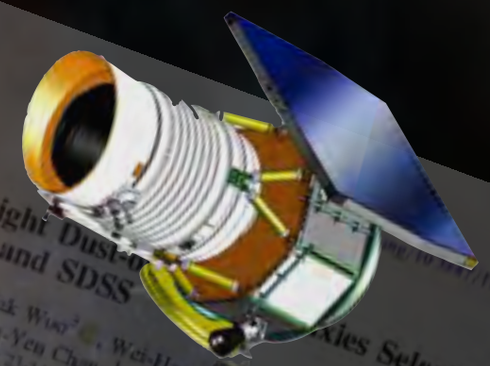
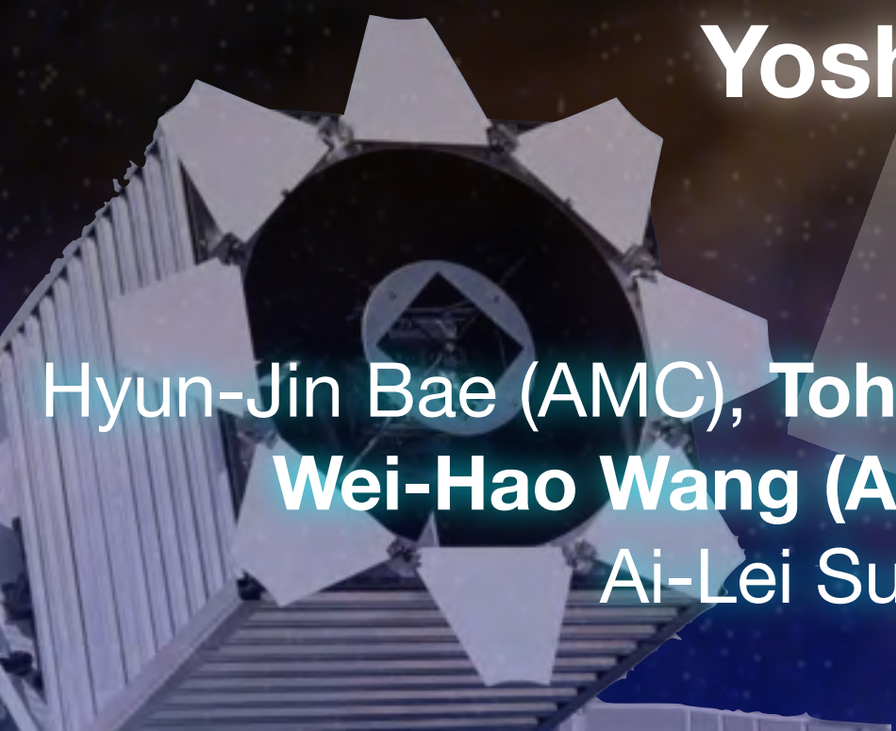
The East-Asia AGN Workshop 2017

2017.12.05



Ionized Gas Outflows in Infrared-bright Dust-Obscured Galaxies at 0 < z < 1

Toba et al. 2017c, ApJ, 850, 140



Yoshiki TOBA (鳥羽 儀樹)

(ASIAA)

Hyun-Jin Bae (AMC), **Tohru Nagao (Ehime Univ.)**, **Jong-Hak Woo (SNU)**,
Wei-Hao Wang (ASIAA), Alexander Wagner (Tsukuba Univ.),
Ai-Lei Sun (JHU), **Yu-Yen Chang (ASIAA)**

We discovered IR-bright DOGs with strong ionized gas outflow

狗 σκυλί hund cane anjing chó

Dogs are obscured by blanket..

Introduction

What are Dust-Obscured Galaxies (DOGs)?

