From BLR and NLR to BH and SF

- Physical processes
- The BLR
- The NLR
- Using BLR properties to infer BH mass and accretion rate
- Using NLR properties to infer L_{AGN} and L_{SF}
- The AGN-starburst connection
- SF and AGN evolution

Physical Processes
(Let There Be Light)

- AGN is born
  - Ionization
  - Recombination
  - Collisional excitation
  - Radiation pressure
  - Shock waves
  - Magnetic fields

How does it look and moves at various times?

Photoionization:
Ionization structure and temperature

Photoionization rate - I_X

Radiative recombination rate - R_X

Time dependent ionization

$$\frac{dN_x}{dt} = -N_x\left[I_x + R_x\right] + \left[N_{x-1}I_{x-1} + N_{x+1}R_{x+1}\right]$$

Heating - H
- photoionization heating
- other heating

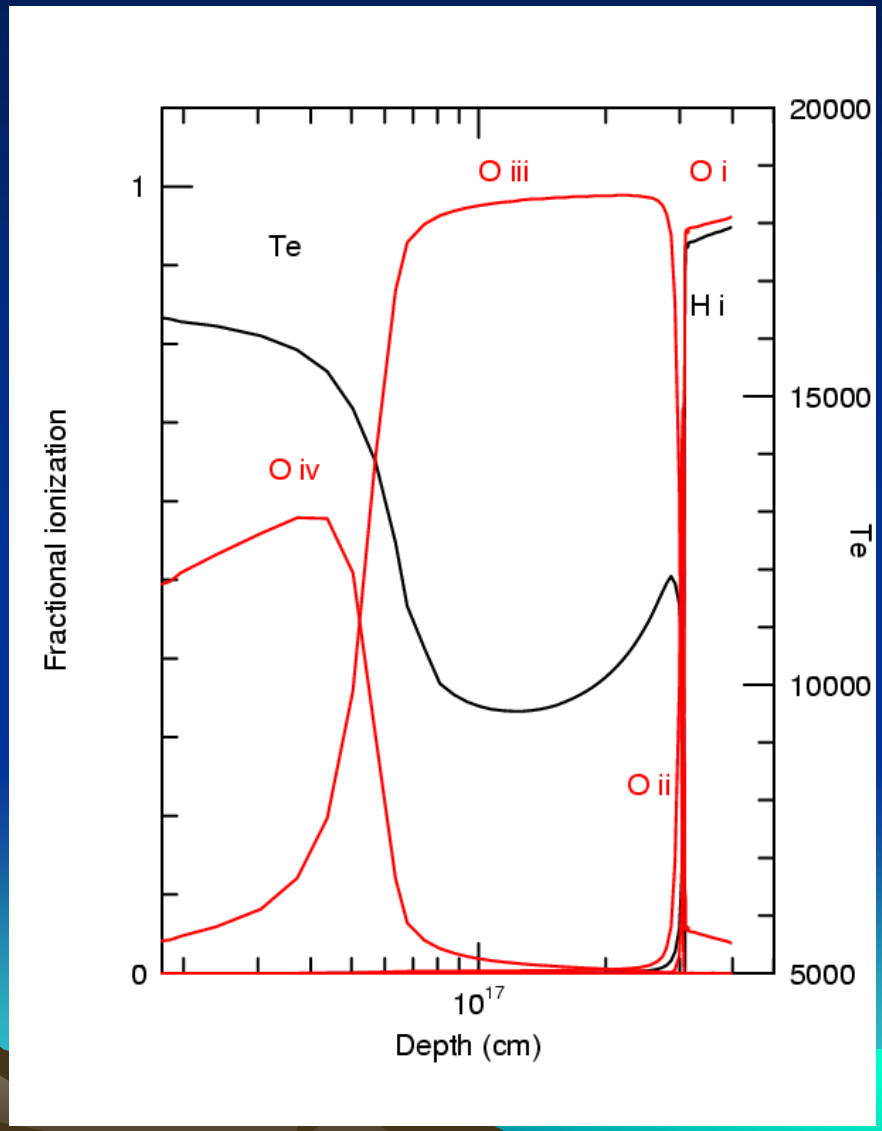
Cooling - C
- collisional cooling
- recombination cooling

$$H = C$$

The spectrum of photoionized gas

Photoionization calculations
- ionization structure
- thermal structure

Spectral calculations
- line emission
- continuum emission
- line and continuum absorption



The motion of ionized gas

- The equation of motion
  - Gravity - g(r)
  - Radiation pressure - $a_{rad}(r)$
  - Drag force - f_d
  - Pressure gradient

$$a(r) = a_{rad}(r) - g(r) - \frac{1}{\rho}\frac{dP}{dr} + \frac{f_d}{M_c}$$

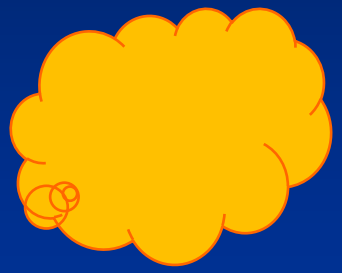
Accelerating a block

$$a_{rad} - a_g = \frac{aL}{4\pi r^2 c M_c} - \frac{GM_{BH}}{r^2} =$$

$$= \frac{L}{r^2}\left[\frac{a}{4\pi r^2 c m_p N_H} - \frac{G}{7.5x10^4 (L/L_{Edd})}\right]$$

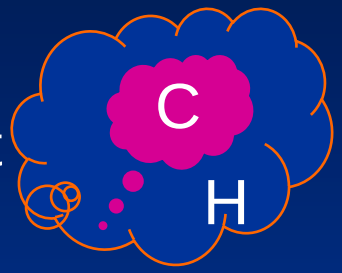
The BLR

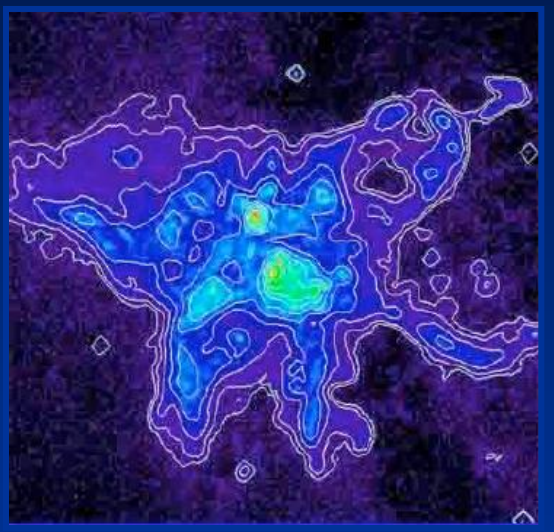
- BLR properties
  - High density clouds
  - LOC
  - Disk outflow
- BLR Boundary
  - Dust in the BLR
- BLR dynamics
- BLR metallicity



