Probing the Feeding and Feedback Processes in Local AGNs with Integral-Field Spectroscopy

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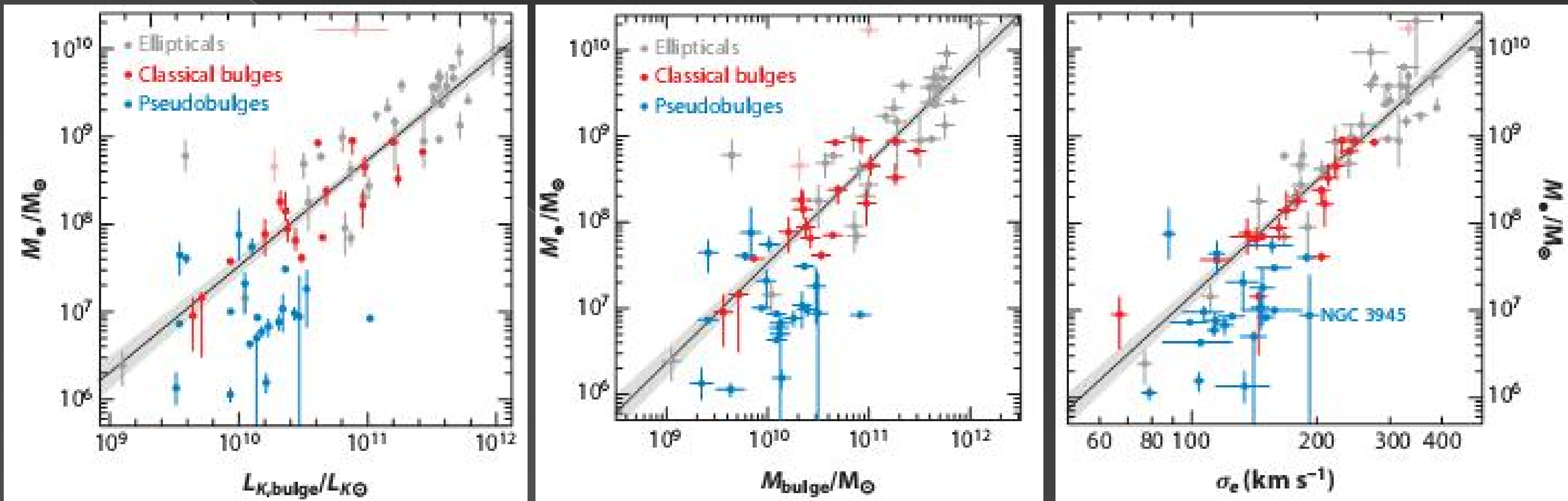
Introduction

Kormendy & Ho (2013)



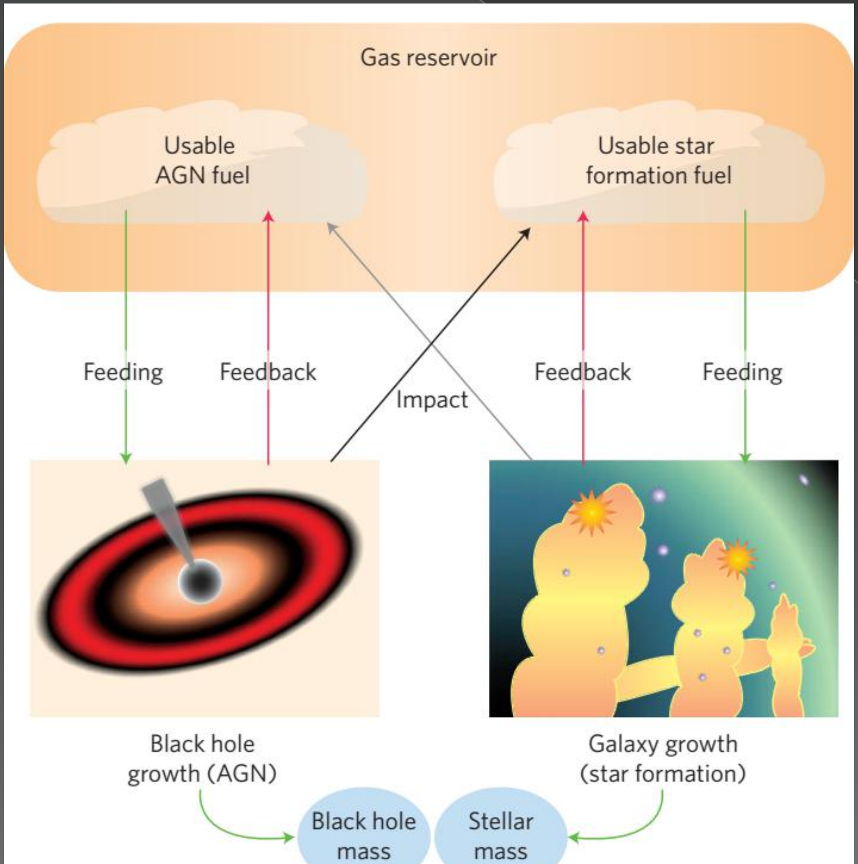
- SMBHs exist in the center of most massive galaxies

- The masses of SMBHs are correlated with different properties of their host galaxies (such as the stellar mass, the luminosity, and the velocity dispersion of bulges)

→ Co-evolution between the SMBHs and their host galaxies

Introduction

AGN feeding and feedback are key processes in the co-evolution picture:



Harrison (2017)

AGN feedback:

- are required by current models of galaxy formation
- can explain the observed link between BH mass and properties of their hosts

AGN feeding:

- gas inflows driven by galaxy interactions, non-axisymmetric structures and smal scale process

More observations are needed!

Wada et al. (2004), Di Matteo et al. (2005), Jorgee et al. (2006), Kormendy & Ho (2013) , Heckman & Best (2014)

Outline

- **Studying the Feeding Mechanisms of Nearby AGNs in VENGA**
  Collaborators: Lei Hao (SHAO), Guillermo Blanc (UChile) & VENGA team

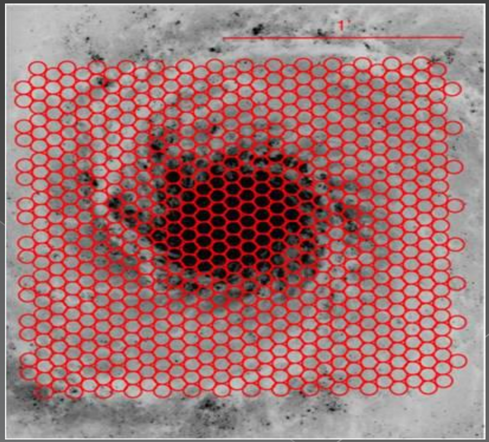
- **GMOS observations of the ionized gas outflows in local type 2 AGNs**
  Collaborators: Jong-Hak Woo (SNU), Daeun Kang (SNU), Jaejin Shin (SNU), Hyun-Jin Bae (Yonsei)

