AGN unification

- Introduction
- Torus Problems
- Modes of activity
- AGN and starbursts

ROYAL OBSERVATORY EDINBURGH

Introduction

The AGN bestiary

QSO, quasar, Seyfert, Type-1, Type-2, LINER, N-galaxy, radio galaxy, BLRG, NLRG, HEG, LEG, WEG, CDQ, LDQ, HPQ, BL Lac, blazar, NELG, NLXG, NLSy1, BALQSO, LBALQSO, HBALQSO ...

1975 : confusion reigns

MRR to the rescue

THE ASTROPHYSICAL JOURNAL, 213:635–647, 1977 May 1

ON THE UNITY OF ACTIVITY IN GALAXIES

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ABSTRACT

A scheme is presented which unites quasars, radio galaxies, N galaxies, and Seyfert galaxies into a single picture of activity in galaxies. Probability functions are given for optical and radio cores, and extended radio sources (in the case of ellipticals), for both spirals and ellipticals. Activity occurs in galaxies of all luminosities, but the strength of it is made proportional to galaxy luminosity. It is assumed that there is dust surrounding the optical cores, to explain the strong infrared emission in Seyferts.

Quasars may, in this picture, occur in both spirals and ellipticals, and in fact most optically selected QSOs are predicted to be in spirals.

- Sy, quasars, N-galaxies, QSO unified with single set of lum fns, and probabilities
- first proposal that Sy 2 = Sy 1 behind dust

Observational Space

- Type 2 *vs* Type 1
- blazarity
- radio loudness
- nucleus *vs* host
- excitation (nature of LINERs)
- quasar *vs* starburst (nature of ULIRGs)

Received Wisdom 2000

- Type 2 *vs* Type 1
  - viewing angle to obscuring torus
- blazarity
  - viewing angle to relativistic jet
- radio loudness
  - connected to galaxy type : no consensus on physical reason
- nucleus *vs* host
  - $L_{nuc} \propto M_H \propto M_{bul}$
- excitation (nature of LINERs)
  - some dilute AGN, some star formation
- quasar *vs* starburst (nature of ULIRGs)
  - 80% starburst, 20% buried AGN

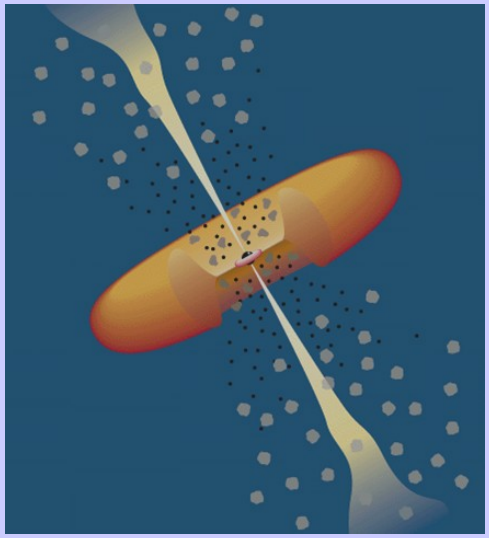
Issues 2007

- Torus problems
- Modes of activity
- Starburst-agn connection

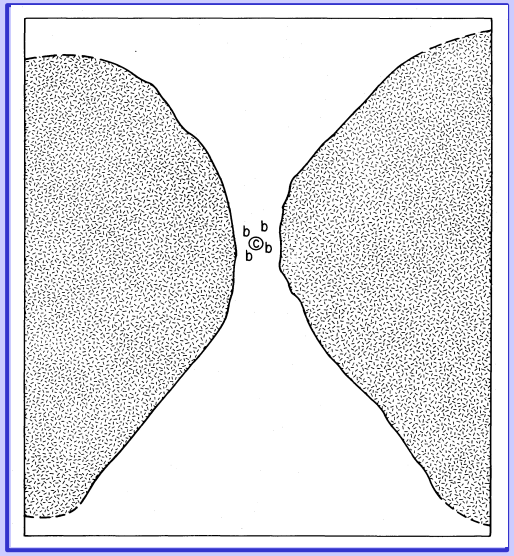
Torus Problems

Rotating donut model

- For
  - ionisation cones
  - polarisation mirrors
  - new VLT-I 11μm images (Tristam et al 2007)



- Against
  - Physically implausible
  - host differences (Malkan, Gorjian and Tam 1998)
  - OIII differences (various refs)
  - no natural explanation for covered fraction



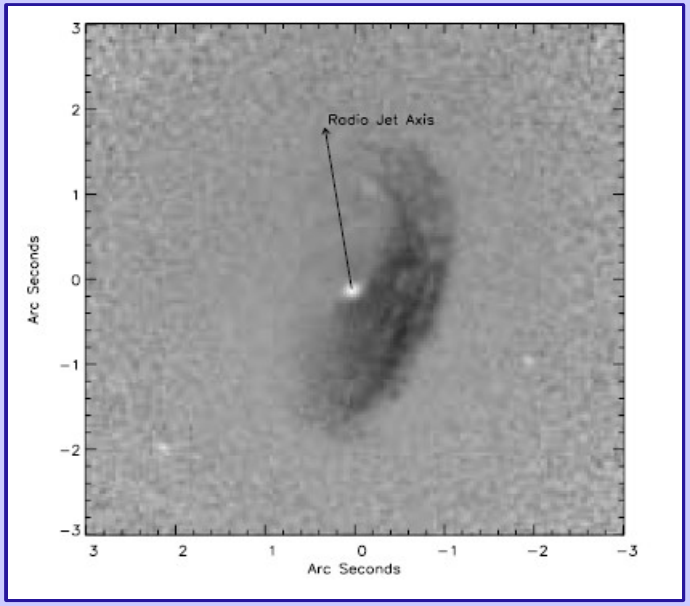
Antonucci and Miller 1985

Other axisymmetric obscurers

- radial outflow with dust formation
  - Konigl et al, Elvis 2000, Elvis Marengo and Karovska 2002
- settling warp
  - Phinney 1989, Sanders et al 1989, Lawrence and Elvis in prep
- driven warp
  - Pringle 1996, Pringle et al 1997

