Radio to infrared spectra of late-type galaxies with Planck and WMAP data

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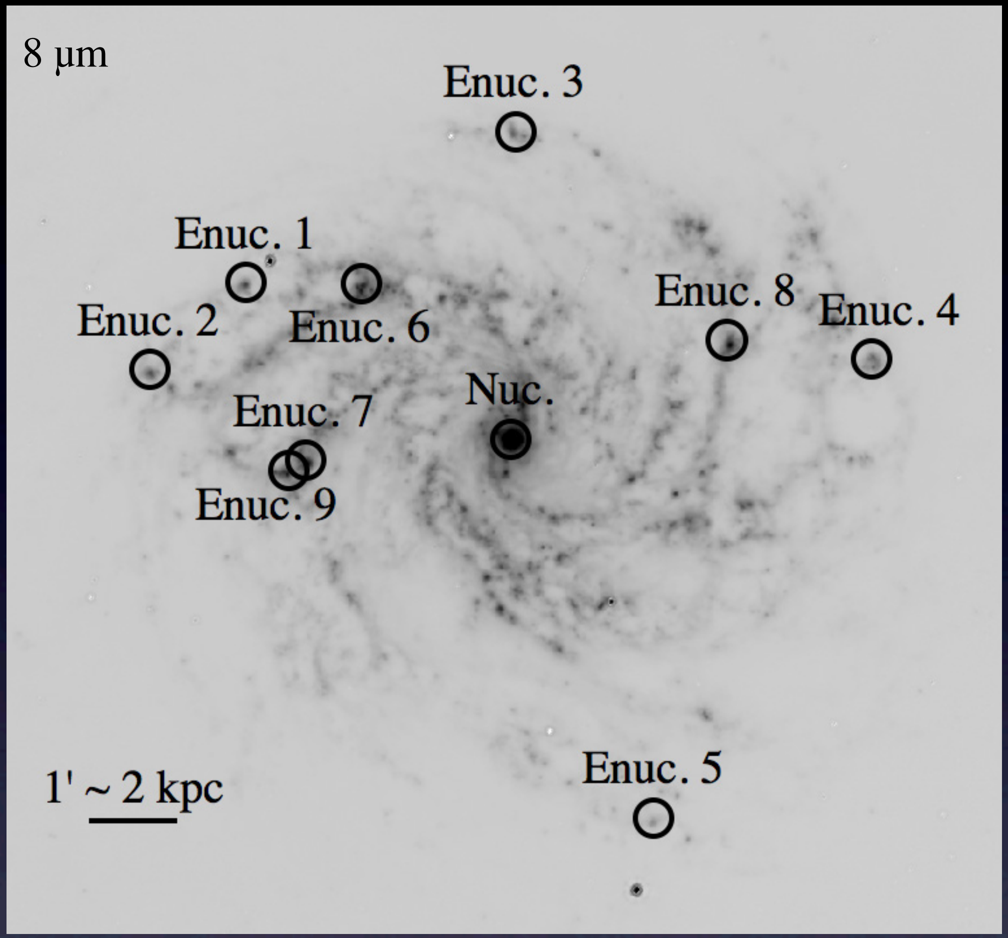
Overview

- Motivation
- Emission components and data
- Individual galaxies
  - M82
  - NGC253
  - NGC4945
- Conclusion