VENGA

- VIRUS-P Exploration of Nearby Galaxies (VENGA)
  - 30 nearby Sa-Sd (~ 44,000 spectra)
  - Field of view: 1.7′ x 1.7′ (coverage out to 0.7 R_{25})
  - Spectral resolution: ~ 120 km s^{-1}
  - Wavelength coverage: 3600Å - 6850Å

2.7 m
Harlan J. Smith
Telescope

VIRUS-P



246 fibers
in one pointing of VIRUS-P

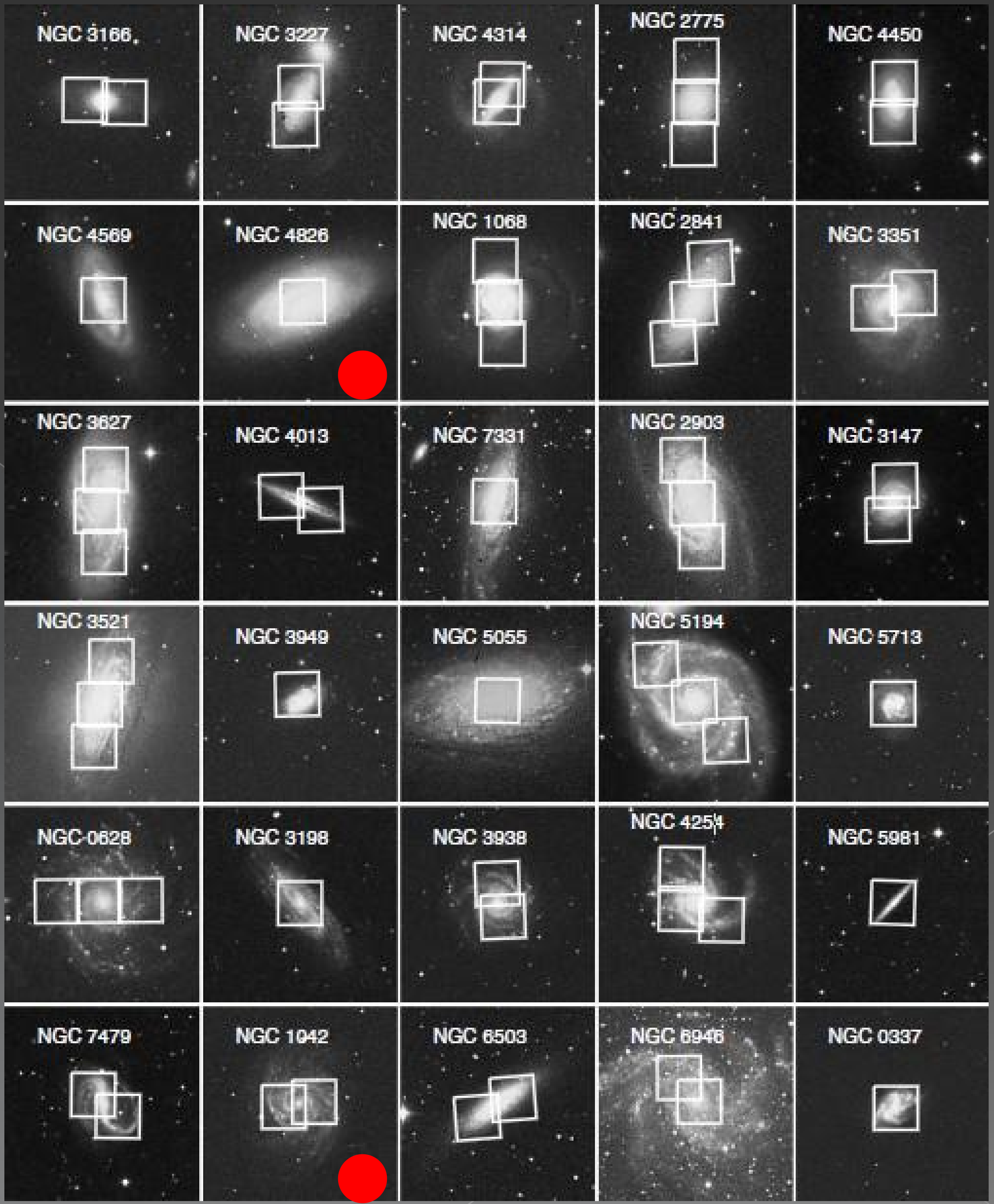
VENGA

- Our Research Goal

To map the feeding processes (gas inflow) from several kpc down to 100 pc in these galaxies.

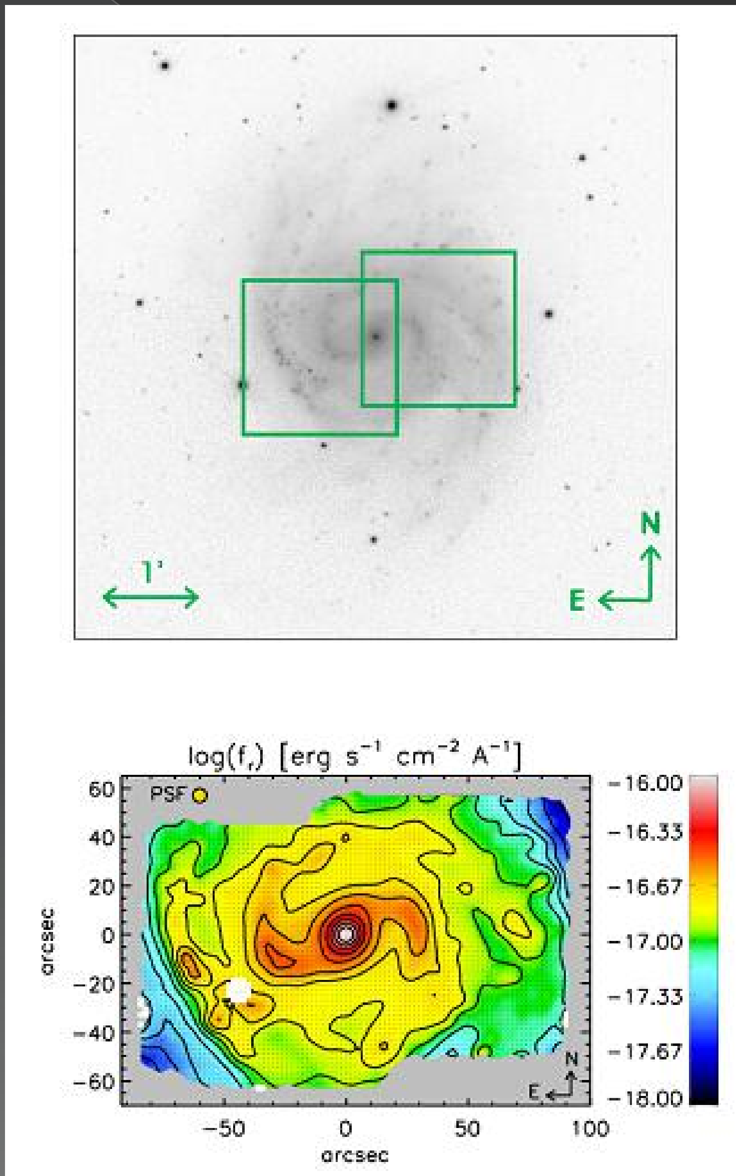
To test the previous observations and models of different feeding mechanisms

