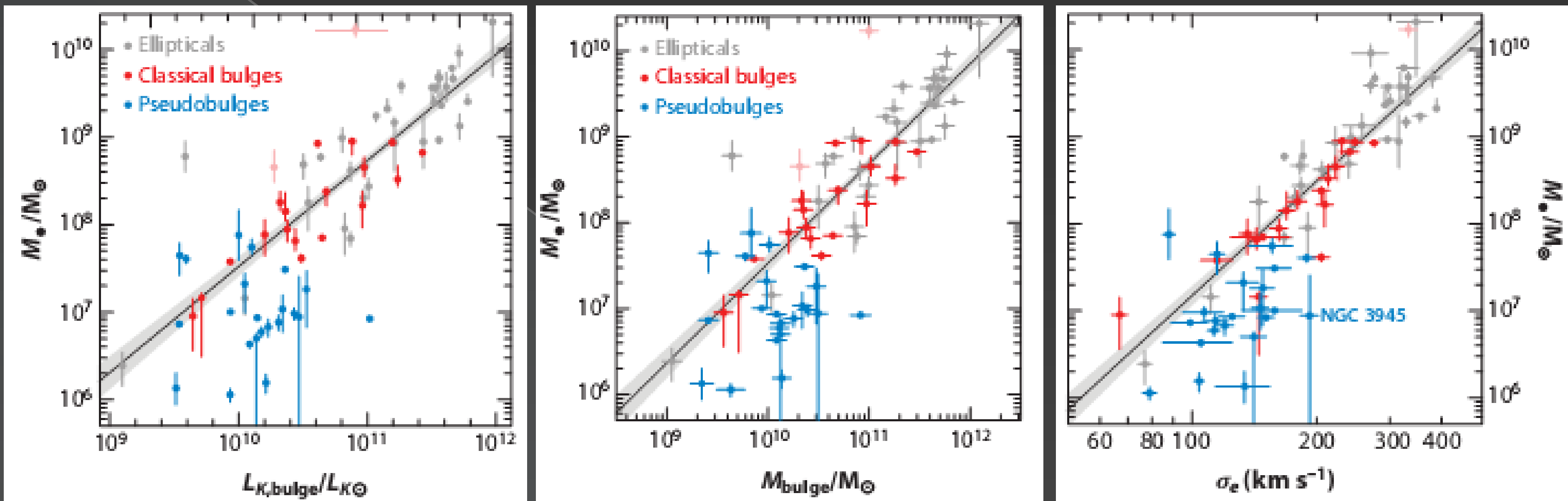
Feeding and Feedback in Nearby Active Galaxies of VENGA

Rongxin Luo

Supervisor: Lei Hao

Introduction



Kormendy & Ho (2013)

- SMBHs are almost universally existed in the center of massive galaxies
- The masses of SMBHs are correlated to different properties of their host galaxies such as stellar mass, luminosity, and velocity dispersion of the bulges

➡ Co-evolution between SMBHs and their host galaxies

Introduction

?

Feeding mechanisms

To lose 99.999% angular momentum

10 Kpc	~ Kpc	~ 100 pc	~10 pc	<1 pc
Galaxy interactions Galaxy major merger Large-scale galaxy bars	Bars Ovals Spiral arms	Nested bars Nuclear spirals arm		Dynamical friction Stellar mass loss Viscous torques

Large-scale gravitational torques (> kpc) | **Small-scale process (< kpc)**

Bulge-dominated, luminous AGNs, z>2 | **Disk-dominated, low to intermediate luminosity AGNs, local universe**

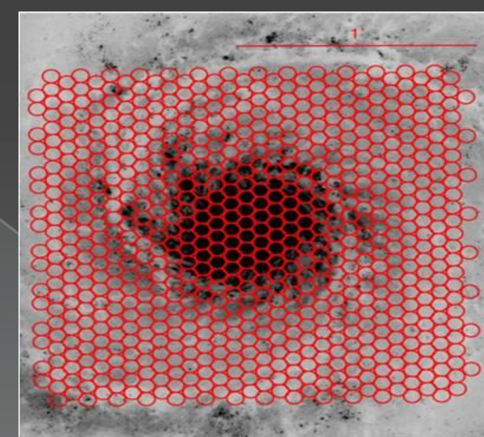
Summary based on Martini et al. (2004), Jorgee et al. (2006), Alexander et al. (2012), Kormendy & Ho (2013) , Heckman & Best (2014)

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: 5Å FWHM
  - Wavelength coverage: 3600Å - 6850Å