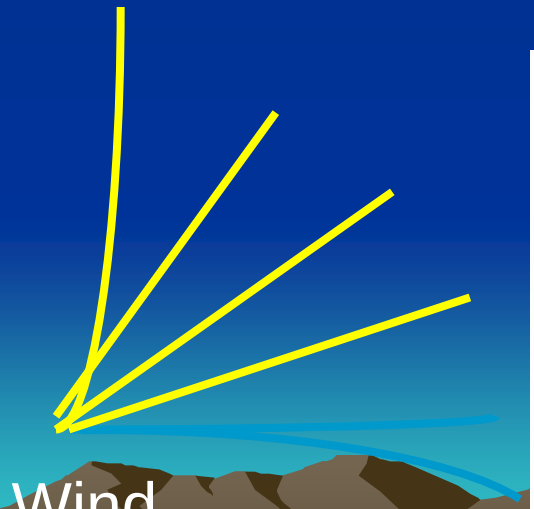
Clouds LOC and winds

- Clouds
  - Thermal confinement
  - Stability
  - Magnetic confinement

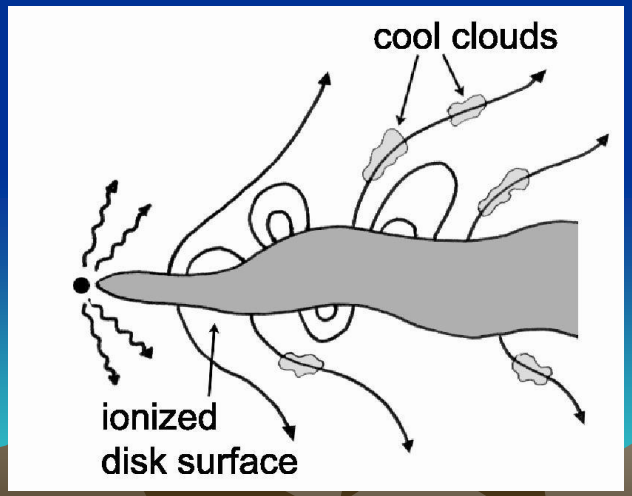




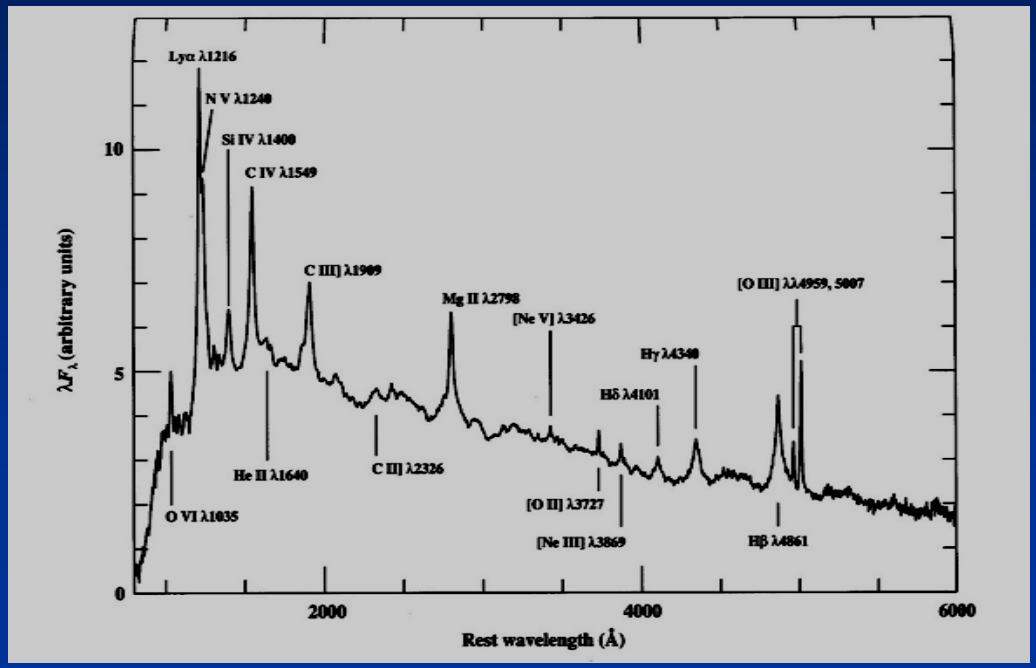
Locally Optimally emitting Clouds (LOC)



Wind



BLR spectrum



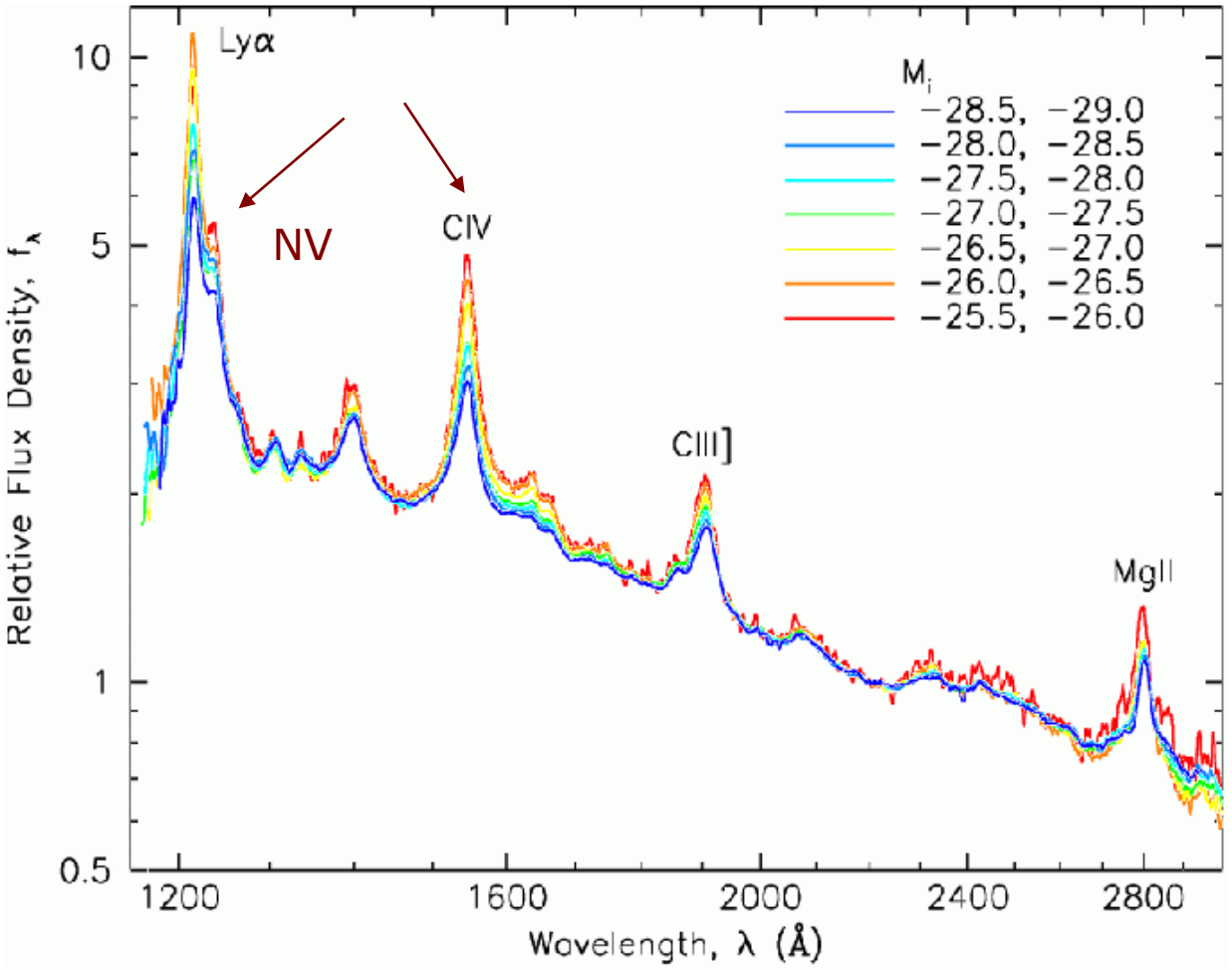
Density $10^{9\text{-}11}$ cm^{-3}

Column density ~10^{23} cm^{-2}

Covering fraction ~0.1

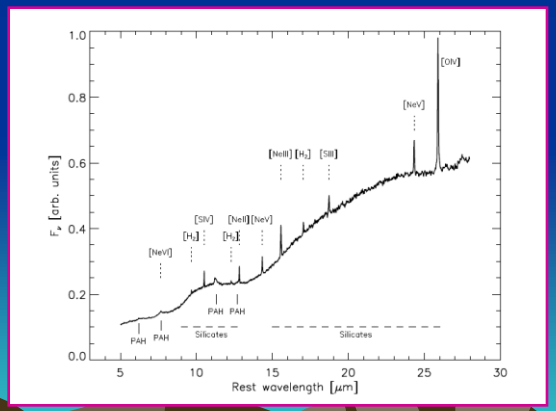
$$r_{BLR} \simeq 0.3 L_{46}^{0.6\pm0.1} \; pc$$

