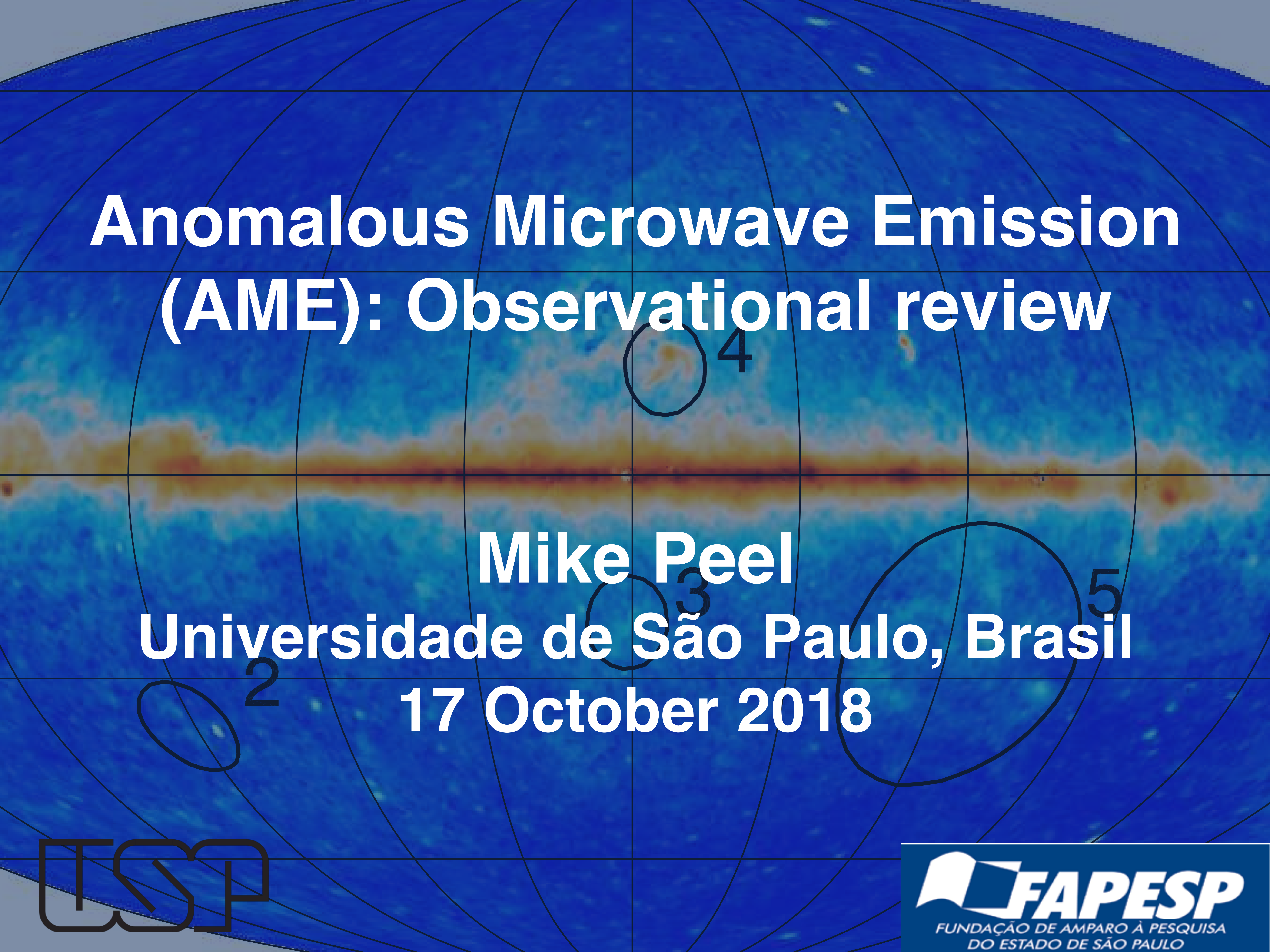

Anomalous Microwave Emission (AME): Observational review

Mike Peel

Universidade de São Paulo, Brasil

17 October 2018

USP

FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO

Outline

Detection

Spectrum

Morphology/known regions

Polarisation

Open (observational) questions

(Brandon talking about AME models in next talk!)

AME Review

New Astronomy Reviews 80 (2018) 1–28

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New Astronomy Reviews

journal homepage: www.elsevier.com/locate/newastrev

The State-of-Play of Anomalous Microwave Emission (AME) research

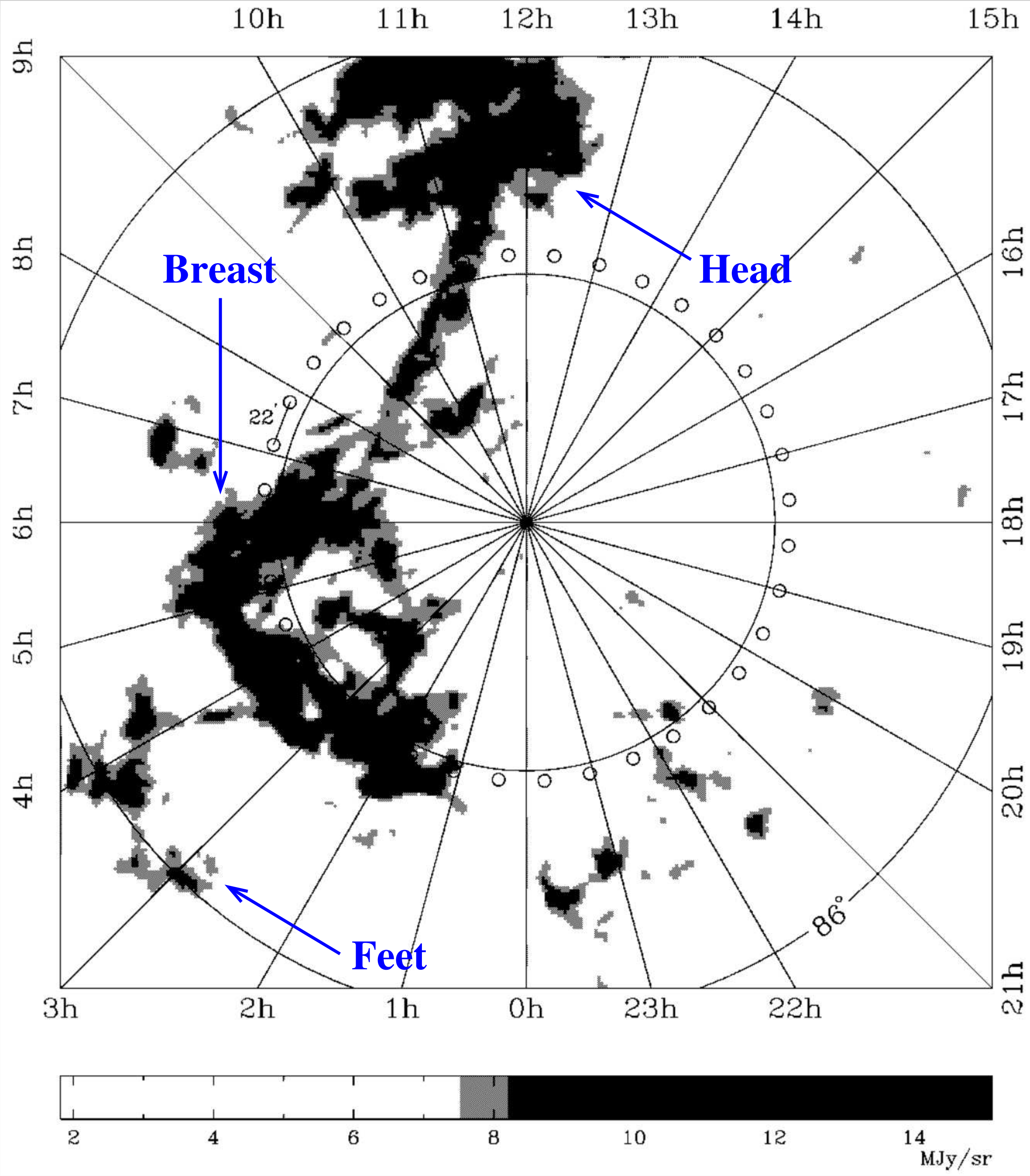
Clive Dickinson[*,a], Y. Ali-Haïmoud[b], A. Barr[a], E.S. Battistelli[c], A. Bell[d], L. Bernstein[e], S. Casassus[f], K. Cleary[g], B.T. Draine[h], R. Génova-Santos[i,j], S.E. Harper[a], B. Hensley[g,k], J. Hill-Valler[l], Thiem Hoang[m], F.P. Israel[n], L. Jew[l], A. Lazarian[o], J.P. Leahy[a], J. Leech[l], C.H. López-Caraballo[p], I. McDonald[a], E.J. Murphy[q], T. Onaka[d], R. Paladini[r], M.W. Peel[s,a], Y. Perrott[t], F. Poidevin[i,j], A.C.S. Readhead[g], J.-A. Rubiño-Martín[i,j], A.C. Taylor[l], C.T. Tibbs[u], M. Todorović[v], Matias Vidal[f]

