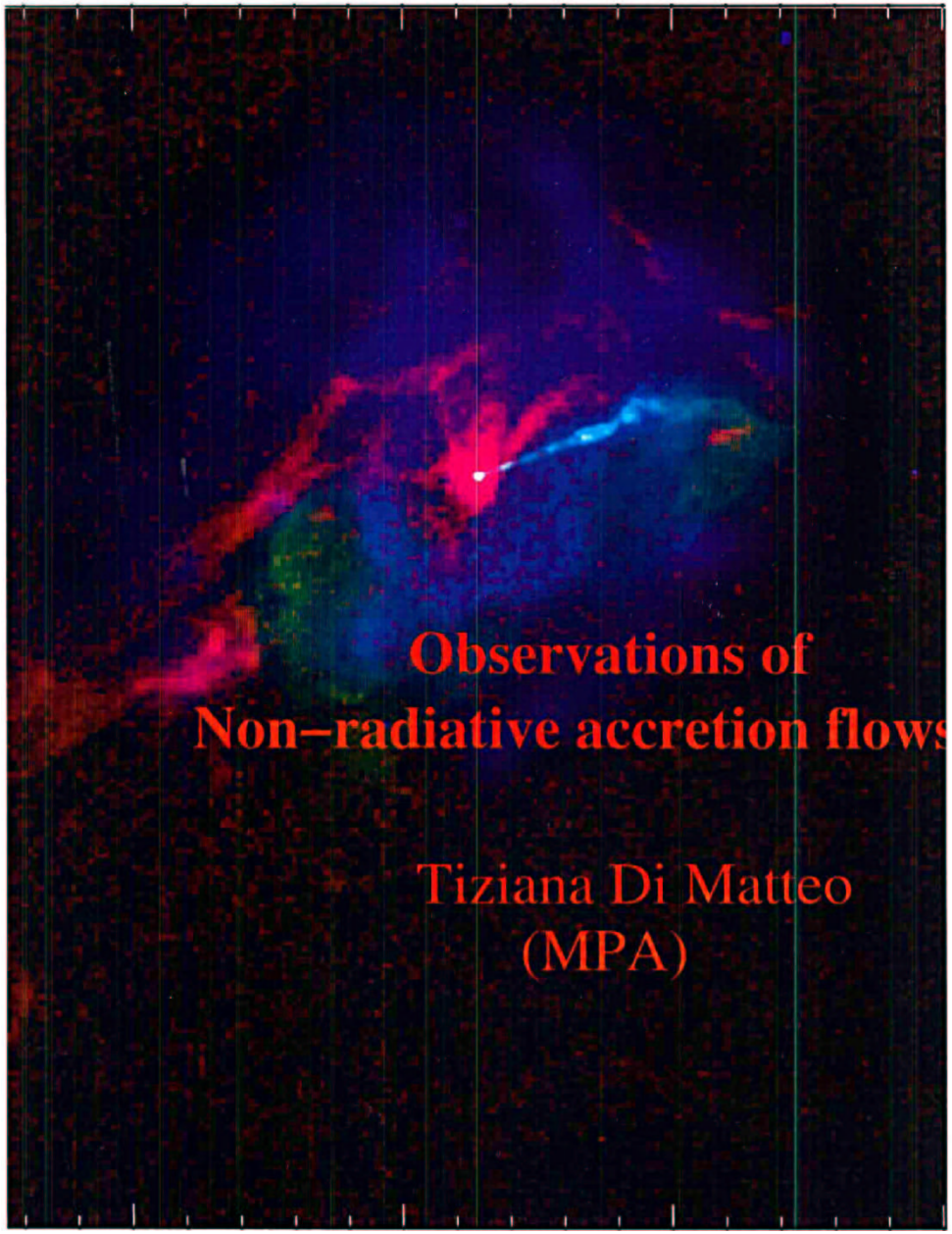


ACCRETION ONTO BHs

$L = \eta \dot{M} c^2$