We select the most nearby AGNs with different morphology type



Blanc et al. (2013)

NGC 1042

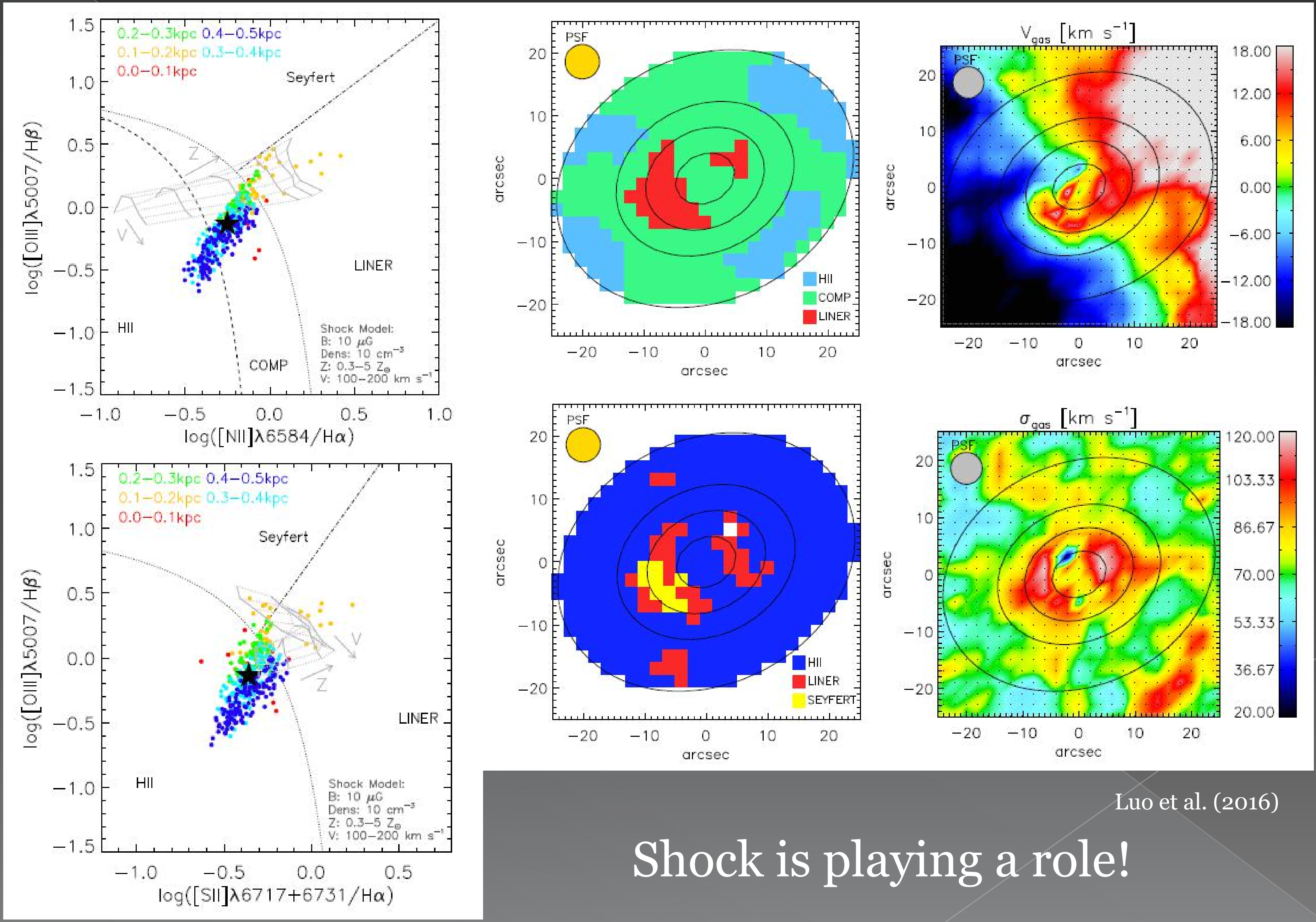


Reconstructed map of r-band flux

- A late-type bulgeless galaxy
- An accreting intermediate-mass black hole ($< 10^6 M_\odot$, Shields et al. 2008)
- Massive nuclear star cluster (NSC) ($3 \times 10^6 M_\odot$, Walcher et al. 2005)
- It is an ideal lab to study the mass growth of blackholes at low mass end

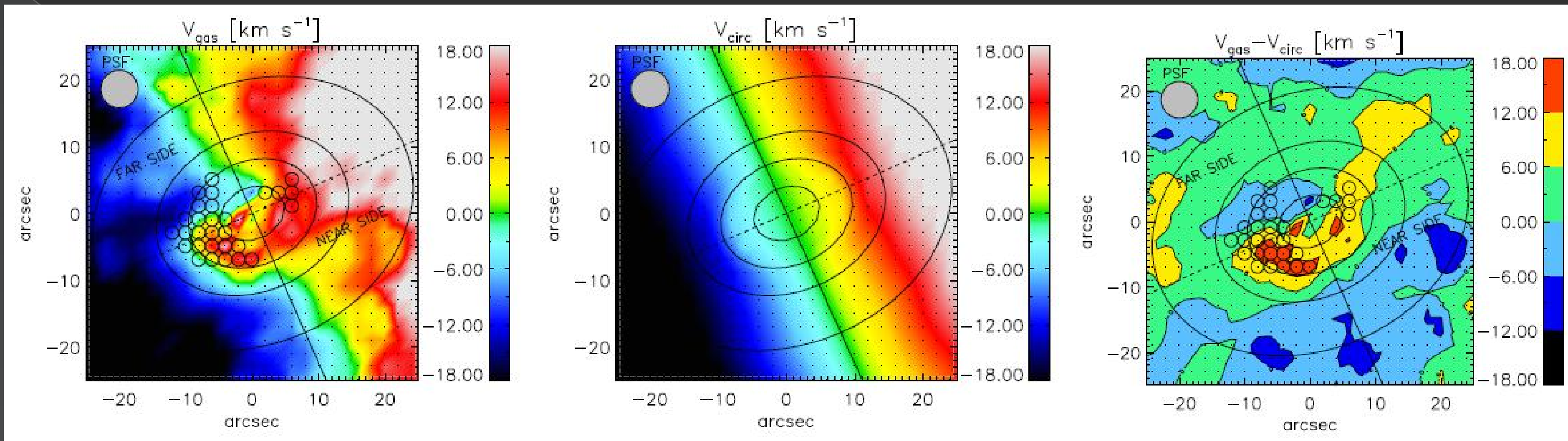
Luo et al. (2016)

The LINER-like Ring Structure



Luo et al. (2016)

Shock is playing a role!