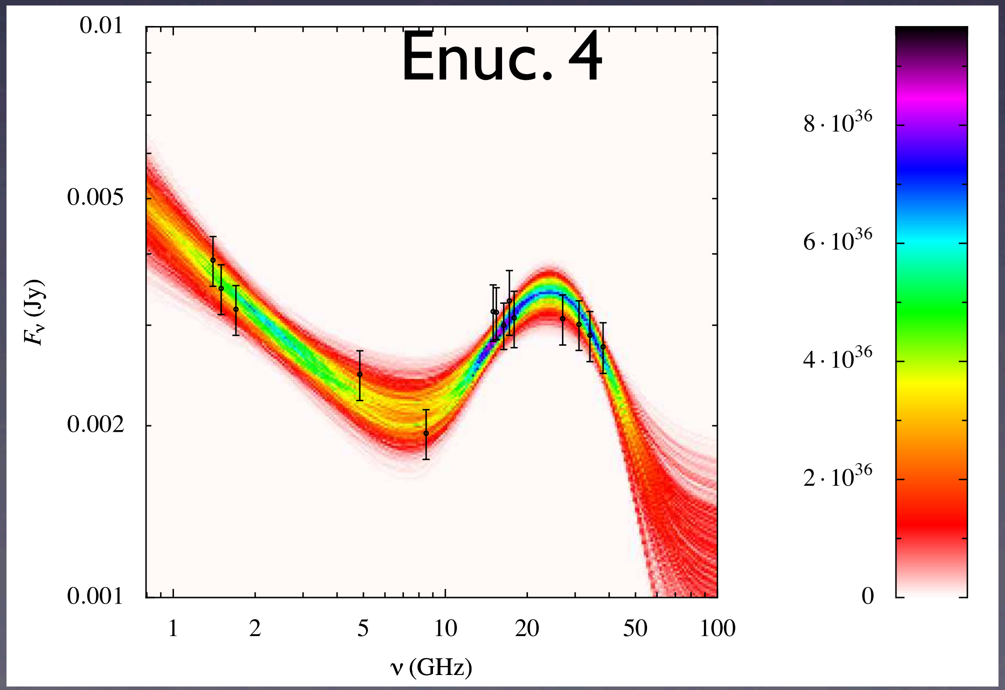
Motivation

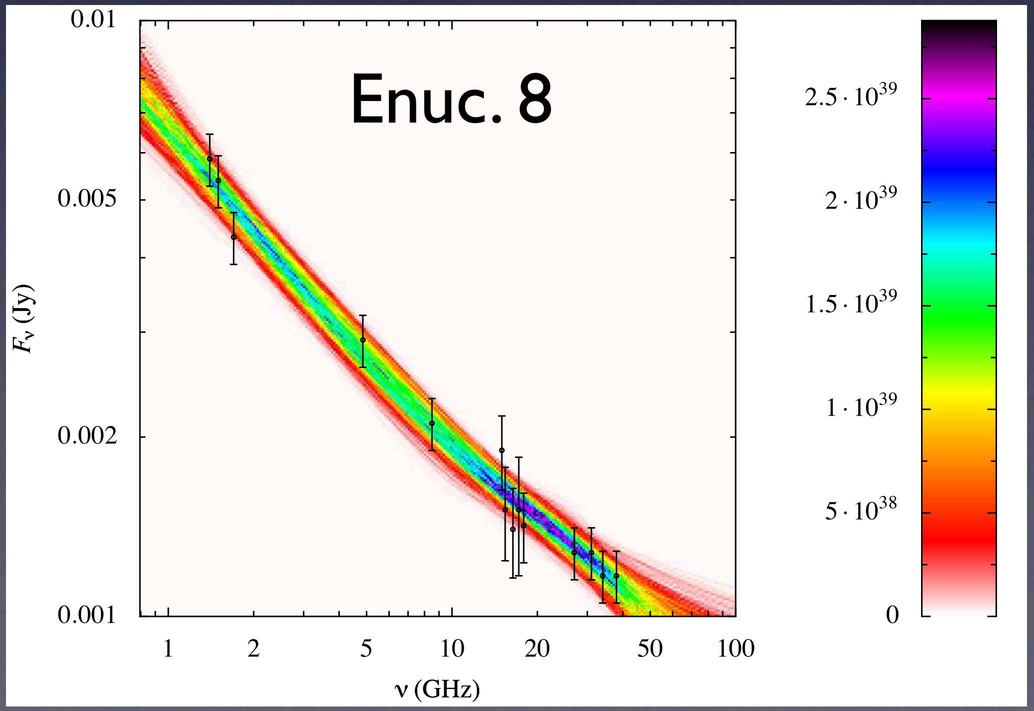
- Measure total emission of late type galaxies to compare with the Milky Way
- First time we can accurately measure the complete spectra from radio to infrared
- Quantify free-free emission, match with star formation rate
- Constrain AME on a global basis - is it everywhere, or patchy?

