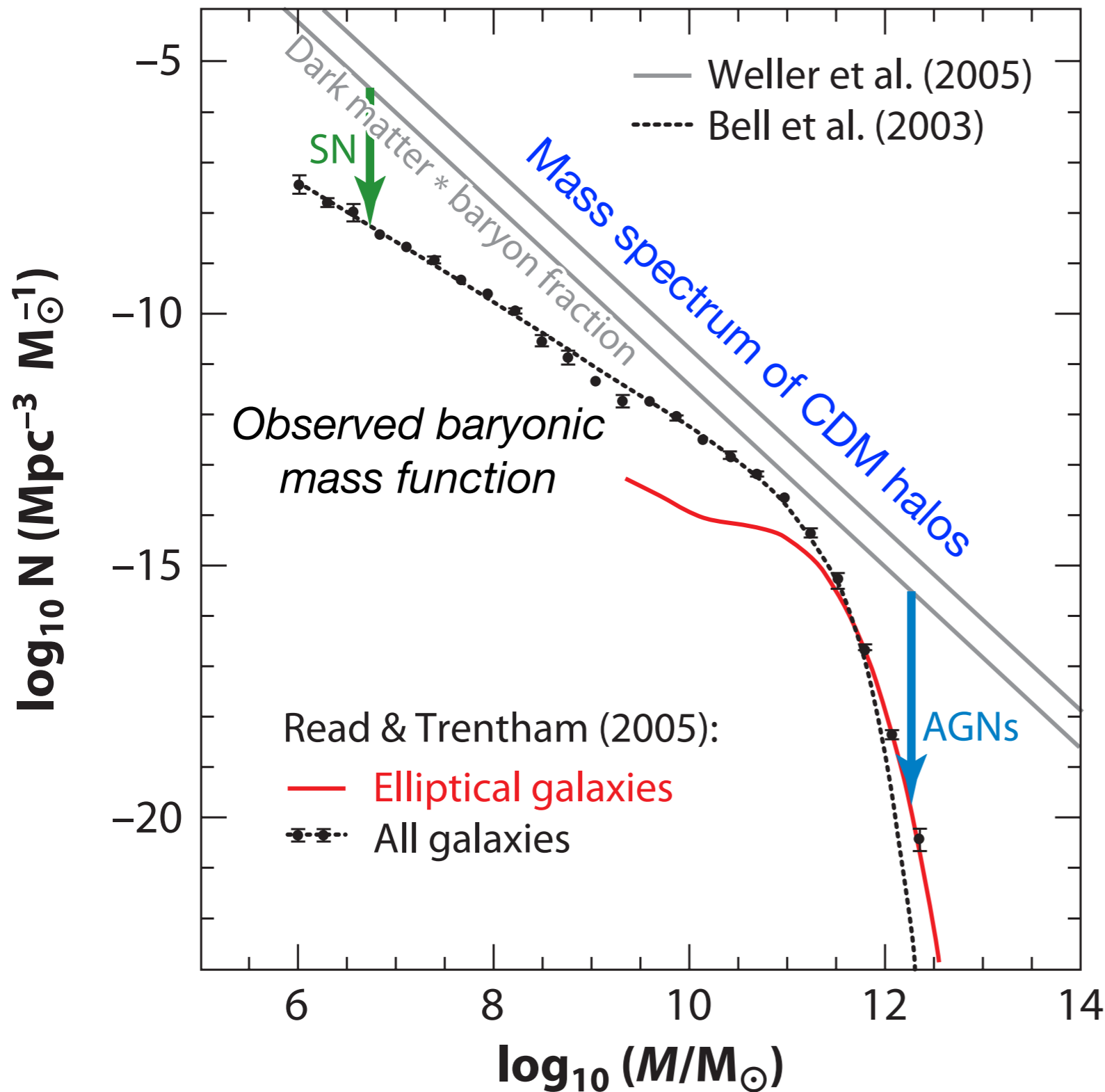


Cosmic Shadow 2018  
2018年11月24-25日@石垣島

**近傍AGN吸収線系における  
ミリ波サブミリ波観測**

**泉拓磨/Takuma Izumi  
(NAOJ Fellow)**

Kormendy & Ho 2013, ARAA, 51, 511



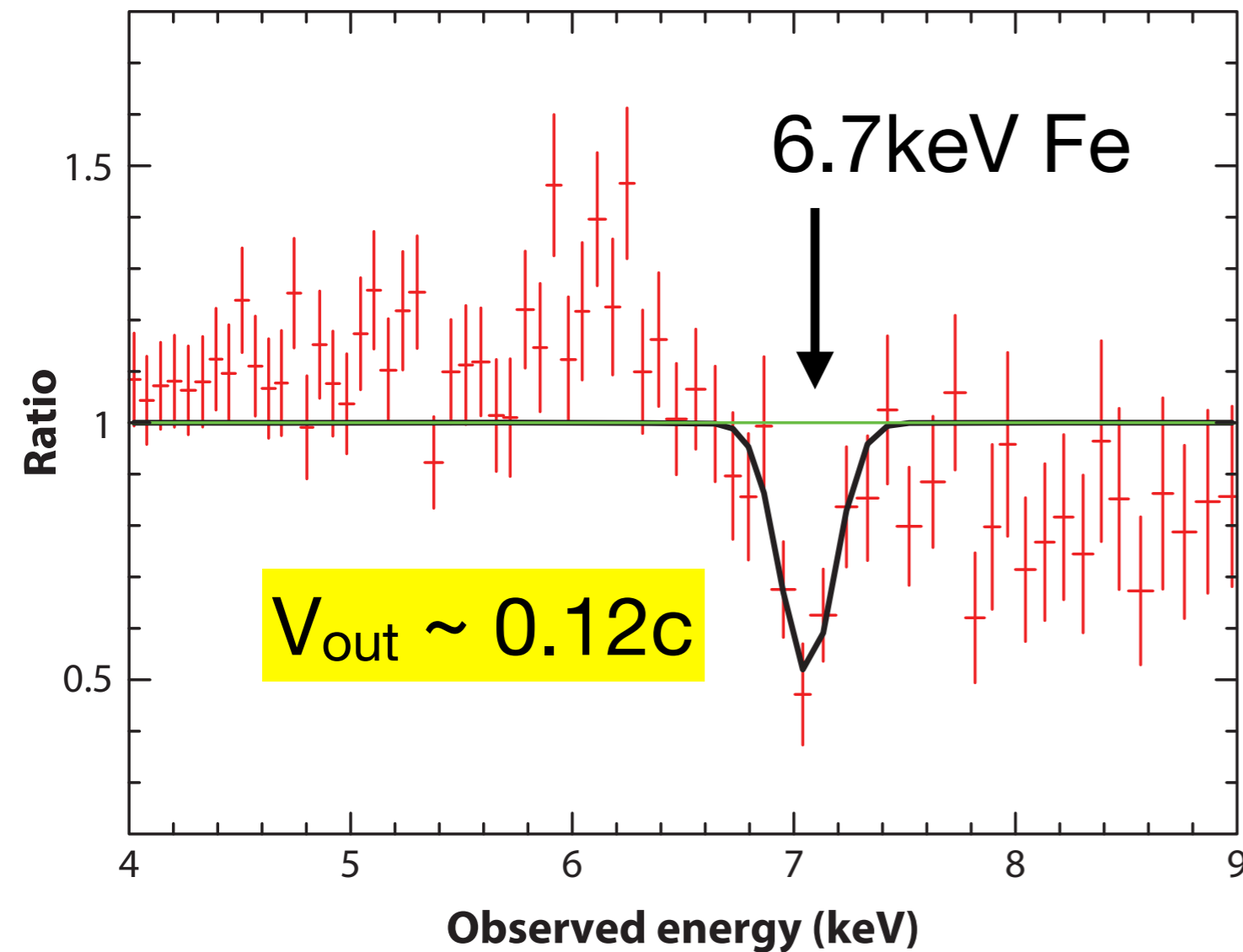