2.7 m
Harlan J. Smith
Telescope

VIRUS-P



246 fibers
in one pointing of VIRUS-P

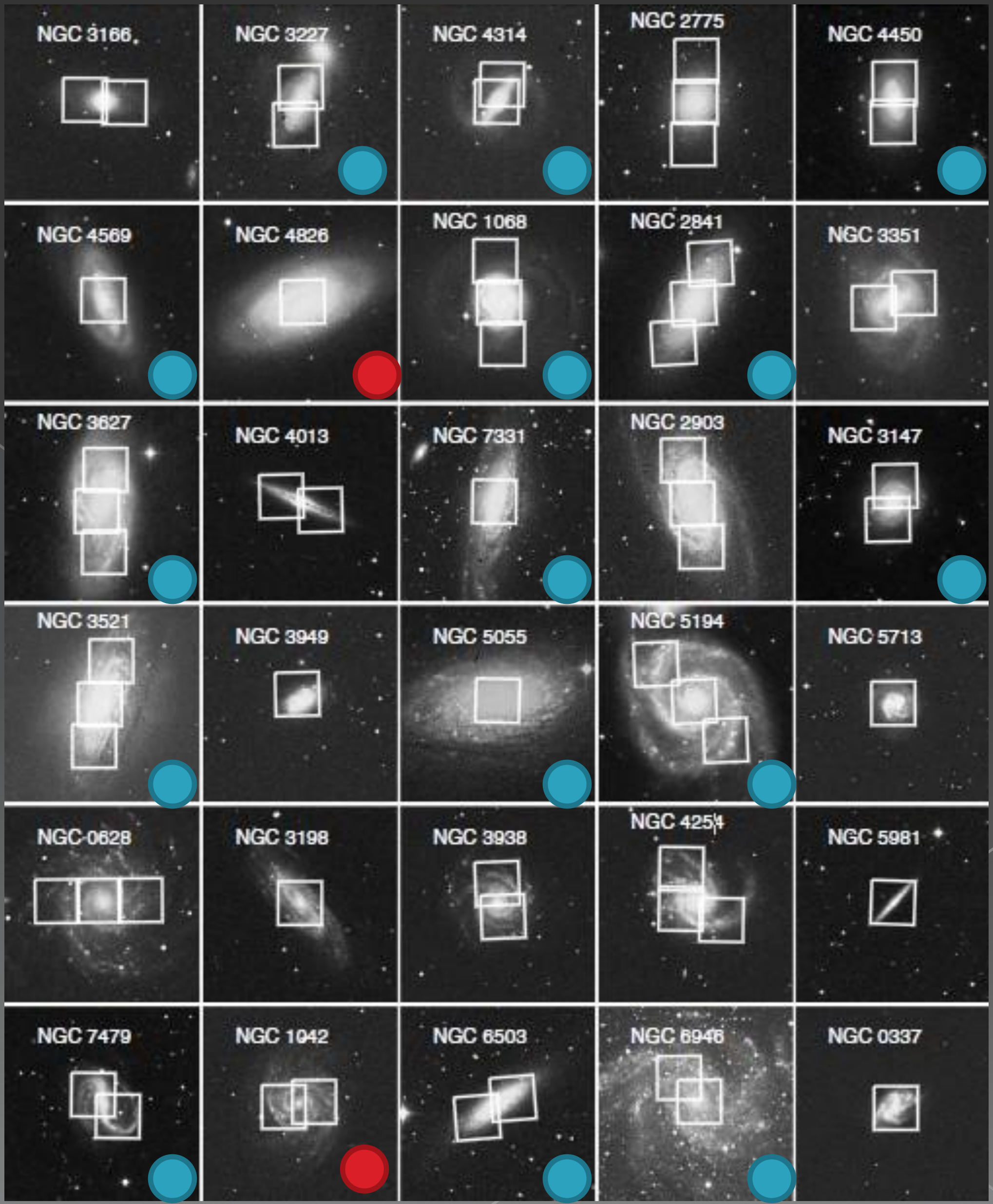
VENGA

- Our Research Goal
  - Feeding Mechanisms

    To test previous observations and models

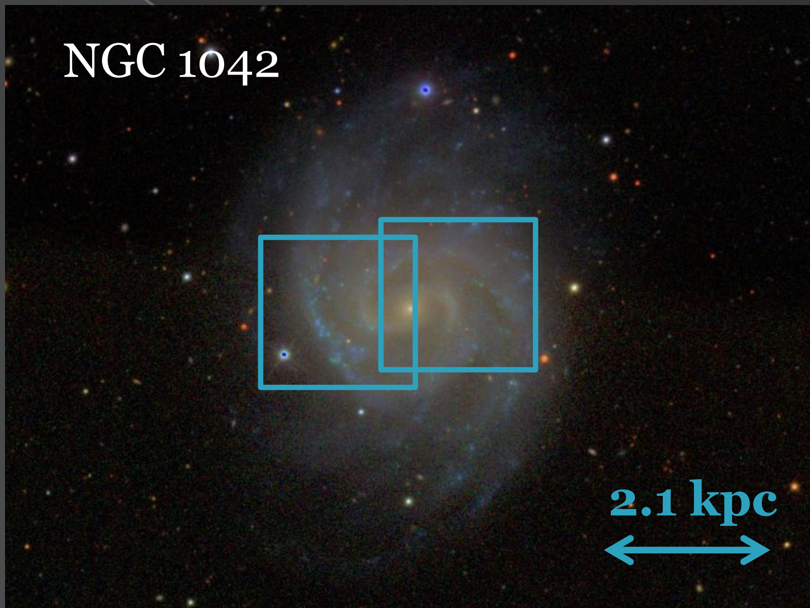
  - Feedback Effects

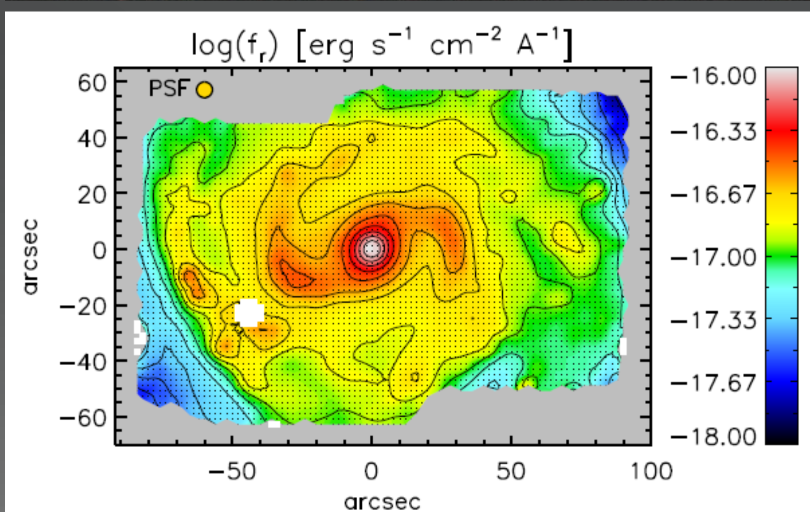
    To explore how can feedback affect feeding process



Blanc et al. (2013)