NGC6946

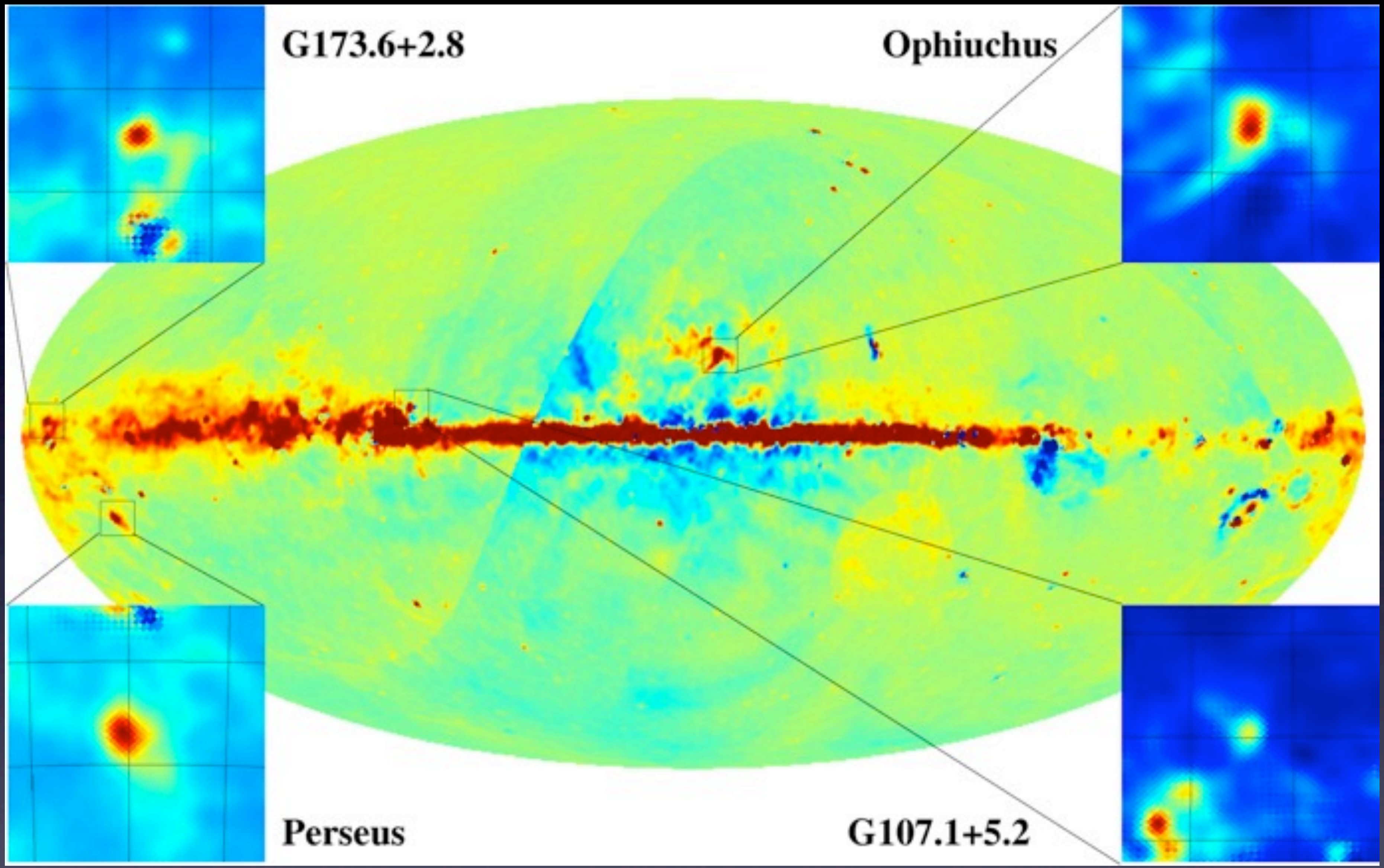


- GBT (Murphy et al. 2010)
- 10 star-forming regions - only 1 anomalous
- Confirmed by AMI (Scaife et al. 2010)





Our Galaxy



- Expect 30GHz AME emission to be around 1/3000th of the 100μm emission

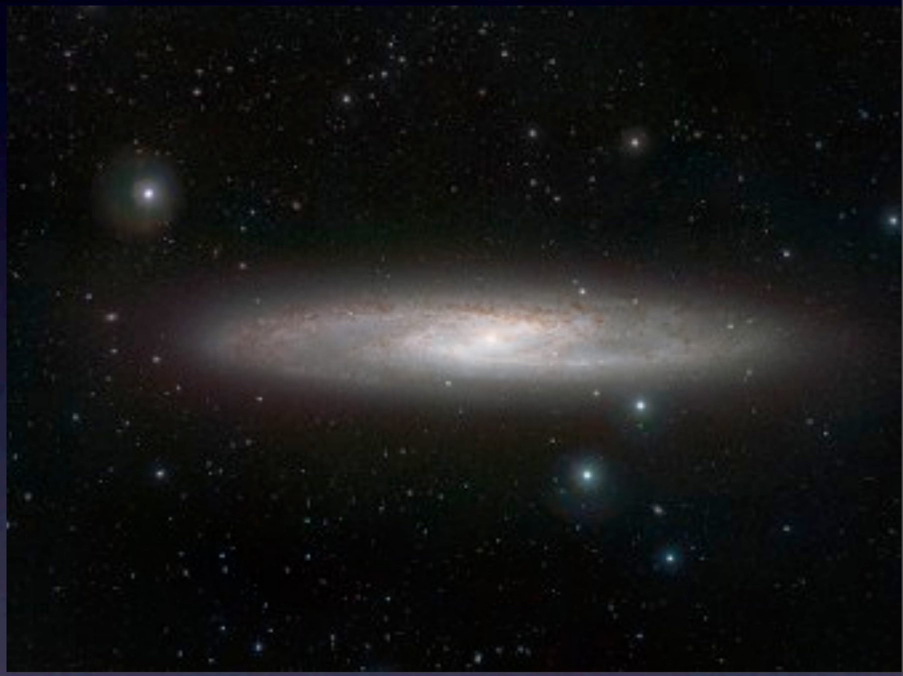
The sample

M82

HST optical (green)
Spitzer infrared (red)
Chandra X-ray (blue)
(Public Domain)

NGC4945

Optical, MPG/ESO 2.2m at La Silla
(CC-BY-3.0 ESO)



NGC253

Optical with VISTA
(CC-BY-3.0 ESO)

Emission components

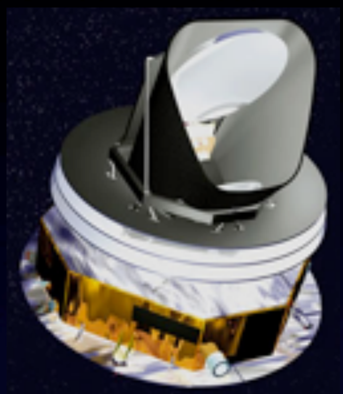
- Galactic emission between 1 and 1000 GHz is a mix of (steepening) synchrotron, free-free, anomalous dust and thermal dust

$$S(\nu) = A_{\rm sync}\nu^{\alpha} + S_{\rm ff} + \frac{A_{\rm dust}h}{k}\frac{\nu^{\beta+3}}{\exp(h\nu/kT_{\rm dust})-1}$$

$$S_{\rm ff} = 2\times10^{26}\,k\,T_{\rm e}(1-e^{-\tau_{\rm ff}})\,\Omega\,\nu^2c^{-2}$$

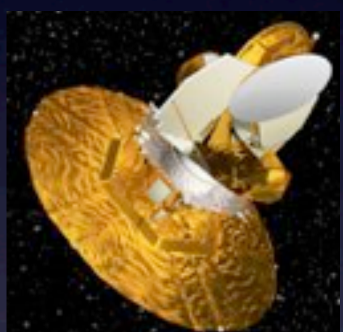
$$\tau_{\rm ff} = 3.014\times10^{-2}\,T_{\rm e}^{-1.5}\,\nu^{-2}\,{\rm EM}_{\rm ff}\,g_{\rm ff}$$

Data



Planck ERCSC at 28.5-857 GHz

Planck Collaboration (2011). 3-7% cal uncertainty; colour corrections applied. Exclude 100 and 217 GHz due to CO.



WMAP 7-yr catalogue at 22.3-93.5 GHz

Gold et al. (2011). 3% cal uncertainty, colour corrections applied (Jarosik et al. 2003).