Dickinson et al.
New Astronomy Reviews 80 (2018), 1-28
arXiv: 1802.08073

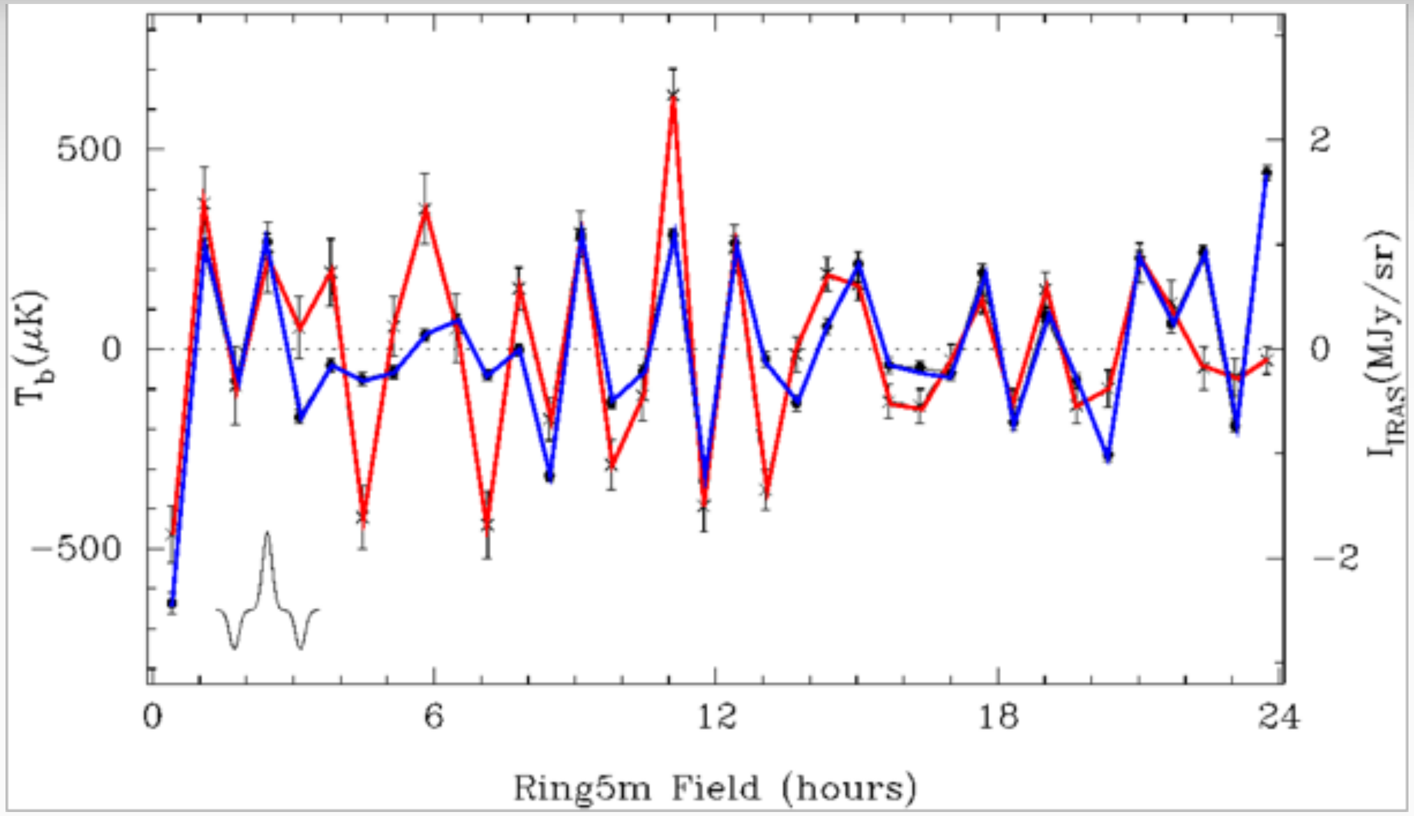
Based on AME workshop at ESTEC in 2016

Detection

First detection



100um dust map of NCP



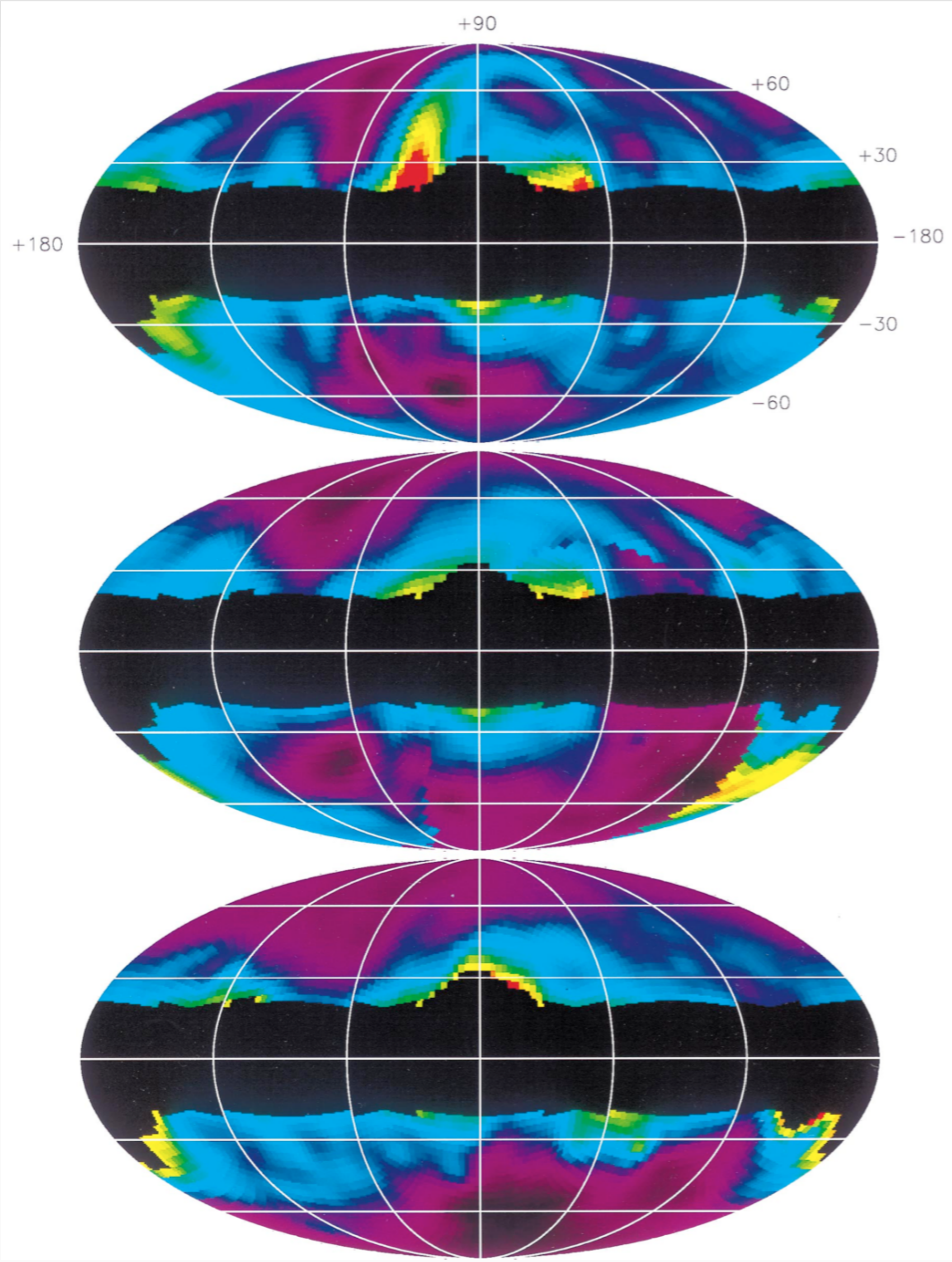
14.5GHz (40-m) data (blue) cf. 100um data (red)

Owens Valley Radio Observatory
40-m and 5.5-m dishes

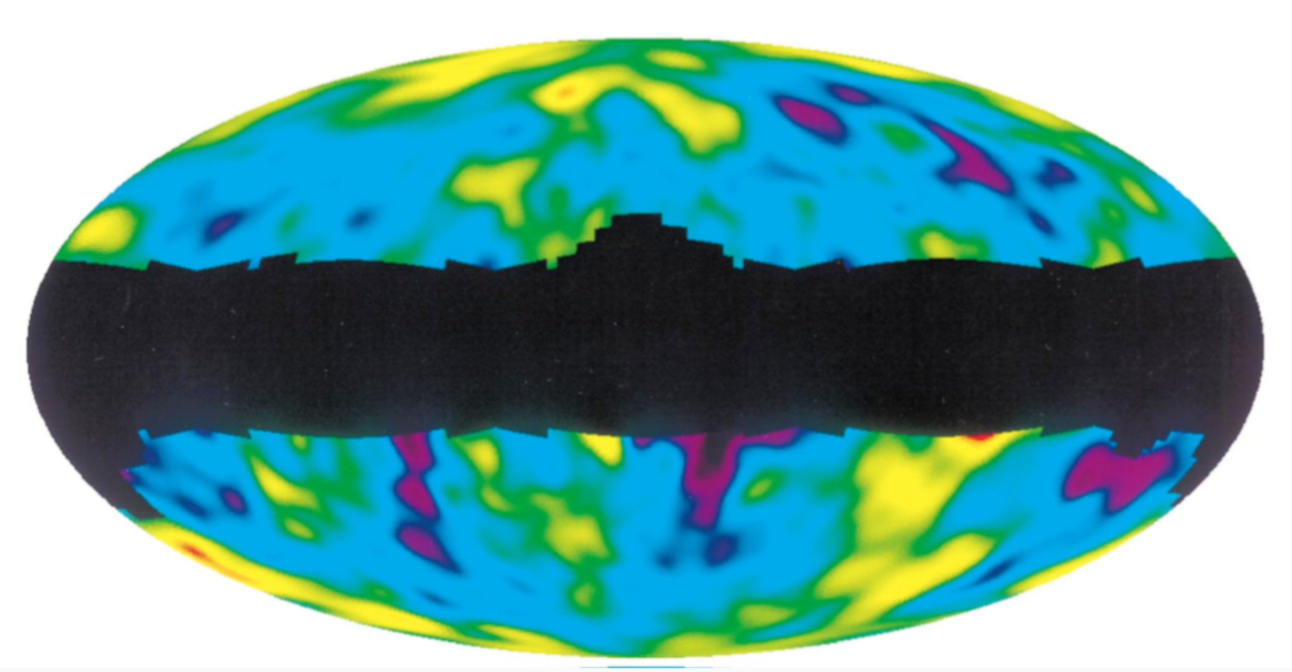
First postulated by Erickson (1957)
40 years before detection

Leitch et al. (1997)

First detection



408, CR & 140um



COBE data after foreground removal

TABLE 1

DMR–Galactic Template Cross-Correlation Coefficients[a]

DMR Frequency (GHz)	Galactic Template: 408 MHz[b]	Cosmic Ray[c]	DIRBE 140 μm[d]
31.5	1.17 ± 1.13	1.88 ± 1.24	6.37 ± 1.52
53	0.69 ± 0.77	0.88 ± 0.81	2.69 ± 1.06
90	−0.14 ± 0.74	0.43 ± 2.55	2.79 ± 1.01

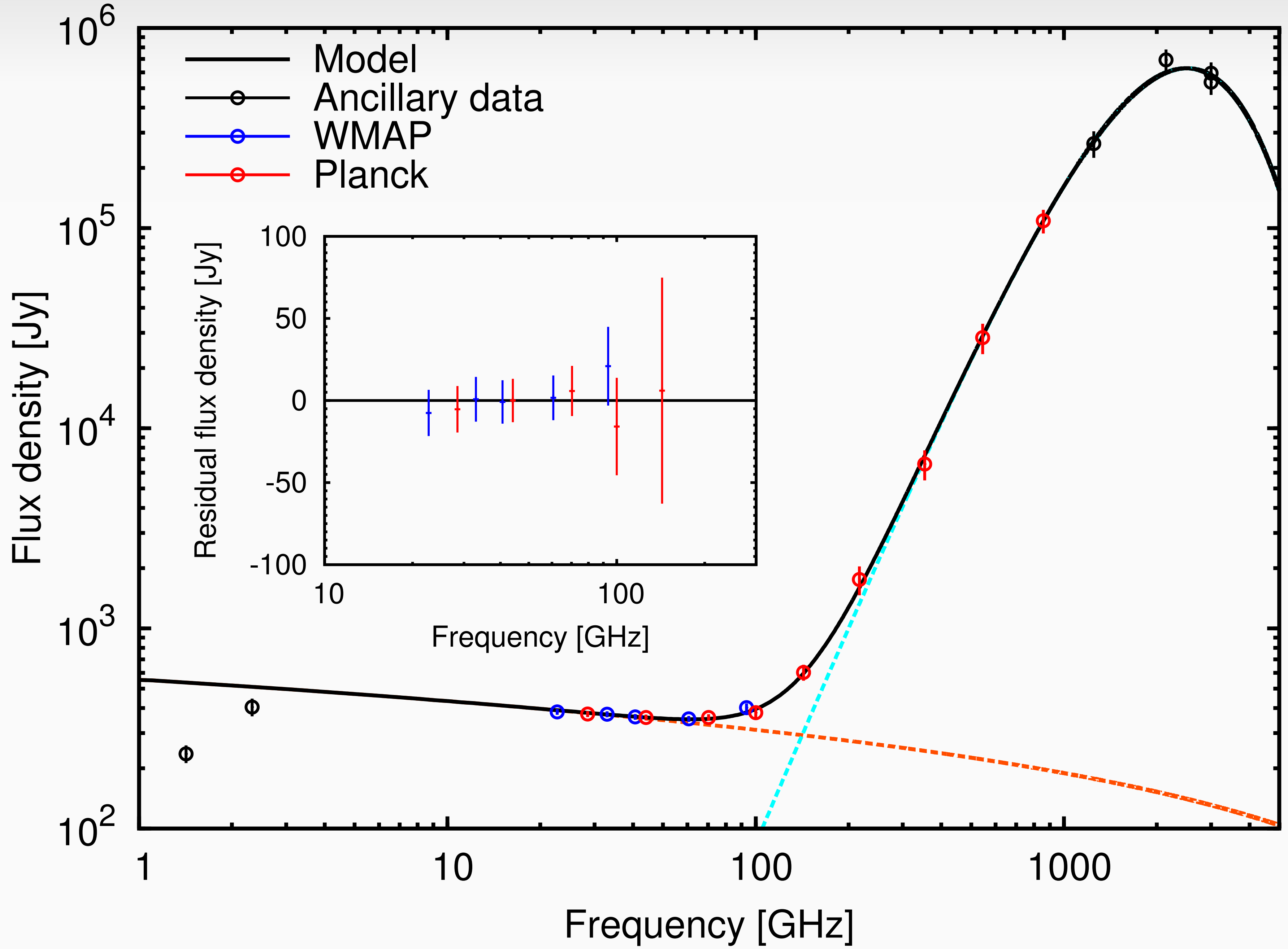
Kogut et al. (1996)

