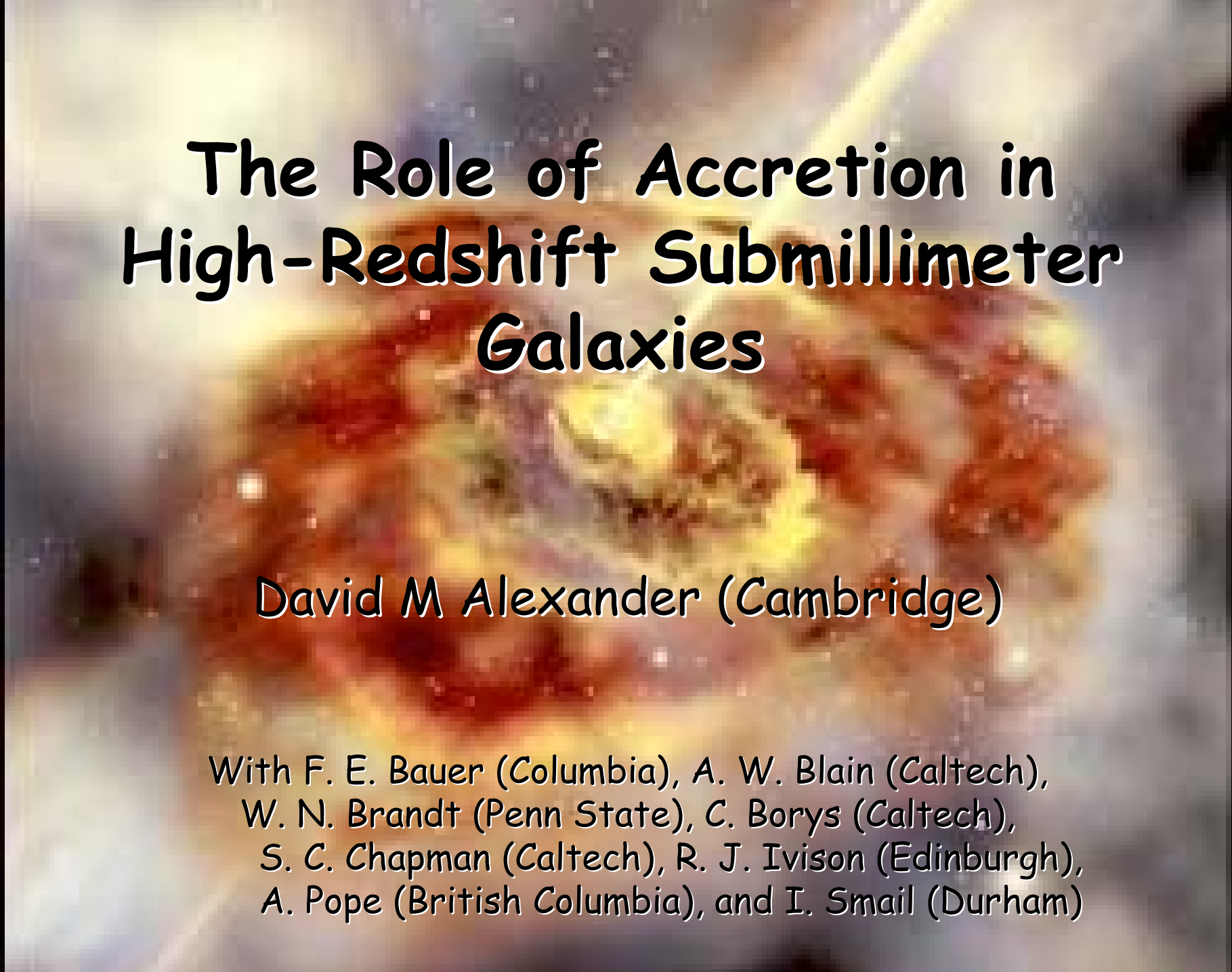
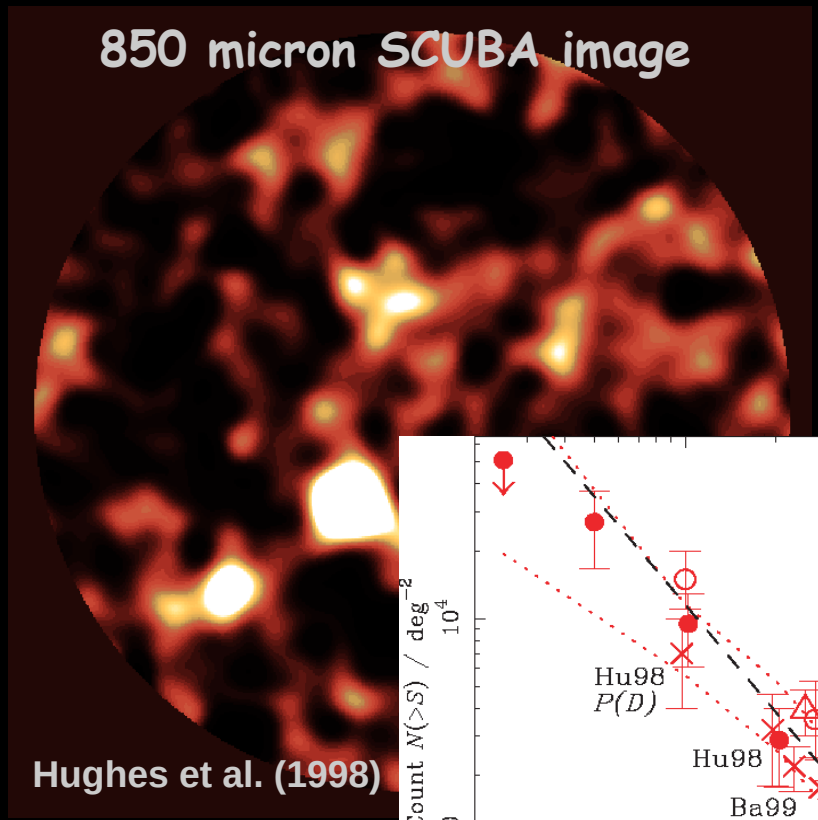


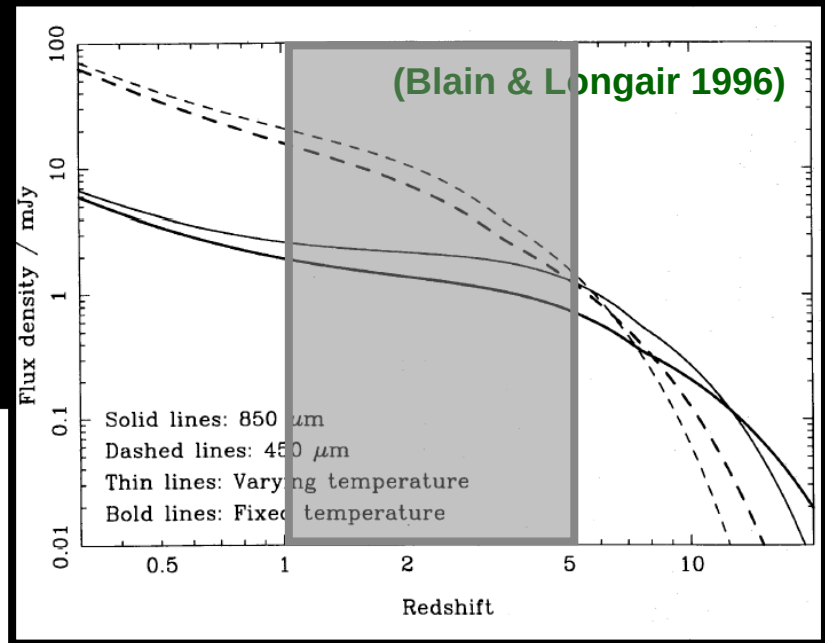
The Role of Accretion in High-Redshift Submillimeter Galaxies