NGC 1042



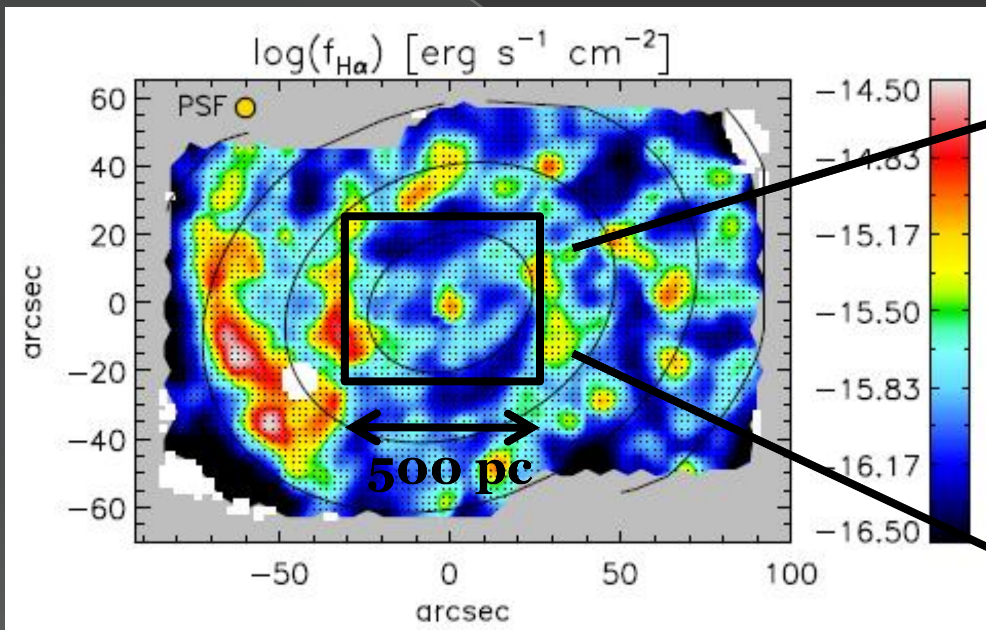


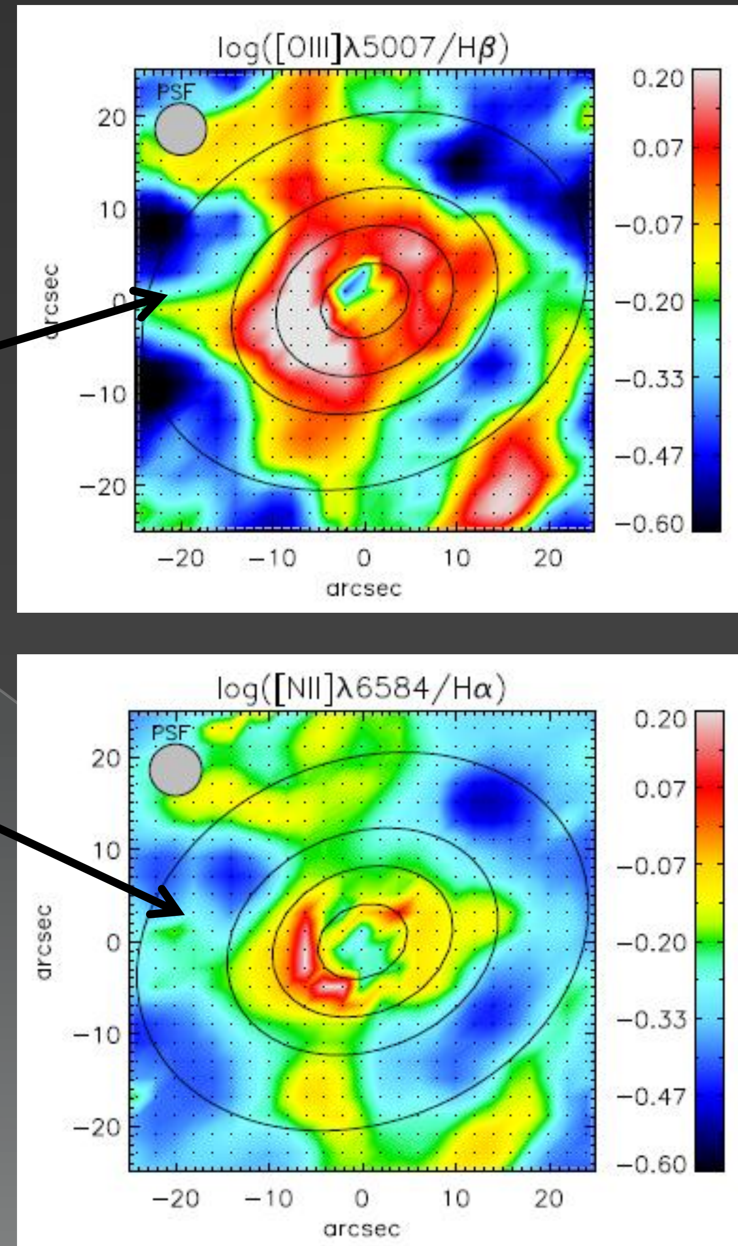
Reconstructed map of r-band flux

- 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. submitted

Emission Line Ratio Maps