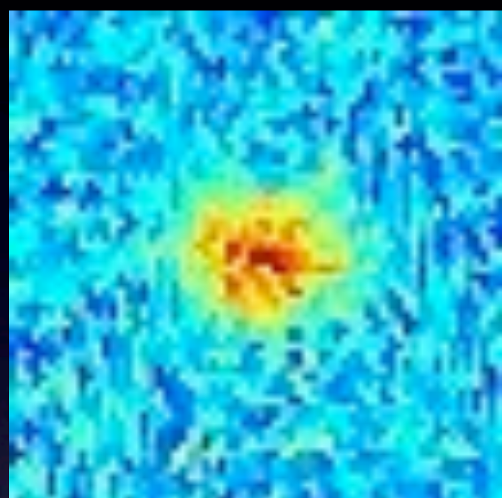
IRAS 100um

Wang & Rowan-Robinson (2009). 13% uncertainty. Don’t use higher frequency data due to small dust grains.

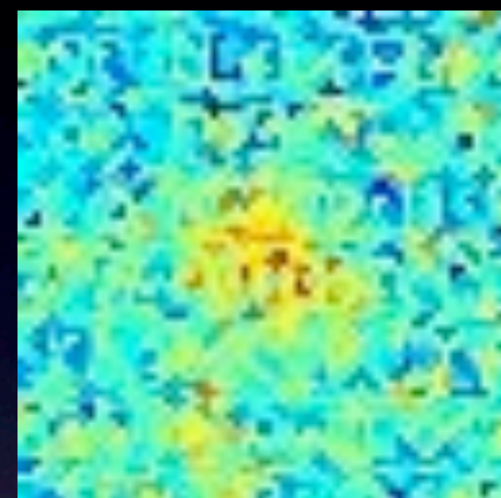
Ancillary radio data

Many references; most found via NED. 5% uncertainty; only fit to data above 1.5GHz due to sync. ageing & free-free absorption.