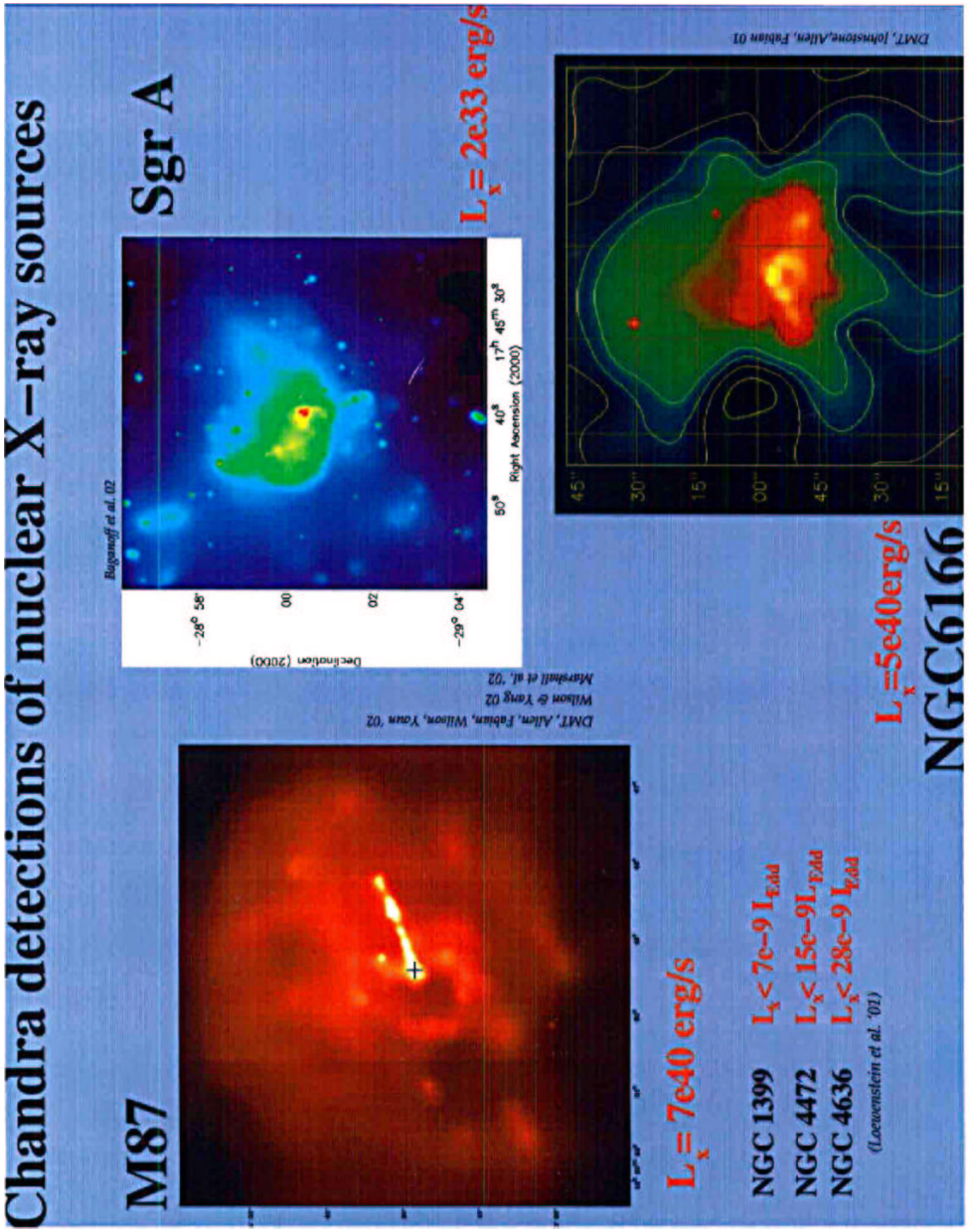
- η: Radiative efficiency — Power output
- $\dot{M}$: Accretion rate onto BH