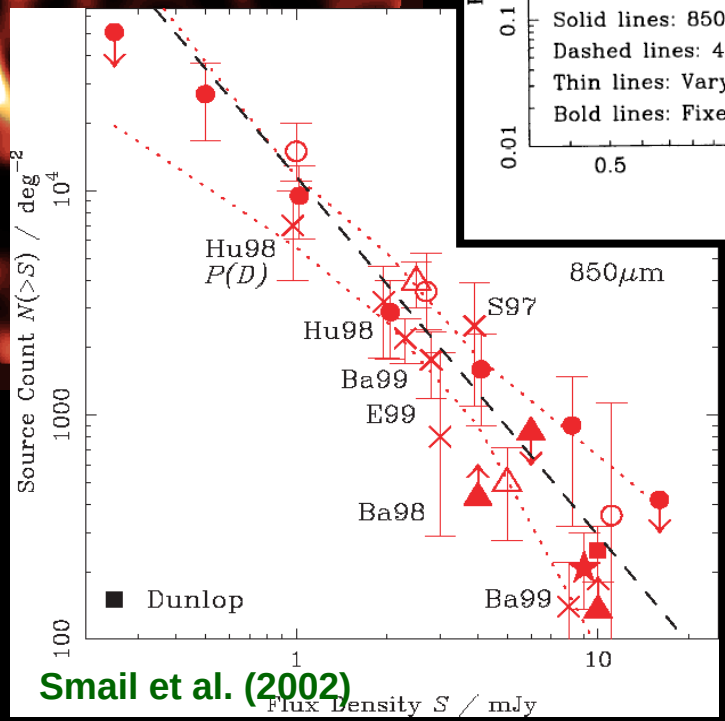
David M Alexander (Cambridge)

With F. E. Bauer (Columbia), A. W. Blain (Caltech),
W. N. Brandt (Penn State), C. Borys (Caltech),
S. C. Chapman (Caltech), R. J. Ivison (Edinburgh),
A. Pope (British Columbia), and I. Smail (Durham)

Submillimeter/Millimeter: efficient identifcation of the most bolometrically luminous far-IR galaxies

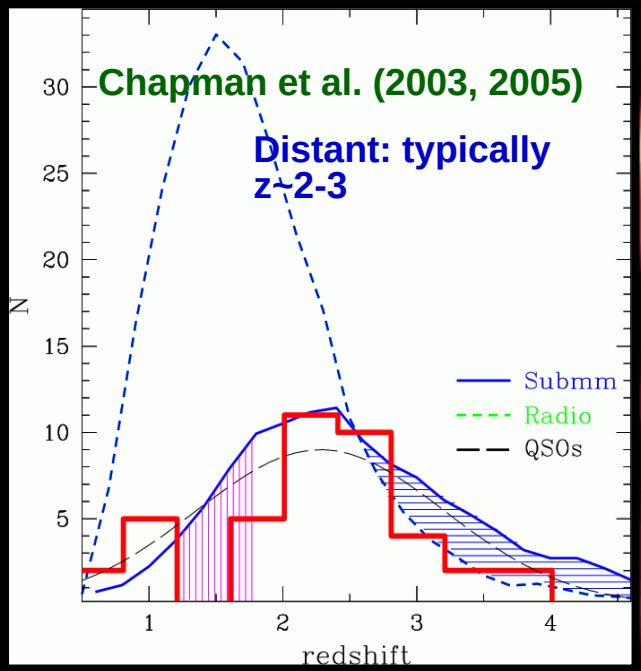


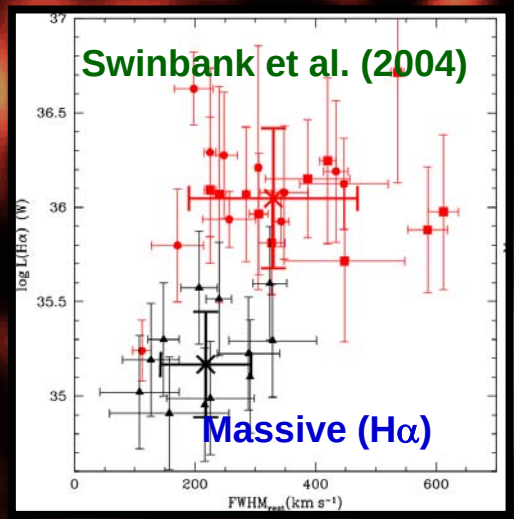


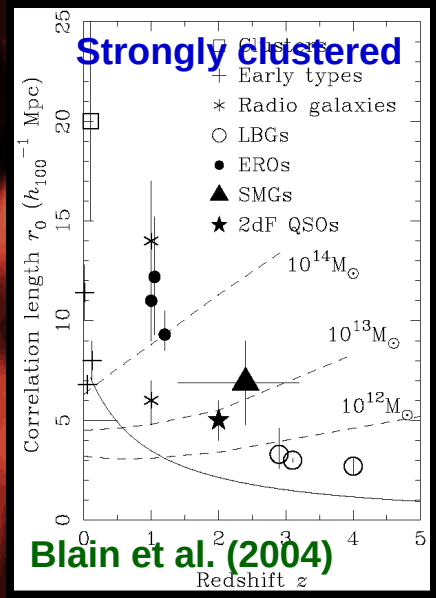


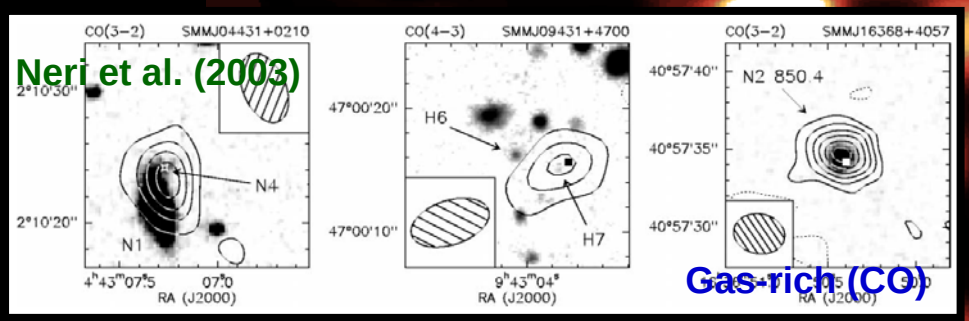
Lots of them!

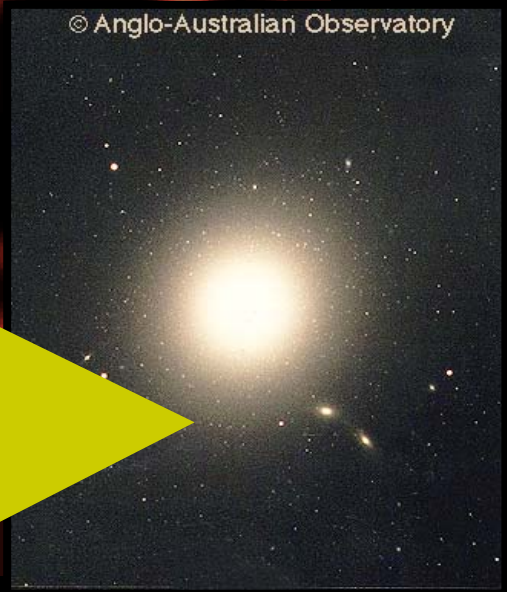
And after intense multi-wavelength follow up…







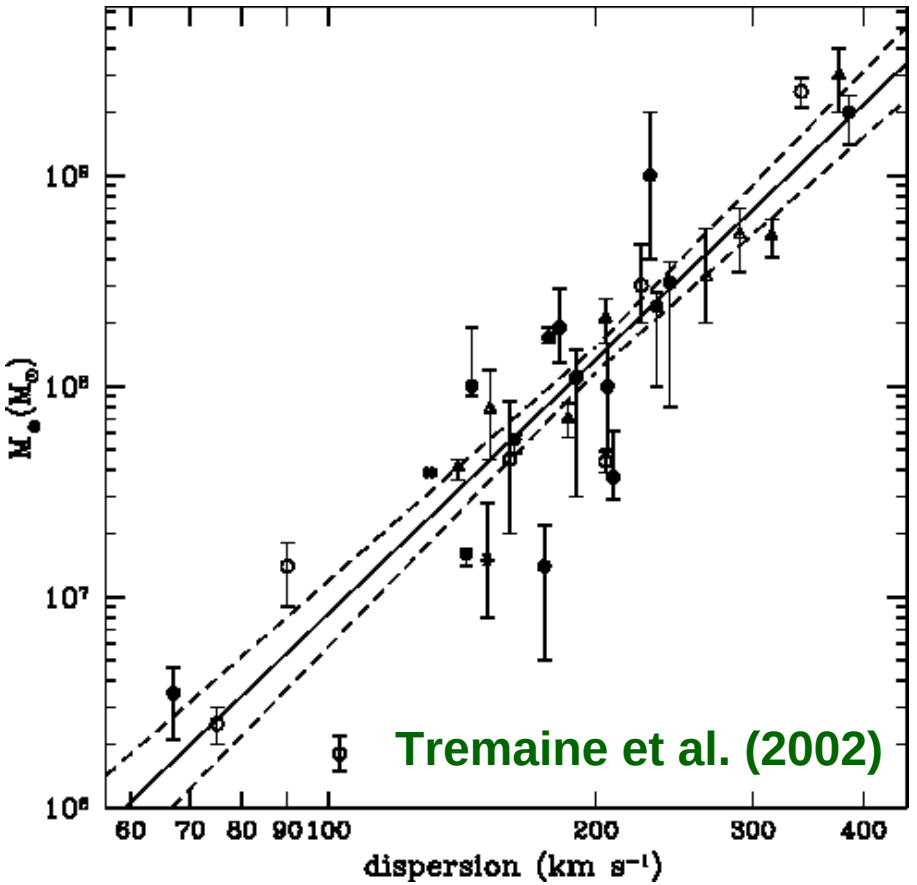




Progenitors of todays massive galaxies?

