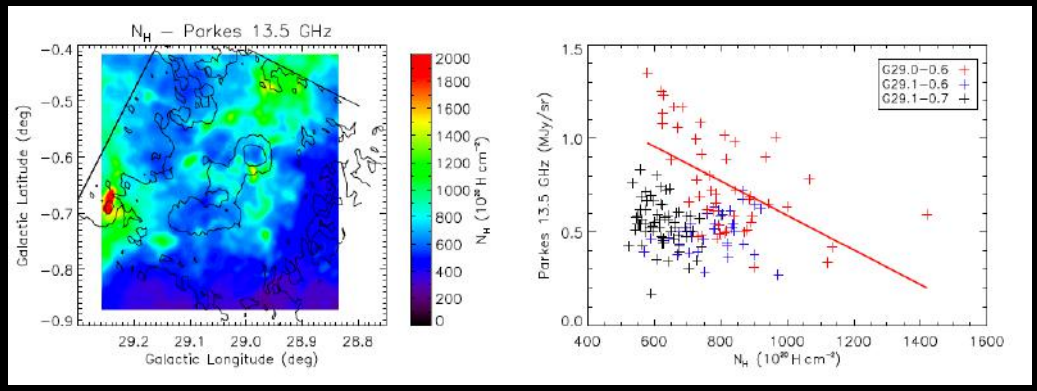
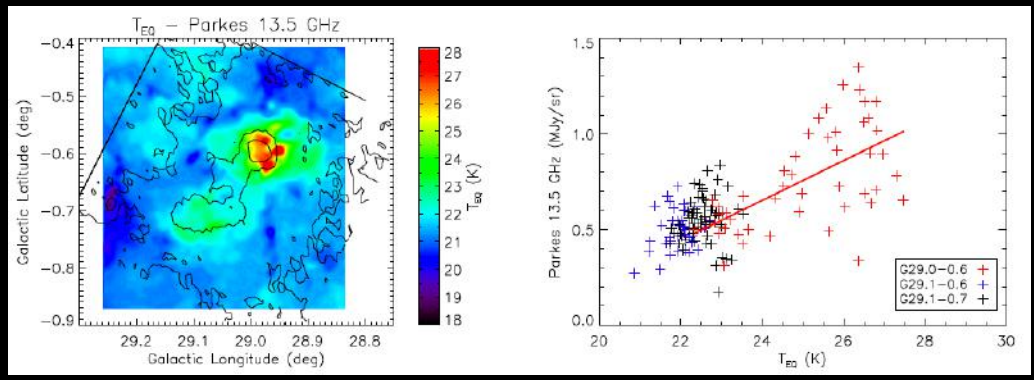




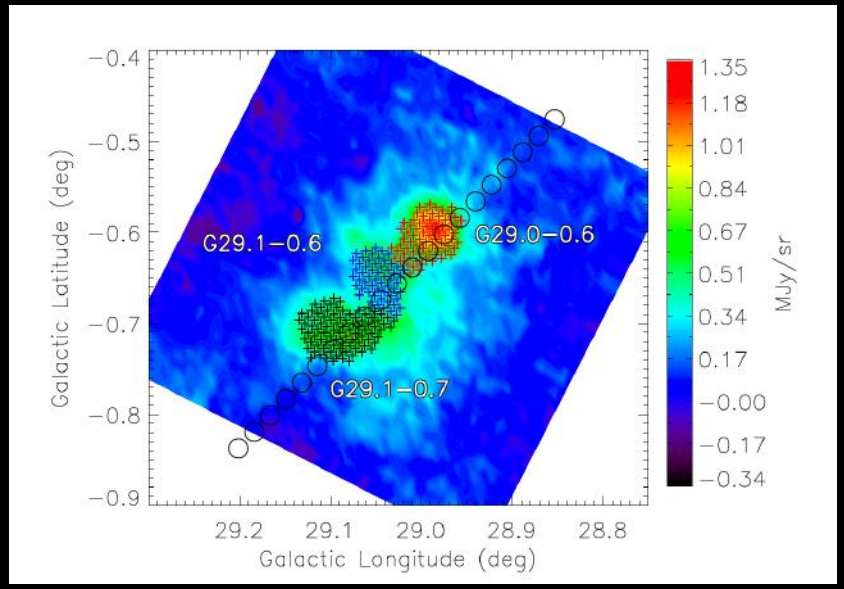
- Picture consistent with:
  - Strong correlation with the compact source where VSG are the probable emitters
  - Diffuse emission still to be understood
  - PDR in HII regions still to be understood

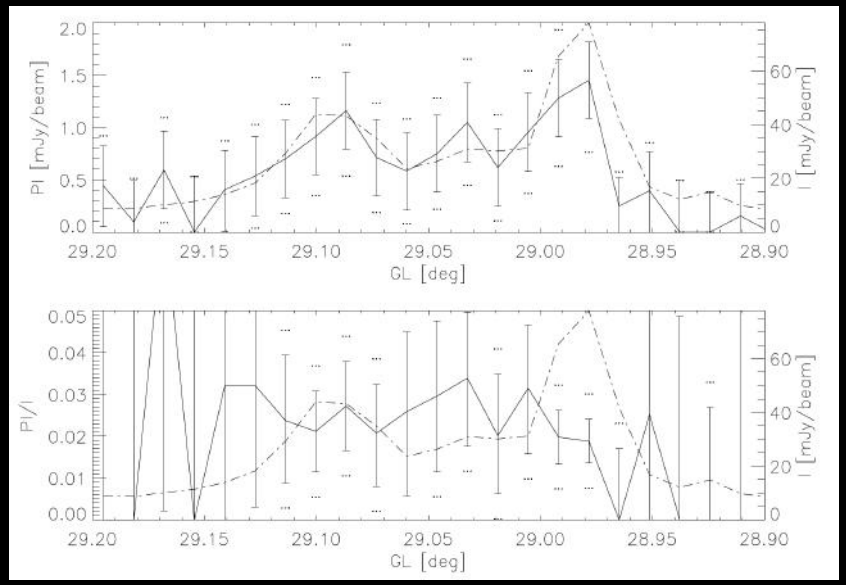
RCW175 POLARIZATION

- Polarization observation have been carried out at 21.5 GHz on one dimensional scan through the center of the region
- Weak polarization has been detected
- Attention has been placed on the estimation of the possible spurious polarization (~0.3% total):
  - On-axis instrumental polarization of 1.5% was corrected with Saturn observation down to 0.2%
  - Off-axis spurious polarization was estimated to be lower than 0.2%
- Weak polarization detected:

  P=2.2 ± 0.2(rand.) ± 0.3(sys) %

- No definitive conclusion: possible synchrotron contamination

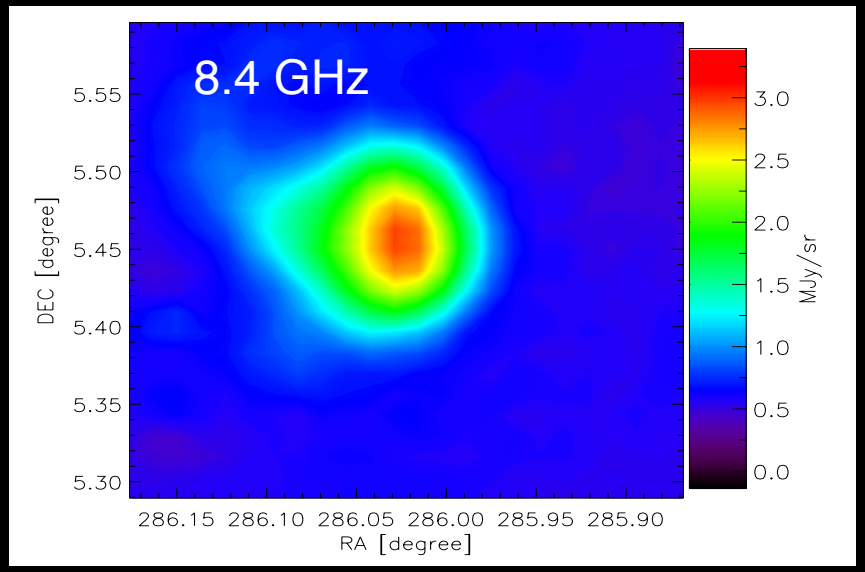


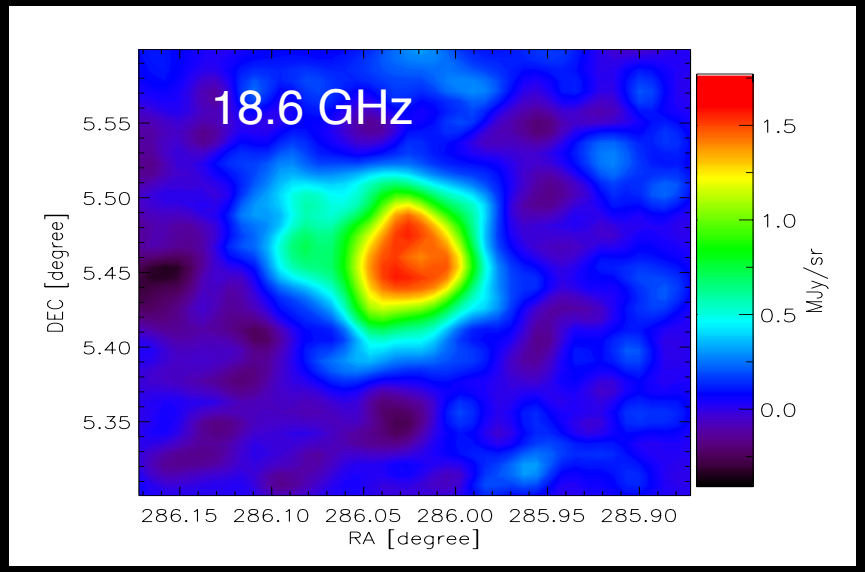


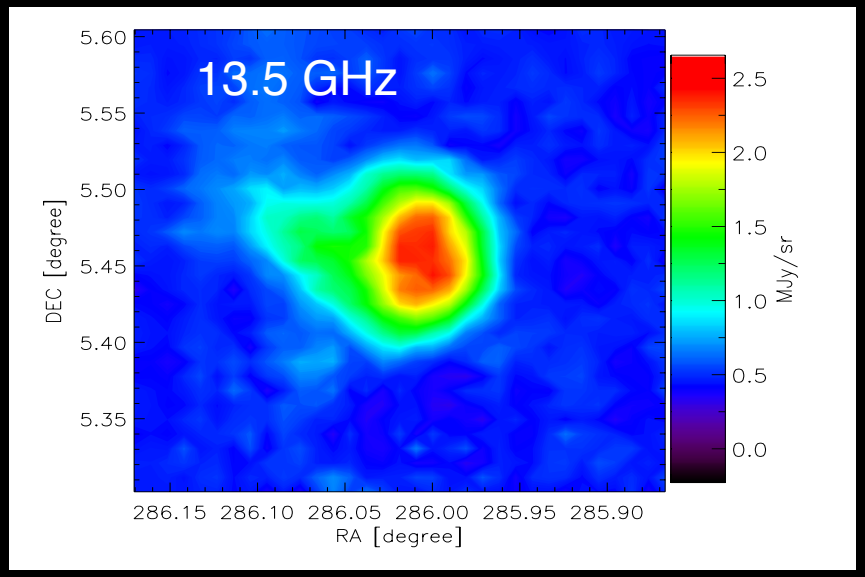
3C396

Detailed study of the microwave emission of the supernova remnant 3C396. Cruciani et al. 2016, MNRAS, 459, 4224

