Extragalactic Astronomy & Cosmology

Highlights 2011-2012

Who ?

- Academic staff
  Richard Battye, Michael Brown, Clive Dickinson, Neal Jackson, Scott Kay, Paddy Leahy, Shude Mao

- PDRAs
  Mike Peel, Melanie Gendre, Bob Watson, Anna Bonaldi, Fabio Noviello (+ 4 to be appointed soon)

- Students
  Rick Newton, Simon Pike, Sam Cusworth, Chris Wallis, Lee Whittaker, Kostantinos Demetroullas, Stuart Harper, Mel Irfan, Mattias Vidal, Kake Voller, Mareike Haberichter, Edward Reeves, Philippa Hartley, Indy Leclercq, Rach Bhatawdekar, Carl Roberts, Jonathan Quinn

- Visitors
  Dick Long, Magda Todorovic

- Associates

  National Facility and ALMA staff: Rob Beswick, Simon Garrington, Tom Muxlow, George Bendo, Anita Richards
  Emeritus: Rod Davies, Alan Pedlar, Ian Browne
  Technology & SKA: Richard Davis, Peter Wilkinson, Giampaolo Pisano, Bruno Maffei, Lucio Piccirillo, Althea Wilkinson, Richard Schilizzi

What do we do ?

- 3 main goals :

  - fundamental cosmology;

  - gravitational lensing (strong and weak);

  - astrophysical processes : star, galaxy and cluster formation; AGNs & SMBH;

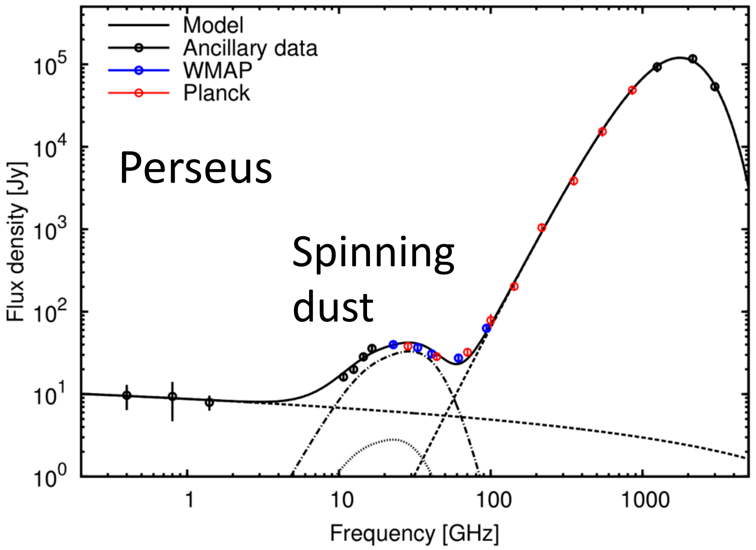
  - galactic foregrounds.

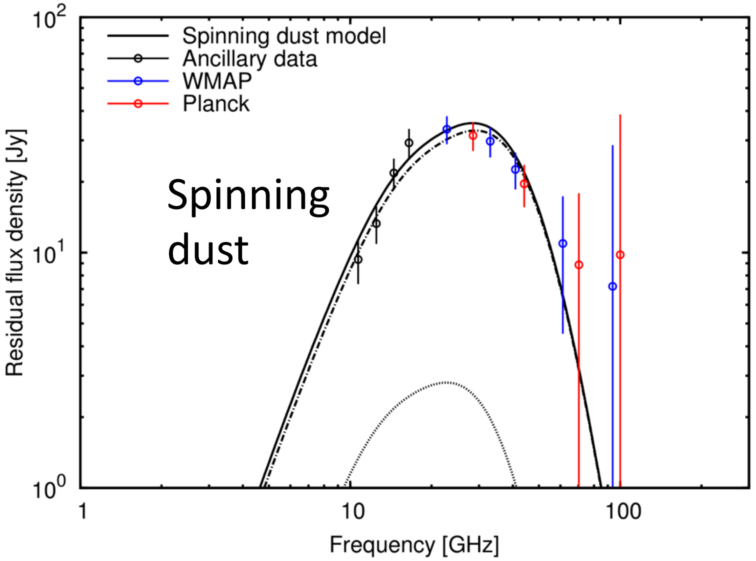
- Observation and theory working together to strengthen both

Planck early paper on AME

Planck collaboration et al. (2011), A&A, 536, A20
Corresponding author: Clive Dickinson

- Accurate SEDs of diffuse Galactic clouds from 408 MHz to 3000 GHz
- Definitive evidence for spinning dust in Perseus and ρ Ophiuchi molecular clouds
- Well-fitted by spinning dust models peaking at ~30 GHz
- First attempt at “realistic” physical modelling of ISM environment using SPDUST and 2 components
  - High density gas appears to dominate the spectrum
- 2 new AME regions identified