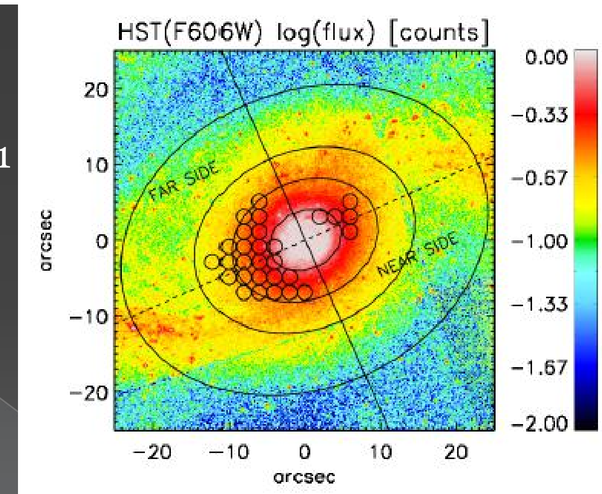
The residual velocity is ~ 20 km s^{-1}

The deprojected gas inflow velocity is ~ 32 km s^{-1}

The mass inflow rate at gas inflow region:

$$\dot{M}_{in} = 2\pi\, n_e\, m_p\, f\, V_{in}\, r\, h$$

~ 1.1 × 10^{-3} $M_\odot$ yr^{-1}



The mass accretion rate at the last stable orbit of the BH and the star formation rate in the NSC:

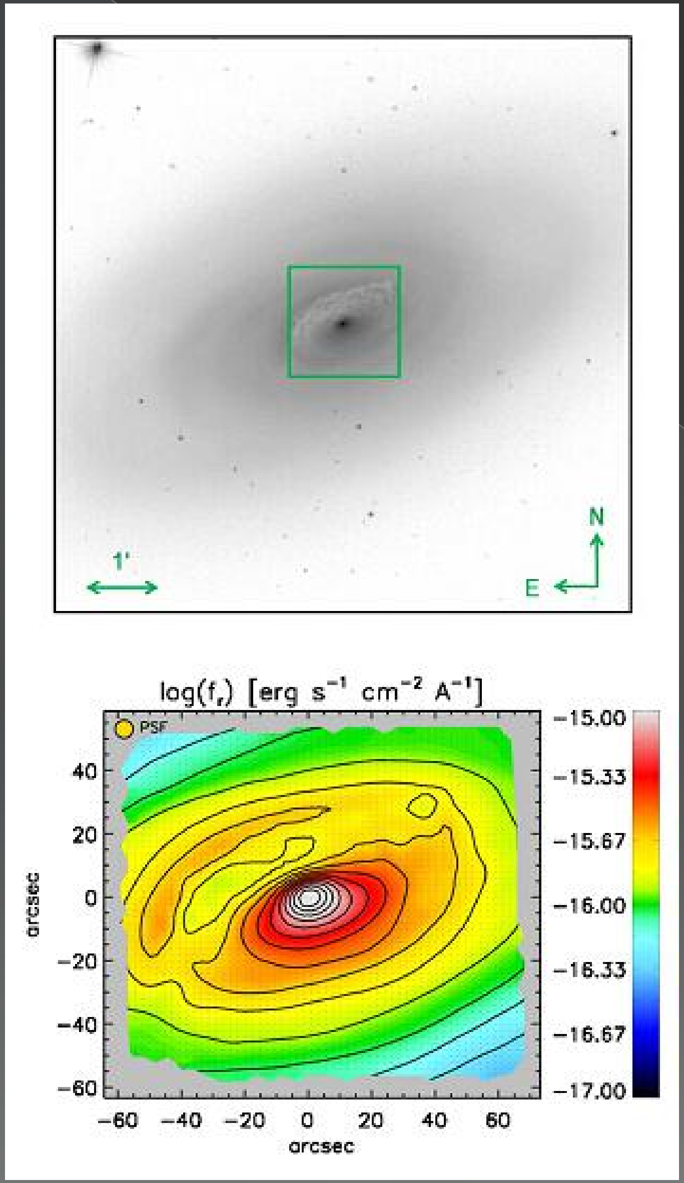
Luo et al. (2016)