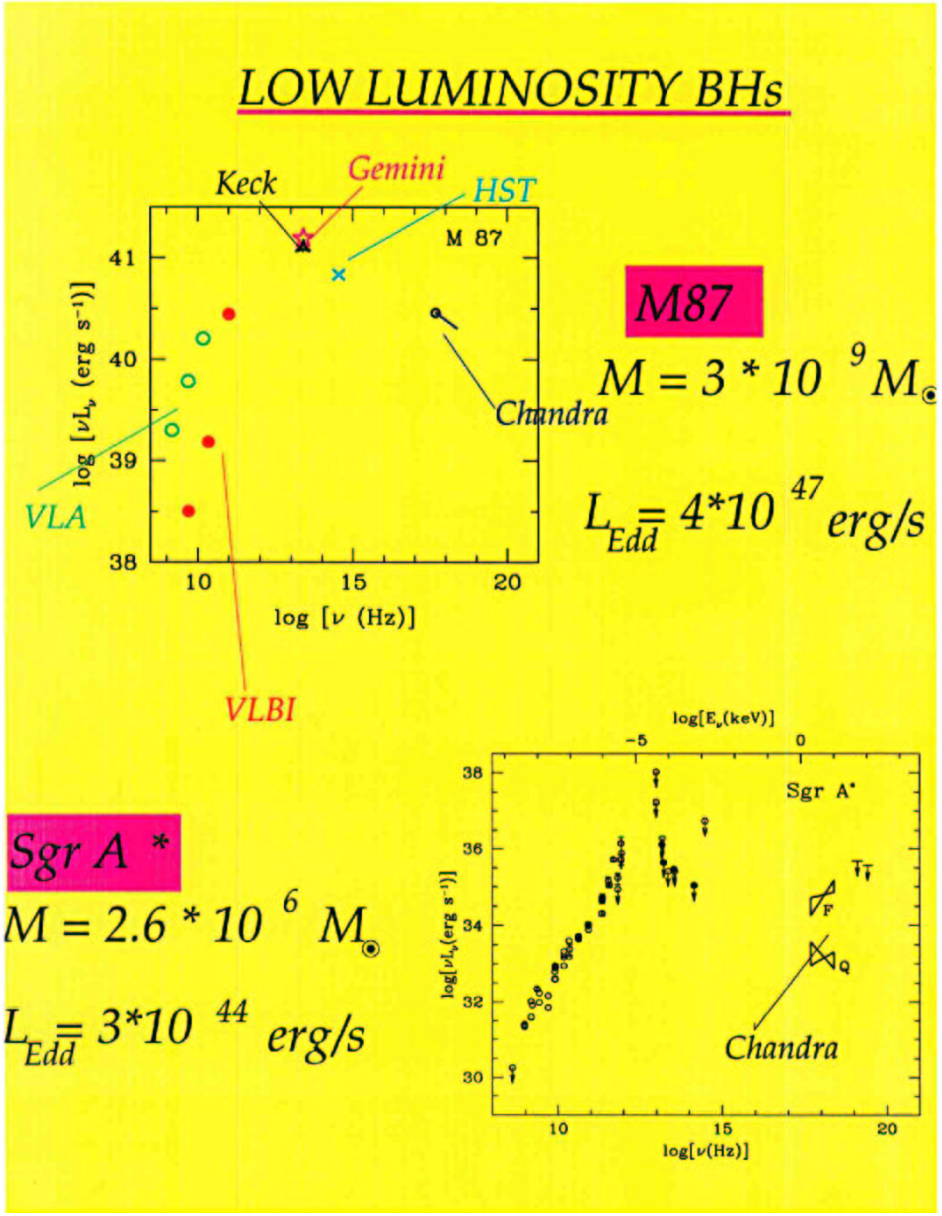
$\eta = 0.1$ – standard accretion
$\eta << 0.1$ – Bondi/Adaf accretion → Need: M_{BH}

Max. L

$L_{Edd} = 1.3 \times 10^{38} \frac{M_{BH}}{M_\odot}$

Chandra! $\dot{M}, L_X$


Chandra detections of nuclear X−ray sources
Sgr A
L_x= 2e33 erg/s
Baganoff et al. 02
Declination (2000)
Right Ascension (2000)
DMT, Johnstone, Allen, Fabian 01
M87
L_x= 7e40 erg/s
DMT, Allen, Fabian, Wilson, Yaun '02
Wilson & Yang 02
Marshall et al. '02
L_x=5e40erg/s
NGC6166
NGC 1399 L_x< 7e−9 I_{Edd}
NGC 4472 L_x< 15e−9L_{Edd}
NGC 4636 L_x< 28e−9 I_{Edd}
(Loewenstein et al. '01)


