Synergies with ALMA and mm/submm facilities

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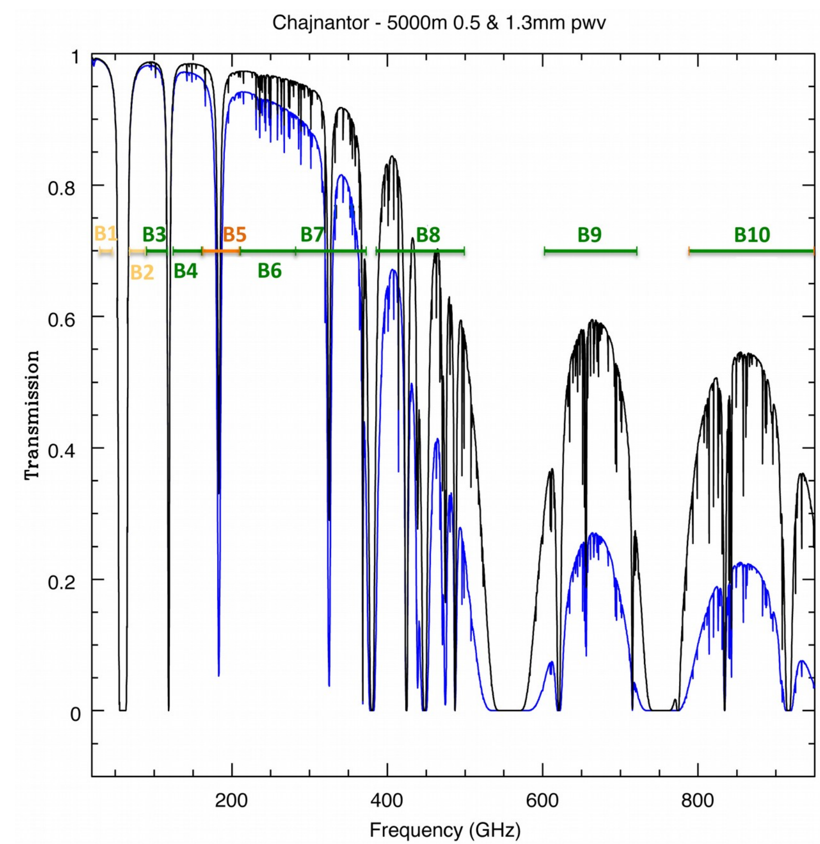
ALMA capabilities: full science

- 50 x 12m antennas in the 12m Array plus 12 x 7m and 4 x 12m antennas in the ACA
- Range of configurations with baselines up to 16km (0.013” at 300GHz)
- Receiver bands cover 84 to 950 GHz in atmospheric windows

Credit: ALMA (ESO/NAOJ/NRAO), J. Guarda (ALMA)



ALMA Cycle 4 + NOEMA

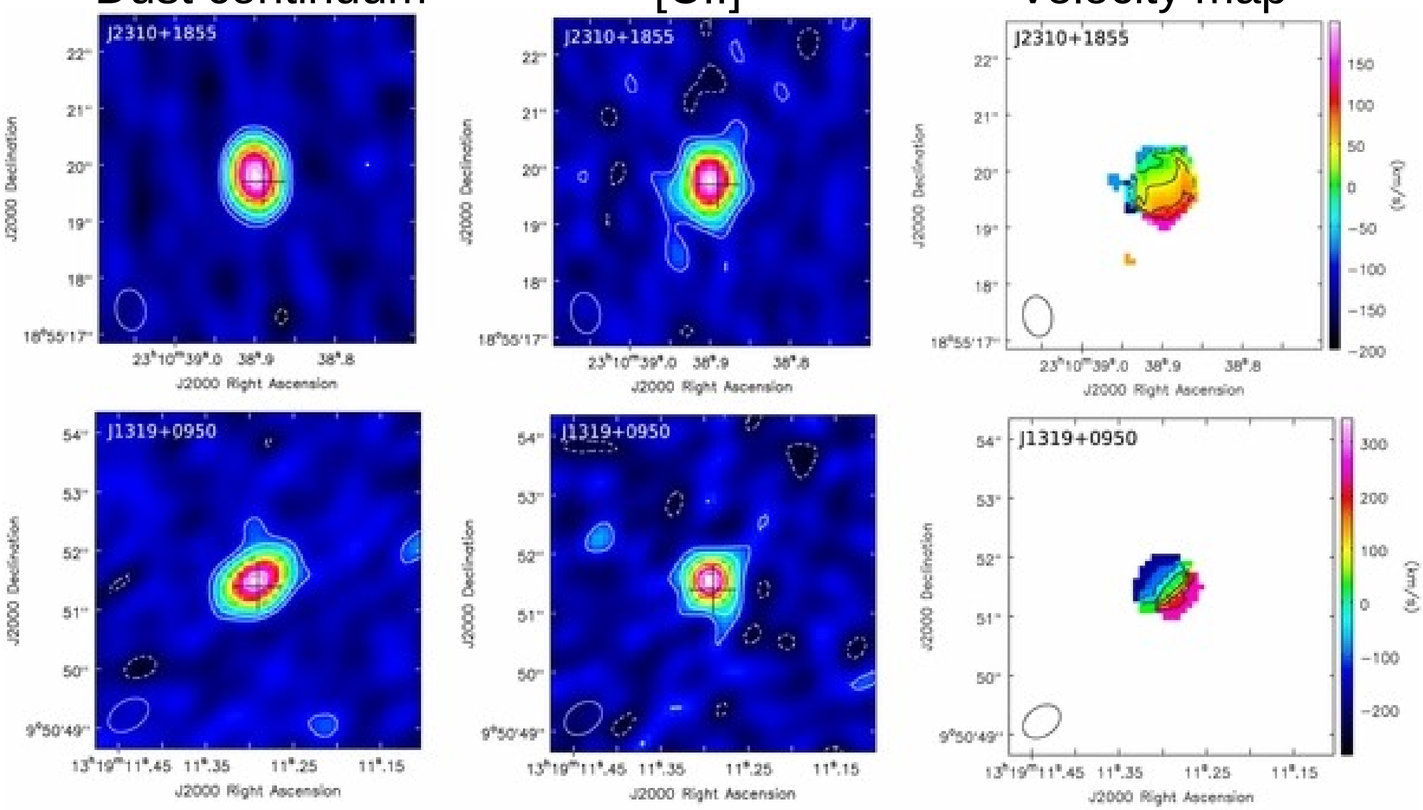
- At least 40 x 12m antennas in the 12m Array plus 10 x 7m and 3 x 12m antennas in the ACA
- Max. baselines 0.15 to 12.6km (0.016” at 300GHz)
- ~1600 proposals submitted including large proposals over 50 hrs