3C396 MAPS



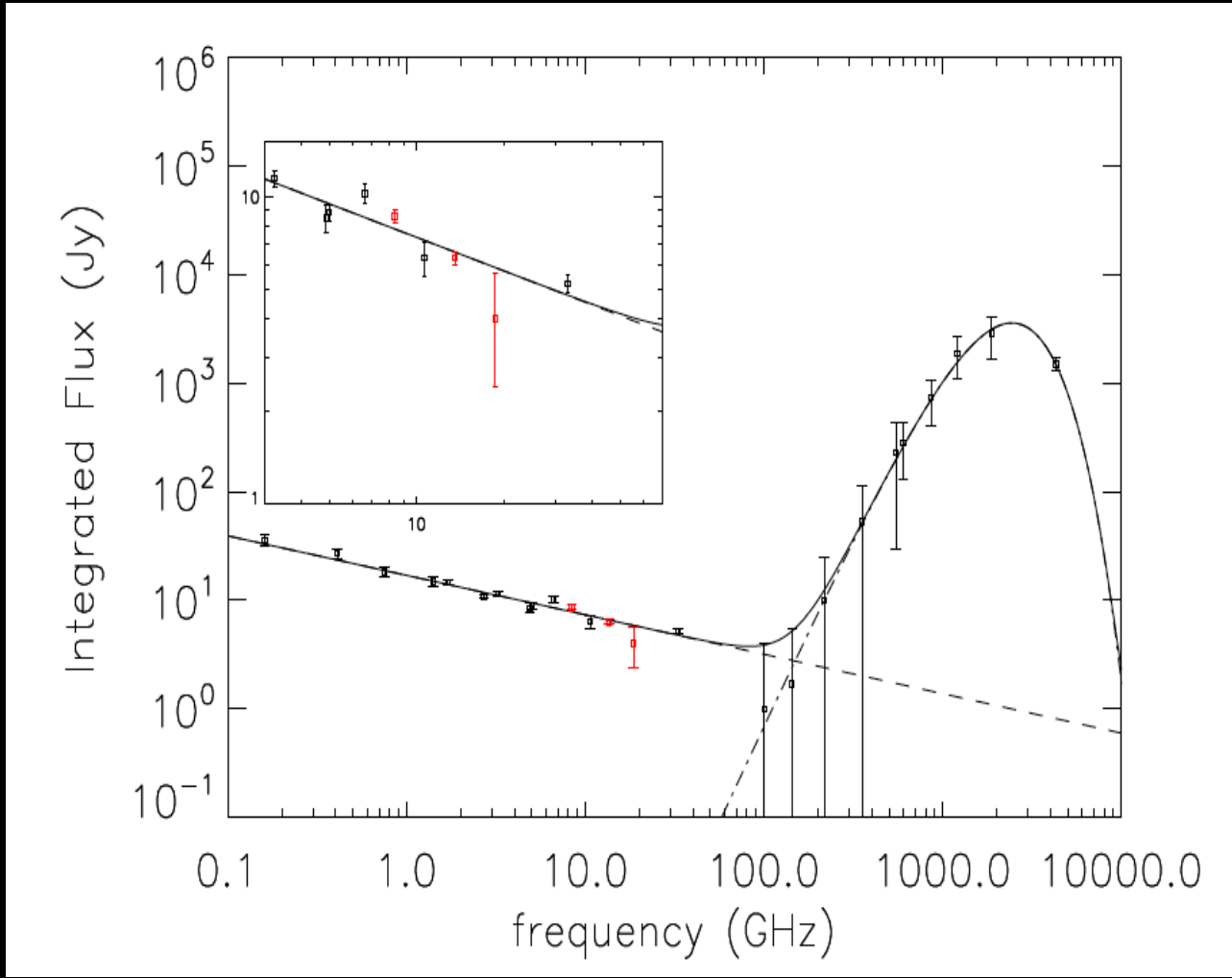




- Shell like SNR: core and tail already seen at 1.4GHz
- Tentatively seen as the first AME SNR by VSA (Scaife et al 2007)
- Parkes data partially resolve the tail in the microwaves
- Tail: 10-20% of the total emission in the microwaves

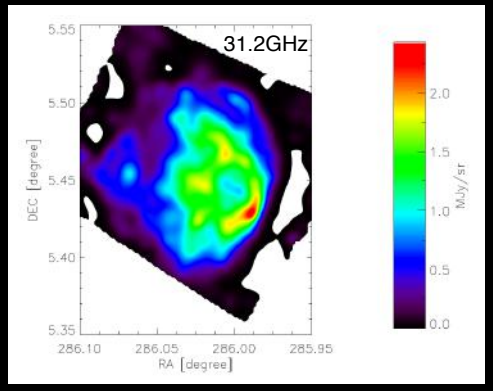
3C396 SED

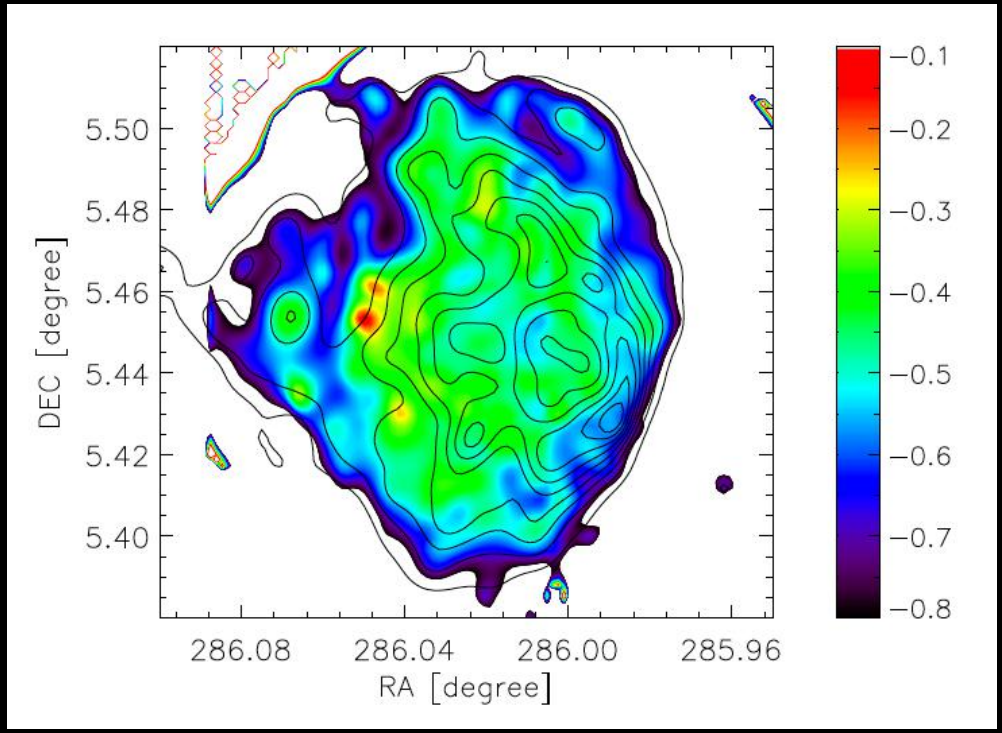
- Integrated emission from 8.5’ radius (background 8.5’-10’)
- Used ancillary data at radio frequencies (VLA, Effelsberg, Urumqi)
- At mm/sub-mm/IR there is no clear detection by Planck, Hershel, IRAS, Spitzer
- Analysis of unpublished GBT data at 31GHz
- Reanalyzed VSA data to account for the different window-functions
- Radio: crab-like synchrotron emission with α=-0.364 ± 0.017
- Microwave: no evidence of AME