LOW LUMINOSITY BHs
Keck
Gemini
HST
M 87
Chandra
VLA
VLBI
log [νL$_ν$ (erg s^{-1})]
log [ν (Hz)]
M87
M = 3 * 10 ^{9} M$_\odot$
L$_{Edd}$ = 4*10 ^{47} erg/s
Sgr A *
M = 2.6 * 10 ^{6} M$_\odot$
L$_{Edd}$ = 3*10 ^{44} erg/s
log[E$_ν$(keV)]
Sgr A*
F
Q
Chandra
log[νL$_ν$(erg s^{-1})]
log[ν(Hz)]

BONDI ACCRETION RATE

BH of mass M immersed in a uniform, spherical medium of density ρ & and sound speed v_S.

Sphere of influence of a BH extends out to a radius where the gravity of the central BH dominates the dynamics of the ISM gas.

BH grav. energy ~ gas thermal energy

$$\frac{GM}{r} \sim \frac{v_s^2}{2}$$

CAPTURE/ACC. RADIUS:

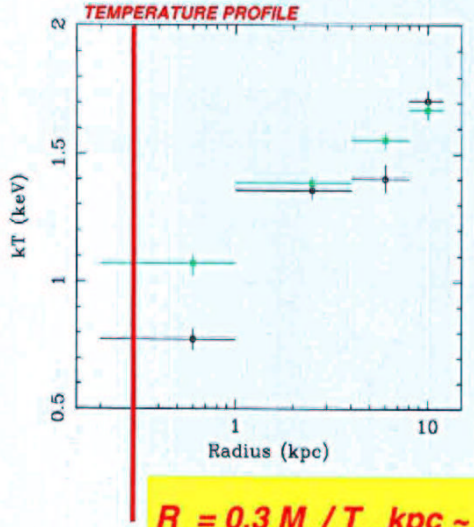
$$R_A \sim \frac{GM}{v_S^2} \qquad v_S \sim 10^4 T^{1/2}$$

mass conservation:

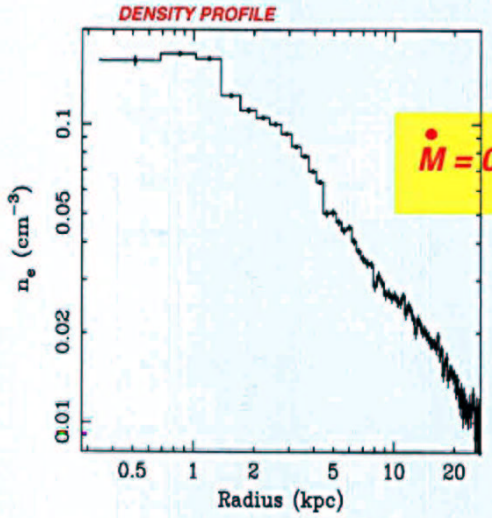
$$\dot{M}_{Bondi} = 4\pi R_A^2 \, \rho(R_A) \, v_S(R_A)$$