Spectrum

M42

Orion Nebula

Free-free dominated

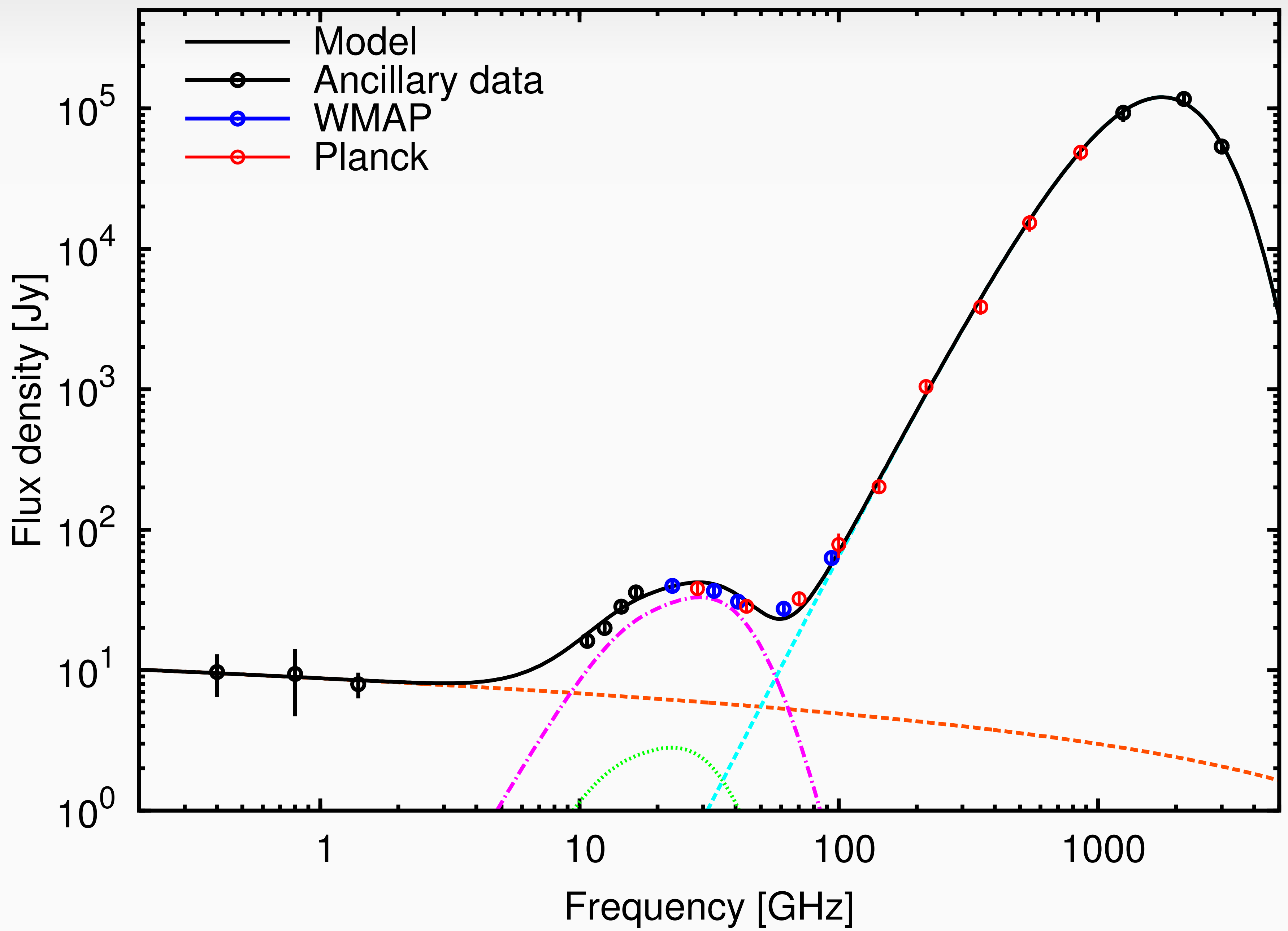


Planck Collaboration (2011), Early results XX, arXiv:1101.2031

Perseus

Discovered by
Watson et al. (2005)
with COSMOSOMAS

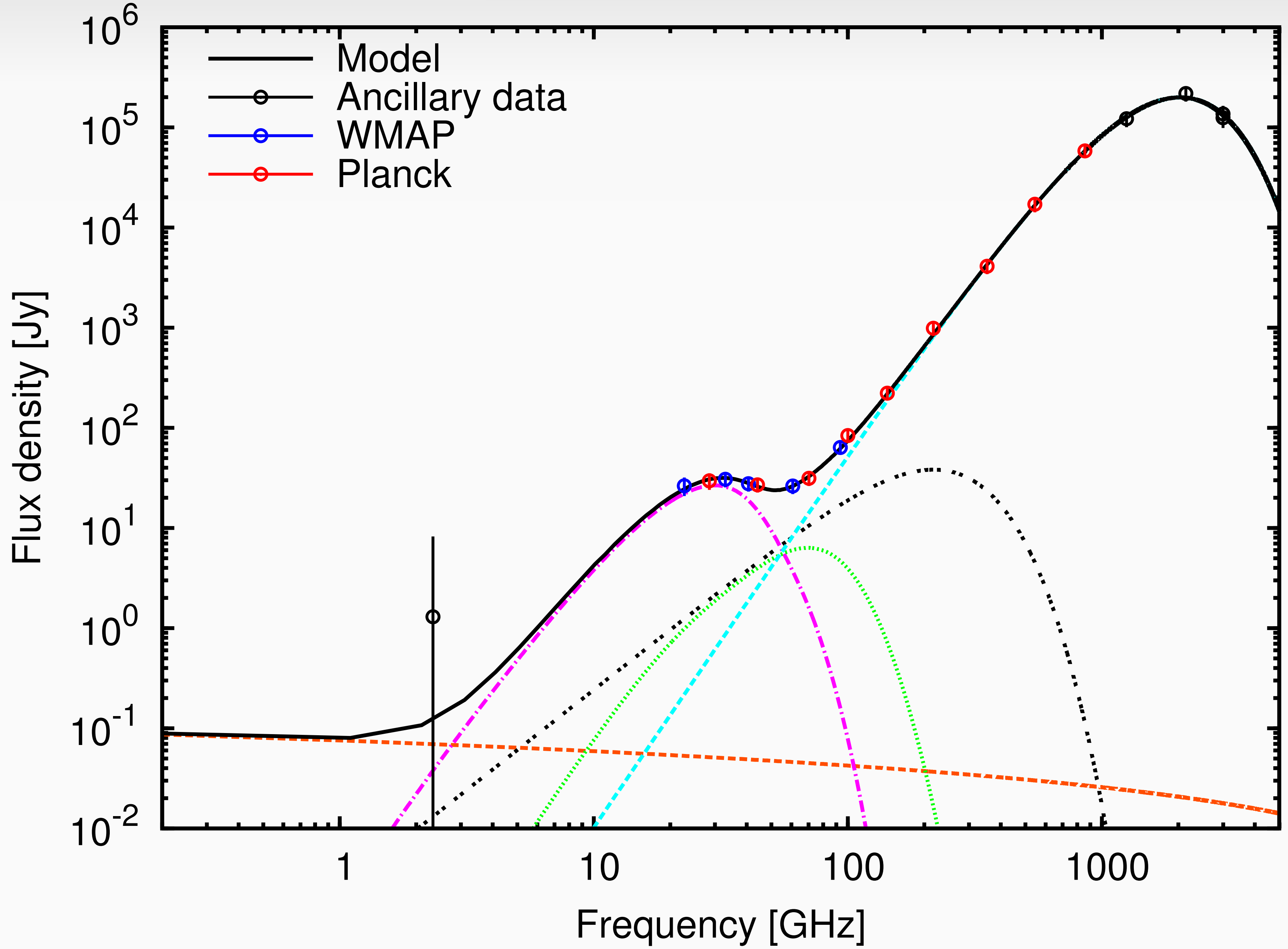
First detection of
low-freq rise



Planck Collaboration (2011), Early results XX, arXiv:1101.2031

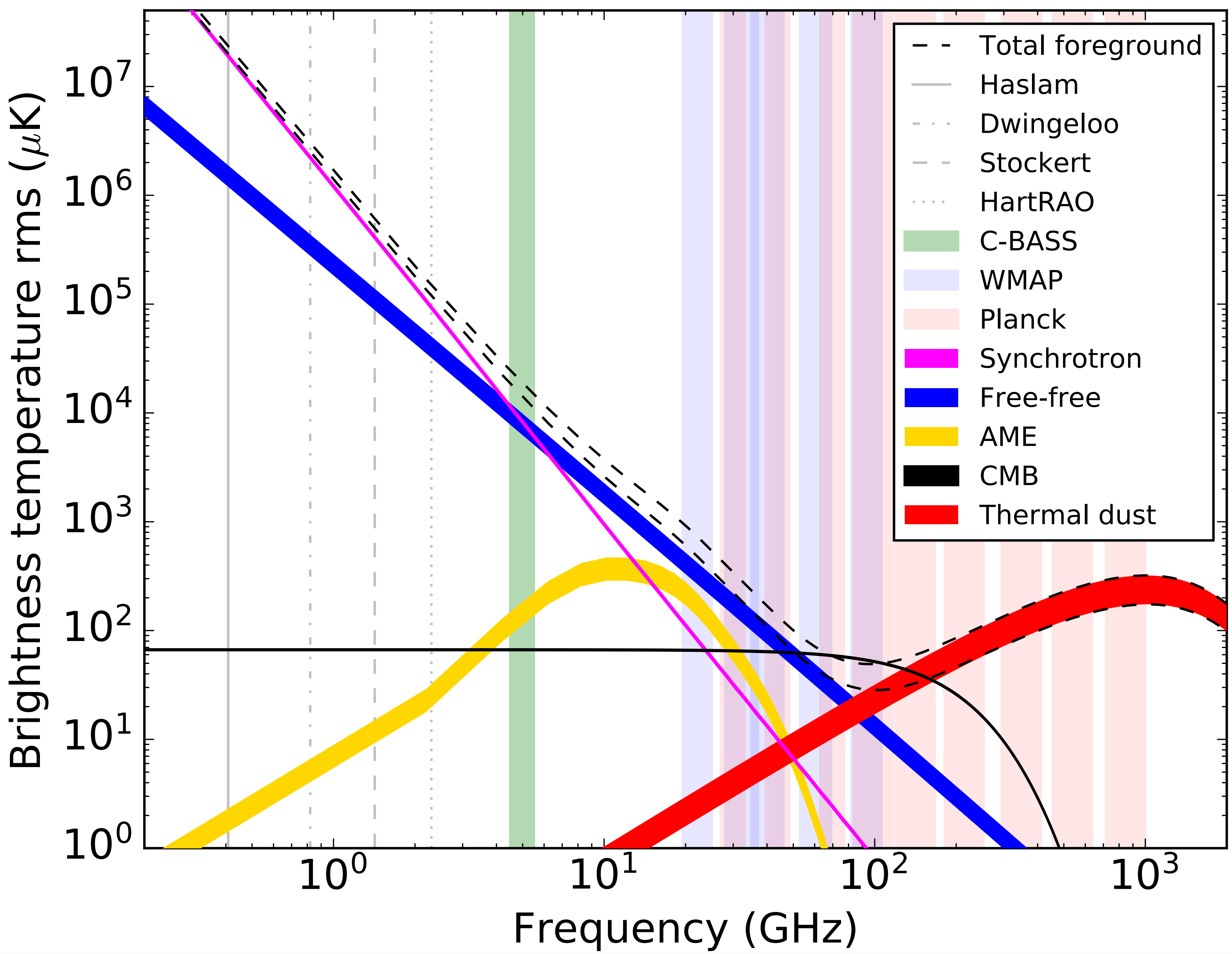
ρ Oph West

Discovered by
Casassus (2008)
Cosmic Background Imager



Planck Collaboration (2011), Early results XX, arXiv:1101.2031

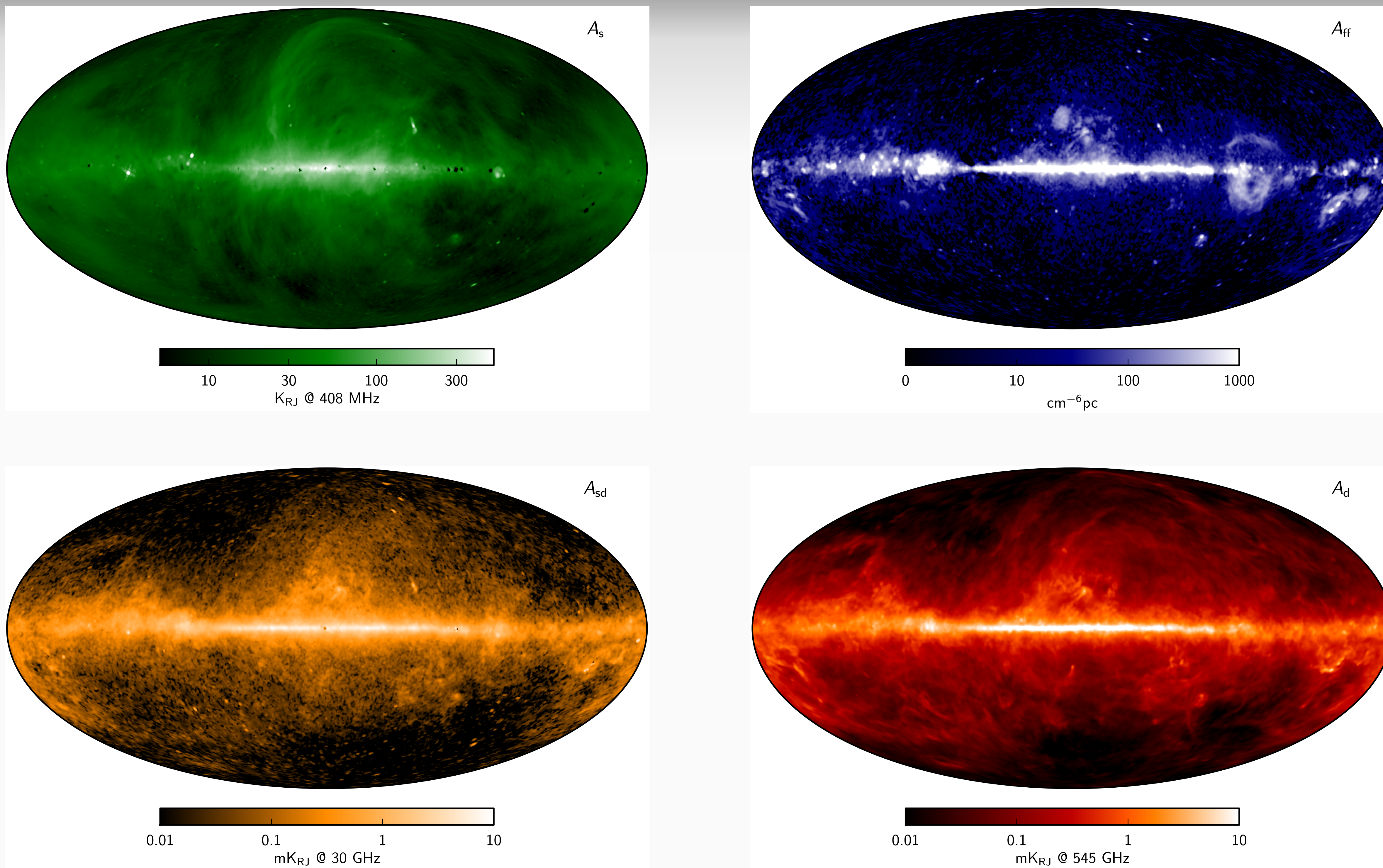
On average in the sky



Jones et al. (2018), 1805.04490, based on Planck Collaboration (2015/6), X, arXiv:1502.01588

