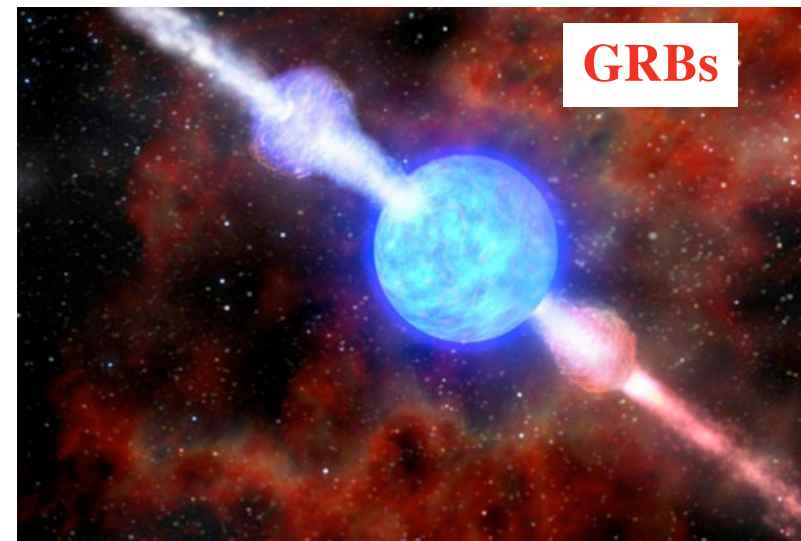
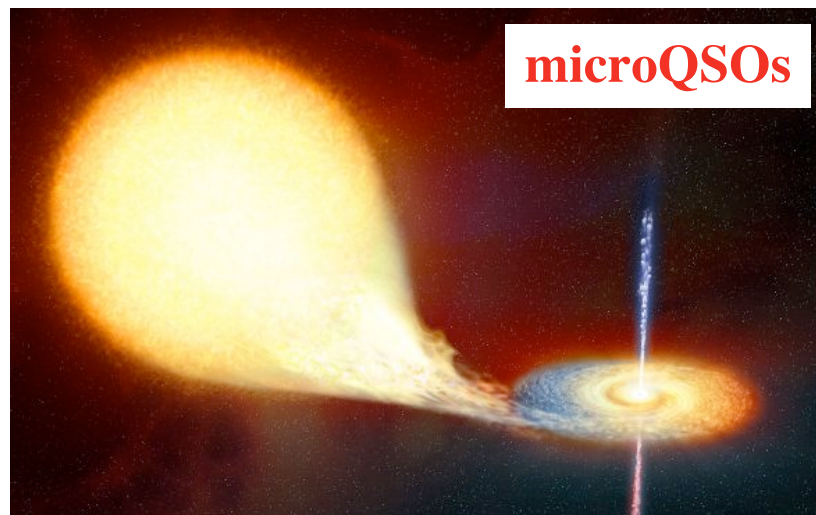
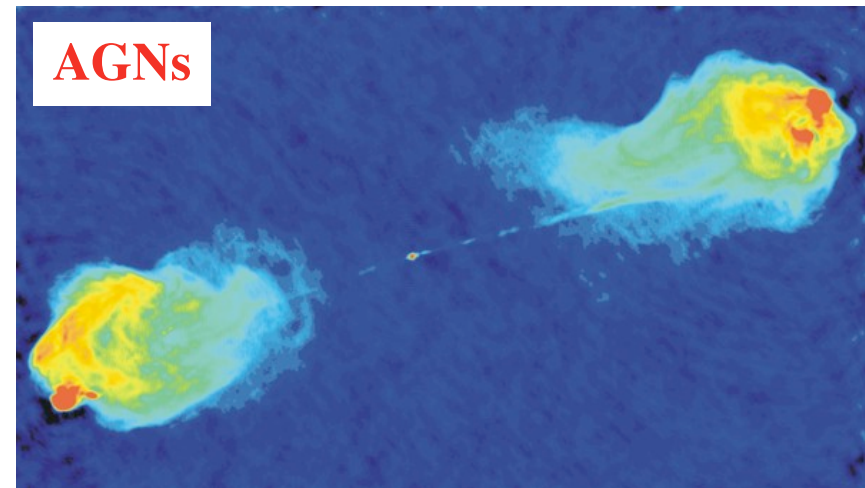
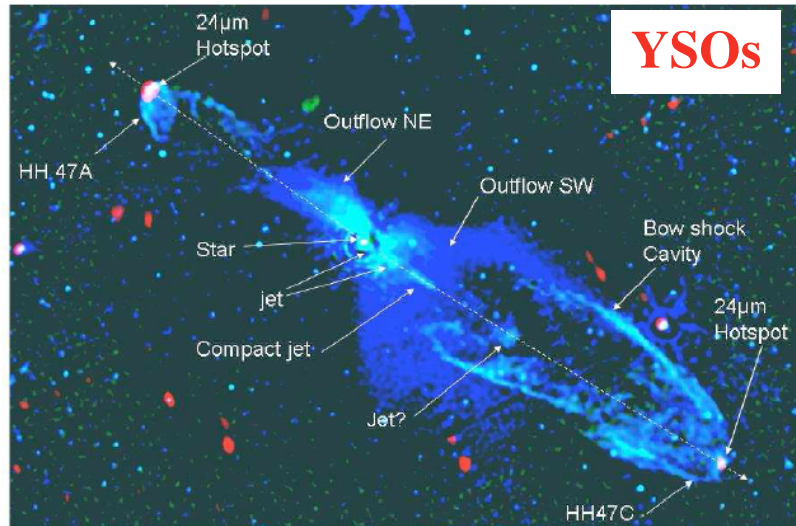


宇宙ジェットの物理とその役割

井上 進 (京大理)



questions about cosmic jets

FAQ: **What?**

How?

Not-so-FAQ: **When/where?**

To jet or not to jet, that is the question!

Question you always wanted to know but were afraid to ask:

Why? (So what?)

Jets, who ordered that?