- Successor to PdB, increase 6 x 15m antennas to 12
- Increase bandwidth and extend baselines to 1.6km

ALMA capabilities

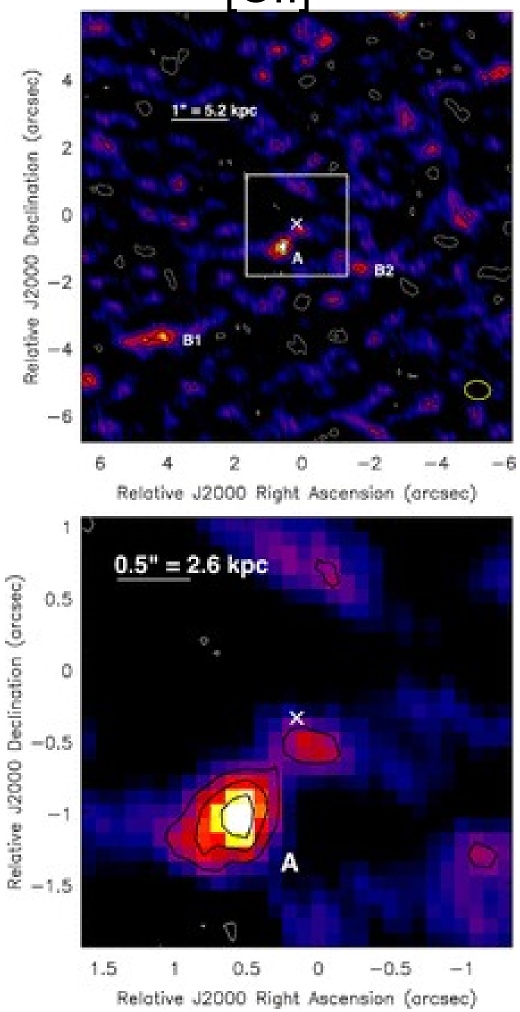
- ALMA will image CO in MW-like galaxies out to z=3 and [CII] or dust continuum in moderate starburst galaxies to epoch of re-ionization

Dust continuum | [CII] | Velocity map



Host galaxies of z~6 quasars, Wang et al. 2013

[CII]