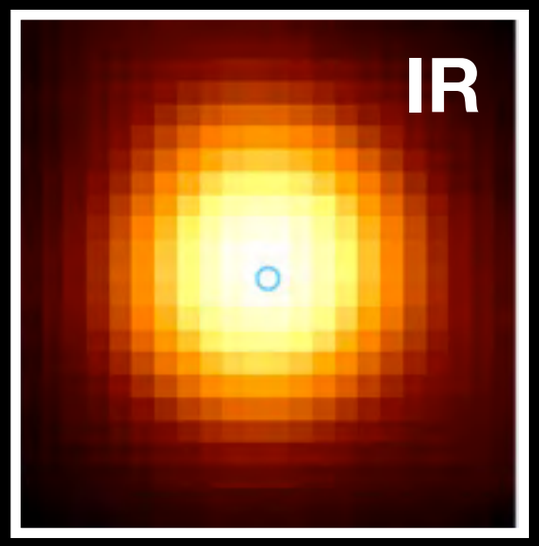
หมา dog 개 chien कुत्ता cão 犬 собака

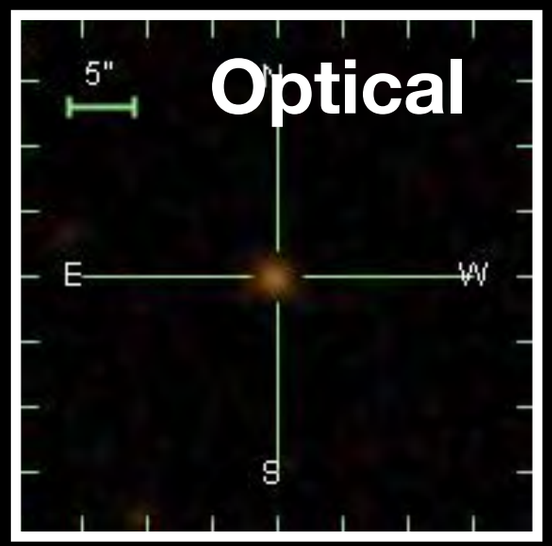
Dust-Obscured Galaxies

i - [22] > 7.0 (AB mag)

Toba et al. 2015, PASJ, 67, 86

- An optically faint but infrared (IR) bright objects.

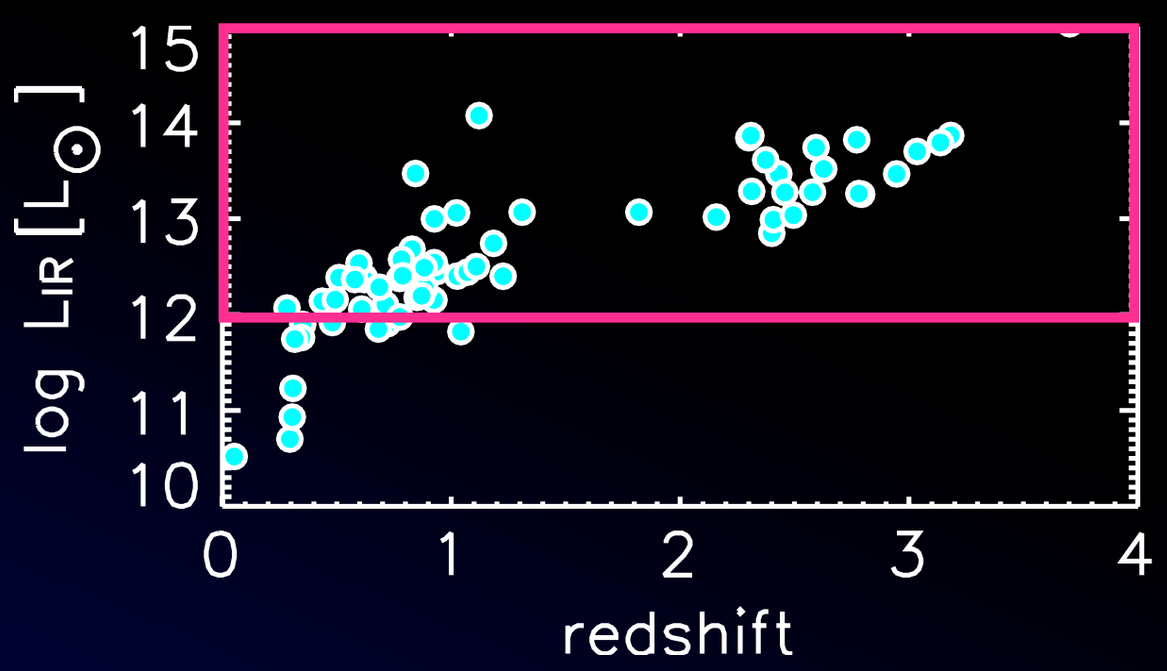




~ ULIRGs, HyLIRGs

- Most DOGs are ultra-luminous infrared galaxies (ULIRGs: $L_{IR} \geq 10^{12}\ L_{sun}$)
- Some DOGs are hyper-luminous infrared galaxies (HyLIRGs: $L_{IR} \geq 10^{13}\ L_{sun}$)