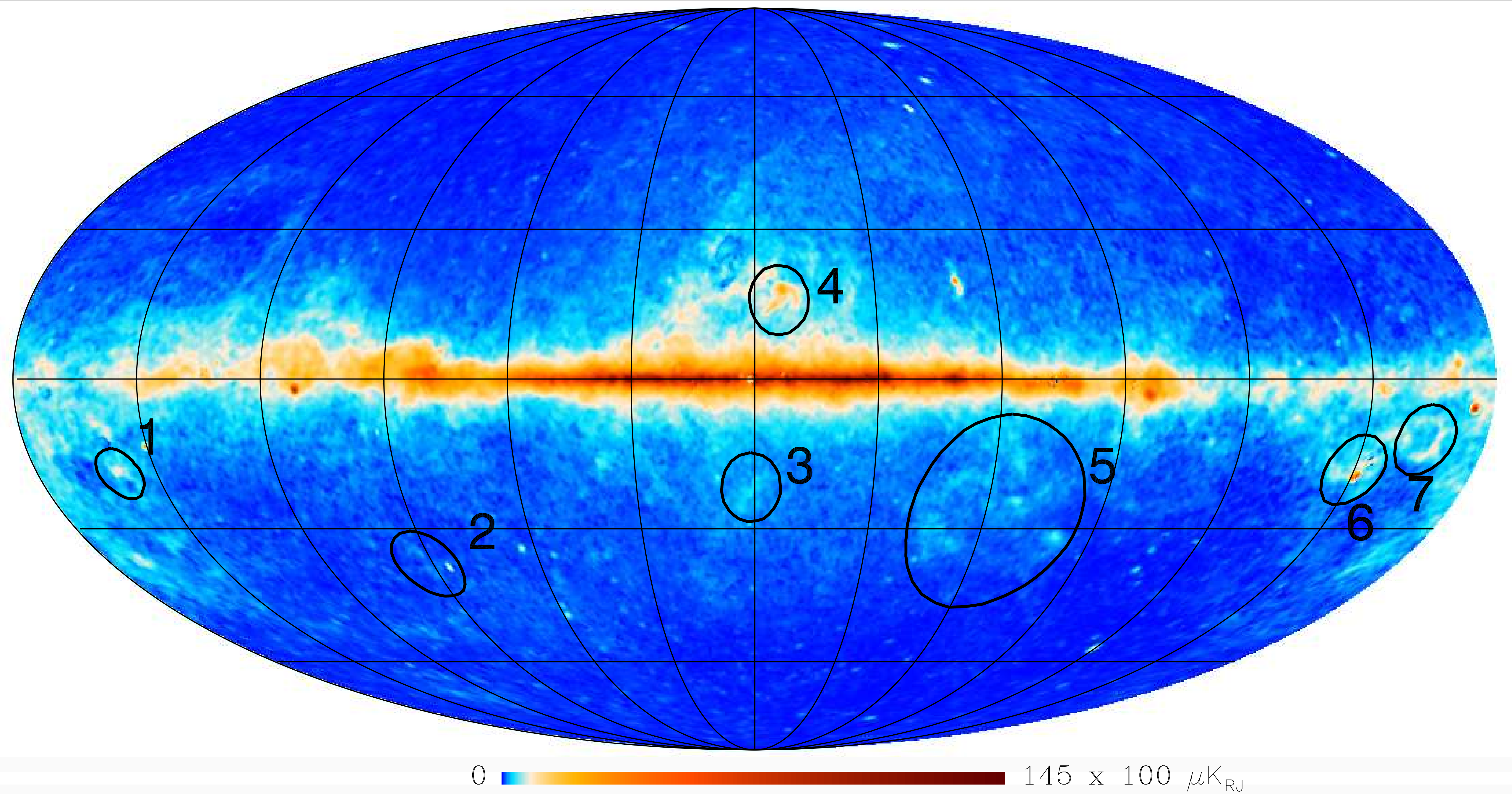
Morphology / known regions

Milky Way



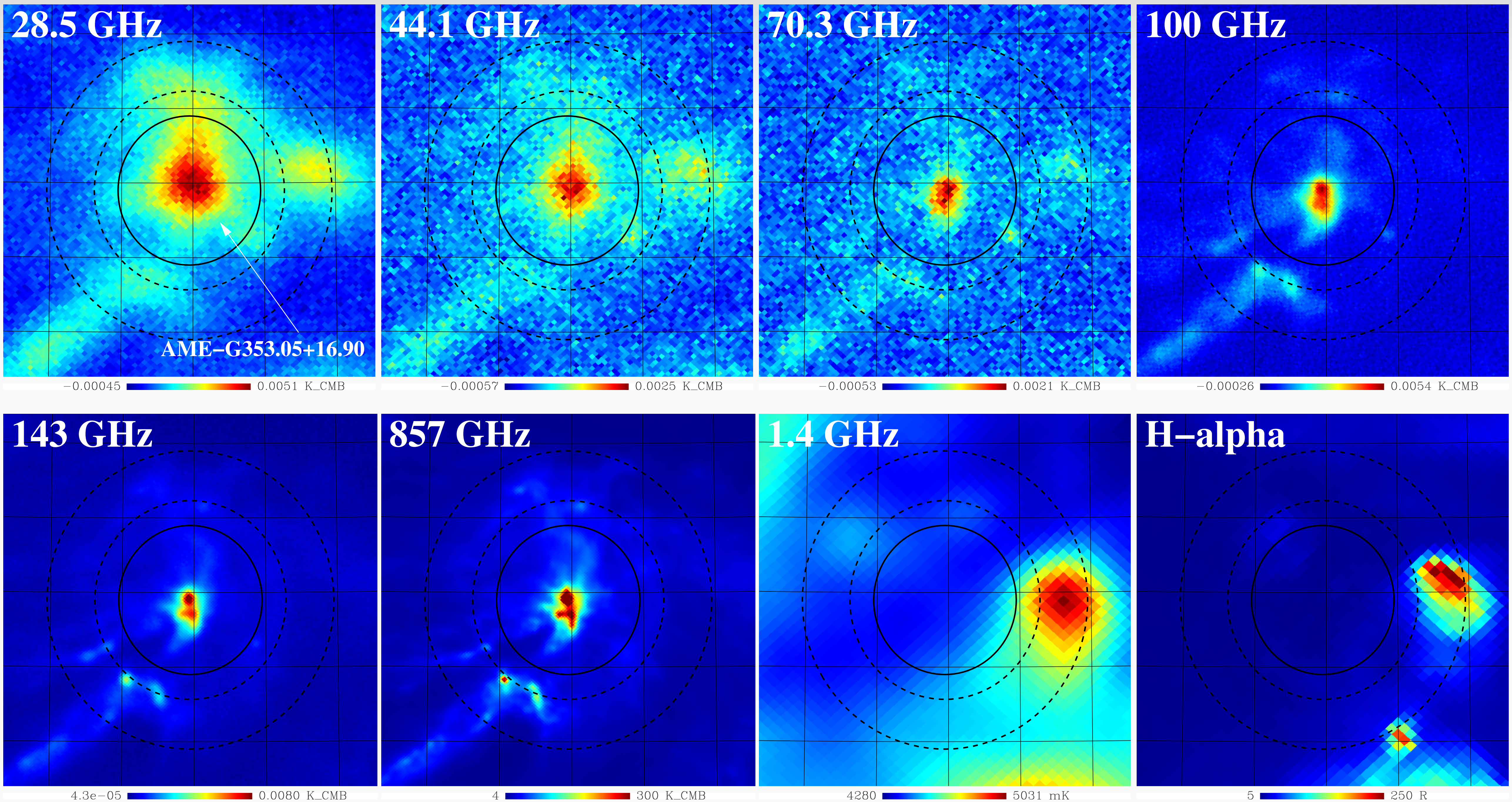
Planck Collaboration (2015/6), X, arXiv:1502.01588

Milky Way



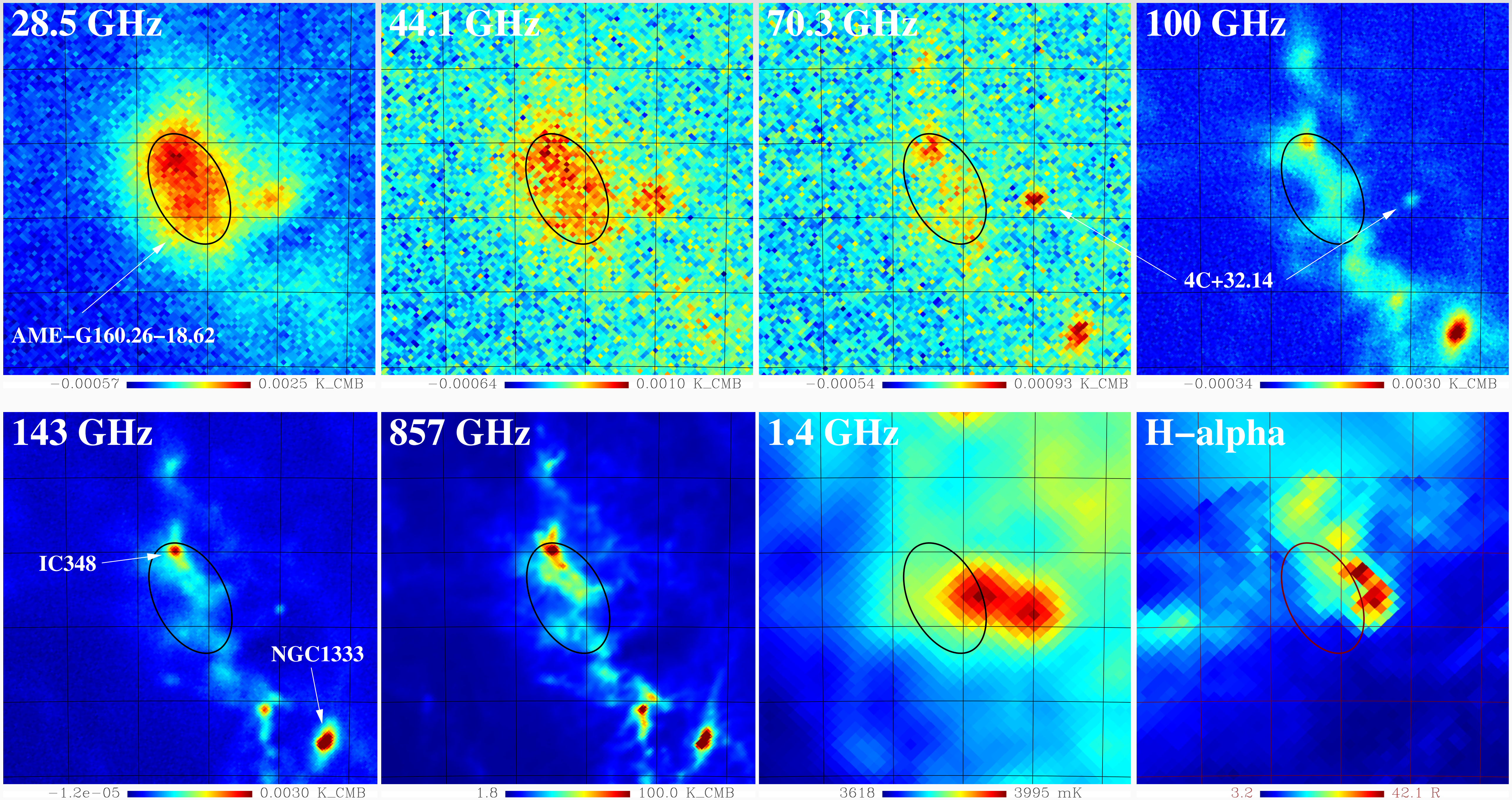
Planck Collaboration (2015/6), XXV, arXiv:1506.06660