## Star formation regulator

- SN feedback  
→ low-mass
- AGN feedback  
→ high-mass

→ to match the mass function of galaxies with the observed one

→ to reproduce the  $M$ -sigma

King & Pounds 2015, ARA&A, 53, 115

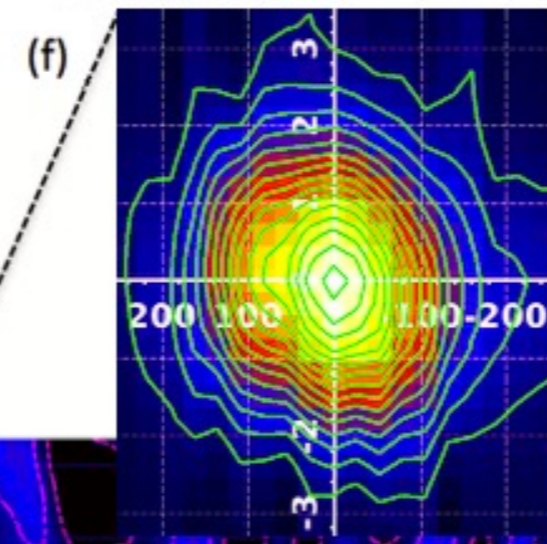
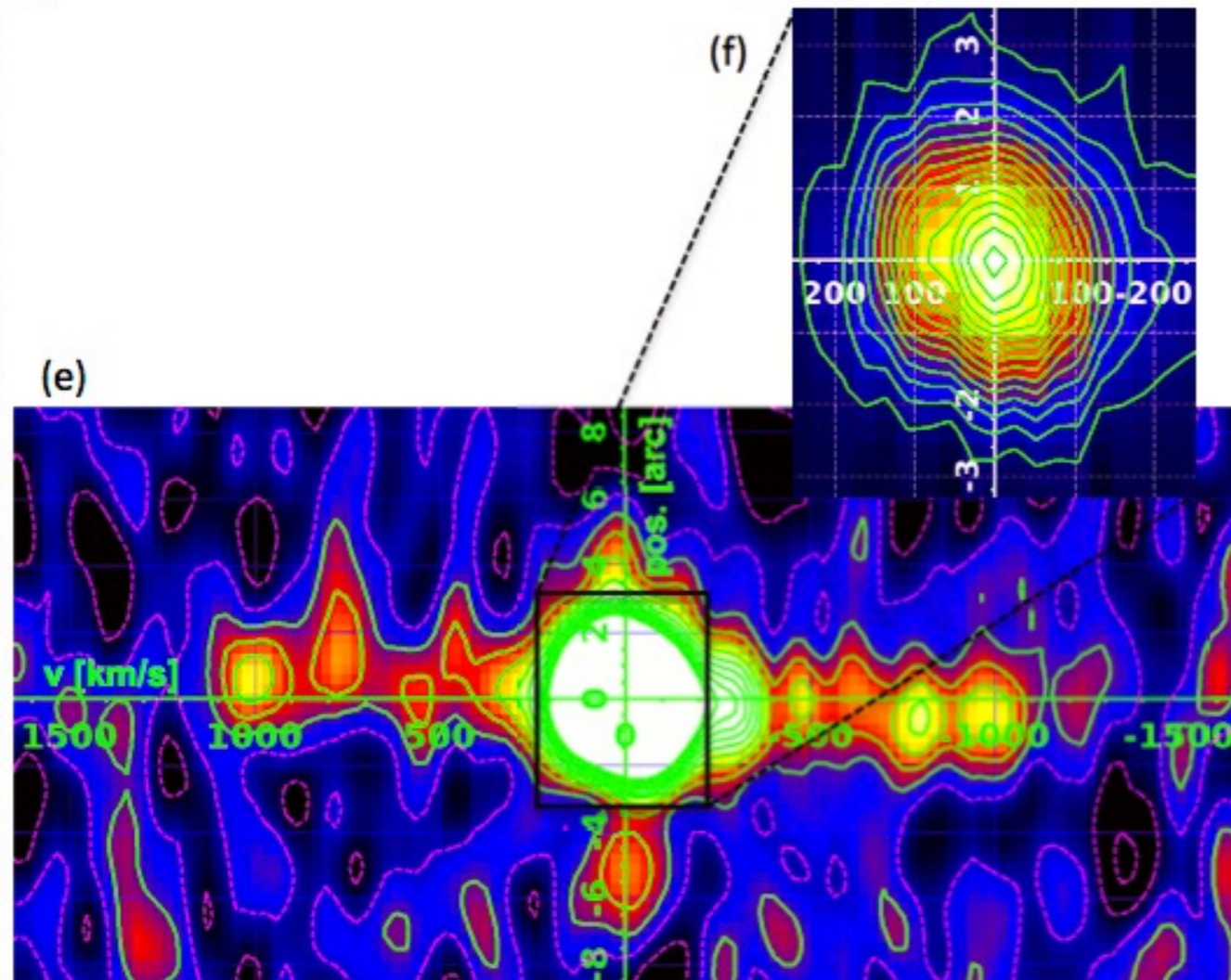
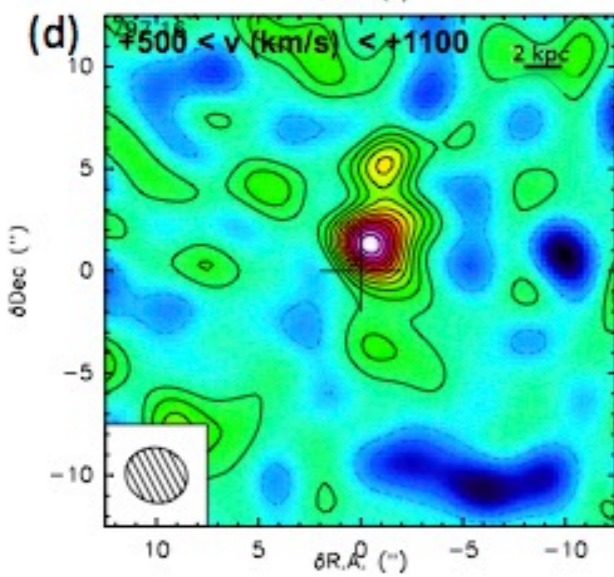
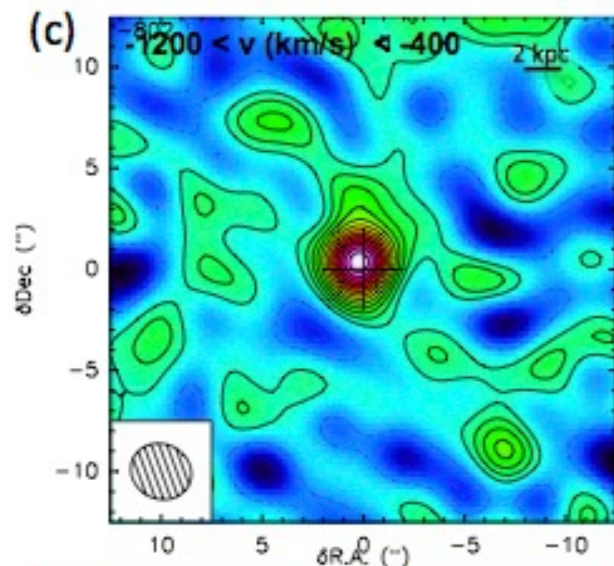
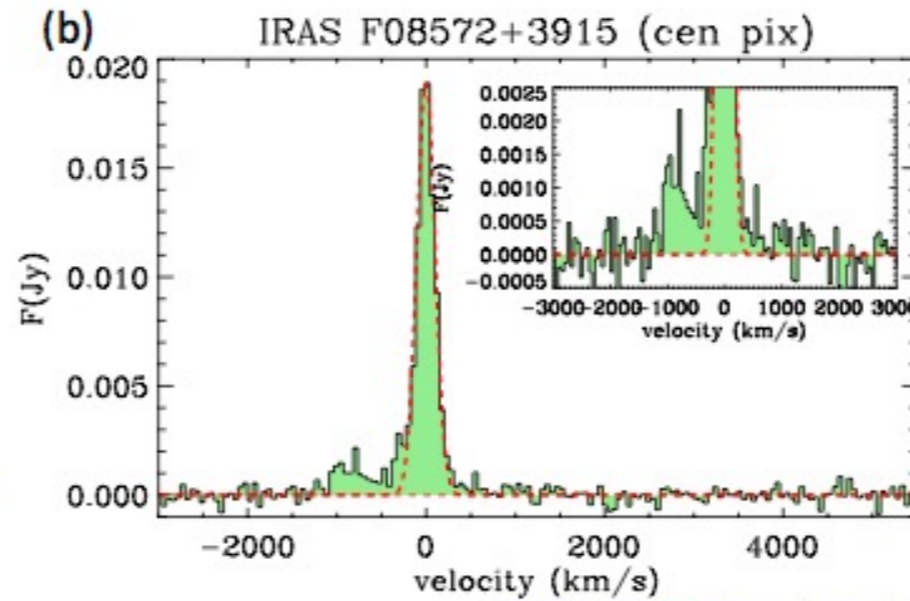
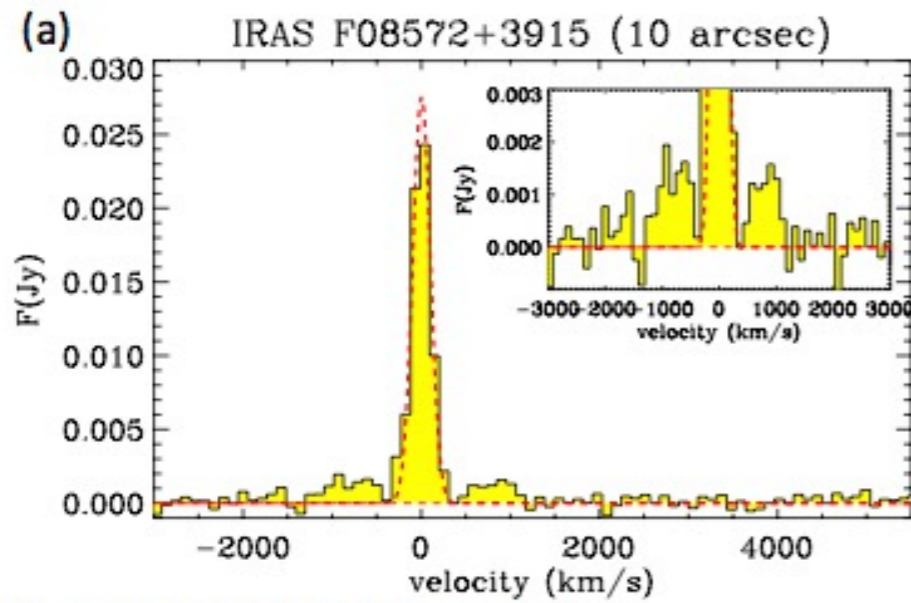