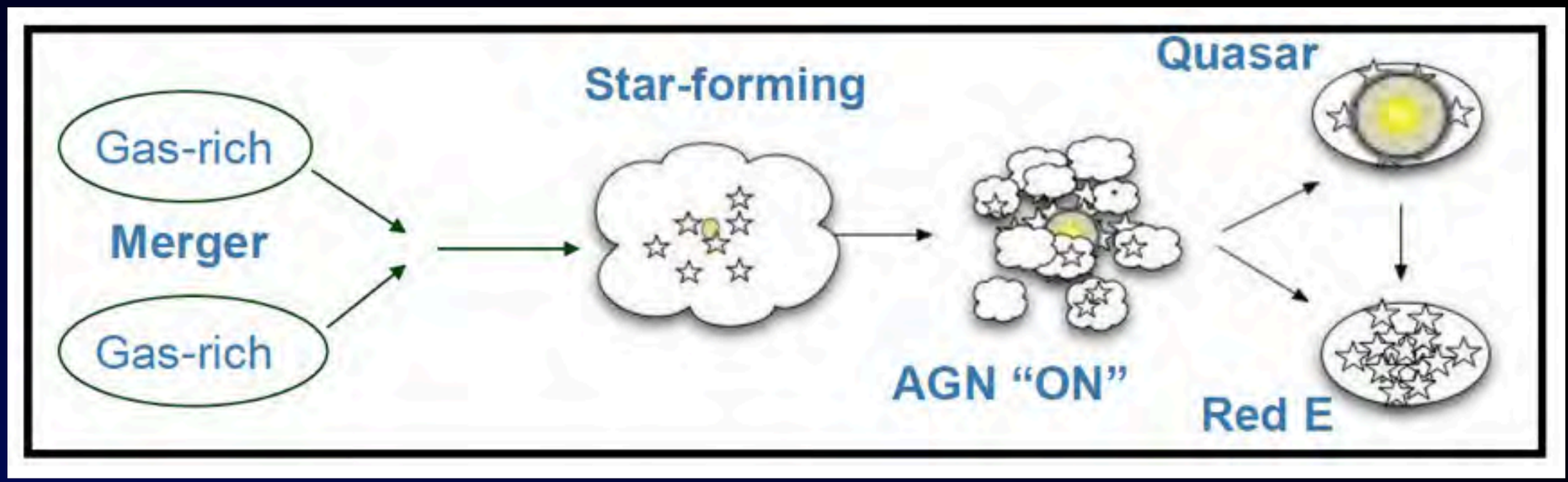
F(IR) > **1000** × F(optical)



Toba & Nagao 2016, ApJ, 820, 46

The importance of IR-bright DOGs

- In the context of major merger scenario, particularly IR-bright DOGs (F_{MIR} > 1 mJy) may correspond to a maximum phase of AGN activity behind a large amount of dust.
- Some IR-bright DOGs are expected to be a “blowout” phase during the co-evolution.



Dey+09

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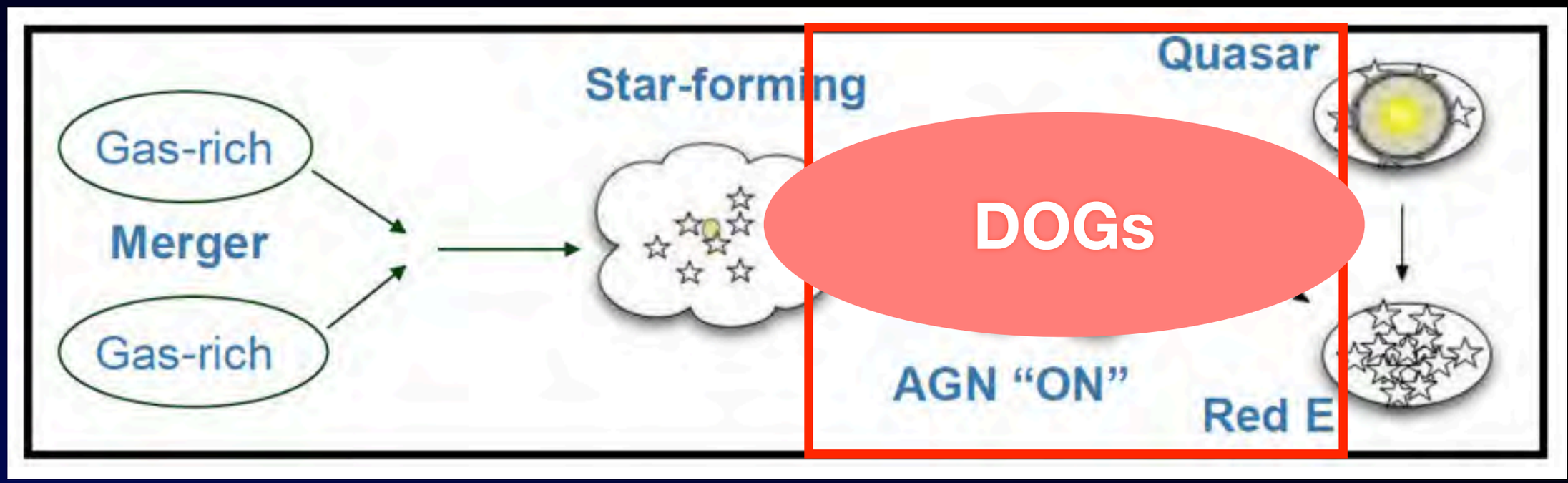