ρ Oph West



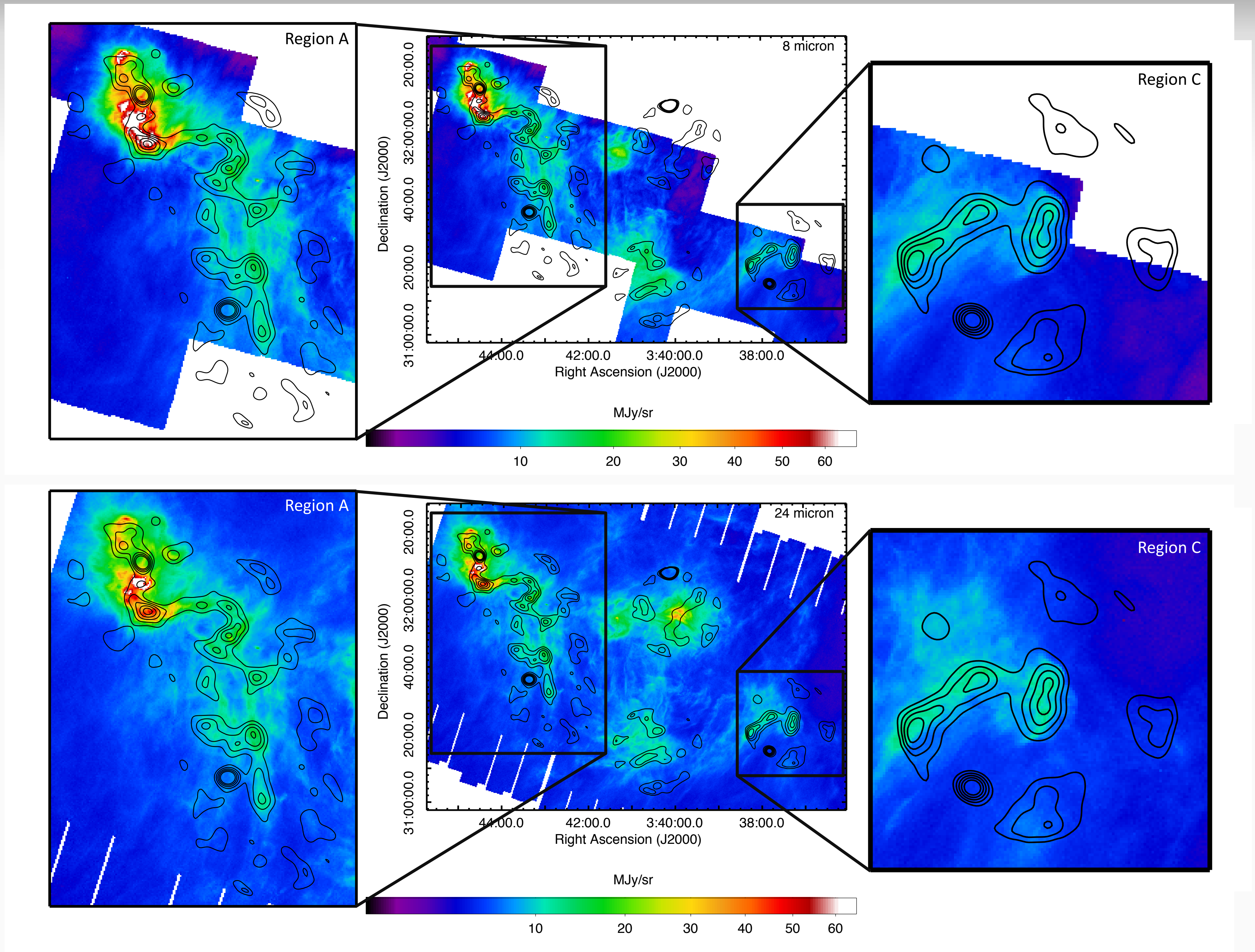
Planck Collaboration (2011), Early results XX, arXiv:1101.2031

Perseus



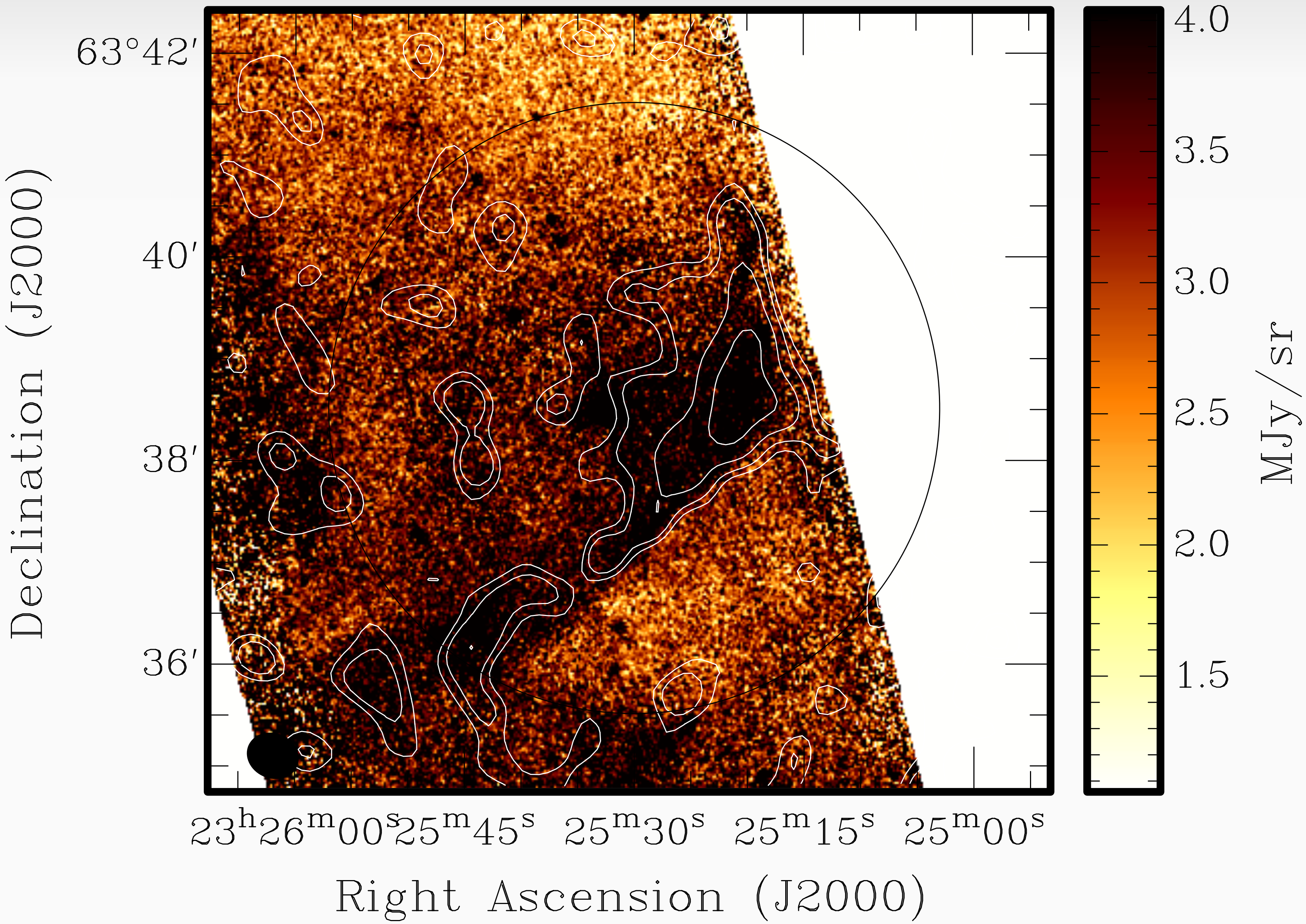
Planck Collaboration (2011), Early results XX, arXiv:1101.2031

Perseus



AMI (contours) vs. 8um (colour, top) and 24um (bottom) Tibbs et al. (2013)

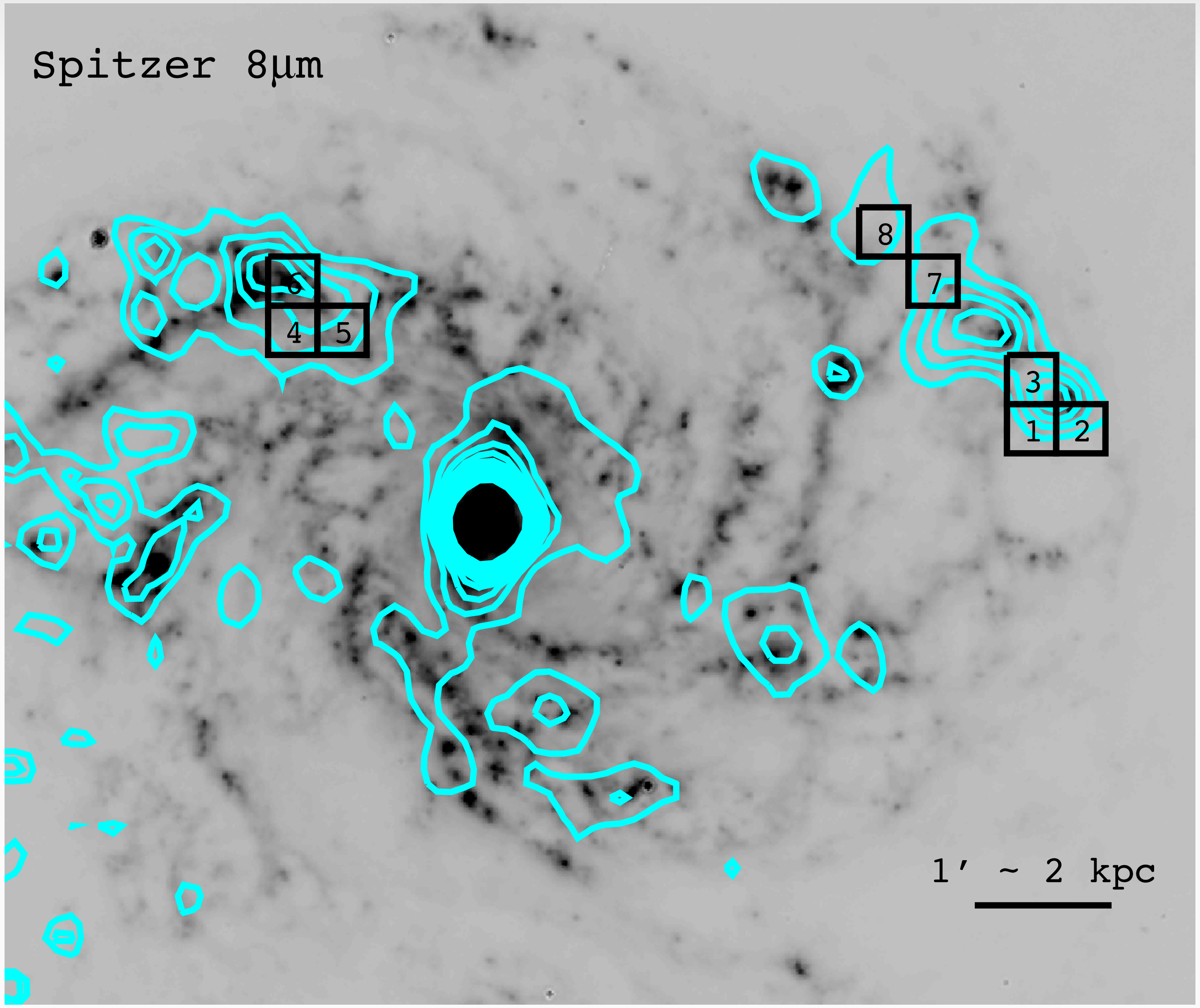
LDN1246



16GHz (white) vs. 8um (colour)

Scaife et al. (2010)