“Normal” galaxy z=7 SFR ~ 10$M_\odot$/yr, Maiolino et al. 2015

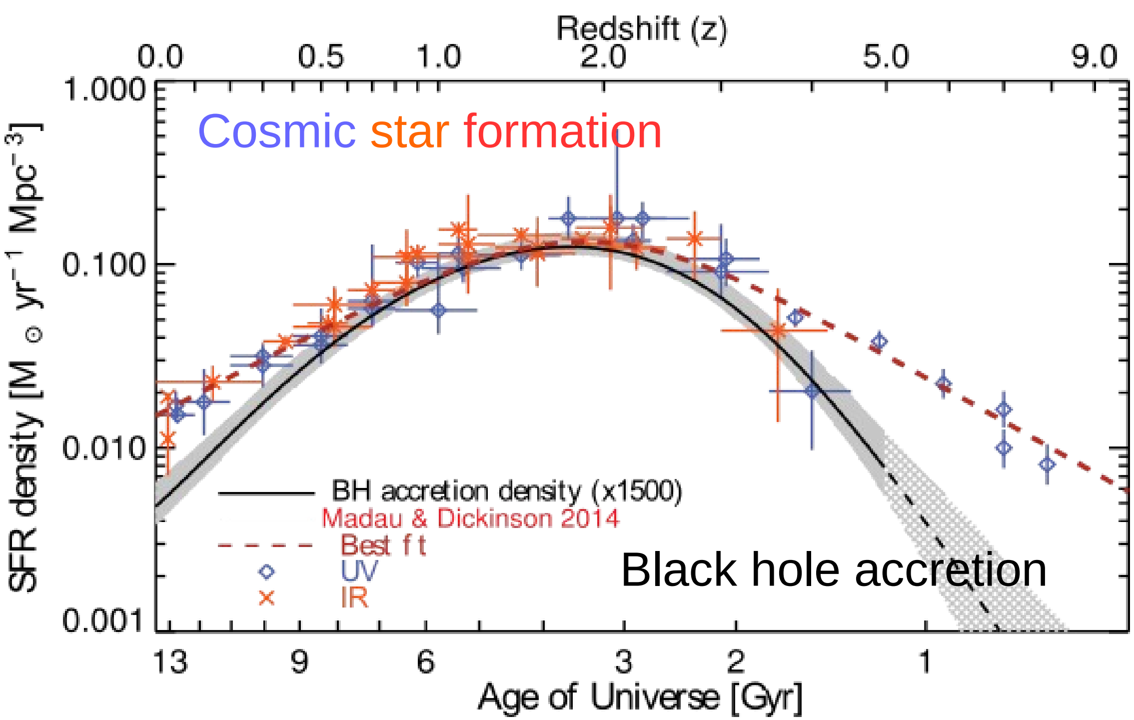
Common science goals

- Galaxy formation and evolution

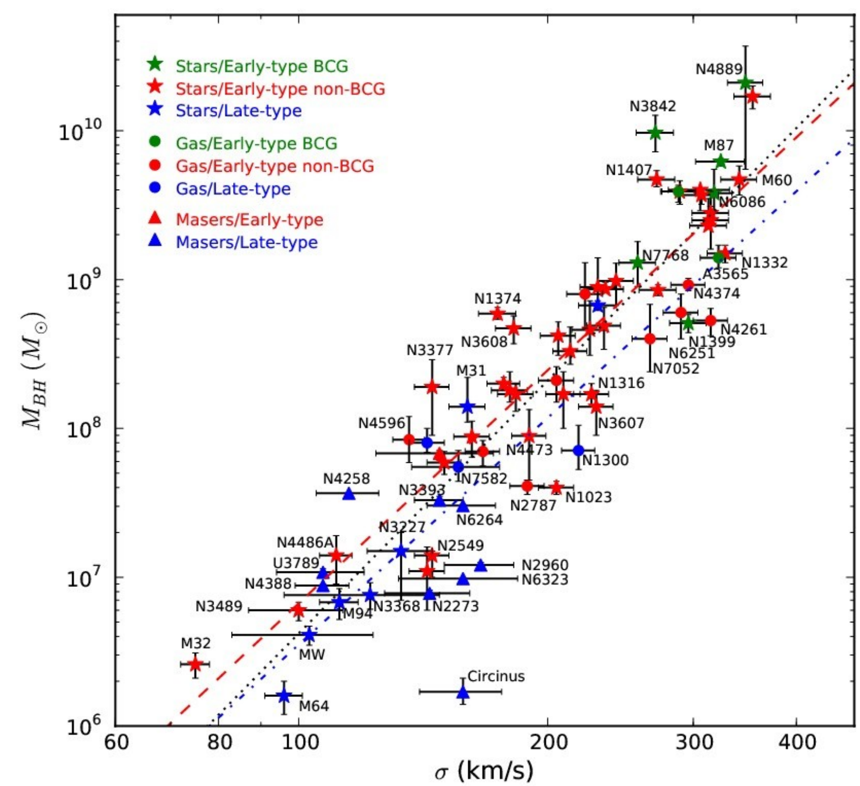
  Mass assembly, large scale structure surveys, WHIM

- Coevolution of black holes and galaxies

  Black hole accretion history, feedback, AGN fuelling, outflows



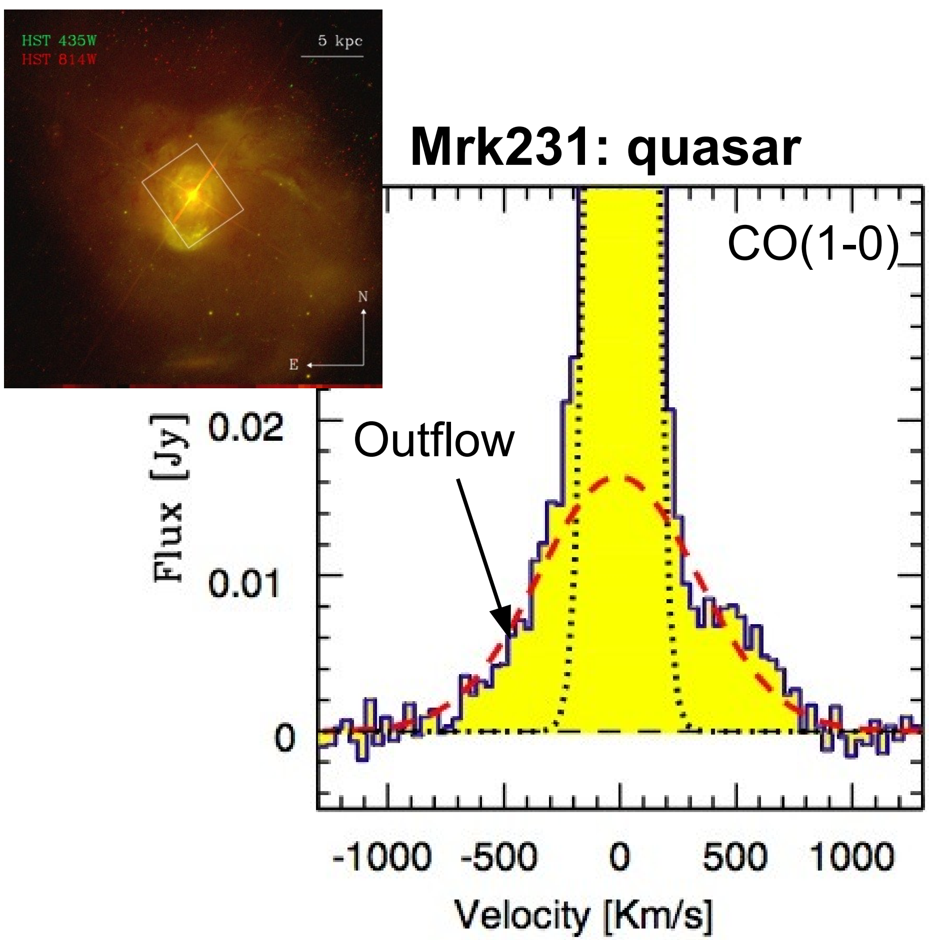
Aird et al. 2015 (see also Ueda et al. 2014, Buchner et al. 2015, La Franca et al. 2005)