3C396 SPECTRAL INDEX MAP

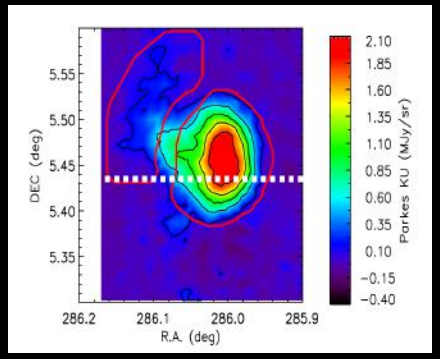
- Radio emission of the tail from VLA 1.4GHz and Parkes 13.5GHz consistent with free-free emission (α=-0.16 ± 0.02 ± 0.05)
- We used unpublished GBT (31.2GHz) and VLA (4.8GHz) data to derive the behavior of the spectral index within the region
- We built a spectral index map
- Steeper (-0.6<α<-0.4) spectral index evident in the outer part of the core than in the center (-0.4<α<-0.3)
- Difficult to extract information from IR correlation due to the proximity with the Galactic plane

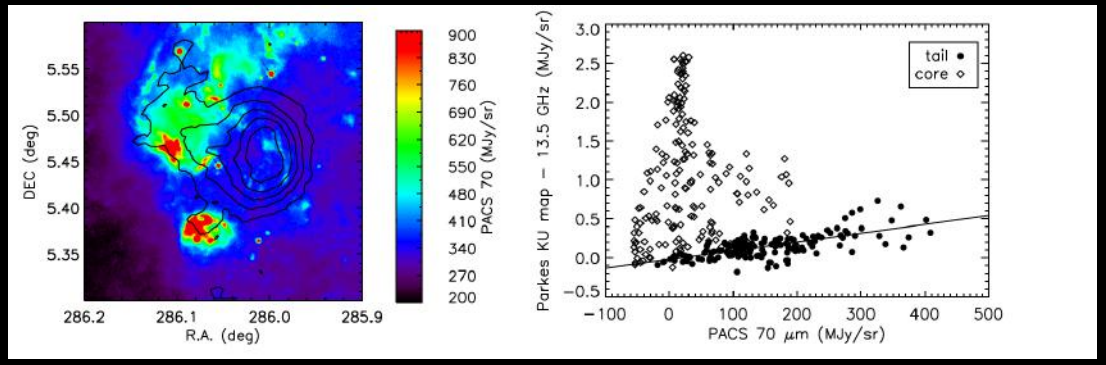


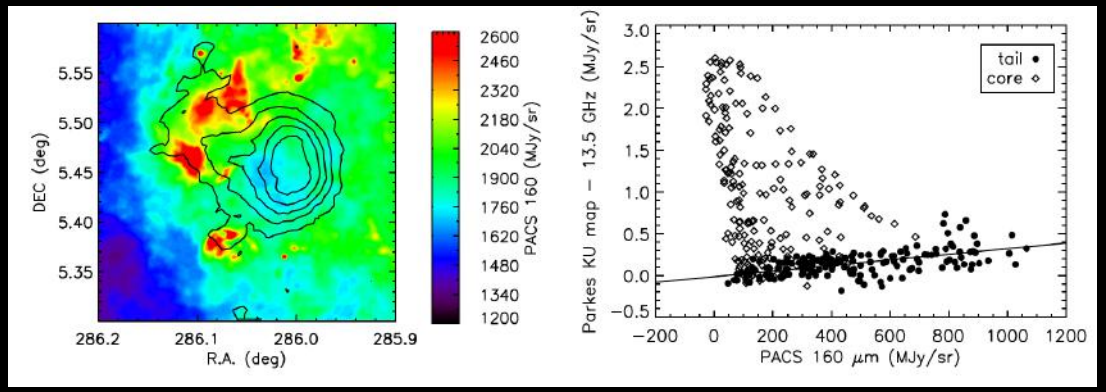


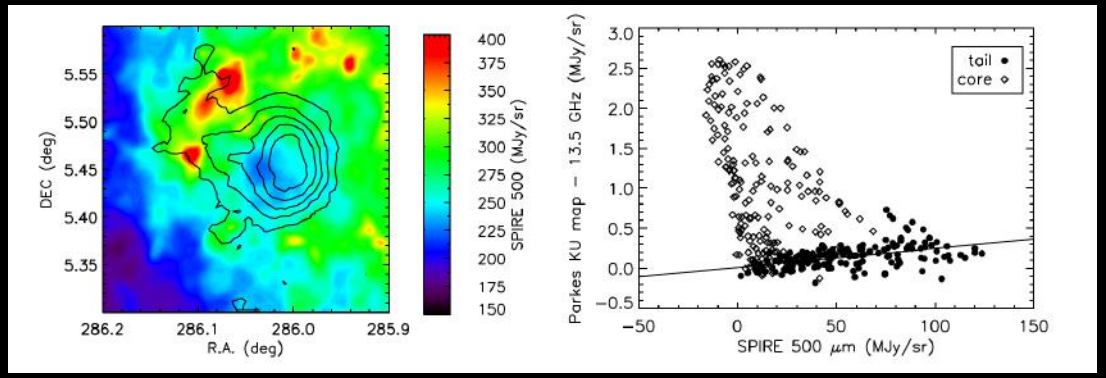
3C396: MW vs IR CORRELATION

- We separated 3C396 in two regions: the core and the tail
- No correlation with the core of the SNR
- Possible correlation with the tail
- Assuming that the correlation is not accidental because of the proximity of the Galactic plane we calculate the emissivity
- Measured emissivities (70-3500 μK/MJy sr^{-1}) are considerable higher that what expected in AME regions