## Ultra Fast Outflow (UFO)

- Very fast:  $\sim 0.1-0.3c$
- Highly ionized
- Wide solid angle:  $\Omega/4\pi \sim 0.4$  (Gofford+15)
- $\log (N_{\text{H}}/\text{cm}^2) > 20-21$



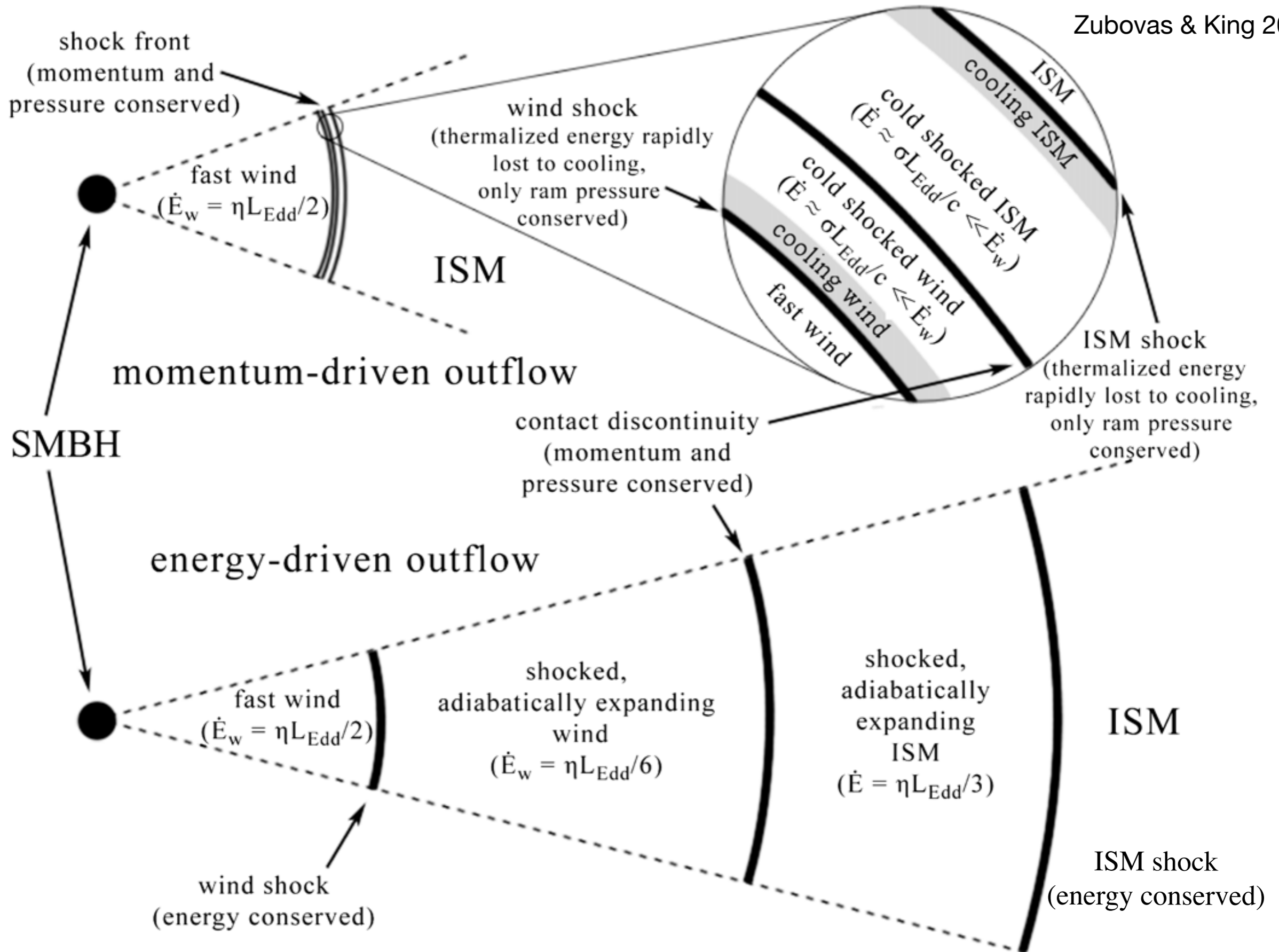