M 87

$M_{BH} = 3e9\ M_\odot$



$R_A = 0.3\ M_{BH} / T_{0.8}$ kpc ~ 10^6 Rs

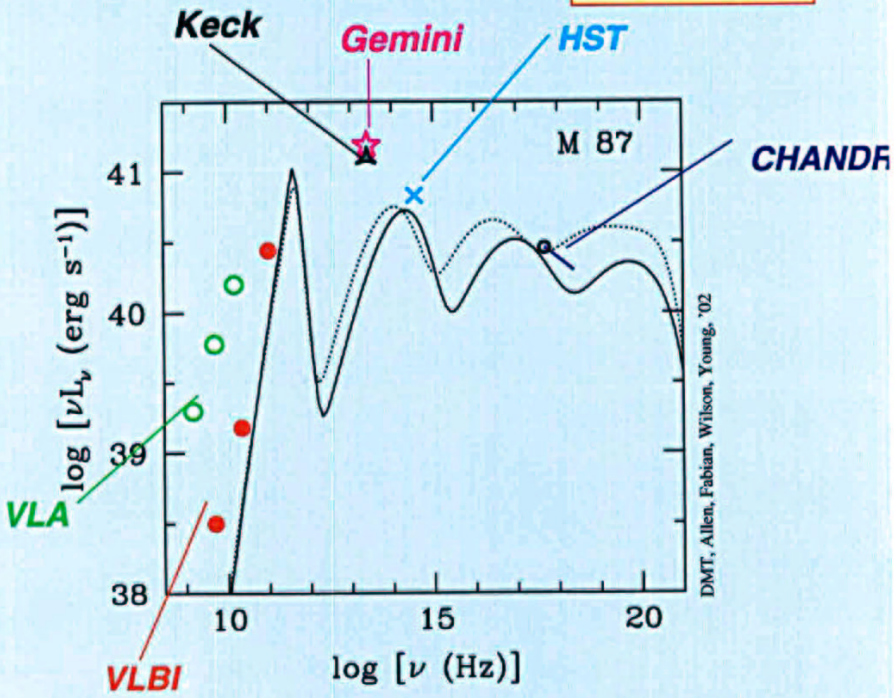


$\dot{M} = 0.2\ M_{BH}^2\ T_{0.8}^{-3/2}\ n_{0.16}\ M_\odot$ /yr

M 87

ADAF MODEL

$\rho \sim R^{-3/2}$
$v \sim \alpha v_{ff}$



$L_B = \eta \dot{M} c^2 = 6e44$ erg/s if $\eta = 0.1$

$L_{Edd} = 4e47$ erg/s

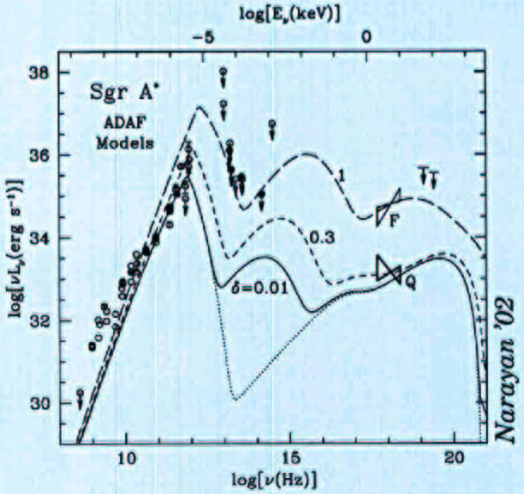
Sgr A*

ADAF MODEL

$\rho \sim R^{-3/2}$
$v \sim \alpha v_{ff}$

$R_A = 0.07 M_{BH}/T_{1\,keV}$ pc

$\dot{M} = (0.3\text{–}1)e\text{–}5\ M_\odot/yr$



$L_B = \eta \dot{M} c^2 = 3e40$ erg/s if $\eta = 0.1$

$L_{Edd} = 3e44$ erg/s

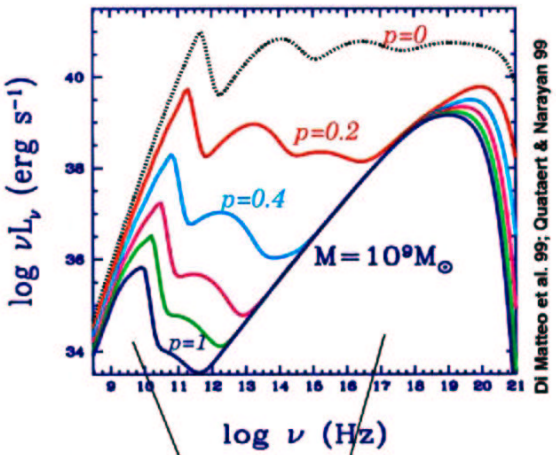
OUTFLOWS (or Convection)

$$\rho \propto R^{-3/2+p} \qquad (0 < p < 1)$$

$$\dot{M}_{BH} = \dot{M}_{out} \left(\frac{R}{R_{\rm out}}\right)^p \quad \text{for} \quad R < R_{\rm out}$$