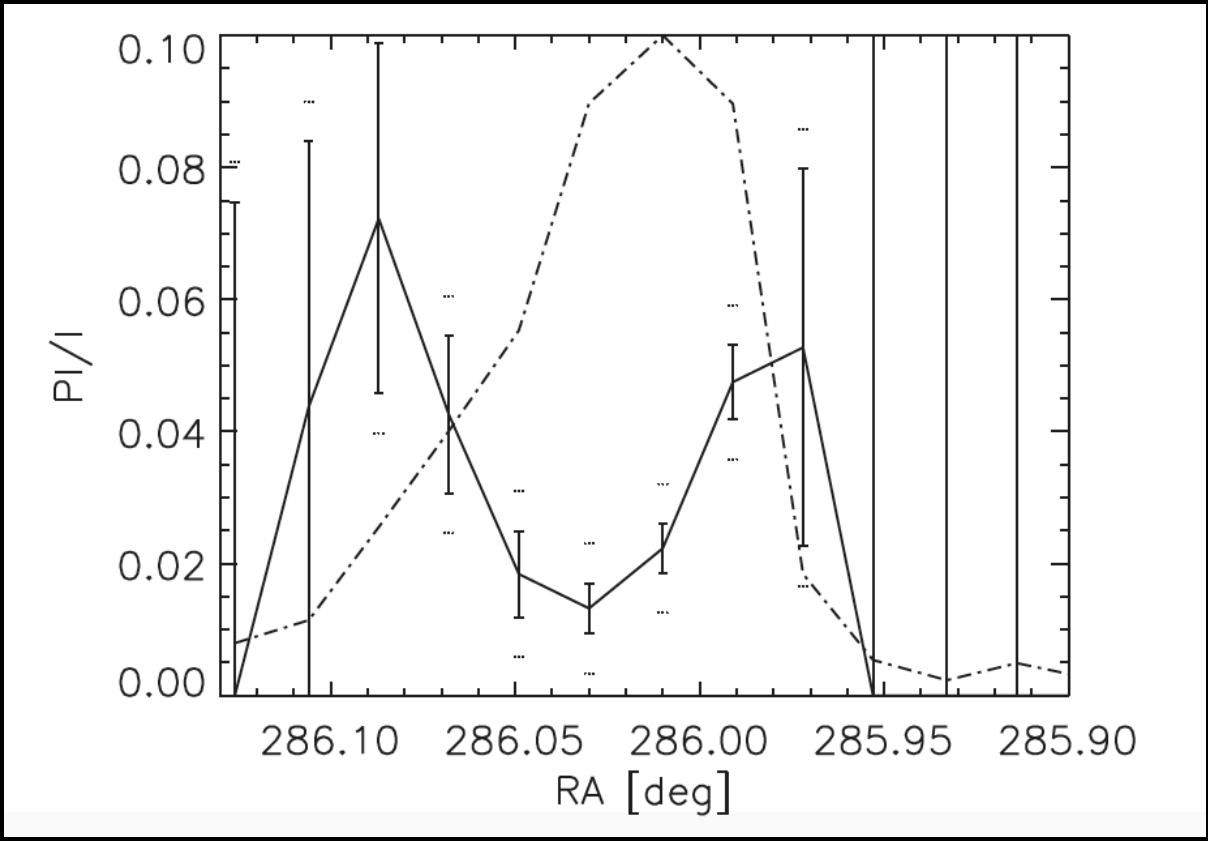


3C396 POLARIZATION

- Also for 3C396 we observed at fixed declination

- Unresolved gain fluctuations have been observed during these observations so no absolute polarized emission has been measured

- We detected up to 5% polarization stronger in the outer regions in agreement with 5GHz observations by Patnaik et al. 1990, and with a steeper spectral index on the outskirts



FUTURE PROSPECTS

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- Keep on using giant radio telescope to study Galactic regions
- Move toward extra-galactic studies

Green bank telescope

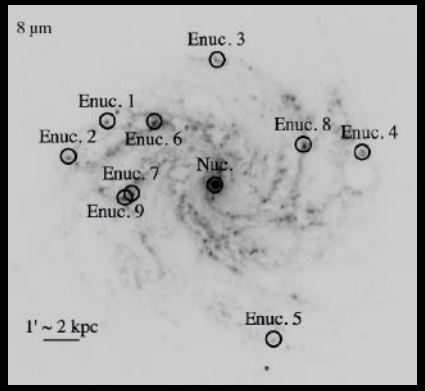
Effelsberg

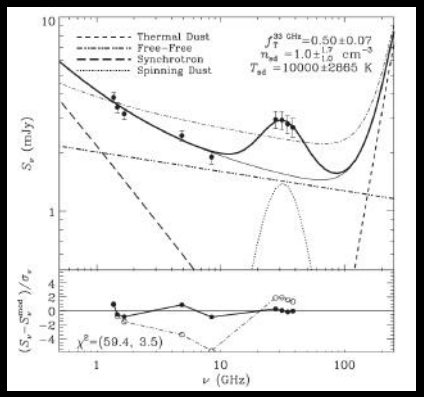
Parkes

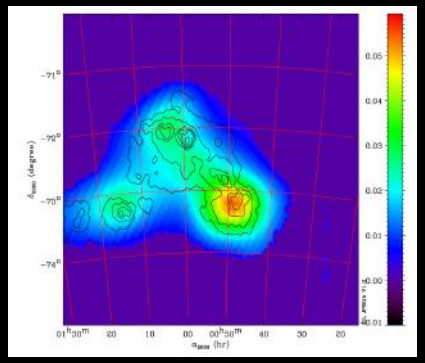
Sardinia Radio Telescope

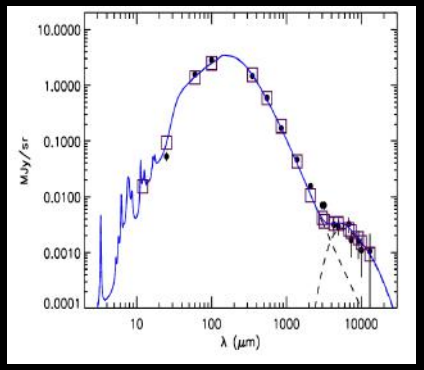
FUTURE PROSPECTS

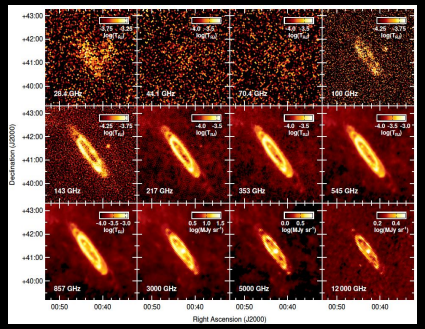
- The picture on extra galactic AME source is not fully consistent:
  - NGC 6946: Murphy et al. 2010 with GBT. Excess confirmed but to a stable picture
  - Small Magellanic clouds: Planck collaboration 2011 with possible thermal dust contamination
  - Andromeda: Planck collaboration 2015 (PIP25) a tentative detection