Other galaxies



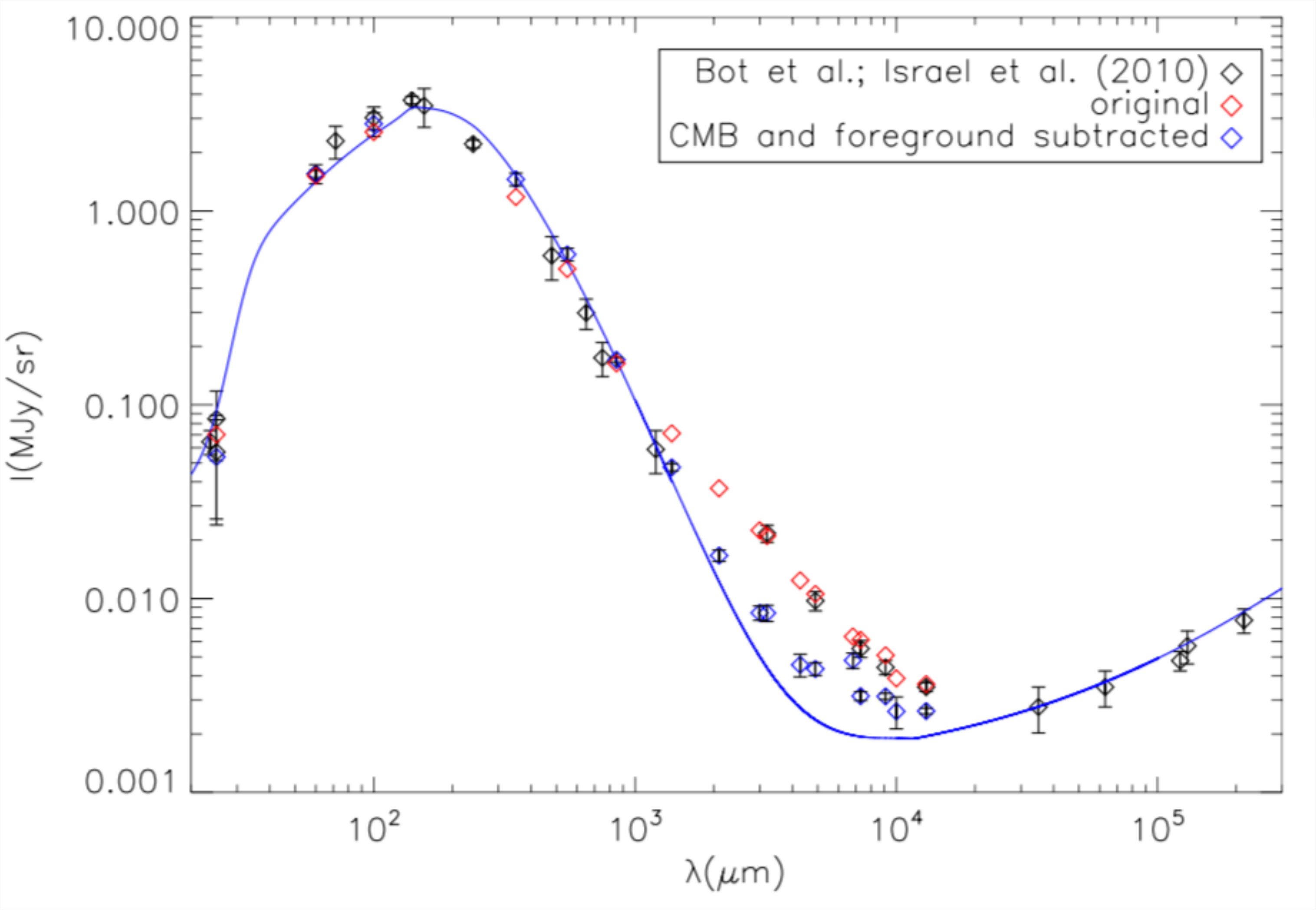
NGC 6946

Only seen in some parts shown by black boxes

(original region is 1-2-3)

Murphy et al. (2010)
Hensley et al. (2015)

Other galaxies

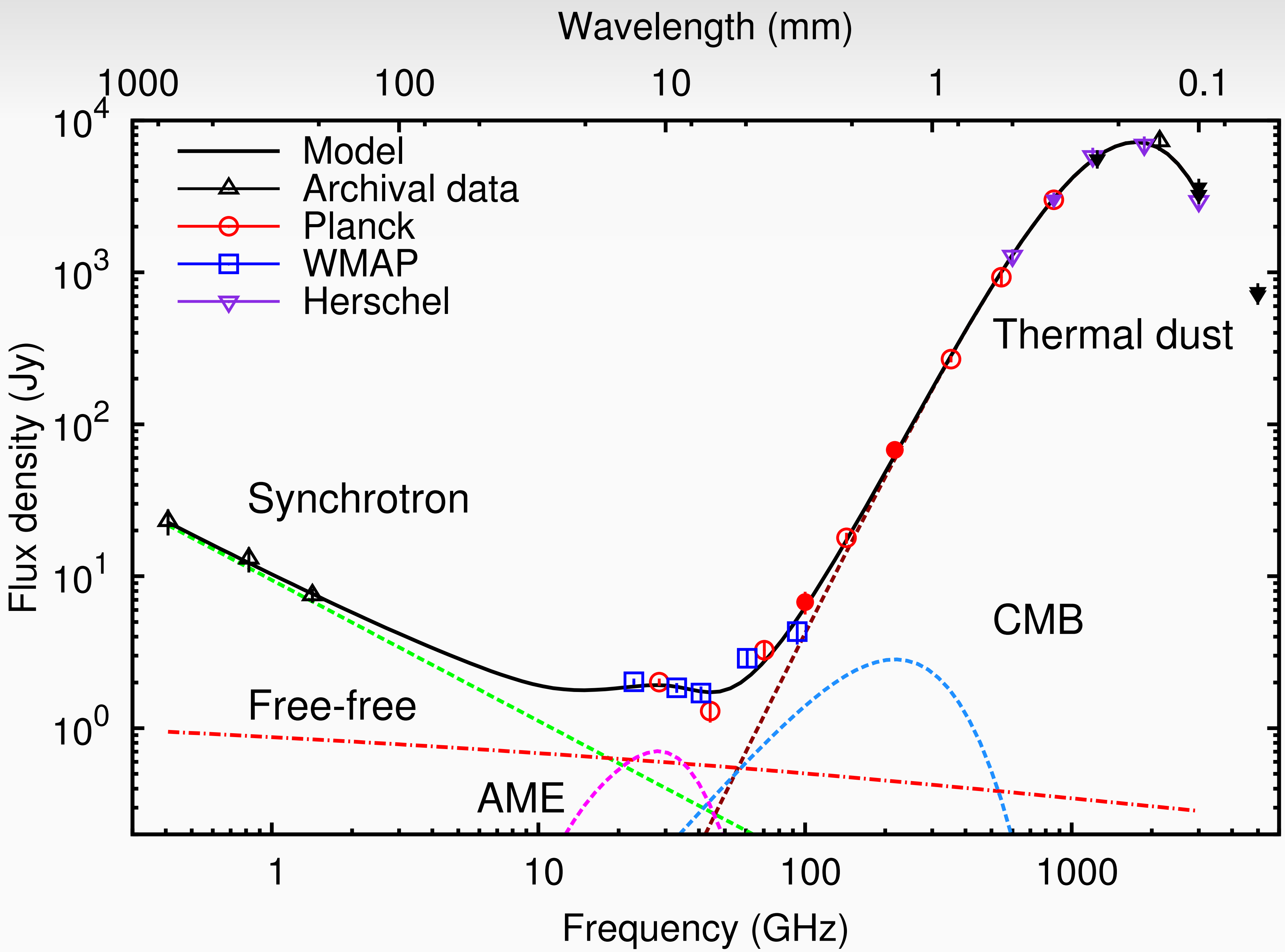


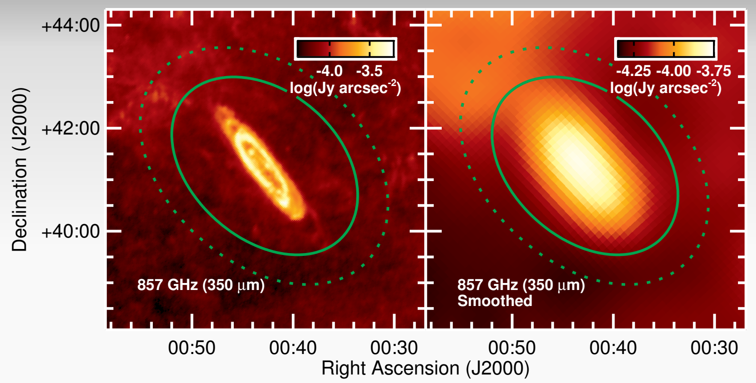
Excess in SMC
AME? But higher freq.

AME or something else?

Bot et al. (2010)
Planck Collaboration (2011), Early results XVII, arXiv:1101.2046

Other galaxies





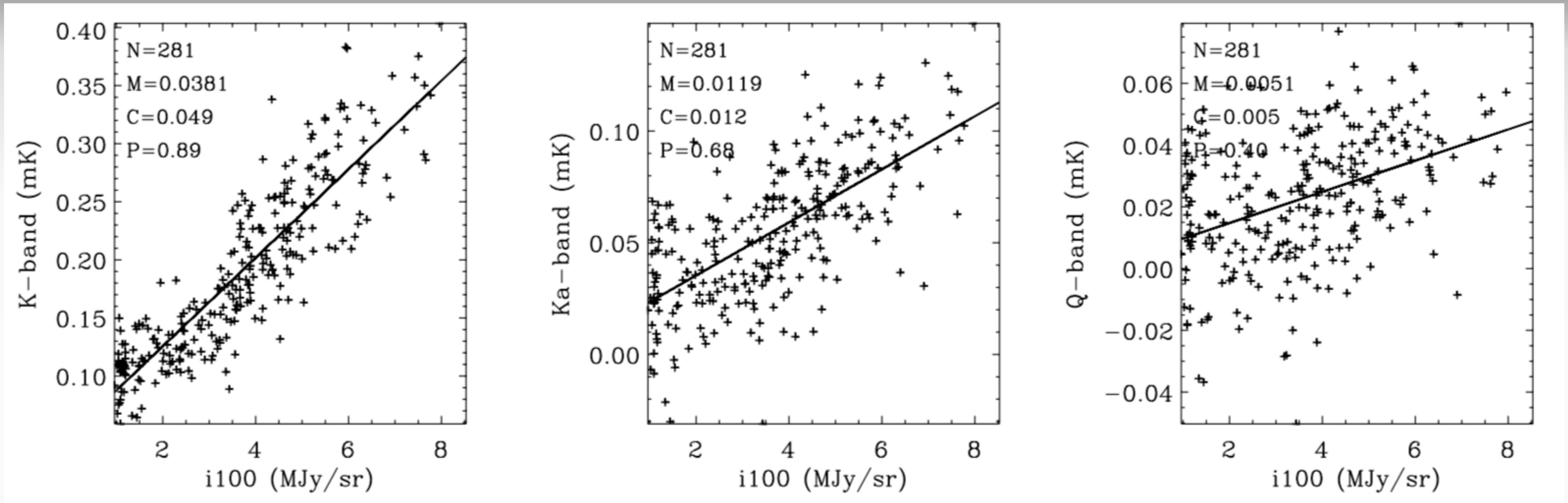
2.3 sigma

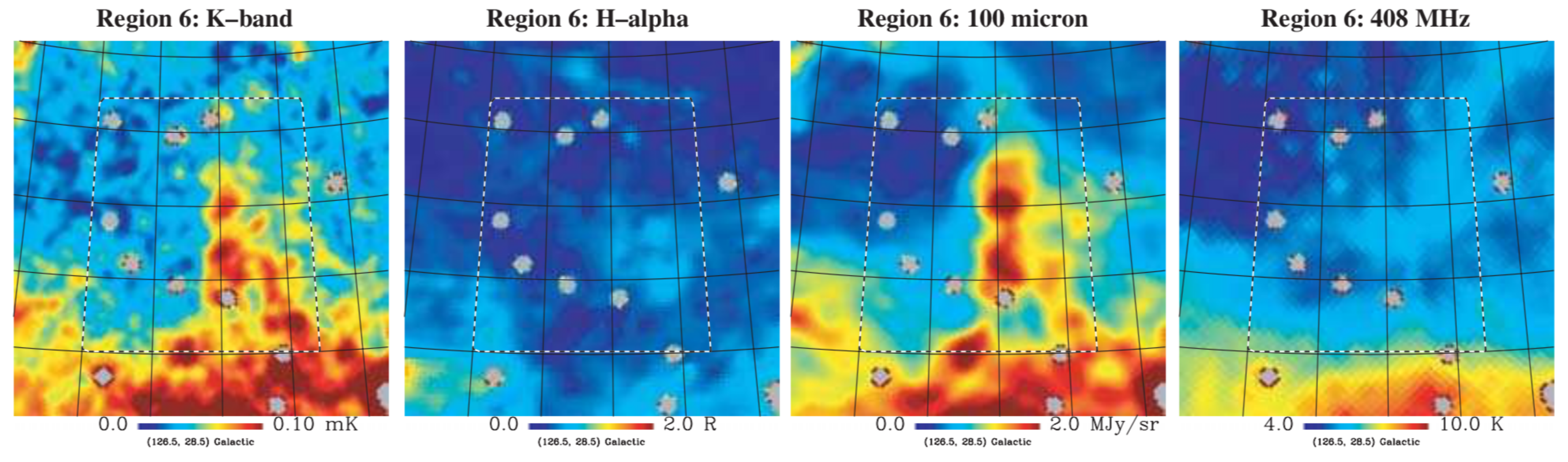
Difficult to see
in integrated SED

(Upper limits only in
NGC253, M82, NGC4945)