$\dot{M}_{\rm Bondi}$

for p>0, central densities smaller –



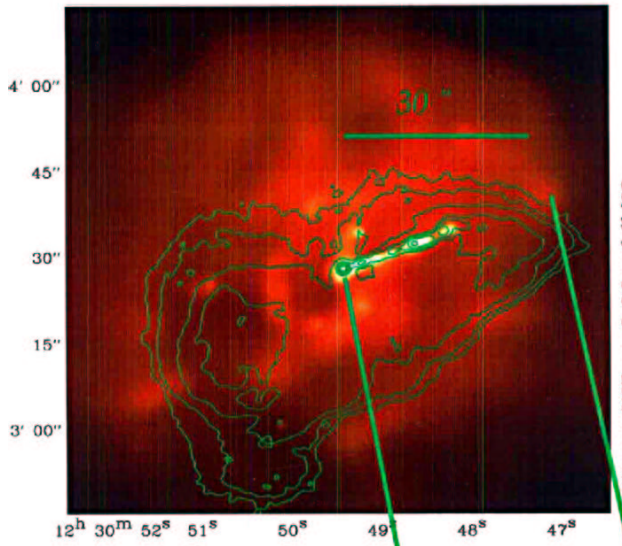
predicts:

RADIO (synch.) / X–ray (brem) << 1

- NO unambiguous observational evidence for these models

M87 – inner regions

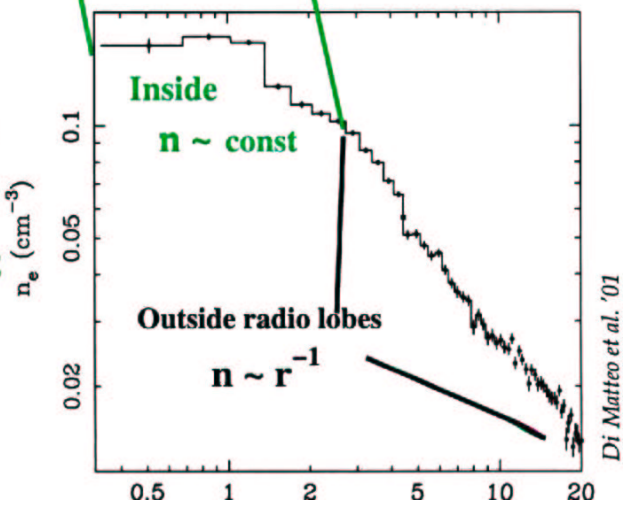
jet – ISM interactions



6cm radio emissio
inner radio lobes

Deprojected radial distribution of X–ray density

FLAT X–ray CORE inside inner radio lobes



ACCRETION RATE $\dot{M} << \dot{M}_{Bondi}$

JET – ISM interaction – VERY ROUGHLY

Sphere of influence of a BH extends out to a radius where the gravity of the central BH dominates the dynamics of the ISM gas.

