More on the Zoo

Class/Acronym	Meaning	Main properties/reference
Quasar	Quasi-stellar radio source (originally)	Radio detection no longer required
Sey1	Seyfert 1	FWHM $\gtrsim 1,000$ km s^{-1}
Sey2	Seyfert 2	FWHM $\lesssim 1,000$ km s^{-1}
QSO	Quasi-stellar object	Quasar-like, non-radio source
QSO2	Quasi-stellar object 2	High power Sey2
RQ AGN	Radio-quiet AGN	see ref. 1
RL AGN	Radio-loud AGN	see ref. 1
Jetted AGN		with strong relativistic jets; see ref. 1
Non-jetted AGN		without strong relativistic jets; see ref. 1
Type 1		Sey1 and quasars
Type 2		Sey2 and QSO2
FR I	Fanaroff-Riley class I radio source	radio core-brightened (ref. 2)
FR II	Fanaroff-Riley class II radio source	radio edge-brightened (ref. 2)
BL Lac	BL Lacertae object	see ref. 3
Blazar	BL Lac and quasar	BL Lacs and FSRQs
BAL	Broad absorption line (quasar)	ref. 4
BLO	Broad-line object	FWHM $\gtrsim 1,000$ km s^{-1}
BLAGN	Broad-line AGN	FWHM $\gtrsim 1,000$ km s^{-1}
BLRG	Broad-line radio galaxy	RL Sey1
CDQ	Core-dominated quasar	RL AGN, $f_{core} \geq f_{ext}$ (same as FSRQ)
CSS	Compact steep spectrum radio source	core dominated, $\alpha_r > 0.5$
CT	Compton-thick	$N_H \geq 1.5 \times 10^{24}$ cm^{-2}
FR 0	Fanaroff-Riley class 0 radio source	ref. 5
FSRQ	Flat-spectrum radio quasar	RL AGN, $\alpha_r \leq 0.5$
GPS	Gigahertz-peaked radio source	see ref. 6
HBL/HSP	High-energy cutoff BL Lac/blazar	$\nu_{synch\ peak} \geq 10^{15}$ Hz (ref. 7)
HEG	High-excitation galaxy	ref. 8
HPQ	High polarization quasar	$P_{opt} \geq 3\%$ (same as FSRQ)
Jet-mode		$L_{kin} \gg L_{rad}$ (same as LERG); see ref. 9
IBL/ISP	Intermediate-energy cutoff BL Lac/blazar	$10^{14} \leq \nu_{synch\ peak} \leq 10^{15}$ Hz (ref. 7)
LINER	Low-ionization nuclear emission-line regions	see ref. 9
LLAGN	Low-luminosity AGN	see ref. 10
LBL/LSP	Low-energy cutoff BL Lac/blazar	$\nu_{synch\ peak} < 10^{14}$ Hz (ref. 7)
LDQ	Lobe-dominated quasar	RL AGN, $f_{core} < f_{ext}$
LEG	Low-excitation galaxy	ref. 8
LPQ	Low polarization quasar	$P_{opt} < 3\%$
NLAGN	Narrow-line AGN	FWHM $\lesssim 1,000$ km s^{-1}
NLRG	Narrow-line radio galaxy	RL Sey2
NLS1	Narrow-line Seyfert 1	ref. 11
OVV	Optically violently variable (quasar)	(same as FSRQ)
Population A		ref. 12
Population B		ref. 12
Radiative-mode		Seyferts and quasars; see ref. 9
RBL	Radio-selected BL Lac	BL Lac selected in the radio band
Sey1.5	Seyfert 1.5	ref. 13
Sey1.8	Seyfert 1.8	ref. 13
Sey1.9	Seyfert 1.9	ref. 13
SSRQ	Steep-spectrum radio quasar	RL AGN, $\alpha_r > 0.5$
USS	Ultra-steep spectrum source	RL AGN, $\alpha_r > 1.0$
XBL	X-ray-selected BL Lac	BL Lac selected in the X-ray band
XBONG	X-ray bright optically normal galaxy	AGN only in the X-ray band/weak lined AGN

The top part of the table relates to major/classical classes. The last column describes the main properties. When these are too complex, it gives a reference to the first paper, which defined the relevant class or, when [illegible]

- For a recent take on the AGN 'Zoo' see
- Active galactic nuclei: what's in a name?
- Padovani,P et al 2017 A&Arv 25,2

arXiv: 1707.07134

Eddington Limit and Growth Rate

- Balance the accretion rate onto the BH against the Eddington limit (λ)
- $dM_{BH}/dt=L_{acc}/\varepsilon c^2 \leq 4\pi G m_p M/\varepsilon c\sigma_t$
- solution is $M=M_o e^{t/\tau}$
- where $\tau=\varepsilon c\sigma_t/4\pi G m_p \sim 45\varepsilon_{0.1}10^6$years, where the efficiency of converting mass to energy $\varepsilon \sim 0.1$ (McLure & Dunlop (2004)) and $\lambda=1$ (remember a Schwarschild BH $\varepsilon \sim 0.057$, Kerr $\varepsilon=0.423$)
- see http://www.astro.yale.edu/coppi/pubs/bhgrowth4.pdf for a discussion of the issues.

Limits to Growth

Eddington implies limit on *growth rate of mass*: since

$$\dot{M} = \frac{L_{acc}}{\eta c^2} < \frac{4\pi G M m_p}{\eta c \sigma_T}$$

we must have

η= efficiency of converting mass to energy

$$M \leq M_0 e^{t/\tau}$$

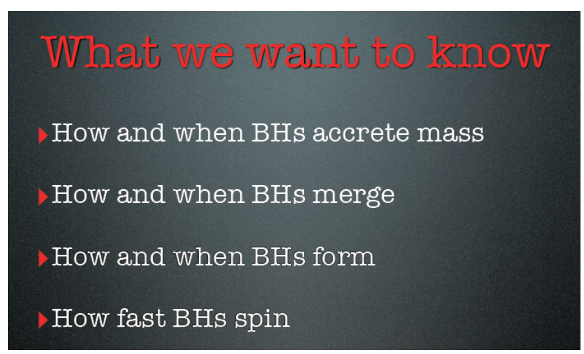
where

$$\tau = \frac{\eta c \sigma_T}{4\pi G m_p} \approx 5 \times 10^7\, yr$$

is the *Salpeter timescale*

Constraints on Growth of Black Holes- Longair 19.4

- To calculate how much mass has been accreted by black holes over cosmic time we need to know how they have grown (Soltan 1982)
  - that is measure the number per unit volume per unit time per unit mass and the energy they emit
  - Adding up the total quasar light and assuming an efficiency of ~0.1 implies that virtually all galaxies should have massive black holes with $<M> \sim 10^7$ M



The average density of mass in the Universe in the form of massive black holes is determined by integrals over the observed number– flux density relation for quasars and the observed redshift distribution in each flux density interval.

Eddington Limit and Growth Rate

- If SMBH grow primarily by accretion then the integral of the accretion rate across cosmic time should be equal to their present mass. (**Soltan** 1982 MNRAS.200..115, 770 citations)-
- Integrating the bolometric luminosity function -compare this to the present day mass of black holes integrated over all objects.
- $L_{bol}=\varepsilon(dM_{acc}/dt)c^2= \varepsilon(dM_{BH}/dt)c^2$
- dM_{acc}/dt=accretion rate
- dM_{BH}/dt= BH growth rate
- ε=efficiency of converting mass to energy
- black hole accretion rate (BHAR) density is (Merloni and Heinz 2011)

$$\Psi_{\rm BH}(z) = \int_0^\infty \frac{(1-\epsilon_{\rm rad})L_{\rm bol}}{\epsilon_{\rm rad}c^2}\phi(L_{\rm bol}, z)dL_{\rm bol}$$

- requires no assumptions beyond the identification of the ultimate quasar power source as black hole accretion
- the directly measured quasar radiation density in the Universe today requires that a corresponding amount of mass per unit volume must have been accreted (assuming that 'light' represents all the energy
- Neither the absolute luminosities of individual quasars(hence cosmological models,H_0 values,beaming factors,and even the attribution of redshifts to the cosmic expansion)affect the result

Choksi and Turner 1992

Total Lifetime of active BHs

- M_{BH} e-fold time (t_{Salp}Salpeter):

$$t_{Salp} = \frac{\varepsilon t_E}{(1-\varepsilon)\lambda} = 4.2\times10^7\,yr\left[\frac{(1-\varepsilon)}{9\varepsilon}\right]^{-1}\lambda^{-1}$$

- To grow a BH SEVERAL t_{Salp} needed: 7 t_{Salp} 10^3 ⇨ 10^6 $M_\odot$
  14 t_{Salp} 10^3 ⇨ 10^9 $M_\odot$
- t_{Salp} independent of M_{BH}, longer t_{BH} at lower M_{BH} indicates a more difficult growth of smaller BHs (feedback?).
- Estimated AGN lifetimes range from 10^6 to 10^8 yr (AGNs from SDSS imply lifetimes > 10^8 yr; Miller et al. 2003).

ε= efficiency
λ= Eddington ratio

$$\langle M_{bh}\rangle = 1.6\times10^7\left(\frac{F_{bol}}{10F_B}\right)\left(\frac{\langle 1+z\rangle}{3}\right)\times\left(\frac{h}{0.75}\right)^{-3}\left(\frac{\xi}{0.1}\right)^{-1}\quad M_\odot \text{ per } L^* \text{ galaxy}.$$

'Soltan' Argument

- If supermassive black holes grow primarily by accretion then the integral of the accretion rate across cosmic time should be equal to their present mass.
- Integrating the bolometric luminosity function and assuming a conversion factor, ε, from mass to energy one can compare this to the present day mass of black holes integrated over all objects

$L_{bol}=\varepsilon(dm_{acc}/dt)c^2=\varepsilon(dm_{BH}/dt)c^2(1-\varepsilon)$

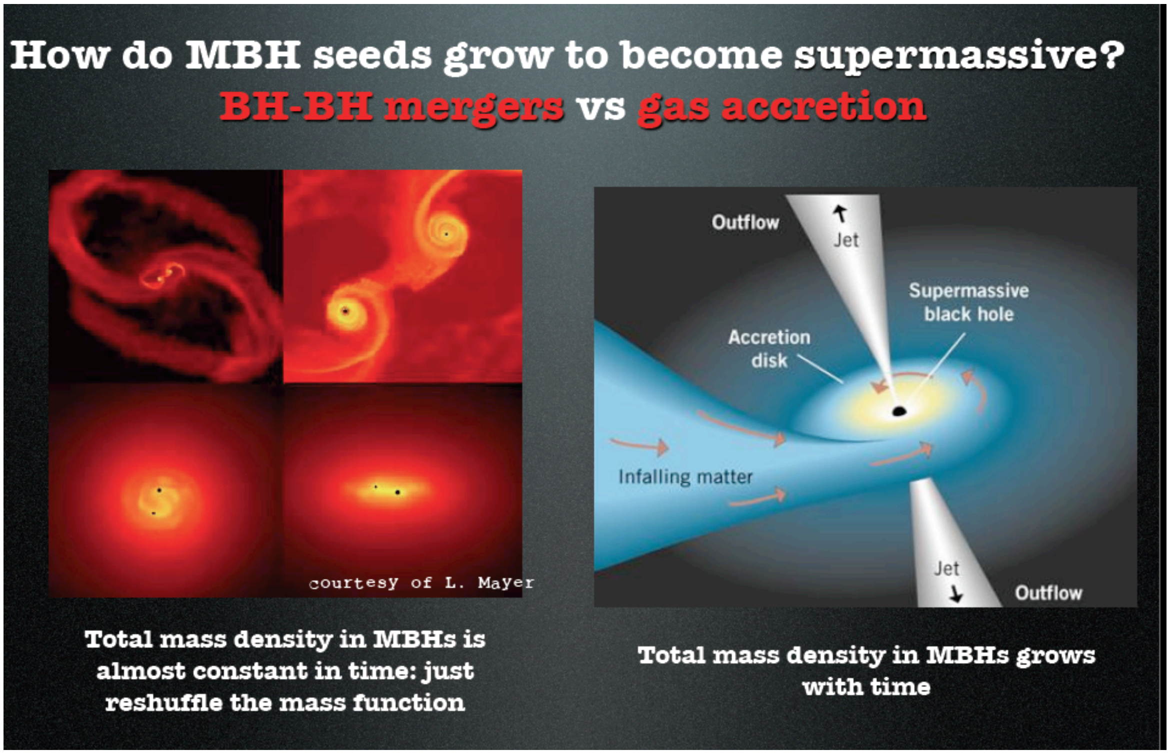
- dm_{acc}/dt=accretion rate
- dm_{BH}/dt= BH growth rate

The higher the conversion factor for converting energy to mass the smaller the predicted BH mass at a given redshift is for a fixed observed luminosity

ε derived this way is independent of the cosmological model

At z=0 the observed BH mass density is ~4×10^5 $M_\odot$/Mpc^3

Utilizing the best estimate of evolution of luminosity vs redshift this gives ε=0.06, marginally consistent with a non-spinning BH