Planck Collaboration (2015), Intermediate XXV, arXiv:1407.5452

TT plots / template fitting

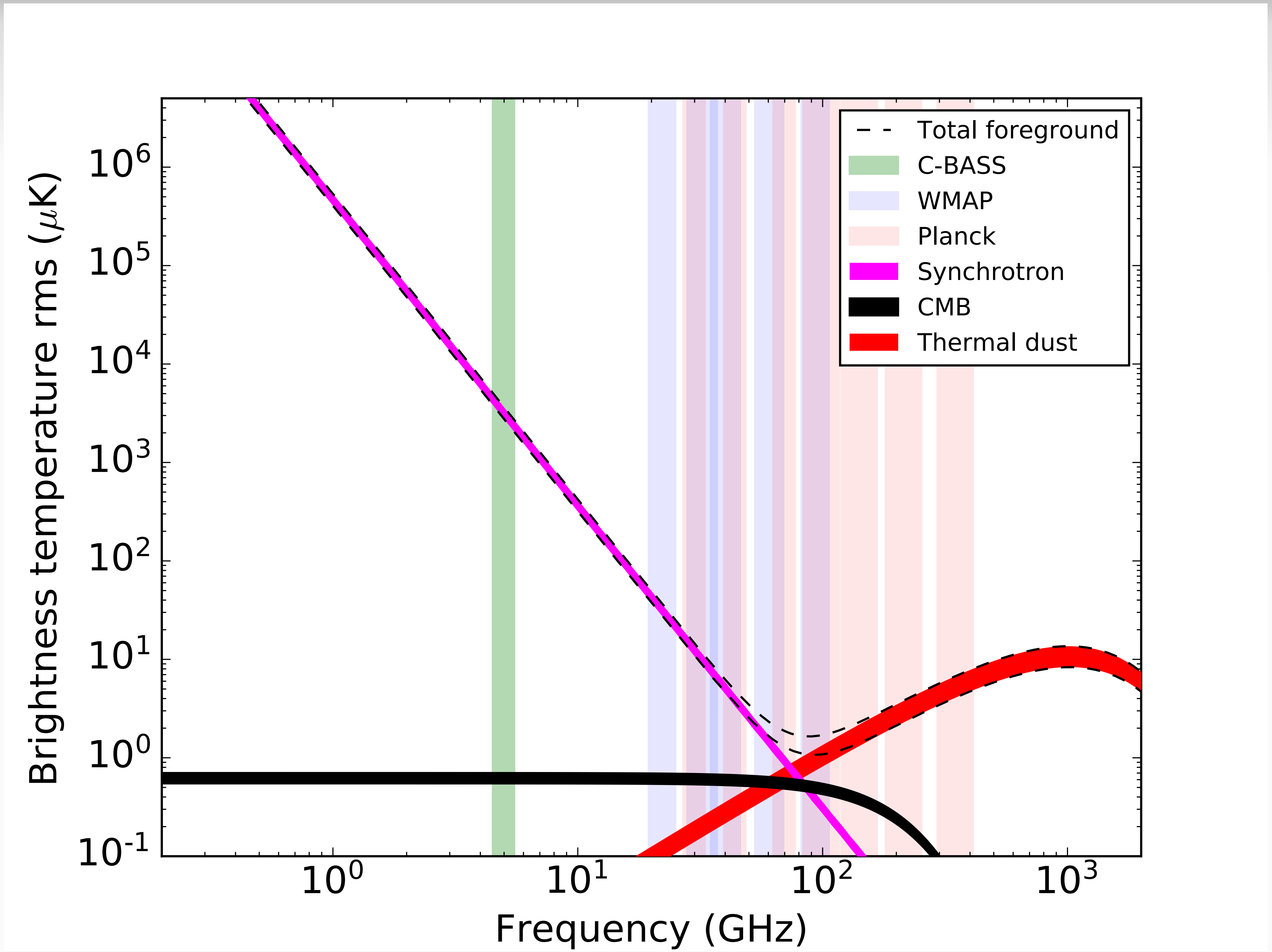




Davies et al. (2006)

Polarisation

On average in the sky

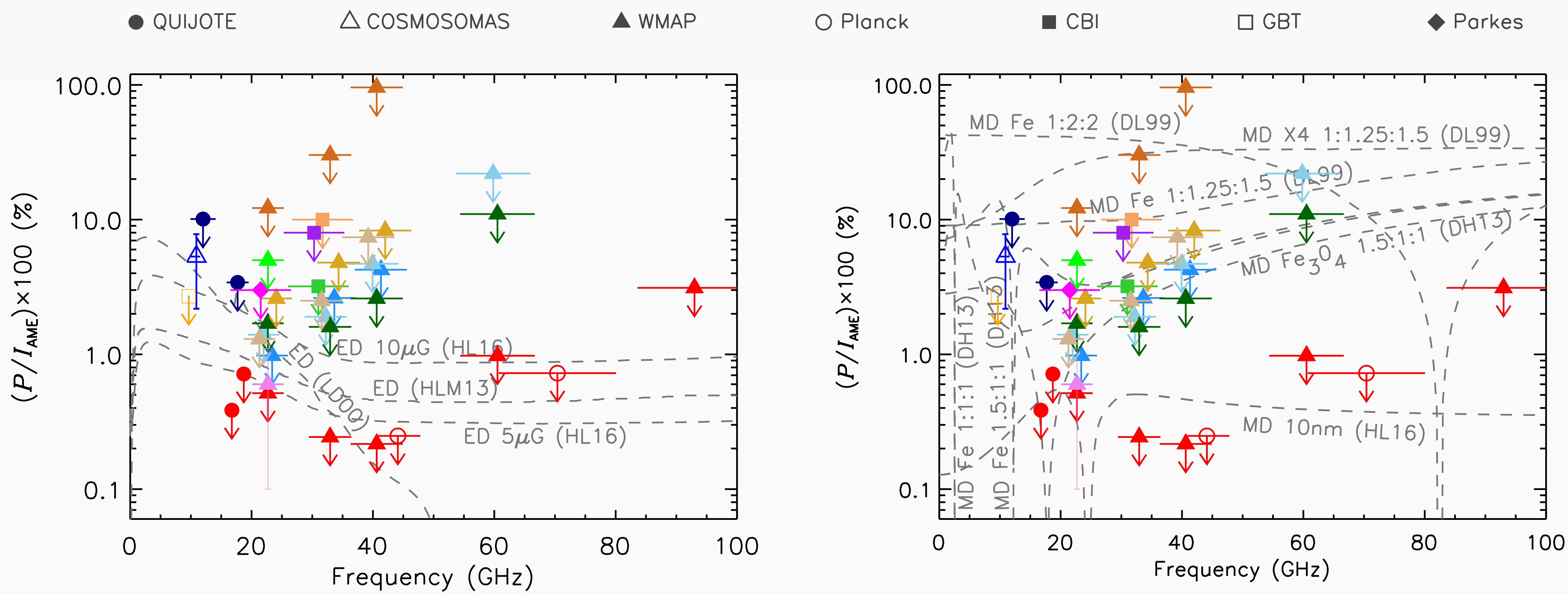


Might be important fg when detecting CMB B-modes?

Constrain dust models

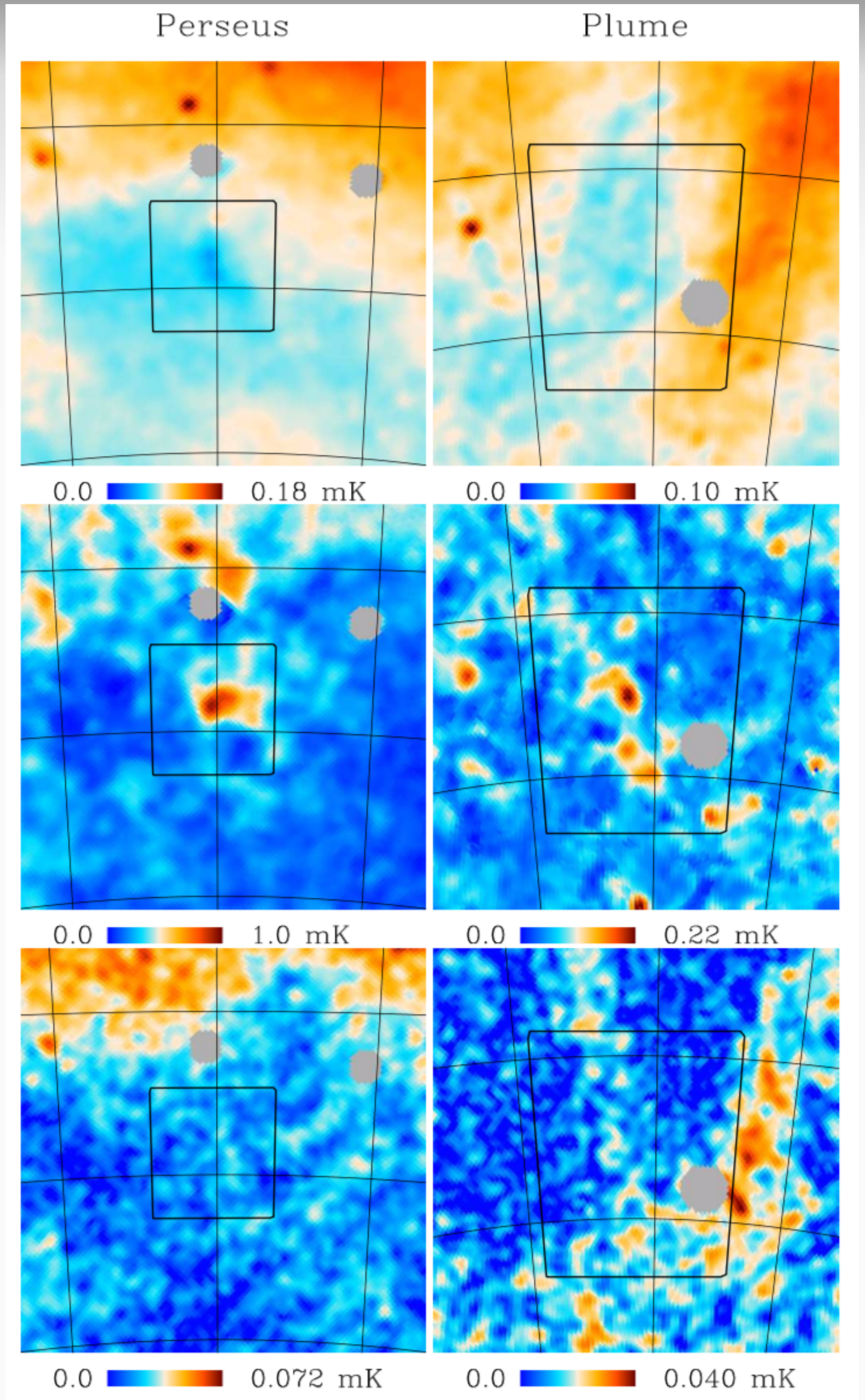
Jones et al. (2018), 1805.04490, based on Planck Collaboration (2015/6), X, arXiv:1502.01588