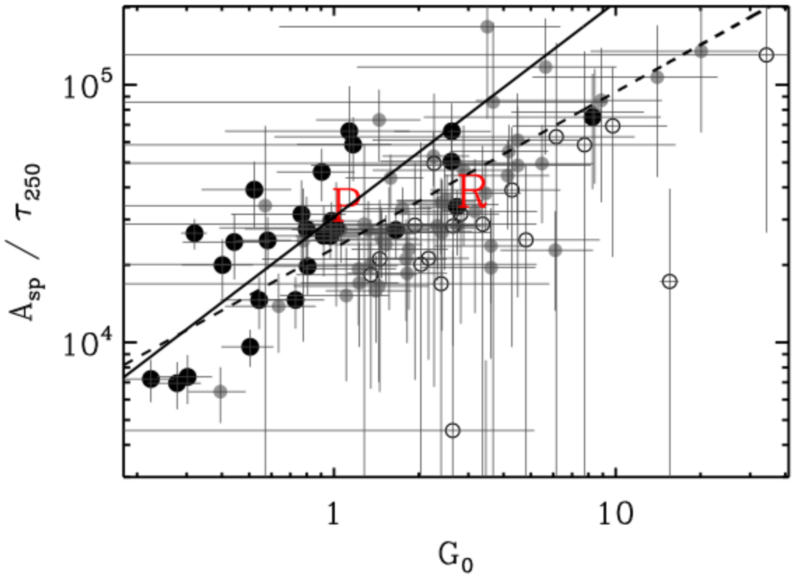


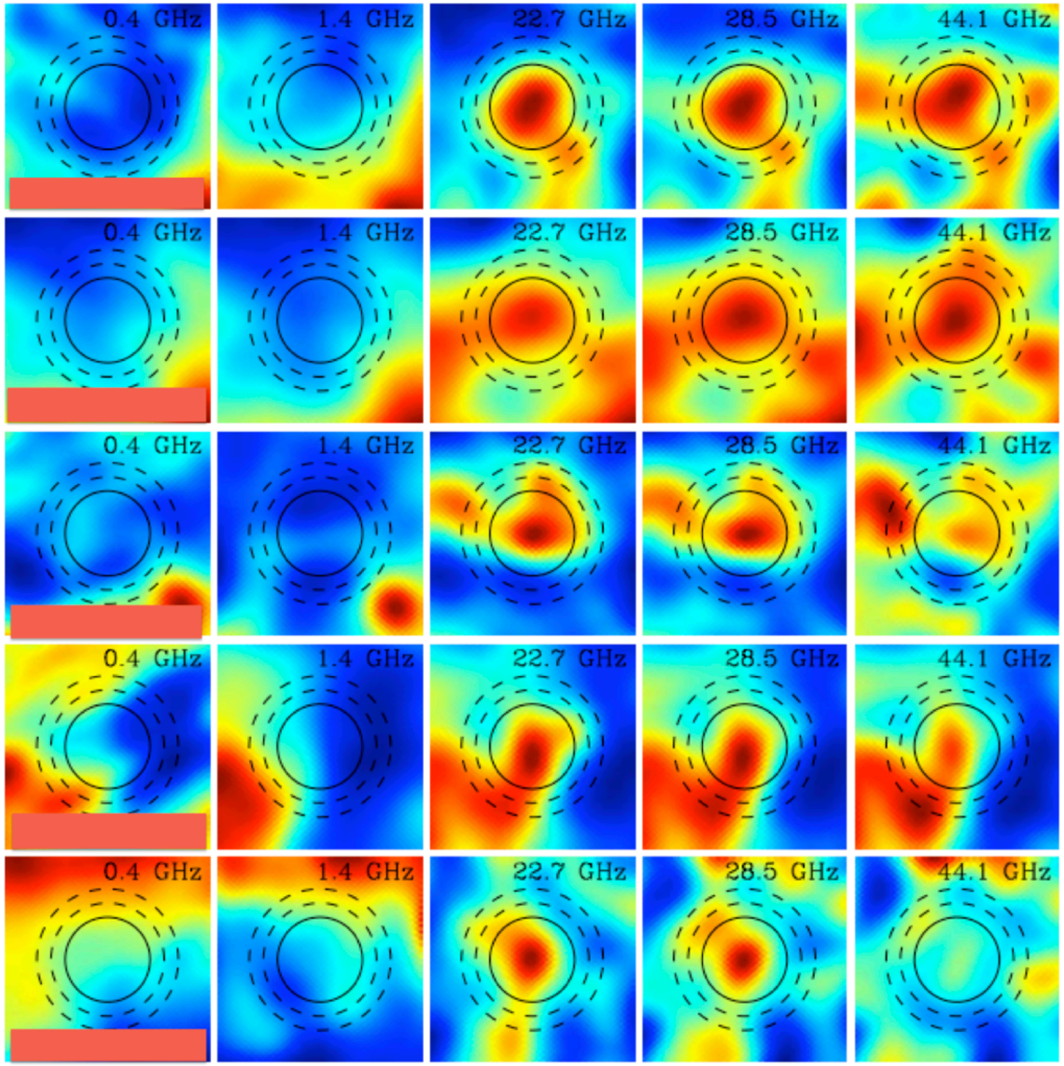


Planck intermediate paper

Planck collaboration et al. (to be submitted soon!)
Corresponding author: Clive Dickinson

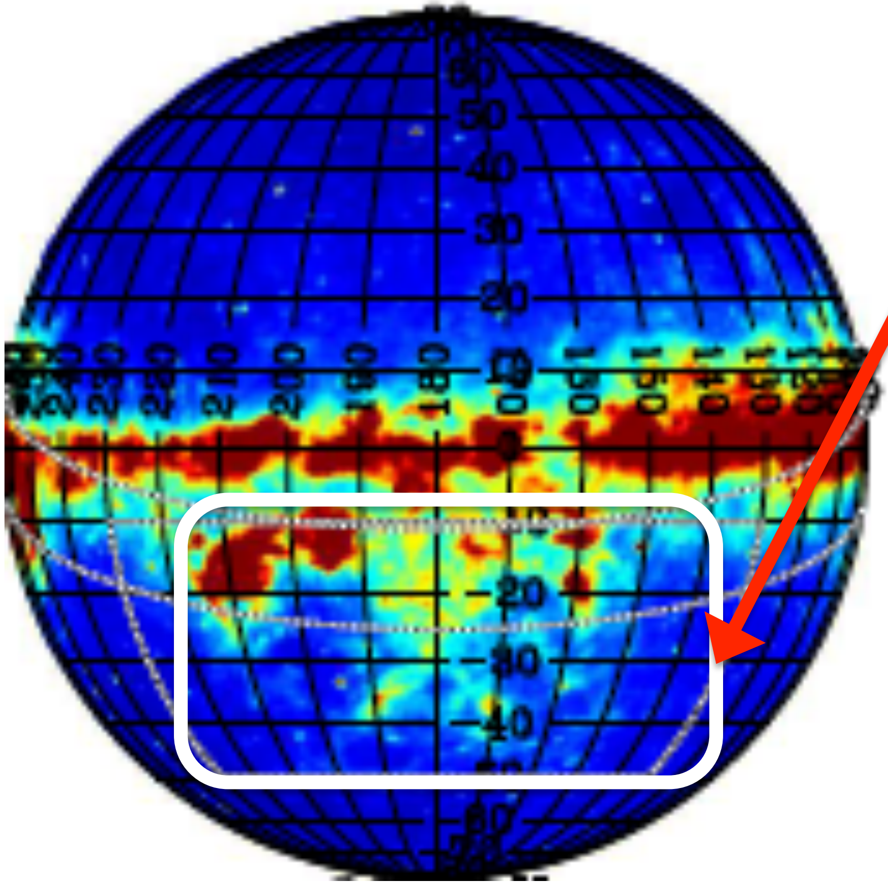
- Study ~100 bright diffuse Galactic clouds
- ~50 candidate AME regions
- ~25 show <u>very</u> significant AME
- Allows a statistical study to be made
- e.g. Correlation with strength of interstellar radiation field is observed (c.f. Tibbs et al. 2012)





Planck Intermediate Results: Diffuse Galactic components in the Gould Belt System

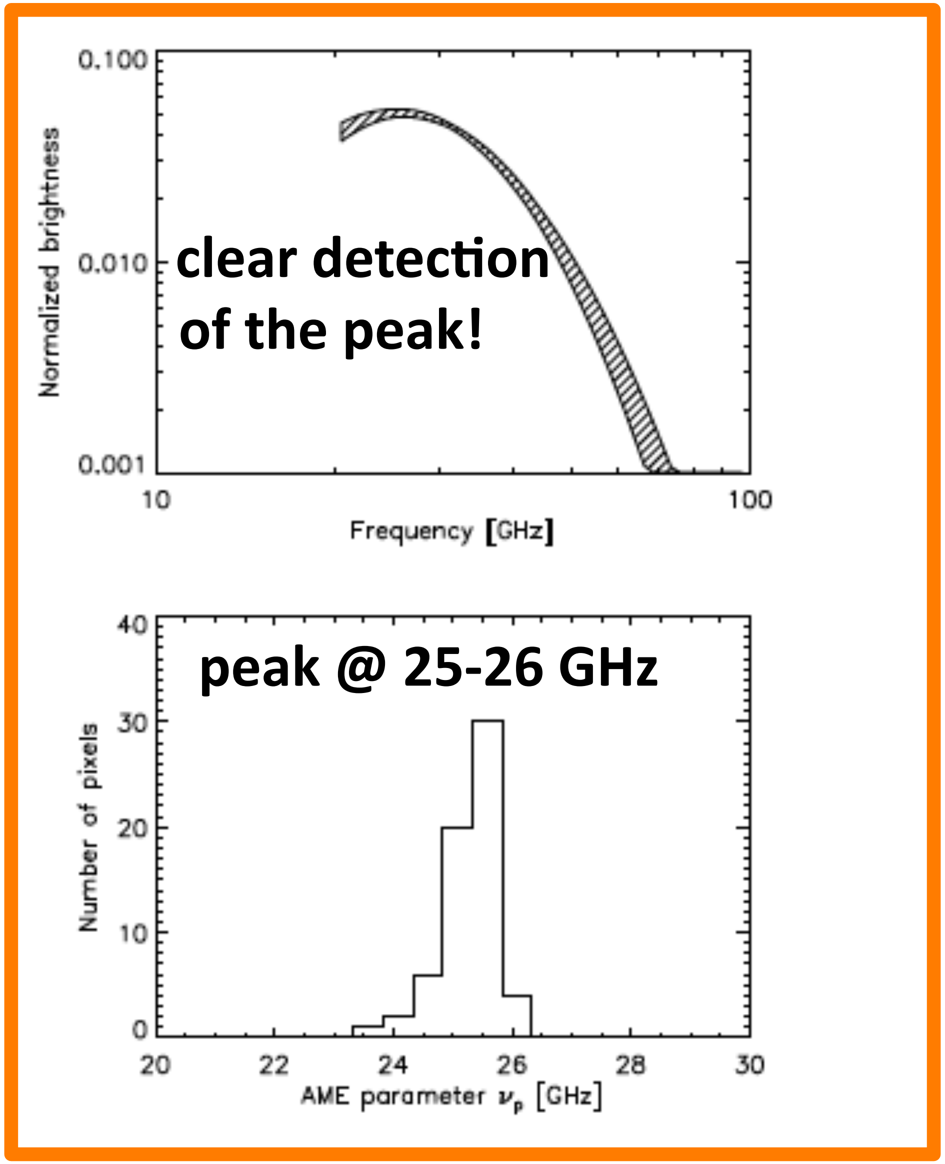
Planck Collaboration, Paper leader: A. Bonaldi
e-mail: anna.bonaldi@manchester.ac.uk



Gould Belt South: bright diffuse foregrounds from the local ISM
AME, synchrotron, dust, free-free