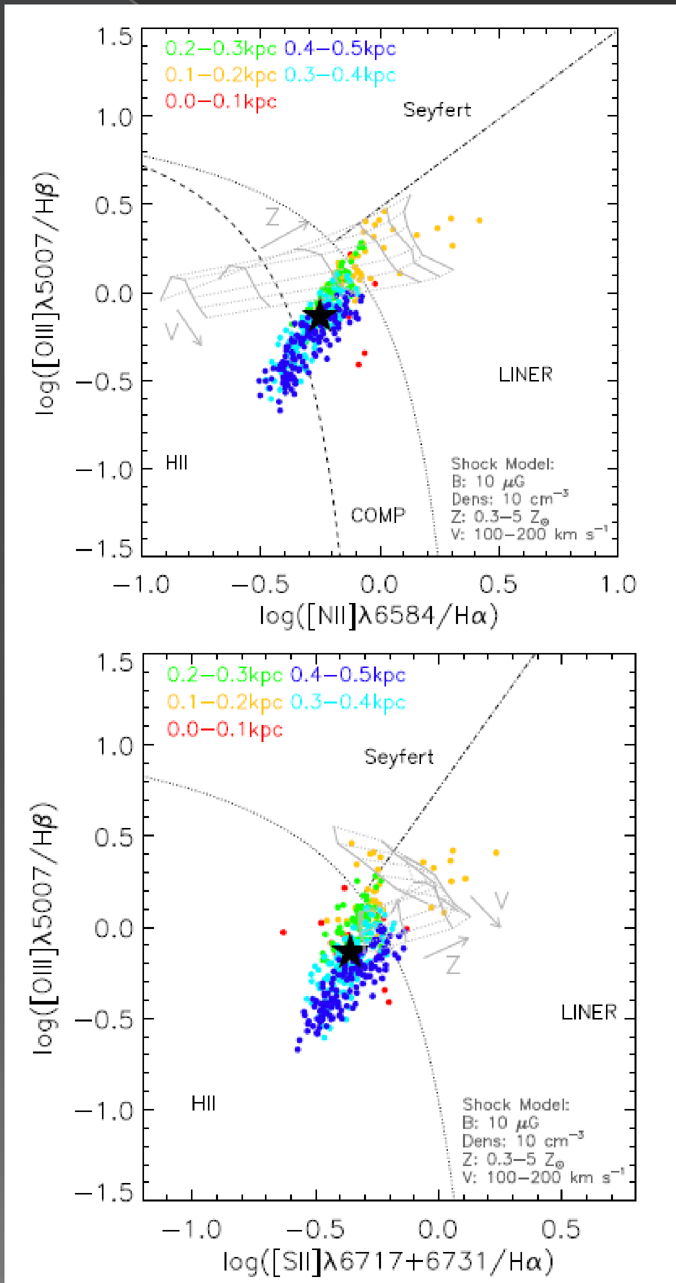


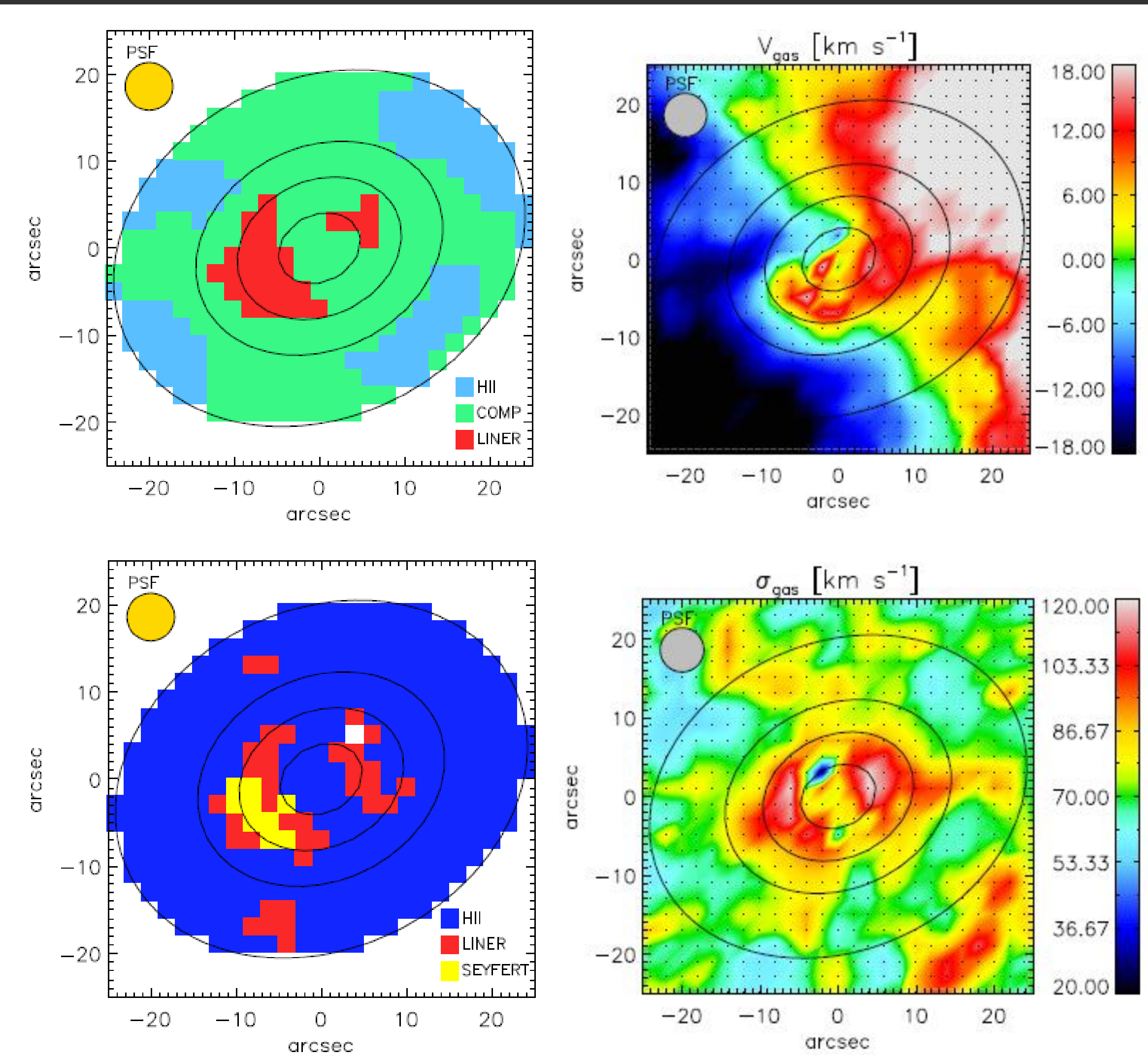


There is a circumnuclear ring-like ionized gas structure in the central 500 pc x 500 pc region of line ratio maps