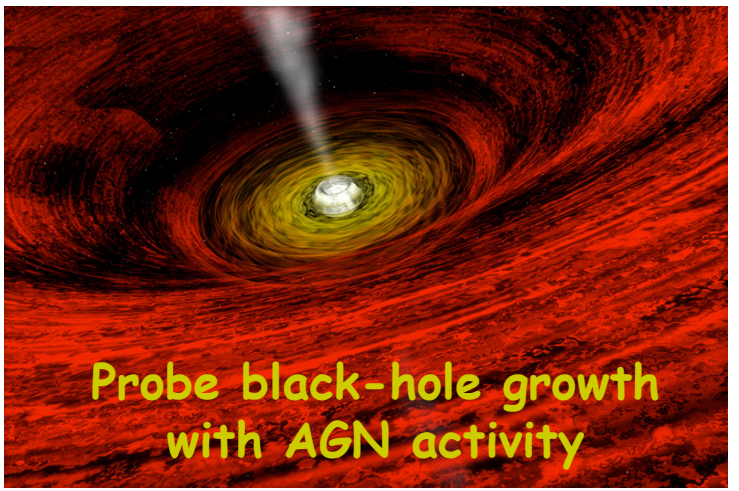
But… massive galaxies also host massive black holes

Black Hole Mass

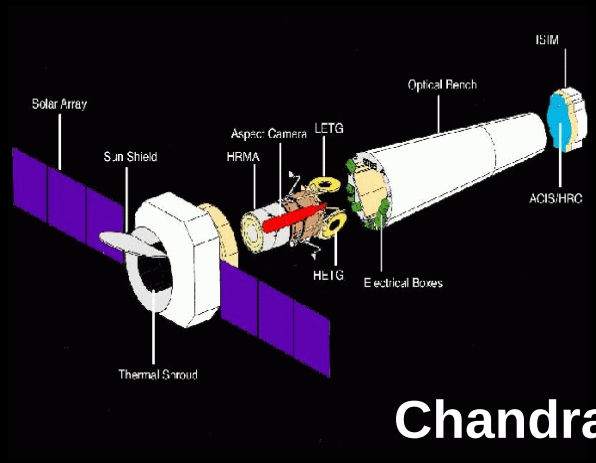


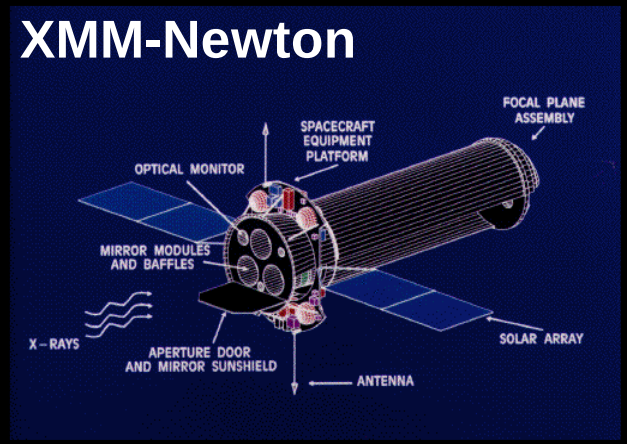
Stellar Bulge Mass

Connection between black-hole growth and galaxy growth?

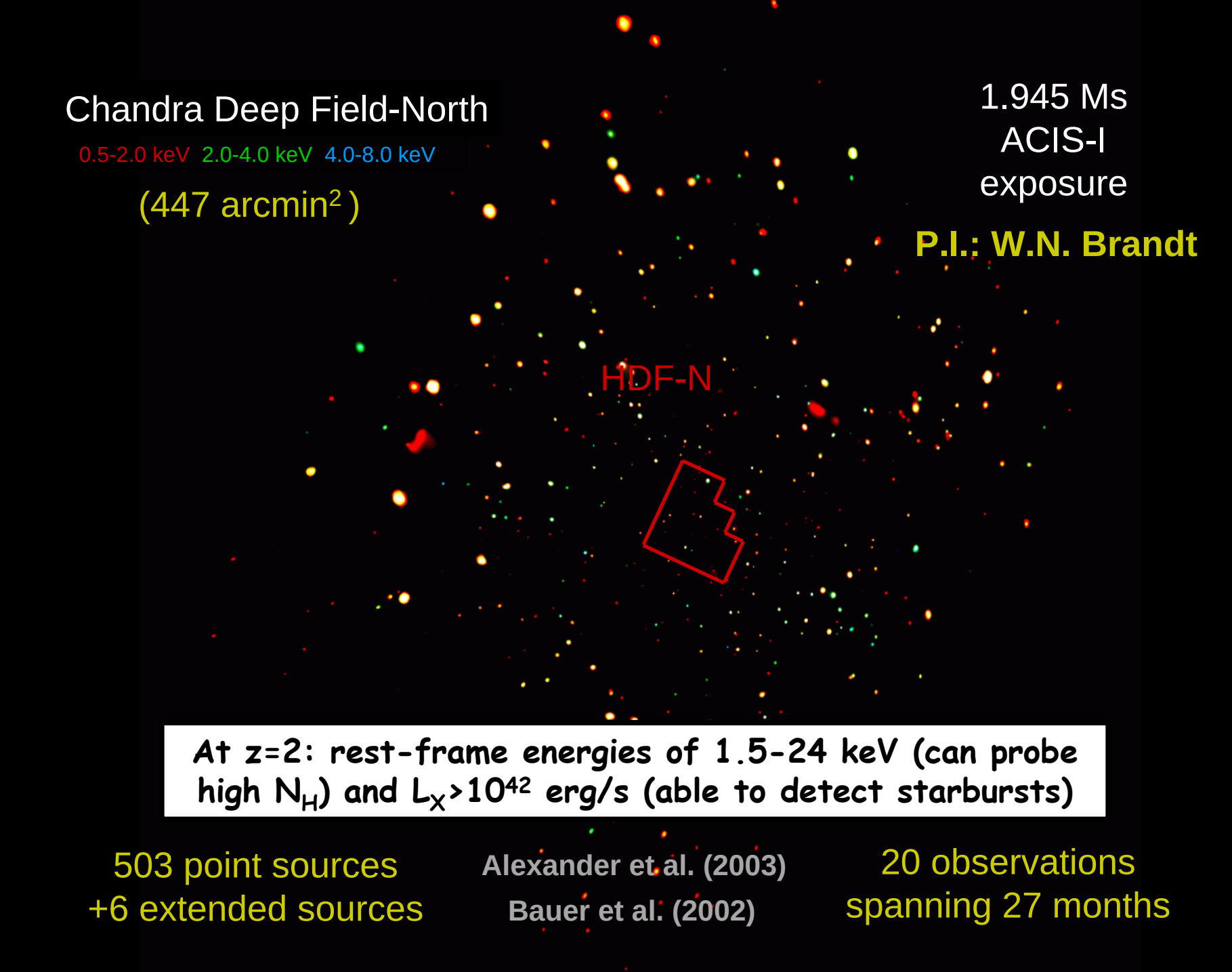


Measuring the "power" of AGN activity with X-rays





X-rays: (1) apparently a universal property of AGNs which allows AGNs to be identified irrespective of their optical/other properties, and (2) can probe heavily obscured objects