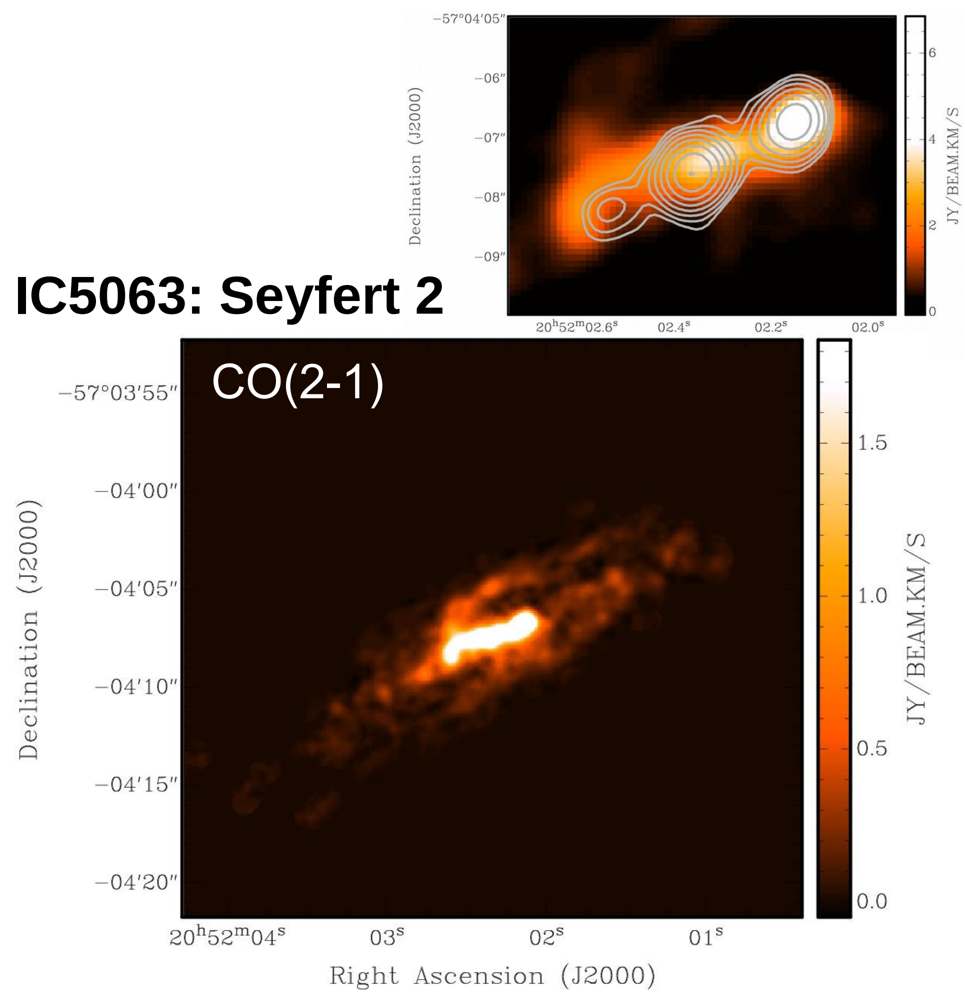
McConnell + Ma 2013

AGN-driven gas outflows

- Radiation and jet-driven ionised and molecular gas winds
- Are these outflows common? Can they drive significant fractions of cold gas out to large radii to suppress cooling and star formation?



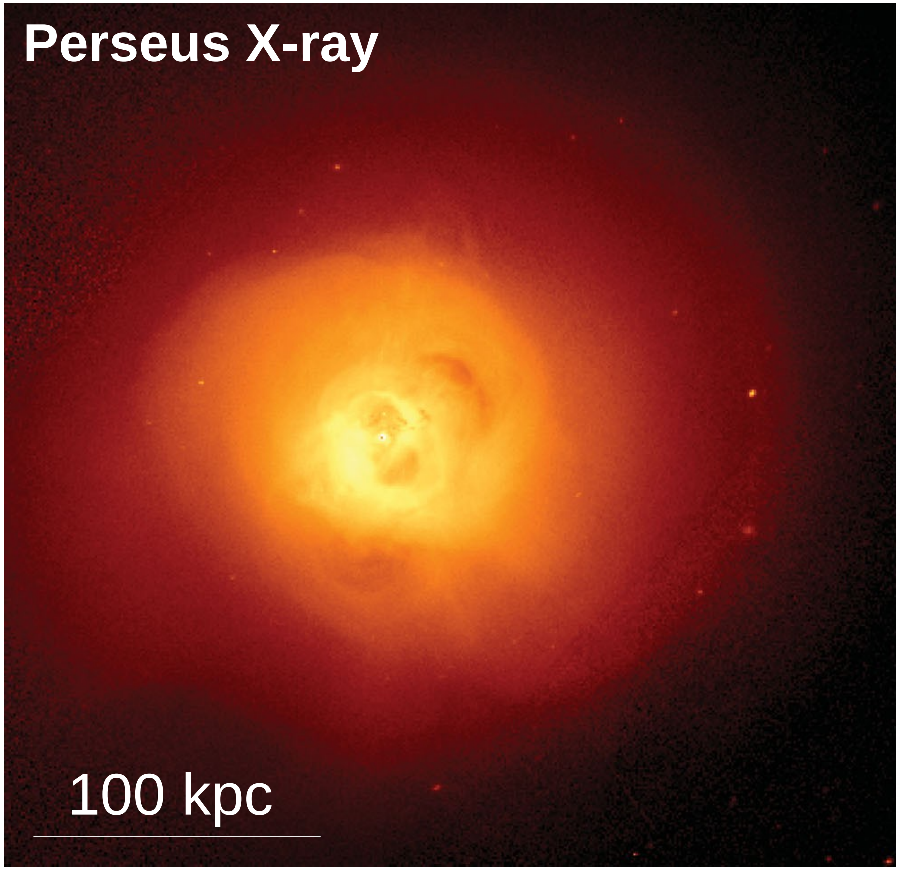
Feruglio et al. 2010; Rupke & Veilleux 2011