1. YSOs

2. AGNs

3. Galactic black holes

4. GRBs

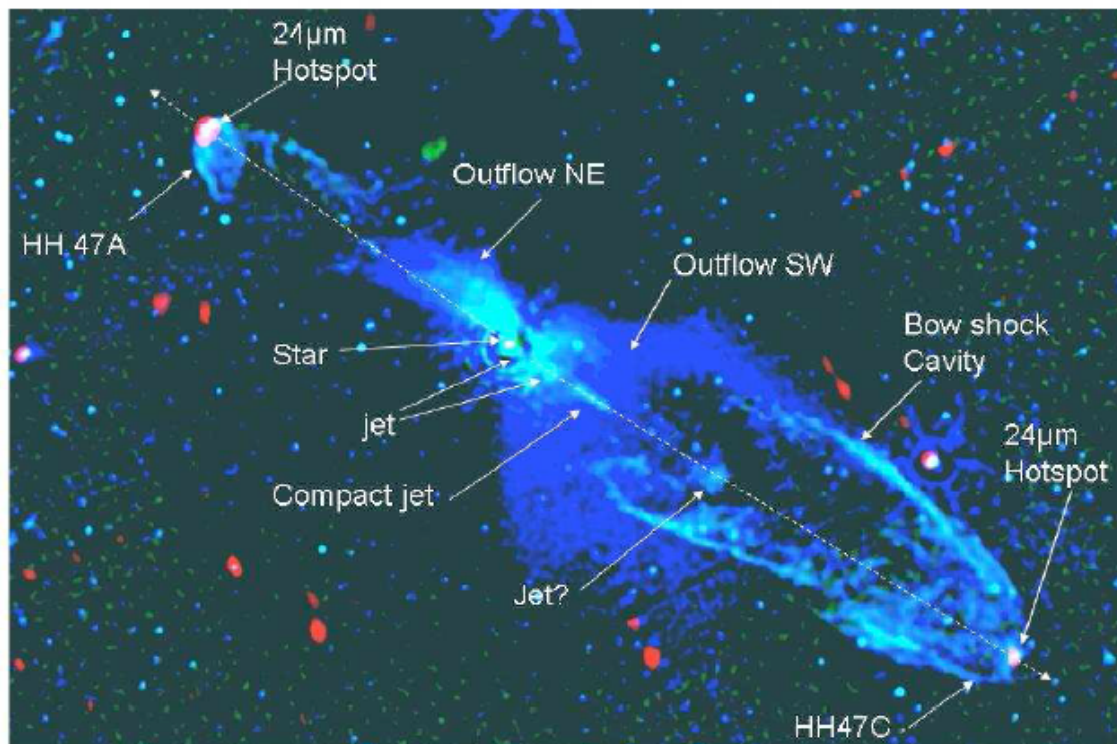
1. Young Stellar Object (YSO) jets

-> 町田さんの講演

What? fast atomic jet + slow molecular outflow

When? stellar collapse phase -> accretion phase

Why? angular momentum ejection -> star formation



星の形成にとって
不可欠！

太陽系内で
他の影響は？

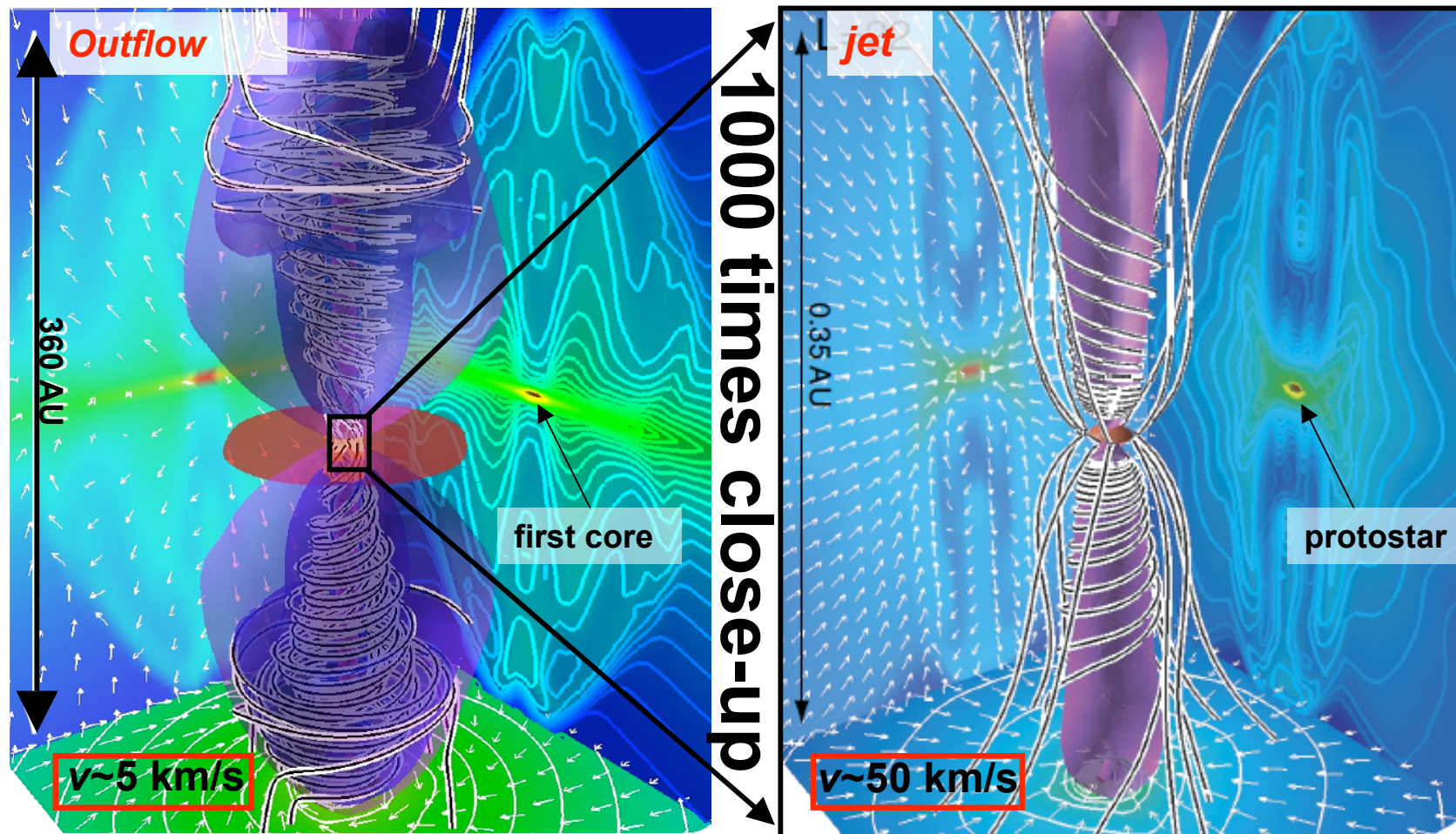
Velusamy+ 07

YSO jet production ほとんど解決？

How? B fields: only viable process
outflow = centrifugally-driven
jet = B pressure driven

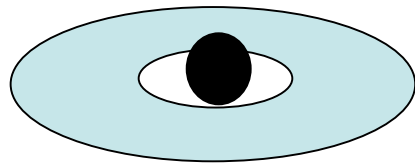
今後の観測による
検証に期待

Machida+ 08



AGN demography

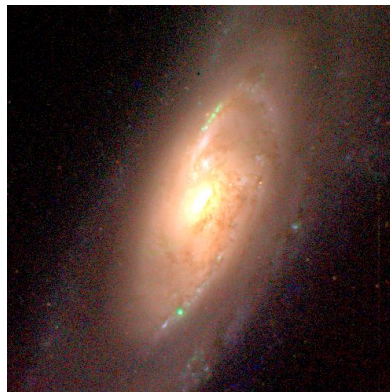
supermassive black hole
+accretion disk (flow)



radio-quiet
(no jet)