Chandra Deep Field-North
0.5-2.0 keV 2.0-4.0 keV 4.0-8.0 keV
(447 arcmin^2)
1.945 Ms
ACIS-I
exposure
P.I.: W.N. Brandt
HDF-N
At z=2: rest-frame energies of 1.5-24 keV (can probe high N_H) and L_X>10^{42} erg/s (able to detect starbursts)
503 point sources
+6 extended sources
Alexander et al. (2003)
Bauer et al. (2002)
20 observations
spanning 27 months

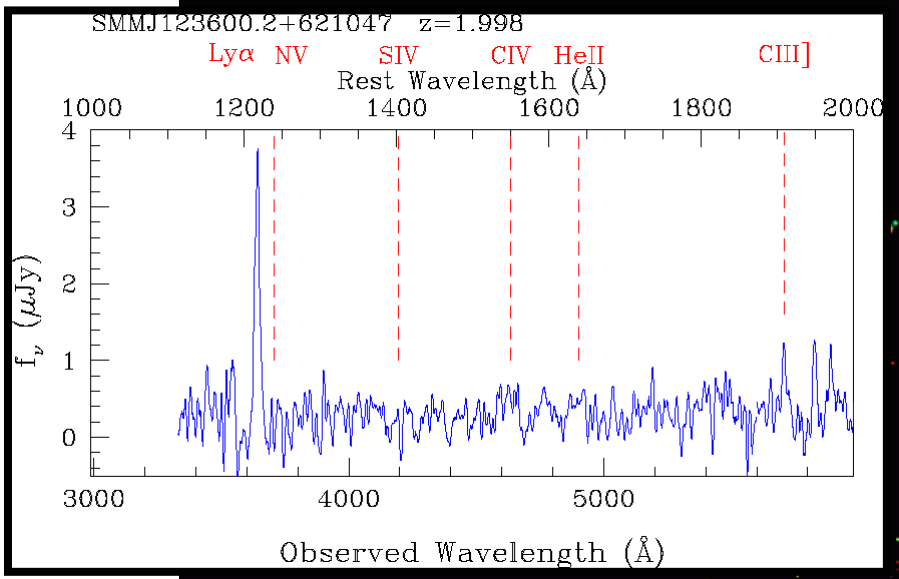
Talk Overview

- What Powers Submm/mm Galaxies?
  Alexander et al. (2005), ApJ, 632, 736

- Black-Hole Growth in Submm/mm Galaxies
  Alexander et al. (2005), Nature, 434, 738
  Borys et al. (2005), ApJ, 635, 853

- Prospects with ALMA

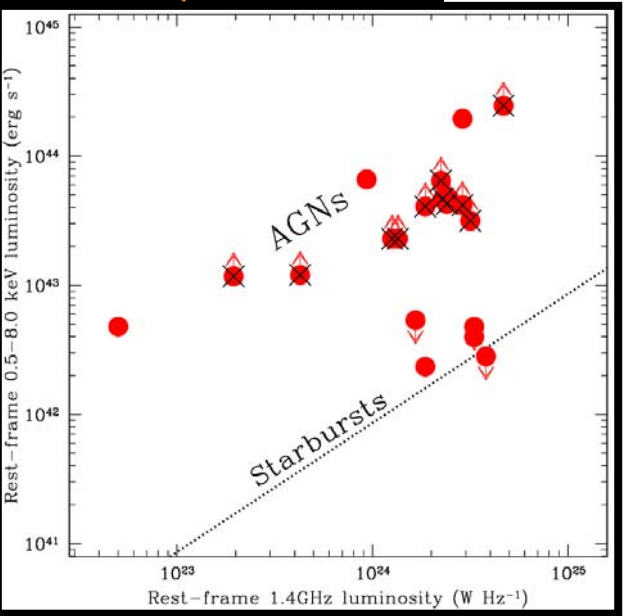
The SCUBA Galaxy Sample



Deep Keck campaign of radio detected SCUBA galaxies (Chapman et al. 2003, 2005); radio bias but should be representative of >50-65% of SCUBA galaxies

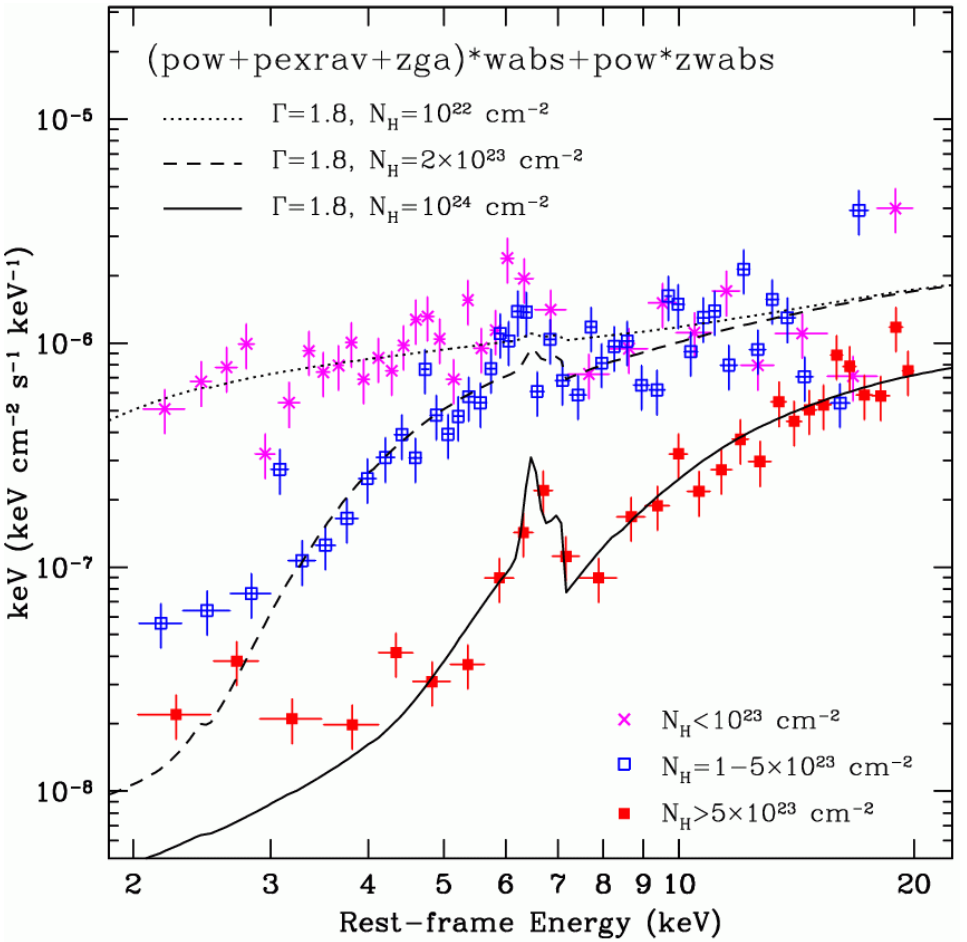
~28-50% AGN fraction for f850um>4 mJy (bias corrected)

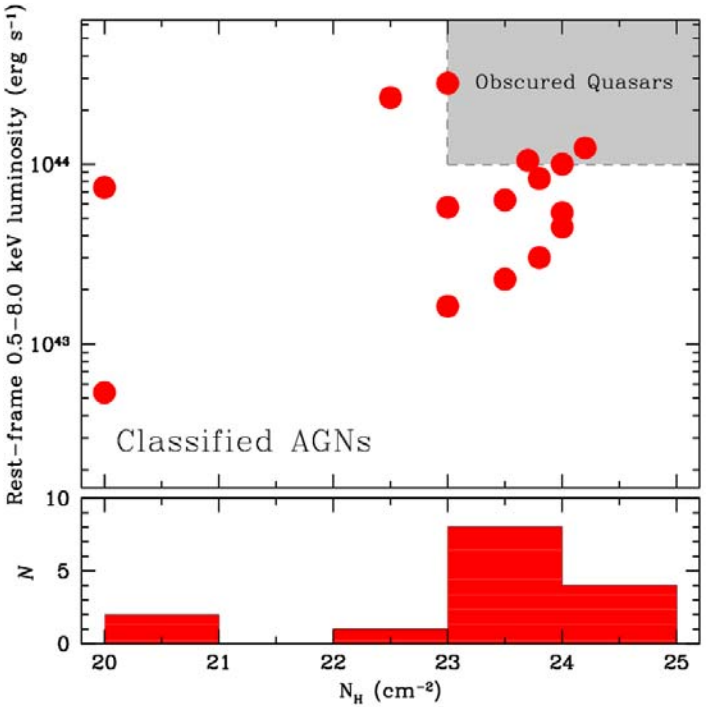
Significantly higher than co-eval optical galaxies (~5%)