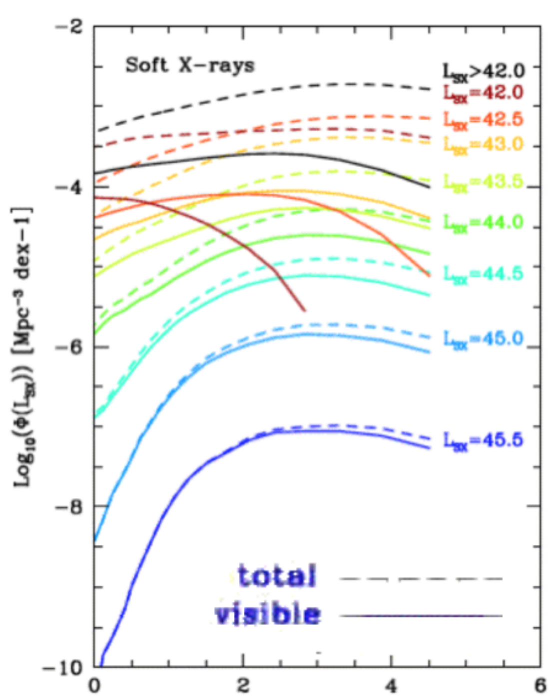


- Volonteri 2008

Downsizing

- The evolution of AGN depends on their luminosity
  - High L AGN were more prominent in the early universe
  - Low L AGN in the low redshift universe
- more massive objects have evolved more rapidly than lower mass BHs

backward from what one naively expects in ΛCDM

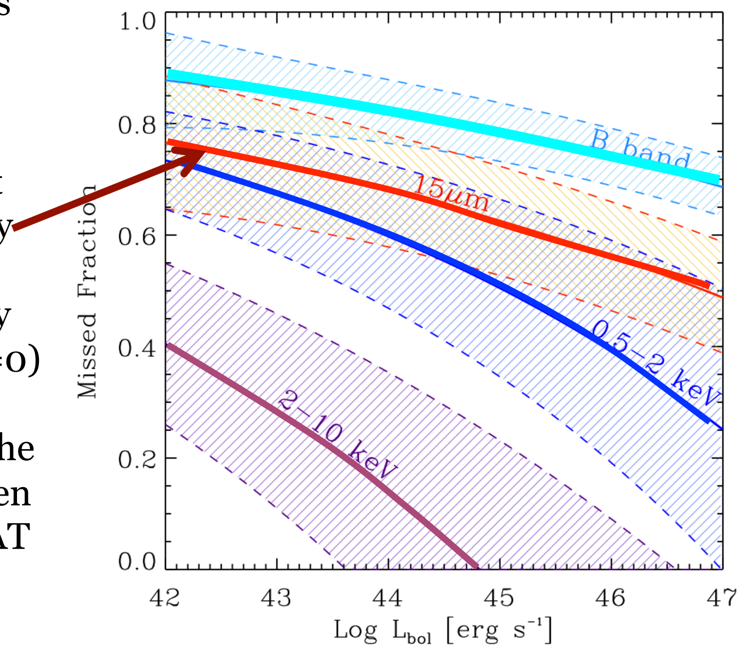


How are AGN Selected

Hard X-rays provide the most complete census of AGN activity (Merloni 2011)

the fraction of AGN that are missed in a survey in a given band as a function of the energy range observed (at z=0)

The fraction missed in the 10-30 keV band is even lower (Nustar and BAT)



Constraints on Mass Growth of Black Holes

- As Just discussed black holes can grow via two paths
  - accretion
  - merger

- It is thought that, at z>1 that many galaxies (esp elliptical galaxies) grow through mergers.

If these galaxies had modest black holes, and if the black holes also merged, one could grow the supermassive black holes that lie in most large galaxies observed today.

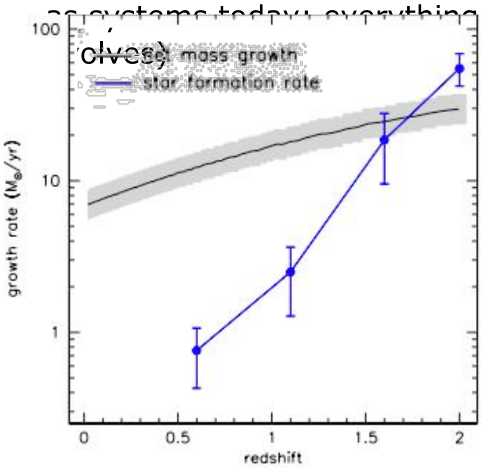
This process would produce strong gravitational radiation which is the goal of the LISA mission

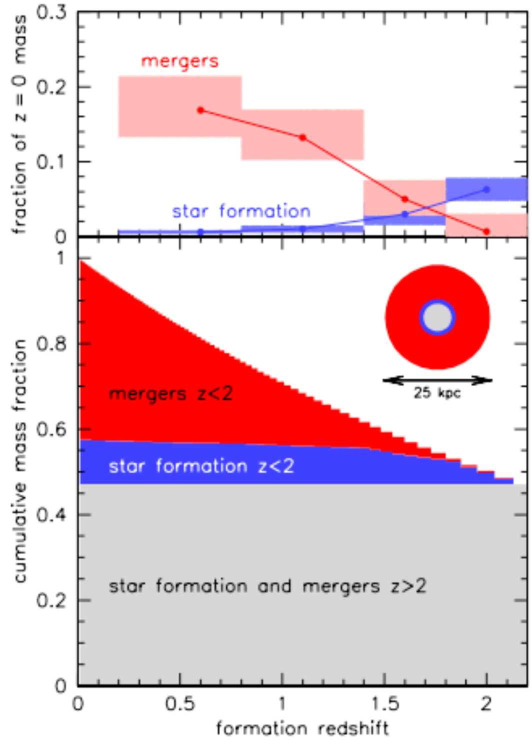
- Alternatively (or in parallel) we know that BHs are growing via accretion.

See Longair ch 23

Growth of Elliptical Galaxies

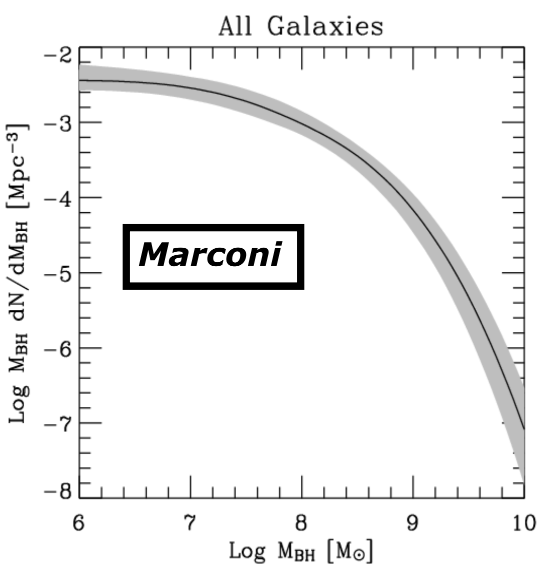
- Massive elliptical galaxies had lots of star formation at high (z>1.5) redshift but more or less stopped forming stars at more recent times
- Growth in E galaxy mass z<2 has been primarily via mergers- this is also consistent with chemical abundance gradients (but the merging galaxies are not the same as systems today; everything evolves)





van Dokkum et al 2010

The local Black Hole Mass Function



Marconi et al. 2004

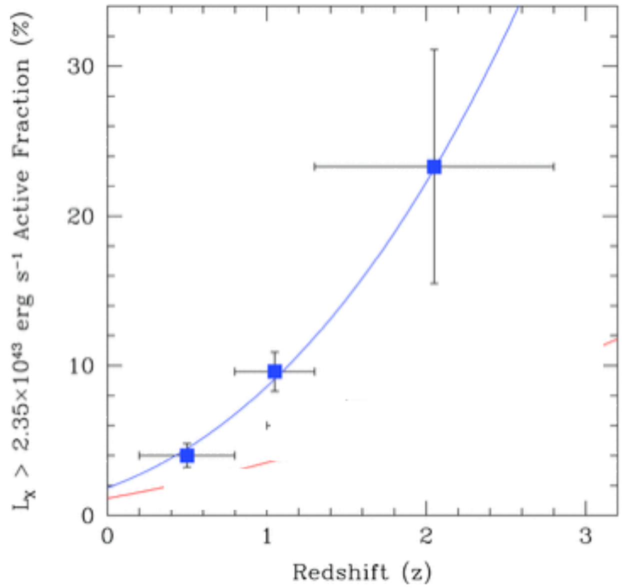
- Convolve Galaxy Luminosity functions with M_{BH}-L_{bulge} and M_{BH}-σ to obtain the local BH mass function.
  - M_{BH}-L_{bulge} and M_{BH}-σ provide consistent BH mass functions

$\rho_{BH} \sim 4.1^{+1.9}_{-1.4} \times 10^5\ M_\odot\ \mathrm{Mpc}^{-3}$

(cf. Merritt & Ferrarese 2001, Ferrarese 2002, Shankar et al. 2004)

Larger Fraction of Galaxies Active in the past

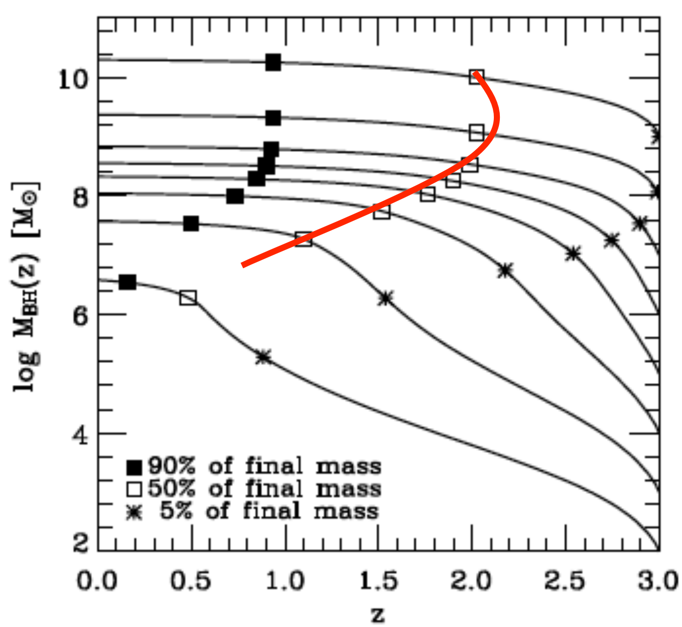
- The evolution seen in luminosity and number is reflected in the fact that a greater fraction of 'normal' galaxies host AGN at higher redshifts



(Bluck et al 2011)

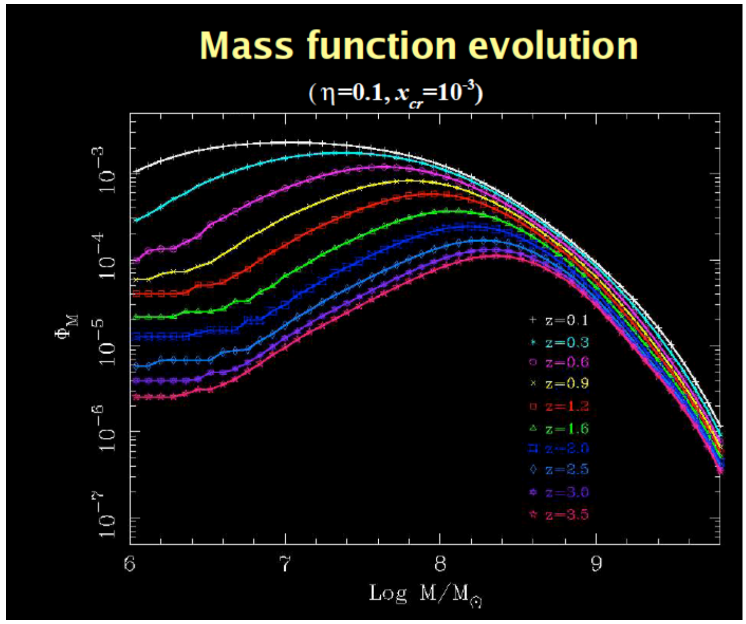
One realization of BH growth

- Big BHs form in deeper potential wells ⇨ they form first.
- Smaller BHs form in shallower potential wells ⇨ they form later and take more time to grow.
  - Marconi 2003, Merloni 2004