~90%

Seyfert galaxy
radio-quiet quasar

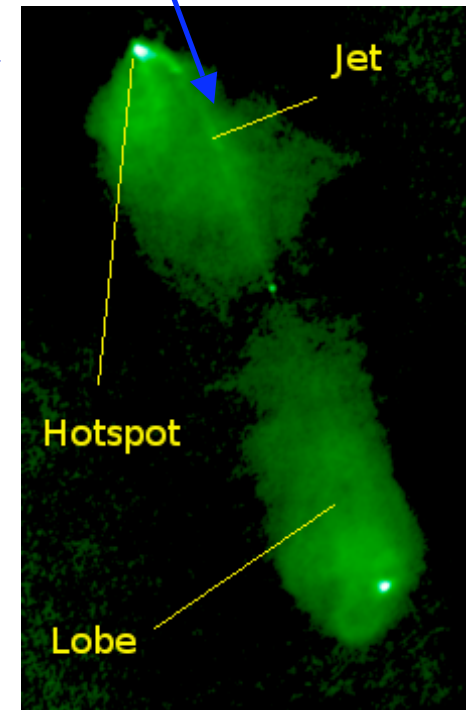


radio-loud
(relativistic jet)

high-
power

~<1%

**FR 2
radio
galaxy**

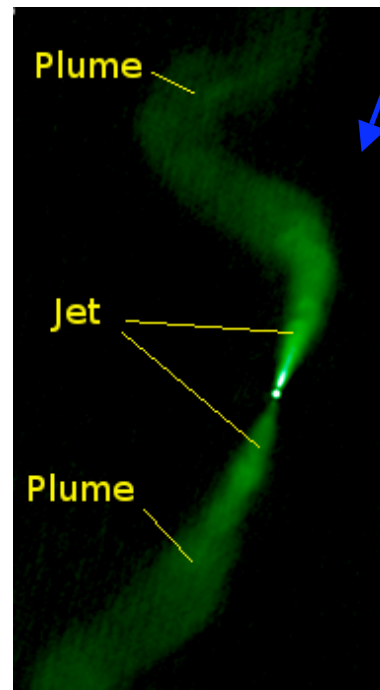


low-
power

~9%

**TeV blazar
(BL Lac)**

**FR 1
radio
galaxy**



activity timescales
~ 10^6 - 10^8 yr

2. AGN jets What?

-> 紀さん、片岡さん他の講演

relativistic $\Gamma_{\text{jet}} > \sim 10$

well-collimated $\theta_{\text{jet}} \sim < \text{few deg}$

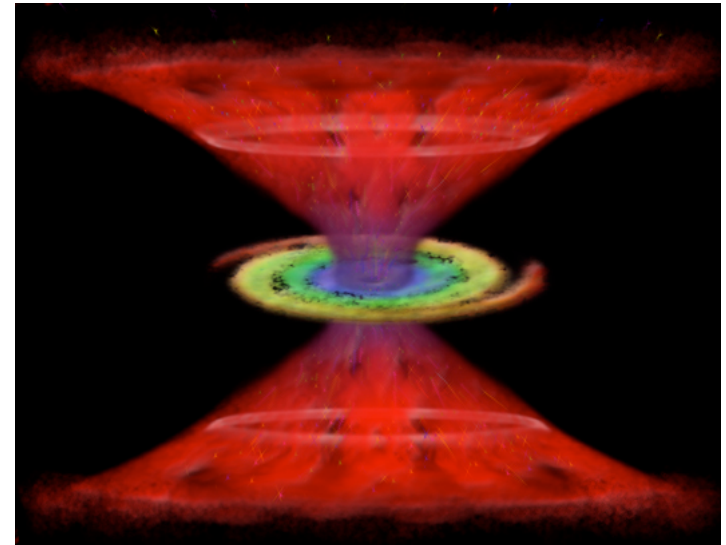
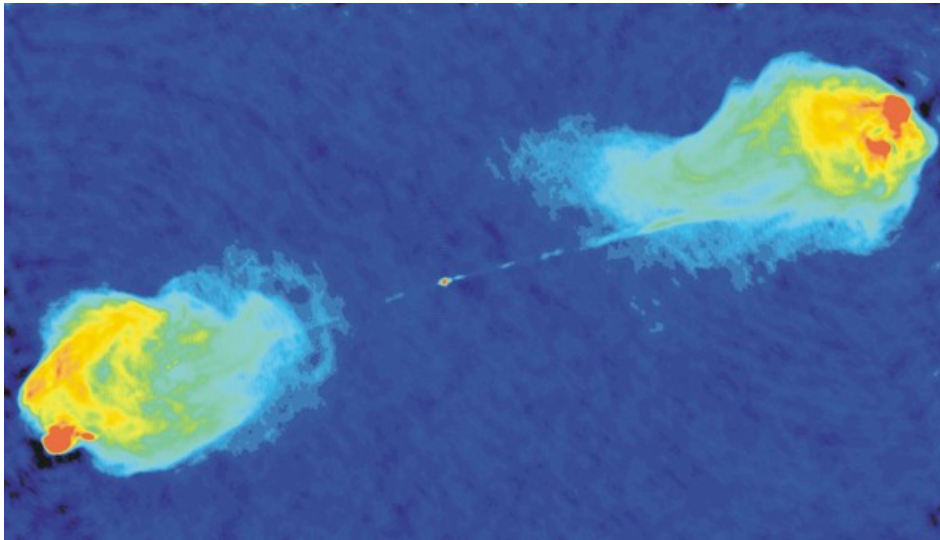
powerful $L_{\text{jet}} \sim < L_{\text{Edd}}$

composition: e-p? e-e⁺? mixture? B?

radio-loud

+ sub-relativistic wind?
(BAL quasars, X-ray absorption)

also in
radio-quiet?



AGN jet production **How?**

radiation-driven?

NO for jet (OK for wind?)

thermally-driven?

? <-> lack of bulk Compton

magnetic disk-driven?

? <-> blazar energy balance

BH spin-driven?

(B sub-dominant)

(Blandford-Znajek process)