Properties of the AGNs

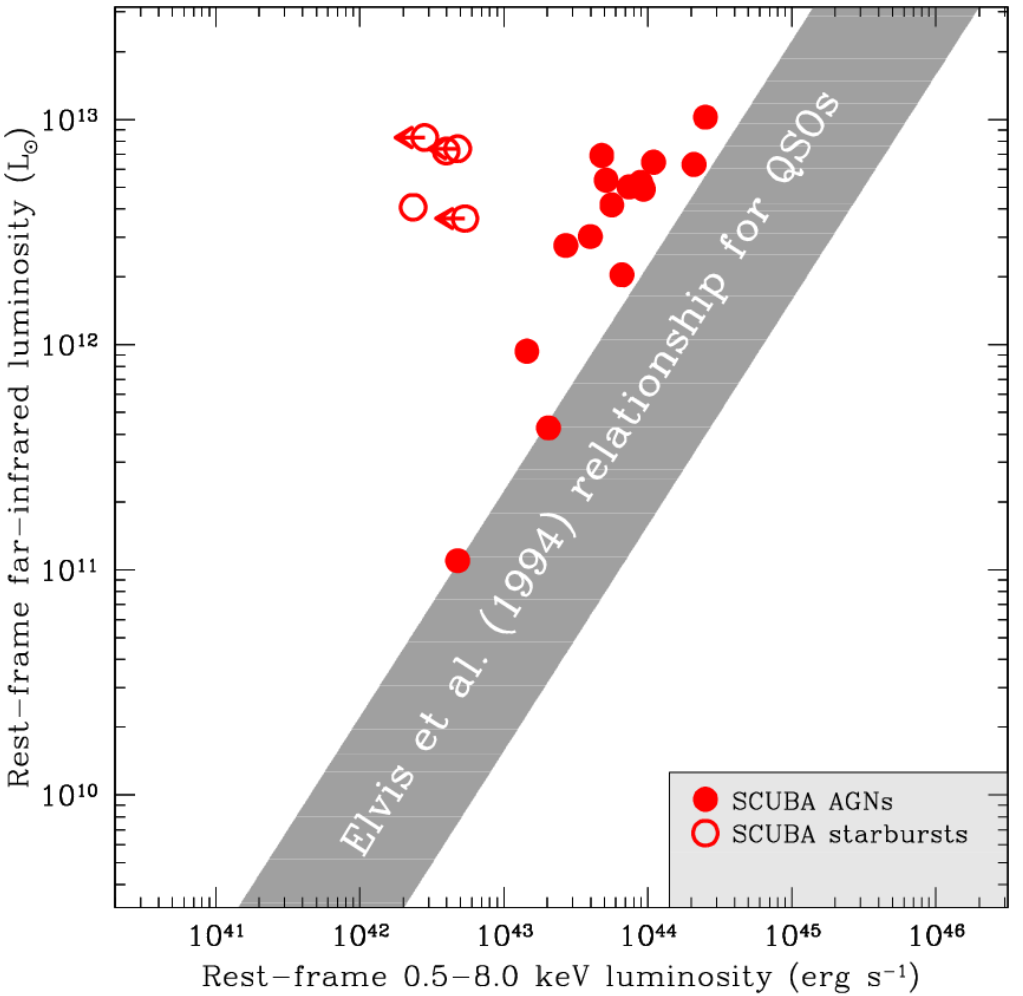
Composite Chandra spectra





Majority of the AGNs are heavily obscured (~85%) but their absorption-corrected luminosities are modest: few are of quasar luminosity

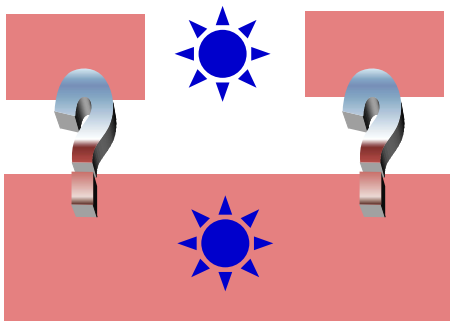
What Powers SCUBA Galaxies?



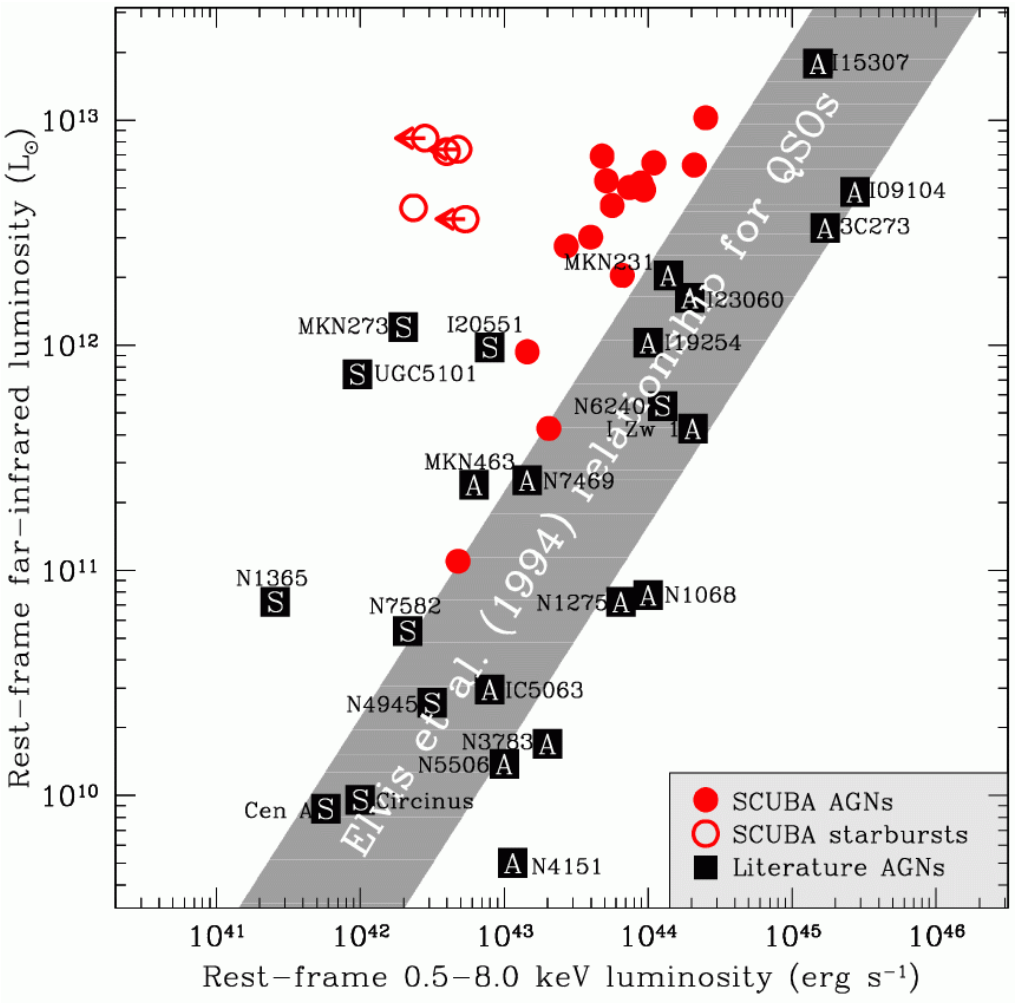
On the basis of this SCUBA galaxies are not typically AGN dominated (average contribution of ~10%)

BUT

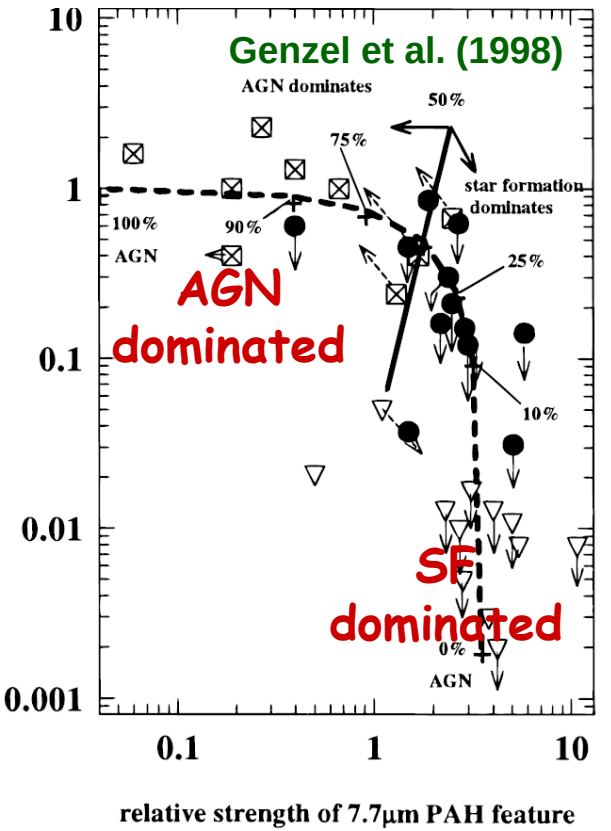
Dust covering factor?