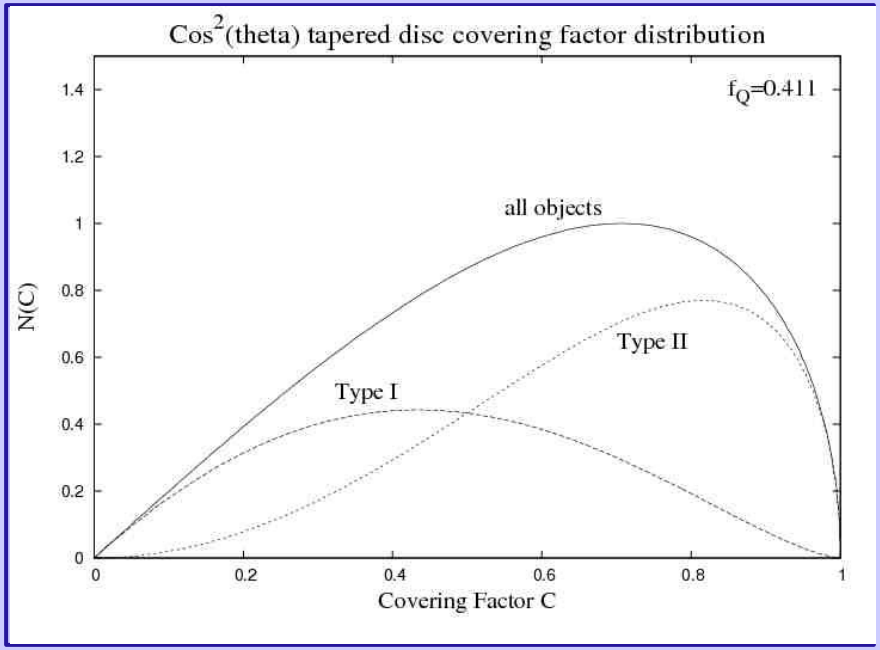
Misaligned fuelling model

- In radio gals, kpc dust disc misaligned with jet
  - Schmitt et al 2002
- Use observed distribution
- Predicts correct quasar fraction and range of covering factors



3C449 HST : Tremblay et al 2006

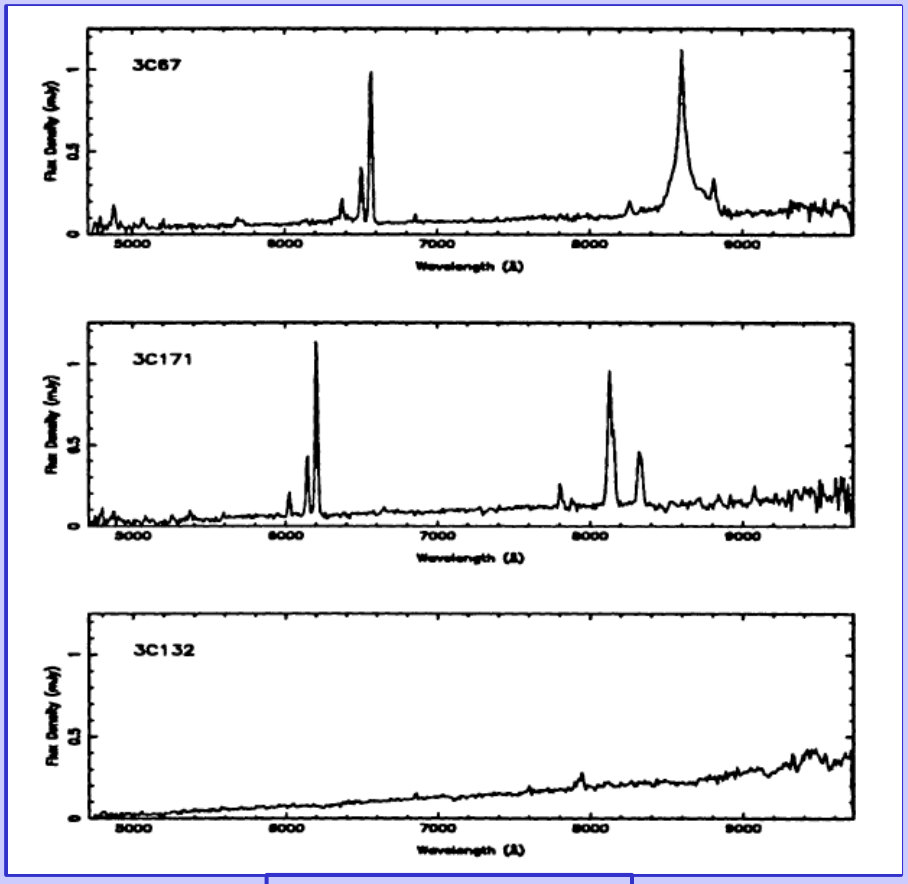
Lawrence and Elvis in prep



modes of activity

Low excitation radio galaxies

- large popn of LEGs
  - often very weak lines
  - all at low Lrad, usually FRI
  - removes $f_Q(L)$ effect (Willott et al 2000)
  - parent population of BL Lacs
  - no X-ray or UV, even scattered (Hardcastle 2007)
  - not larger than low-L BLRGs ==> not edge on (Kapahi 1990)