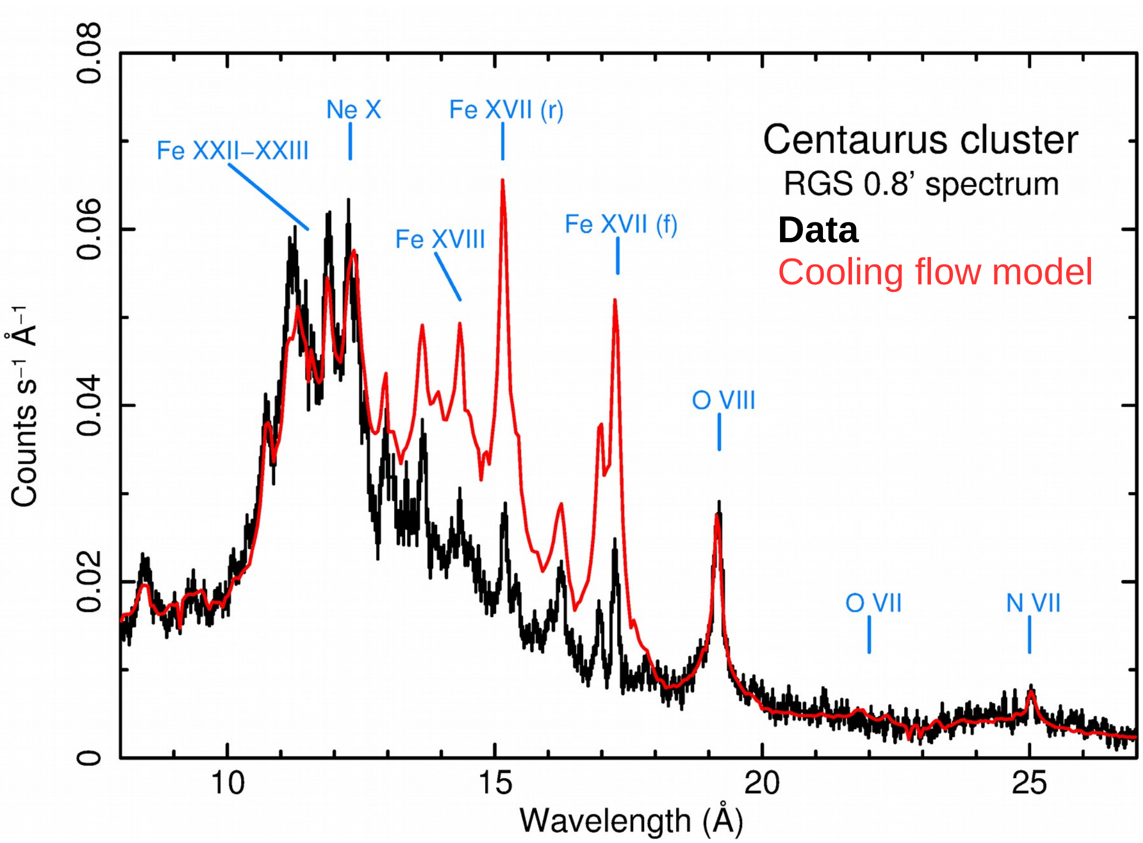
Morganti et al. 2015

AGN feedback in clusters

- AGN feedback required to prevent overcooling of hot atmospheres at the centres of galaxy clusters
- XMM RGS spectra find weak FeXVII lines and reduced cooling