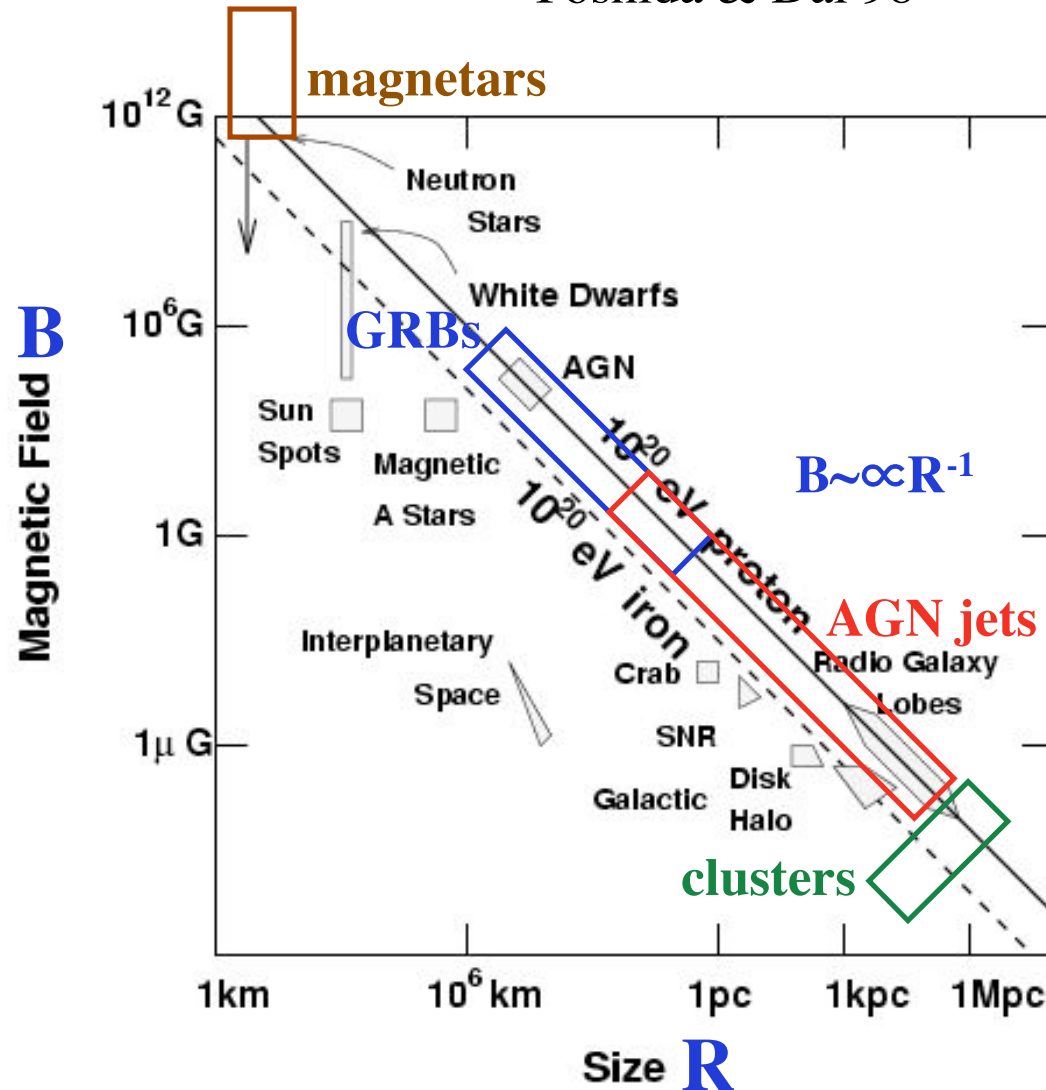
Why? UHECR source candidates

“Hillas plot” adapted from
Yoshida & Dai 98

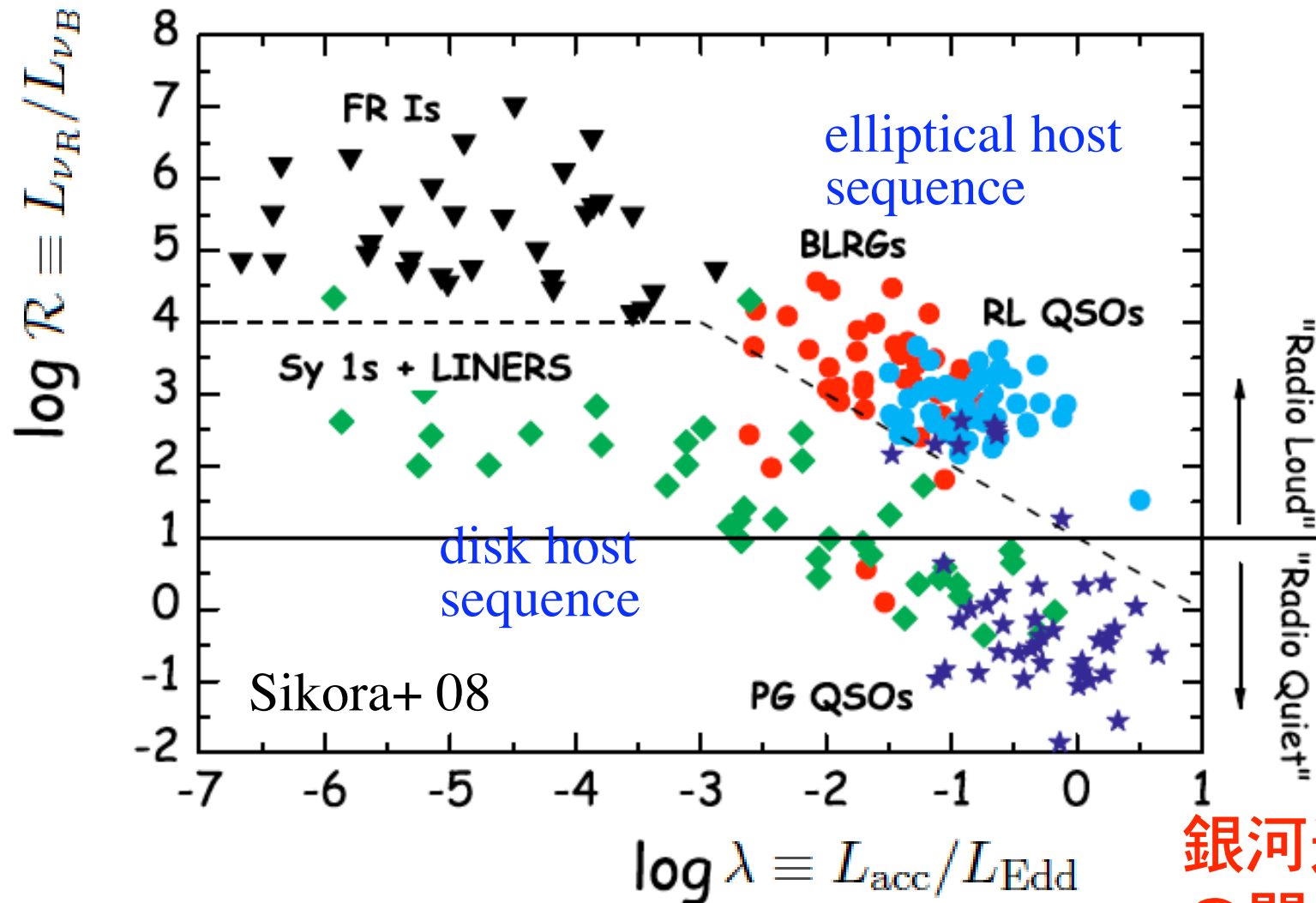
$$E \leq Ze B R (v/c)$$

confinement

$E_{\max}$ acceleration vs:
escape
source lifetime
adiab. expansion loss
radiative loss



radio dichotomy When/Where?



銀河進化と
の関係を示唆

- connection with host morphology
- control parameter related with merging -> BH spin?