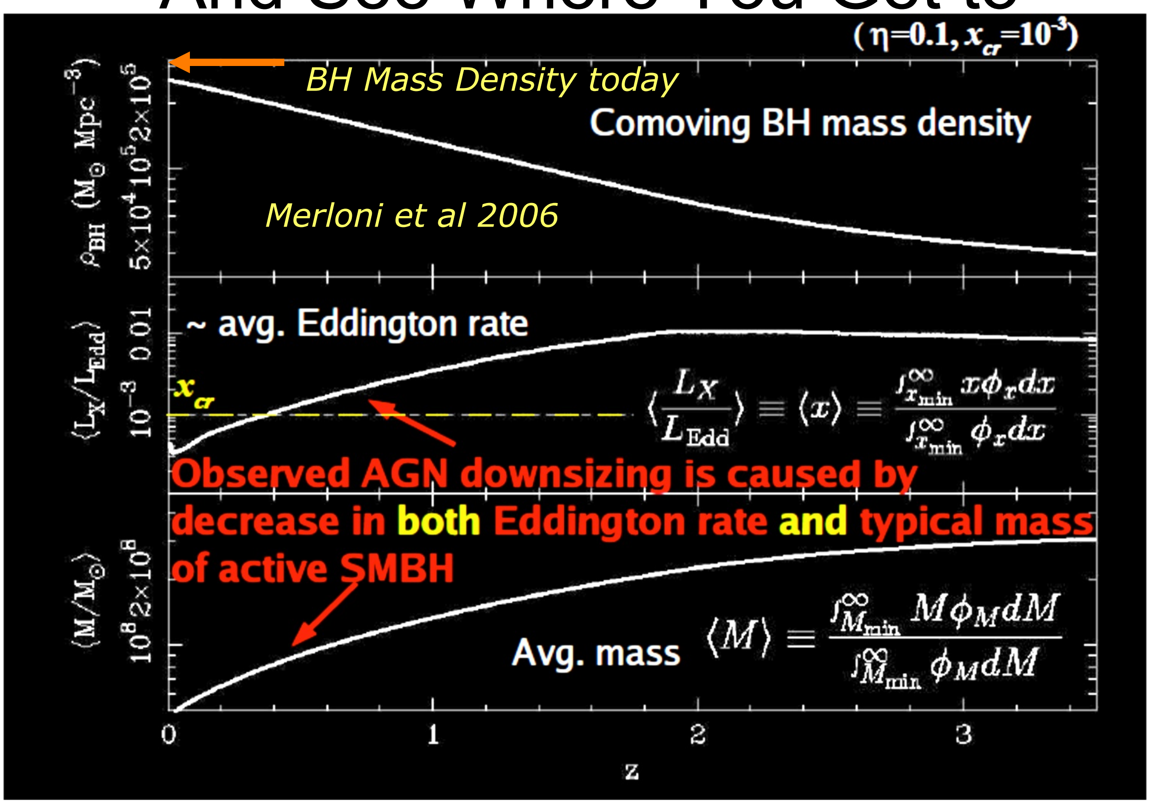


Transform to Mass Growth

- Take accretion rate and some model of initial BH mass distribution and watch them grow (Merloni et al 2006)
- Notice 'down sizing' big black holes grow first and small black holes later

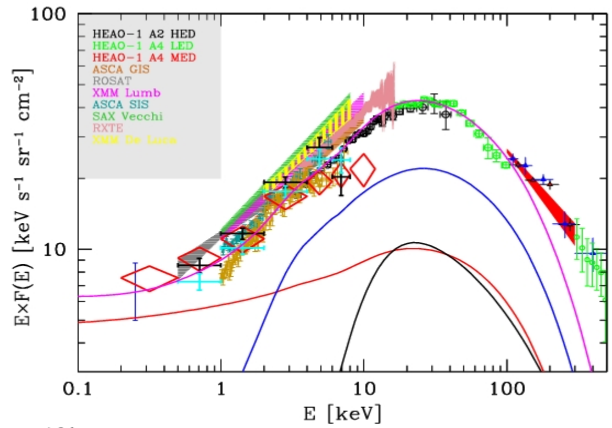


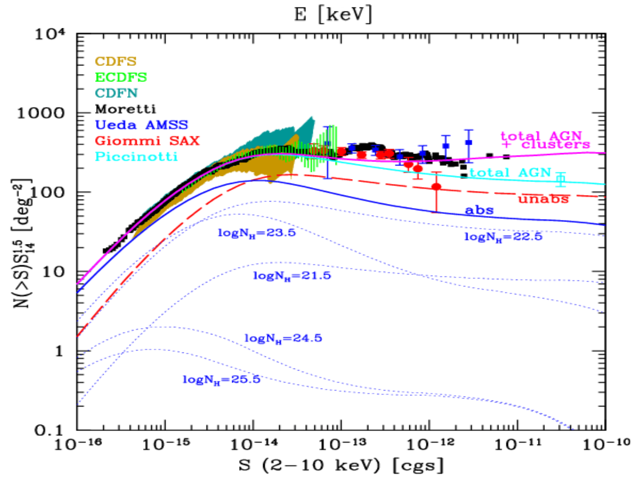
And See Where You Get to



X-ray Background constraints

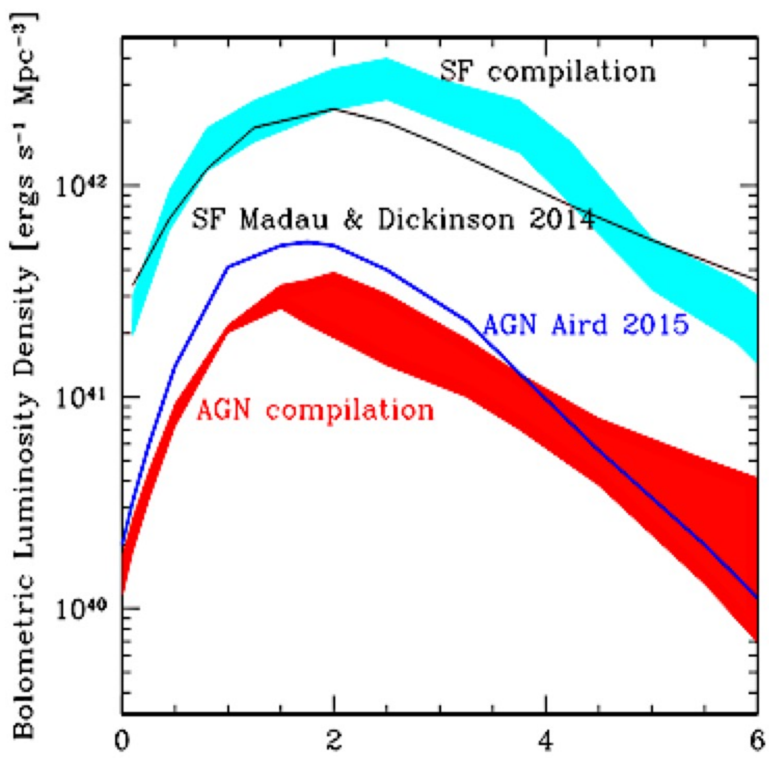
- Integral of x-ray emission over cosmic time produces the XRB
- XRB models provide the total x-ray energy emitted by AGN summed over cosmic time.
  - Synthesis models of the XRB (Gilli et al 2007) involve how the sources evolve and the properties of the sources
  - 3 types of sources
    - unabsorbed (Seyert Is)
    - absorbed (log N(H)>22
    - Highly absorbed ($\tau_{Compton}$>1)





Co-evolution of Galaxies and Black Holes

Comparison of growth of galaxies (Star formation luminosity density) vs growth of AGN (luminosity density) of AGN (Fiore et al 2018)



First “diffuse” cosmic background detected (Giacconi et al. 1962)

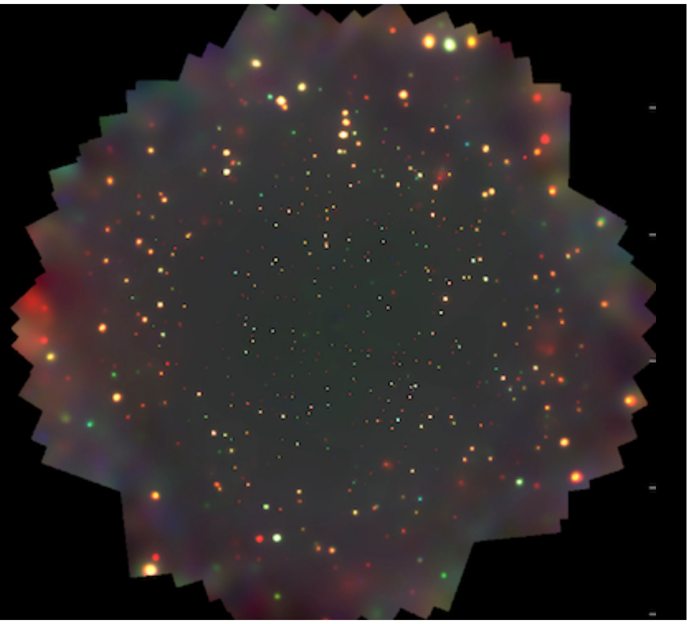
Nobel prize 2003)

Chandra Deep Fields (CDFs)

CDF-N (~2 Ms), CDF-S (~7 Ms)

(e.g., Alexander et al. 2003; Xue et al. 2011)

Hickox 2013)



Montage of many Chandra pointings- PSF strong function of off-axis angle almost all the sources are AGN

Summary

- z~1 is the peak epoch of AGN where the energy density peaks, consistent with the peak in the integral star formation
- AGN evolve very rapidly to z~1, consistent with pure luminosity evolution-
- total energy radiated is consistent with the present day mass of black holes if efficeincy of accretion is ~0.05-0.1
  - Observed x-ray sources can produce "all" of the mass of z~0 black holes via accretion
- The data point to downsizing- massive luminous systems dominate at high z, low mass lower luminosity at lower z.

NEXT topics

- How to find AGN (broad and narrow line objects)
- Many of the non-broad line objects (the dominant population) having high column densities-effect of obscuration is a major effect
- Unified model

The AGN BH Mass Function

A. Marconi

- Assume accretion onto BH is the powering mechanism of AGN to link L_{AGN} with M_{BH}
- $L = \lambda M_{BH} c^2/t_E = \varepsilon (dM/dt) c^2$; alternatively the accreted mass is
  - $M_{BH} = L t_E / c^2 \varepsilon$
- λ= Eddington ratio; ε= accretion efficiency;

Saltpeter time (e-fold time increase mass)

$t_{saltpeter} = \varepsilon\, t_E/(1-\varepsilon)\, \lambda = 4\text{x}10^7\text{yr}$ for $\varepsilon=0.1$, $\lambda=1$

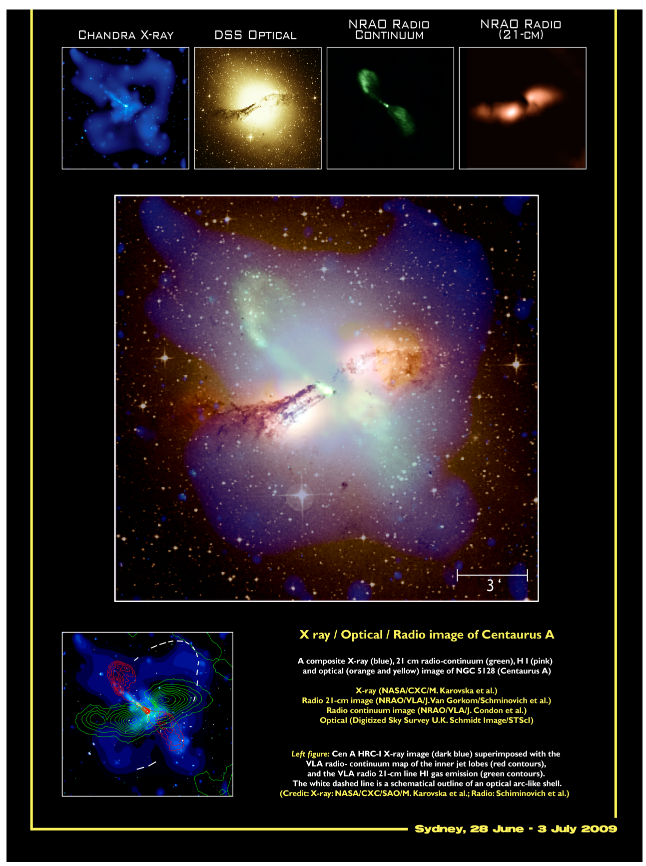
Or more generally $t_{saltpeter} = 4\text{x}10^7\text{yr}\, [(1-\varepsilon)/9\, \varepsilon)]\, \lambda^{-1}$