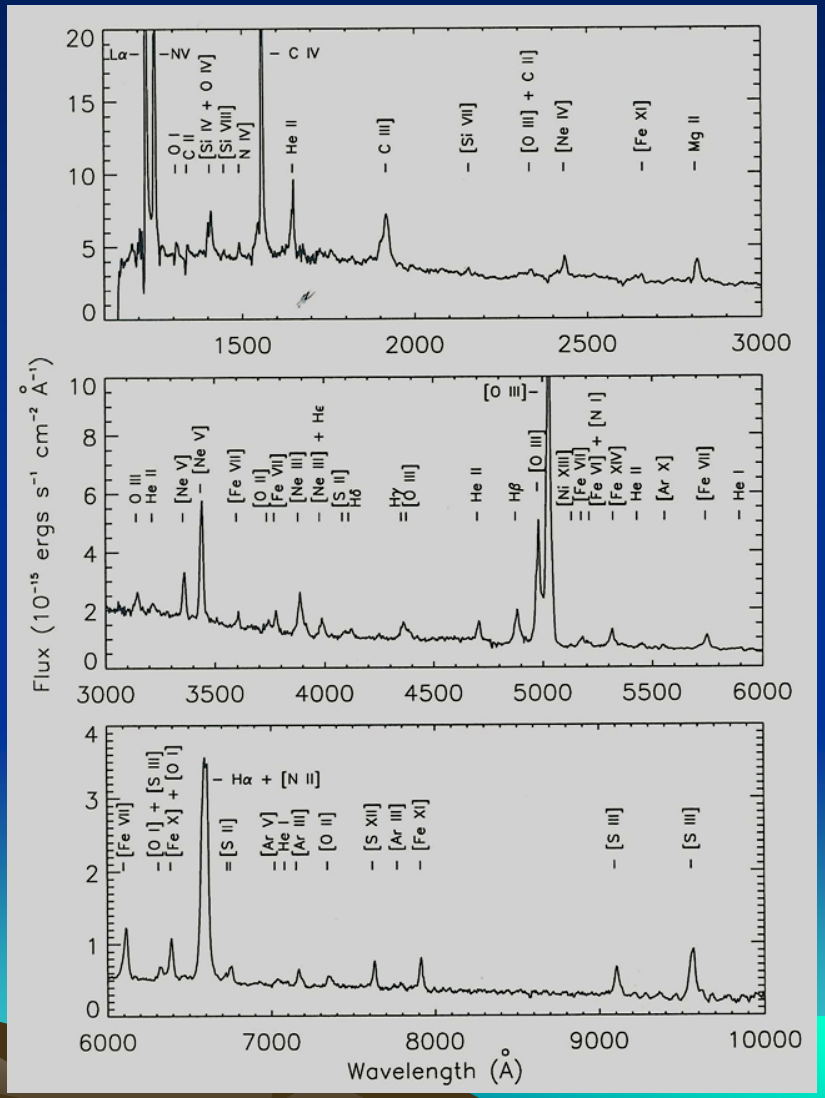
BLR metallicity



The narrow line region – NLR

spectrum
Dynamics
metallicity
Dust in the NLR





Let There Be Dust

Sublimation distance

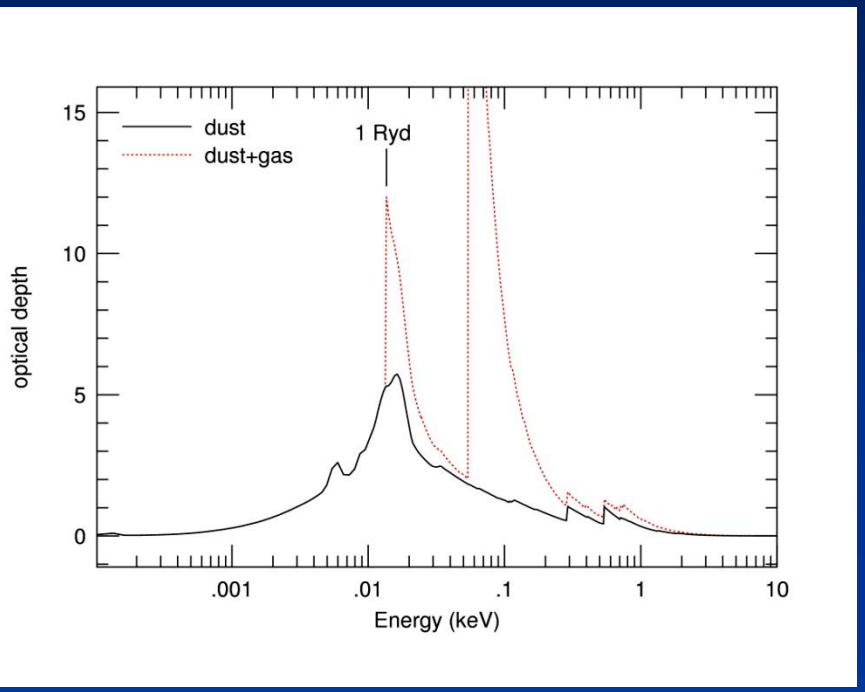
$$r_{sub,Si} \cong 1.3 L_{46}^{1/2} \left(\frac{1500K}{T_{sub}} \right)^{2.6} pc$$

$$r_{sub,C} \cong 0.5 L_{46}^{1/2} \left(\frac{1800K}{T_{sub}} \right)^{2.6} pc$$