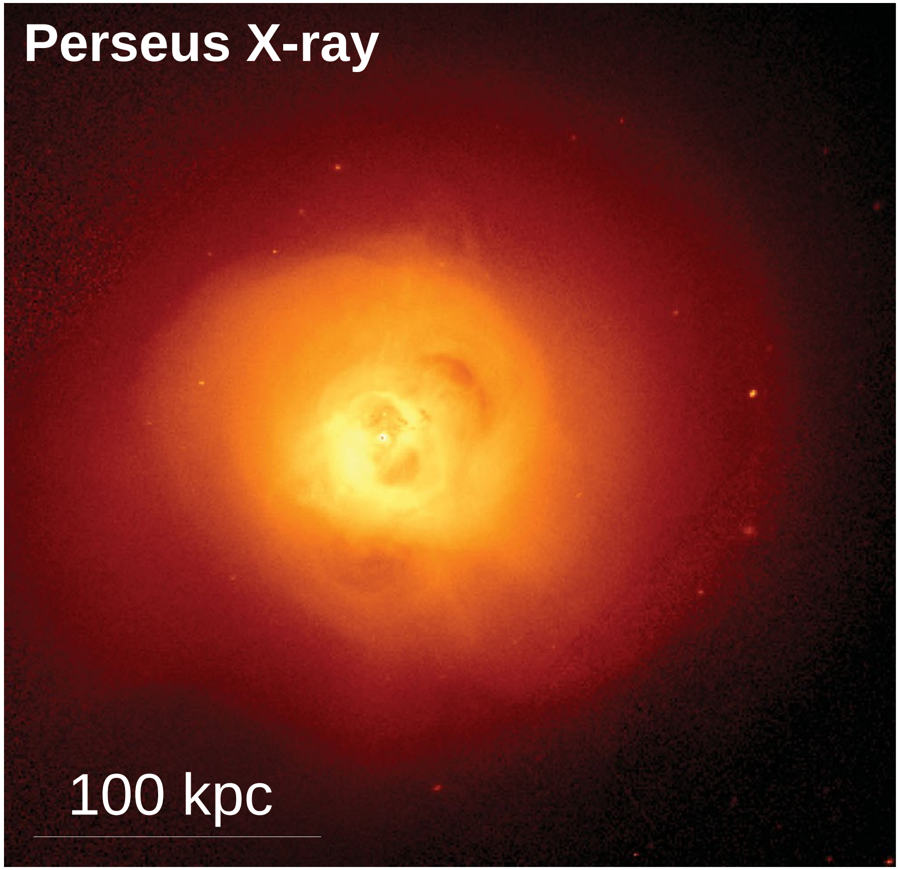
Fabian et al. 2011



Pinto et al. 2016

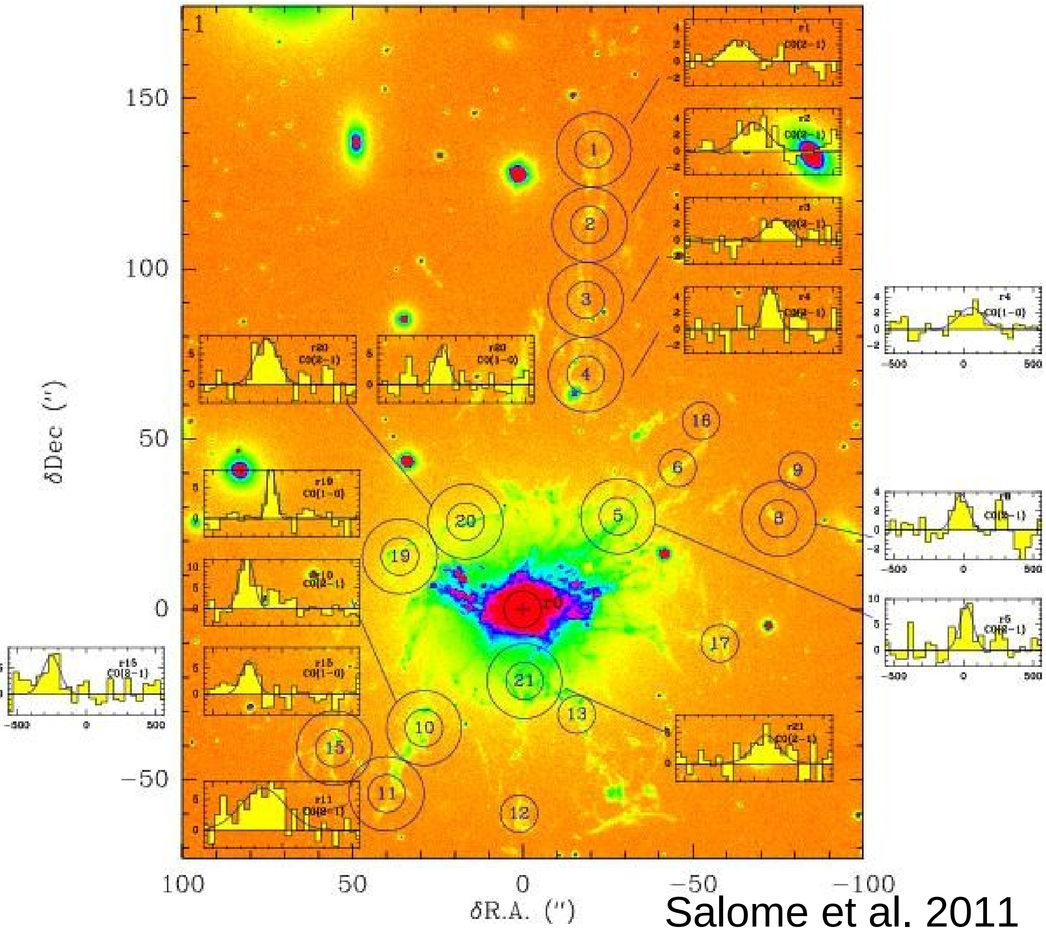
AGN feedback in clusters

- AGN feedback required to prevent overcooling of hot atmospheres at the centres of galaxy clusters
- Ionized and cold gas drawn into long filaments beneath radio bubbles