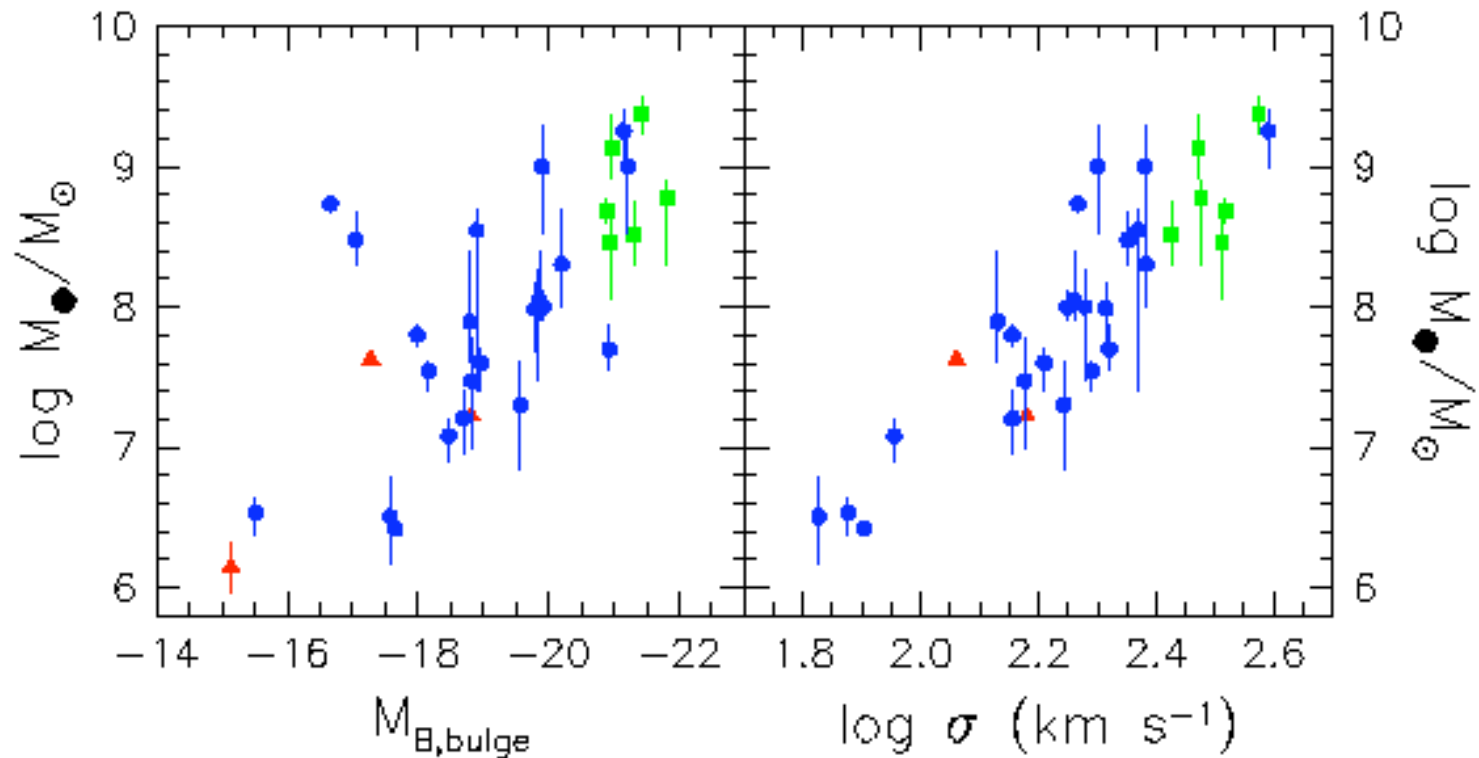
BH - host galaxy bulge relation

Black Hole Mass
versus

Bulge Luminosity

Bulge Dispersion

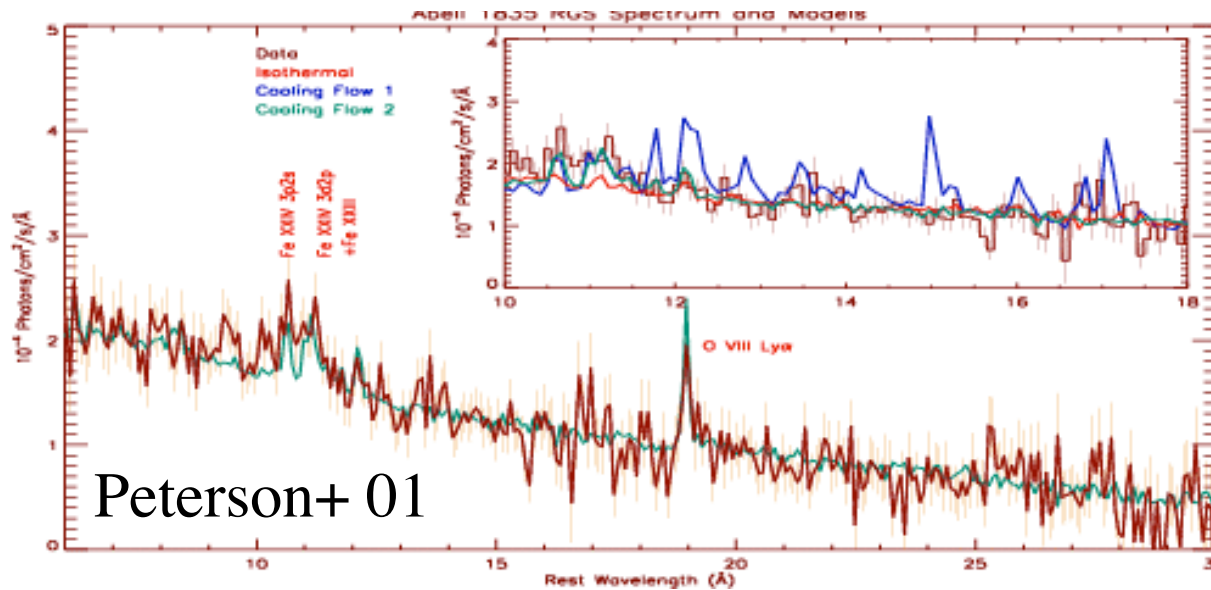
BHと母銀河の
密接な関係



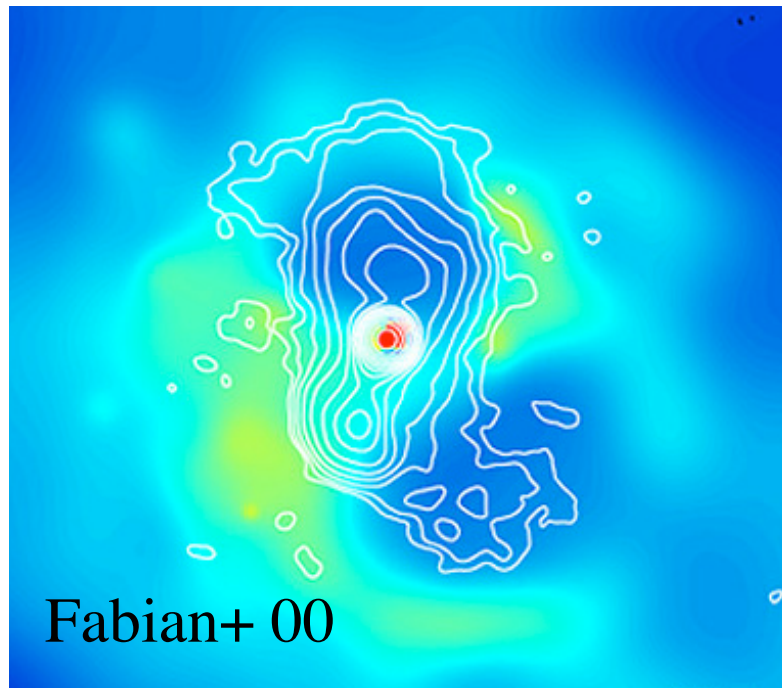
Kormendy 93
Magorrian+ 98
Gebhardt+ 00

...