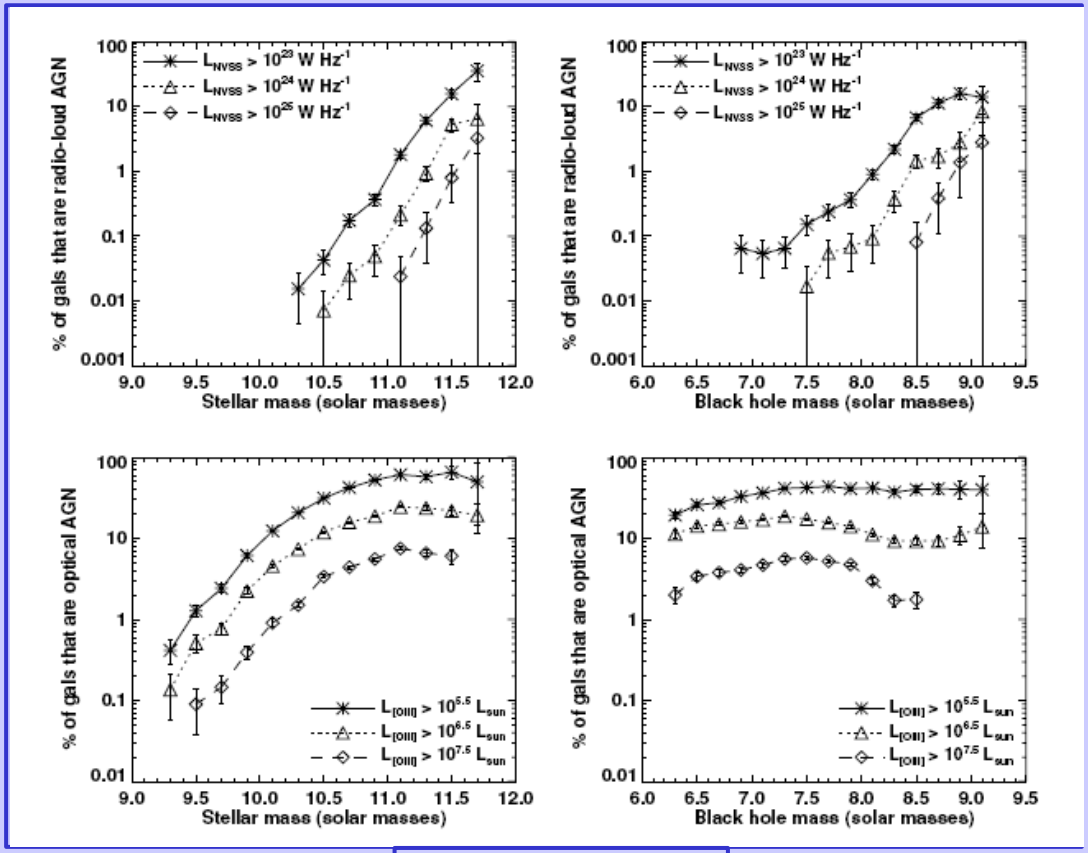


Laing et al 1994

NOT OBSCURED AGN : DIFFERENT MODE OF ACTIVITY

Host galaxy connection

- Prob(active) steep fn of galaxy lum
  - Huchra & Sargent 1974, MRR 1977,
    Sadler et al 1989, Kaufmann et al 2003, Best et al 2005
- SDSS/radio sample
  - have M_H as well as M_{gal}
  - P(radio-active) :
    steep fn of M_H
  - P(opt-active) :
    weak dependence on M_H
  - Radio and optical activity :
    unconnected
- two modes of activity

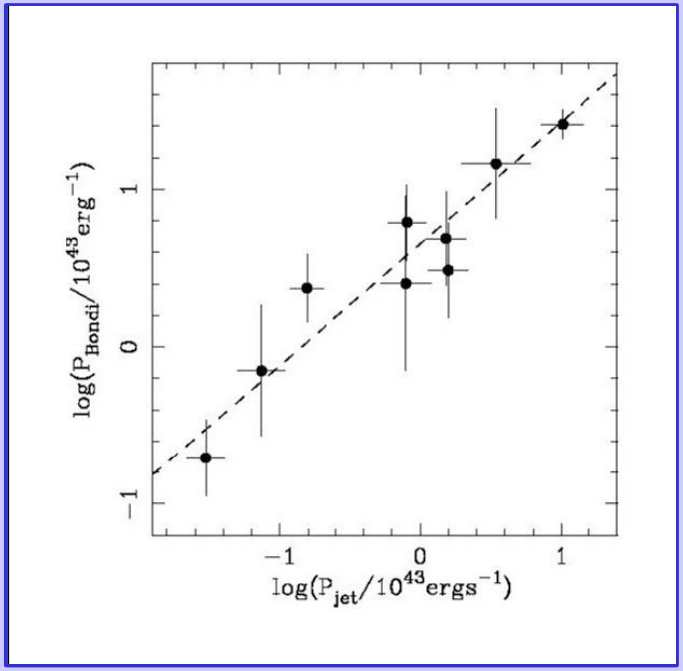


Best et al 2005

Two modes of accretion ?

Best et al 2006
Allen et al 2006

- Cold mode
  - cool and dissipate ; fill nuclear disc
  - viscous accretion; UV bump
- Hot mode
  - virial temp gas
  - Bondi accretion
  - predicted accn rate
    + efficiency=0.1 explains jet power
- problems
  - bound to stall and cool long before BH
  - cold and hot modes occur together at high-L ?



- what about spin energy extraction ?