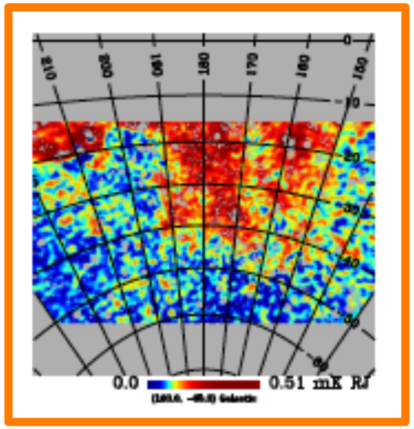
1) Component separation and analysis of the diffuse Galactic components
3) Understanding the physics of the Galactic emission
4) Improving CMB cleaning capabilities

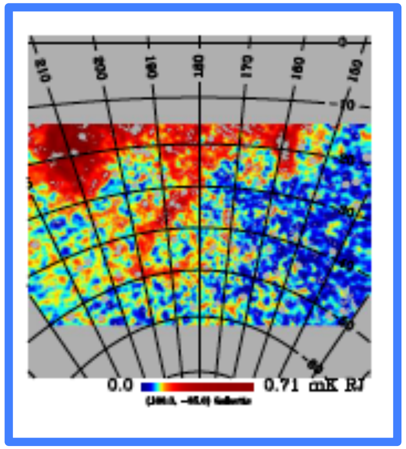
Anomalous microwave emission (AME)



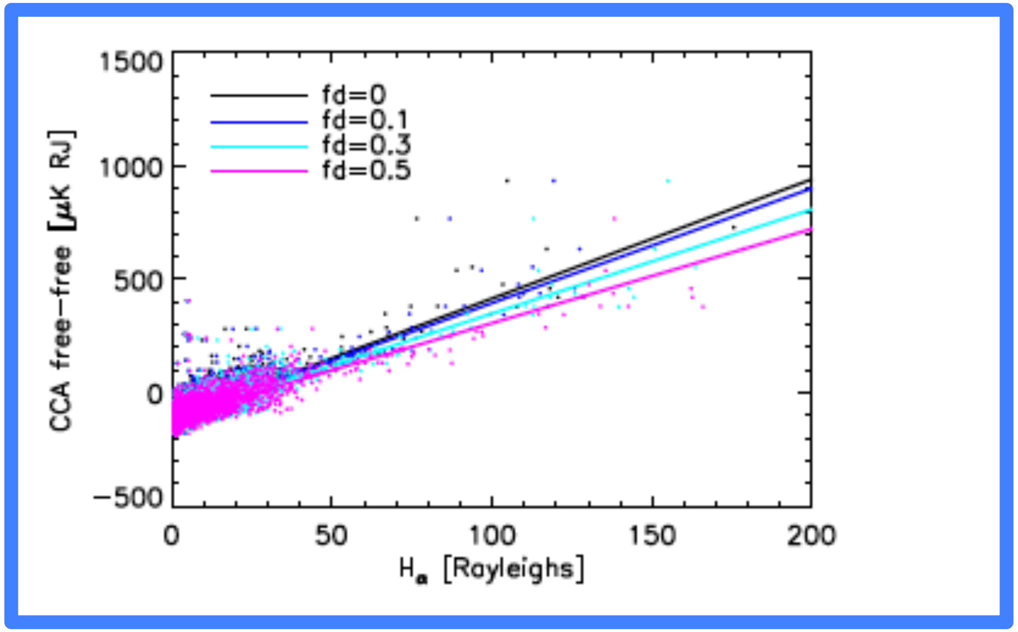
clear detection of the peak!

peak @ 25-26 GHz

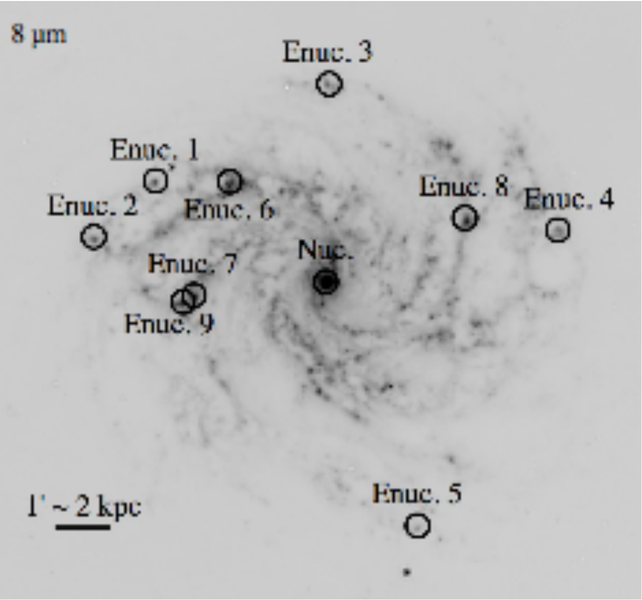




Free-free emission vs Hα

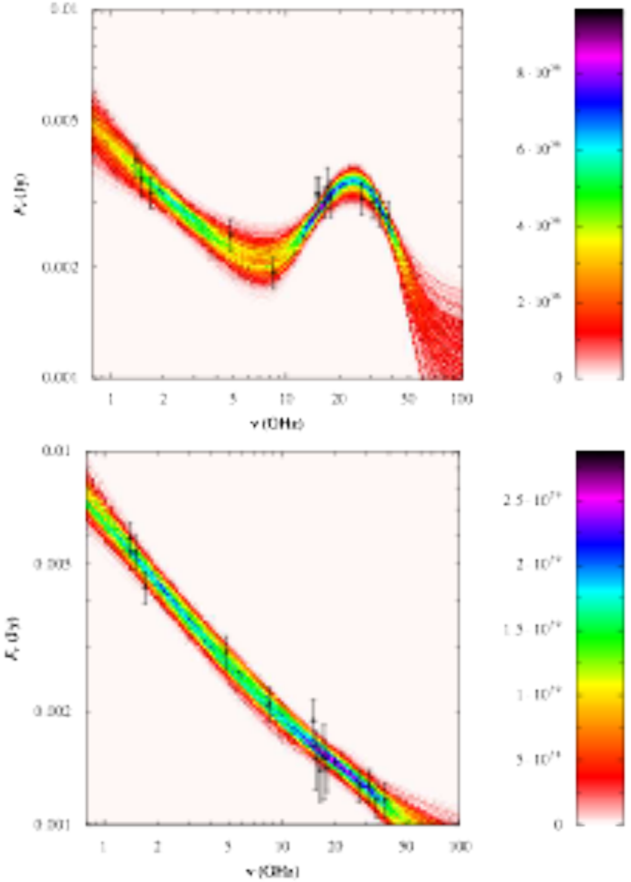


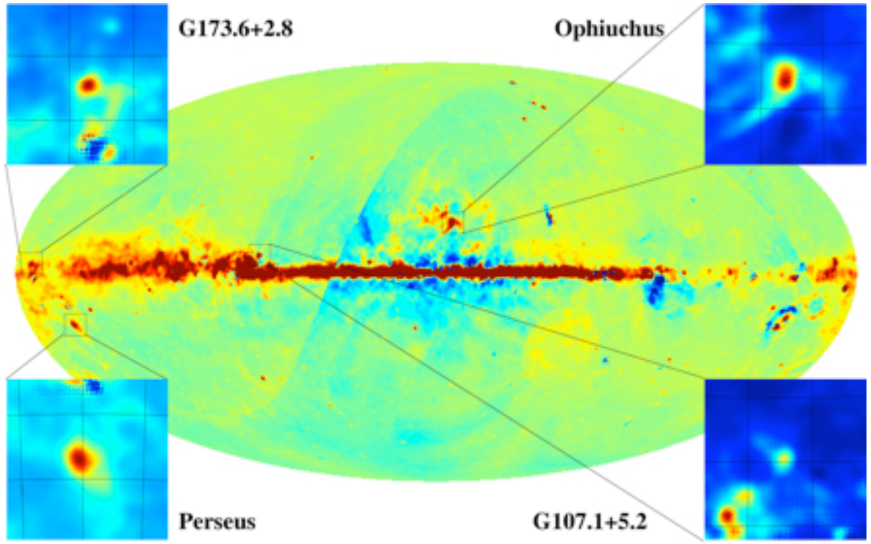
Electron temperature:
Te ~ 6000 K for fd=0
Te ~ 5000 K for fd=0.3
Te ~ 3500 K for fd=0.5