If jet with (L_j, v_j) expanding in ISM at velocity

$v_h \sim (L_j/\rho r^2 v_j^2)^{1/2}$

Energy deposited within r in ISM in time

$t \sim r/v_h$

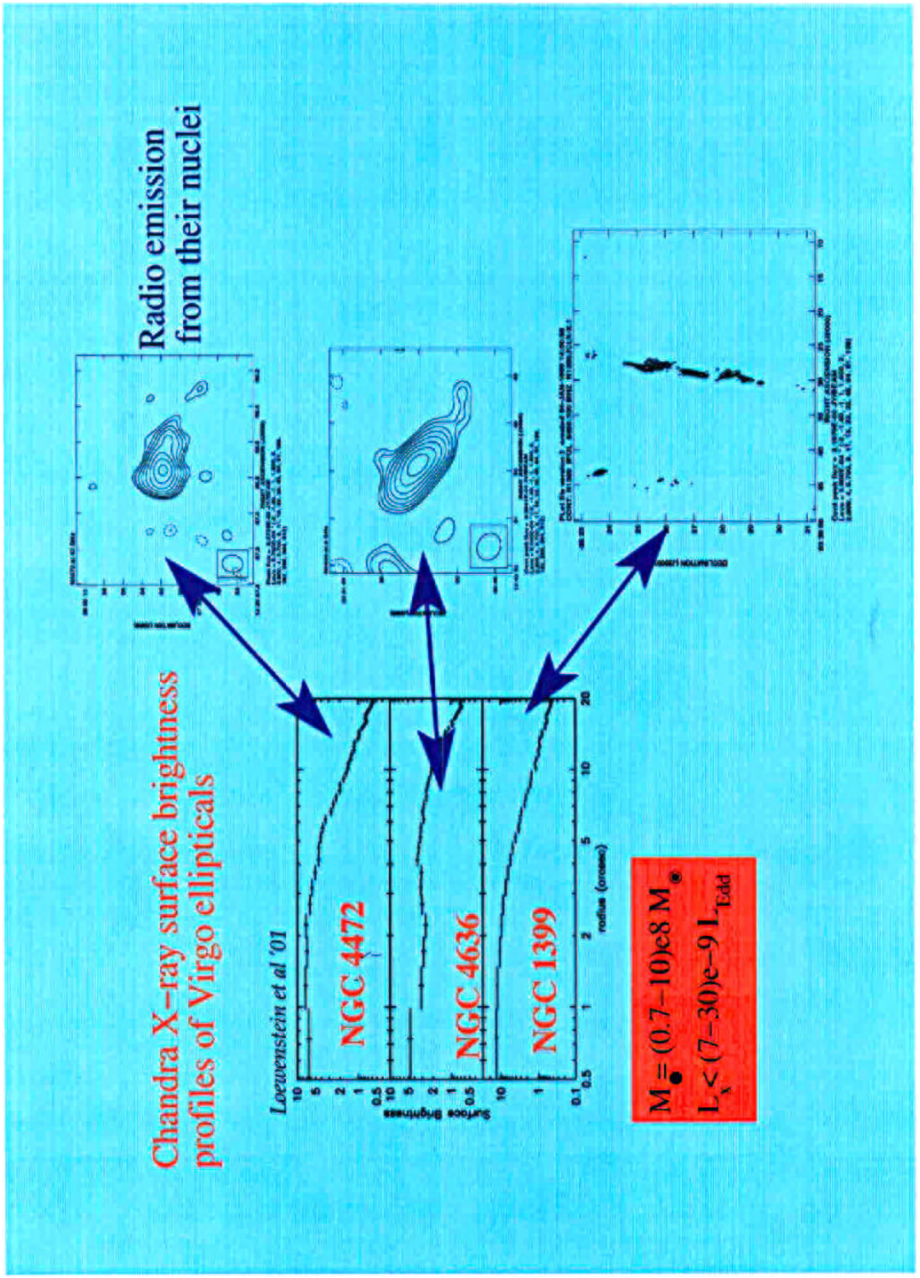
$$E \sim \pi r^3 \rho v_j v_h$$

BH grav. ~ gas energy + jet deposited energy

$$\frac{GM}{r} \sim \frac{v_s^2}{2} + v_j v_h \quad \text{for } v_h \sim v_s$$

CAPTURE/ACC. RADIUS

$$R_A \sim \frac{GM}{v_s^2}\left(\frac{v_j}{v_s}\right)^{-1} \lesssim 10^3\text{–}4$$



M87 ENERGETICs – $\dot{M}_{Bondi}$

- Jet Kinetic Energy (*Owen et al. '00*) (*Bicknell & Begelman '99*)