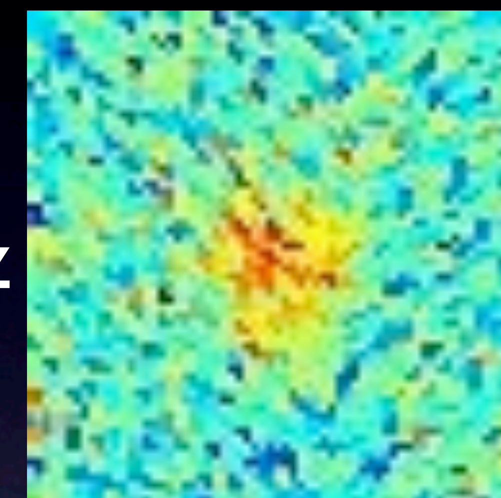
The sample



28.5 GHz

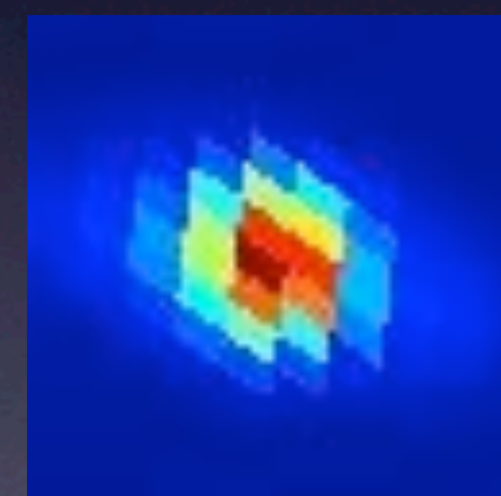


28.5 GHz



857 GHz

857 GHz



M82

G141.40+40.56

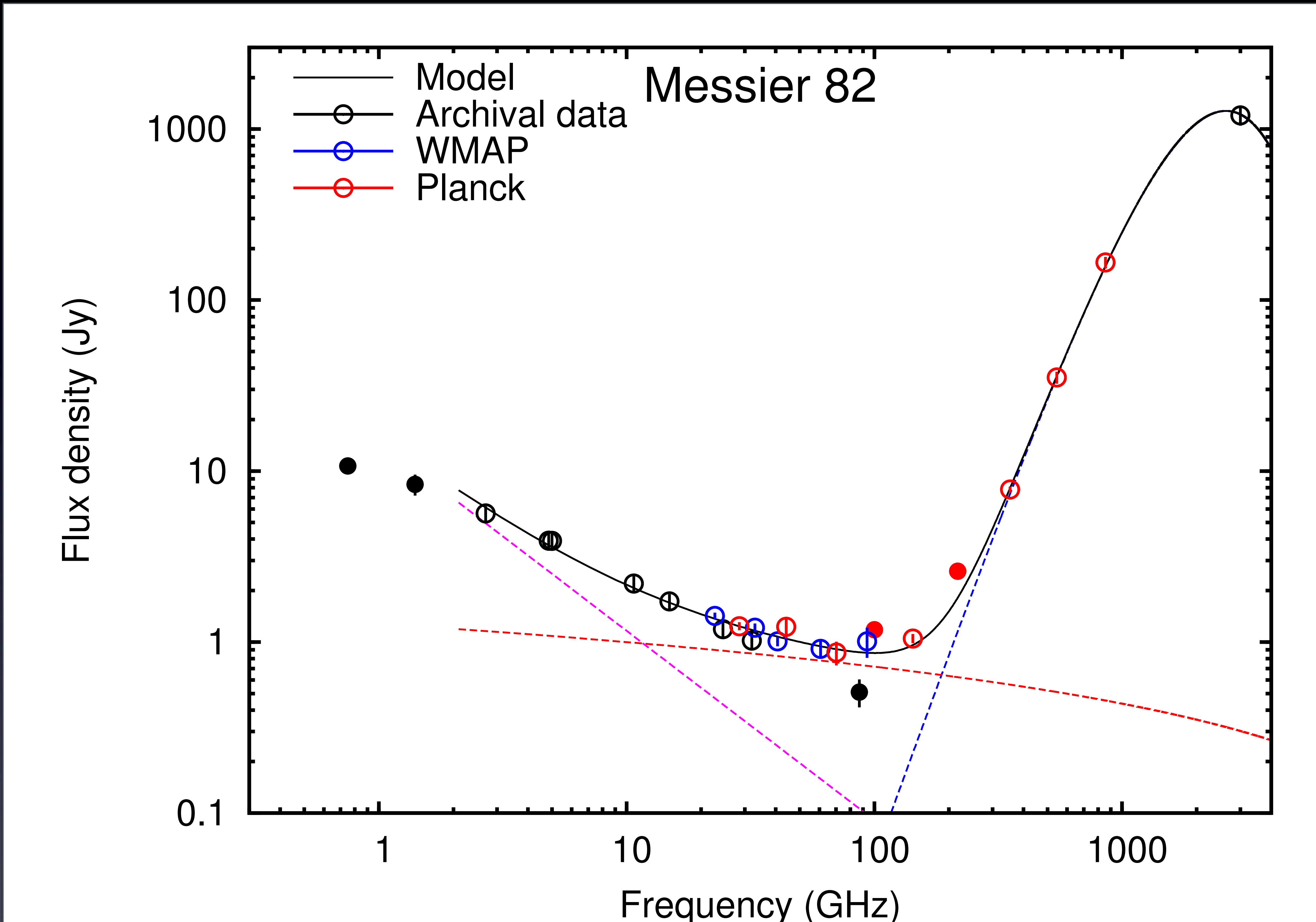
NGC4945

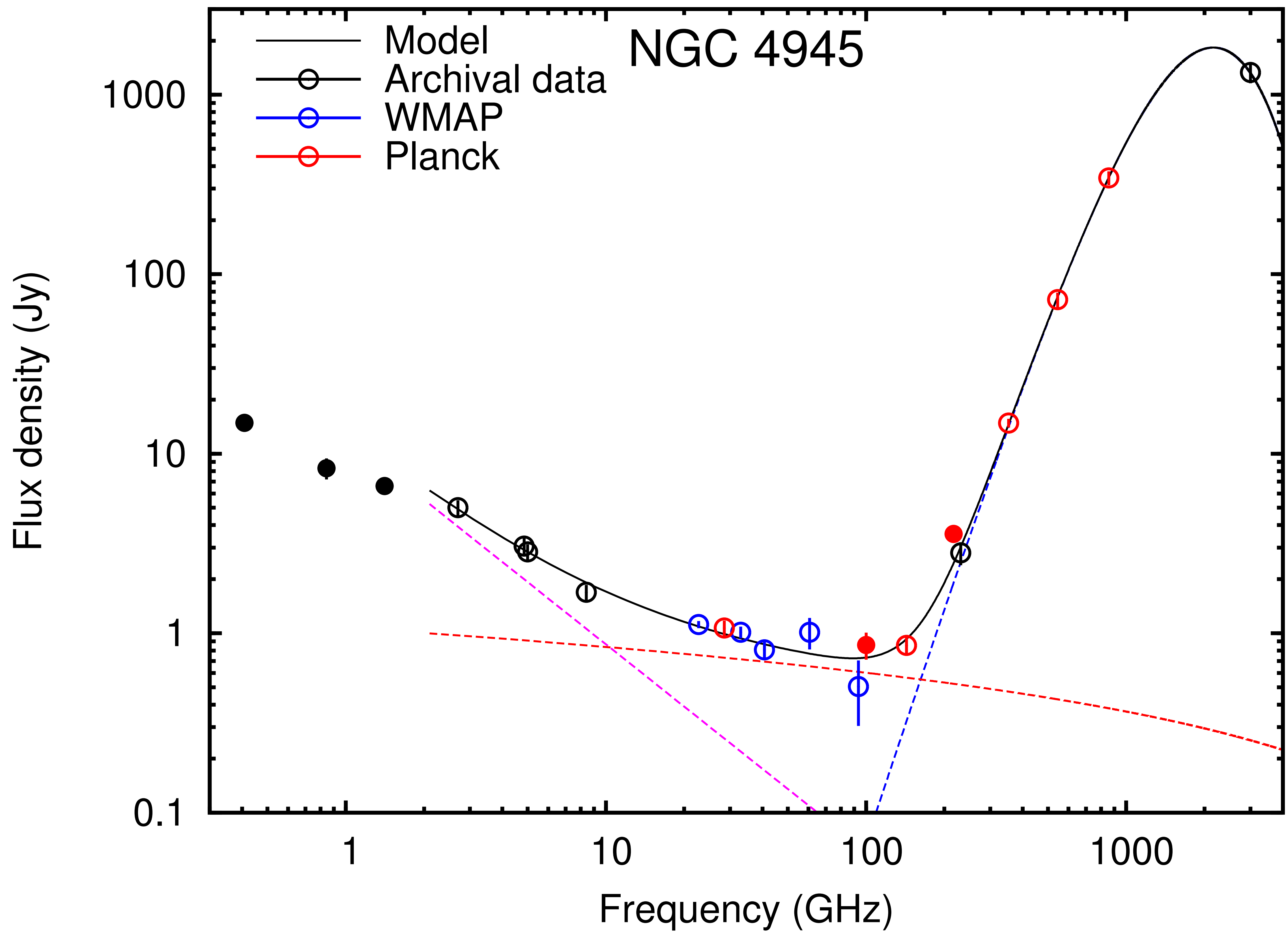