Luo et al. submitted

The LINER-like Ring Structure

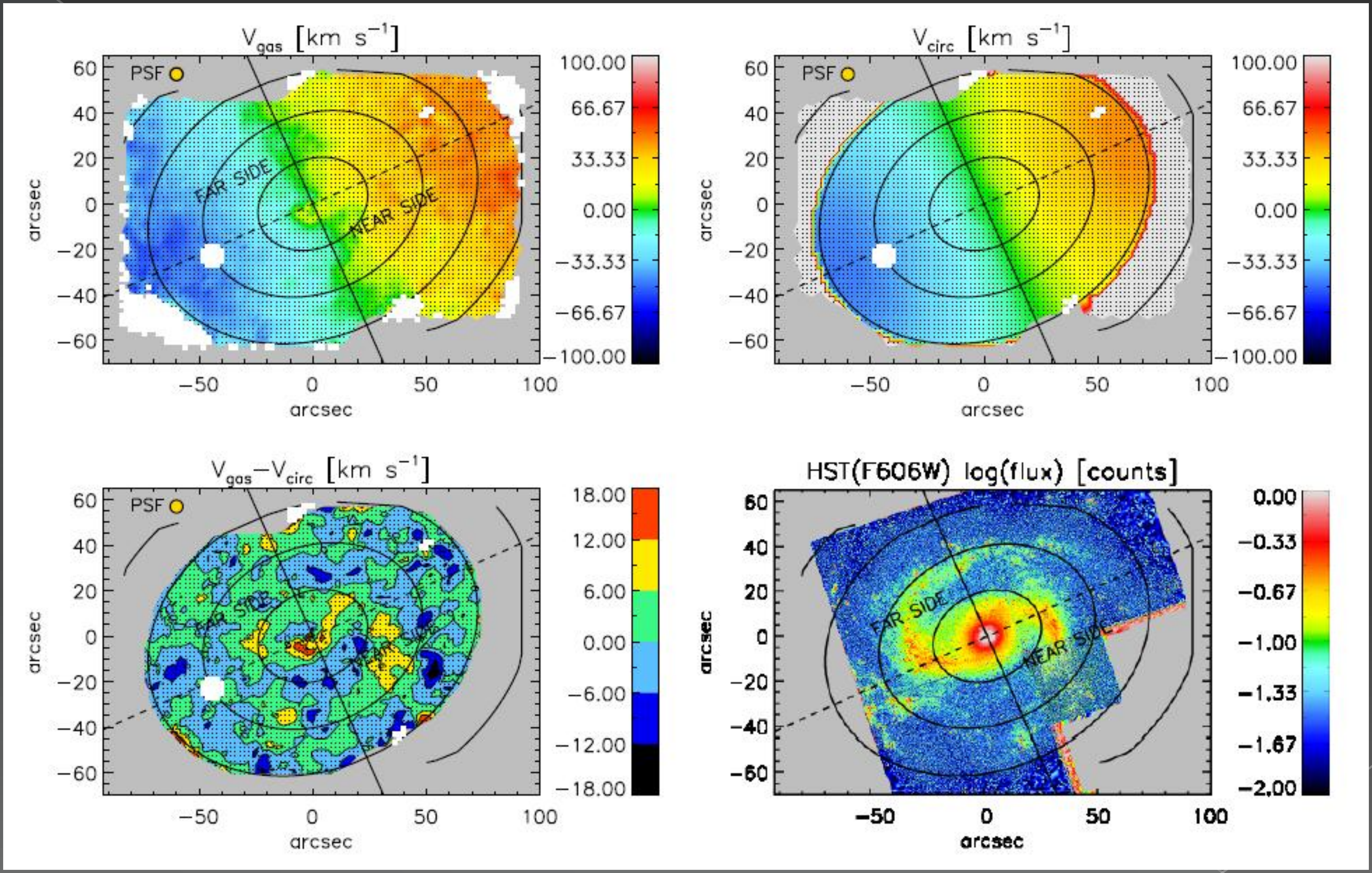




Luo et al. submitted

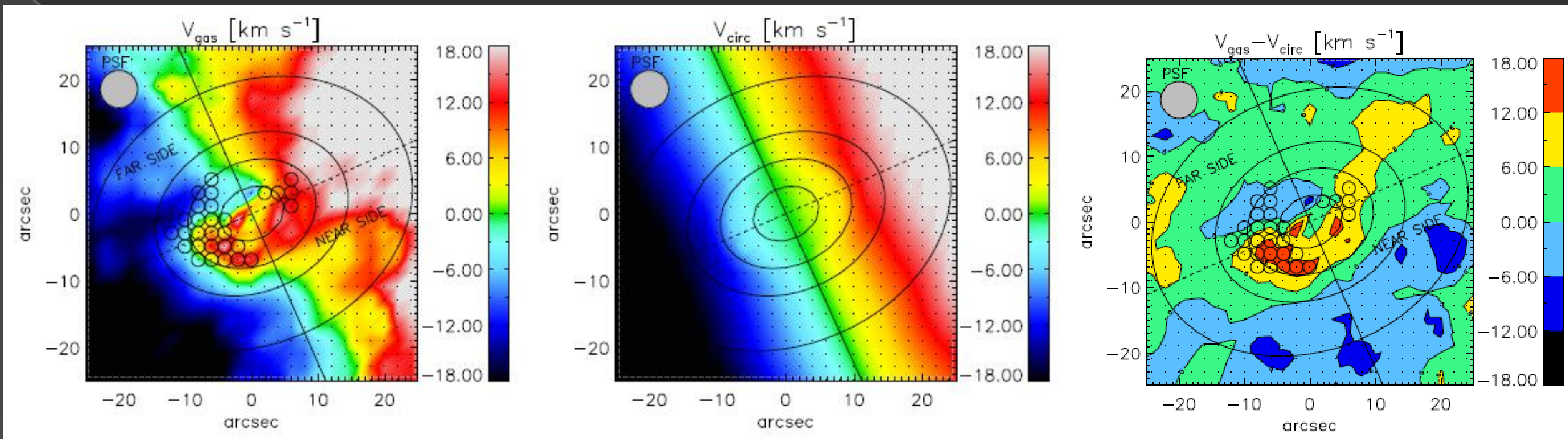
Shock is playing a role!

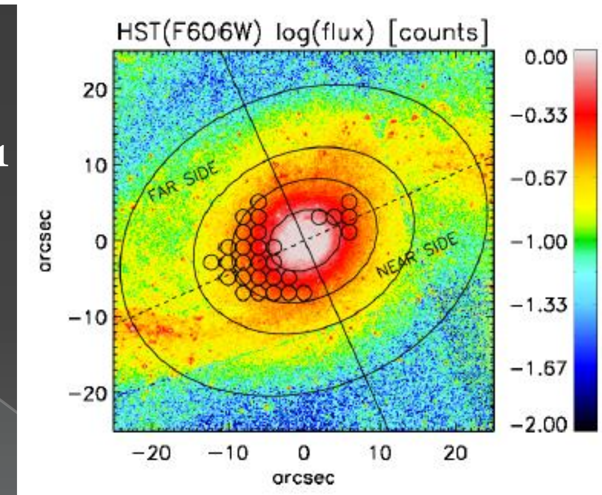
Harmonic analysis



Luo et al. submitted

No significant gas flows have been found at large radii of the disk
Strong gas flows only exist within the inner 500 pc





Luo et al. submitted

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:

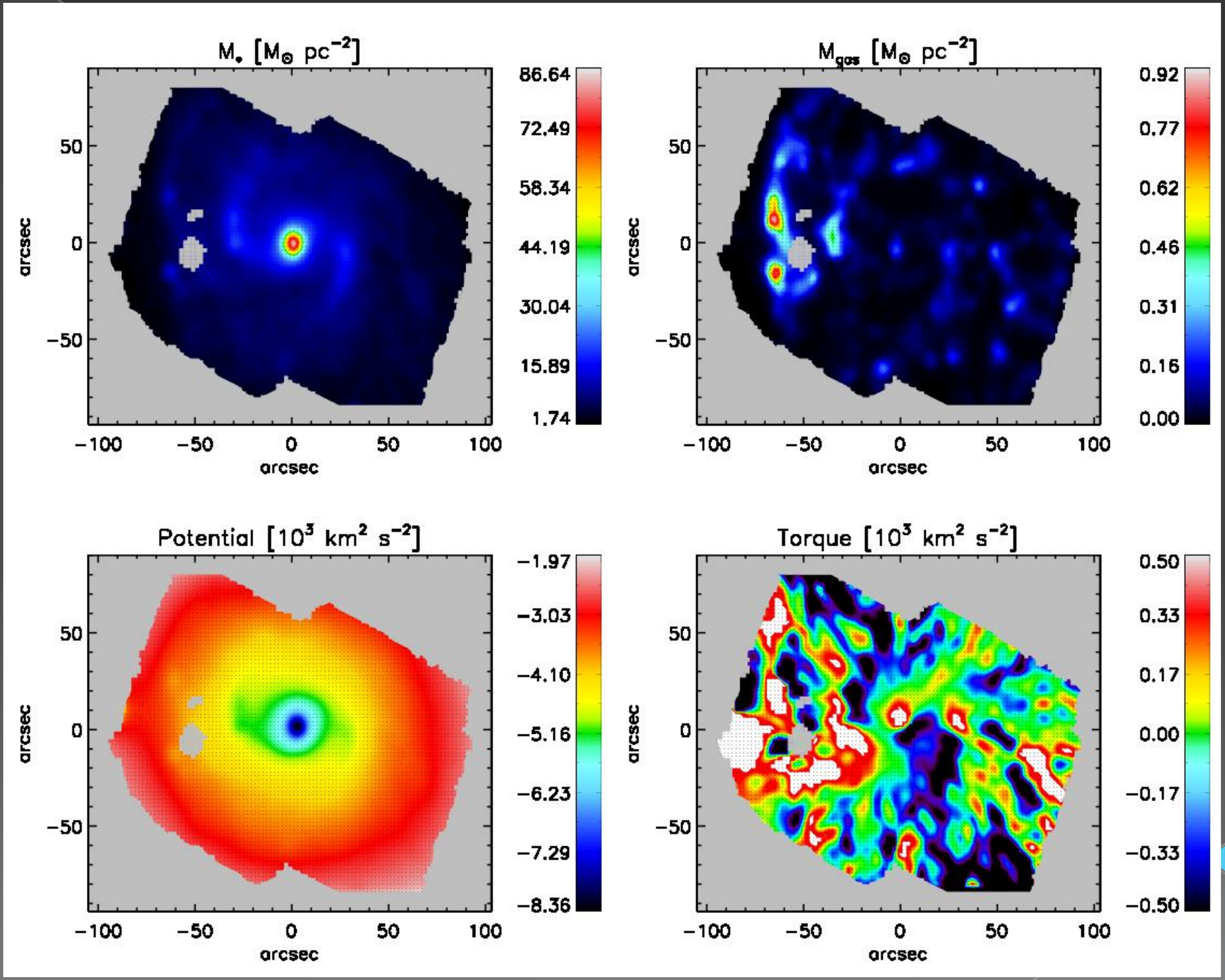
$$\dot{M}_{in} = 2\pi\, n_e\, m_p\, f\, V_{in}\, r\, h$$ ~ $1.1\times 10^{-3}\ M_\odot\ yr^{-1}$