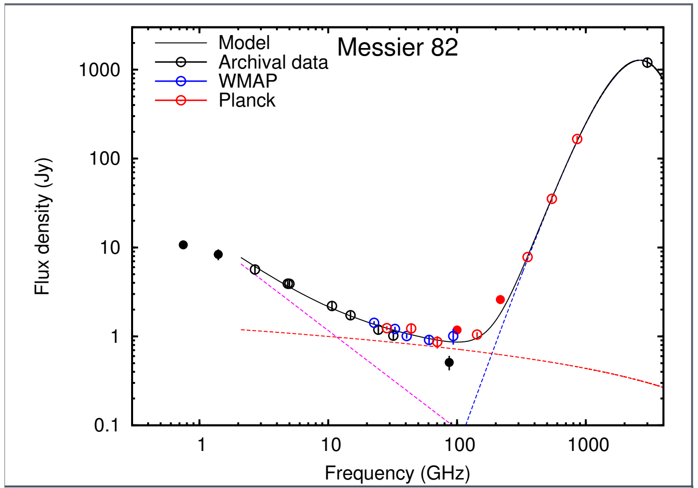


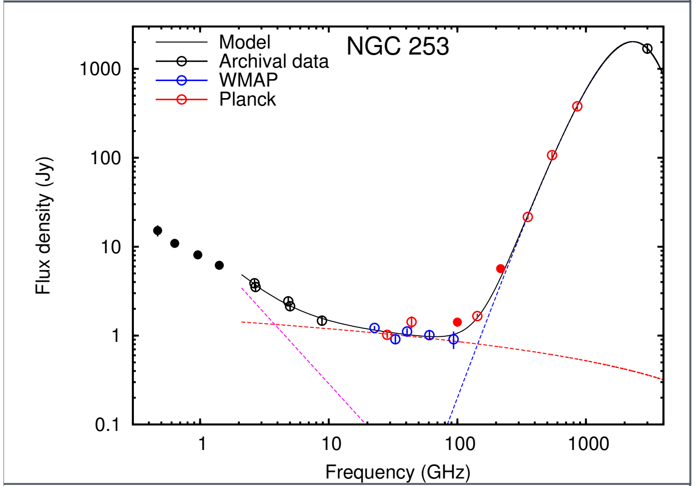
AME in nearby galaxies

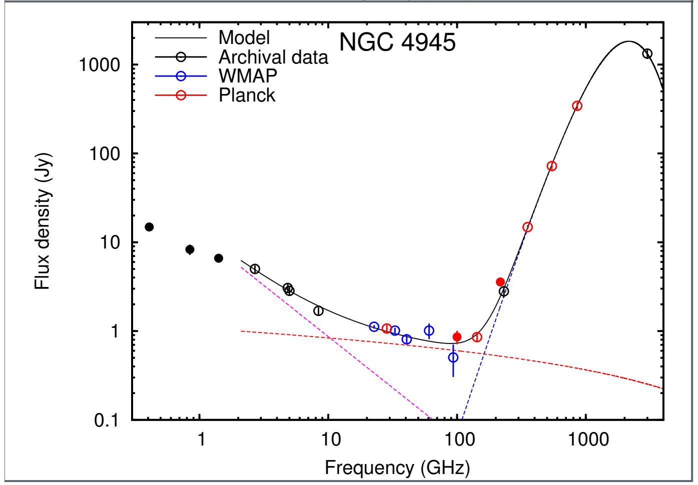
- AME is known in our Galaxy (see map below)
  ~40% of 30GHz emission
  ~1/3000th of 100um thermal dust emission
- Only one known extragalactic example, NGC4946
- Discovered by Murphy et al. (2010) with GBT
  Confirmed by Scaife (2011) with AMI
- Only in 1 of 10 star-forming regions measured
- But if it's a major component everywhere, should be able to see it in integrated galaxy spectra at ~30GHz
- So...











Spectra of late-type galaxies

M. Peel, C. Dickinson, R. Davies, R. Beswick, D. Clements

MNRAS Letters, 416, 99; arXiv:1105.6336

- Combine Planck, WMAP & ancillary data for 3 galaxies
- M82, NGC253, NGC4945 - star forming, IR-bright
- First complete spectra from radio to infrared
- Fit for synchrotron, free-free, thermal dust
- Steep synch spectra & cold dust emission (19-25K)
- Star formation rates more consistent than previous estimates (Niklas 1997)
- Don’t see significant AME (but hint in NGC4945?) Expect ~0.35-0.5Jy, residuals are <0.13-0.15Jy.
- AME patchy? Need more data on more galaxies.

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	...

FLUX VARITIONS IN M82

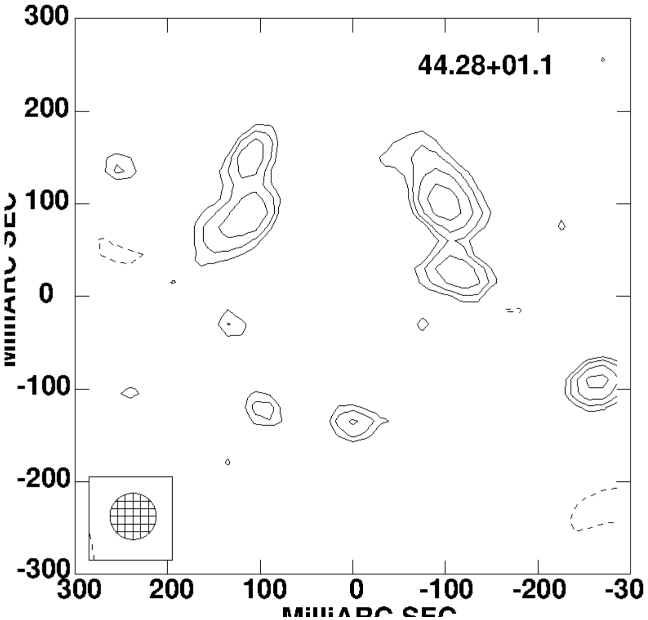
7 MERLIN + 1 eMERLIN C-band observations, combined to improve S/N for sources identification, with a total on source time = 286.5 hrs .

➔ 52 identified sources (including 3 new ones since 2002):

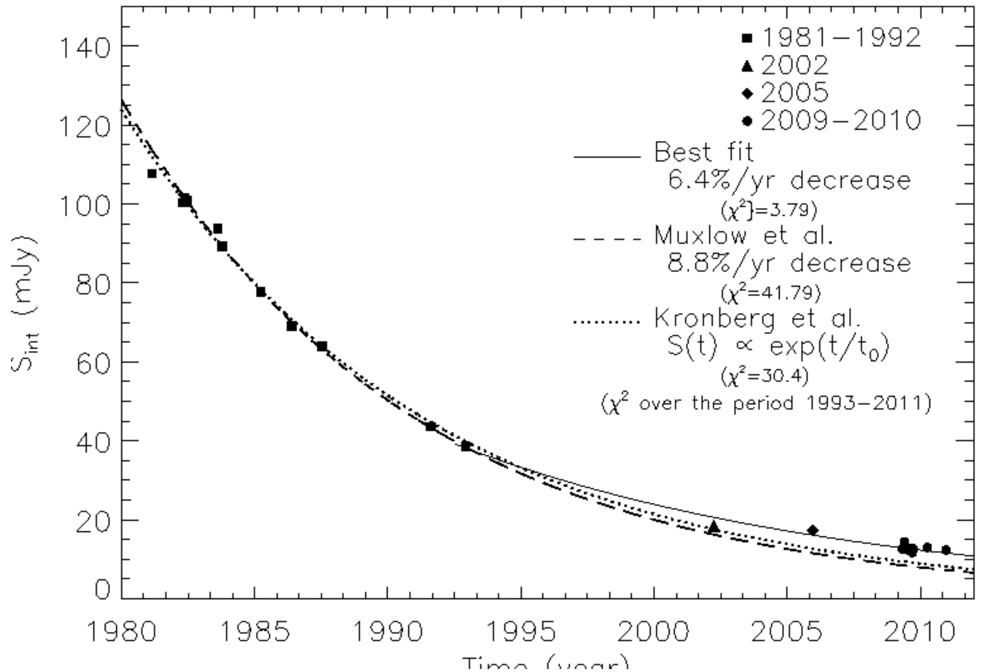
SN2008iz, transient & new SNR

➔ Includes a study of the variable source 41.95+57.5:

It appears that the continued decrease in flux density of 8.8%/yr has decreased to 6.4%/yr