Independent of M_{BH}

So to grow from, $10^3 M_\odot - 10^6\, M_\odot$ requires 7 $t_{saltpeter}$

So to grow from, $10^3 M_\odot - 10^9\, M_\odot$ requires 14 $t_{saltpeter}$

Centaurus-A The Nearest AGN



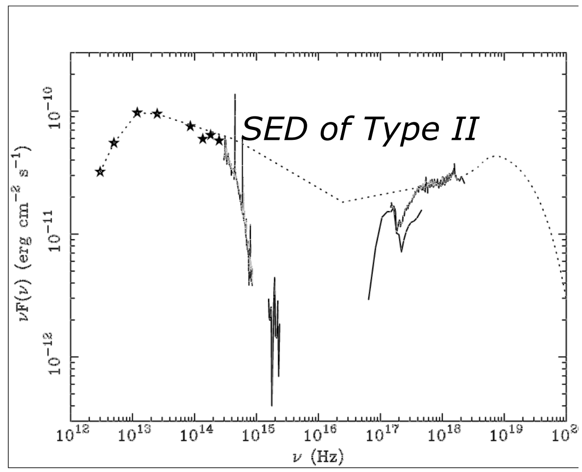
What Are Active Galactic Nuclei

Radiating supermassive black holes in the centers of galaxies

Properties

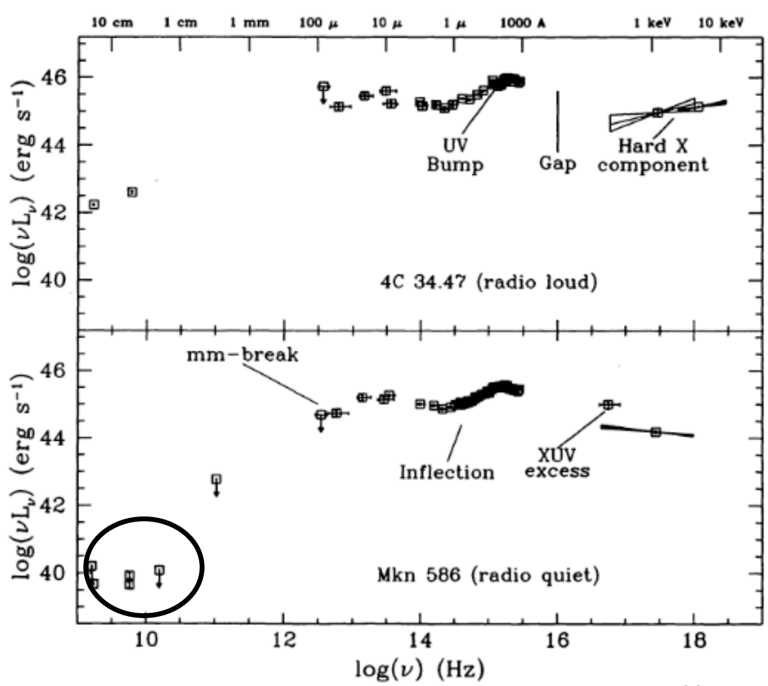
- 'Point-like'
- luminous non-stellar broad band spectra- very broad range in luminosity log L~ 40-48 ergs/sec
- located in center of *some* galaxies at any one time
  - but SMBHs in 'all' massive galaxies
- More details
  - Optical spectra 3 classes
    - strong broad emission lines
    - strong narrow emission lines
    - strong non-thermal continuum
  - radio ~10% of AGN show strong radio emission (jets/extended emission) due to synchrotron radiation
  - IR- emission reprocessed from optical-UV-soft x-ray via dust
  - Optical/UV- in most AGN due to accretion disk - variable
  - X-ray

    non-thermal power law spectra highly variable



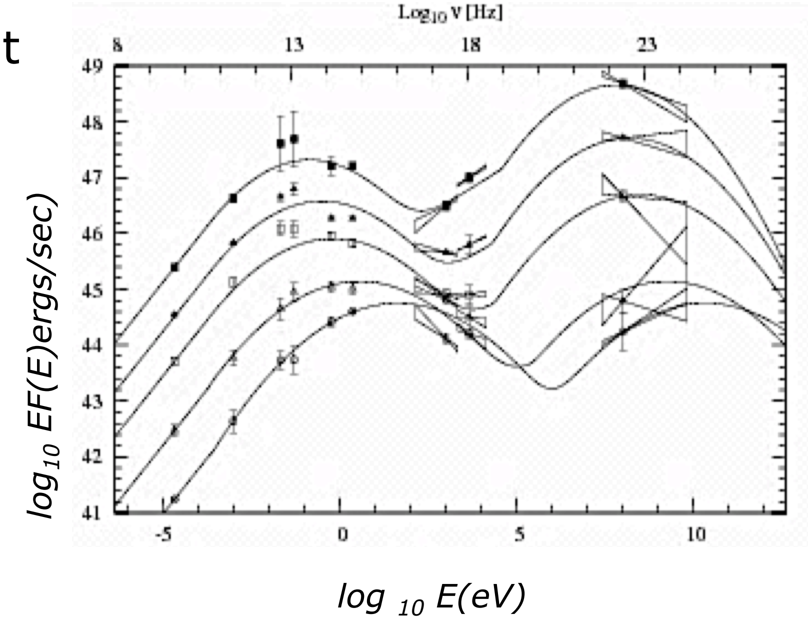
Observational Details of AGN

- Type I AGN SED (radio loud and radio quiet Elvis et al 1994)

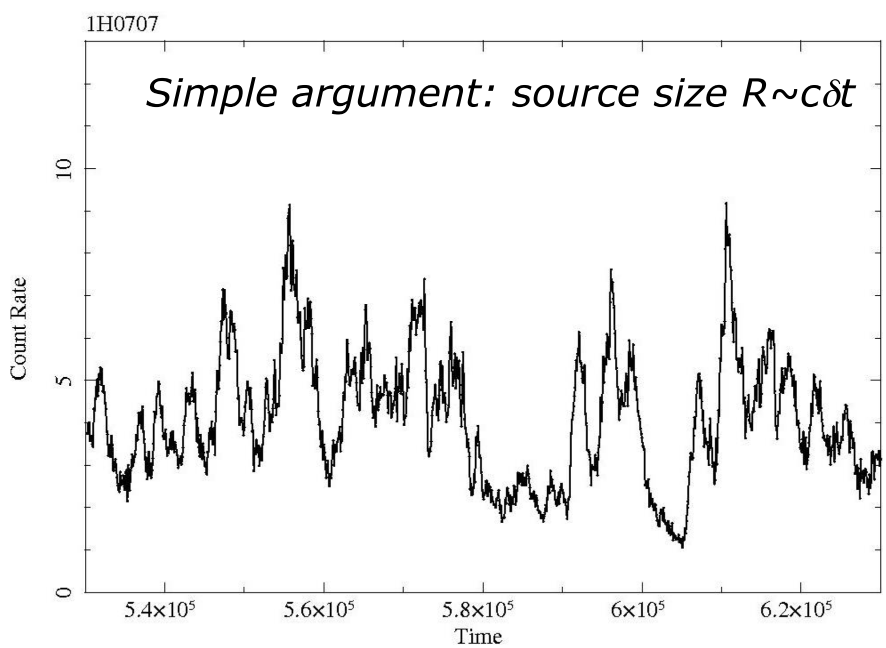


Blazar SED

- Very broad, very different from Seyferts/ quasars

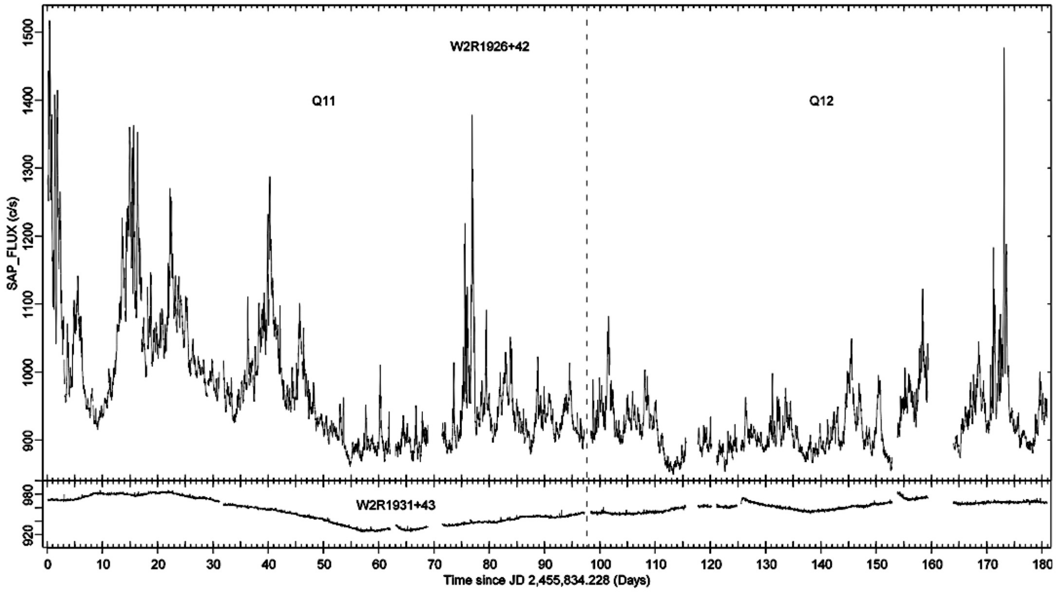


Rapid x-ay variability in AGN luminosity ~5×10^{43} ergs/sec



Simple argument: source size $R \sim c\delta t$

Kepler optical light curve of a Bl Lac Object W2R1926+42



AGN Zoo

"Radio-loud" objects show jets and enormous lobes of relativistic plasma

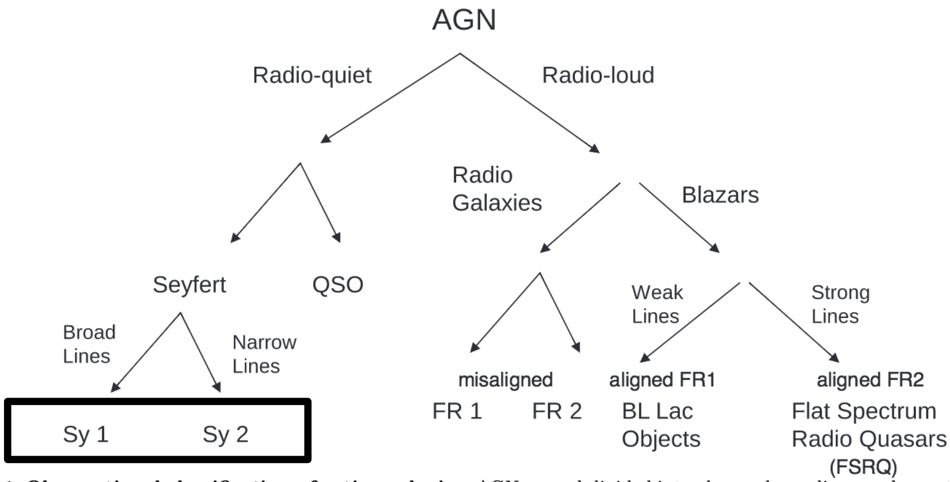
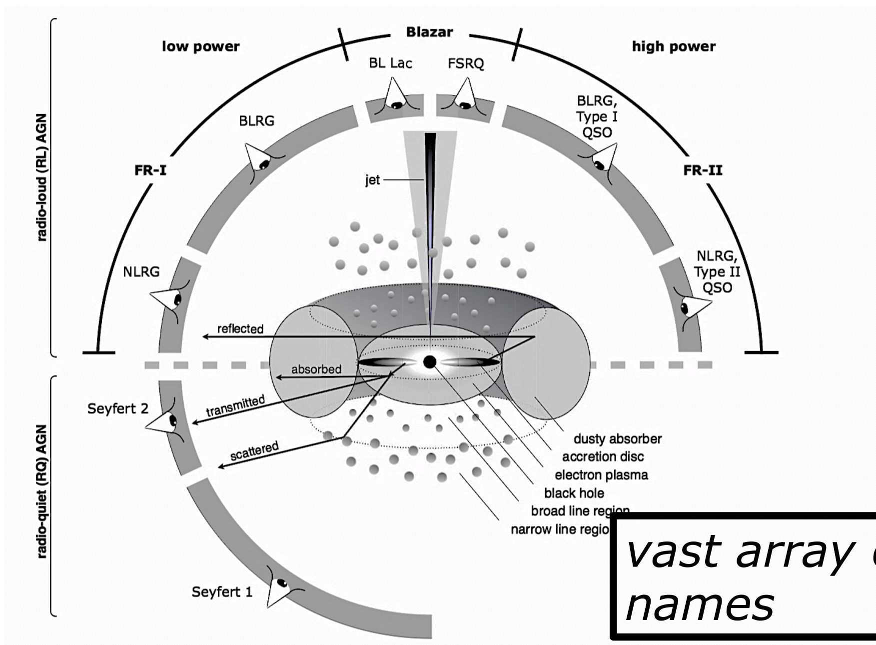


Figure 1. **Observational classification of active galaxies.** AGN are subdivided into classes depending on observational aspects, such as their radio loudness or the presence of optical lines in their spectra. QSO = quasi-stellar objects; Sy1 and Sy2 = Seyfert 1 and 2; FR1 and FR2 = Fanaroff-Riley 1 and 2.