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

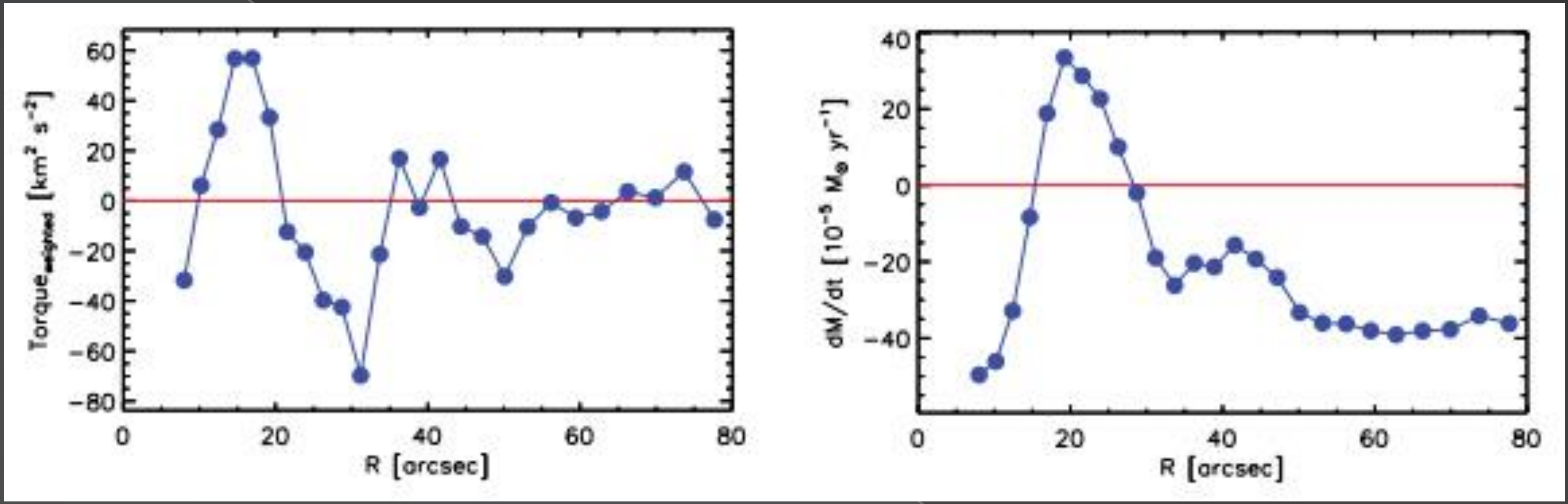
$$\dot{M} = \frac{L_{bol}}{c^2\eta}$$ ~ $1.4\times 10^{-5}\ M_\odot\ yr^{-1}$

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

Gravitational Torque Analysis



Gravitational Torque Analysis



- The negative torques within 15" (300 pc) indicating the gas inflow
- The mass inflow rate is 1/10 of that estimated from kinematic analysis

Summary

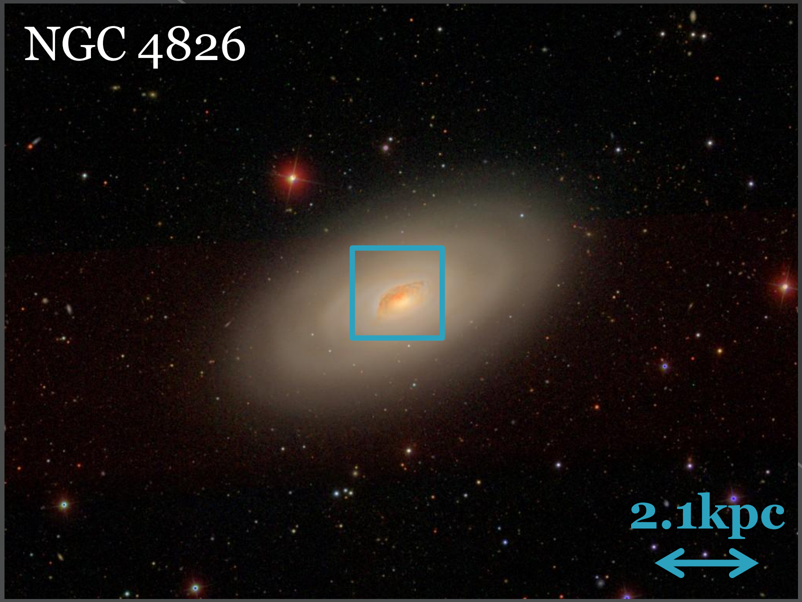
- We present VIRUS-P IFU observation of NGC1042 and find a LINER-like ring structure in the central 500 pc x 500 pc region.

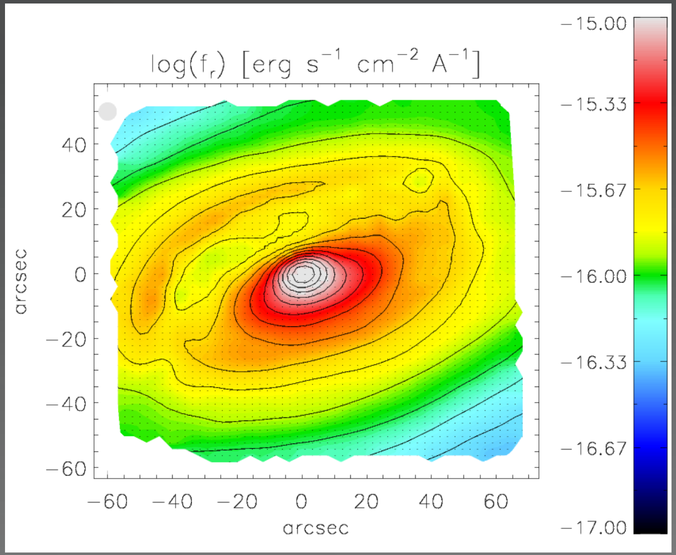
- By examining different excitation mechanisms, we conclude that shocks are the dominant ionization source in this LINER-like ring structure. This result is supported by the violent gas kinematics in this region.

- Combining the harmonic decomposition analysis of the velocity field of ionized gas, we propose that the shocked gas is the result of gas inflow driven by the inner spiral arms. The results of torque analysis are consistent with the kinematic annlysis.

- The estimated mass inflow rate ($\sim 1.1 \times 10^{-3}\ M_{\odot}\ yr^{-1}$) is about 100 times of the mass accretion rate, which means the inflow material is enough to feed the nuclear activity in this galaxy. Our study highlights the contribution of spiral arms in secular evolution, especially for the late-type unbarred galaxies like NGC 1042.