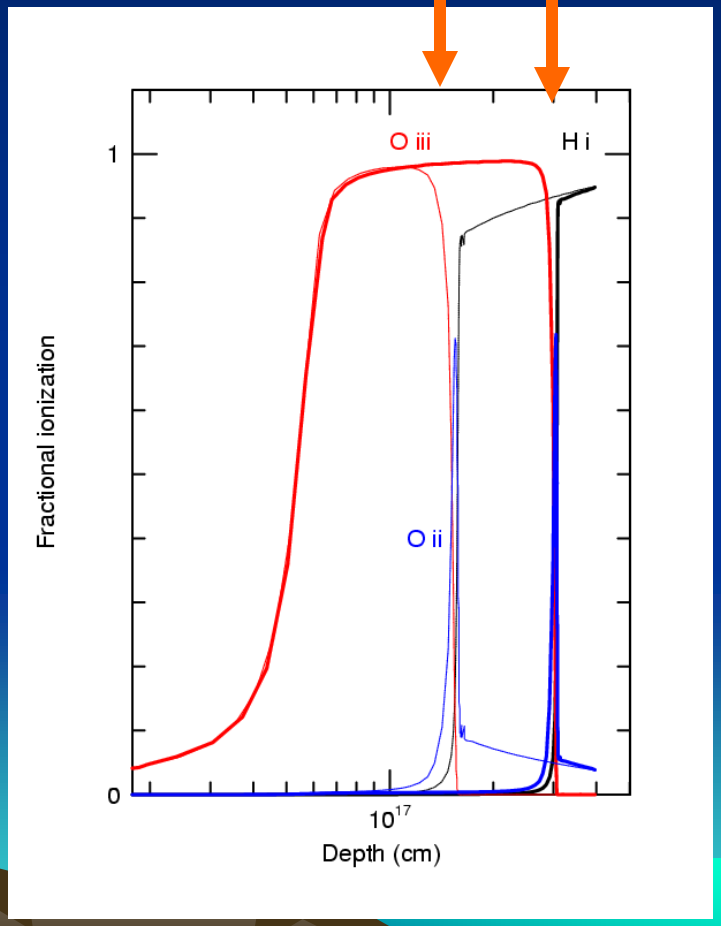
The BLR radius

$$r_{BLR} \simeq 0.3 L_{46}^{0.6\pm0.1} pc$$

Photoionized dusty gas

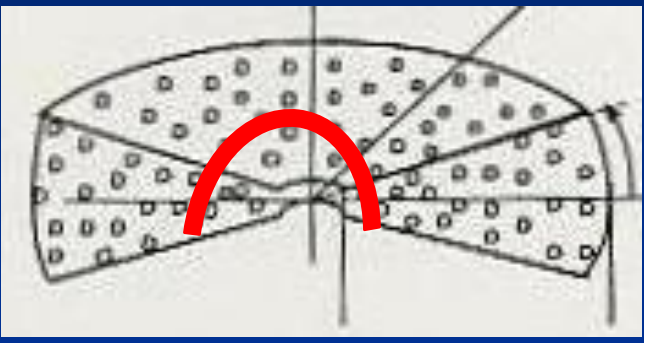


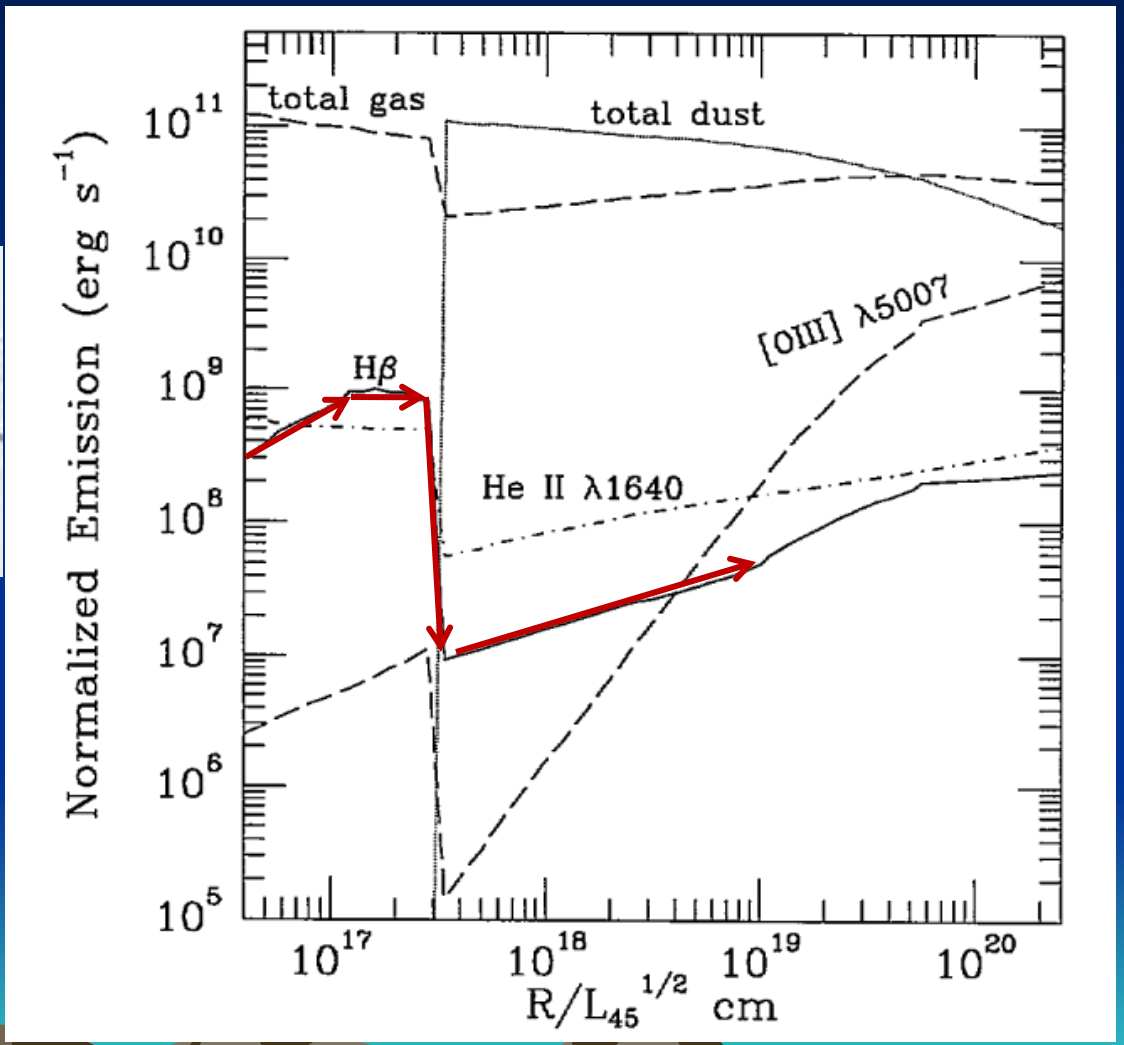
Dust no dust



$$\frac{\tau(dust)}{\tau(gas)} \propto \frac{N_{dust}}{N_{H^0}} \propto \frac{N(H^+)}{N(H^0)} \propto U(hydrogen)$$