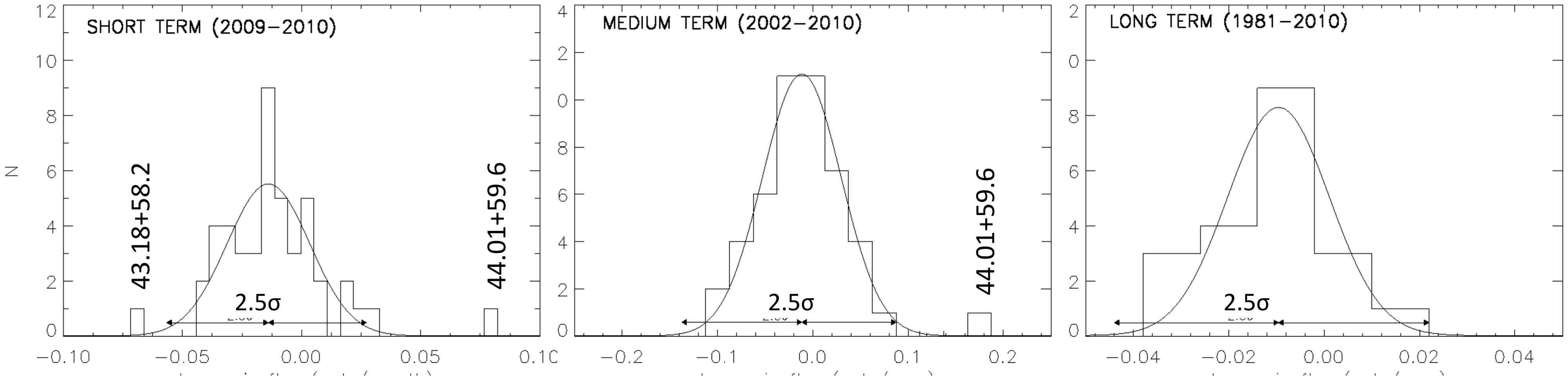
New SNR shell



Flux density decrease of 41.95+57.5

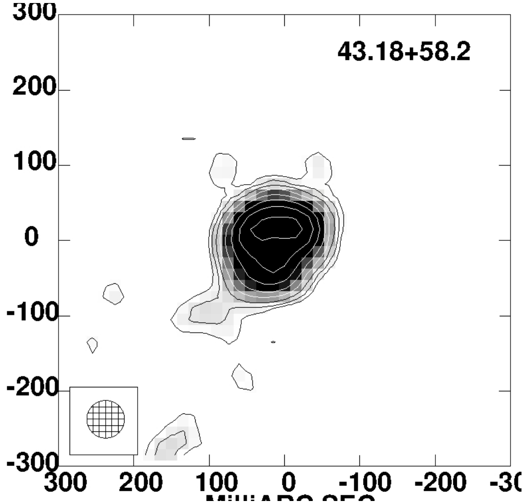
FLUX VARITIONS IN M82

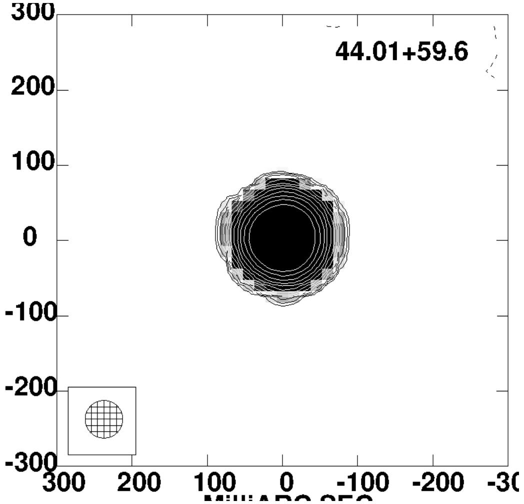
Measured slope of fitted line through light curves of all 52 sources and looked at the distributions in the short, medium and long term:



Two varying sources in the short and medium term: 43.18+58.2 & 44.01+59.6

Both are part of the most compact sources in M82 after SN2008iz & 41.95+57.5

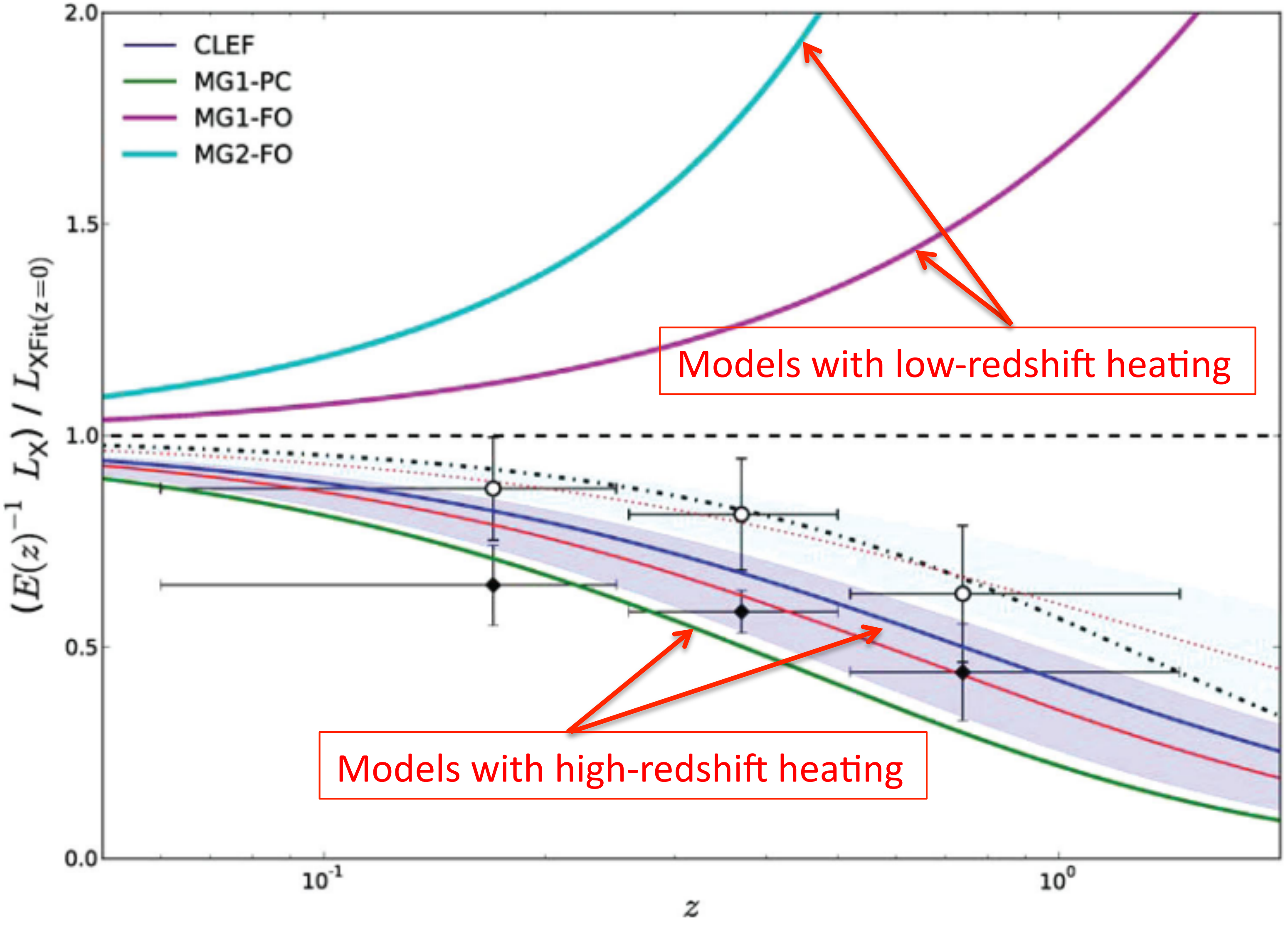




Evolution of X-ray L-T relation

XMM Cluster Survey data favours models with AGN feedback at high-redshift

Hilton et al. (XCS Consortium), 2012, MNRAS, 424, 2086



Models with low-redshift heating

Models with high-redshift heating

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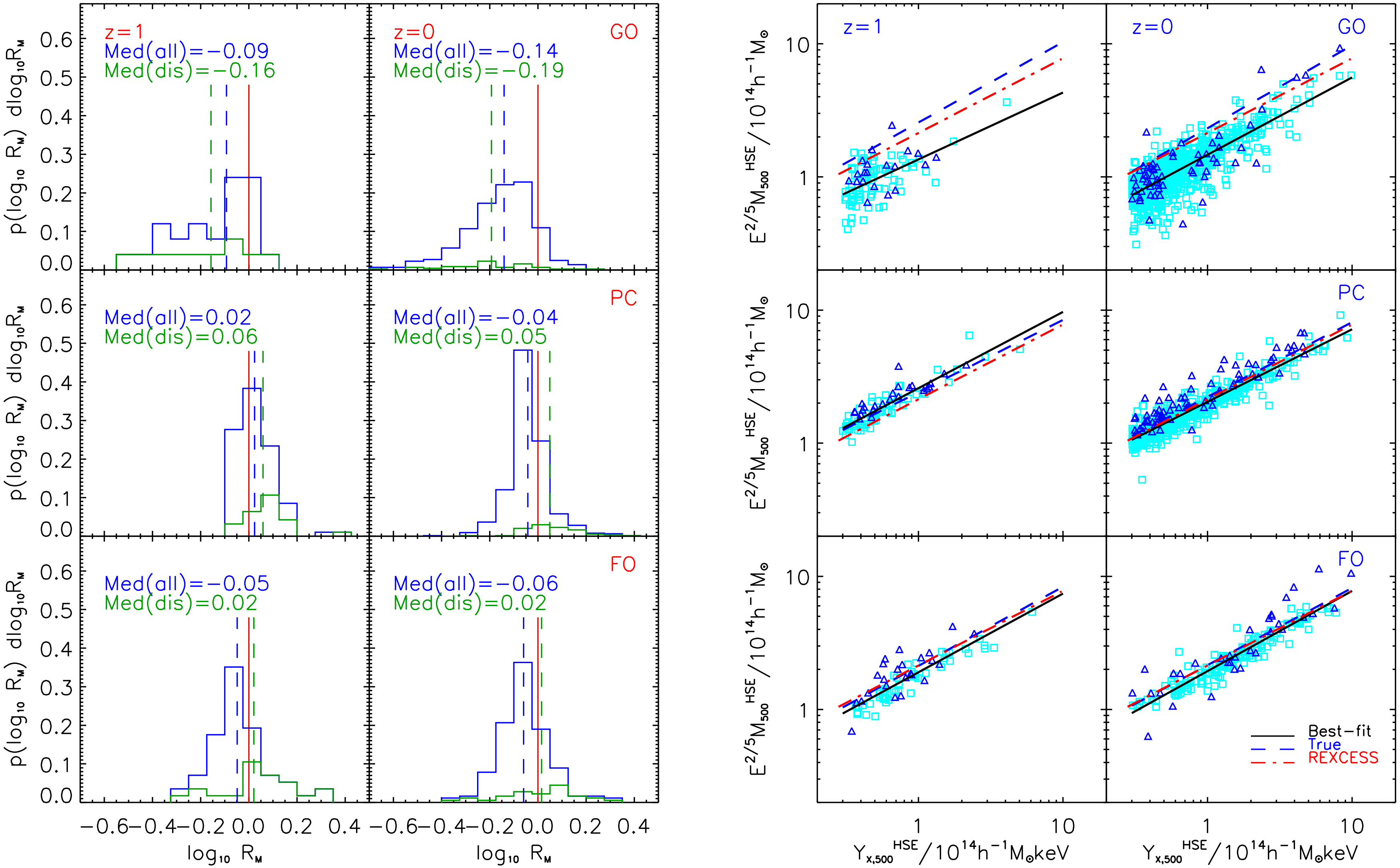
X-ray + SZ scaling relations

Hydrostatic bias (left) and its effect on M_{500}-Y_X relation (right)

Kay et al., 2012, MNRAS, 422, 1999



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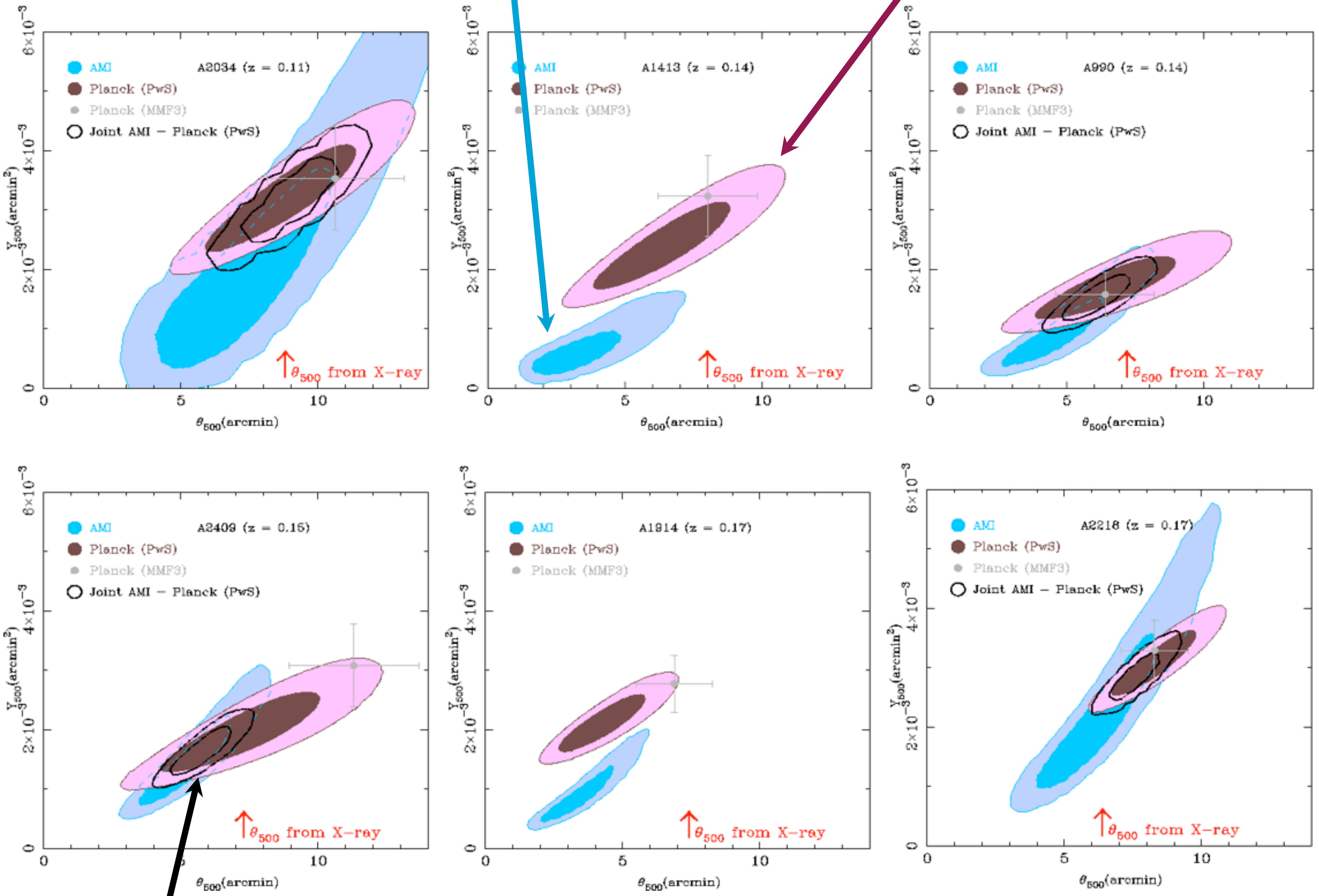
Results:

AMI constraints

Planck constraints

SZ flux

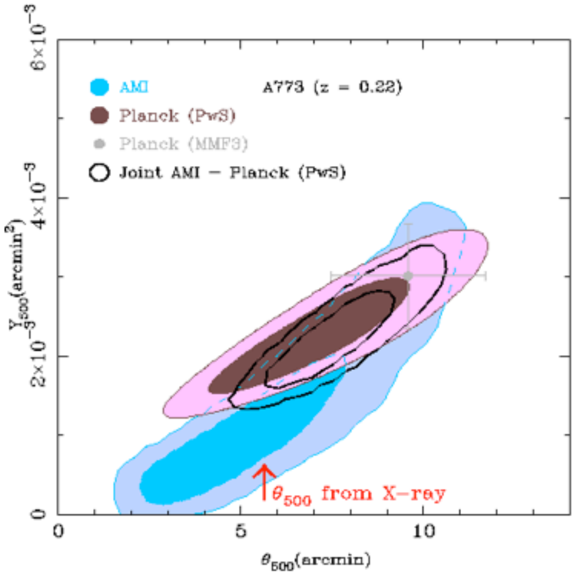


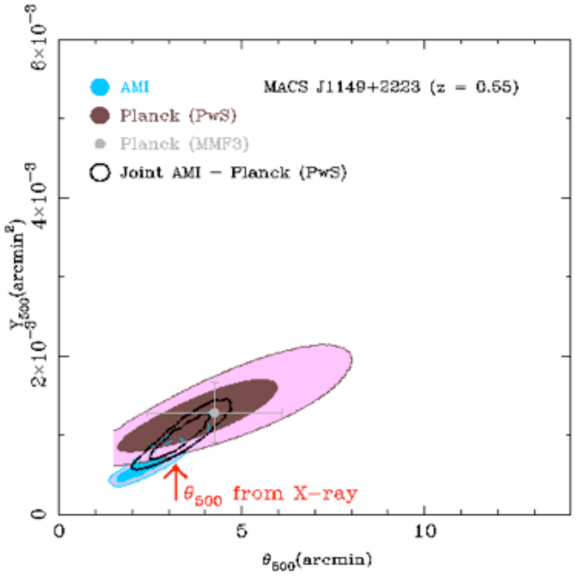
Joint constraints

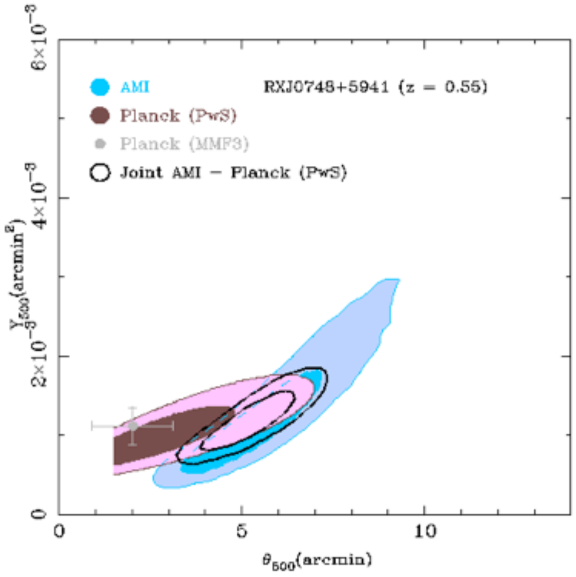
Angular size

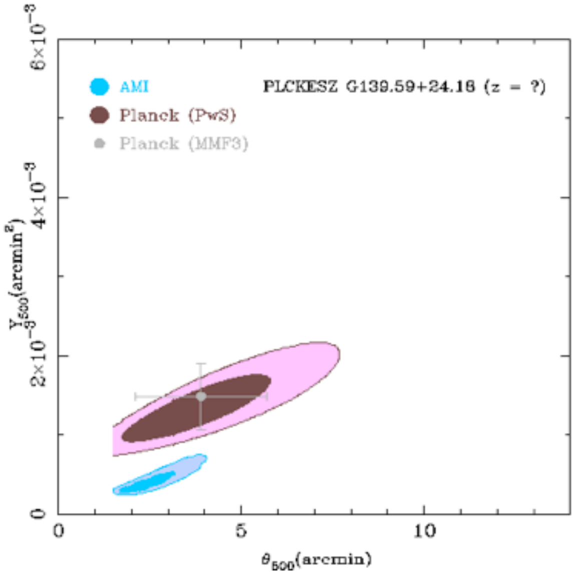
Results: AMI constraints *Planck* constraints

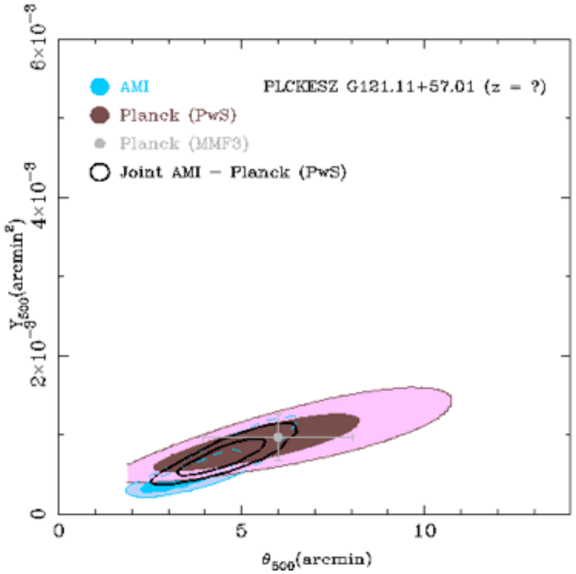
SZ flux









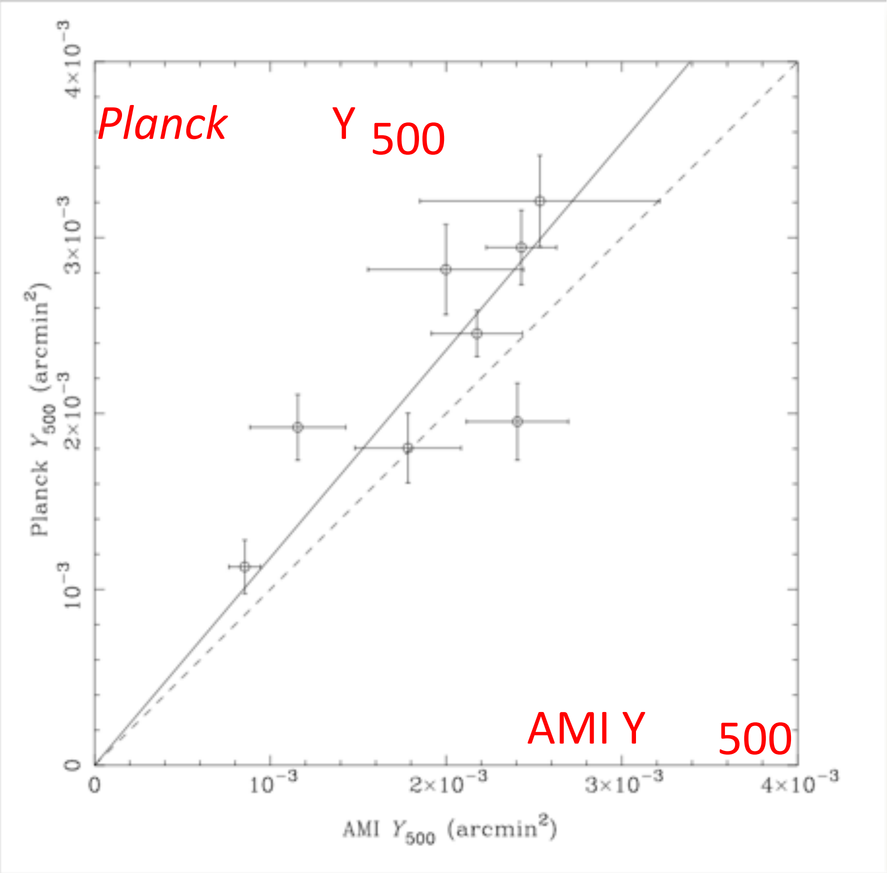


Angular size

Observations

- For three clusters (A1413, A1914 and PLCKESZ G139.59+24.18), *Planck* and AMI constraints are clearly discrepant.
- Significant overlap in posterior distributions for remaining eight clusters.

- Taken as an ensemble, AMI finds SZ signal to be, on average, smaller in extent and fainter than *Planck* finds.
- Where results are consistent overlap region provides tighter combined constraint.