$$\dot{M} = \frac{L_{bol}}{c^2 \eta}$$

~ 1.4 × 10^{-5} $M_\odot$ yr^{-1}

M_{SR} ~ 7.94 × 10^{-5} $M_\odot$ yr^{-1}

NGC 4826



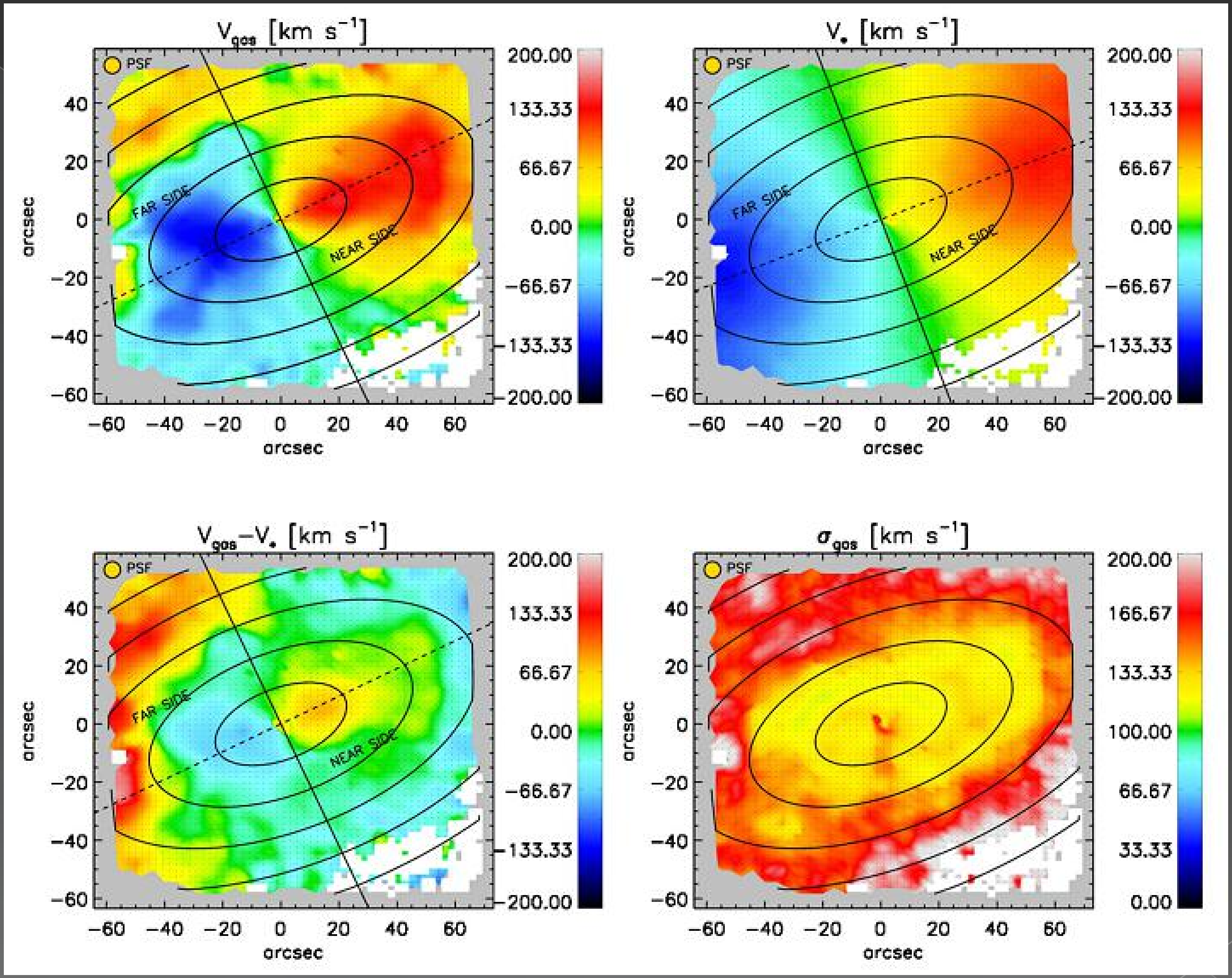
Reconstructed map of r-band flux

- Past gas accretion has produced two counter-rotating HI and ionized gas disk (Braun et al. 1992; Braun et al. 1994):

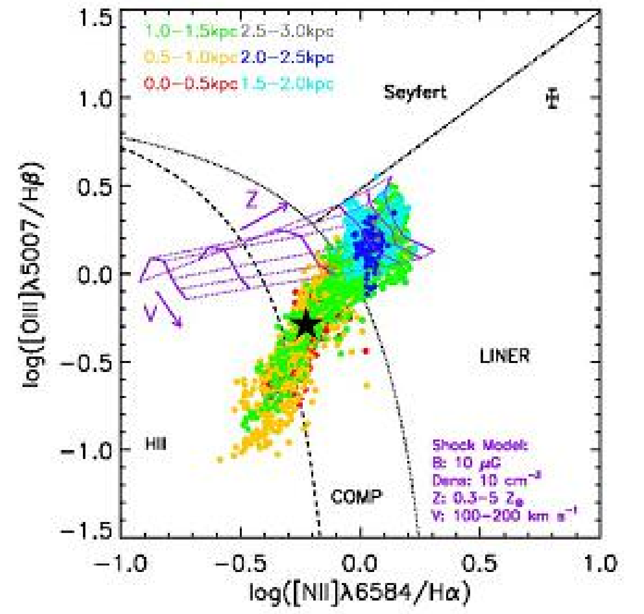
  R < 1kpc

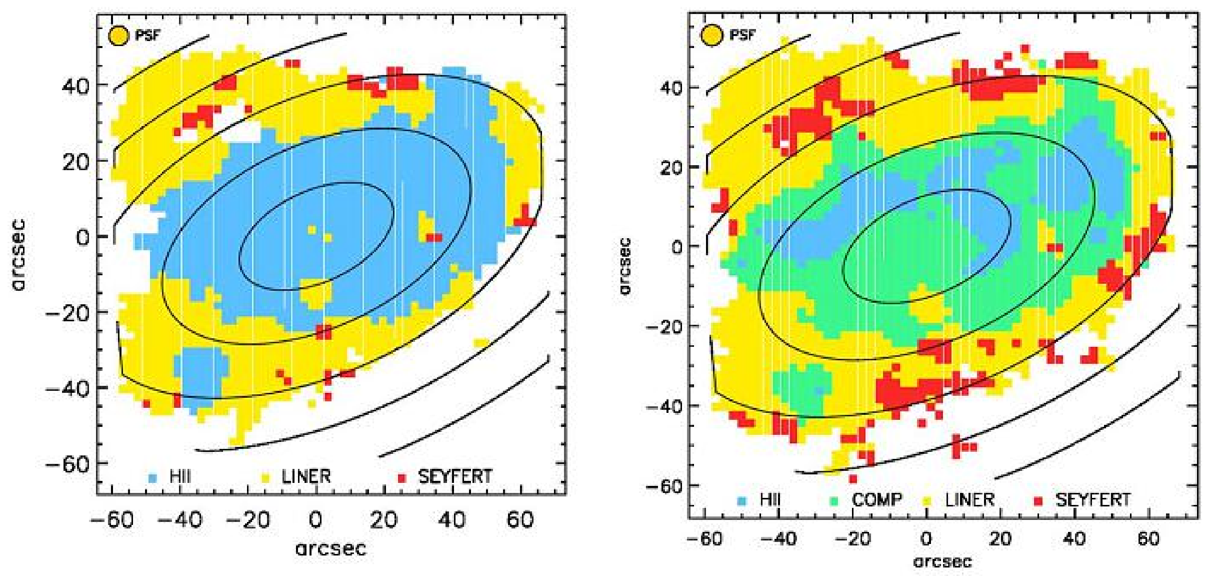
  1.5kpc < R < 11kpc

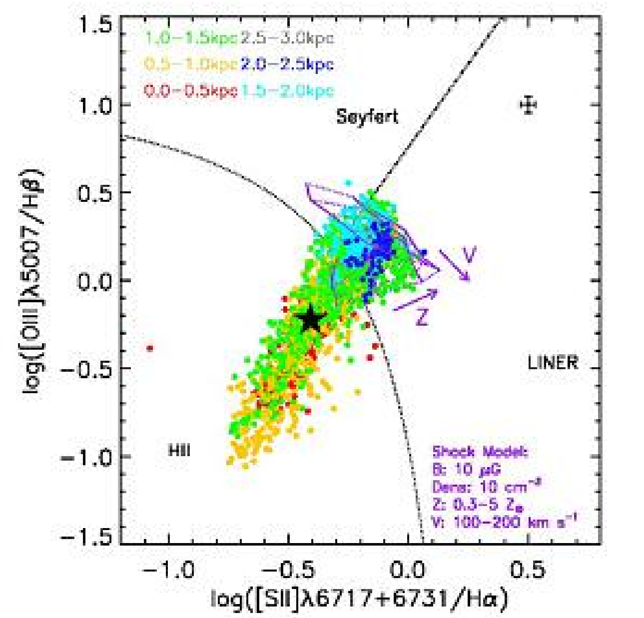
- The complex ionized gas kinematics and excitation in the transition region (Braun et al. 1994; Rix et al. 1995)