cluster cool cores and radio galaxies



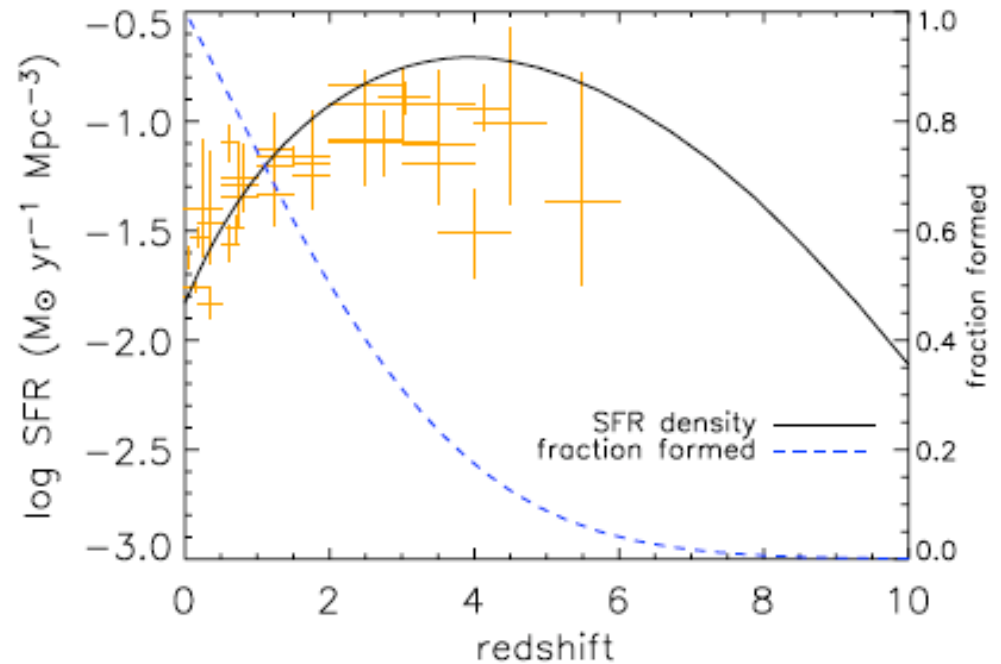
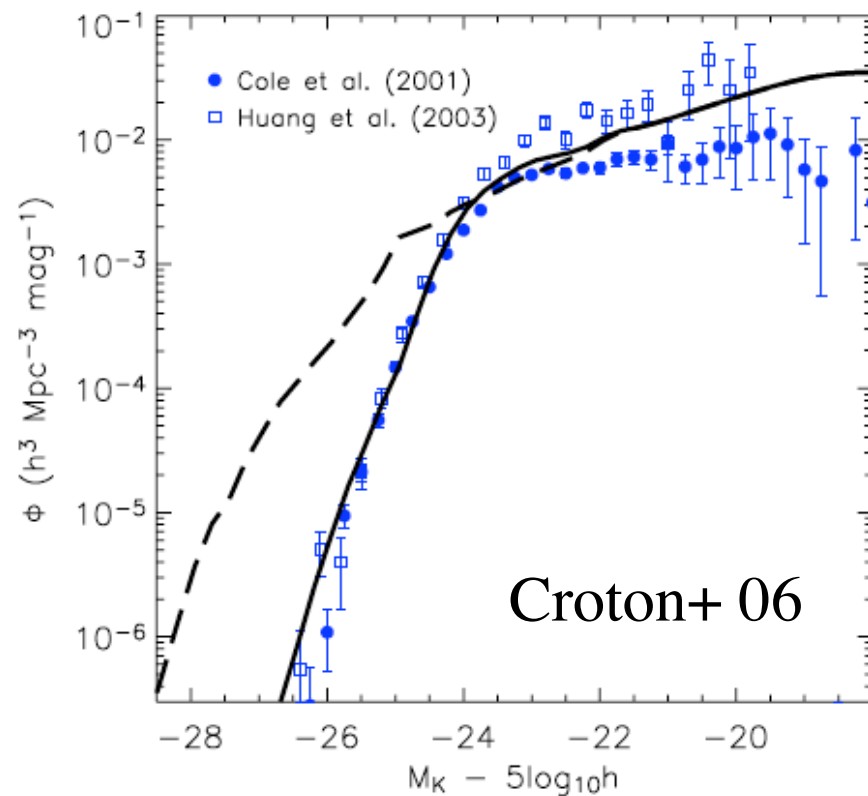
no “cooling flow”
-> heating source



radio bubbles
in X-ray cavities

電波銀河と
銀河団ガス
の密接な関係

Why? AGN “feedback” heating in galaxy formation



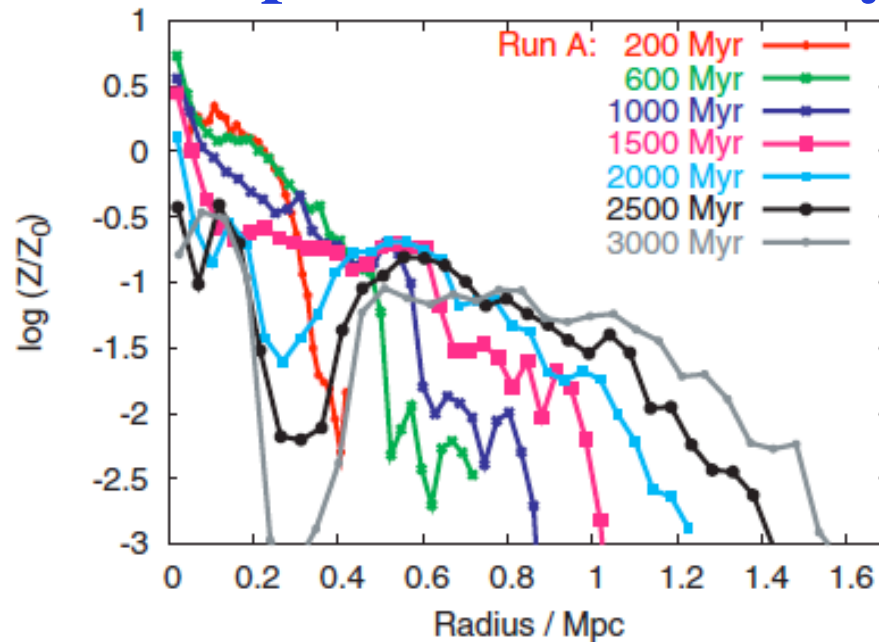
星形成を抑制

- suppress cooling flows in clusters
- suppress overproduction of high-L galaxies
- explains cosmic downsizing

physics of feedback:
jet?
wind?

metal dispersal in clusters by radio galaxies

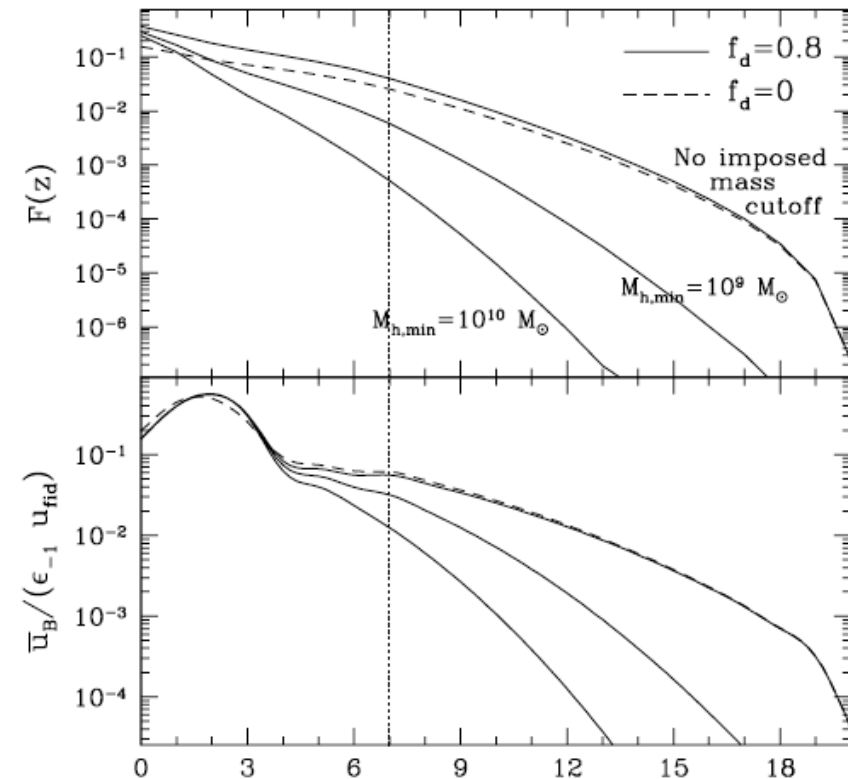
Why?