The Overall Picture (Beckman and Shrader 2013)



vast array of names

1: Schematic representation of our understanding of the AGN phenomenon in the unified scheme
: type of object we see depends on the viewing angle, whether or not the AGN produces a significant
sion, and how powerful the central engine is. Note that radio loud objects are generally thought to

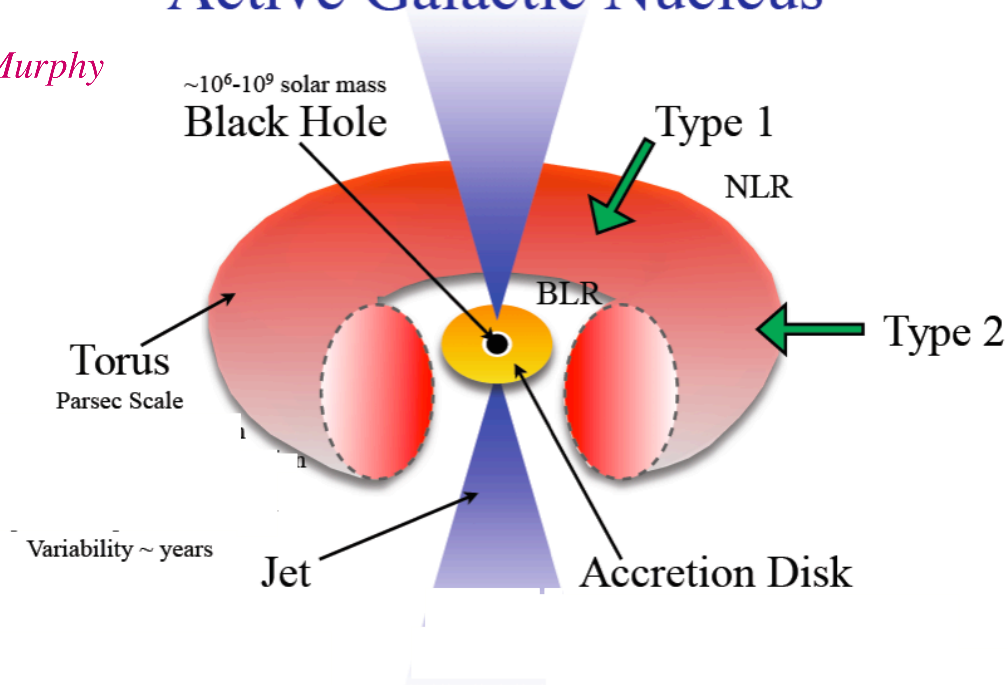
AGN Unification

General comments

- *AGN are diverse… they have a vast range of properties*
- *In general, there are three "axes" to consider…*
- *Luminosity*
  - *Range from <10^{40} erg/s to ~10^{48} erg/s*
  - *Fundamental parameters controlling this is* ***mass accretion rate+BH mass***
  - ***But geometry has a major role in observational appearance***

Active Galactic Nucleus

K. Murphy

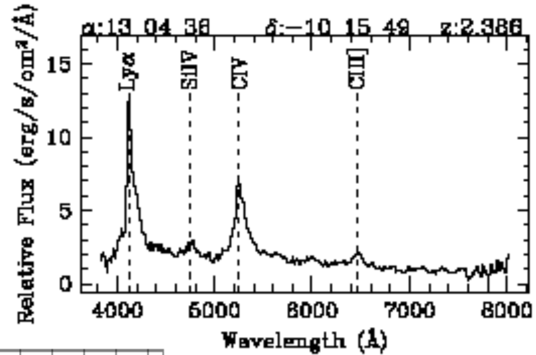


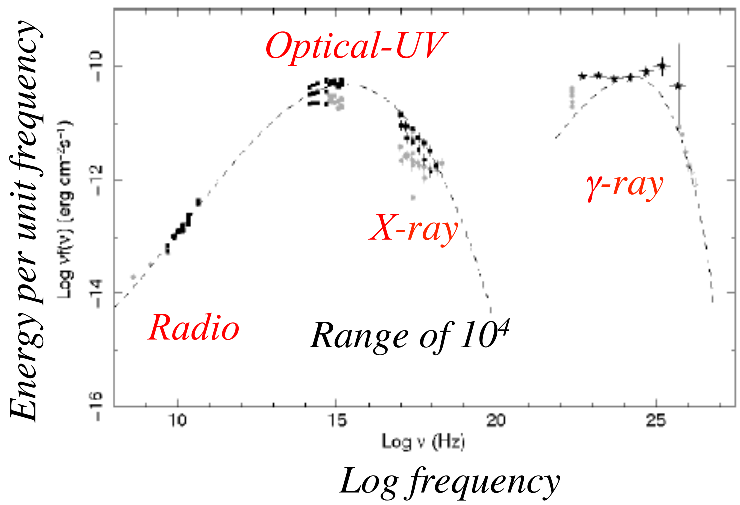
AGN Unification General comments

- *Level of obscuration*
  - *In some objects, can see all of the way down to the SMBH*
  - *In other objects, view at some wavelengths is blocked by column of obscuring material (some objects are blocked at all wavelengths)*
  - *Level of obscuration connected to **viewing inclination***
- *Presence of powerful relativistic (radio) jets*
  - *Radio-loud AGN : generate powerful jets, seen principally via synchrotron radiation in the radio band*
  - *Radio-quiet AGN : lack these powerful jets (often possess weak jets)*
  - *Fundamental parameter controlling jet production **unknown** **(maybe black hole spin; or magnetic field configuration)***

Broad Band Properties of AGN

- **Broad band continuum- very different from stars or galaxies**
- **Strong UV lines not seen in stars**
- Can be very variable



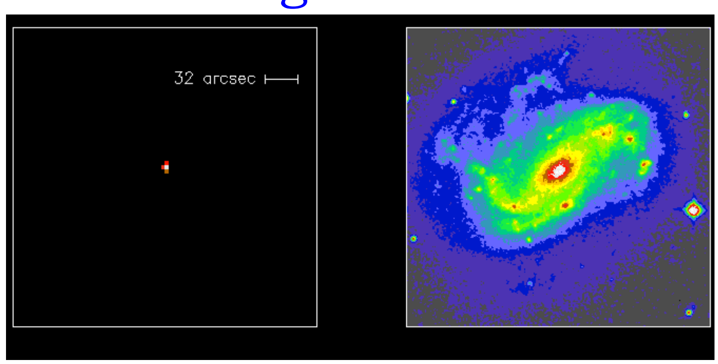


Broad band spectral energy distribution (SED) of a 'blazar' (an active galaxy whose observed radiation is dominated by a relativistic jet 'coming at' us

A large fraction of the total observed energy appears in the ***γ-ray*** *band (due to relativistic beaming)*

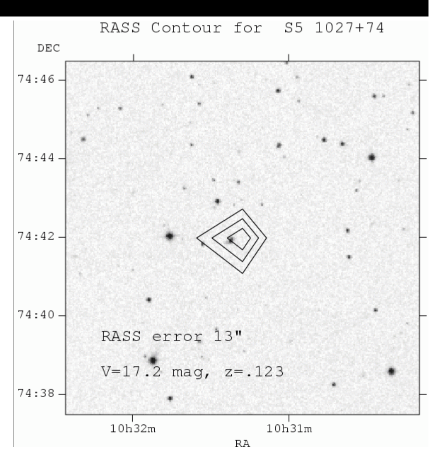
X-ray Selection of Active galaxies

- X-ray and optical image of a nearby AGN NGC4051-
- Note the very high contrast in the x-ray image
- Find x-ray AGN via
  - luminous* pointlike x-ray source in nucleus of galaxy
  - hard x-ray spectrum
  - frequently variable



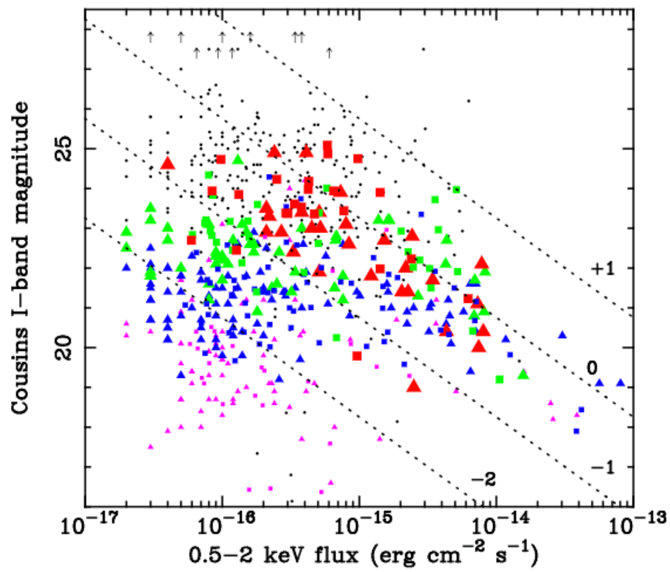
* Have to distinguish from x-ray binaries located near nucleus

Rosat x-ray all sky survey image overlaid on sky survey image



X-ray Selection of AGN

- Comparison of x-ray luminosity of AGN vs the total galaxy luminosity in a 'blind' x-ray survey
- AGN have log L(x)~L(opt)

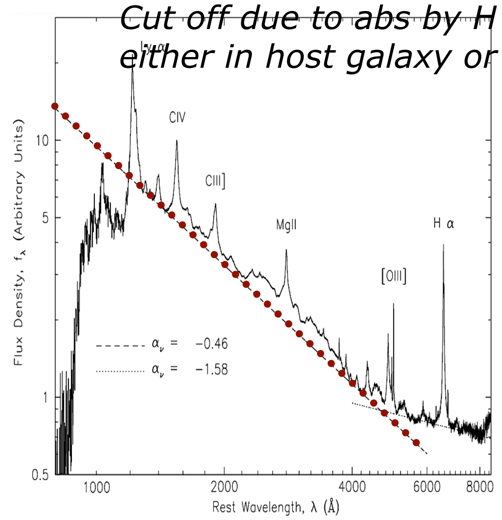


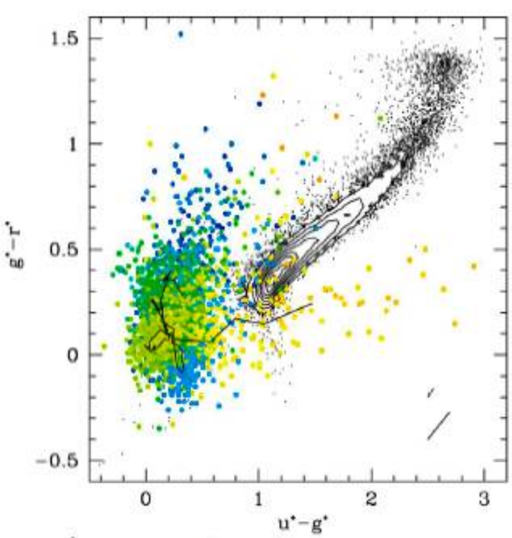
Hasinger and Brandt ARAA 2005
color code is which observation the data were obtained from- lines represent log o ratio of x-ray to optical flux

Optical Properties of AGN

- **Strong lines** of hydrogen, carbon, oxygen from highly ionized species ….

Cut off due to abs by H either in host galaxy or IGM



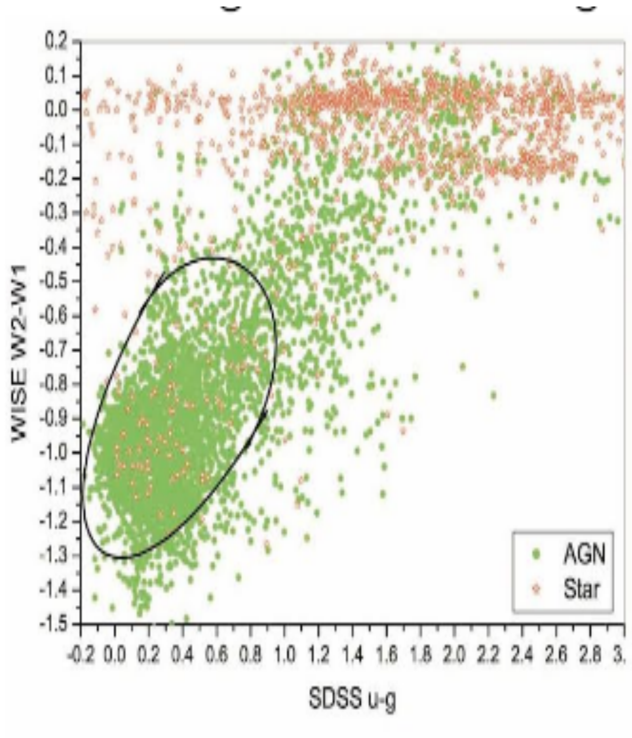


Unusual optical colors
(Richards et al SDSS)- quasars in color, stars are black

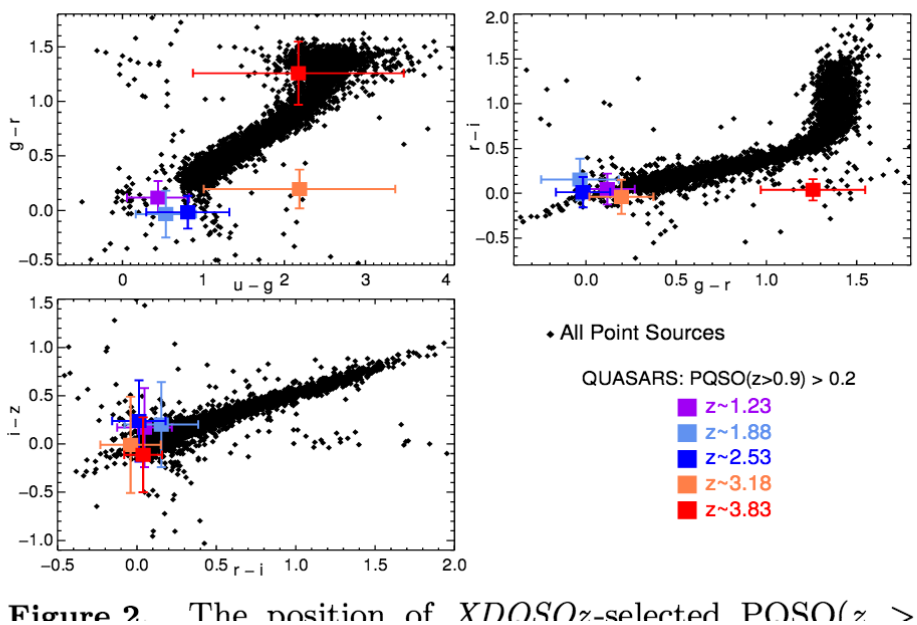
UV-Optical Continuum is thought to arise via thermal emission in an accretion disk

Color Selection

- AGN have different IR/optical colors than stars or galaxies
- http://arxiv.org/1511.07012 Mickaelian et al

