AO-Assisted Optical IFU Study on Fast Outflow from Active Galactic Nuclei with High Gas Accretion Rates

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< Key questions >

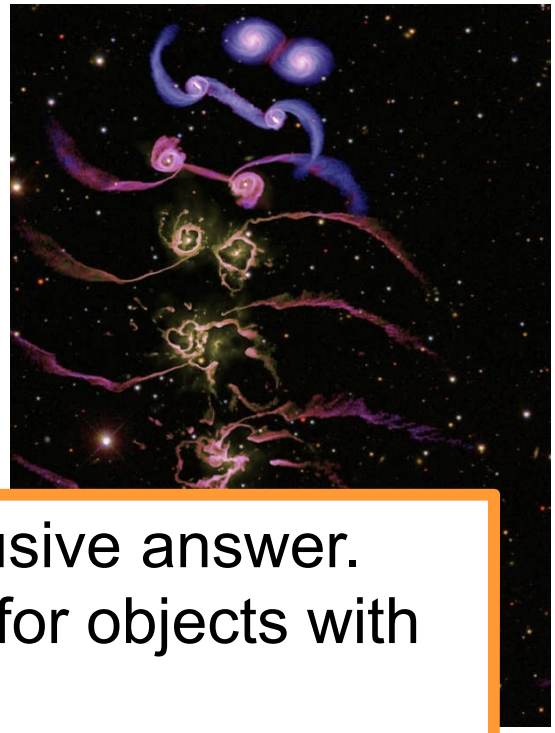
* Is there really quasar-mode feedback?
* Is it powerful enough to quench star formation?

Velocity Field around Black Hole

(Kawaguchi + in prep.)

AGN outflows regulate black hole and galaxy evolution?

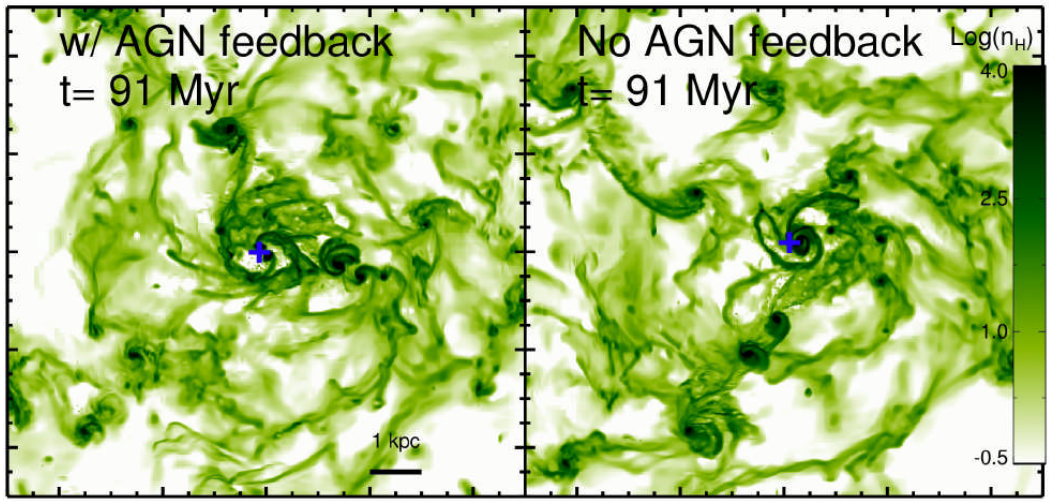
Yes: Silk & Rees 98; Fabian 99; King 03;
Schawinski +07; Wylezalek +16, ...



Di Matteo +05:
Galaxies collide,
Gas inflow towards

「Is there really AGN feedback?」 No conclusive answer.
→ Observations with high-spatial resolution for objects with galactic-scale outflow

No: Balmaverde +16; Kakkad +16;
Carniani +16;
Villar-Martin +16;
Mahoro +17 ...