G305.27+13.34

NGC253

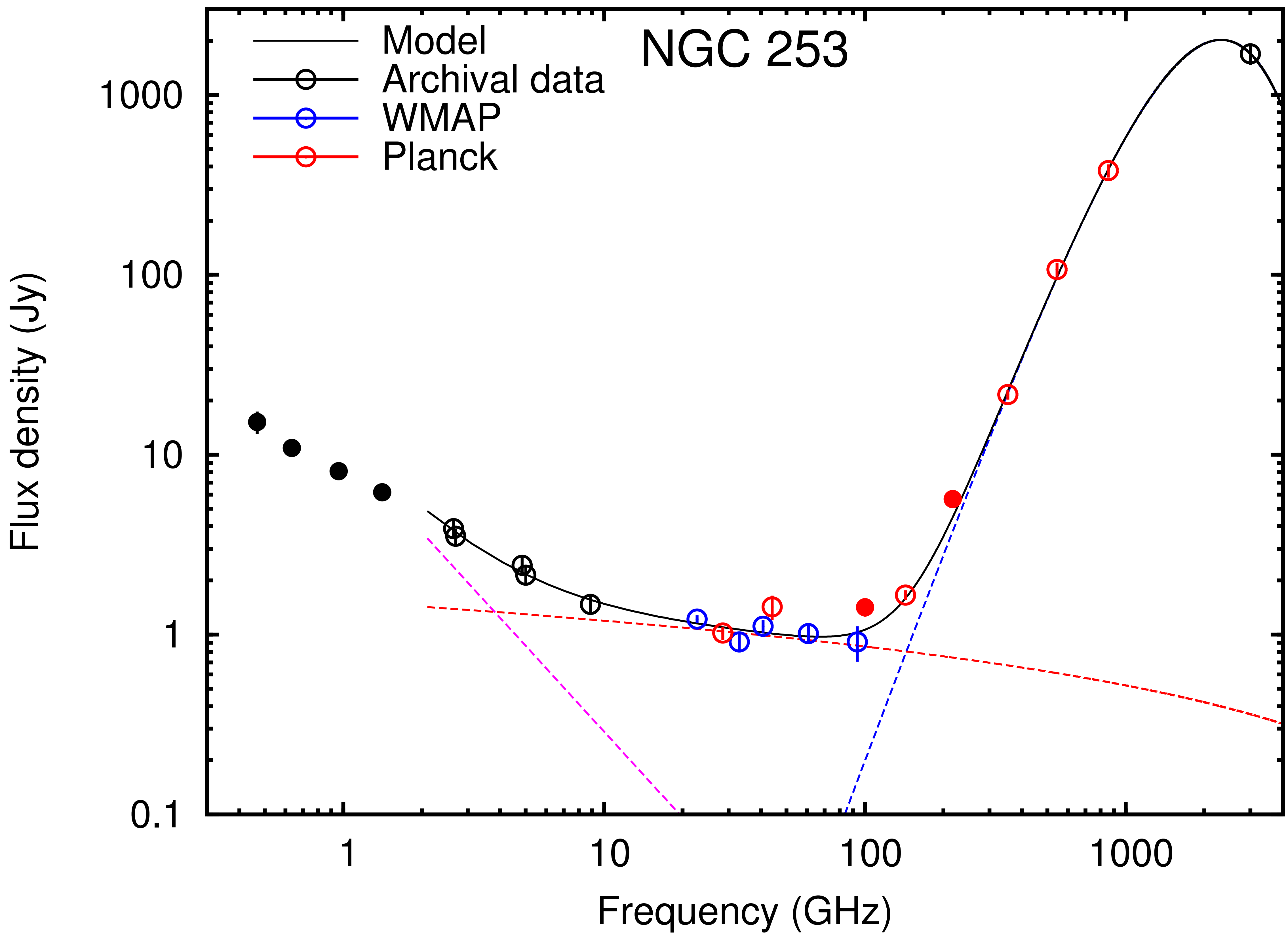
G097.18-87.96

(Planck ERCSC postage stamps)


Model
Archival data
WMAP
Planck
Messier 82
1000
100
10
1
0.1
Flux density (Jy)
1
10
100
1000
Frequency (GHz)