# AGN wind@host galaxy-scale



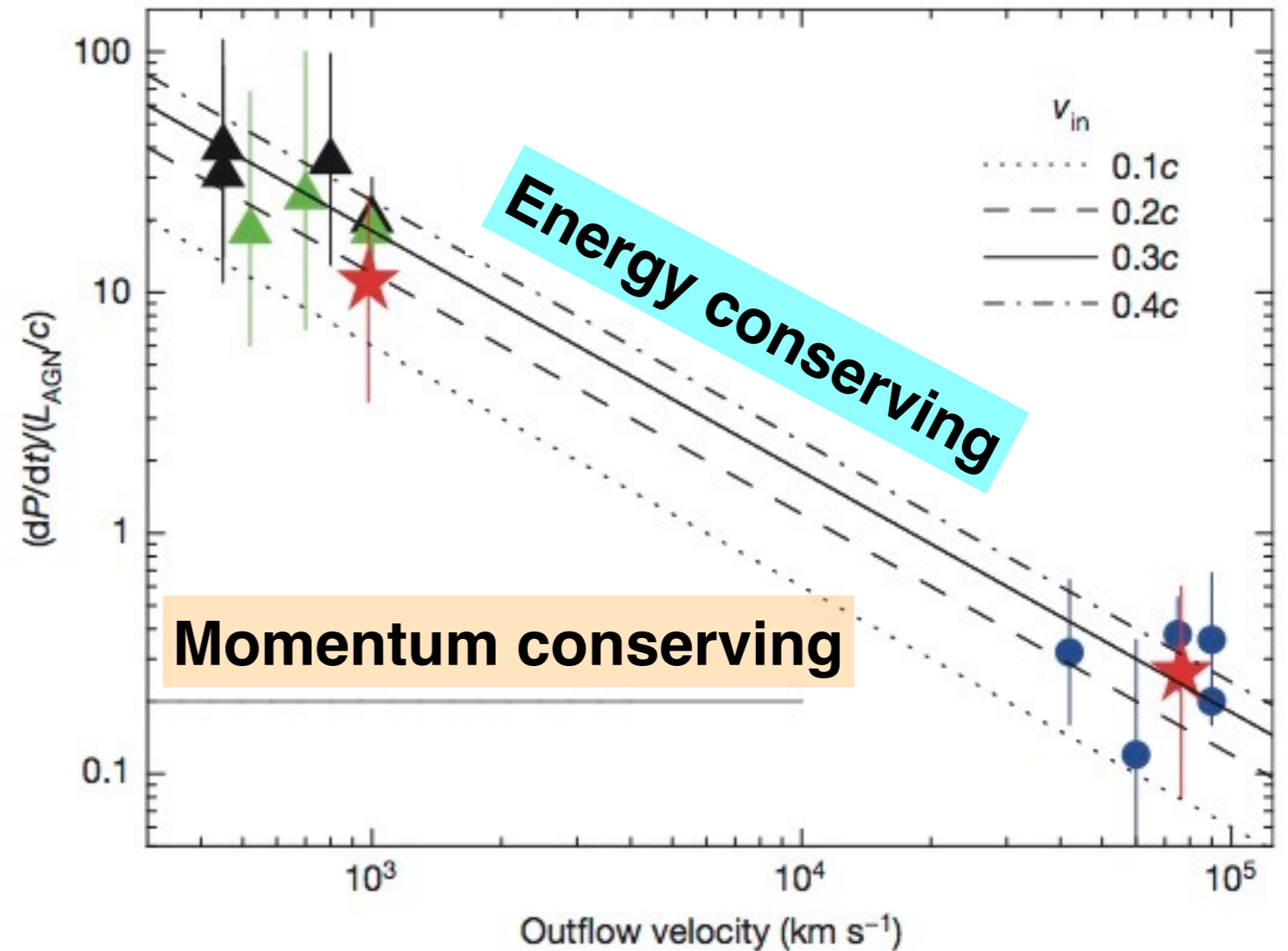
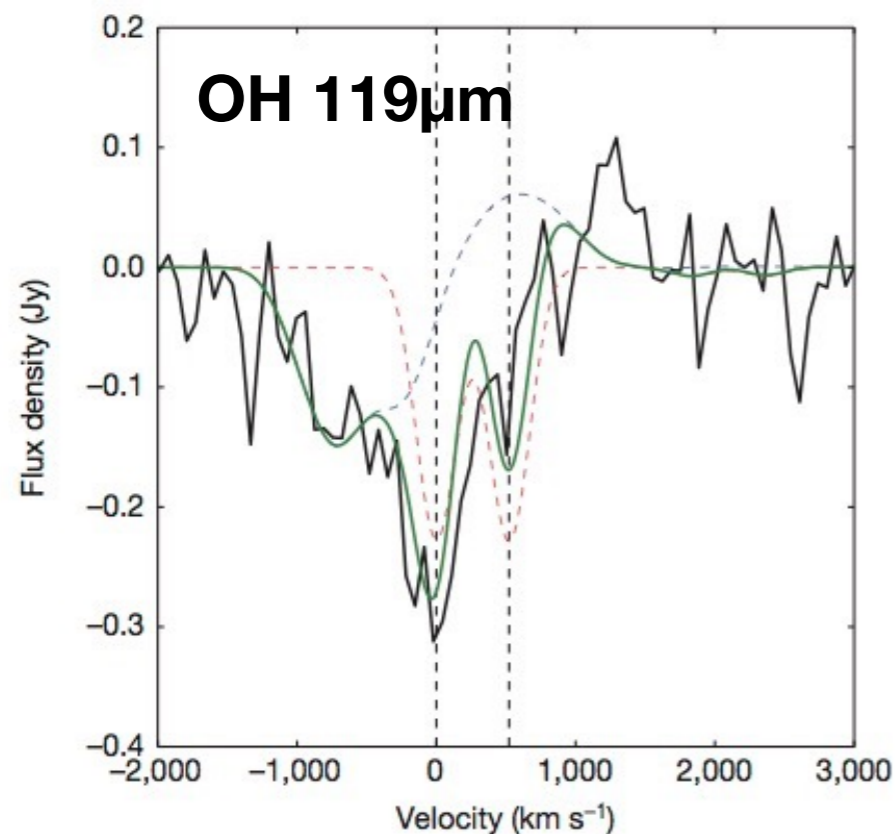
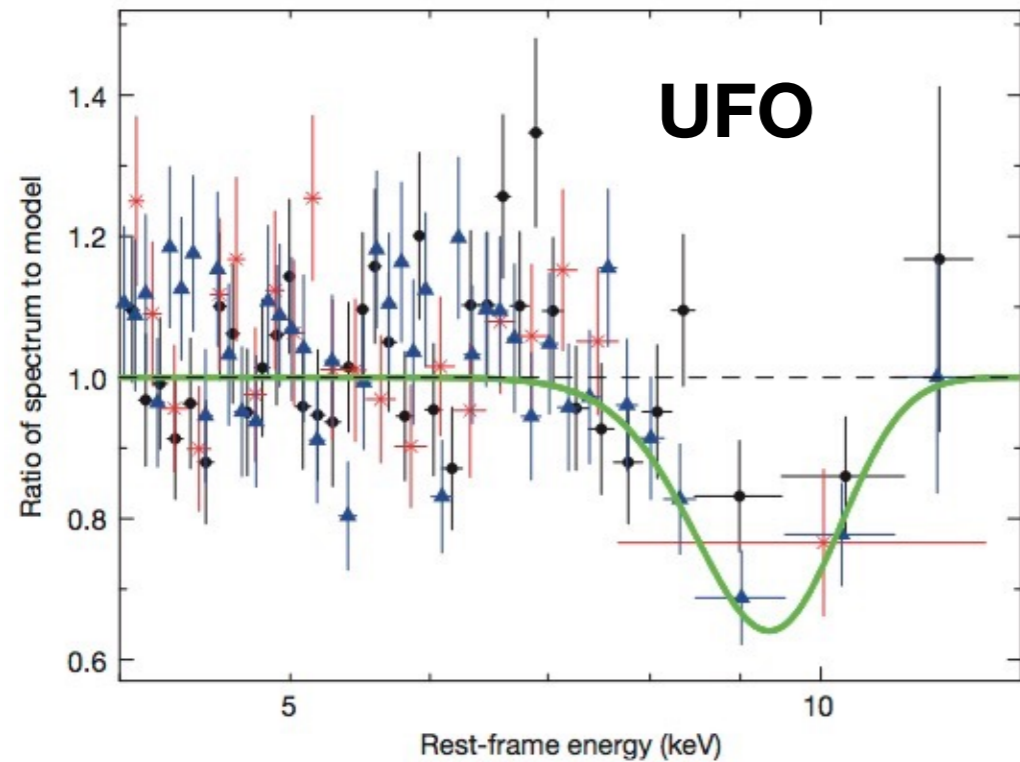
- $V_{out}$ : up to  $\sim 1000$  km/s
- $R_{out}$ : up to  $\sim 1$  kpc
- Mass outflow rate is well correlated with the AGN power