Counter-rotating ionized gas disk and ehanced σ in the transition region







Central region (<1kpc):
HII and composite emission dominates

Outer region (>1.5kpc):
LINER-like emission dominates

Luo et al. to be submitted

- The supersonic Kelvin–Helmholtz instability at the interface will enable mixing of the two components, which will induce strong shocks and heat the mixed gas
- The heated gas will lose their angular momentum and free-fall towards the disc's centre over the surface of the inner disc
- At the transition region, assuming the residual velocity as the inflow velocity, we estimate the inflow timescale $T \sim 1\ \mathrm{kpc}/100\ \mathrm{km\ s^{-1}} = 1.5 \times 10^{7}\ \mathrm{yr}$

Luo et al. to be submitted

Quach et al. 2015

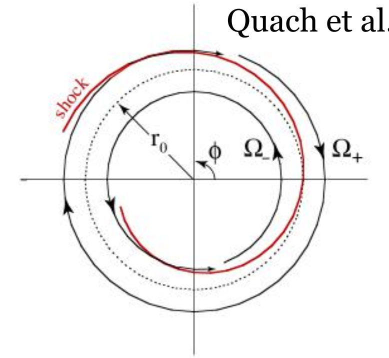


Figure 4. Polar plot of a one armed ($m = 1$) perturbation which has steepened to form an oblique shock. The gas crossing the shock is deflected towards the interface of the two components.

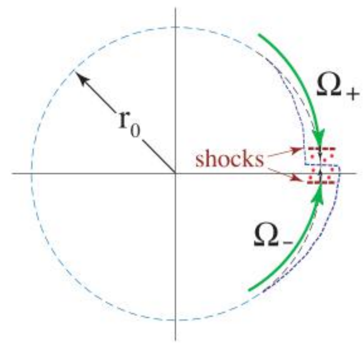
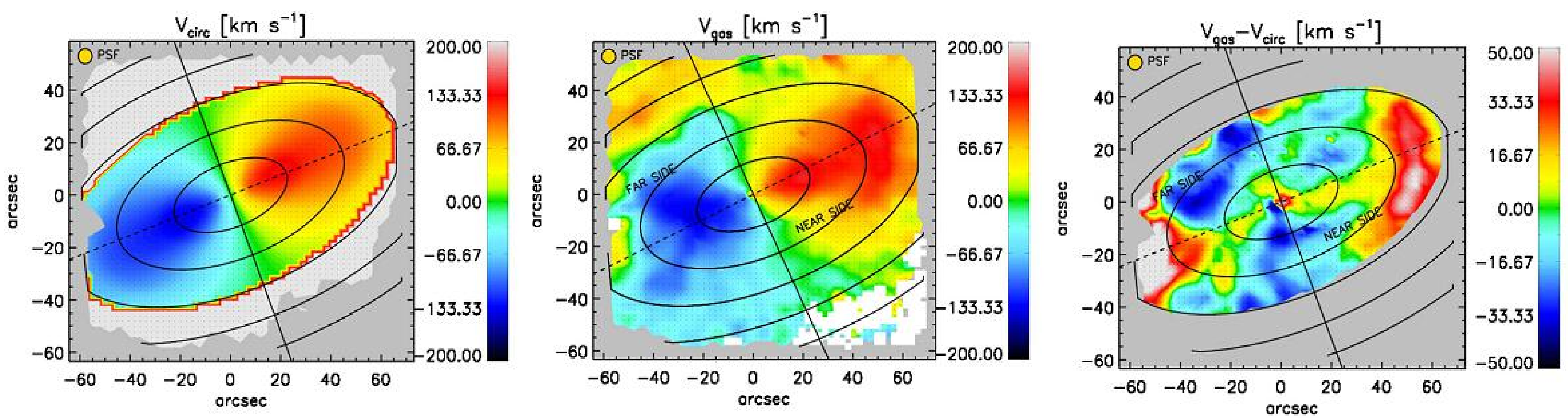


Figure 5. Polar plot suggesting the formation of strong normal shocks leading the annihilation of the angular momenta of the co- and counter-



Summary

NGC 1042:

- In the central region of NGC 1042, we find shock excitation and ionized gas inflow driven by the inner spiral arms. The mass inflow rate is about one hundred times the blackhole's mass accretion rate and slightly larger than the star formation rate in the nuclear star cluster, implying that the inflow material is enough to feed both the AGN activity and the star formation in the nuclear star cluster. This study highlights that **secular evolution can be important in late-type unbarred galaxies like NGC1042.**

NGC 4826:

- In the transition region of two counter-rotating gaseous disks, we find the ionized gas is shocked and moving inwards to the galaxy center. These phenomena can be qualitatively explained by the non-linear effects of Kelvin-Helmholtz instability. The estimated inflow timescale is within the same order of the AGNs' lifetime, suggesting that the inflowing gas could feed the nuclear activity in NGC 4826. This research indicate that **external accretion could drive gas to the center of galaxies and feed the nuclear activity.**

Introduction

Outflow census in large sample:

- Type 2 AGNs in SDSS DR7, $z < 0.3$
- Outflow are prevalant, the marjority of high luminosity AGN show strong outflows (Bae & Woo 14, Woo+16, Woo+17, Kang+17)

IFU follow-ups of the AGNs with strong outflow:

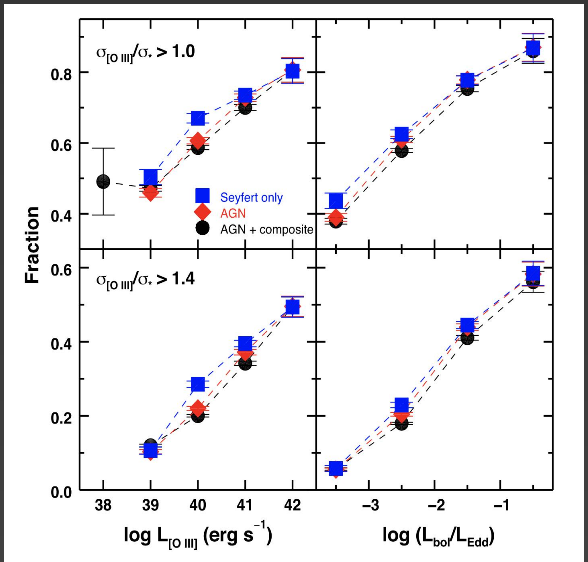
- $L_{[OIII]} > 10^{42}$ erg s^{-1}, redshift < 0.1
- $|V_{[OIII]}| > 250$ km s^{-1}, or $\sigma_{[OIII]} > 400$ km s^{-1}
- GMOS, IMACS, and SNIFS observations
- Study the details of the AGN-driven outflows