AGN and starbursts

Two Old Questions

- Are ULIRGS buried AGN ?
  - Soifer et al 1986
- Do ULIRGS evolve into QSOs ?
  - Sanders et al 1988

- Questions re-heated in the 1990s :
  - IRAS F10214+4724 starburst requires >10**9 Msun of dust
  - SMGs : if all starbursts, dominate early SF history
  - (MRR et al 1991, Hughes et al 1998)

AGN fraction in ULIRGs

- Optical spectra : 20% AGN
  - 7% Sy 1 14% Sy2 : Lawrence et al 1999
  - maybe increasing at highest L : Sanders and Mirabel 1996
- IR spectra : a few added AGN
  - but mostly, IR-class = optical class
  - Lutz et al 1998, 1999; Genzel et al 1998
- opt spectra SMGs : ~20 % again
- X-ray IDs of SMGs : 70% ?
  - Smail, this meeting
  - but L(X)<<L(FIR) : sideshow
- "contains AGN" ≠ "explained by AGN"

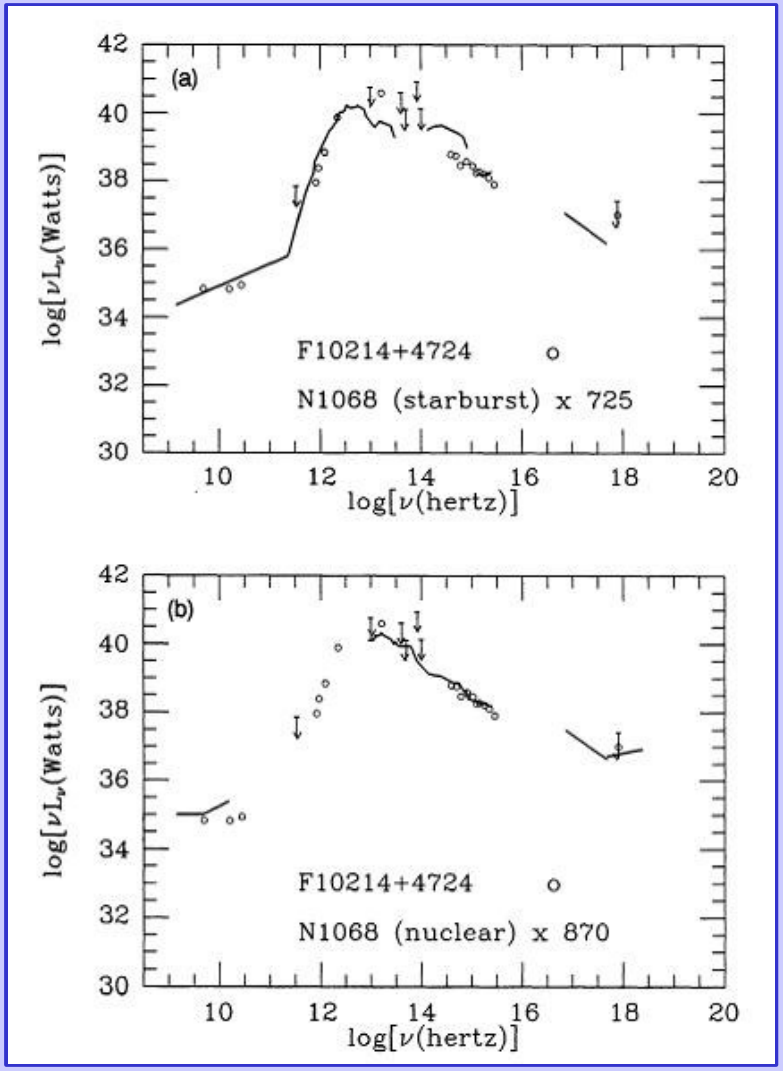
Some objects composite

- IRAS F10214+4724 :
  SED, emission lines,
  and polarisation
  all similar to NGC 1068