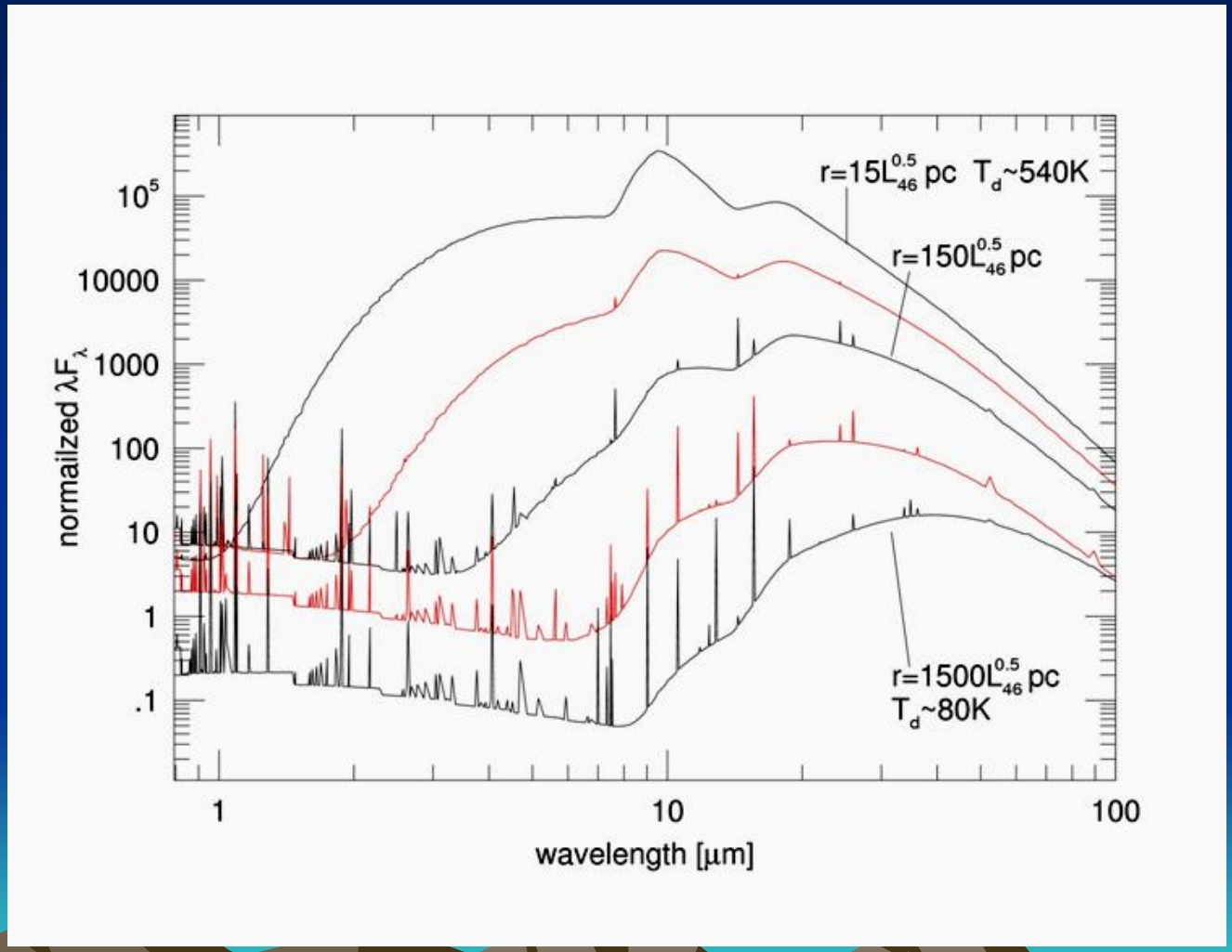
Dust outside the BLR



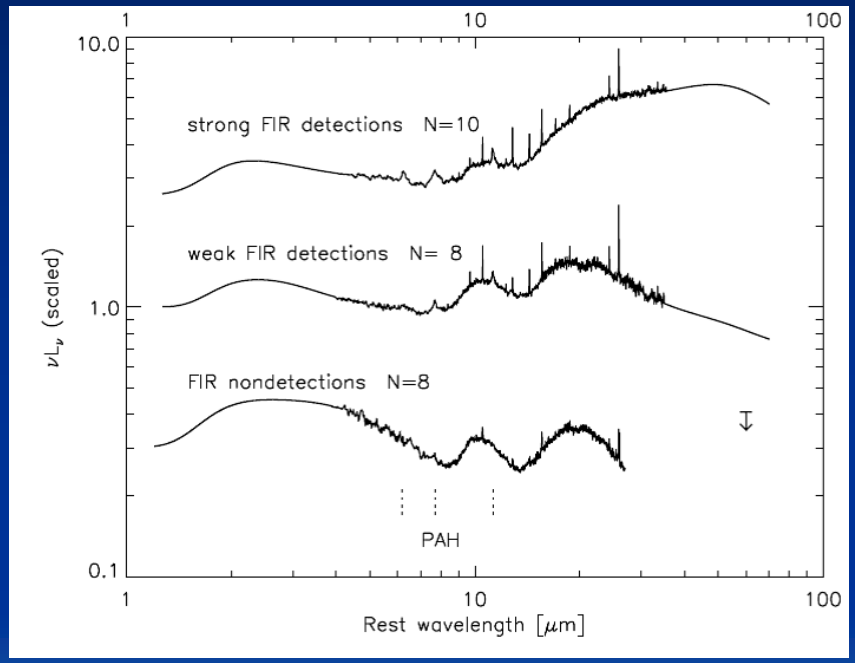


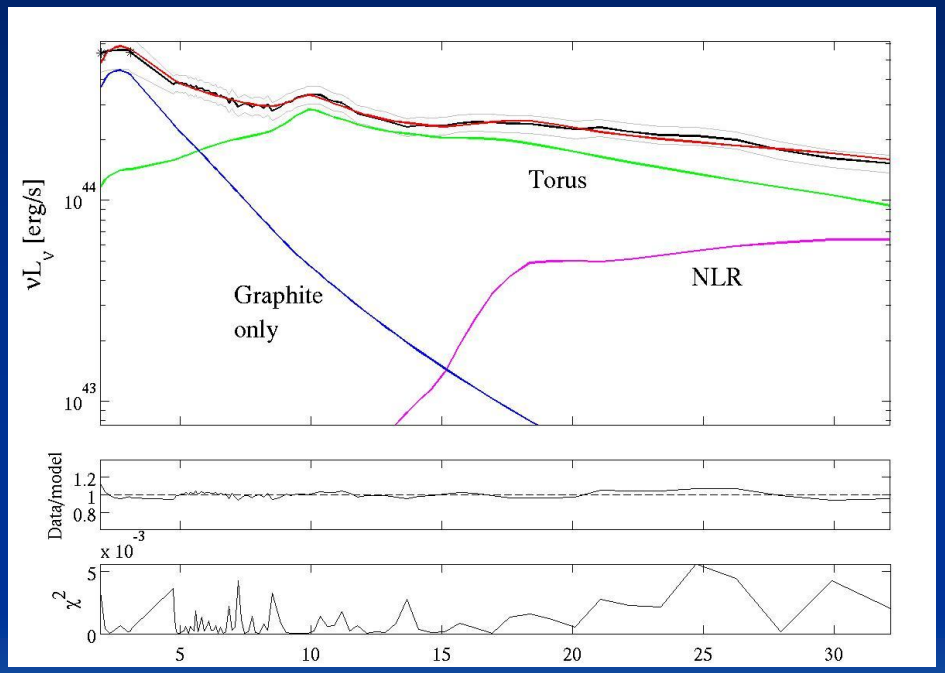
Netzer and Laor 1993

Dust in the NLR



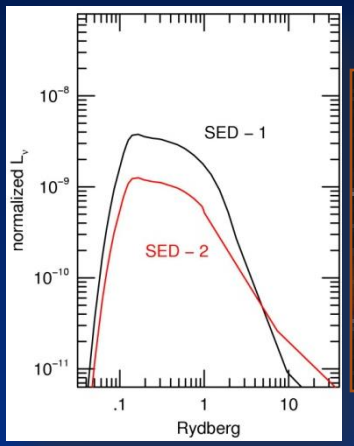
Dusty torus and dusty NLRs

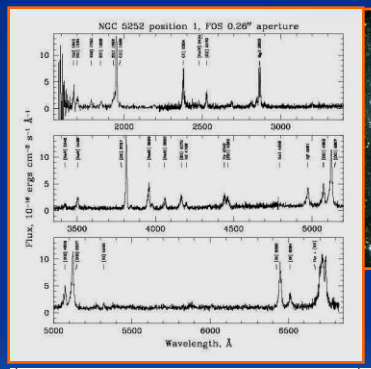


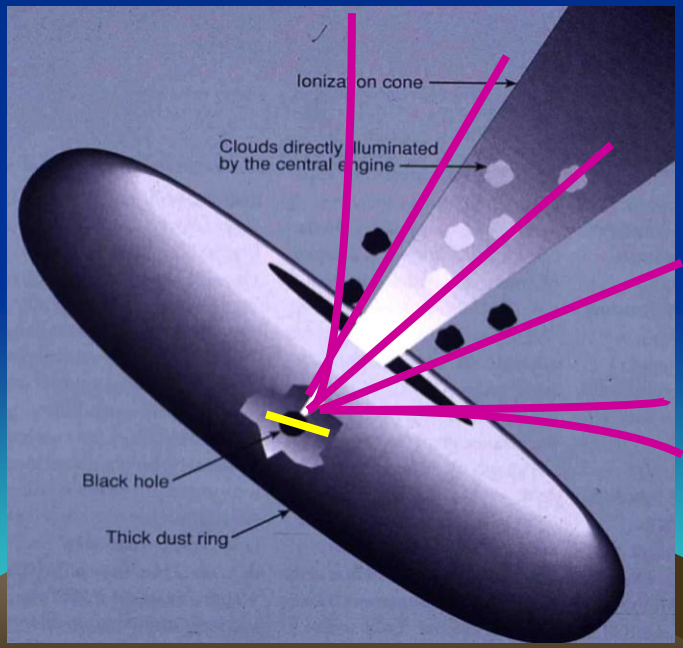


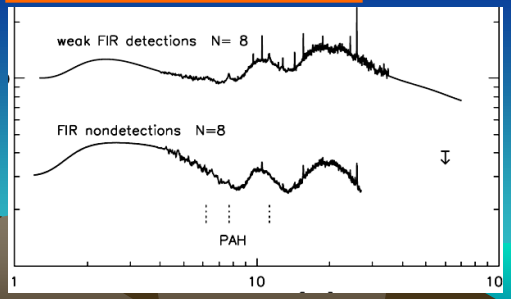
Mor, Netzer, Elitzur 2009

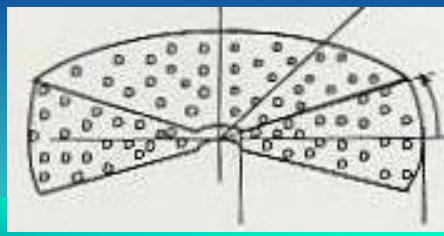
Miracles


SED – 1
SED – 2
normalized L_ν
10^{-8}
10^{-9}
10^{-10}
10^{-11}
.1
1
10
Rydberg


NGC 5252 position 1, FOS 0.26" aperture
Wavelength, Å


Ioniza on cone
Clouds directly lluminated
by the central engine
Black hole
Thick dust ring