Fabian et al. 2011

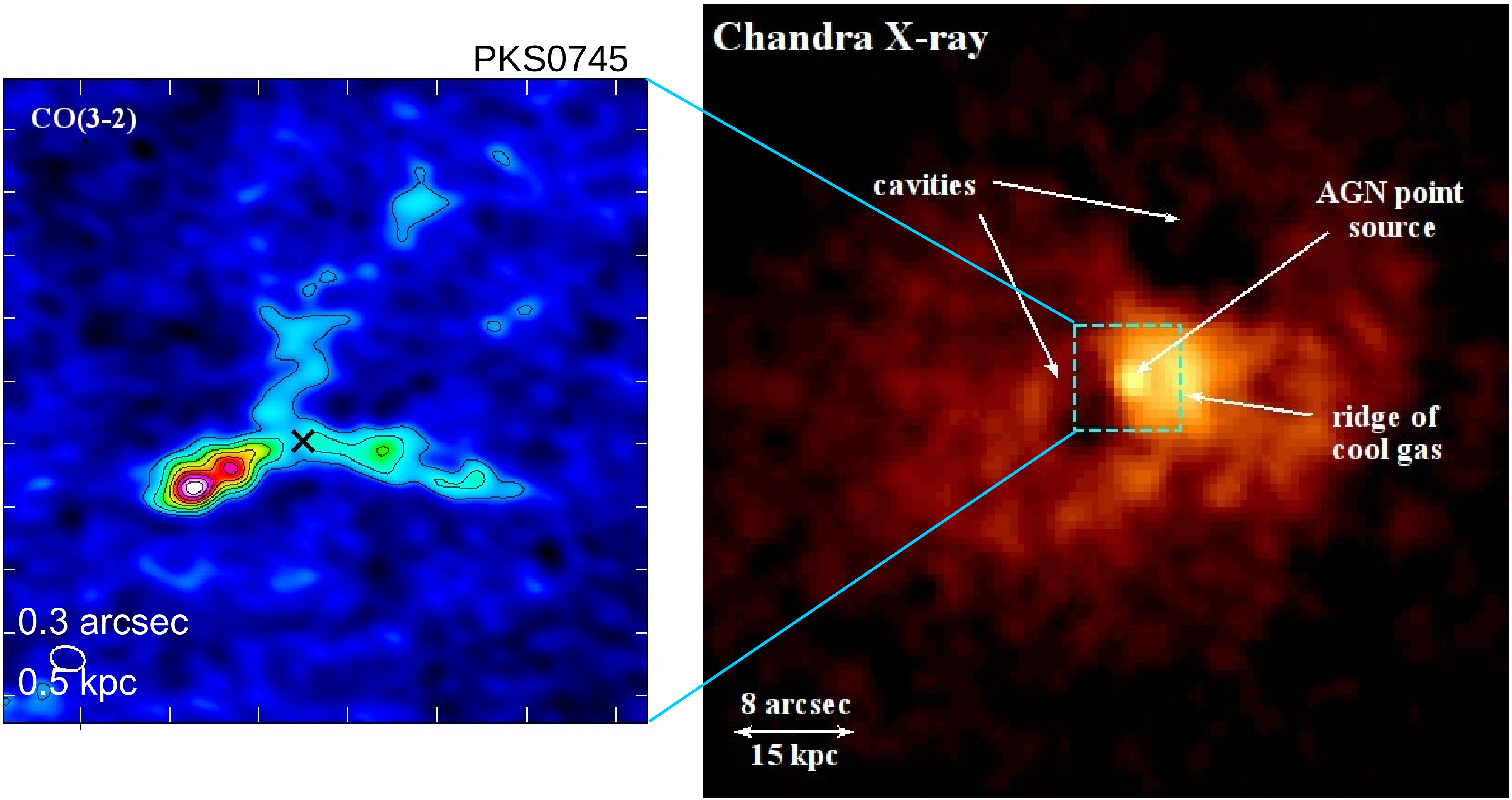
Hα image with CO detections



Salome et al. 2011

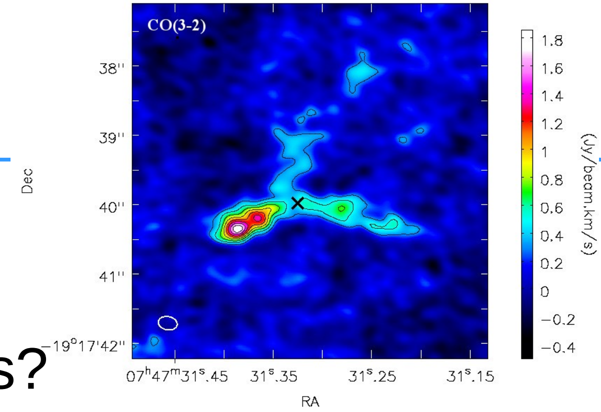
Extended molecular filaments behind radio bubbles

- A1835: $10^{10}M_\odot$ flow of gas extends to 10kpc at 200-400km/s
- PKS0745: $10^{9}M_\odot$ filaments extend 3 – 5 kpc with low velocities ±100 km/s