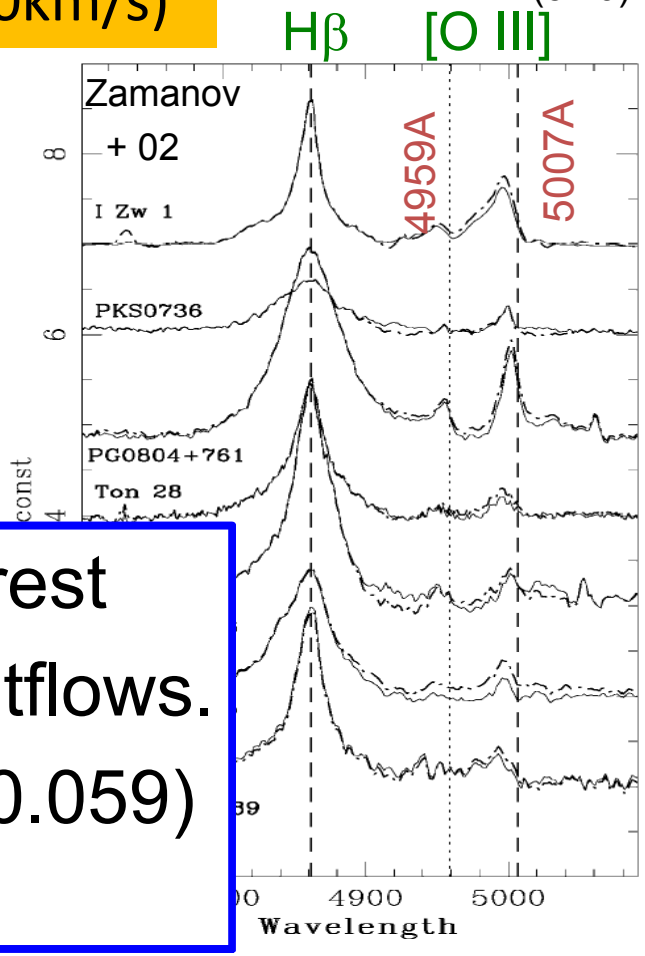


Gabor +14

Our targets: AGNs with [O III] blueshifts (>= 300km/s)

* Outflow in narrow line region
  (Radio-quiet = not jet-driven)

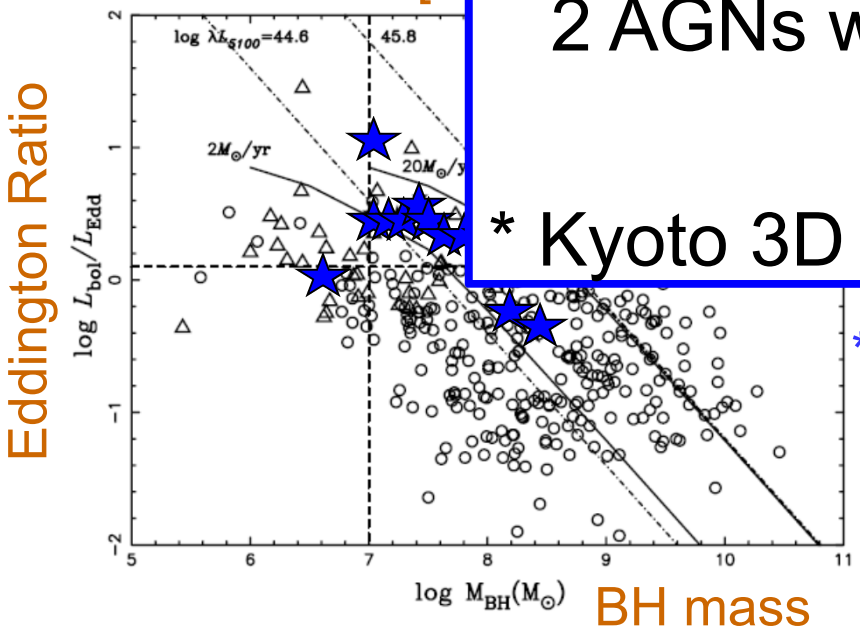
* Outflows occur when accretion rates onto central BHs are large (super-Eddingoton), e.g., Narrow-line Seyfert 1 galaxies.



* We observed the nearest 2 AGNs with [O III] outflows. (z=0.036, 0.059)