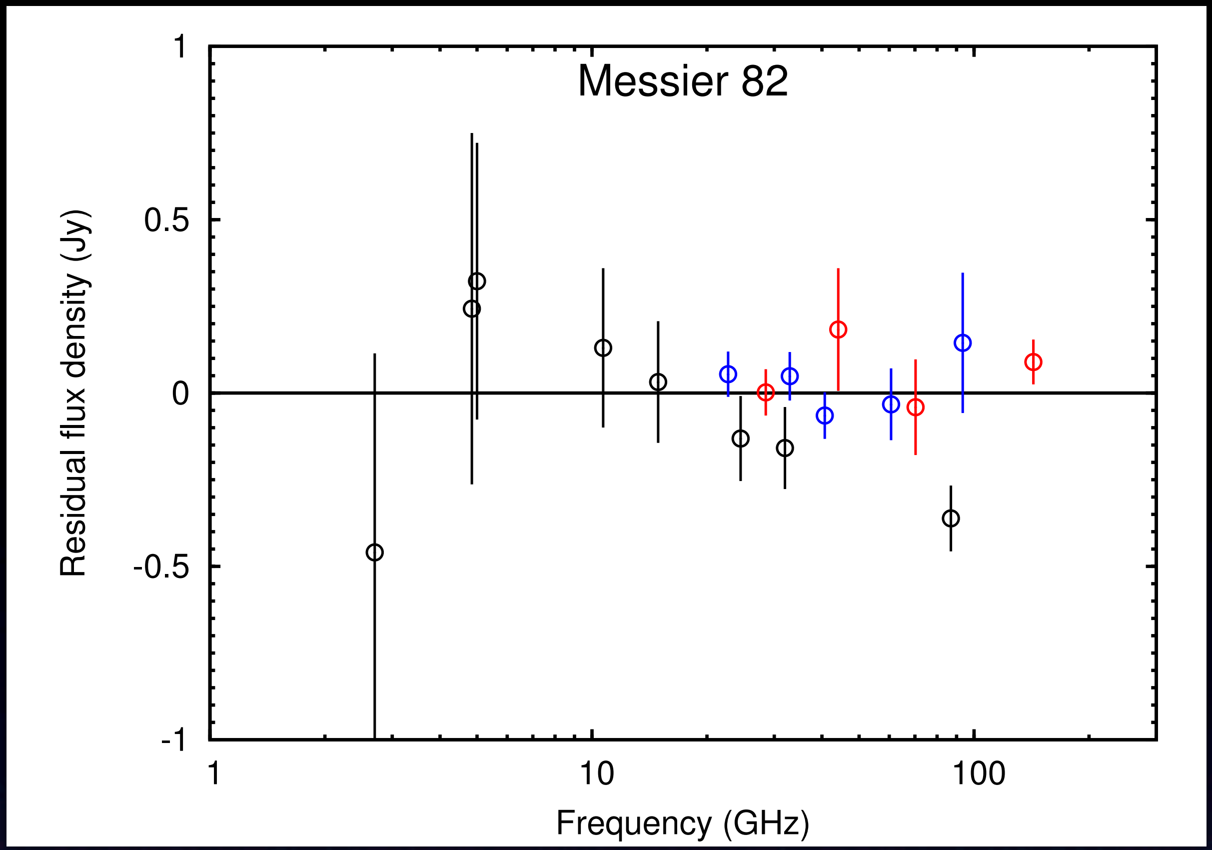
Model
Archival data
WMAP
Planck
NGC 4945
1000
100
10
1
0.1
1
10
100
1000
Flux density (Jy)
Frequency (GHz)

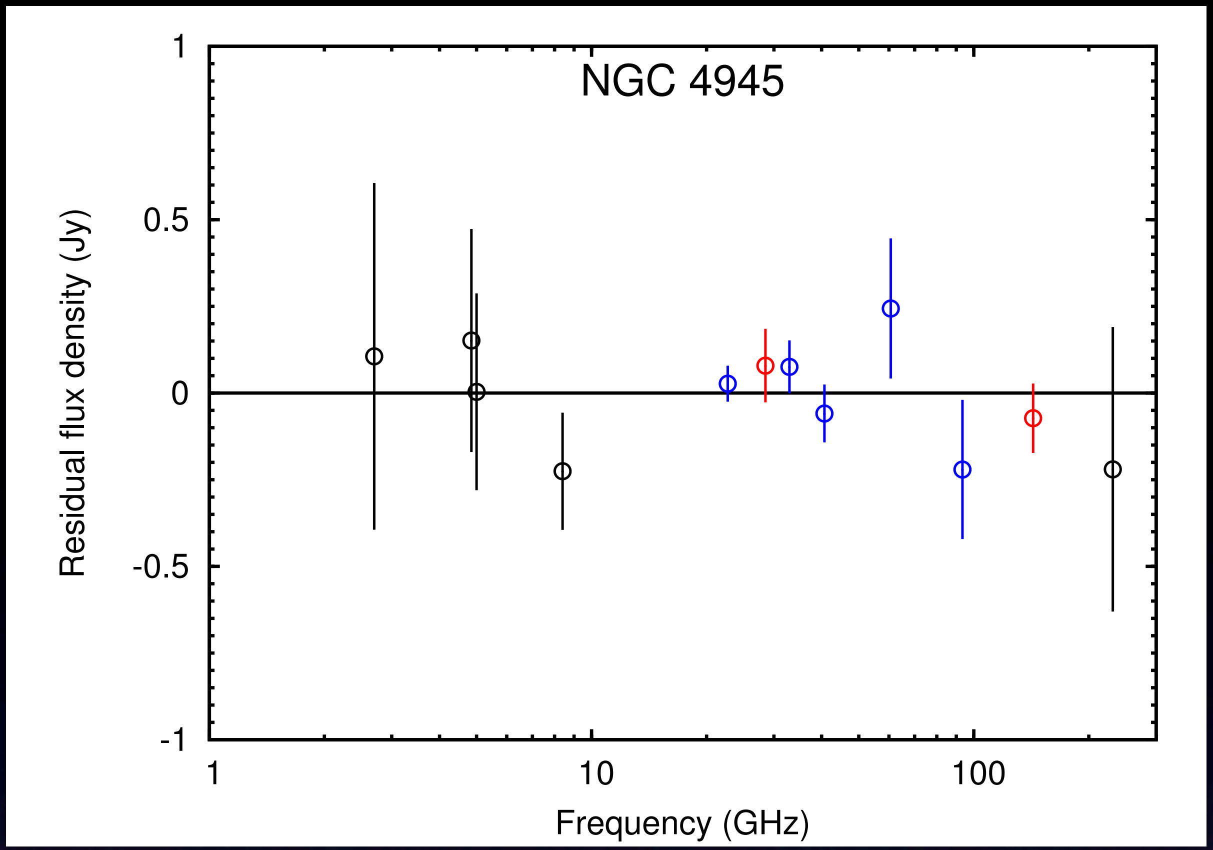

NGC 253
Model
Archival data
WMAP
Planck
1000
100
10
1
0.1
1
10
100
1000
Flux density (Jy)
Frequency (GHz)