Dey+09

The importance of IR-bright DOGs

IR-bright DOGs are key population to understanding the co-evolution.

They are a good laboratory to investigate the AGN feedback phenomenon.

Dey+09

IR-bright DOGs survey with SDSS and WISE

Toba & Nagao 2016, ApJ, 820, 46

SDSS spec

WISE

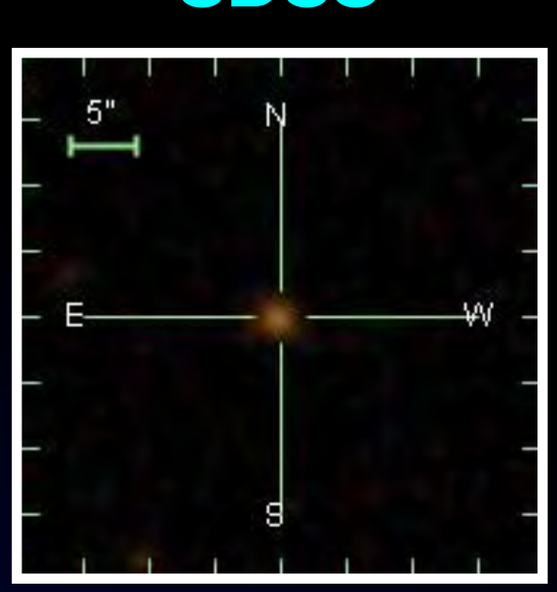
SDSS-WISE object

i - [22] >7

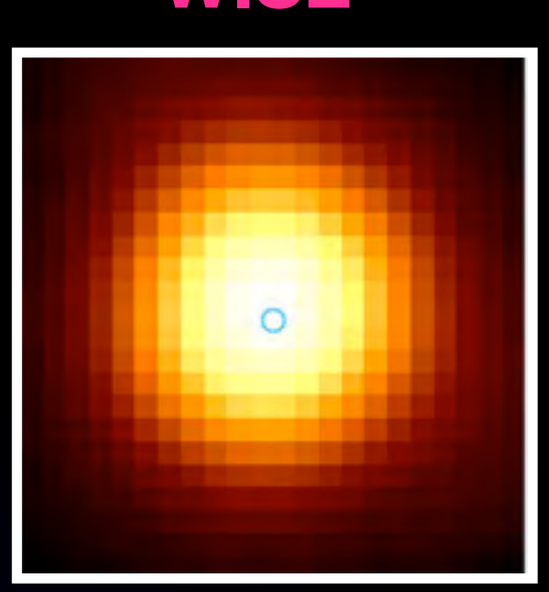
SDSS-WISE DOGs

67

SDSS



WISE



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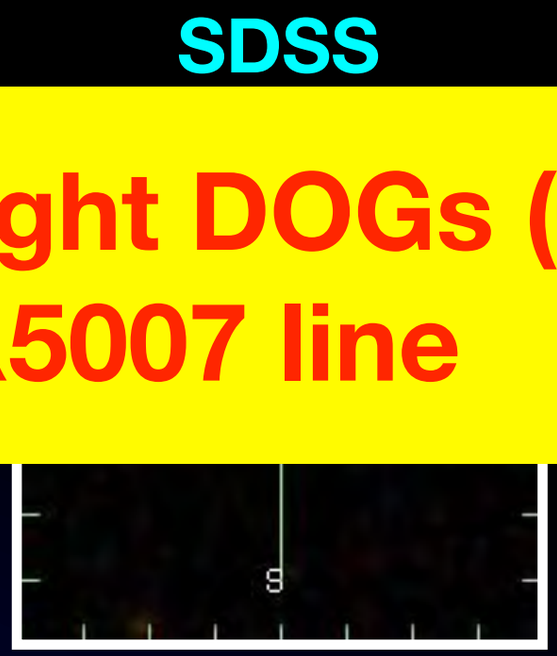
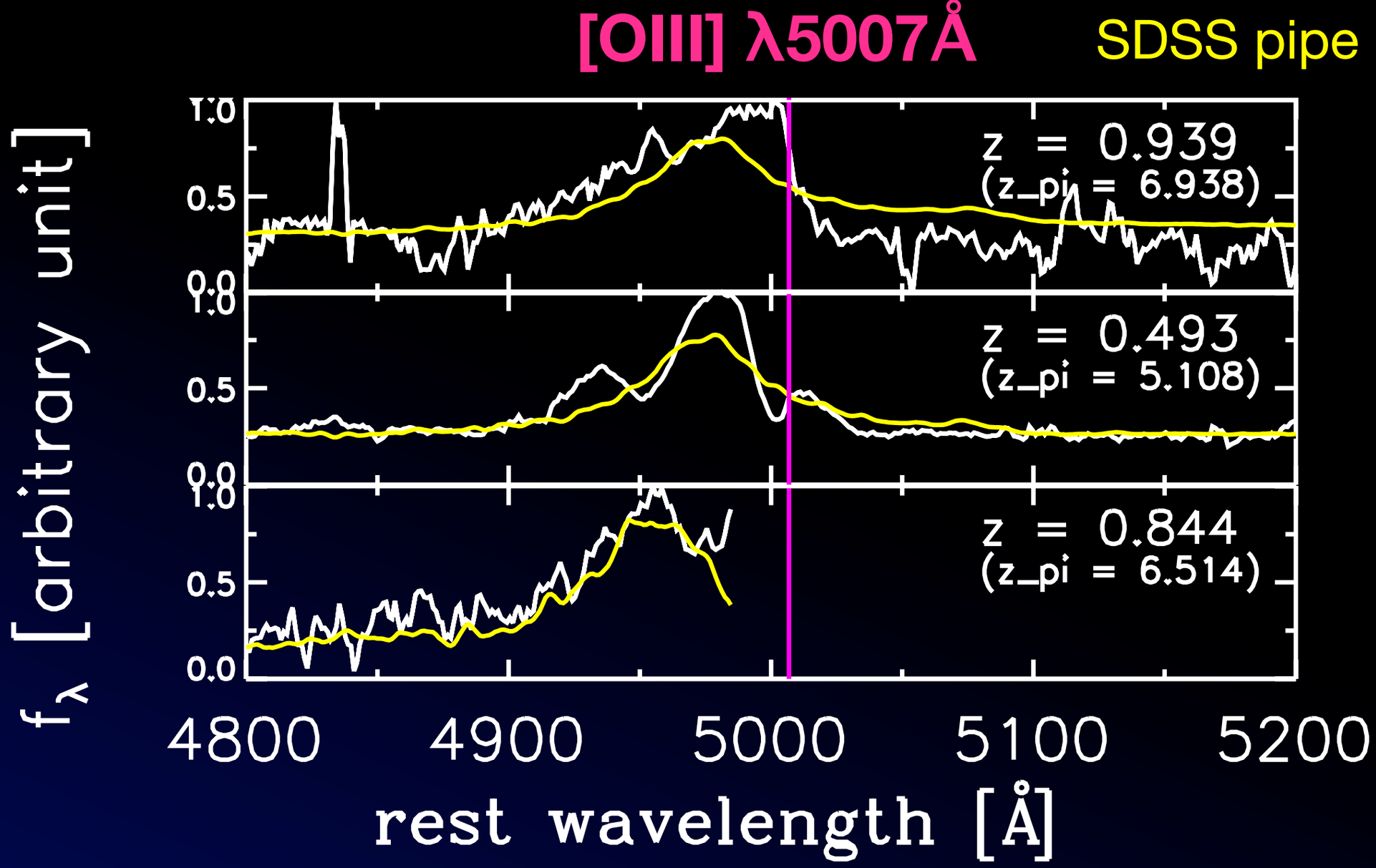