- Shortwave : Type-2 AGN

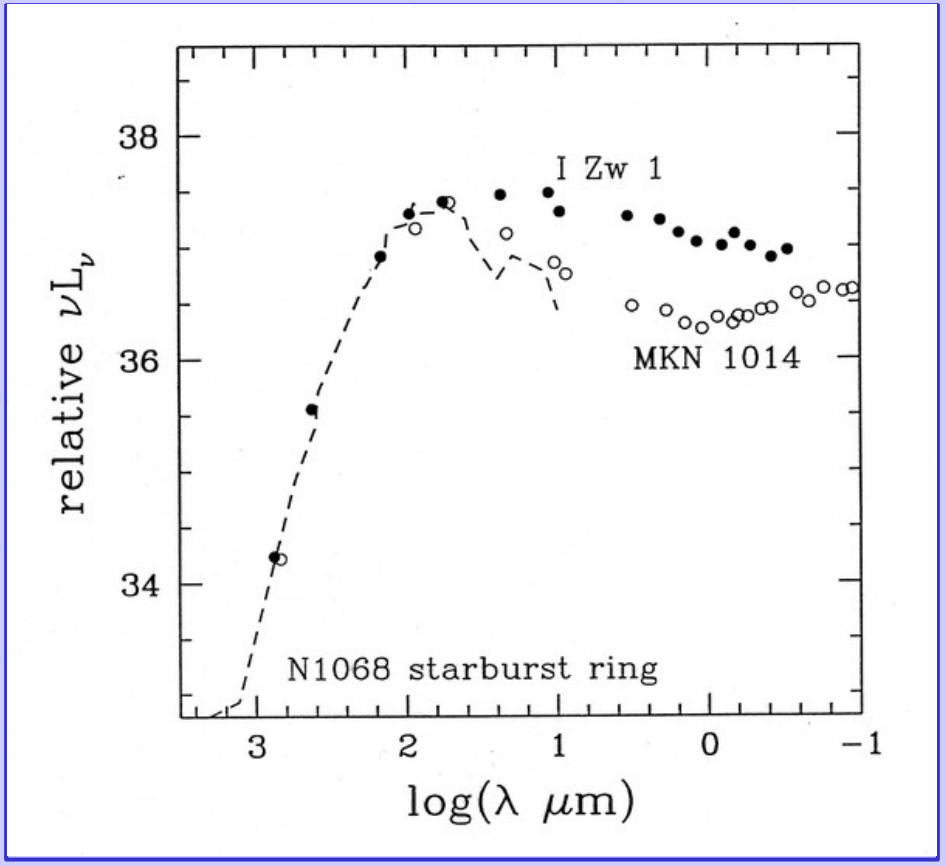
- Longwave : starburst ring

Lawrence et al 1994



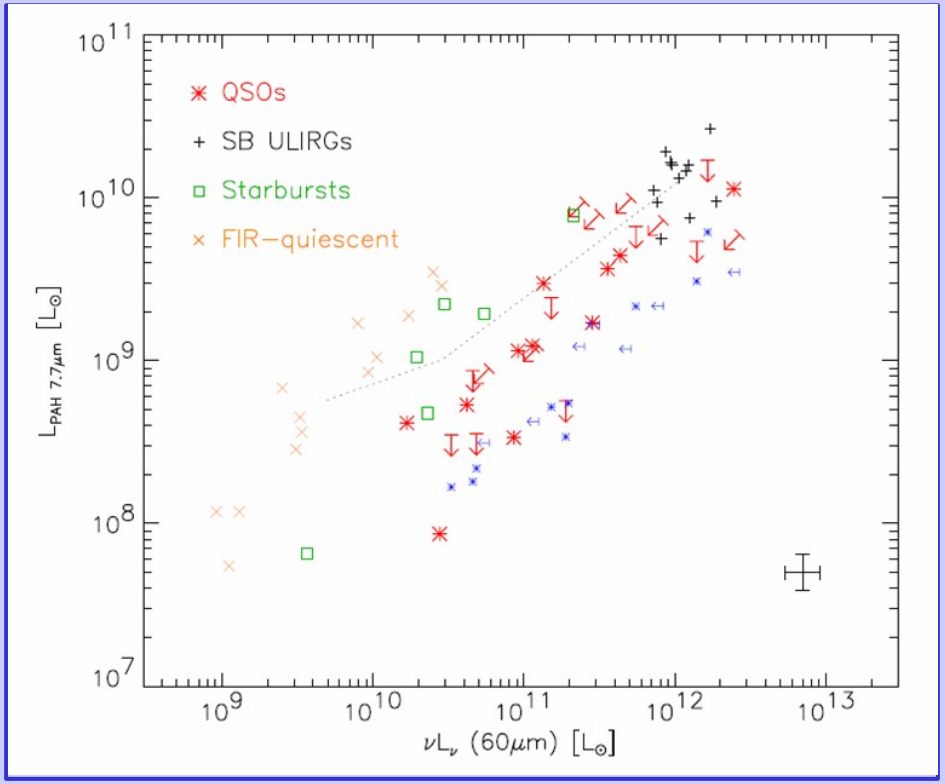
AGN FIR = starburst

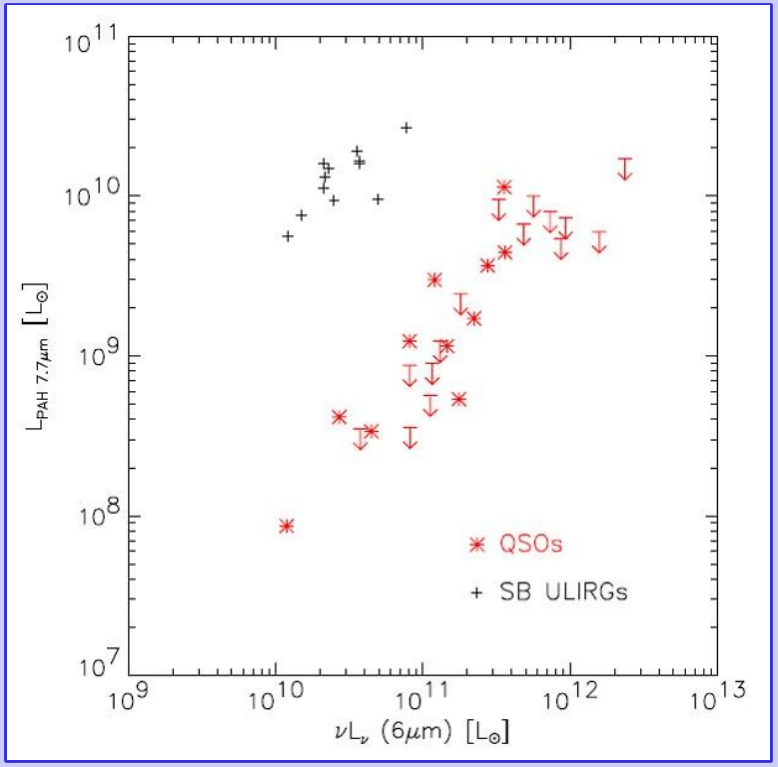
- AGN SEDs
  - shortwave : heterogeneous
  - longwave : all the same = starburst



AGN FIR = starburst

- AGN, ULIRGs, starbursts fall on same relations for :
  - L60 vs radio (Sopp and Alexander 1991)
  - L60 vs CO (Alloin et al 1992)
  - L60 vs PAH (Schweizer et al 2006)