# Types of conservation (energy vs momentum)

Zubovas & King 2012



Tombesi et al. 2015, Nature, 519, 436



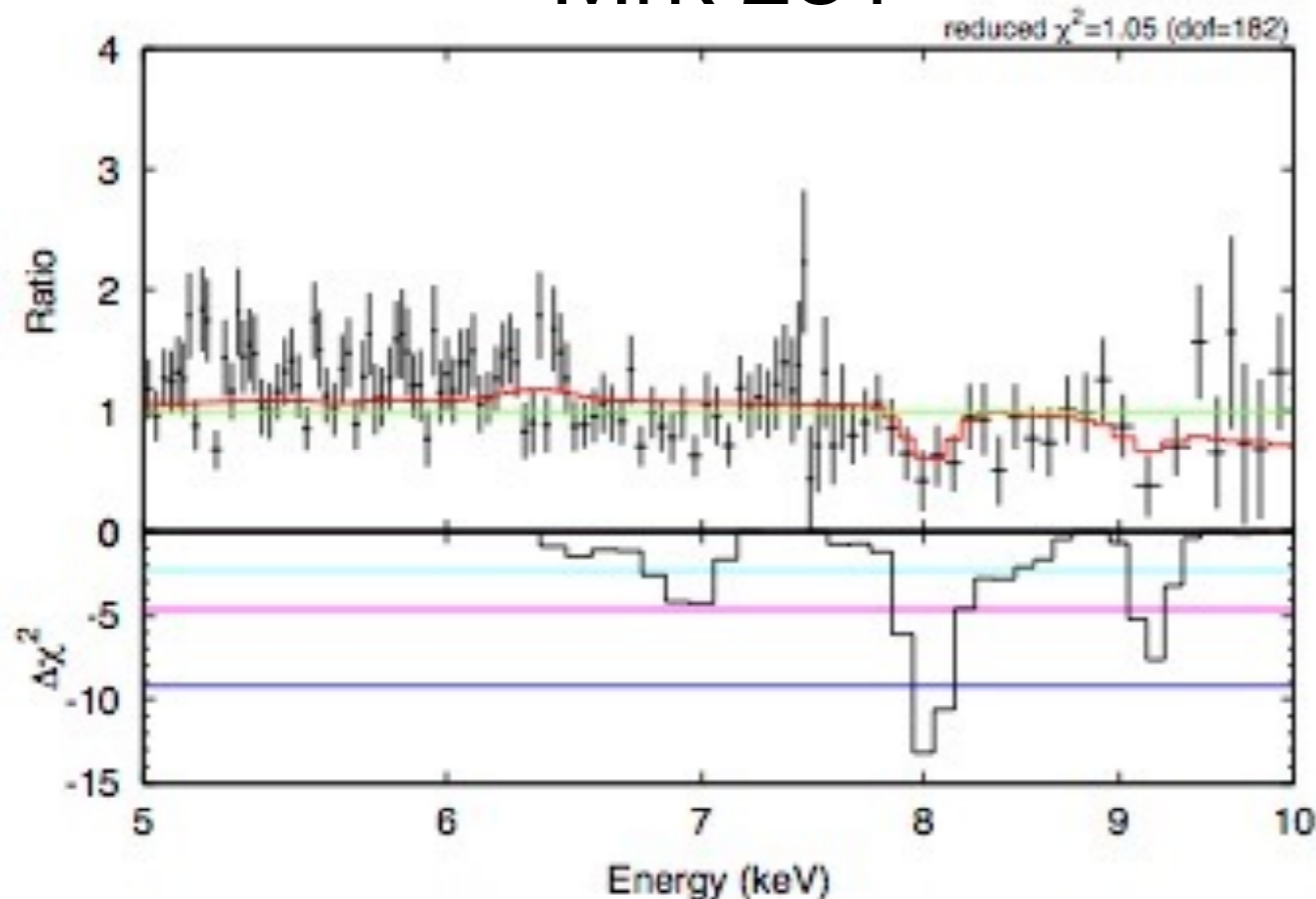
- Luminous AGN/ULIRG: QSO-mode
- Clearly, “**energy-conserving**”