$L_j \sim 10^{44}$ erg/s

- Bondi Luminosity

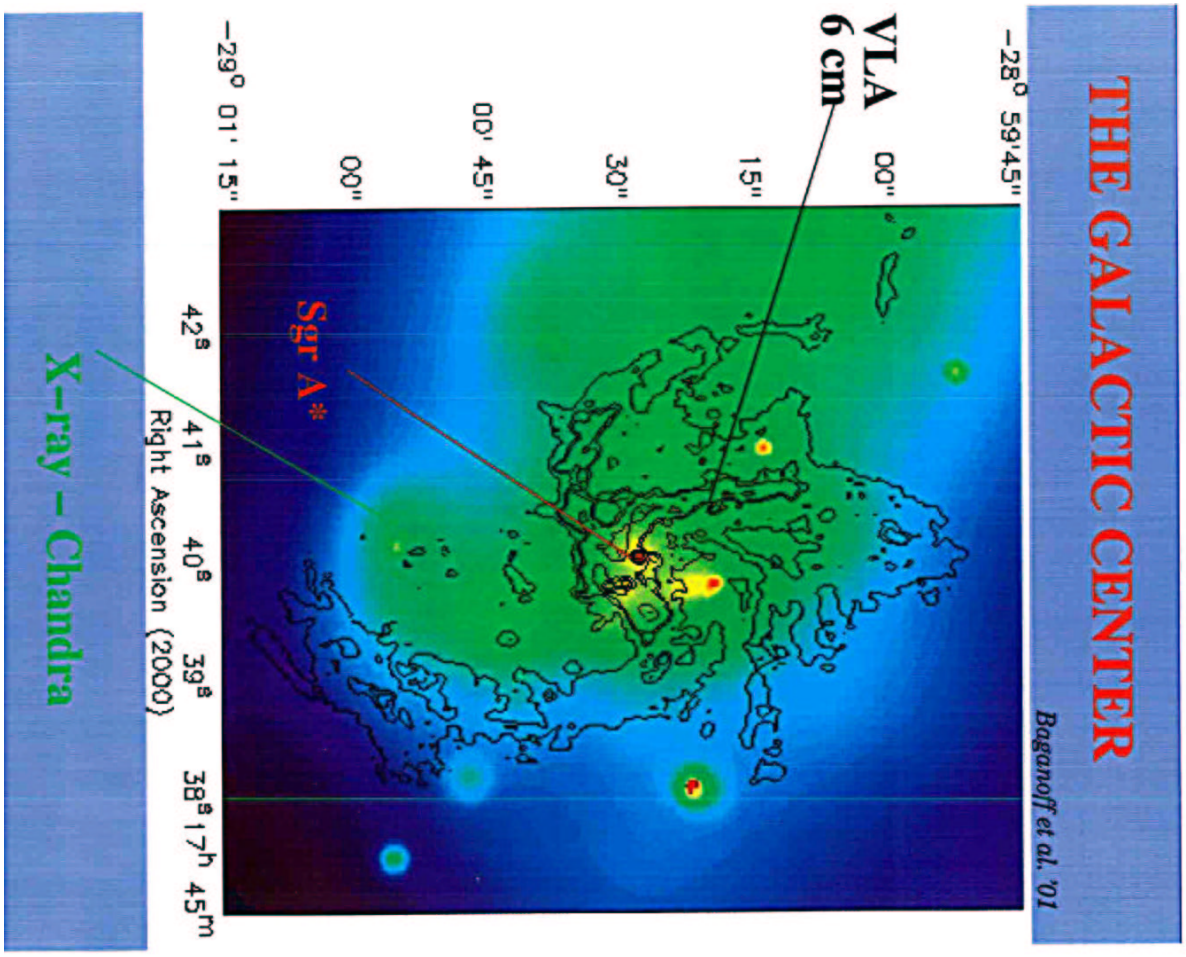
$L_{Bondi} \sim$ few 10^{44} erg/s

(*DMT et al. '02*)

- Energy in X–ray Cavity

$L \gtrsim 10^{43}$ erg/s (*Young & Wilson '02*) (*DMT et al. '02*)

($L_{ISM} \sim 10^{43}$ erg/s)



CONCLUSIONS:

CHANDRA has provided direct evidence/measurements:

- L nuclear X-ray point sources
- ρ_{ISM} and T_{ISM} at R_{Bondi}

  → $\dot{M}_{Bondi}$

  → $L_{Acc} << 0.1\ \dot{M}_{Bondi}\ c^2$

  low η (adaf/bondi) CONSISTENT
  (no evidence for adios/cdafs)

- flat ISM density profiles in cores corresponding X-ray cavities and radio lobes

  → ISM close to R_h significantly disturbed by the jet

  → $\dot{M} << \dot{M}_{Bondi}$