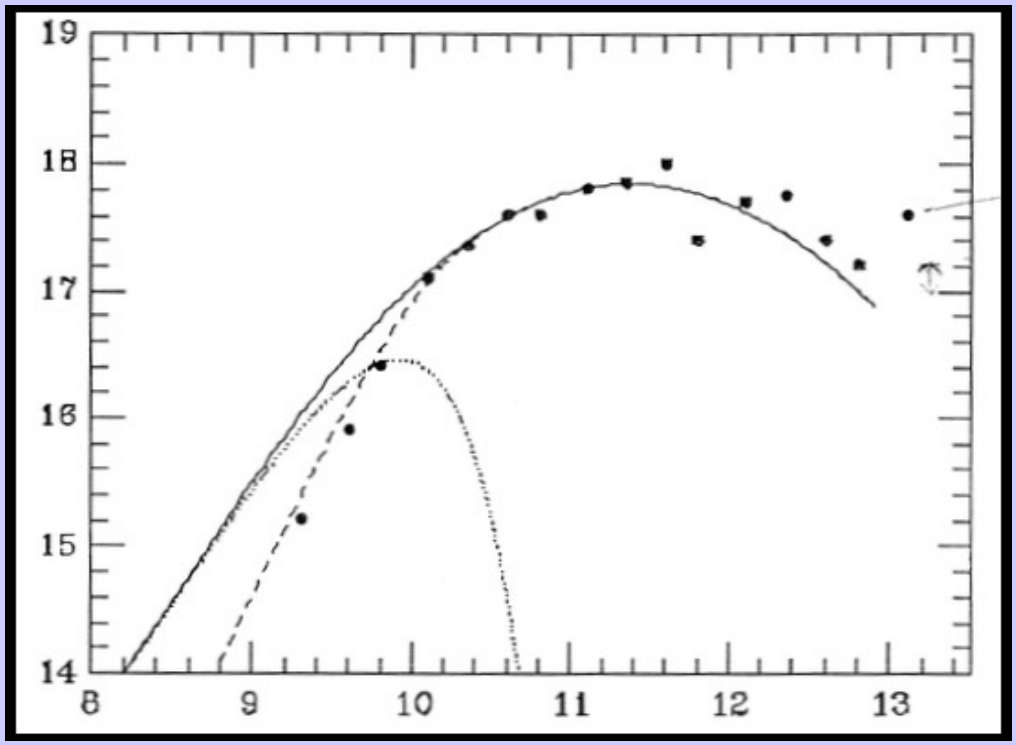


AGN vs Starburst space density

- L60<12
  - shape agrees well
  - AGN = SB/16
  - all AGN have SB
  - 6% of SB have concurrent AGN
  - BH is fuelled for 6% of time ?
- L60>12
  - fit breaks down
  - AGN=ULIRG/4
  - do the rest evolve into QSOs ?

- Φ(starburst) =$\Phi(L_{60})$ - Φ(Schechter)
- dots = $\Phi(L_x) \times$ mean $(L_{60}/L_x) \times 1.5 \times 16$ (factor 1.5 for Type 2 AGN)

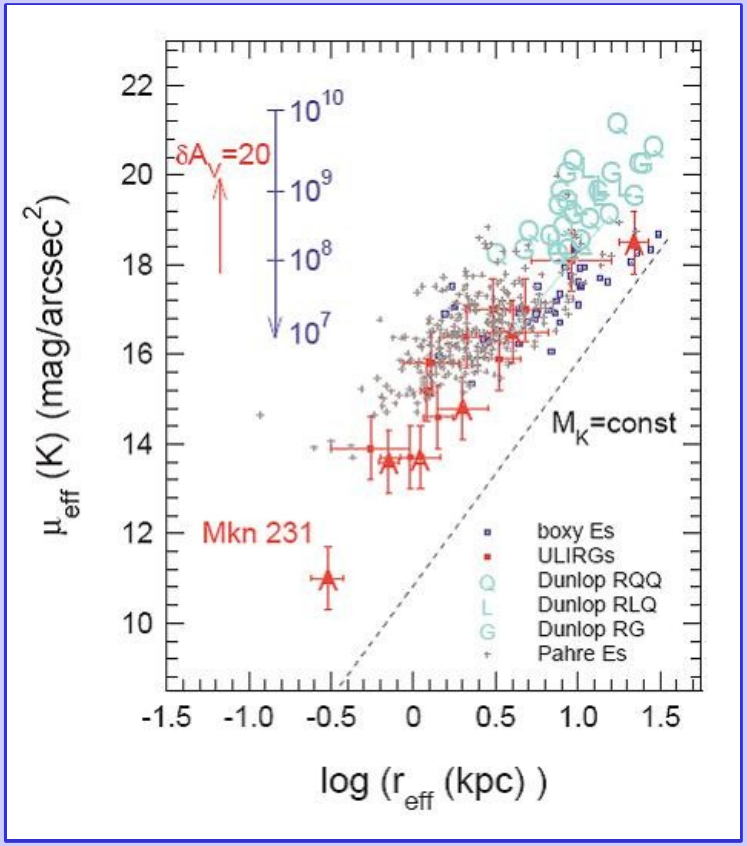
Lawrence 1996 in prepn...



SMGs and QSOs

- SMGs are forming $3L_*$ Es
- most have AGN but $L_{AGN} < L_{FIR}$
- M_H sub-Magorrian
- t(growth) ~ 1 Gyr
- t(gas consumption) ~100 Myr
- ==> QSO phase 10 x SMG

- possible problem : QSO fuzz BIGGER than ULIRGs ...