What Powers SCUBA Galaxies?

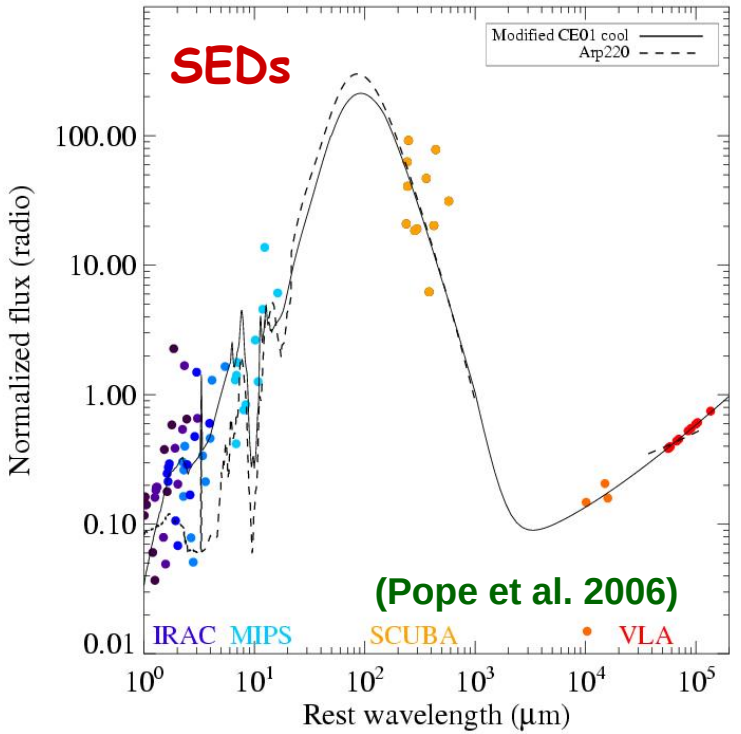


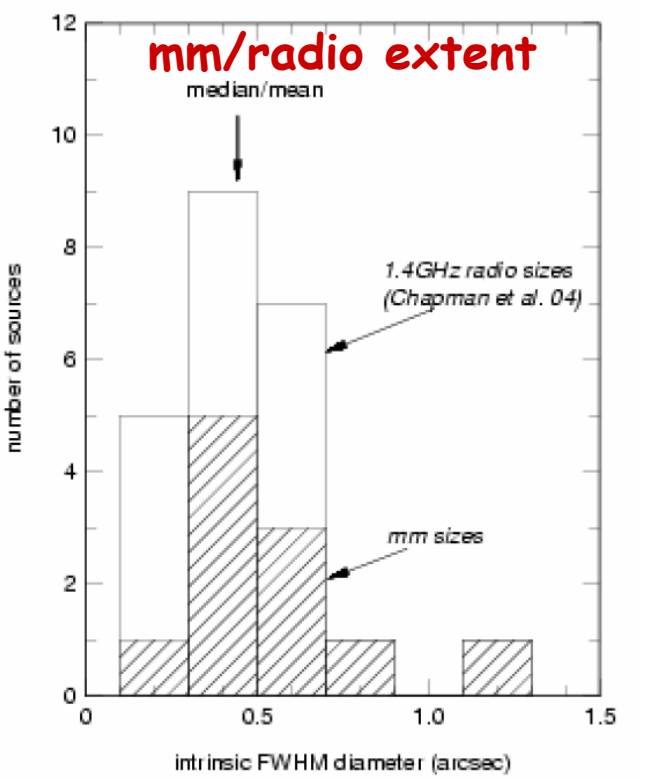
Dusty local AGNs classified on basis of mid-infrared spectral features



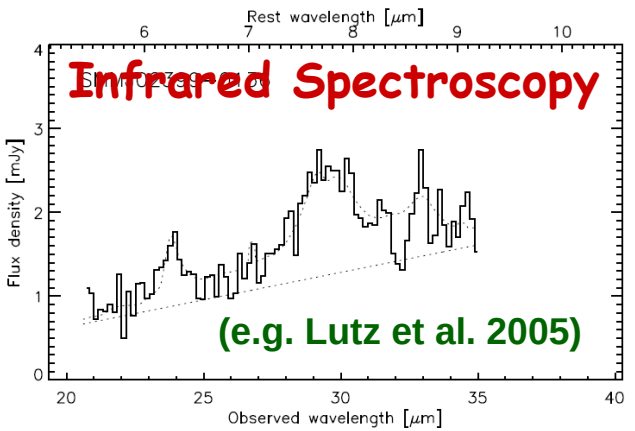
Some of the SCUBA galaxies could be AGN dominated but the majority are probably star-formation powered

Other Evidence that Star-Formation Dominated





(Chapman et al. 2004; Tacconi et al. 2005)



Multi-wavelength analyses also suggest that star-formation activity dominates the energetics of submm/mm galaxies

Conclusion: intense star formation (of order 1000 solar masses/year) appears to dominate the energetics of bright submm/mm galaxies

So AGNs are unimportant in submm/mm galaxies?

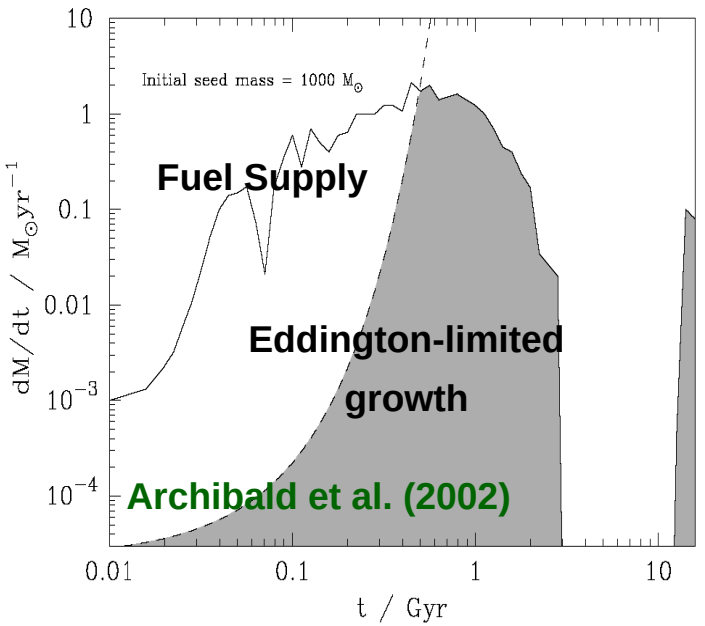
NO! The large AGN fraction implies almost continuous (~28-50% duty cycle) black-hole growth whilst undergoing star formation