NGC 4826



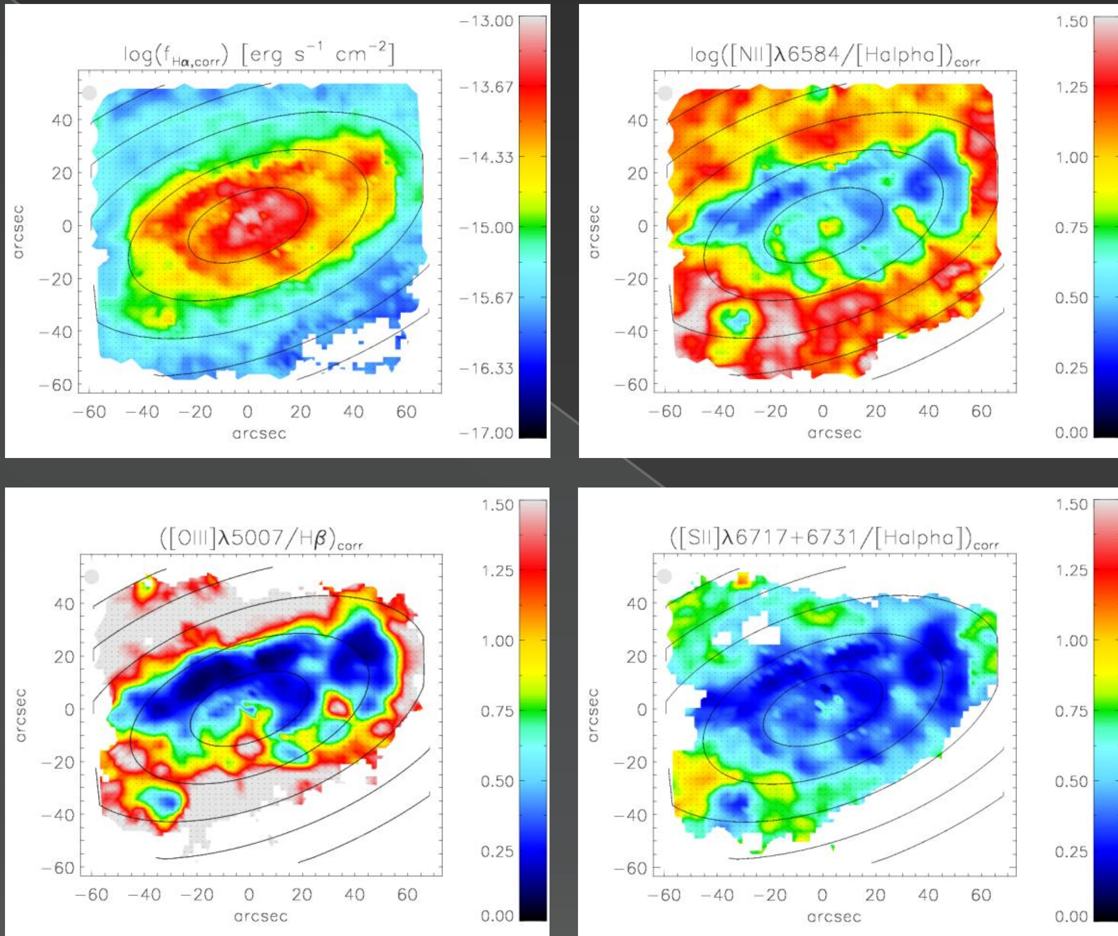


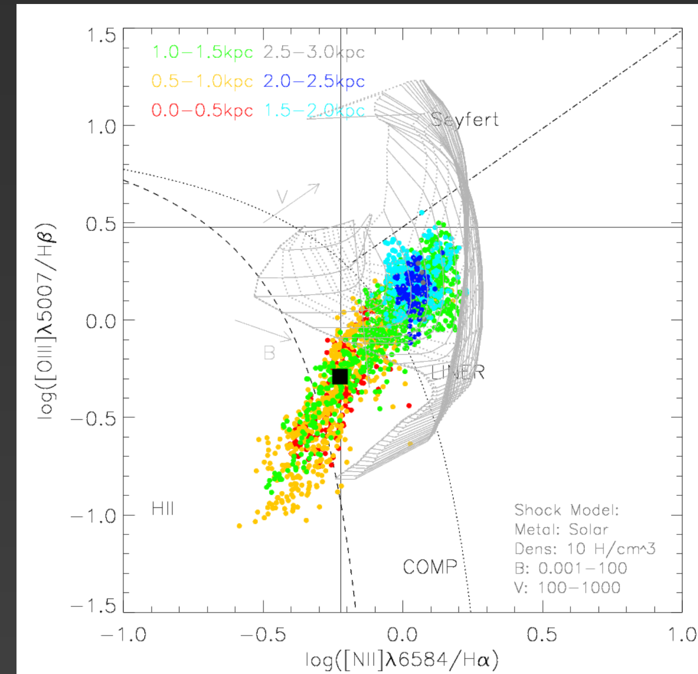
Reconstructed map of r-band flux

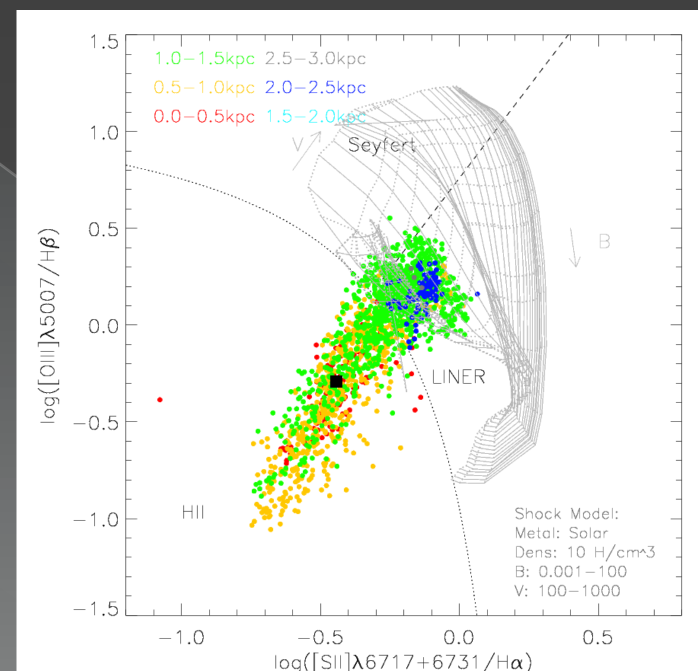
- The famous "Black Eye" galaxy
- Two counter-rotating HI gas disk (Braun et al. 1992; Braun et al. 1994):