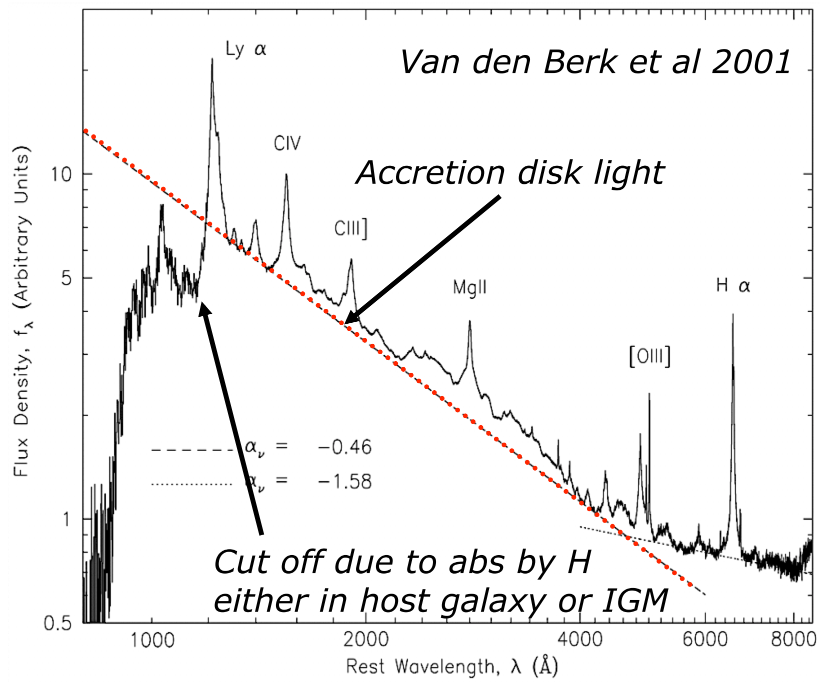


AGN Colors Change with Redshift



- Selecting AGN via colors requires modeling of selection effects

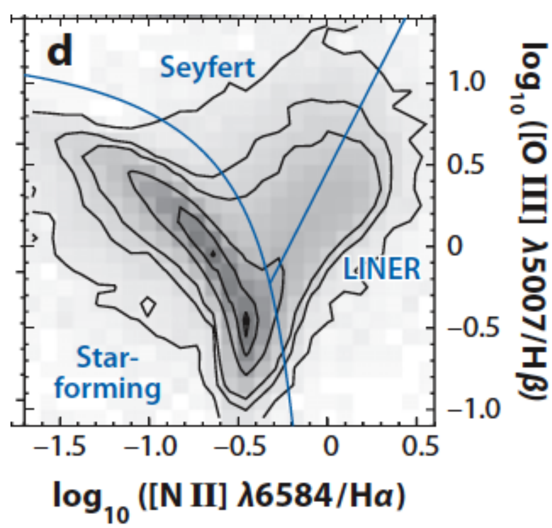
- AGN (type I) optical and UV spectra consist of a 'feature less continuum' with strong 'broad' lines superimposed
- Typical velocity widths (σ, the Gaussian dispersion) are ~2000-5000km/sec
- The broad range of ionization is due to the 'photoionzation' of the gas- the gas is **not** in collisional equilibrium
- At short wavelengths the continuum is thought to be due to the accretion disk



Origin of λ>4000Å continuum not know

Optical Emission Lines

- Remember that star forming galaxies also can have strong emission lines
- *AGN emission line ratios are different*- indicating ionization by a different type of source ('harder' spectrum- more energy at shorter wavelengths than stars)



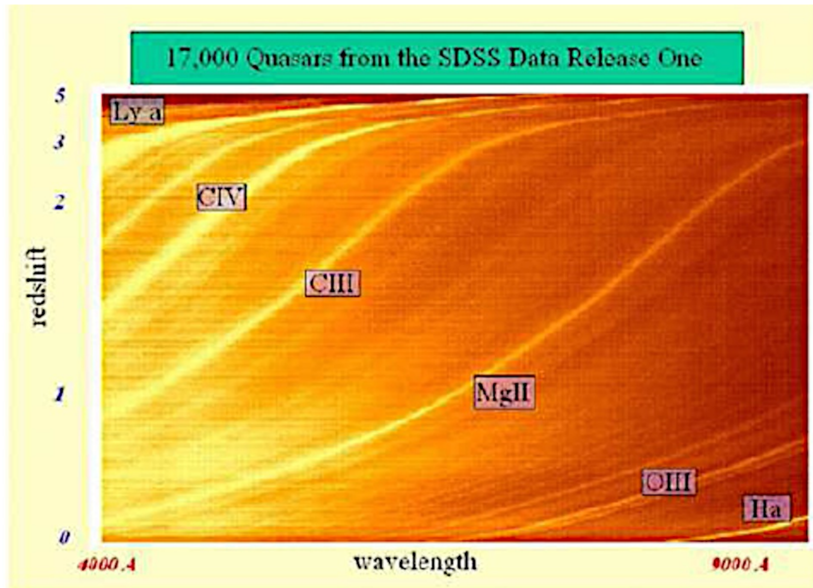
line ratio plot NII/Hα compared to OIII/Hβ−

AGN lie in a particular part of this diagram

Darkness of plot is log of the number of objects inside the contour

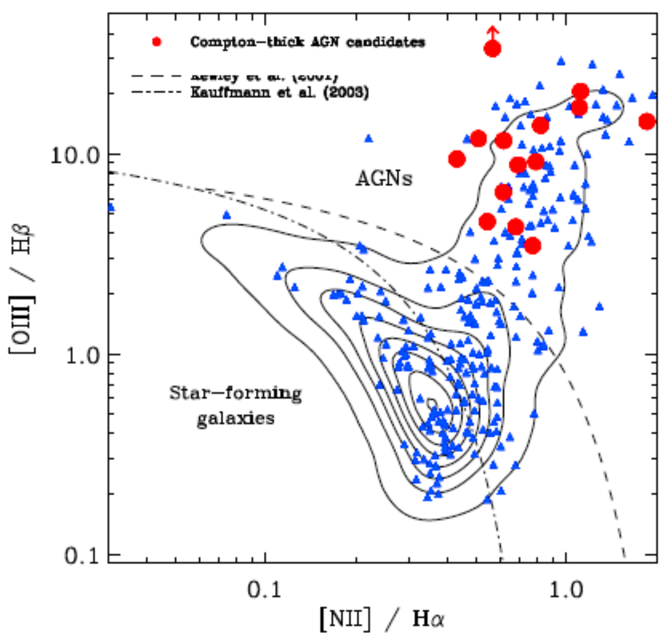
AGN Optical Spectra Across Cosmic Time

- There is very little evolution in the optical spectra of AGN out to z~5 (Fan 2009)



Comparison of Optical and X-ray AGN Selection

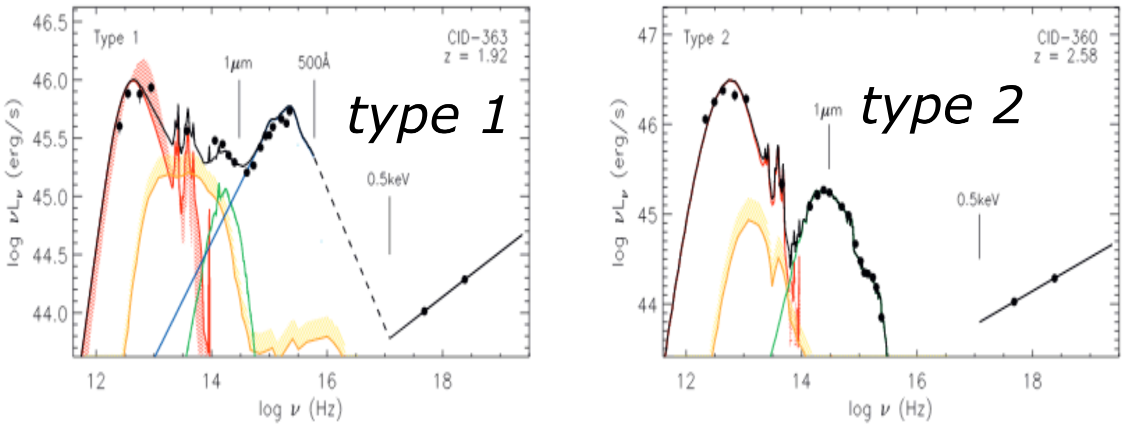
- Best" way to find AGN: classical optical line ratio indicators miss (even at low z) many AGN (>1/2)- same with IR
- The broad properties of x-ray selected AGN are representative of the total population (Hickox et al 2009)- IR selected AGN tend to have high Eddington ratios and small masses, radio selected high black hole masses , low Eddington ratios



x-ray detected AGN

Goulding et al 2010
Trouille and Barger 2010

Total Emission-Galaxy+AGN



- Red is dust emission from star formation
- Green is starlight, yellow AGN driven dust emission, blue accretion disk (Suh et al 2018)

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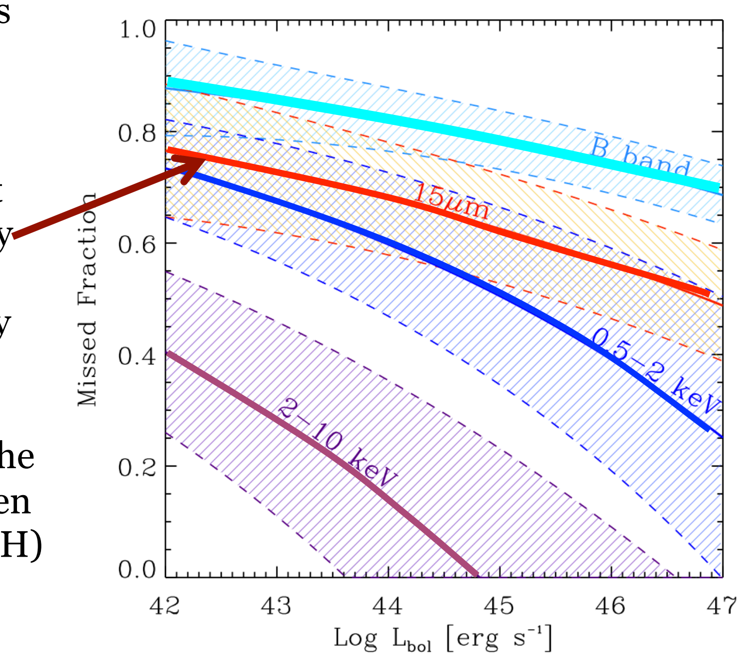
How are AGN Selected

Hard X-rays provide the most complete census of AGN activity (Merloni 2011)

the fraction of AGN that are missed in a survey in a given band as a function of the energy range observed

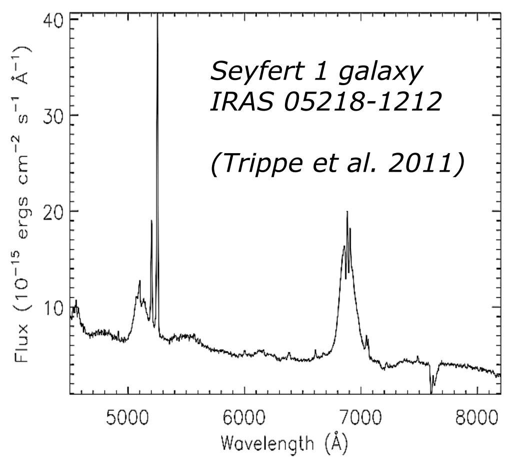
The fraction missed in the 10-30 keV band is even lower (HXI on Astro-H)



AGN Unification

Broad line (type-1) objects

- Blue optical/UV continuum
- Broad optical/UV lines
  - Emission lines from permitted (not forbidden) transitions
  - Photoionized matter $n>10^9 cm^{-3}$
  - BLR lines FWHM~2000-20000 km/s
- Narrow optical/UV lines
  - Emission lines from both permitted and forbidden transitions
  - FWHM~500km/s
  - Sometimes spatially resolved 0.1-1kpc



- **Overall spectrum reveals unabsorbed/unreddened nucleus**

AGN Types

Narrow line (type-2) objects

- Reddened Optical/UV continuum
- Optical Emission line spectrum
  - "Full light" spectrum only shows narrow (~500km/sec) optical/UV lines
  - Broad optical/UV lines seen in *polarized* light… shows that there is a hidden broad line region seen via scattering (Antonucci & Miller 1985)
- **X-ray spectrum usually reveals highly absorbed nucleus ($N_H>10^{22}cm^{-2}$)**
- Intermediate type objects (type-1.2, 1.5, 1.8, 1.9) have obscurers which become transparent at sufficiently long/short wavelengths