## KINETIC ENERGY TRANSFER FROM X-RAY ULTRAFAST OUTFLOWS TO MM/SUB-MM COLD MOLECULAR OUTFLOWS IN SEYFERT GALAXIES



MISAKI MIZUMOTO,<sup>1</sup> TAKUMA IZUMI,<sup>2,3</sup> AND KOTARO KOHNO<sup>4</sup>

Mrk 231

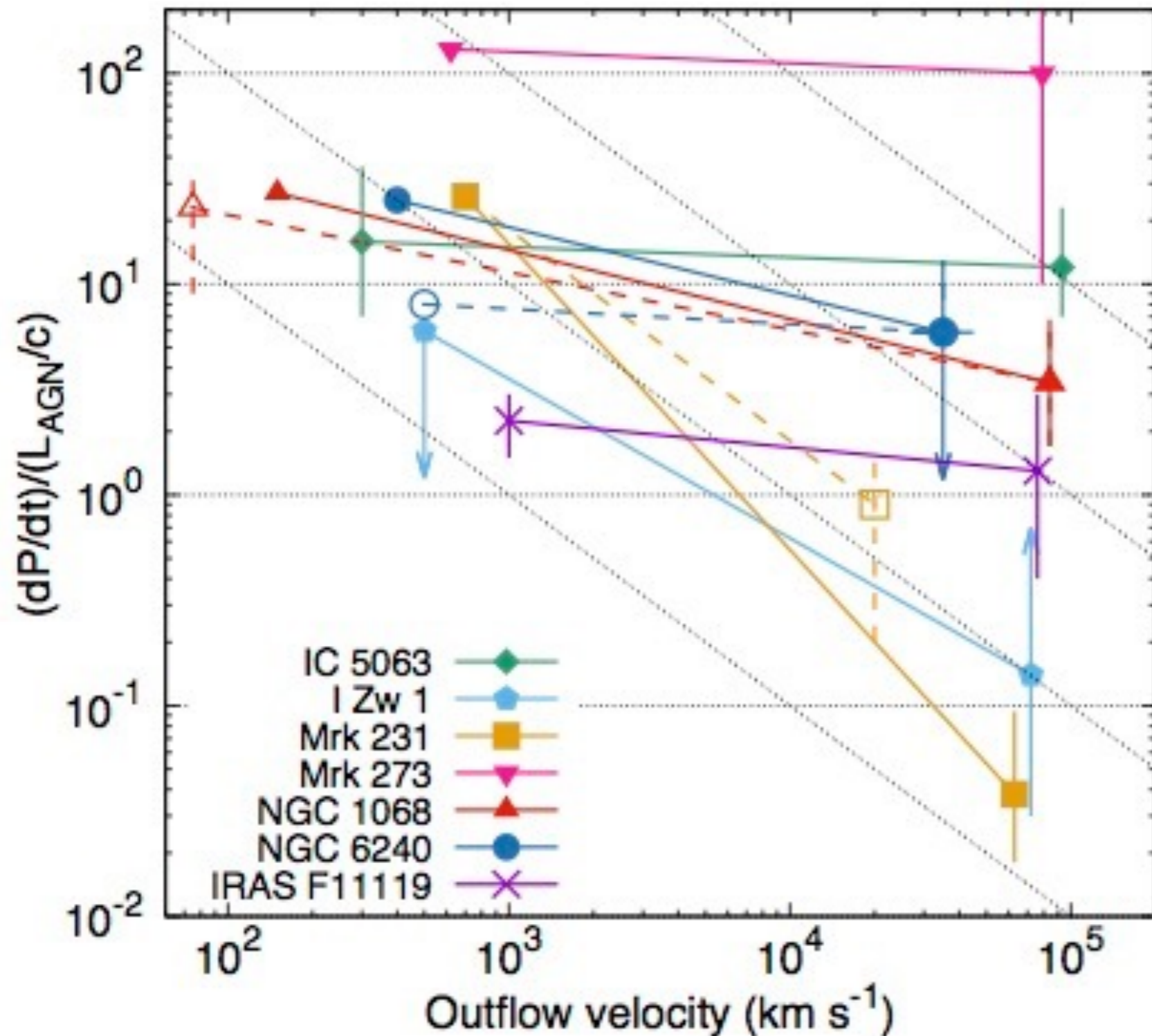


- UFO search in galaxies hosting mol. outflows (Cicone et al. 2014)
- Six AGNs are found to host UFOs (XMM, Suzaku)
- Measure “energy transfer rate” from UFOs to mol. outflows.