Heath+ 07

magnetization of intergalactic/intracluster gas

Furlanetto & Loeb 01



銀河中心ブラックホールの系内での影響は？

3. Galactic black hole jets

-> 上田さんの講演

What? relativistic $\Gamma_{\text{jet}} > \sim 2-10$?

How? issues similar to AGNs

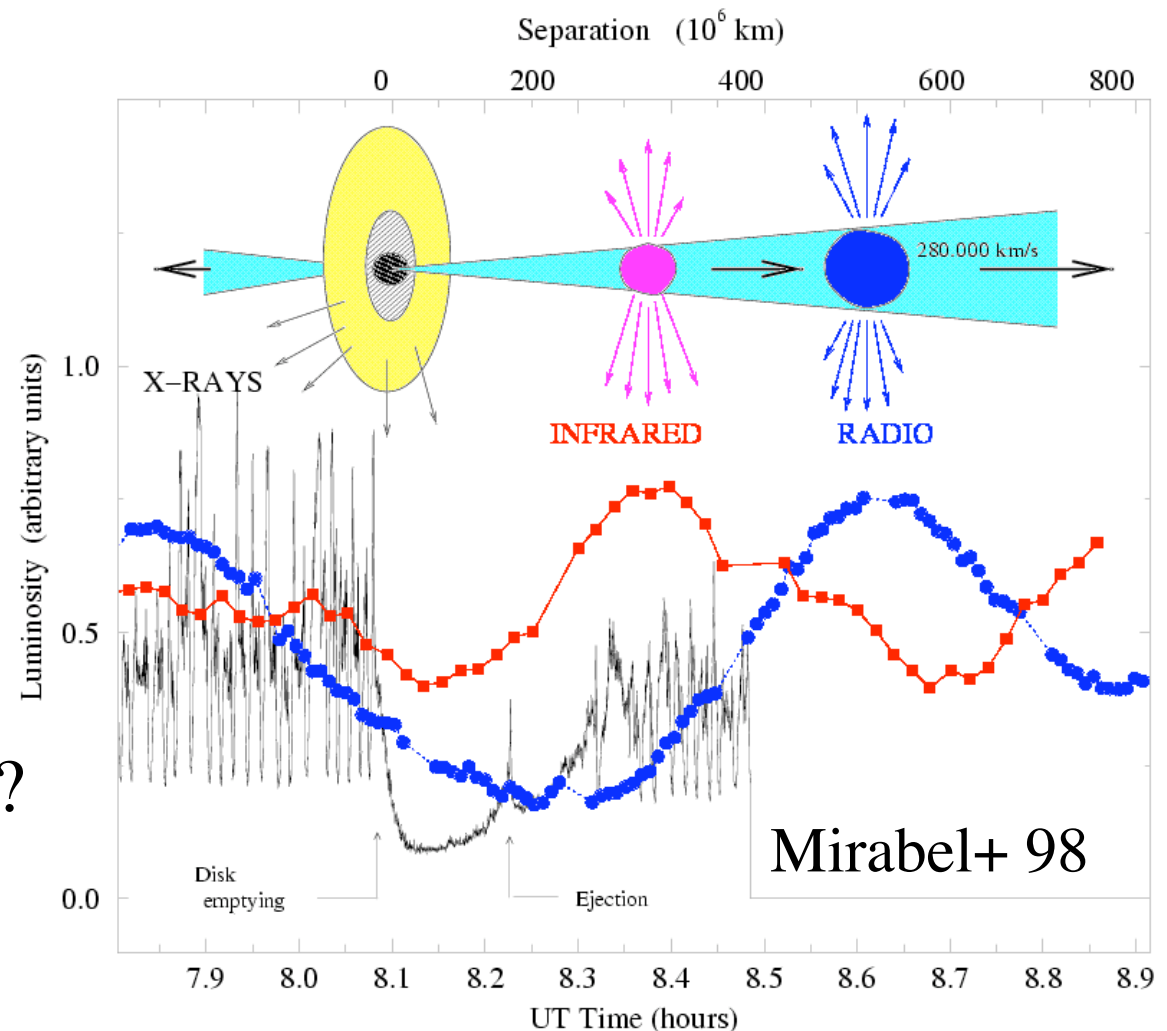
When/Where?

disk-jet connection

low hard state?

persistent (HMXB)?

<-> transient (LMXB)?