weak FIR detections N= 8
FIR nondetections N=8
PAH
1
10

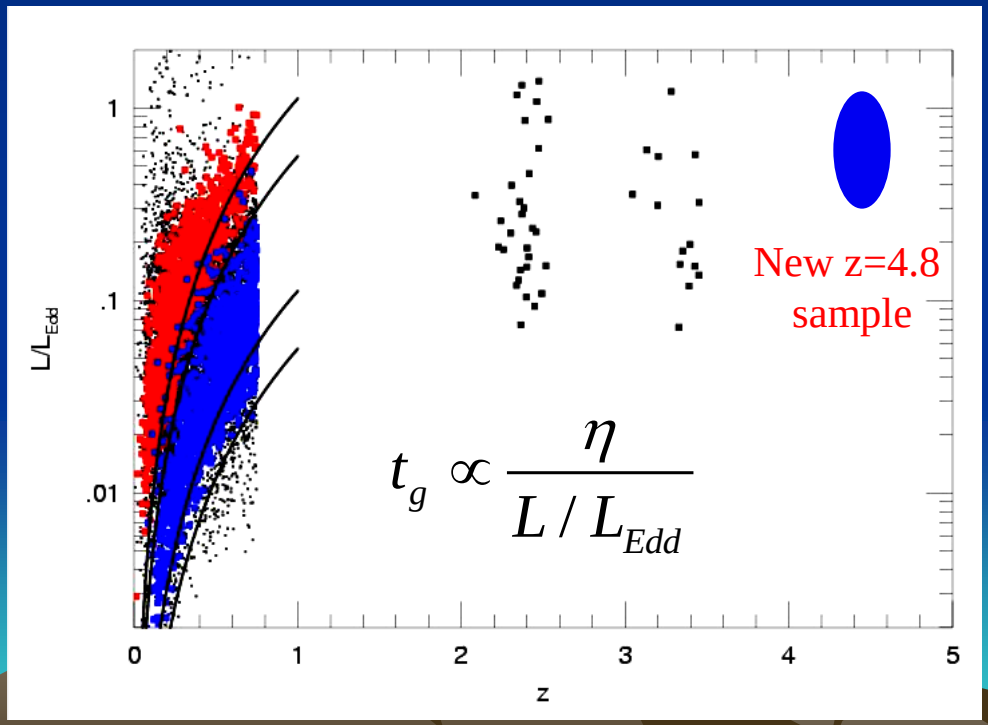


Using BLR properties to infer BH mass and accretion rate

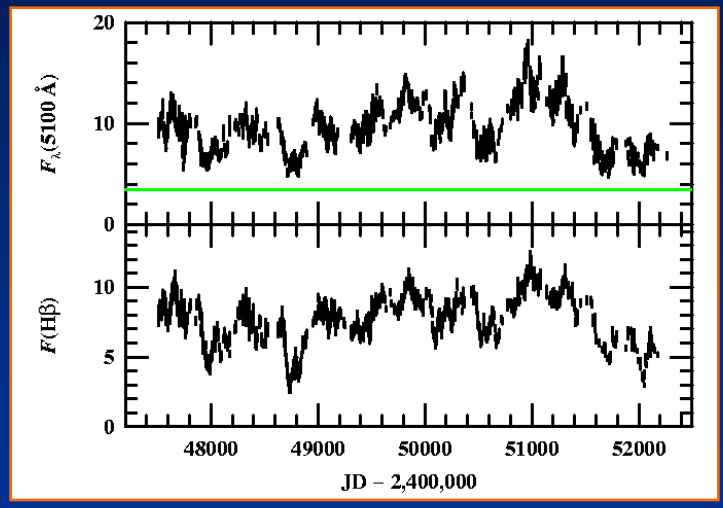
Reverberation Mapping

Single epoch mass determination

M_{BH} and L/L_{edd} distributions



Netzer et al 2007



$$r_{BLR} \simeq 0.3 L_{46}^{0.6\pm0.1}\ pc$$

$$M_{BH} = f V_{line}^2 r_{BLR}$$

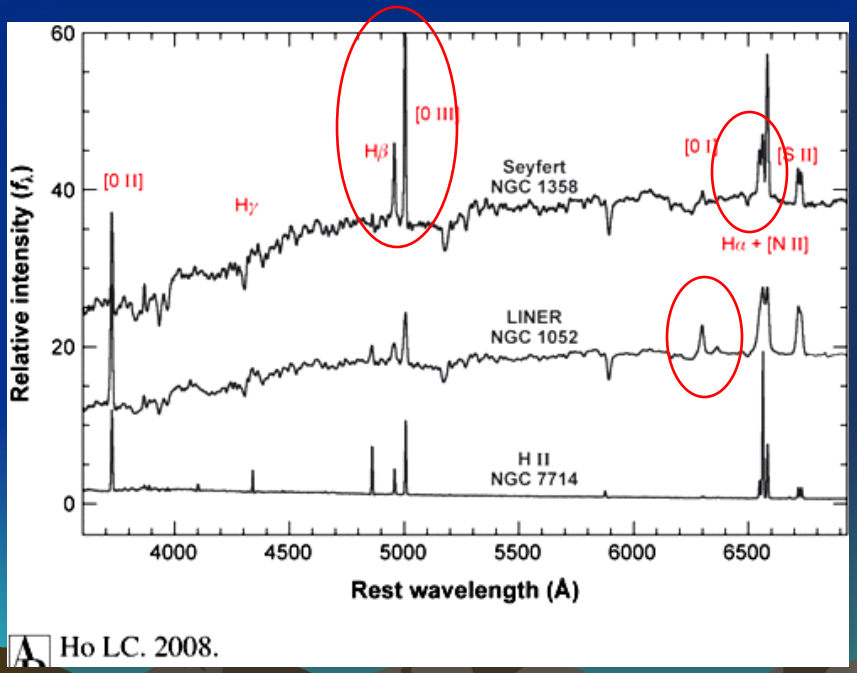
$$a_{rad} - a_g = \frac{aL}{4\pi r^2 c m_c} - \frac{GM_{BH}}{r^2} =$$

$$= \frac{L}{r^2}\left[\frac{a}{4\pi r^2 c m_p N_H} - \frac{G}{7.5x10^4 (L / L_{Edd})}\right]$$

Using NLR properties to infer L_{AGN} and L_{SF}

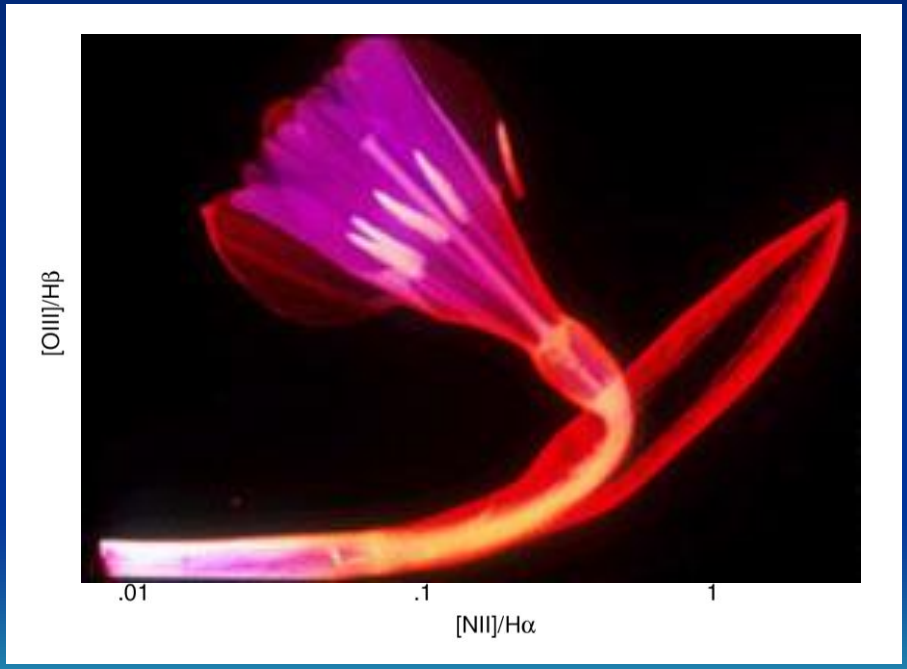
M_{BH} from M-σ*

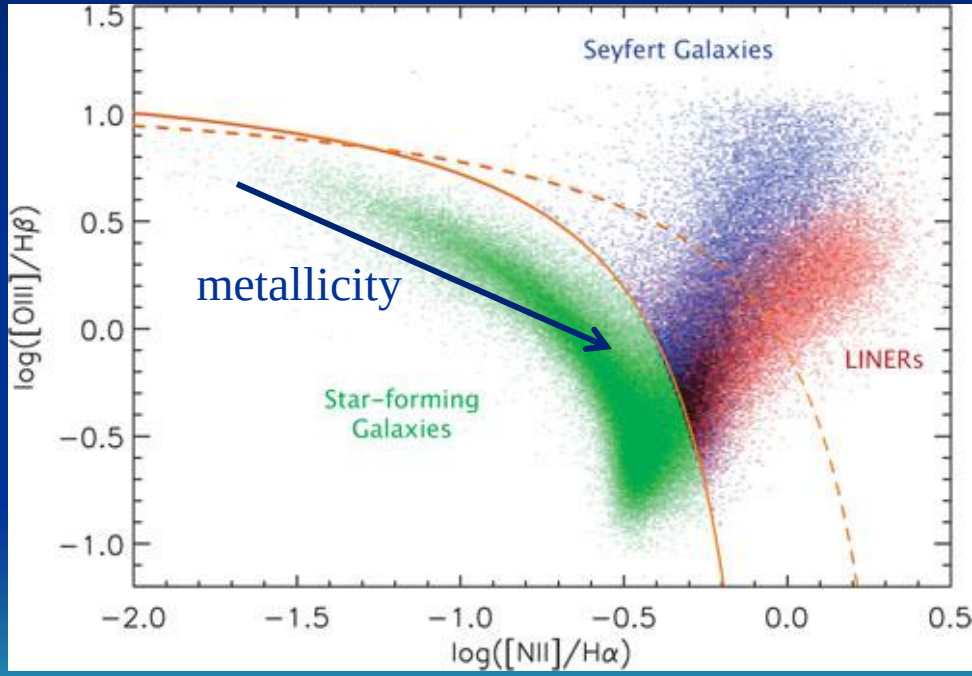
L_{AGN} from narrow emission lines



Ho LC. 2008.