Tacconi et al 2002

Growth scenarios

- big galaxies
  - major merger z=3
  - starburst 100Myr
  - BH : Eddington growth to 10^9 Msun over 1Gyr (mostly unobscured)
  - z=0 mostly unfuelled but extracting spin : LEG radio galaxy
  - periodic short refuellings → HEG radio galaxy

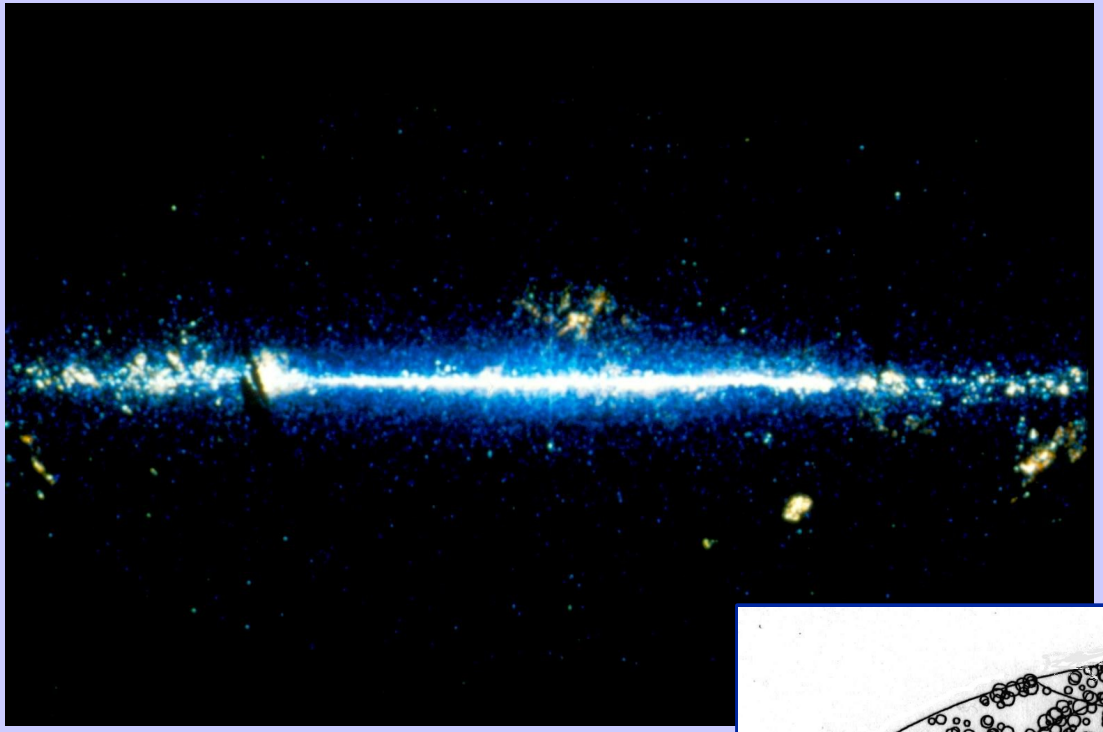
- small galaxy
  - multiple minor mergers z=3 to z=0
  - feed bulge → nuclear disk → starburst → AGN
  - short bursts of feeding : MH grows slowly to $10^{7\text{-}8}$ Msun