* Kyoto 3D II + AO188

AGNs with [O



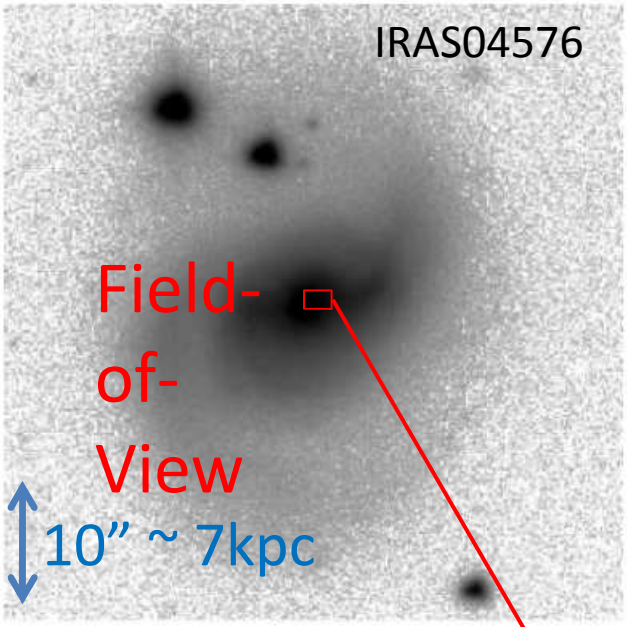
Aoki, Kawaguchi, Ohta 05

* Galactic-scale fast outflow (AGN feedback site?) associated with rapid BH growth (Kawaguchi 03; +04)

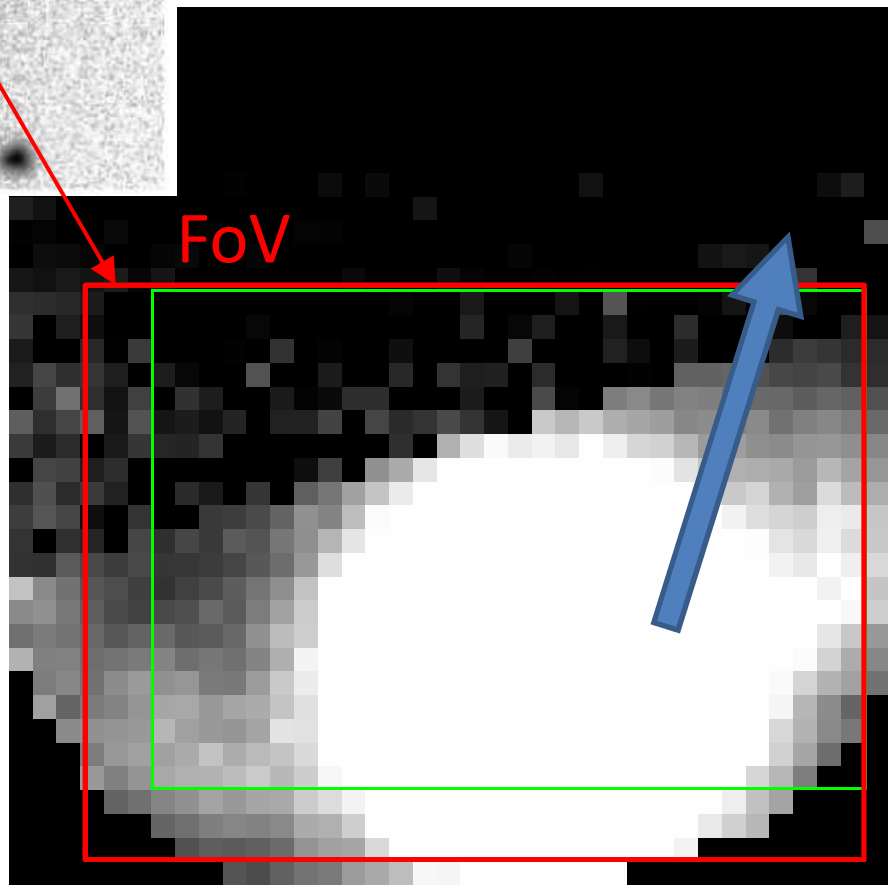
→ Laboratory for BH-galaxy coevolution

Data analysis for IRAS 04576

Example of Spectrum (4/10)



Ohta, Aoki,
Kawaguchi, Kiuchi
2007



Hα: narrow & broad

[N II] [N II] [S II] doublet

Density-sensitive [S II] emission lines (6716, 6731 Å)

Flux Map of Hα Broad Emission Line: PSF

(Actual size of Broad-line-region ~ 0.01pc << 1pixel)