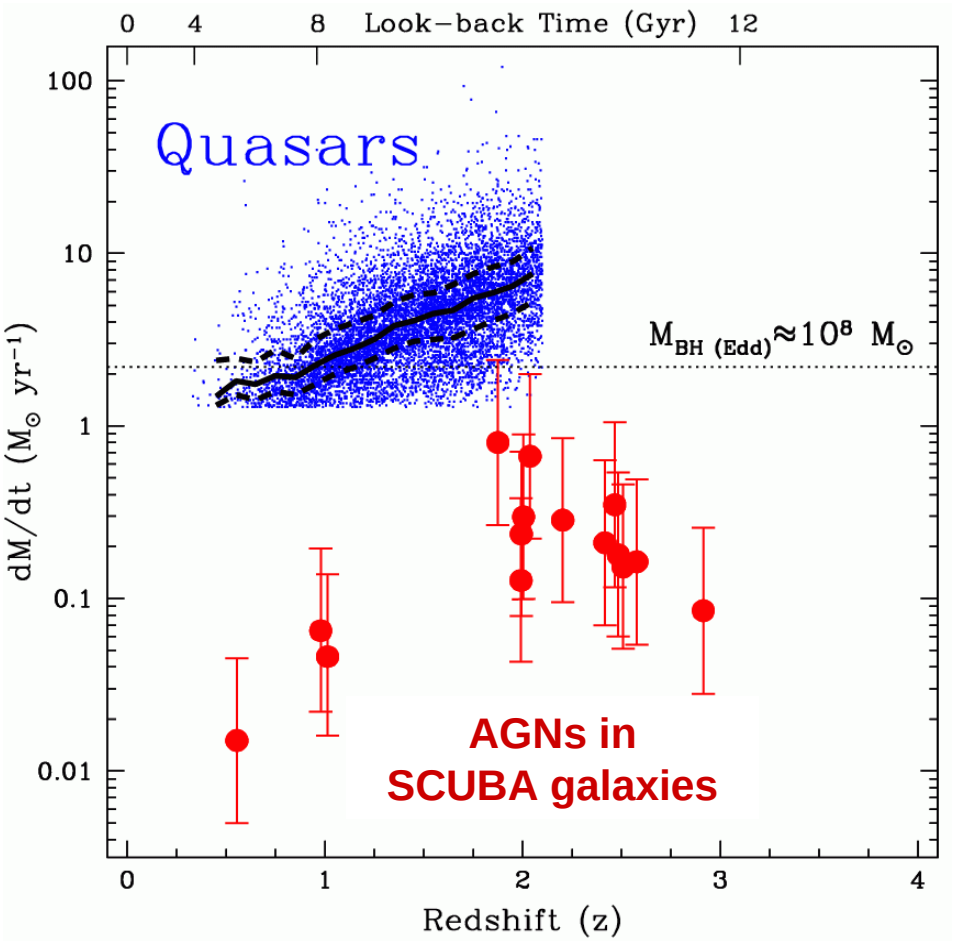
More closely tied than other co-eval galaxy populations, which typically have a ~5% AGN fraction

Joint black hole-stellar growth?

Rapid Black-hole Growth Phase?

Rapid Eddington-limited OBSCURED black-hole growth phase of massive galaxies (e.g., Fabian 1999; Archibald et al. 2002; King 2003; Di Matteo et al. 2005)?

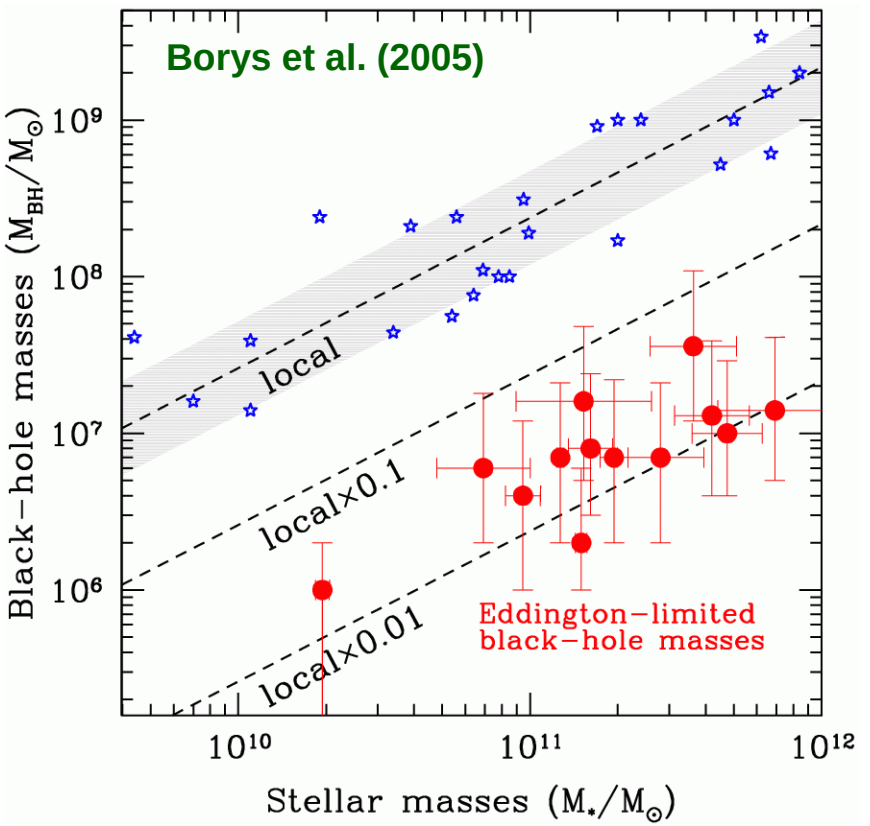


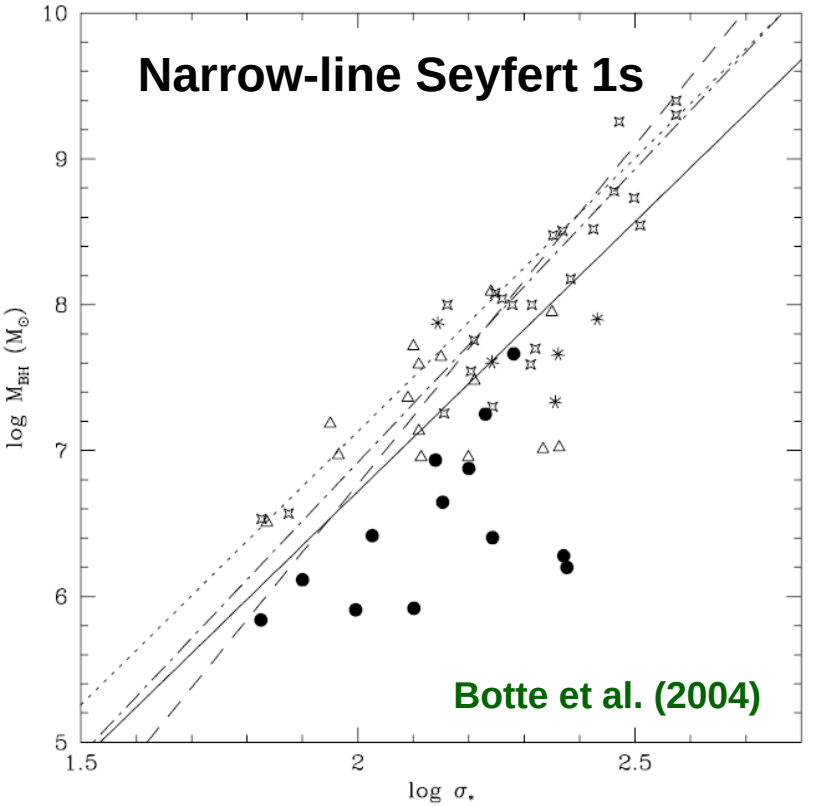


Broad lines, when present, are typically <2500 km/s (Ledlow et al. 2002; Swinbank et al. 2004), similar to narrow-line Seyfert 1s, which also suggests <10^8 M_{solar}