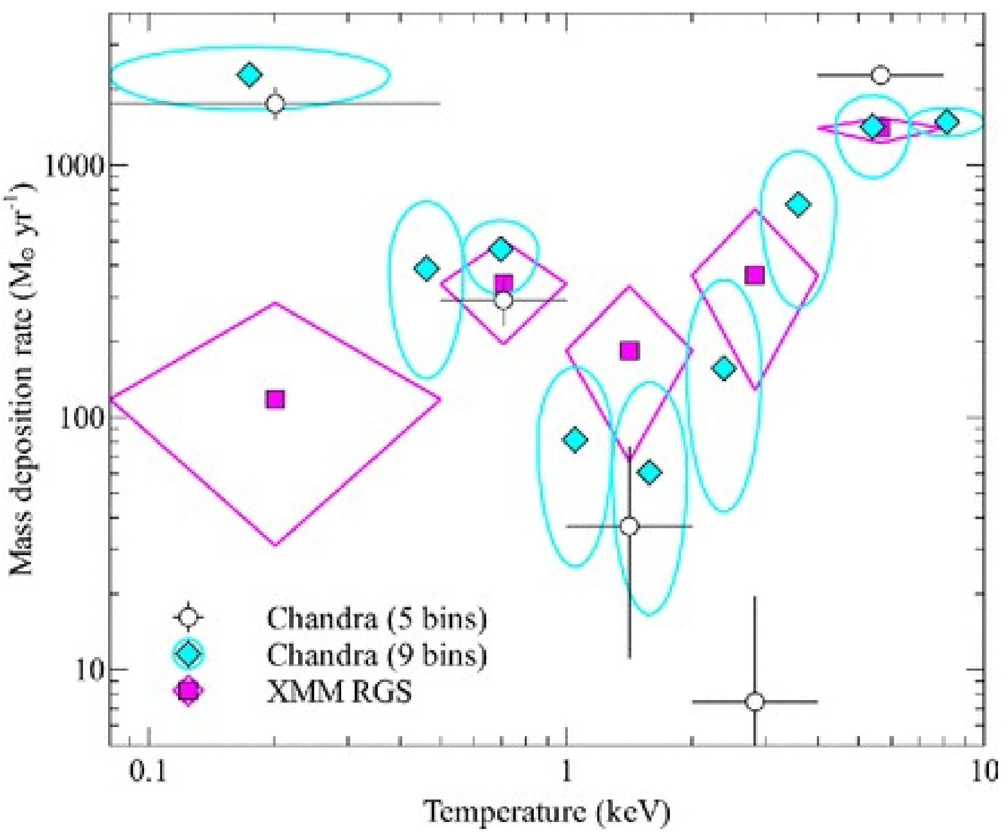
Russell et al. 2014, 2016, McNamara et al. 2014, David et al. 2014

Rapid gas cooling in situ?

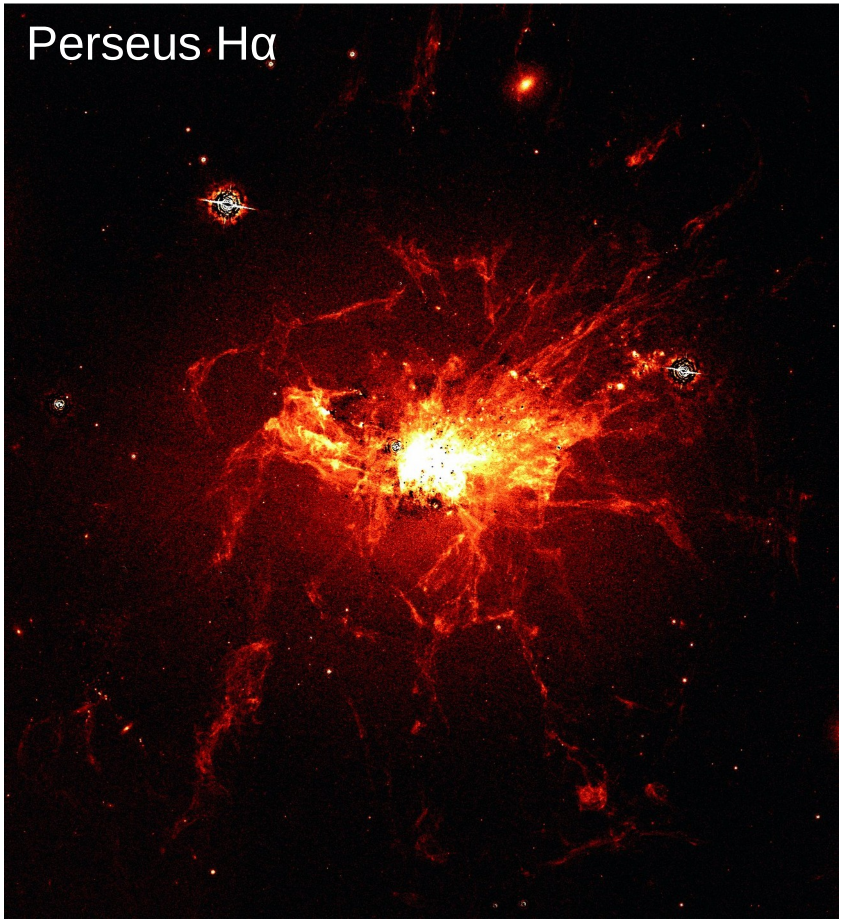


- Direct uplift of molecular gas?
- Or rapid cooling of outflowing gas to form molecules?
- Problems of hot gas depletion and magnetic pressure support

PKS0745



Sanders et al. 2014



Fabian et al. 2008

Conclusions

- Galaxy formation and evolution

  Mass assembly, large scale structure surveys, WHIM

- Coevolution of black holes and galaxies

  Black hole accretion history, outflows, feedback, AGN fuelling

- Observations of AGN and galaxy clusters
- X-ray cooling rates in cluster cores are crucial to understand AGN fuelling, outflows and feedback

Credit: ESO