3.1” ~ 2.2kpc

Black Hole

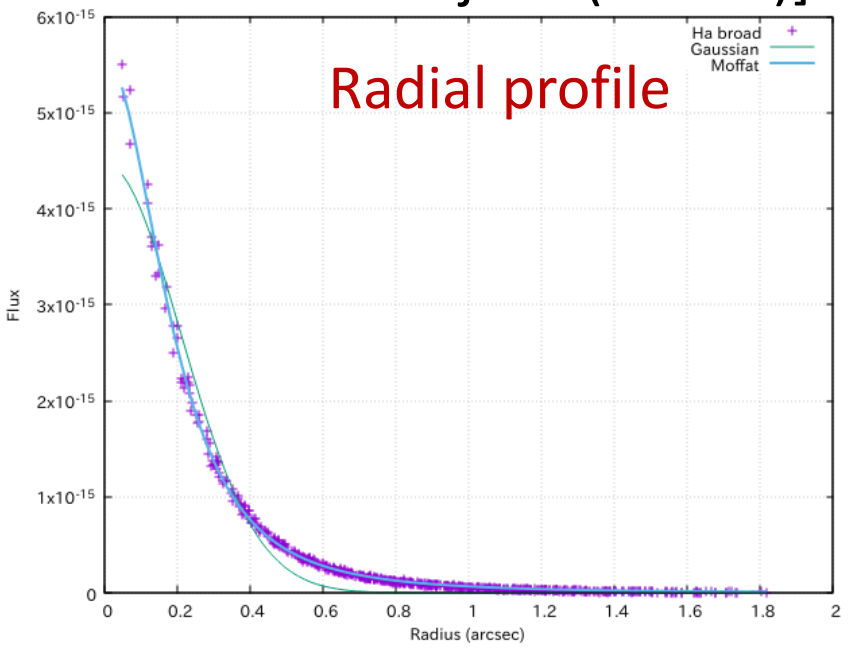
FWHM

1 lenslet (0.084”) = 60pc

Spectral fit for 615 lenslets

* Round shape of PSF

* FWHM ~ 0.37”
[Better FWHM for another object (~0.2”?)]



Blue tails of [S II] lines in many lenselets

Whole λ-range

1-component Fit

Close-up View around [S II] :

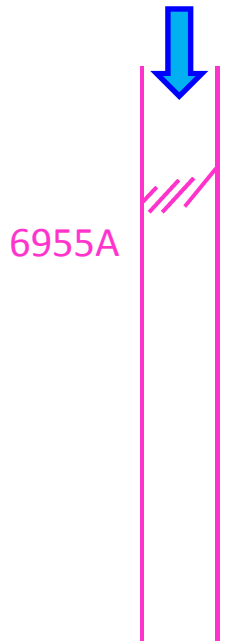
→ Clear blue tail

[S II] ratio (6716/6731)

= 1.7

= not allowed

(= bad fit)



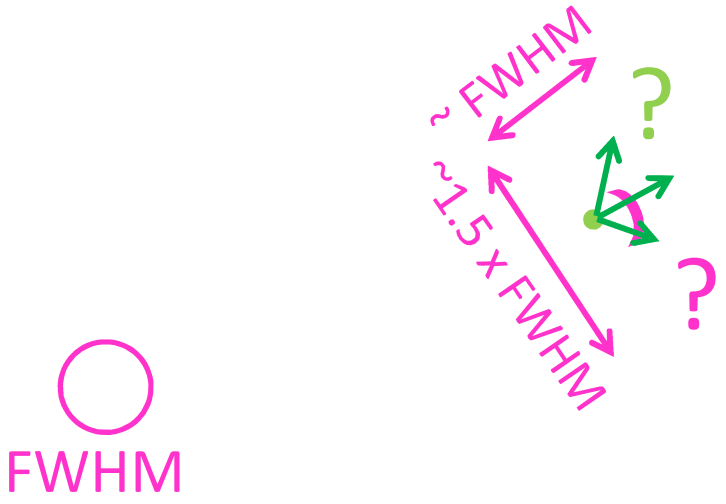
Identifying the outflowing region

→ Excess flux (data - model)

in 6955-6970 Å map

Excess Flux Map at 6955-6970 Å

(● = excess flux >= 3 x 10^-17 [erg/s/cm^2] = peak / 2)



* Outflow Region = Located mainly at upper-left (North-West)
* 100s pc -scale outflow
* Offset from BH; disfavors pole-on view of outflow ?
* Half opening angle of outflow ~ 50 deg ? (not jet like)

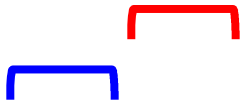
Velocity and density of the outflowing gas

Whole λ-range

2-component Fit

* 780km/s blueshift
* FWHM = 1070km/s

Close-up View around [S II]



--- [S II] 6716/6731 ratio ---

Stronger component:

1.16 → n ~ 300/cc

Outflowing component:

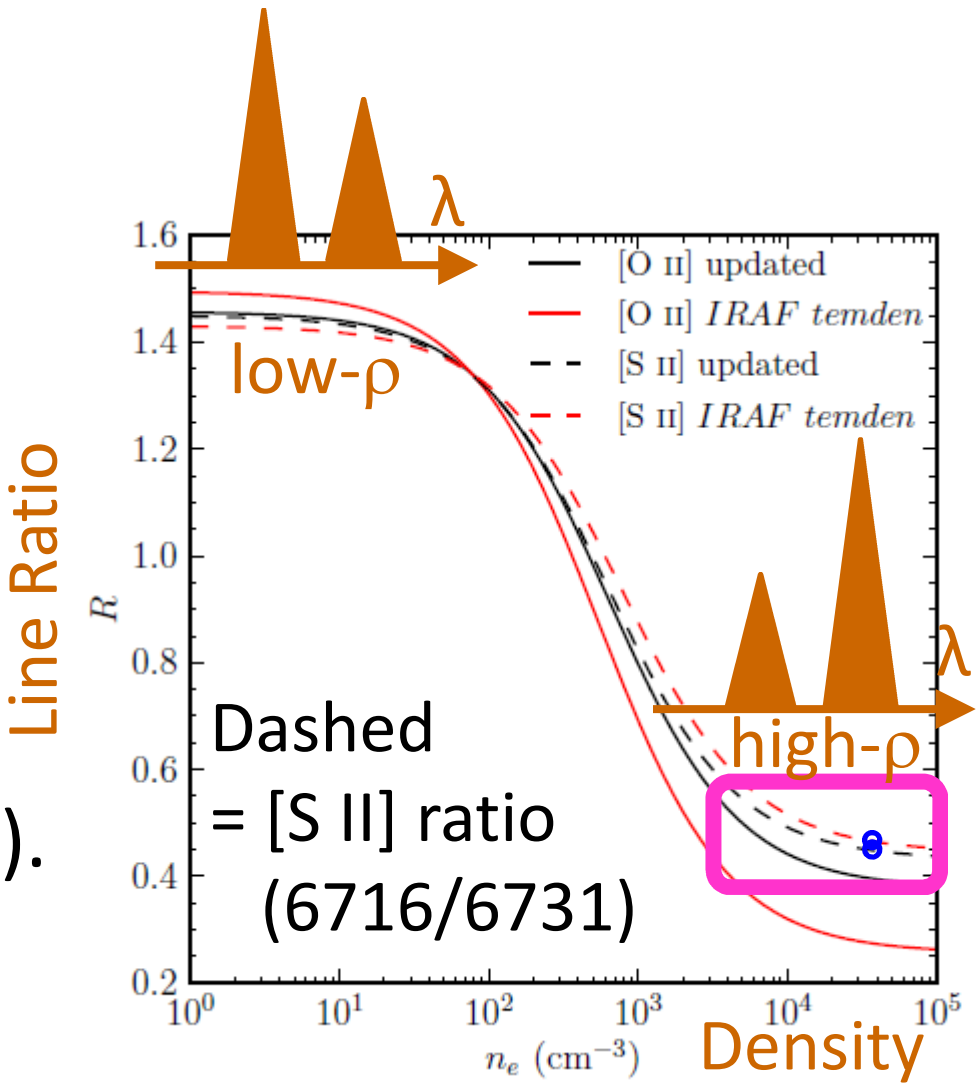
0.452 → n >~ 5 10^4 /cc

Outflowing Gas = Dense

Taking into account the large uncertainty, n >~ 3000/cc.

So far, typical density of Narrow-line-region (100/cc) has been assumed (e.g., Storchi-Bergmann group).

Density-sensitive [S II] emission lines

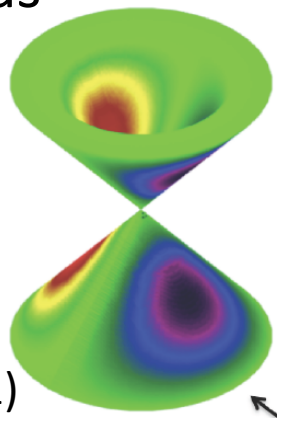


(Sanders +16)

Summary & Future Steps

* Testing "AGN feedback to host galaxy" hypothesis
* AO + Optical IFU capability of Subaru
  → Density-sensitive [S II] emission lines observable
* Data analysis in progress:
  * ~ 100s pc scale structures in
    velocity, gas density, ionization source
  * Fast, Dense, Broad-angle, Offset Outflow
    (~ 1000km/s, > 3000/cc, not jet-like)

* Next:
  * Better spatial resolution IFU at NIR; Gemini/NIFS, JWST/NIRSpec
    Now that we obtained the density of outflow gas
  * VLT/MUSE narrow-field mode (optical AO IFU);
    [O III] (= strong) observable
  * Modeling geometry & kinematics



(Muller-Sanchez+11)