  R < 1kpc

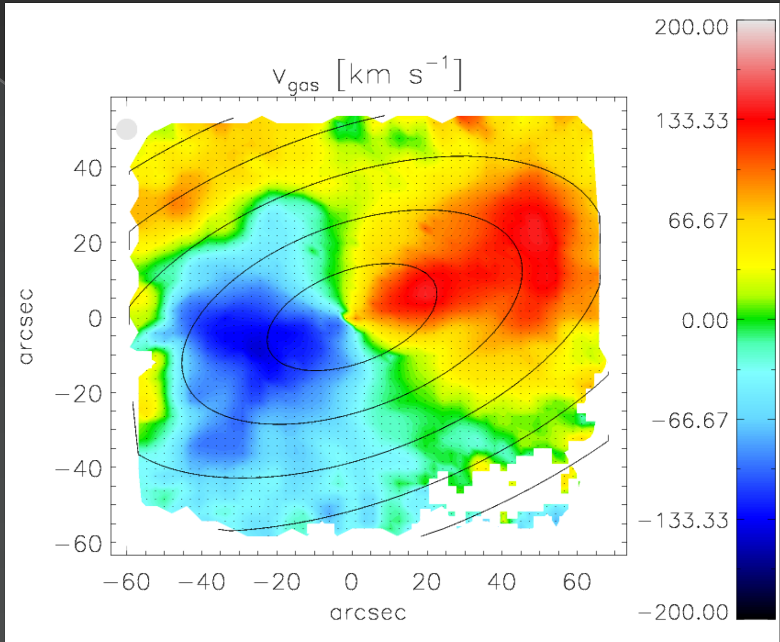
  1.5kpc < R < 11kpc
- The complex ionized gas kinematics and excitation in the transition region (Rix et al. 1995)

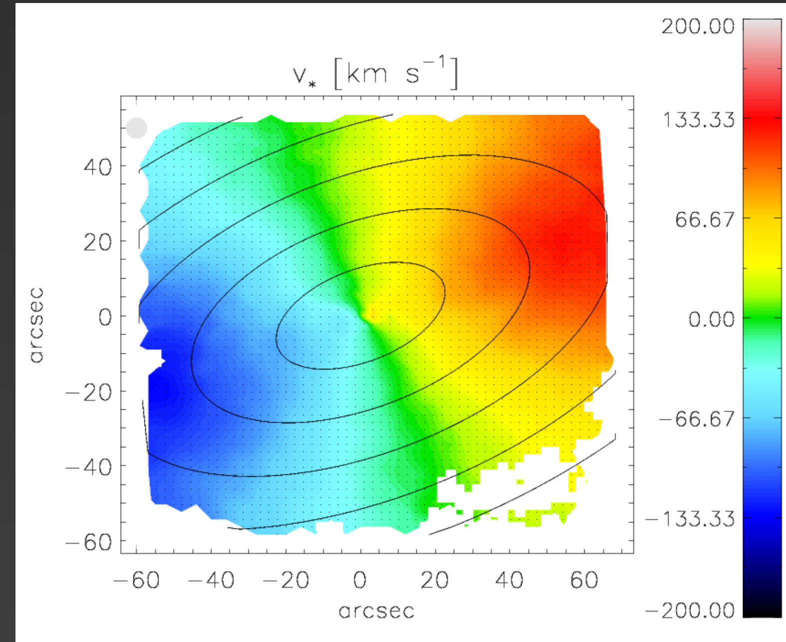




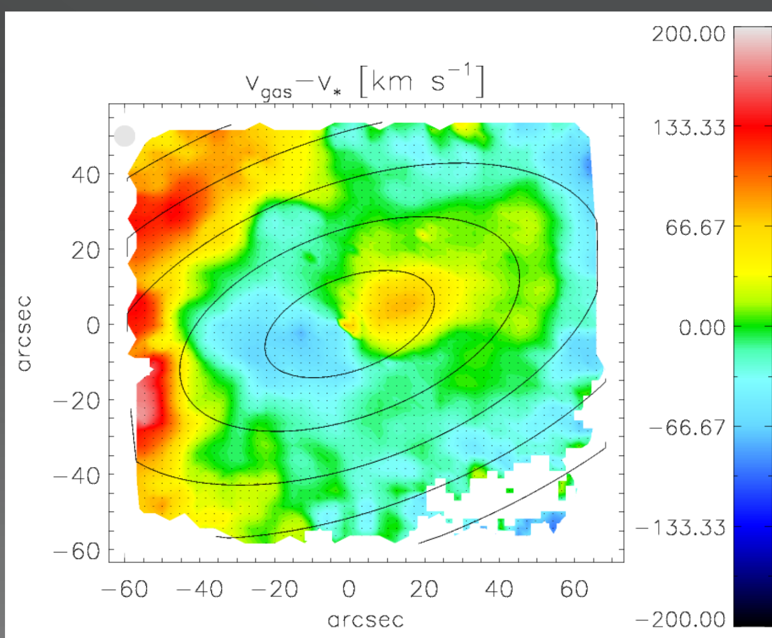


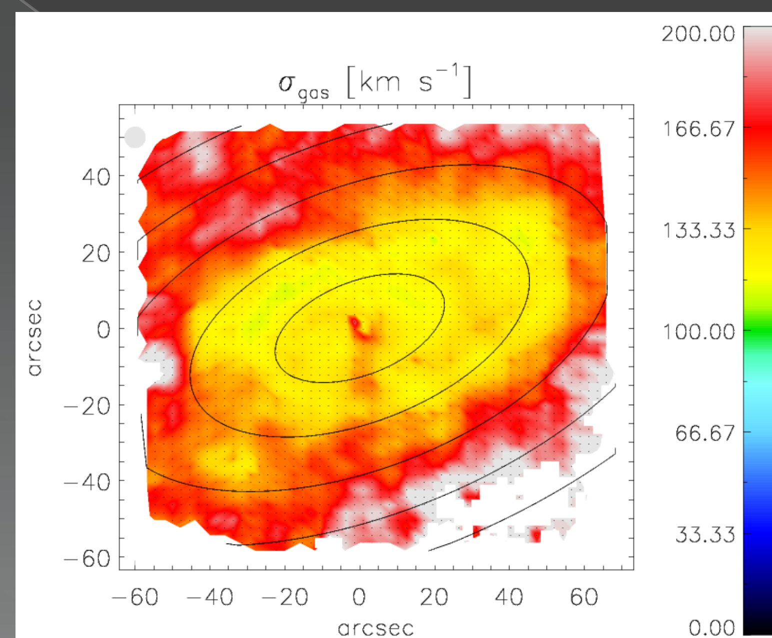
Central region (<1kpc):
HII-like emission dominates
Outer region (>1.5kpc):
LINER-like emission dominates





Complex gas kinematics! Counter-rotating ionized gas disk?





Future Work

- To improve the kinematic analysis of velocity field: more physical, from 2D to 3D
- To improve the calculation of the gravitational potential： Multi-Gaussian Expansion
- Directly comparison with the analytic models or hydrodynamic simulations
- To extend to large sample of galaxies and also study the role of secular evolution

Thanks !