Upper limits

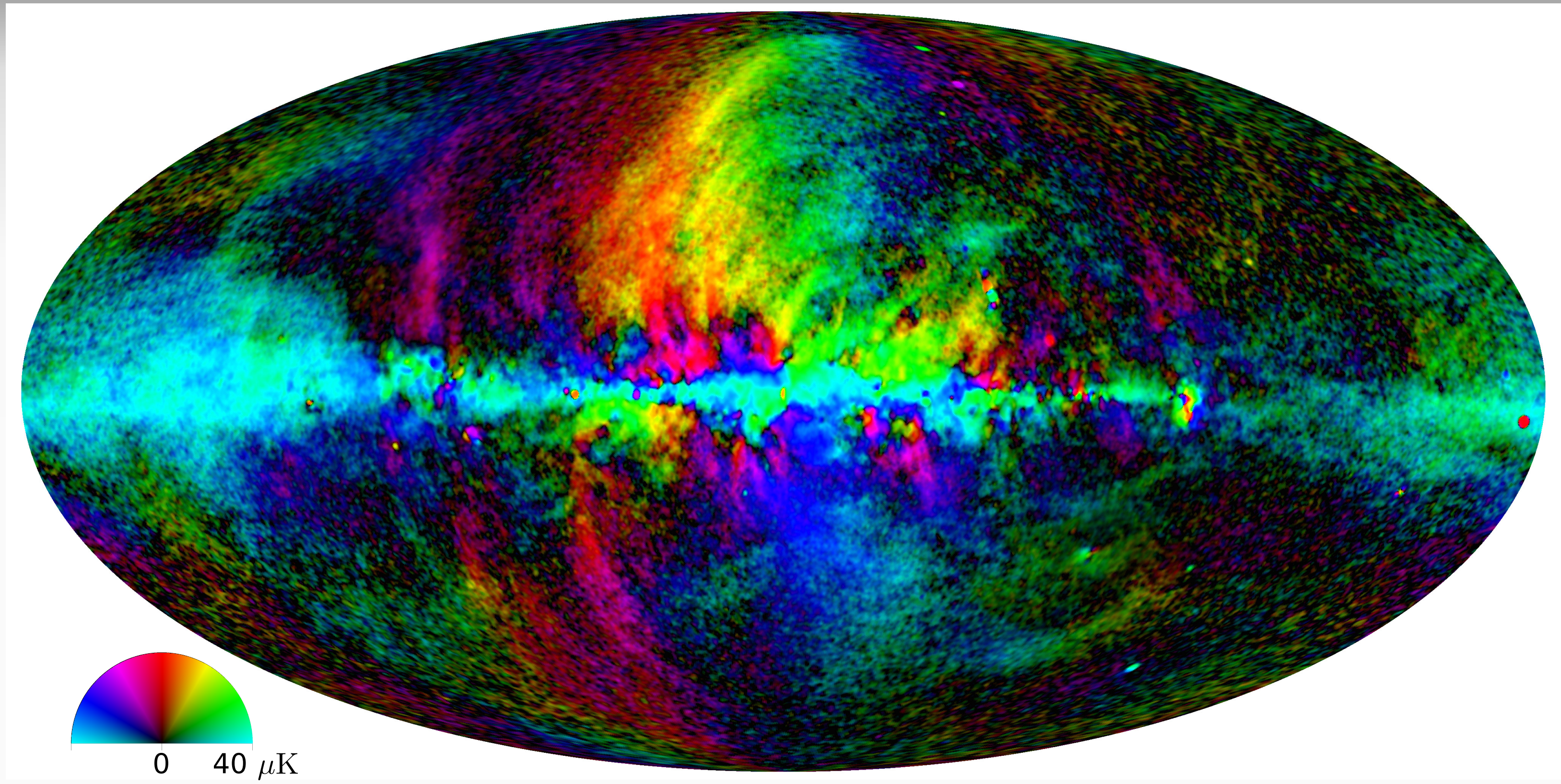


Génova-Santos et al. (2015, 17)

Beware of synchrotron spurs!



Sync, AME, pol



Cover large amounts of the sky

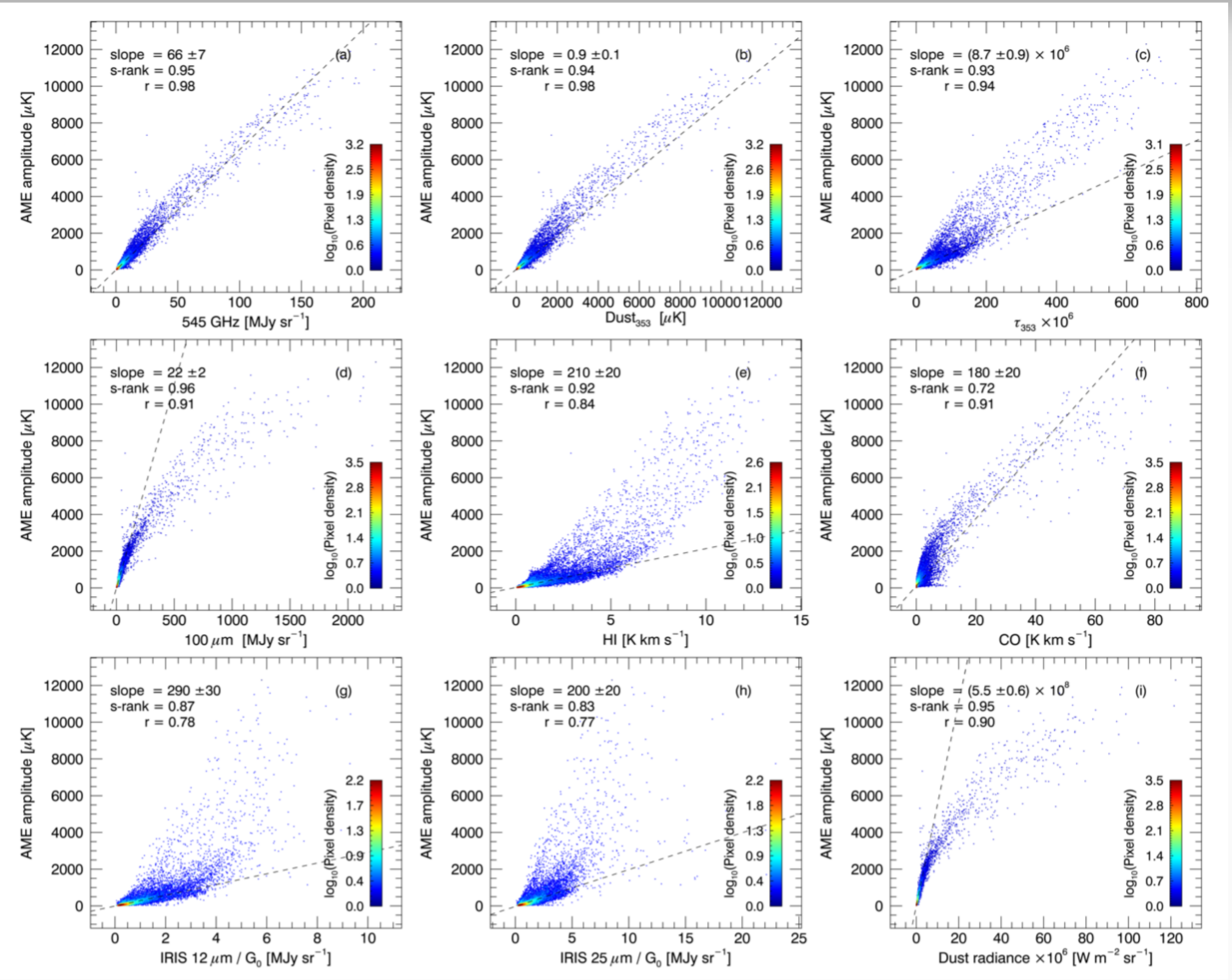
Don't all have the same % polarisation!

(See talks later today for more info!)

Planck Collaboration (2015/6), XXV, arXiv:1506.06660

Open questions

Correlations?



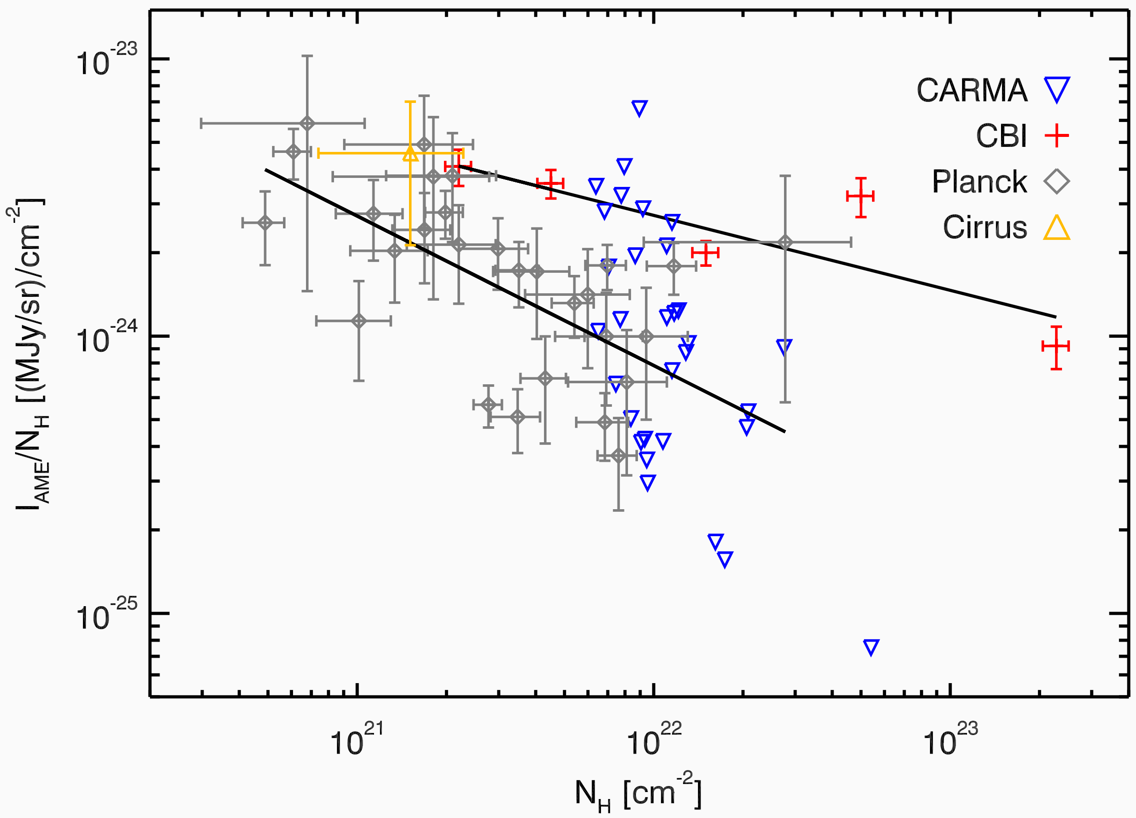
Cold dust
Radiance
8um
PAHs
nanodiamonds
…

(not 100um: temperature effects)

Planck Collaboration (2015/6), XXV, arXiv:1506.06660

Emissivities

Sky region	Freq. (GHz)	AME emissivity	Units	Template	Reference
WMAP Kp2 mask (85% sky)	22.8	21.8 ± 1.0	μK/(MJy/sr)	100 μm (IRIS)	Davies et al. (2006)
$\|b\| > 10°$	22.8	21 ± 2	μK/(MJy/sr)	100 μm (IRIS)	Planck Collaboration et al. (2016d)
Perseus	22.8	24 ± 4	μK/(MJy/sr)	100 μm (IRIS)	Planck Collaboration et al. (2014d)
ρ Oph W	22.8	8.3 ± 1.1	μK/(MJy/sr)	100 μm (IRIS)	Planck Collaboration et al. (2014d)
32 source mean	22.8	32 ± 4	μK/(MJy/sr)	100 μm (IRIS)	Planck Collaboration et al. (2015b)
Diffuse HII regions	33	4.65 ± 0.40	μK/(MJy/sr)	100 μm (IRIS)	Todorović et al. (2010)
$\|b\| > 10°$	22.8	9.7 ± 1.0	$10^6\,\mu$K	τ_{353} (*Planck*)	Planck Collaboration et al. (2016d)
Perseus	28.4	12.3 ± 1.2	$10^6\,\mu$K	τ_{353} (*Planck*)	Planck Collaboration et al. (2014d)
ρ Oph W	28.4	23.9 ± 2.3	$10^6\,\mu$K	τ_{353} (*Planck*)	Planck Collaboration et al. (2014d)
26% high latitude sky	30	7.9 ± 2.6	$10^6\,\mu$K	τ_{353} (*Planck*)	Hensley et al. (2016)
$\|b\| > 10°$	22.8	70 ± 7	μK/(MJy/sr)	545 GHz (*Planck*)	Planck Collaboration et al. (2016d)
26% high latitude sky	30	6240 ± 1210	MJy/sr /(W/m^2/sr)	(*Planck*) ($\mathscr{R}$)	Hensley et al. (2016)
26% high latitude sky	30	271 ± 89	μK/(MJy/sr)	12 μm (WISE)	Hensley et al. (2016)



Range of emissivities

Trend for lower emissivity with higher column densities

Ongoing/future observations

S-PASS, C-BASS, QUIJOTE, AMI
COMAP?
SKA (high-freq)?
ALMA (low-freq)?

+ GBT, VLA, Effelsberg, Parkes, …

Key facts

- Appears at 10-60GHz, with peaked spectrum
- Peak frequency ~ 30GHz, but can be ~50GHz

  (in flux density)
- Dust-correlated (best correlation unclear)
- Diffuse (on large not small angular scales)
- Weakly polarised (<1%)
- Appears in our Galaxy, + at least 1 extragalactic
- In HII regions, dark clouds, … maybe SNe, PNe?
- Spinning dust, magnetic dust, … -> next talk

An optimum strategy?

In summary, the optimal strategy that will allow moving forward with AME research is a combination of the following:

1. A set of observables and clear predictions from models, allowing to bridge the gap between theory and observations;
2. Systematic observations of statistically representative samples of astrophysical classes of sources (e.g., PDRs, cold cores, nearby galaxies) that allow investigating correlations between AME (e.g., peak intensity, peak frequency) and quantities that regulate the physics of the observed sources (e.g., radiation field intensity, density, abundance of dust grains, gas species abundance);
3. Within a given astrophysical class of objects, targeted observations of sources whose properties are well known from prior investigations and for which a plethora of ancillary data exist, thus allowing careful modelling and interpretation of the observations.