M-σ relationship in SCUBA galaxies

Stellar masses estimated using Spitzer infrared observations

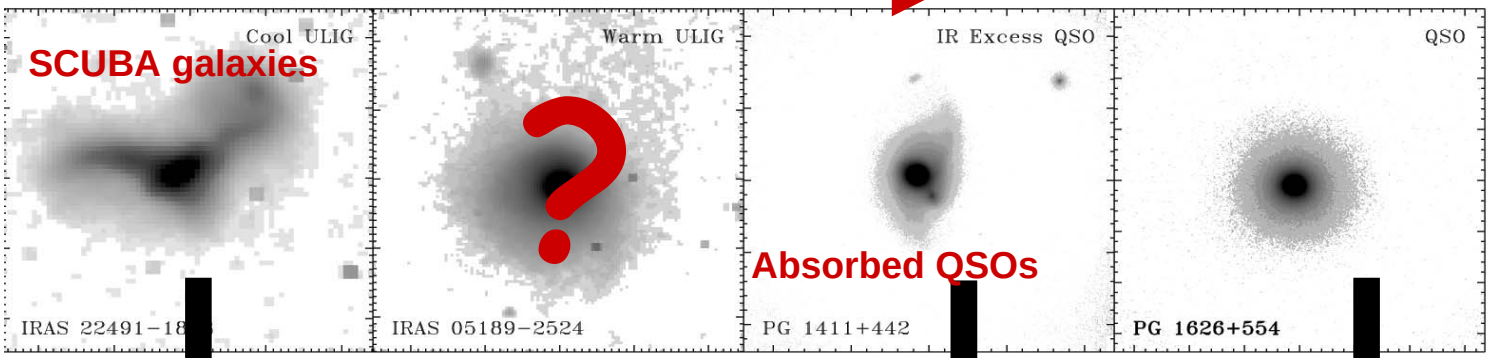


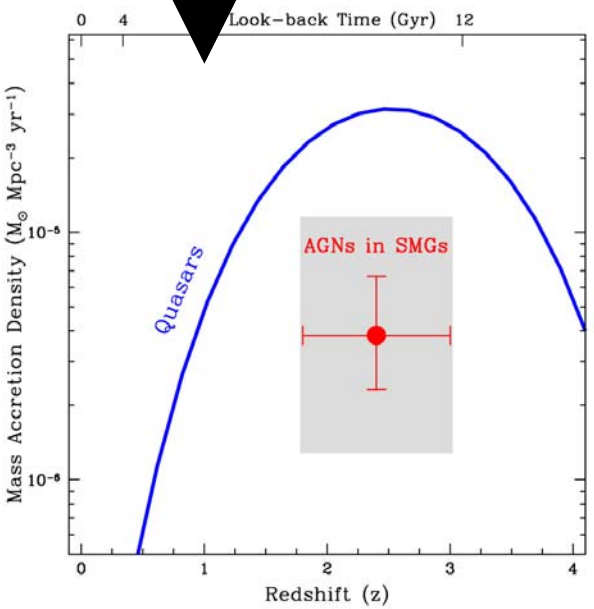


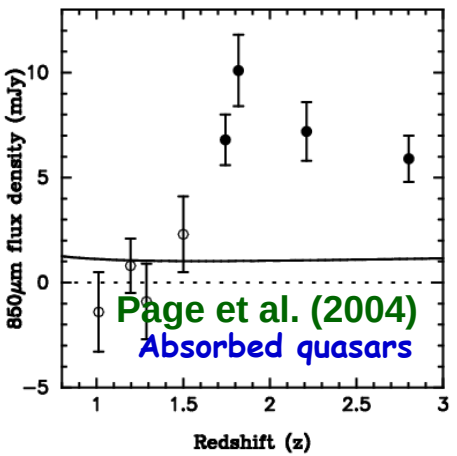
Data suggests that the black-hole growth lags stellar growth unless substantially sub-Eddington accretion (which disagrees with the models): similar to narrow-line Seyfert 1s

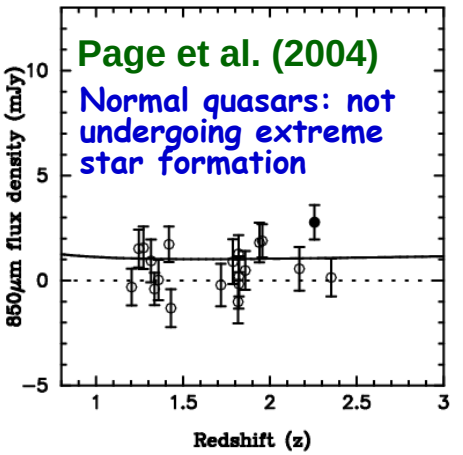
The Growth Phase of Massive Galaxies?

The Dave Sanders et al. evolutionary picture









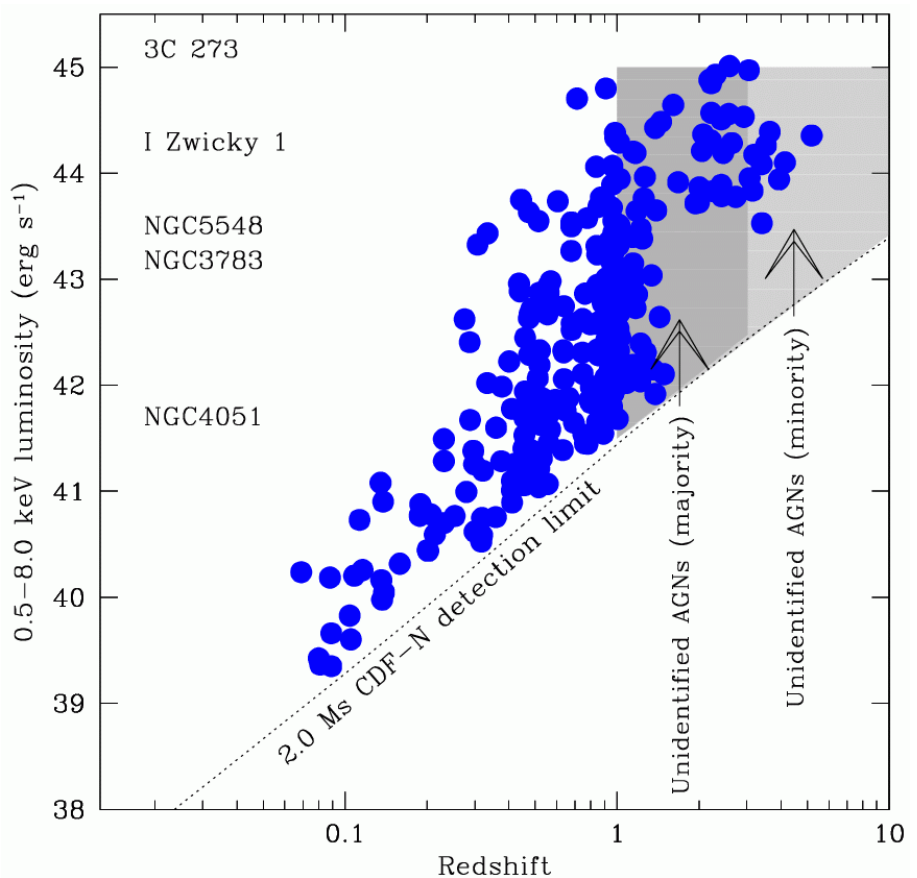
Black-hole growth from SCUBA galaxies is ~4-40% the quasar black-hole growth…

Other pre-quasar growth phases to be found (fainter submm galaxies?)

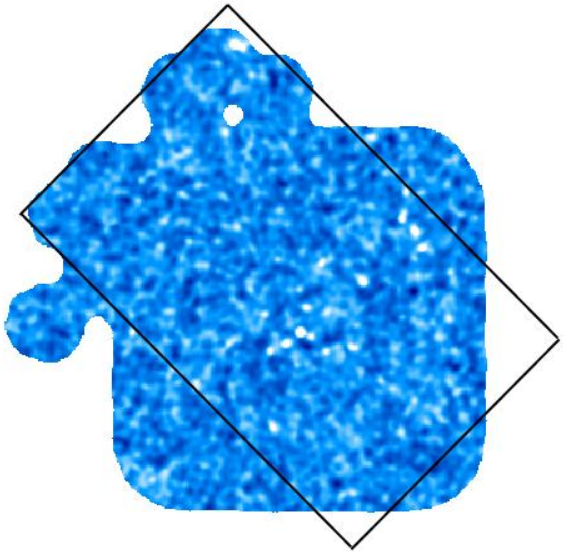
Conclusion: the black-hole growth appears to lag the stellar growth in submm/mm galaxies

The black-hole growth from bright submm/mm galaxies does not appear to be sufficient for the pre-quasar growth phase of massive galaxies: another growth phase required (submm faint galaxies?)

Tracing black-hole growth with ALMA



Pope/Borys Super Scan Map



Submm stacking (by A. Pope) of submm undetected z>1 AGNs: f850=0.6mJy (3σ), most don't have accurate redshifts

ALMA: very effective method to constrain redshifts (in addition to CO and continuum constraints) and provide physical insight into the cosmic growth of black holes and the AGN-star formation connection

General Conclusions

- A large fraction (~28-50%) of SCUBA galaxies host moderate-luminosity, heavily obscured AGN activity

- This AGN activity occurs almost continously during intense star formation (~1000 solar masses/year): joint star formation and black-hole growth, in contrast to co-eval optical galaxies

- The black-hole growth is probably Eddington limited ($M_{BH}<10^8\ M_{solar}$): similar to narrow-line Seyfert 1s?

- The black-hole growth appears to lag the stellar growth; these massive galaxies probably don't lie on the local M-σ relationship until after an AGN-dominated quasar phase

- Bright submm/mm galaxies produce insufficient black-hole growth to represent the entire pre-quasar phase: X-ray faint z>1 AGNs (f850um=0.6mJy, average) probably contribute the additional black-hole growth; ALMA will provide an efficient method to obtain redshifts for these optically faint sources