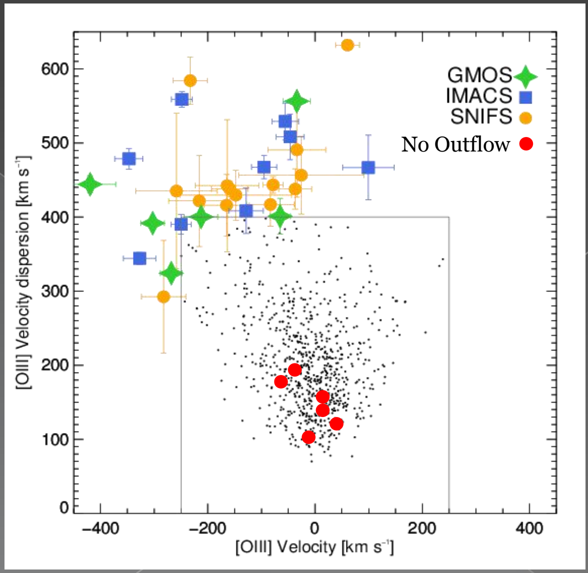
(Karouzos+16a, Karouzos+16b, Bae+17, Daeun's talk)

IFU follow-up of the AGNs with no/weak outflows:

- Six objects with $|\sigma_{[OIII]}/\sigma_* - 1| < 0.2$ and $|v_{[OIII]}| < 50$ km s^{-1}
- Matched $L_{[OIII]}$, stellar mass, redshit
- GMOS observations
- Study why only a fraction of luminous AGN launch powerful ionized gas outflows.

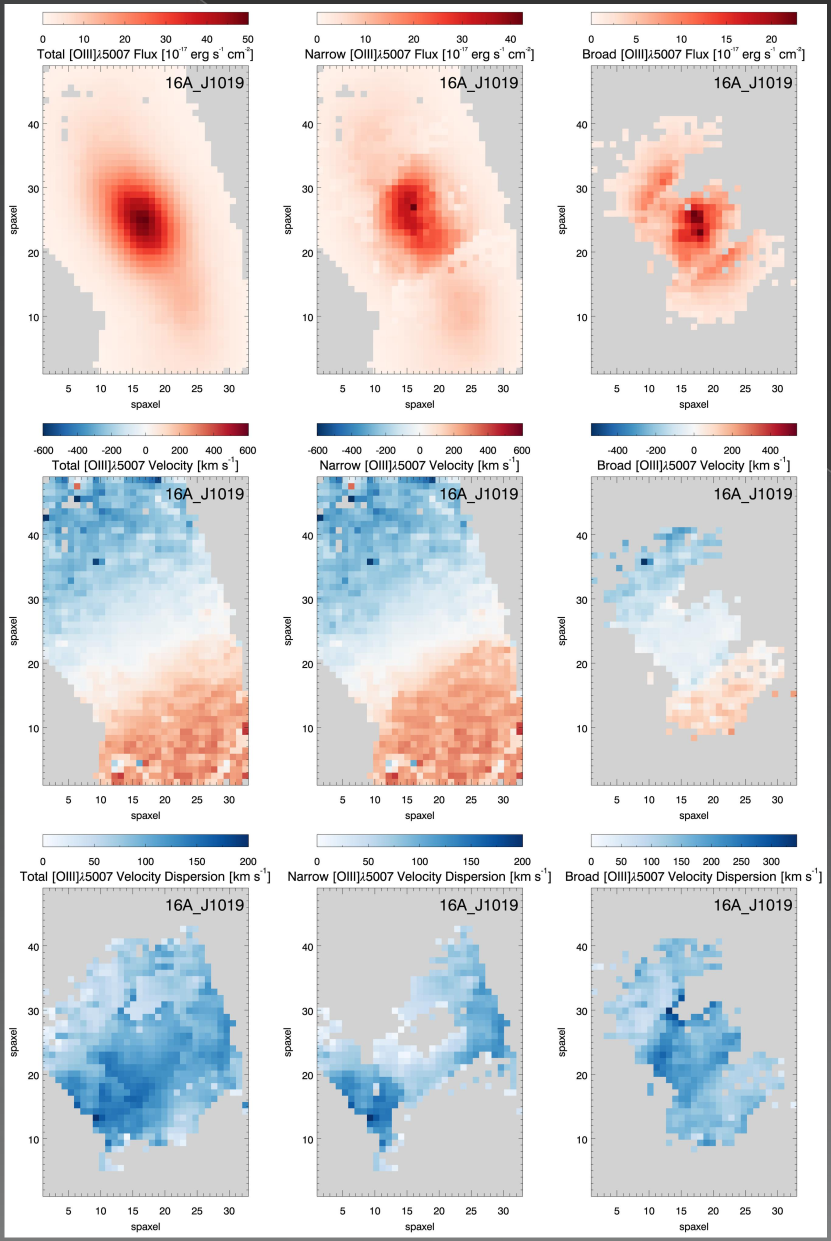
Woo et al. (2016)





Karouzos et al. (2016a)

Data Analysis



Stellar continuum substraction:

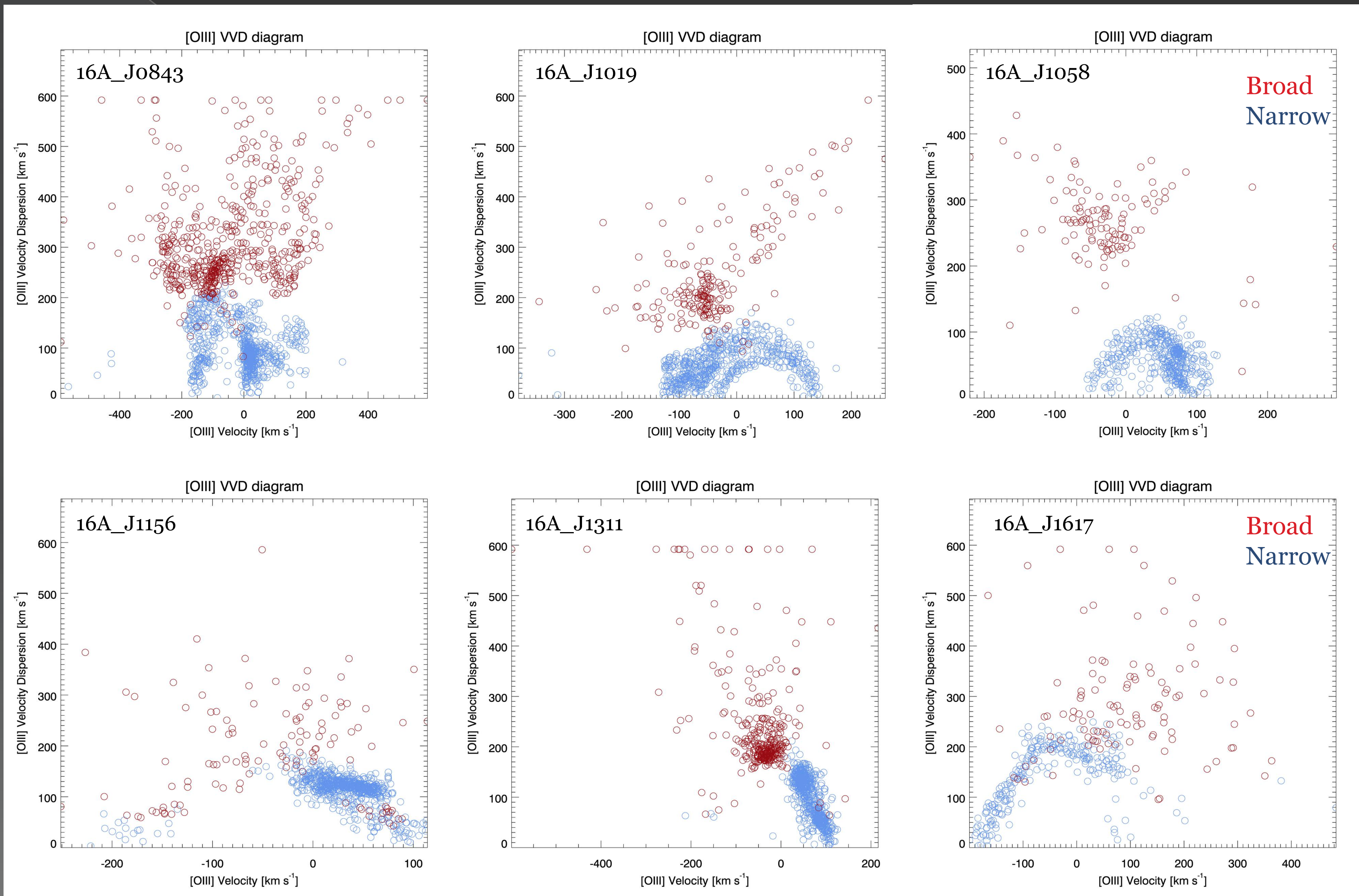
- PPXF (47 stellar template)

Emission line fitting:

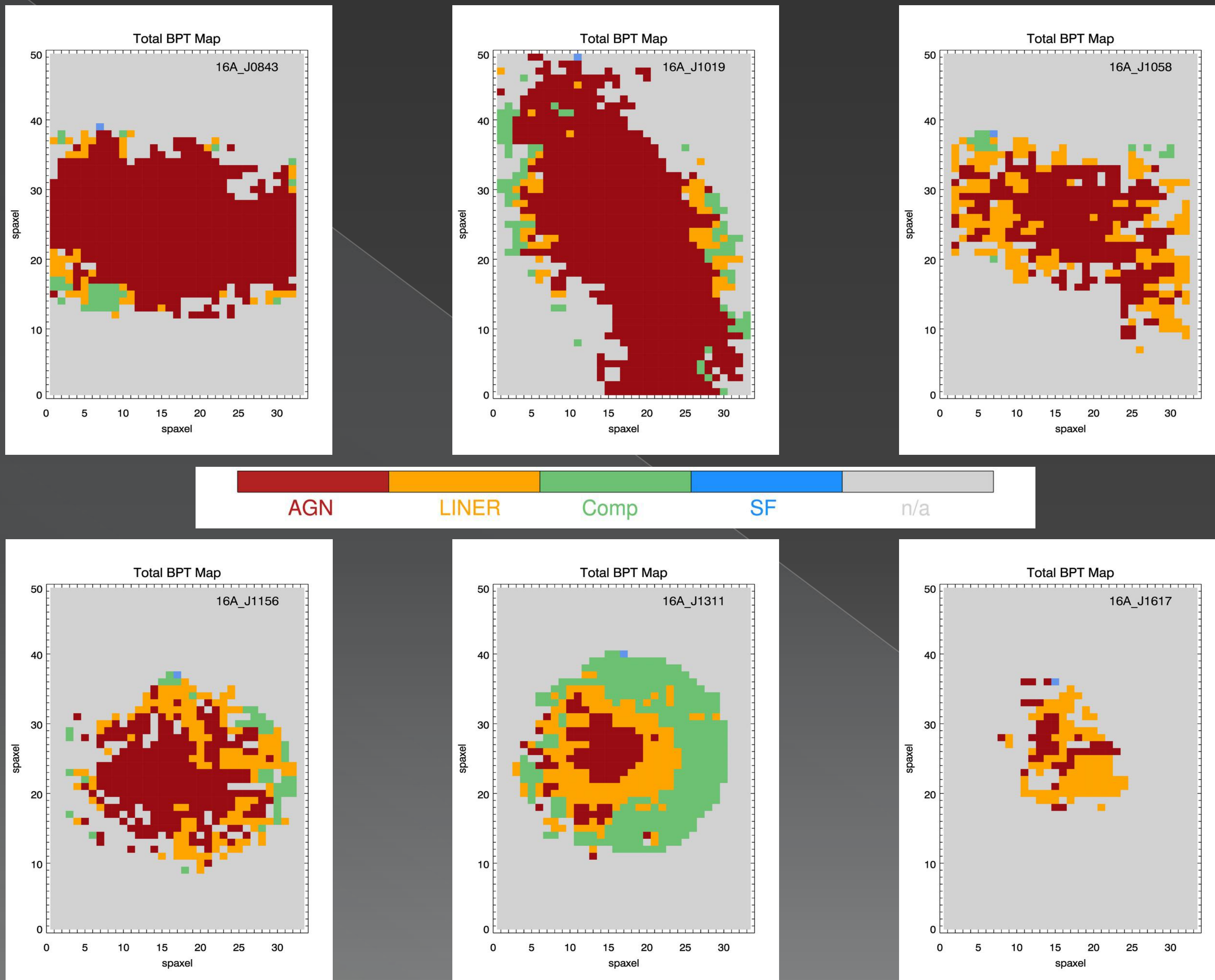
- Multi-gaussians (up to two)
- Hb, [OIII], [NII], Ha, [SII]
- flux, velocity shift and velocity

dispersion (based on the flux-weighted 1st and 2nd moment)

[OIII] VVD diagram



BPT diagram


Total BPT Map
16A_J0843
Total BPT Map
16A_J1019
Total BPT Map
16A_J1058
AGN
LINER
Comp
SF
n/a
Total BPT Map
16A_J1156
Total BPT Map
16A_J1311
Total BPT Map
16A_J1617
spaxel
spaxel
0
10
20
30
40
50
0
5
10
15
20
25
30

Thanks !