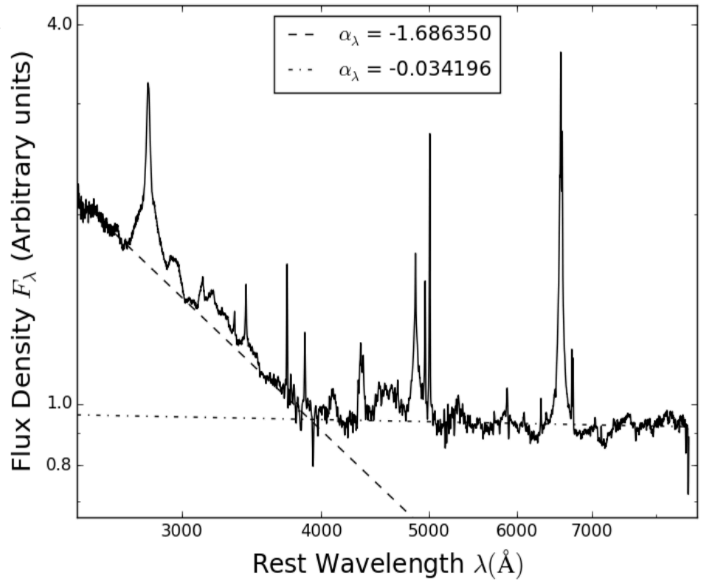
Seyfert I Composite Spectra (SDSS)

- Pol& Wadadekar 2016

UV-NIR

TABLE 2
MEASURED EMISSION LINES

Line Identification	Wavelength (Å)
Lyα	1216
C IV	1548, 1550
He II$_1$	1640
C III]	1908
C II]	2326
[Ne IV]	2424
Mg II	2796, 2803
[Ne V]	3426
[O II]$_1$	3726, 3729
[Ne III]	3869
Hγ	4340
[O III]$_1$	4363
He II$_2$	4686
Hβ	4861
[O III]$_2$	5007
He I	5876
[O I]	6300
[N II]	6584
Hα	6563
[S II]$_1$	6717
[S II]$_2$	6731
[Ar III]	7135
[O II]$_2$	7319, 7330
[S III]$_1$	9069
[S III]$_2$	9532



gure 4. Seyfert 1 composite spectrum generated using median

Seyfert I strong Optical/UV lines

- The strongest lines are both 'permitted' (Ha,Hb,CIV) broad lines
- and forbidden narrow lines (OIII,NII)

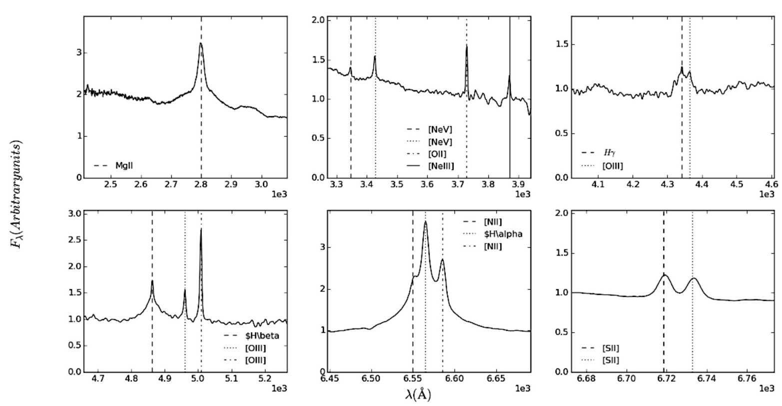
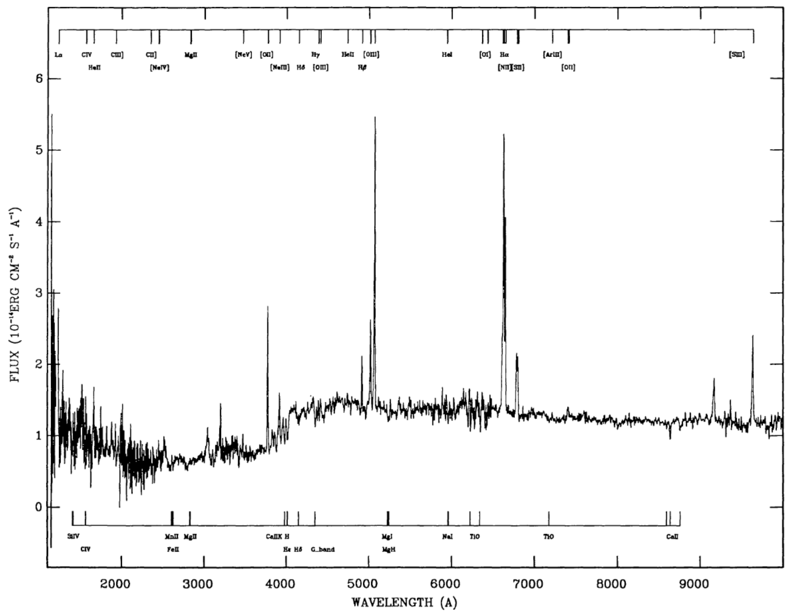


Figure 10. Strong emission line features in the composite Seyfert 1 spectrum

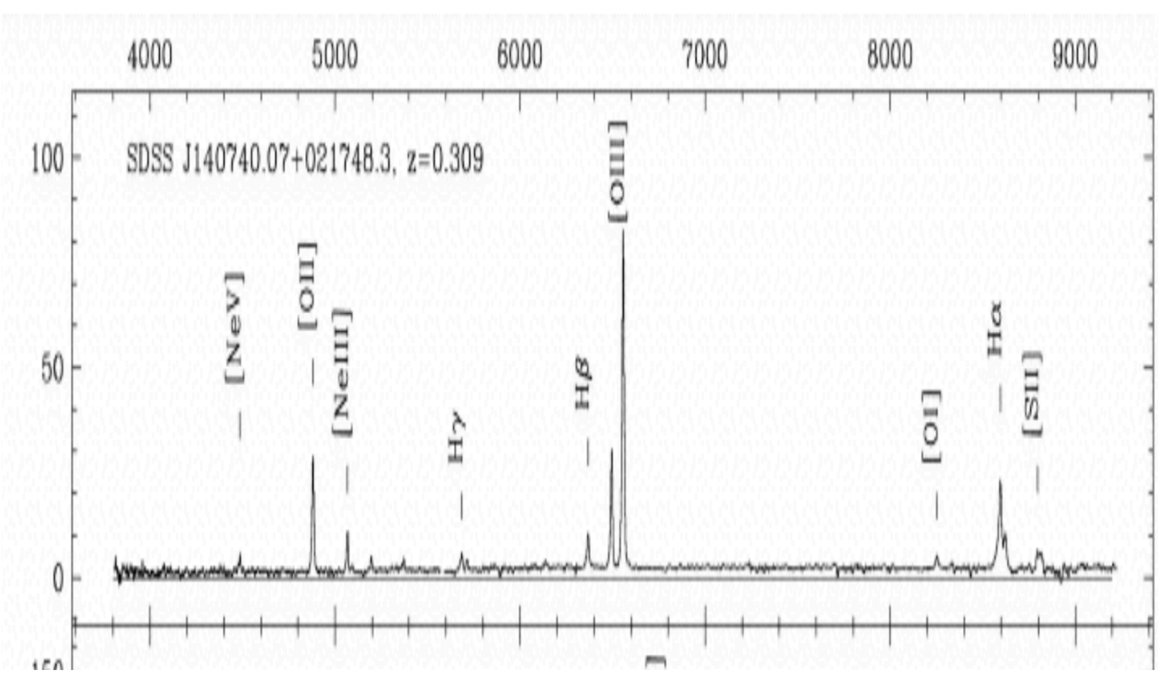
Strength and width of lines only weak function of luminosity (wide range of M& dM/dt at fixed luminosity

Seyfert II Optical/UV spectrum

- Only narrow lines , weak UV spectrum



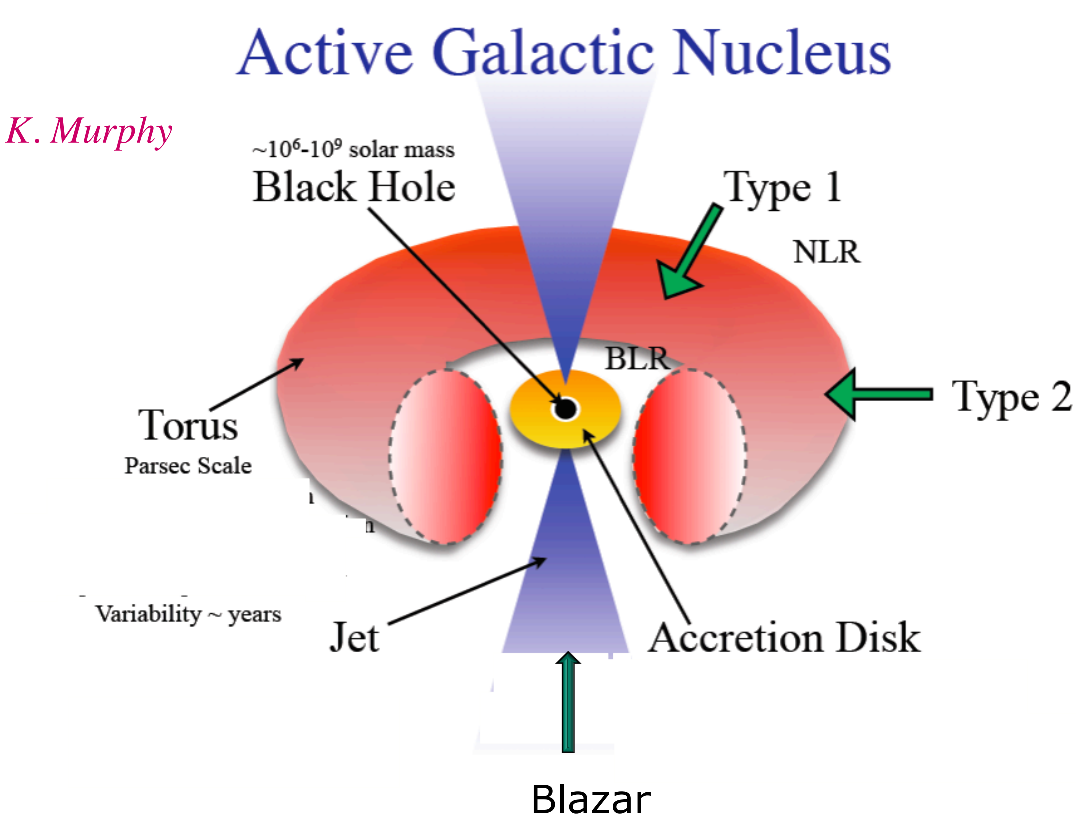
Seyfert II Optical Spectrum



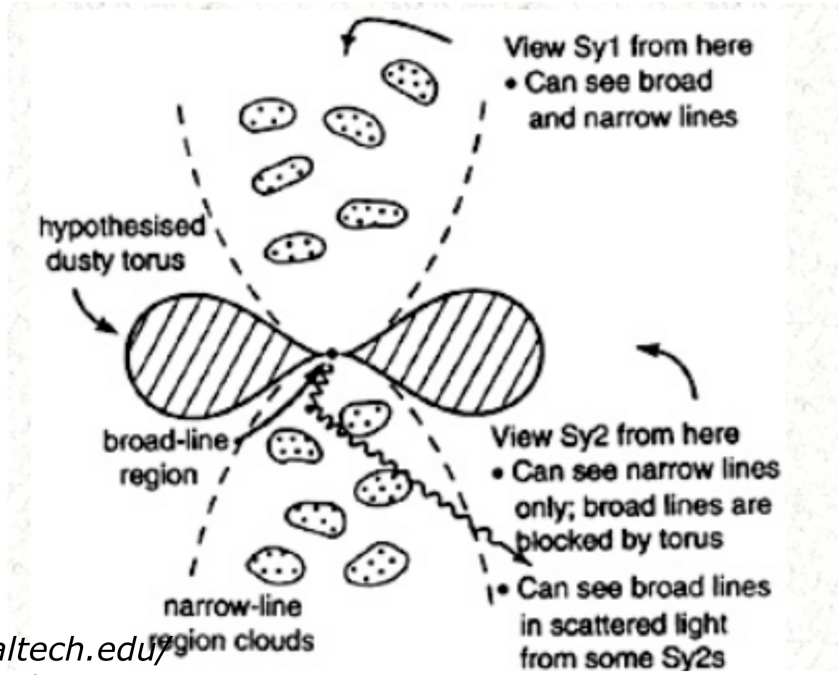
ZAKAMSKA et al 2003

AGN Unification-Narrow line (type-2) objects

- Reddened Optical/UV continuum
- Emission line spectrum
  - "Full light" spectrum only shows narrow optical/ UV lines
  - Broad optical/UV lines seen in polarized light… shows that there is a hidden broad line region **seen in scattered light** (Antonucci & Miller 1985)
- **X-ray spectrum usually highly absorbed nucleus ($N_H > 10^{22} cm^{-2}$)**
- type II **<u>do not</u> have broad lines and have a weak or absent 'non-stellar' continuum**
- **Depending on the type of survey and luminosity range ~50% of all AGN are of type II**