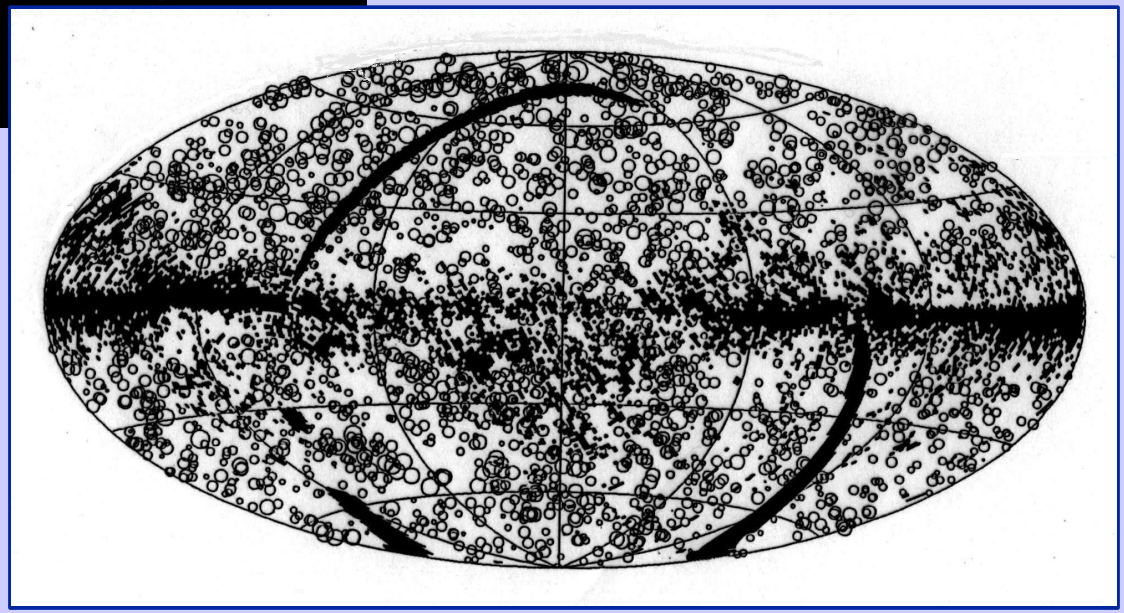
summary

take home messages

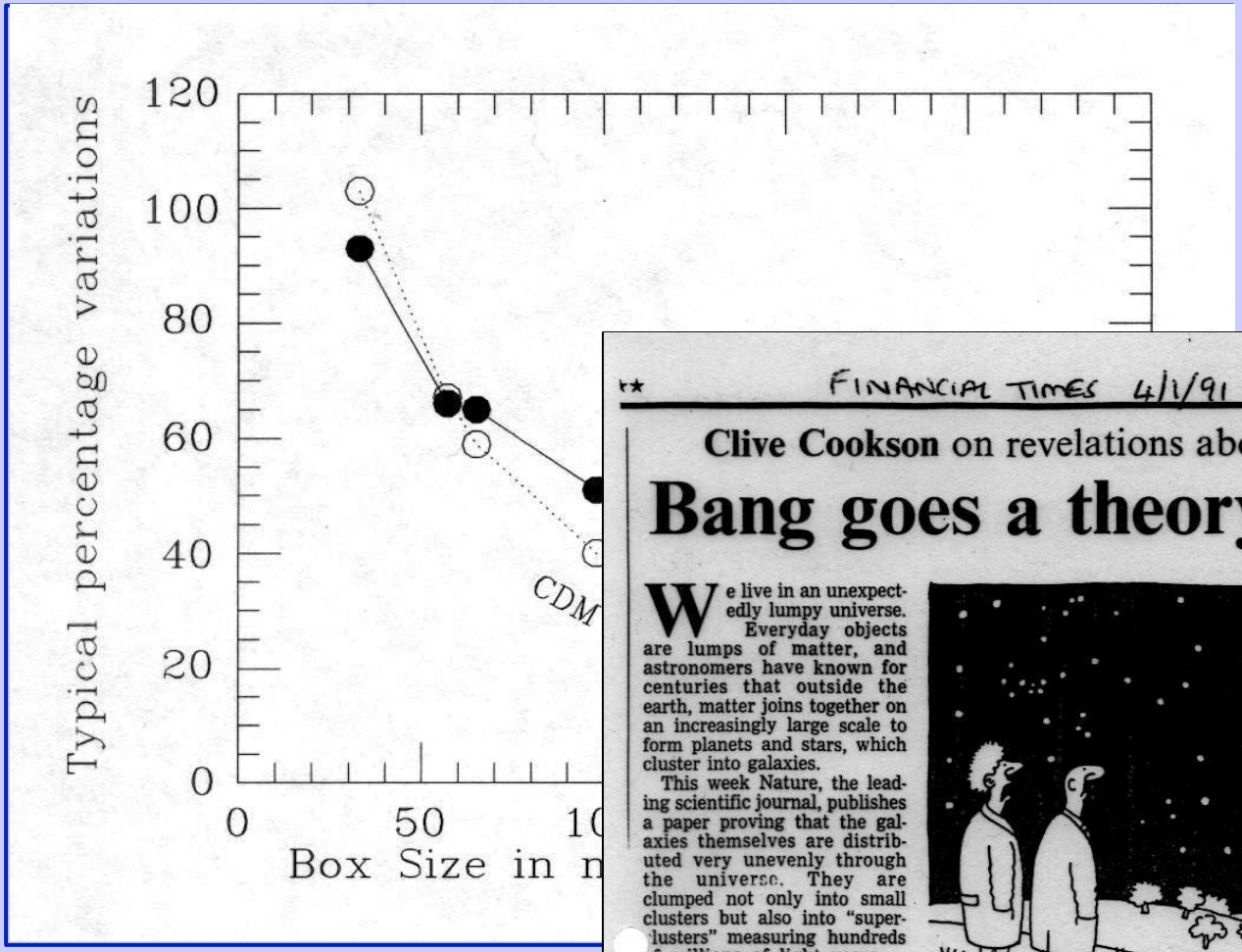
- There are two modes of activity
- Radio activity is in the most massive black holes
- The "torus" could be a warped disk
- Every AGN has a concurrent starburst
  - same thing as the warped disk ?

The scientific product





The cultural product



★★ FINANCIAL TIMES 4/1/91 15

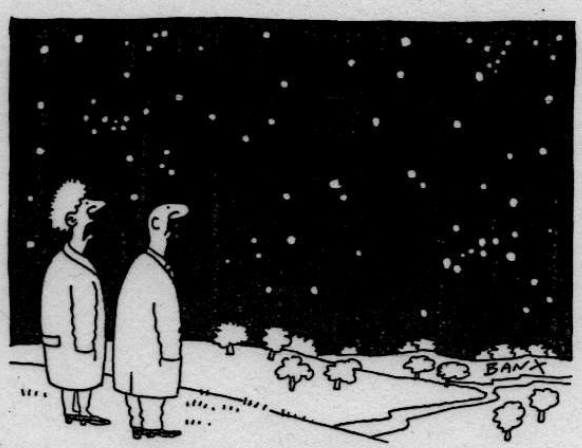
Clive Cookson on revelations about how galaxies are formed

Bang goes a theory of the universe

We live in an unexpectedly lumpy universe. Everyday objects are lumps of matter, and astronomers have known for centuries that outside the earth, matter joins together on an increasingly large scale to form planets and stars, which cluster into galaxies.

This week Nature, the leading scientific journal, publishes a paper proving that the galaxies themselves are distributed very unevenly through the universe. They are clumped not only into small clusters but also into "superclusters" measuring hundreds of millions of light years – that is 100m times greater than the distance from the sun to the nearest star.

Nature calls the findings "sensational" because they demolish the standard theory of the way stars and galaxies formed after the Big Bang – the cosmic explosion about 15bn years ago which gave rise to the universe. This theory, known as the cold dark matter



"WILL YOU TRY TO BE ROMANTIC AND STOP CALLING IT LUMPY?"

a year ago at the Harvard-Smithsonian Centre for Astrophysics; it is a continuous sheet of galaxies running through the universe for 500m light years.

schel observatories and the Anglo-Australian telescope) to measure the "red-shift" of each galaxy; this reveals its distance from the earth.

The ground-based observa-

dark matter model can be bent to take account of the new observations, because it doesn't have any free parameters to tweak. But I think someone will come up with a brilliant lateral leap of logic."

The latest observations leave astronomers uncertain not only about the way galaxies formed but also about what matter actually exists in the universe today. The visible matter – galaxies and intergalactic dust – accounts for less than 10 per cent of the mass of the universe, and perhaps as little as 1 per cent.

The so-called "missing mass" – which many astronomers believed was the same as "cold dark matter" – is now more of a mystery than ever. Some of it may consist of gas or small cool stars that are too faint for astronomers to detect even with the most sophisticated instruments. According to this theory, the universe is swarming with a myriad of invisible bodies rather like the planet Jupiter.

FIN