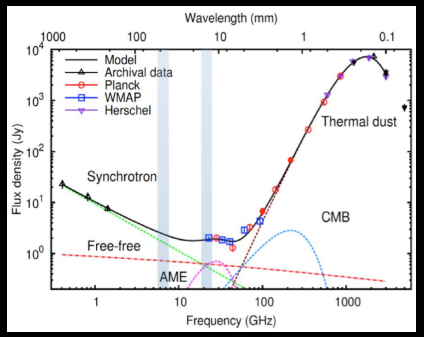




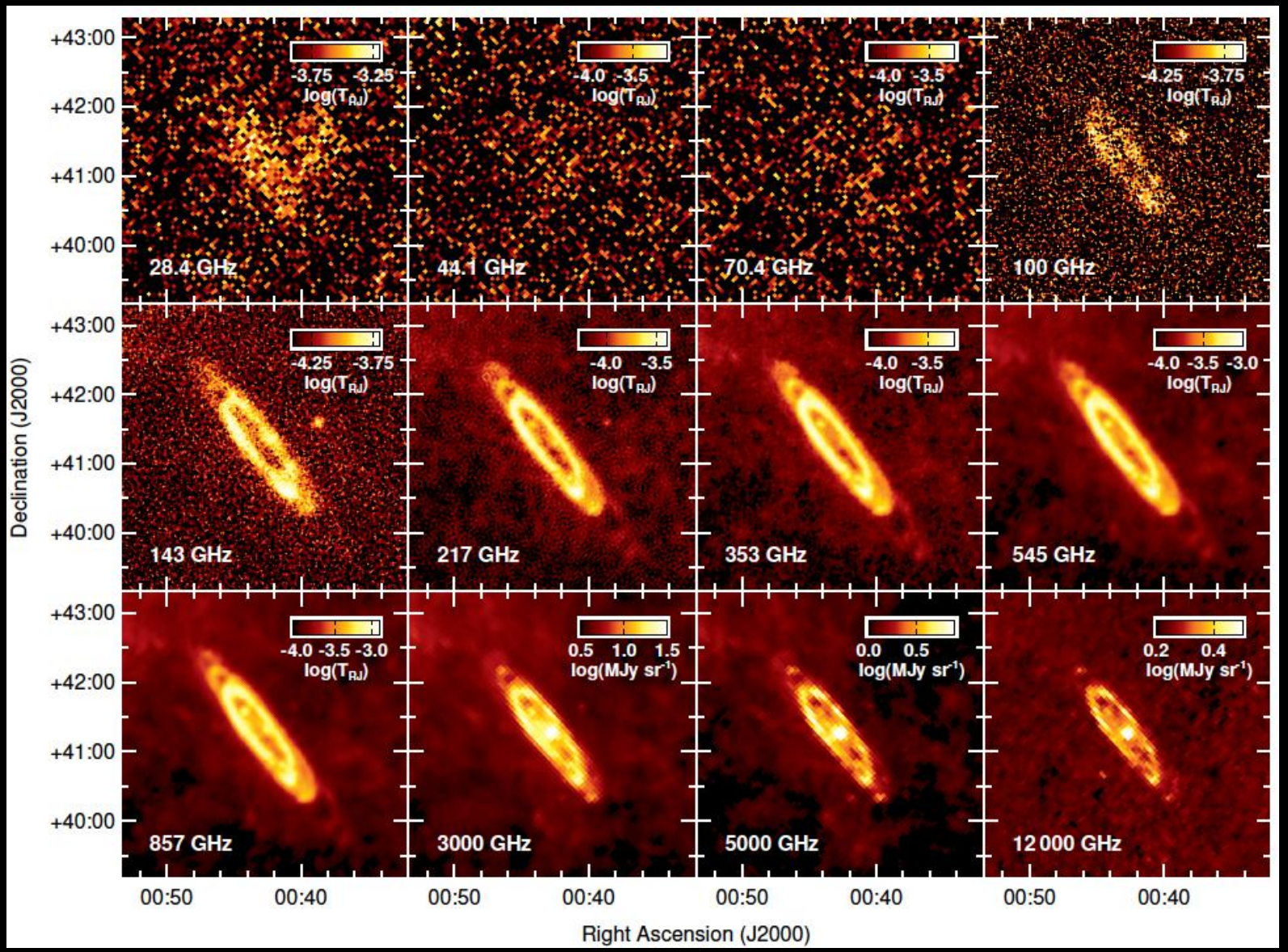






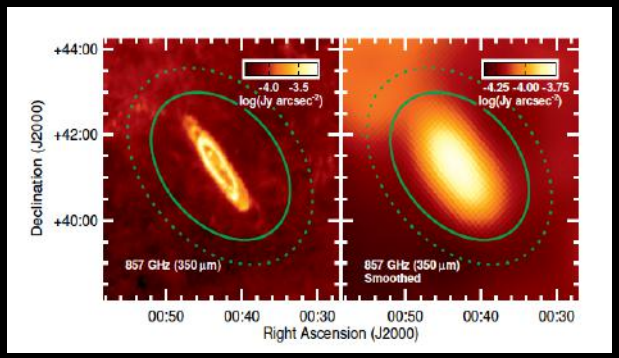


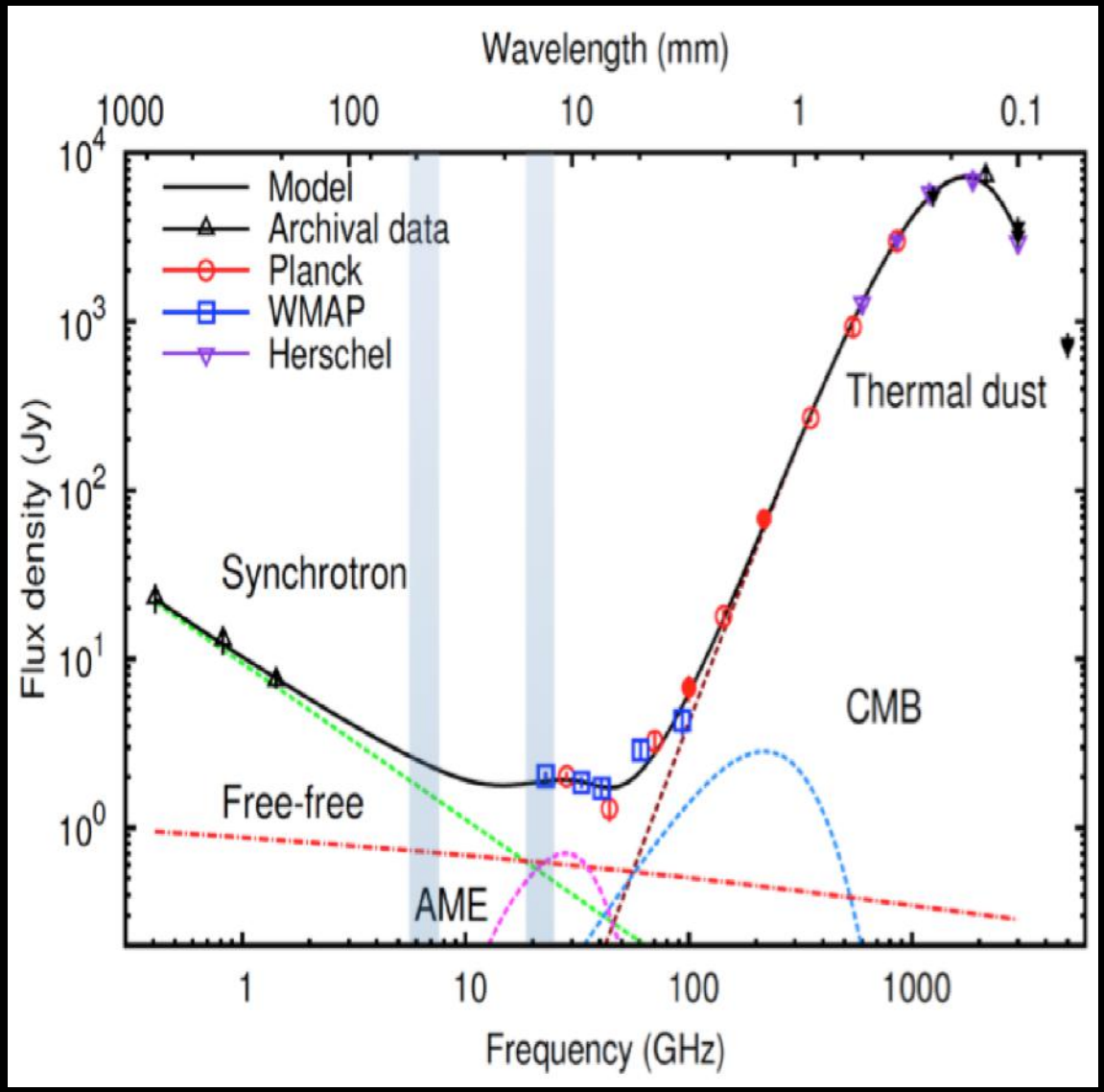
ANDROMEDA: CURRENT STATUS



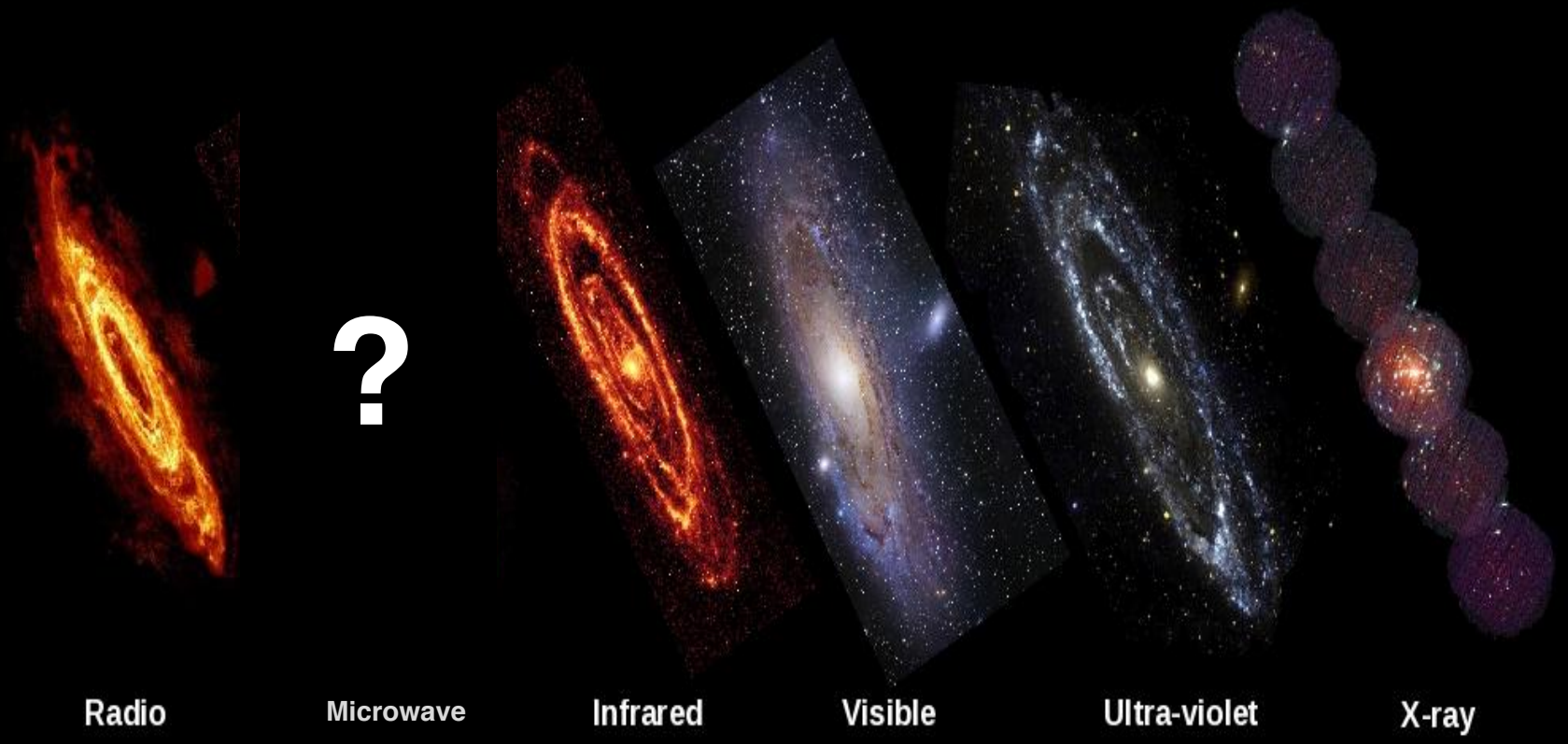
ANDROMEDA: CURRENT STATUS

- Integrated flux with background subtraction
- 2.3σ spinning dust
- Tentative but consistent with expectations
- Similarly good fit is obtained without SD





ANDROMEDA: CURRENT STATUS



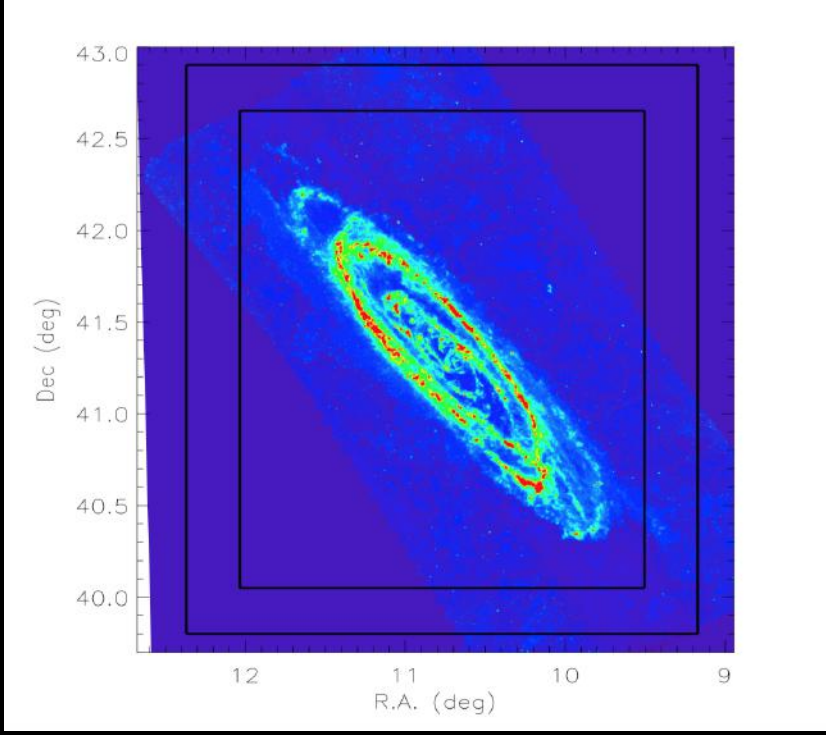
- Widely studied object including its dust (Draine et al. 2014)
- In the microwave we have Effelsberg observations of the core and Planck+WMAP low resolution obs
- We plan to study it at higher angular resolution and sensitivity

SARDINIA RADIO TELESCOPE

- 64-m radio telescope
- State of the art technology
- Active surface (can work up to 100GHz)
- Radio quite zone
- Multibeam (7-beam) in the K band
- Sub-mJy/beam sensitivity in the microwave