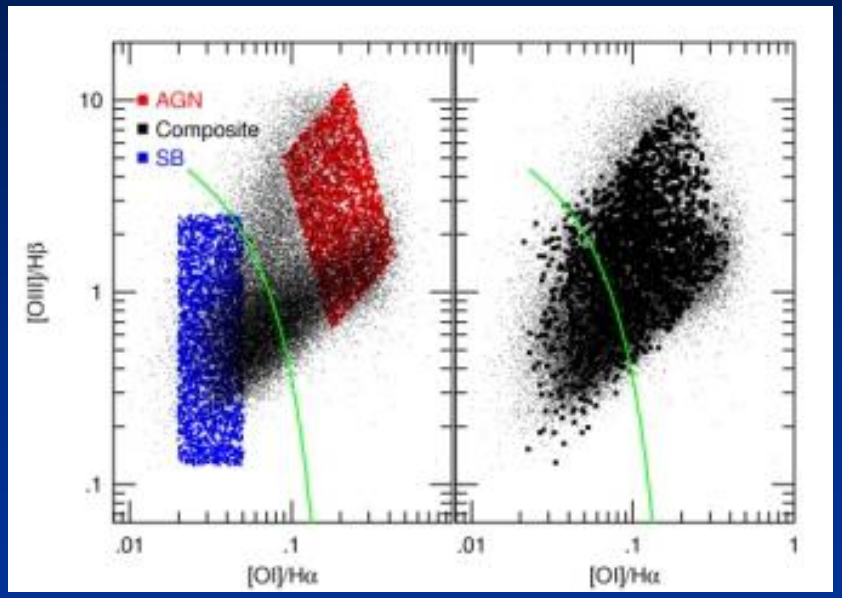
Diagnostic (BPT) diagrams

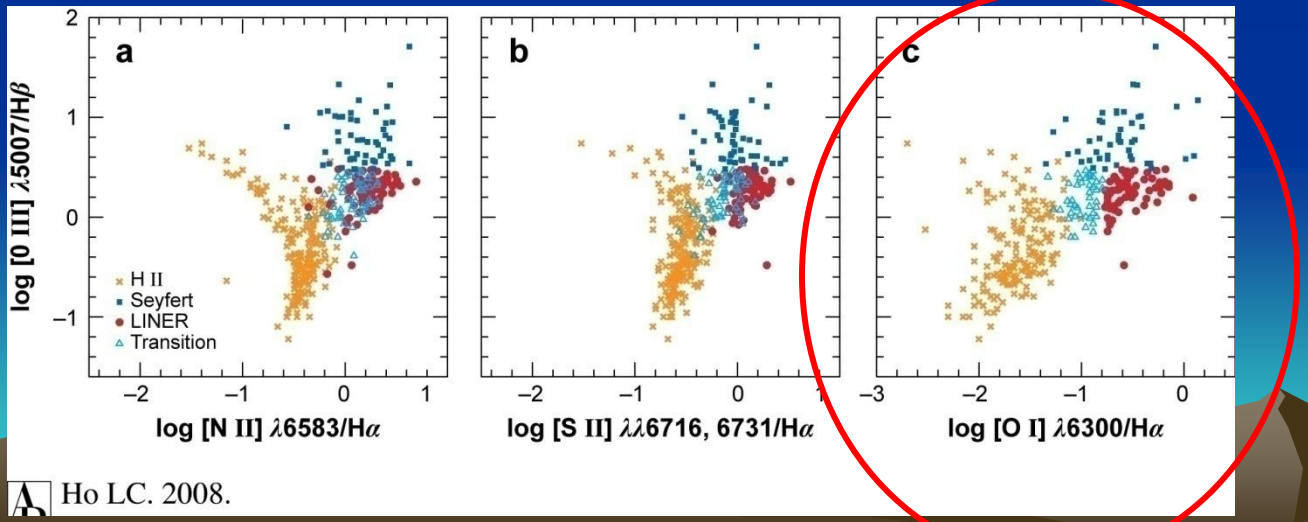




More diagnostic diagrams

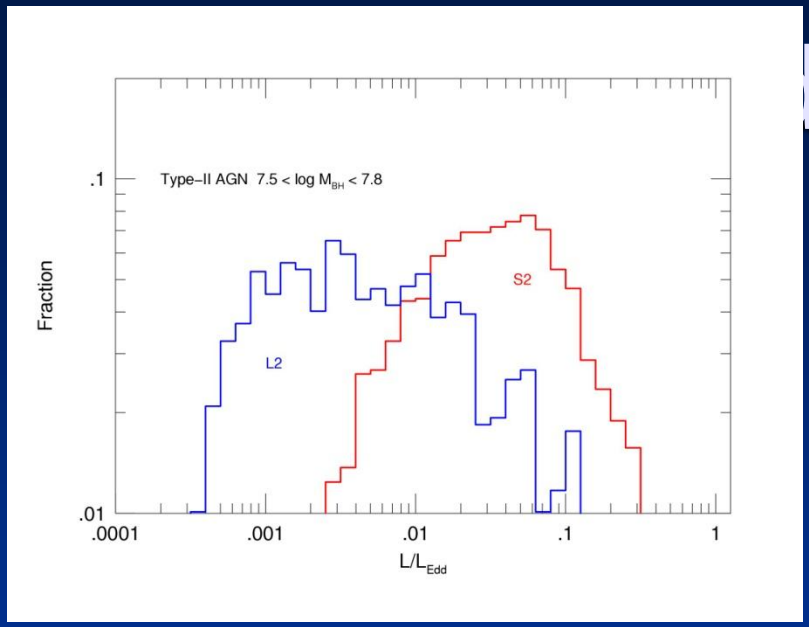
Conclusions:
Many objects classified as SBs contain active BHs?
Many objects classified as AGN contain SF regions

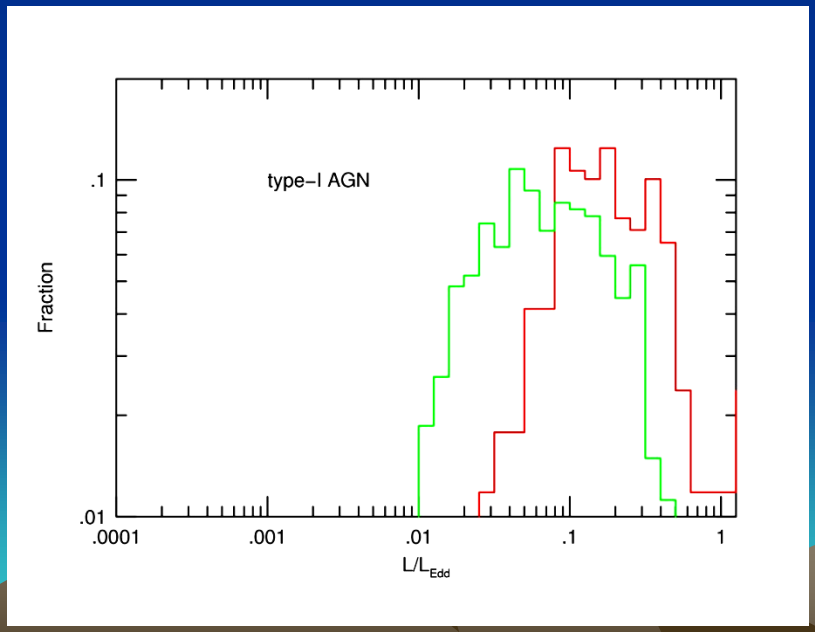


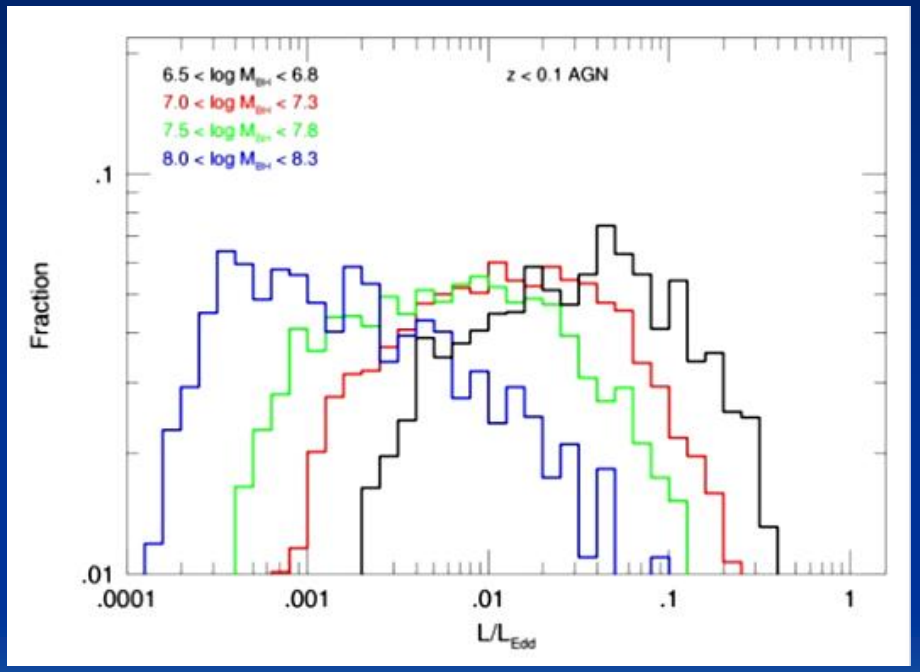


Ho LC. 2008.