$$C = \dot{K}_{\text{mol}} / \dot{K}_{\text{UFO}}$$

# Wide variety in the energy transfer rate

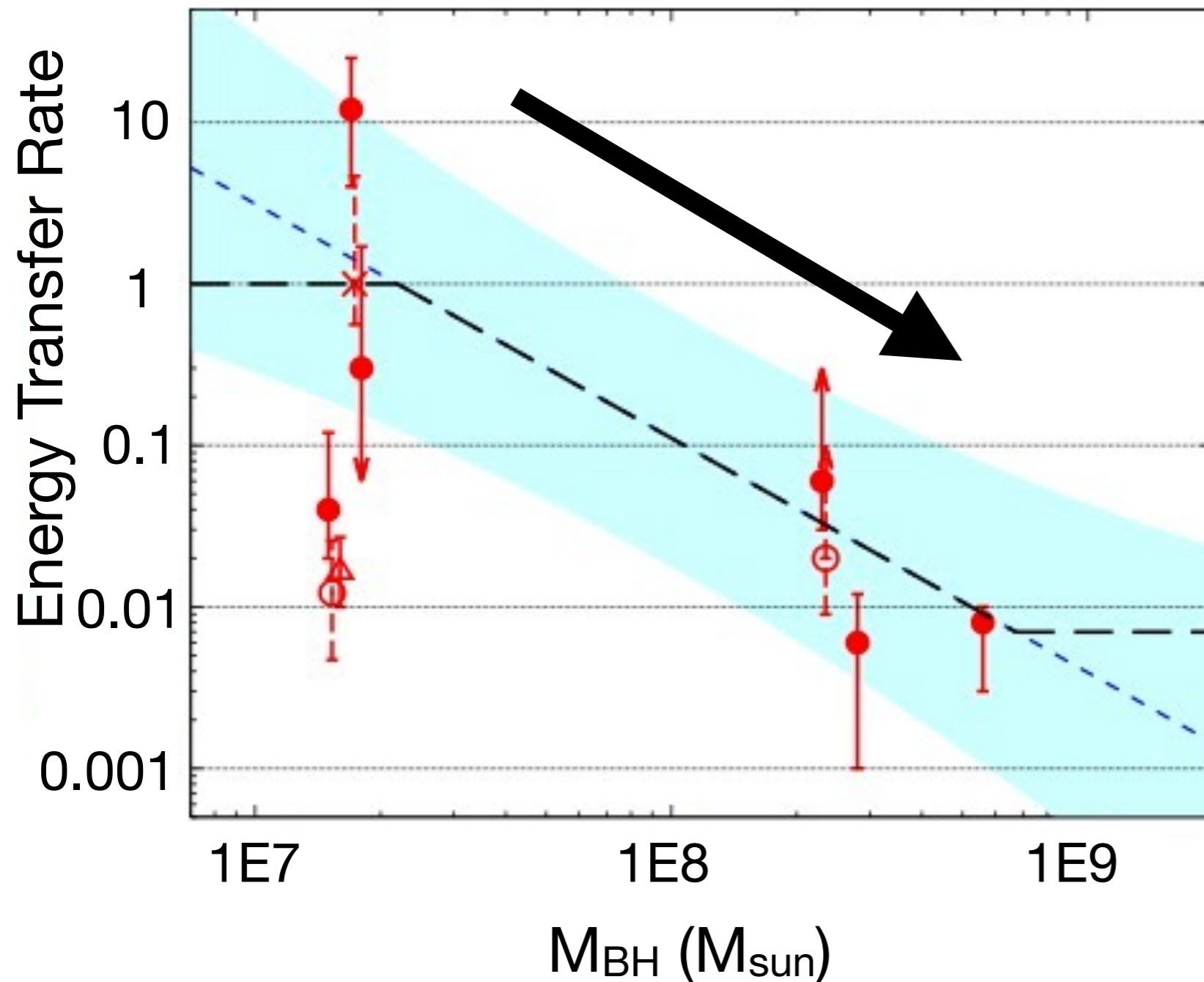
8



- Some favour energy conserving, some do momentum conserving, the others in between...
- **$C \sim 0.7\% - 100\%$**
- Can we explain this messy trend by a physical model??



# Dependence on $M_{\text{BH}}$ may be the key?



- Both “energy-” and “momentum-” conserving modes exist.
- Roughly a negative trend with  $M_{\text{BH}}$
- Radiative cooling is more efficient for higher  $M_{\text{BH}}$  objects

# Dependence on $M_{\text{BH}}$ may be the key?

$$t_{\text{cool}} = \frac{2cR^2}{3\pi GM_{\text{BH}}} \left(\frac{m_e}{m_p}\right)^2 \left(\frac{v}{c}\right)^{-2} b, \quad \textit{(Compton cooling)}$$

$$t_{\text{flow}} = R \left(\frac{2\pi G^2 M_{\text{BH}}}{f_g \sigma^2 \kappa}\right)^{-1/2}, \quad \textit{(Flow time-scale)}$$

$$\frac{t_c}{t_f} = \frac{2}{3\pi} cR \left(\frac{m_e}{m_p}\right)^2 \left(\frac{v}{c}\right)^{-2} b \left(\frac{2\pi}{M_{\text{BH}} f_{\text{gas}} \sigma^2 \kappa}\right)^{1/2}$$

$$\simeq 1.8 \left(\frac{M_{\text{BH}}}{10^8 M_{\odot}}\right)^{-1/2} \left(\frac{R}{1 \text{ kpc}}\right) \left(\frac{v}{0.1c}\right)^{-2}.$$

- Powerful AGN-driven winds are one of the key components to regulate galaxy-evolution.
- Both accretion disk-scale winds (UFOs) and galaxy-scale winds (molecular outflows = MOs) have been extensively studied.
- We examined physical connection (energy transfer rate) between UFOs and MOs, and found a wide variety from 0.7% to 100%.
- The energy transfer rate seems to correlate with  $M_{\text{BH}}$   
→ balance of cooling and flow time scales may explain.

- **Geometry of UFOs?? Radius, Covering factor...**
- **Statistical sample of MOs → ALMA!**