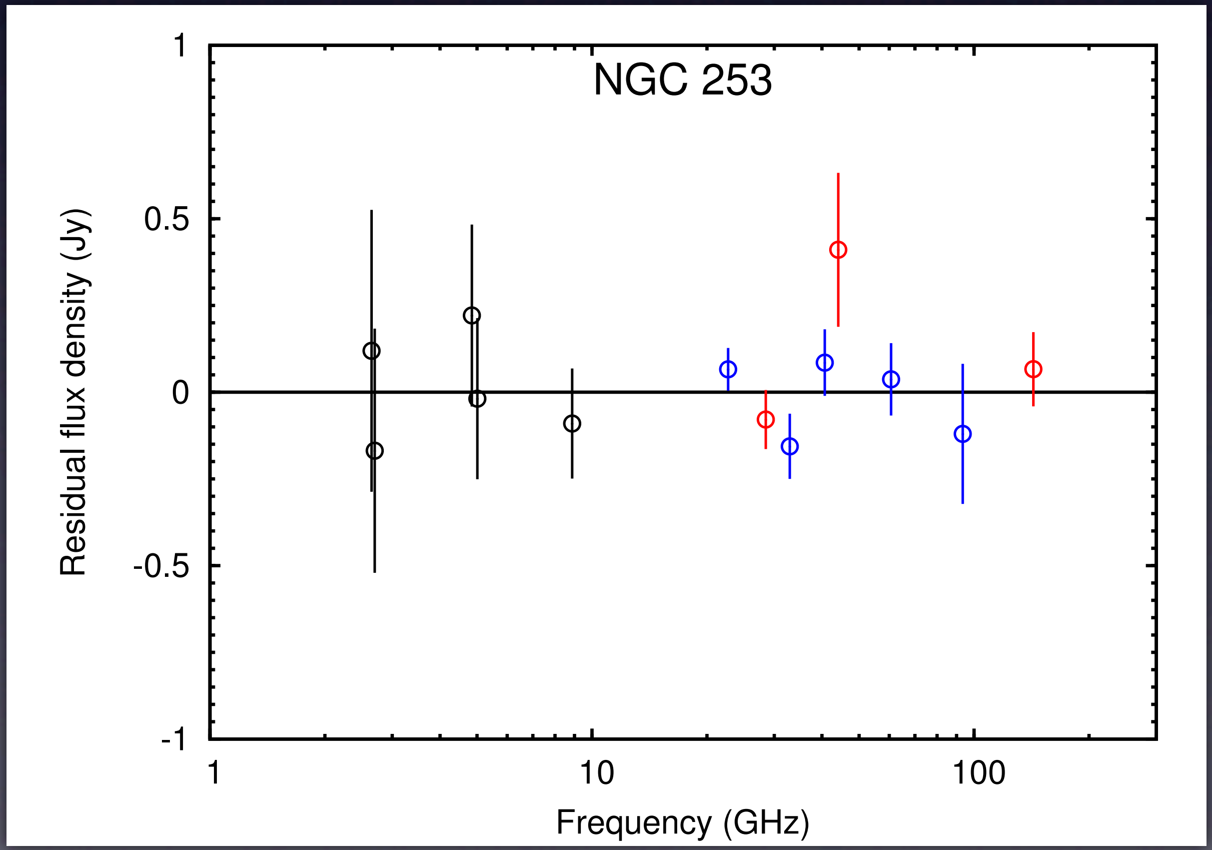
Fit values

Parameter	M82	NGC253	NGC4945
A_{sync} [Jy]	14.9±2.9	11.1±4.3	12.3±3.1
α_{sync}	-1.11±0.13	-1.59±0.35	-1.15±0.20
EM_{ff}	920±110	284±17	492±81
β_{dust}	2.10±0.13	1.96±0.11	2.5±0.2
T_{dust} (K)	24.8±1.9	22.6±1.3	18.9±1.1
Residual (3σ)	<0.15 Jy	<0.14 Jy	<0.13 Jy
100μm/3000	0.36 Jy	0.5 Jy	0.4 Jy

NB: high-frequency synchrotron index, hence steeper than low frequency end.







Residuals all consistent with zero.

Hint of AME in NGC 4945?

Star Formation Rates

SFR ($M_\odot$/yr)	M82	NGC253	NGC4945
Sync	2.6	1.3	2.7
Free-free	3.0	2.2	2.9
Radio SN	1.8-2.0	-	-
RRL	-	-	2-8
Niklas (1997)	<0.2	1.0	-

Using formulae from Condon (1992)

Conclusions

- Find substantially more free-free emission
- Higher FF brings SFR into better agreement
- AME constraints lower than expected c.f. our Galaxy - supports 'patchy' AME
- Cold dust with high β (but degeneracies)
- Need to improve modelling of synchrotron and dust (simplistic approach taken here)
- Need more sources - next Planck catalogue? Also more data from ground-based telescopes (RRLs particularly useful).

Thanks for listening!

Questions?

For more info, see:
MNRAS Letters, 416, 99
arXiv:1105.6336