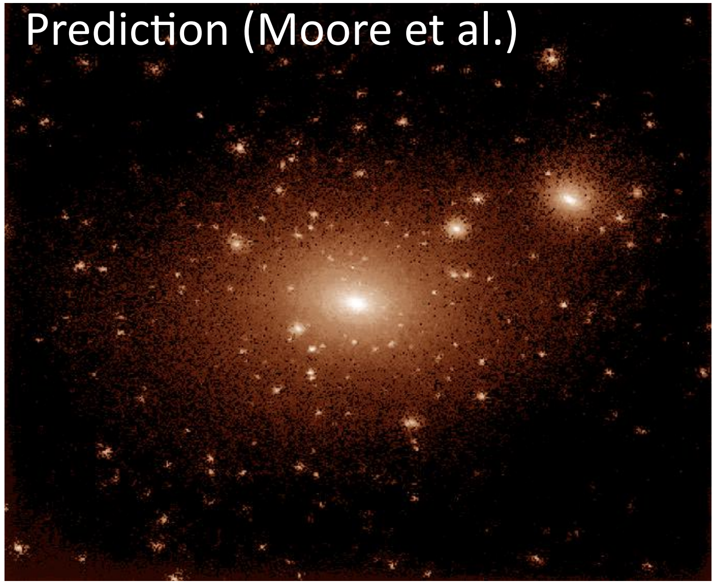


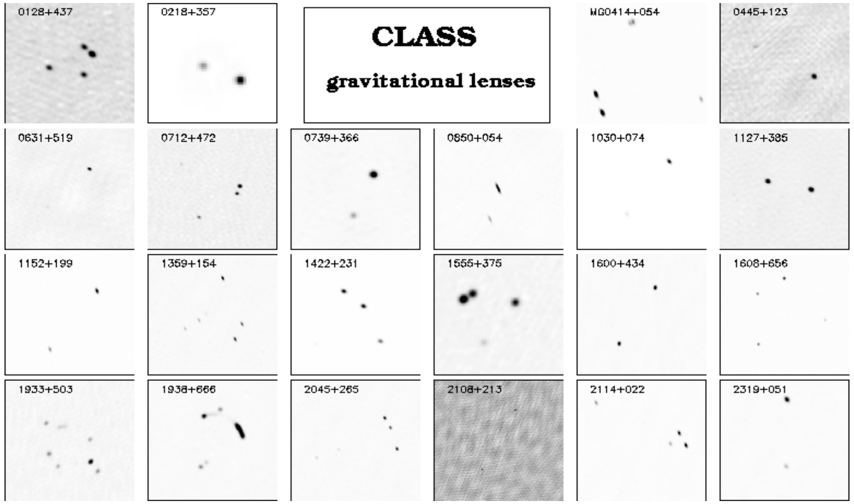
(adopting X-ray determined cluster size)

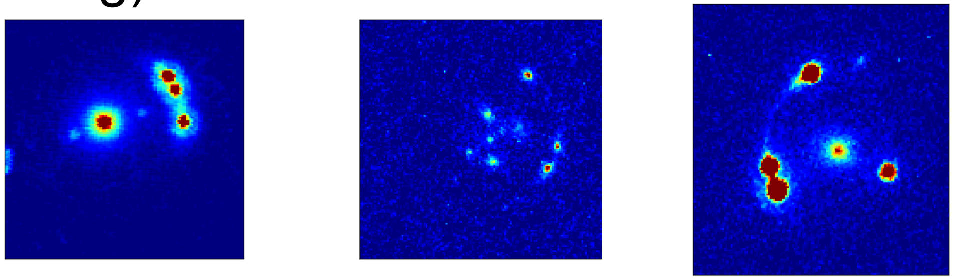
Sub-galaxy scale DM substructure is predicted by CDM – but not seen in the right quantities/mass properties in the MW

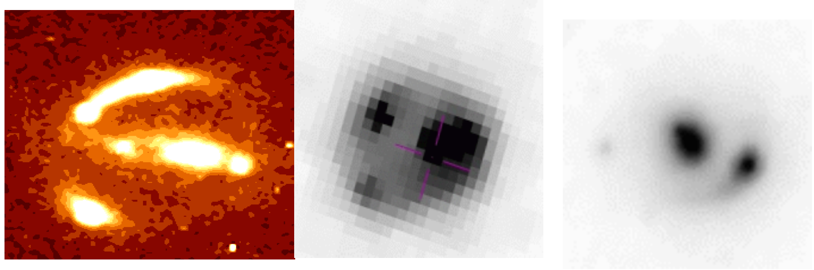
Lensed images of 4-image sources are sensitive to this – but appear to show more than the prediction!! (DM along line of sight?)

Vital to sort out (possible CDM failure mode) but important conclusions still based on the same sample of ~7 radio (CLASS) lenses (radio fluxes important as insensitive to microlensing)





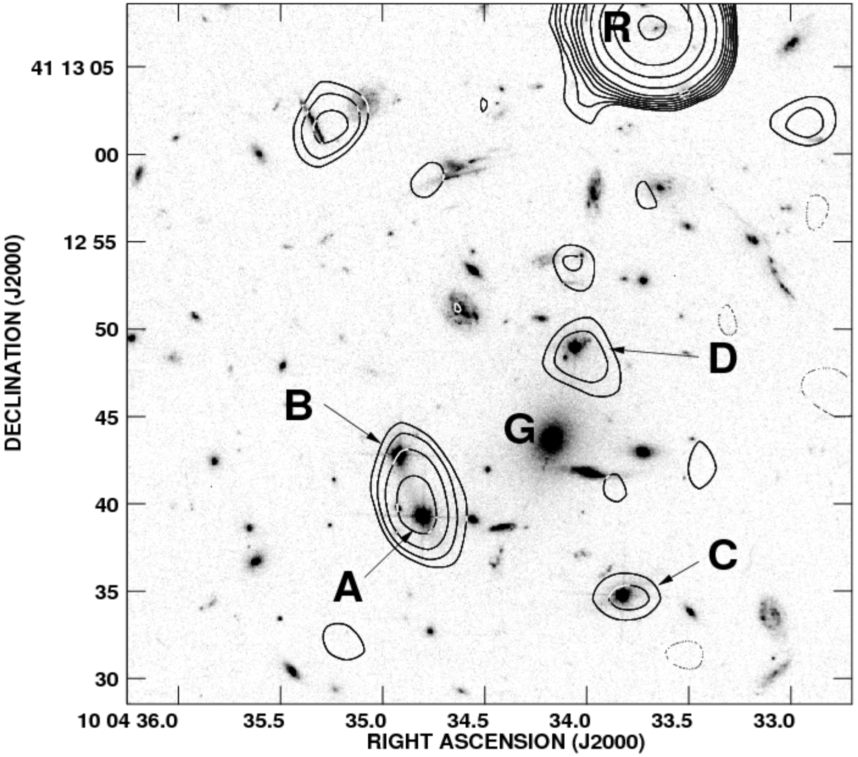




Two approaches – better flux constraints on existing lenses (improves constraints by factor ~2-3?)

Or increase sample – can do by getting radio fluxes for radio-quiet lenses (should have ~10-20 microJy in reality)

Programme with JVLA ongoing; first result 2011 (though in cluster lens)



Intrinsically (correcting for lensing magnification) flux density is ~1 microJy – faintest radio source yet (routine only with SKA)

JVLA contours/HST greyscale (Jackson 2011)

PERTURBATIONS IN DARK ENERGY/MODIFIED GRAVITY

Perturbed conservation equation $\delta(\nabla_\mu U^\mu{}_\nu) = 0$

$$\dot{\delta} = -(1+w)\left(\nabla_\mu v^\mu + \frac{1}{2}\dot{h}\right) - 3\mathcal{H}\left(\frac{\delta P}{\delta\rho} - w\right)\delta$$

$$\dot{v}_\alpha = -\mathcal{H}(1-3w)v_\alpha + (\bar{\nabla}_\alpha\phi - \mathcal{H}n_\alpha) - \frac{1}{\rho(1+w)}\bar{\nabla}_\alpha\delta P - \frac{w}{1+w}\nabla_\mu\Pi^\mu{}_\alpha$$

$$\delta P = \delta P(\delta, \theta, \dot{\delta}, \dot{\theta}, h, \eta, \ldots) \qquad \Pi = \Pi(\delta, \theta, \dot{\delta}, \dot{\theta}, h, \eta, \ldots)$$

Equations of state for dark sector perturbations

$$w\Gamma = \left(\frac{\delta P}{\delta\rho} - w\right)\delta$$

Write perturbed pressure as entropy perturbation

$$\delta U^{0}{}_{i} \sim v_i = \partial_i\theta$$

Very different “classes” of theories & field contents of the dark sector

$$\mathcal{L} = \mathcal{L}(g_{\mu\nu})$$

$$w\Gamma = (\kappa - w)\delta \qquad w\Pi = (w - \lambda)\left[\delta - 3(1+w)\varepsilon\eta\right]$$

$$\mathcal{L} = \mathcal{L}(g_{\mu\nu}, \phi, \nabla_\mu\phi, \nabla_\mu\nabla_\nu\phi)$$

$$w\Gamma = (\alpha - w)\left[\delta - 3\mathcal{H}(1+w)(\beta + k^2\gamma)\theta\right] - \frac{3}{2\rho\mathcal{H}}\zeta\dot{h}$$

$$\gamma = \zeta = 0$$

$$\mathcal{L} = \mathcal{L}(\phi, \mathcal{X})$$

$$\beta = 0 \qquad \mathcal{L} = \mathcal{L}(\mathcal{X})$$

$$\alpha = \beta = 1 \qquad \mathcal{L} = \mathcal{X} - V(\phi)$$