Distributions





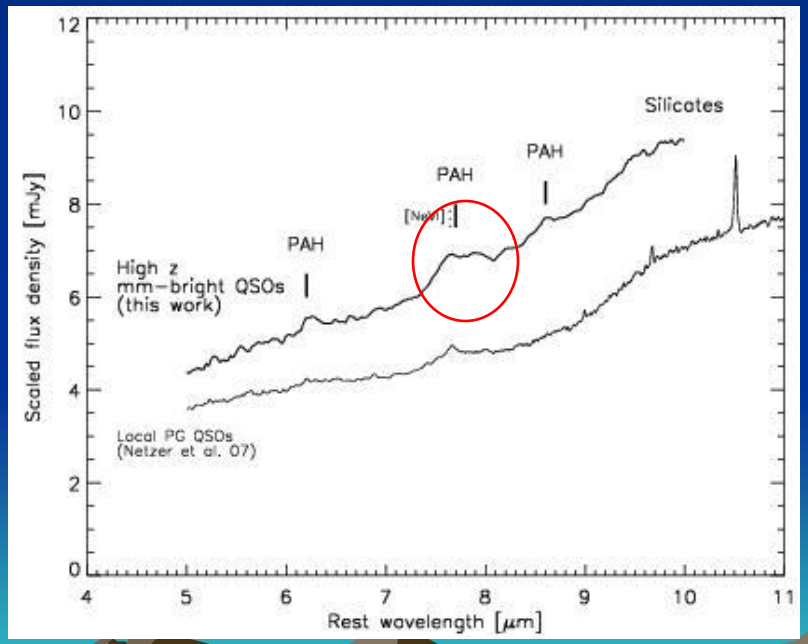


The AGN-SB connection

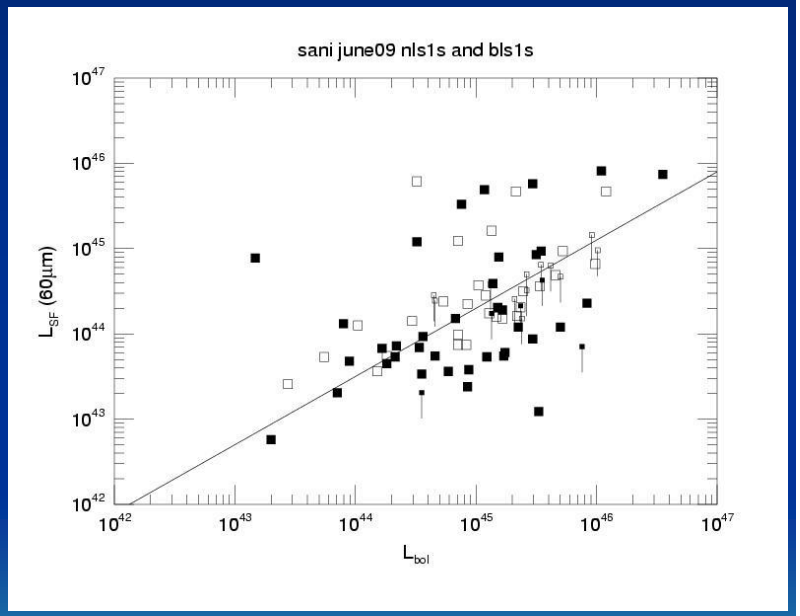
SF in AGN-dominated systems

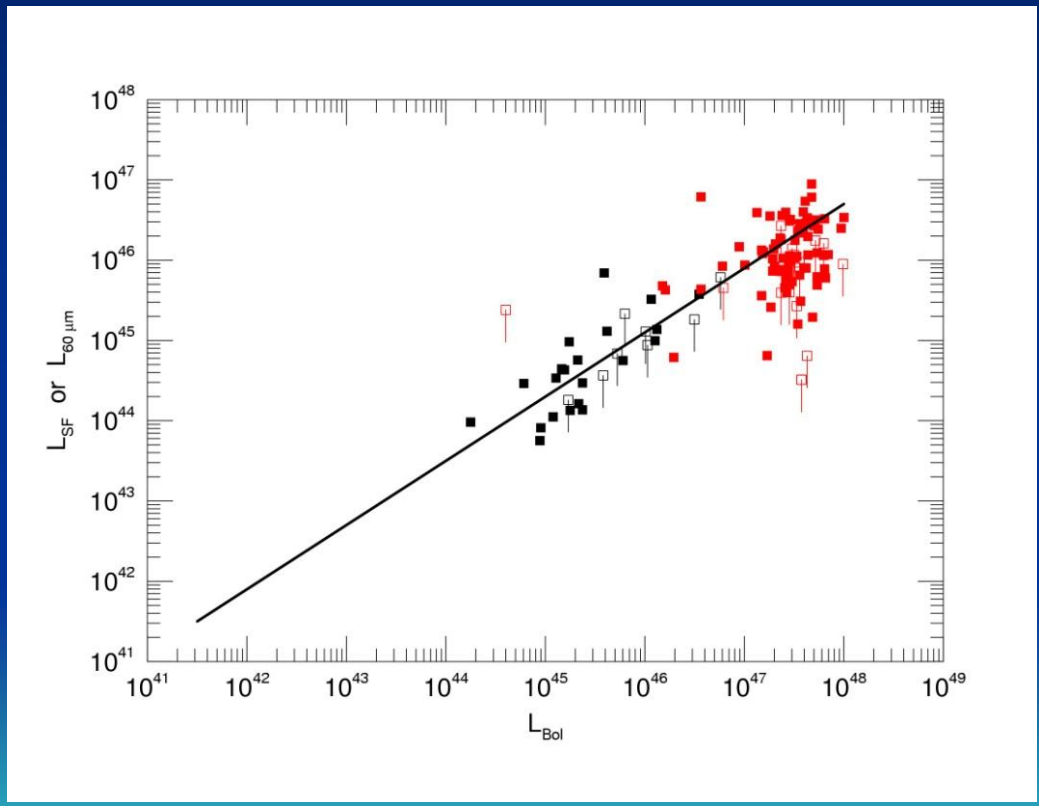
L_{AGN} and L_{SF} correlations

Simple evolution scenarios

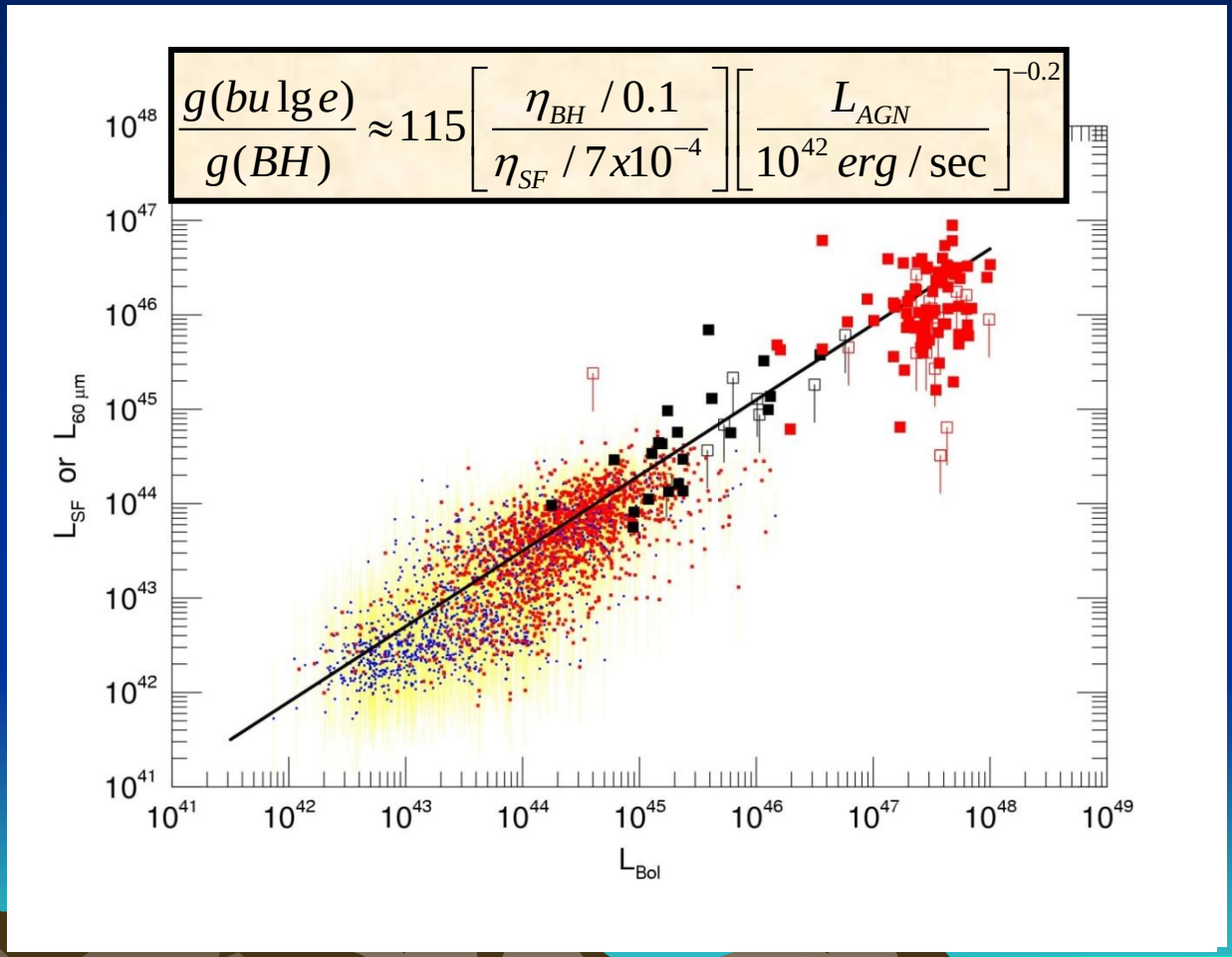


Lutz et al. 2008


sani june09 nls1s and bls1s
L_{SF} (60μm)
L_{bol}
10^{42}
10^{43}
10^{44}
10^{45}
10^{46}
10^{47}


L_{SF} or $L_{60\,\mu m}$
L_{Bol}
10^{41}
10^{42}
10^{43}
10^{44}
10^{45}
10^{46}
10^{47}
10^{48}
10^{49}

L_{AGN} vs. L_{SF} in AGN-dominated systems



Netzer et al. 2007; Lutz et al. 2008, Netzer 2009

SF and AGN evolution