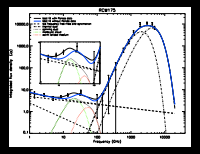
SRT OBSERVATIONS OF ANDROMEDA

- We proposed to map the whole Andromeda (7deg^2) in total power with also spectroscopic capabilities
- C and K band observations down to 0.1mJy/arcmin^2
- Proposed and partially (C band) accepted for the early science (shared risk) call of the SRT
- Several expected scientific outputs:
  - Study the interplay between thermal and non-thermal emission
  - Star Formation Rate
  - AME as overall emission and in specific regions
  - Methanol (CH3OH) maser in M31
  - Hydrogen Radio Recombination Lines map at 6.676GHz



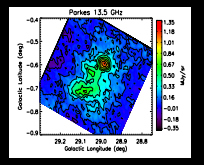
	C band	K band
Frequency	5.7-7.7GHz	18-26GHz
T_{sys}	28K	90K
Continuum required sensitivity	$0.20 mJy/beam$	$0.15 mJy/beam$
Line required sensitivity	26mJy/beam	no
Brightness required sensitivity	$1.96 mJy/arcmin^2$	$0.1 mJy/arcmin^2$
Beam size	2.8arcmin	0.83arcmin
Scan speed	6°/min	6°/min
Scans spacing	52arcsec	16arcsec
Required time per beam sized pixel	14 sec	207 sec
Overall required time from radiometer formula	5 h	116 h
Overall required time from on-the-fly map	15 h	320 h
Overall required time including all overheads	17 h	350 h

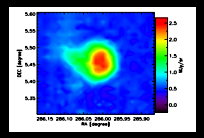
CONCLUSIONS



- High angular resolution AME observations are key to distinguish models
- Big (giant!) radio telescopes can be better than interferometers to retrieve large scales

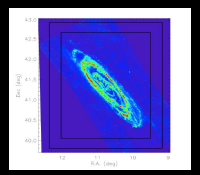
- Parkes already did well:
  - RCW175 HII region was carefully studied and multiple AME emitters have been found therein
  - 3C396 SNR was also studied in detail finding no evidence of AME





- More observations are needed with new giant radio-telescopes

- Sardinia Radio Telescope is a brand-new state-of-the-art 64-m radio telescope



- Within the early science shared risk call for observations we proposed to fully map M31 in the C and K down to 0.1mJy/arcmin^2
- C band observations start…on Sunday!