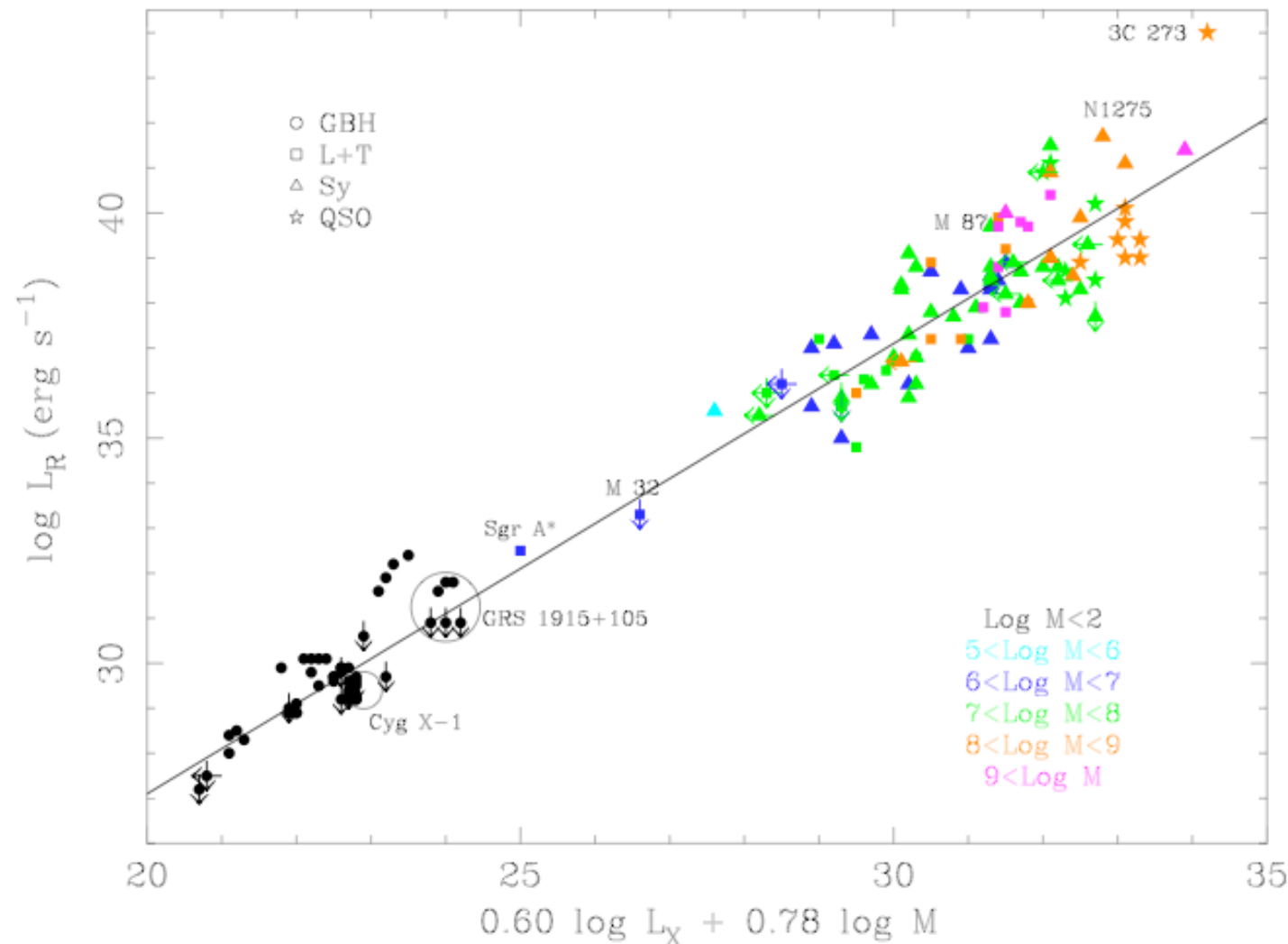


Galactic BHs - AGNs

fundamental plane?

Merloni+ 03

Falcke+ 04



$$L_{\text{radio}} \propto \dot{m}^{1.4}$$

$$L_X/L_{\text{Edd}} \propto (\dot{m}/\dot{m}_{\text{Edd}})^2 \quad \text{RIAF}$$

$$\rightarrow L_{\text{radio}} \propto L_X^{0.7} M^{0.7}$$

Galactic BH jets Why?

energetics $L_{\text{XB}} \sim 10^{39} \text{ erg/s}$
(fund. plane + X binary LF)

Heinz & Grimm 05
Fender +05

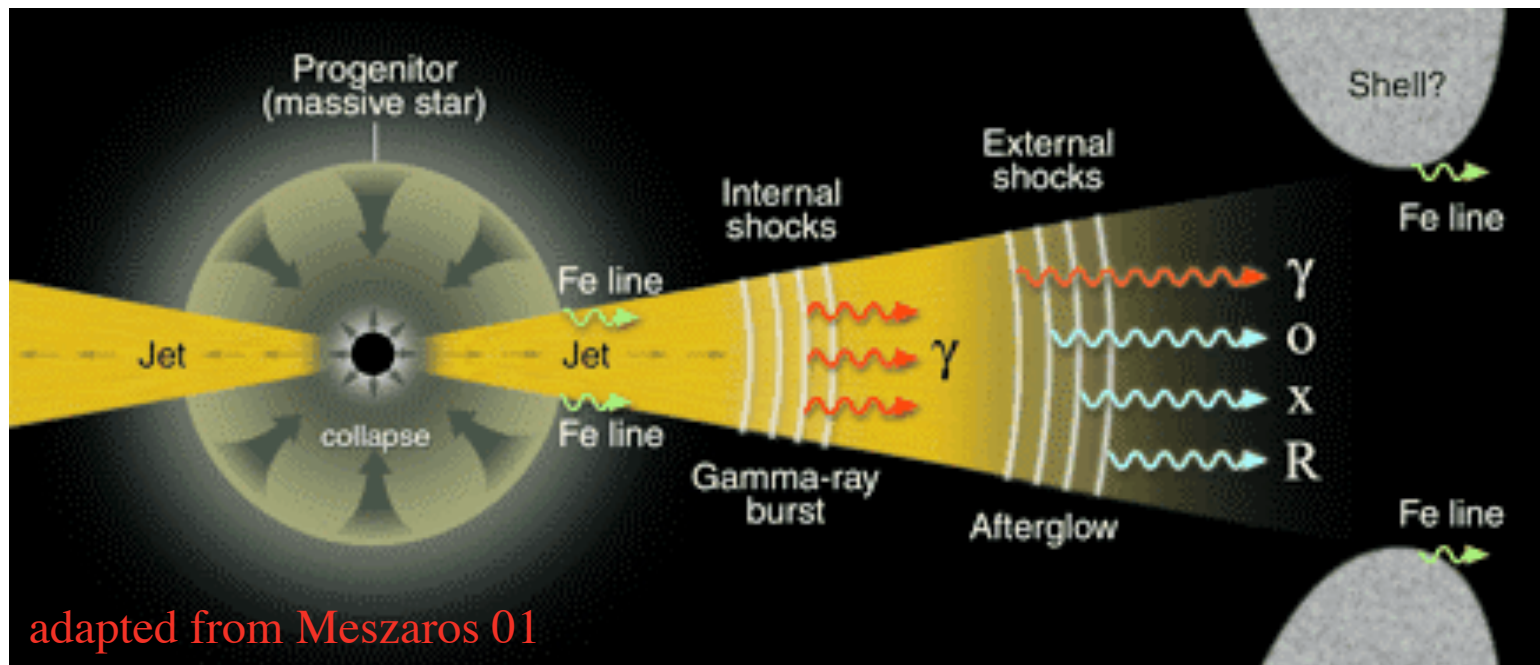
$$\leftrightarrow L_{\text{SN}} \sim E_{\text{SN}} R_{\text{SN}} \sim 3 \times 10^{41} \text{ erg/s}$$

- Galactic cosmic rays (positrons)? Heinz & Sunyaev 02
- ISM magnetization? Heinz+ 08

案外何かに効いてるかも？

4. GRB jets

-> 山崎さんの講演



What? ultrarelativistic $\Gamma_{\text{jet}} > 100$
extremely powerful $L_{\text{jet}} \gg L_{\text{edd}} (\tau \gg 1)$
likely collimated $f_{\text{jet}} \sim 0.001 - 0.01?$

How? long GRBs: collapsar -> BH?
short GRBs: NS-NS merger -> BH?
issues similar to AGNs?

GRB jets

When/Where?

GRB rate/SN rate $\sim 10^{-5}$ - 10^{-3} ? core angular momentum?

Why?

$L_{\text{GRB}}/L_{\text{SN}} \sim 10^{-3}$ - 10^{-2} ?

- UHECRs?

- ???

宇宙で最も謎のジェット...

GRBs, who ordered that?

まとめ **cosmic jets: What? How? When/Where? Why?**

YSOs 役割も含め最もよくわかっている
ほぼ解決に近い！

AGNs 物理はまだまだ未解明
が役割の認識は増えつつある

Galactic BHs 物理はAGN同様
何かの役割も果たしてるかも？

GRBs 物理も役割もようわからん

ジェットの物理機構を追求するだけでなく
宇宙における役割を理解することも解明につながるかも