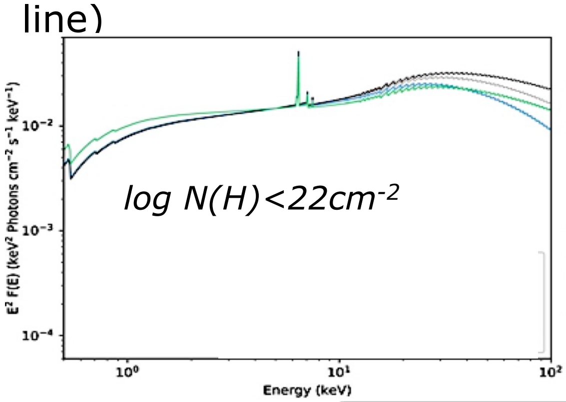


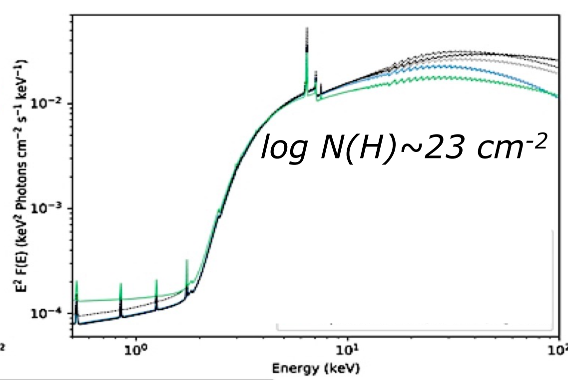
"See" Into Central Regions via Scattering

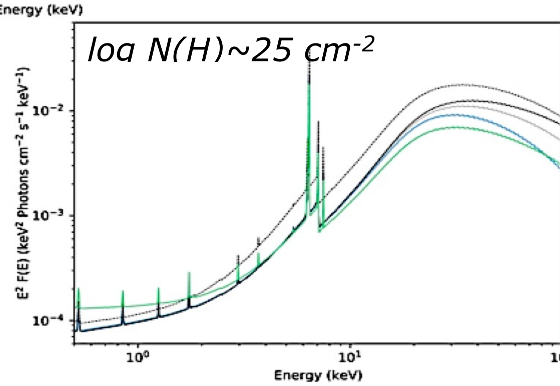


https://ned.ipac.caltech.edu/level5/March02/Roy/Roy_contents.html

- Examples of x-ray spectra illustrating the effects of absorption (Ananna et al 2019) and reprocessing (Fe K line)



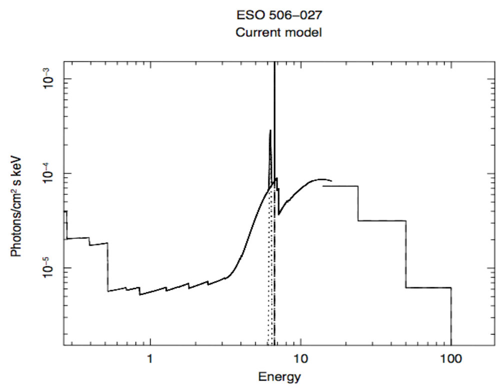




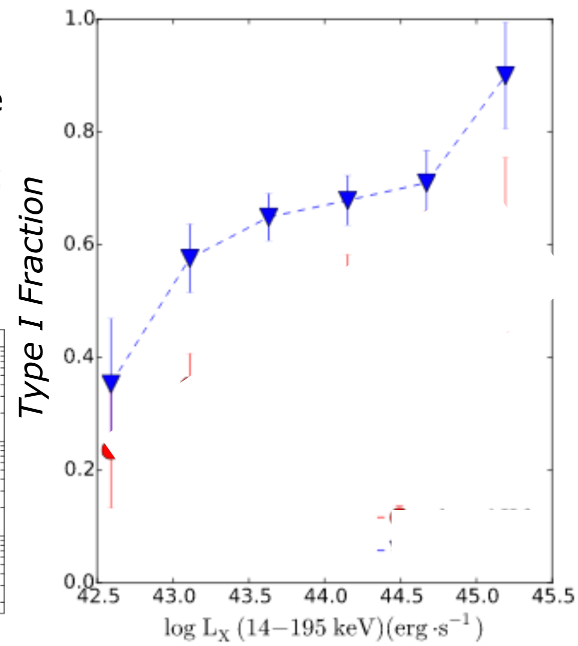
"Compton thick"

Fraction of Type I and II in Hard X-ray Survey

- Hard X-rays are much less effected by absorption
- As a function of luminosity the fraction of type Is increases, but ~1/2 are type IIs (Koss et al 2017)



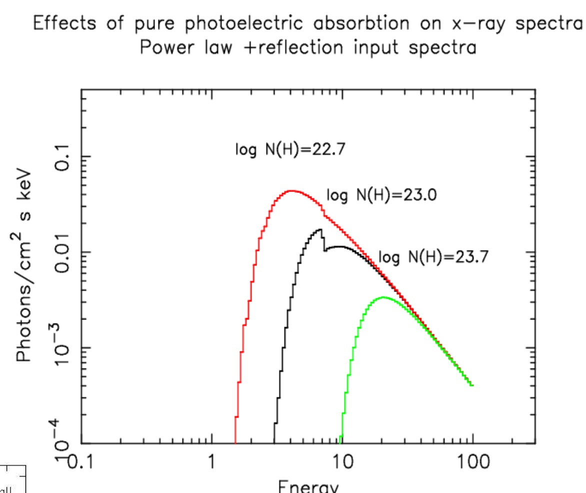
Seyfert II x-ray spectrum .5-100 keV

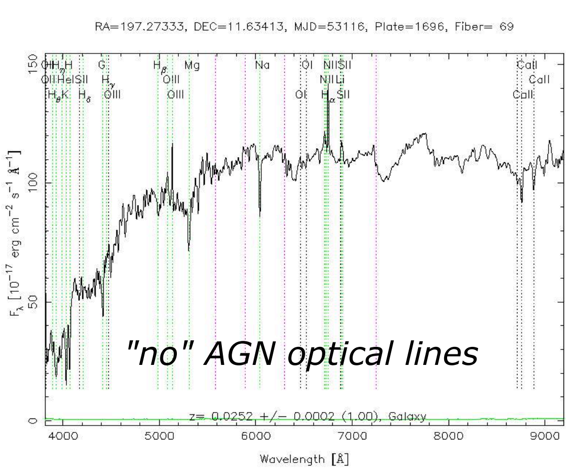


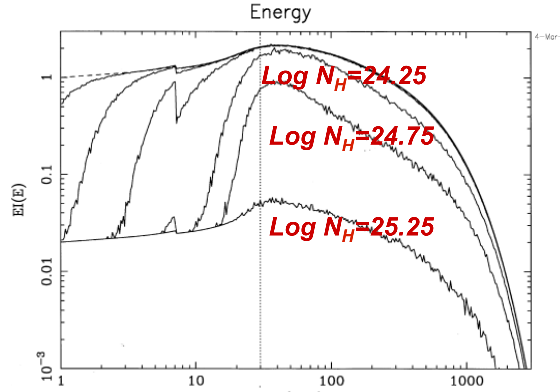
log X-ray Luminosity

Effect of Absorption on X-rays

- Top plots is in photons
- bottom in energy and includes Compton scattering)
- In optical absorption can totally wipe out AGN signature



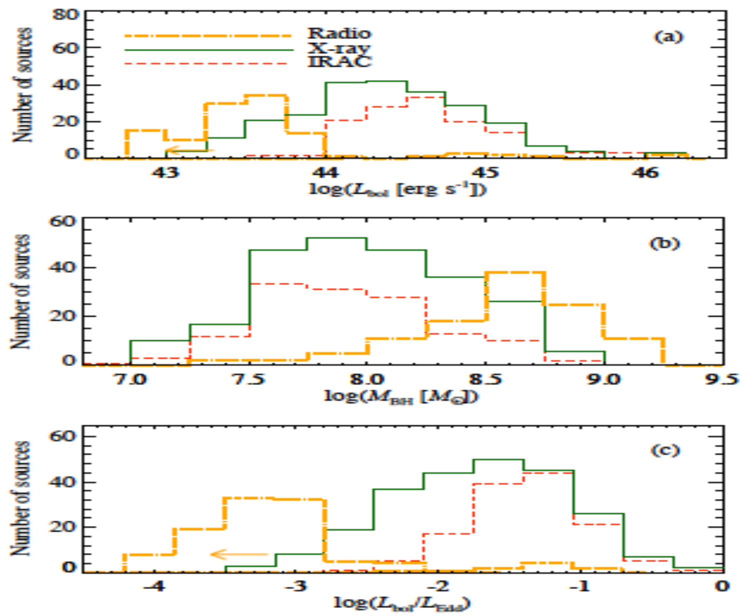




Effects of Different Selection Criteria
(Hickox et al 2010)

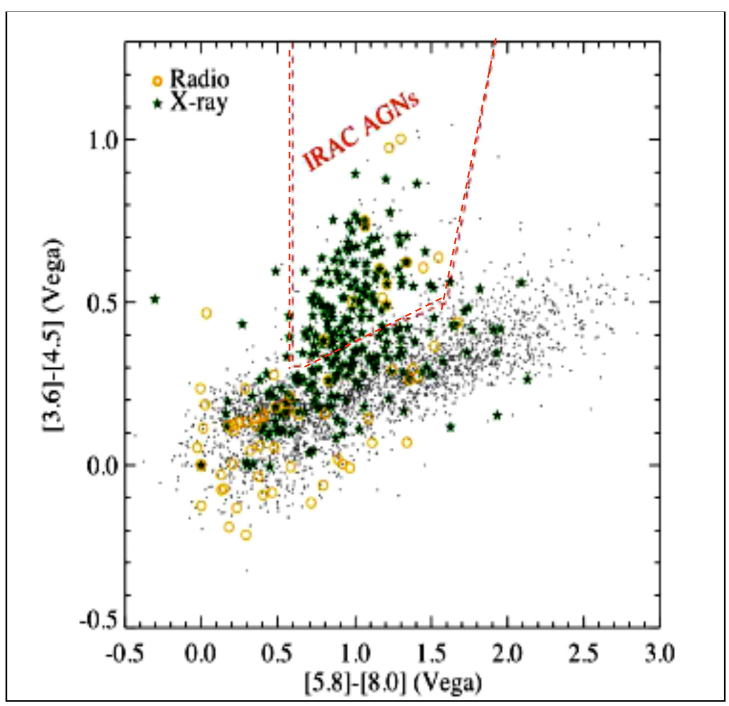
- Radio selected AGNs are found in luminous red-sequence galaxies.
- X-ray AGNs are found in galaxies of all colors, with a peak in the “green valley”.
- IR AGN hosts are relatively bluer and less luminous than those of the X-ray or radio AGNs

Radio loud AGNs have massive black holes (M_{BH} > 10^8 $M_\odot$) and small Eddington ratios ($\lambda < 10^{-3}$).
*X-ray AGNs have wide range of M_{BH} **and λ***
IR AGNs have relatively small black holes ($3\times10^7 < M_{BH} < 3\times10^8$ $M_\odot$) and high Eddington ratios($\lambda > 10^{-2}$).



Selection Effects- What is an AGN

- Hickox et al find that radio and IR selected AGN are in different places in the IR color diagram, x-ray AGN are ‘all over’: however IR color selection finds <1/2 of x-ray AGN and VV
- Why are some IR selected AGN not x-ray sources? - *Not yet clear*

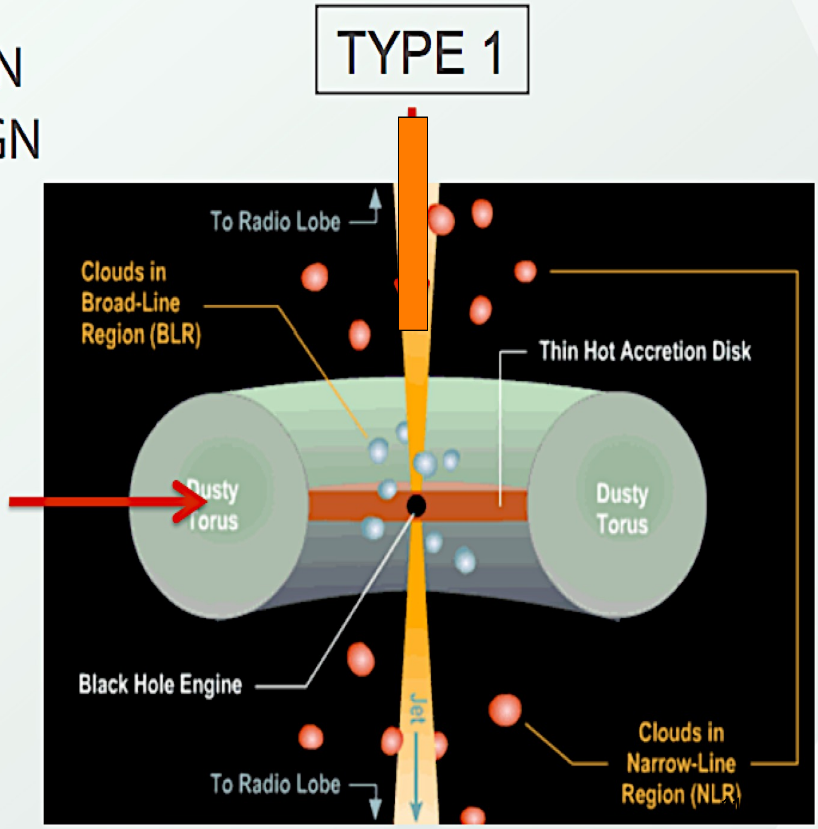


IR color-color diagram based on Spitzer data
*Radio selected AGN in yellow, x-ray in **green***
Red box is region of IR selected AGN

UNIFICATION MODEL of AGN

DUSTY TORUS

TYPE 2



orientation effect

- Anna Feltre