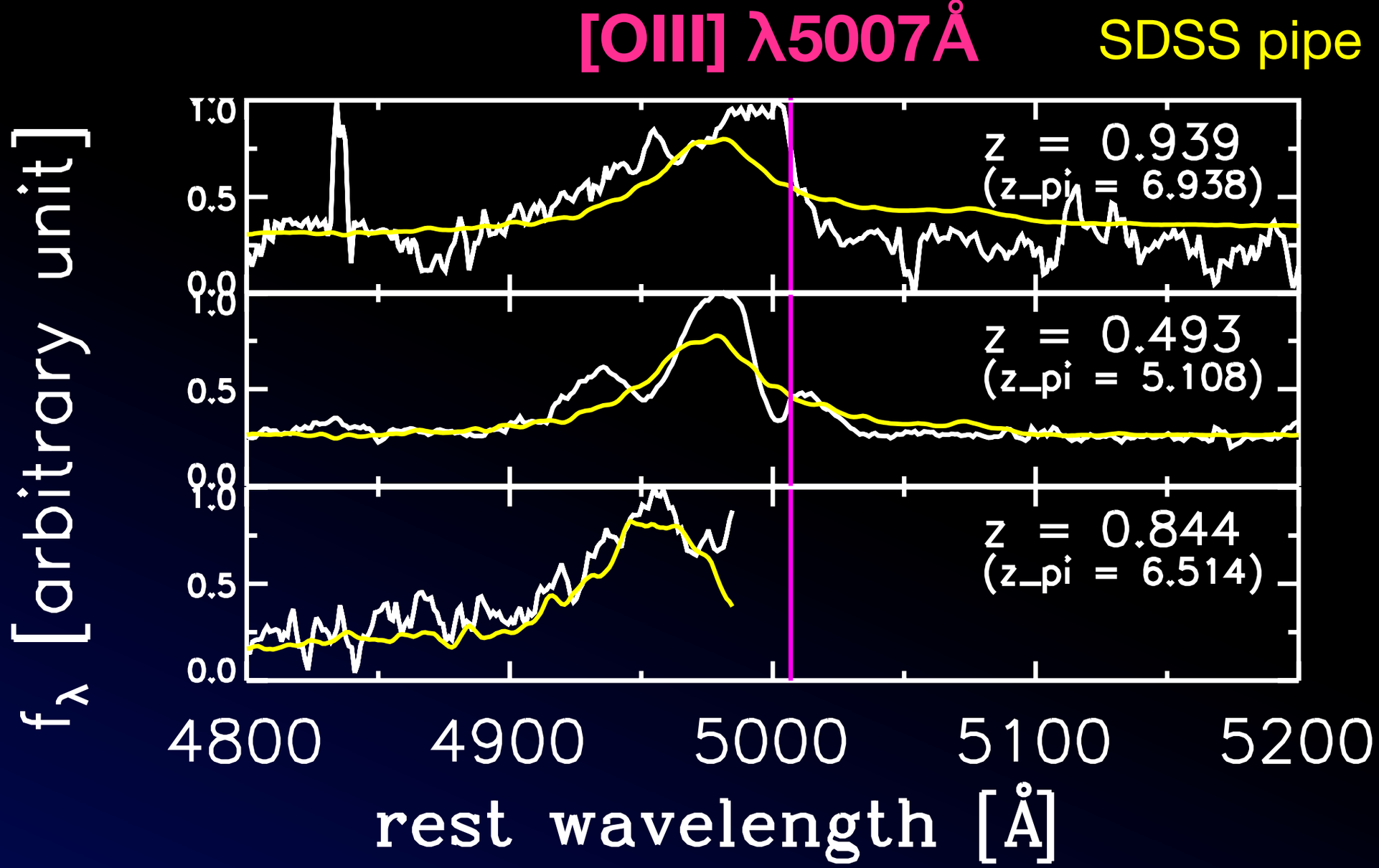


We focus on 32 IR-bright DOGs ($0 < z < 1$) with [OIII]λ5007 line

Broad & blue-shifted [OIII]λ5007Å



Some objects have broad and blueshifted [OIII] line that is mis-identified as Lyα based on the SDSS pipeline



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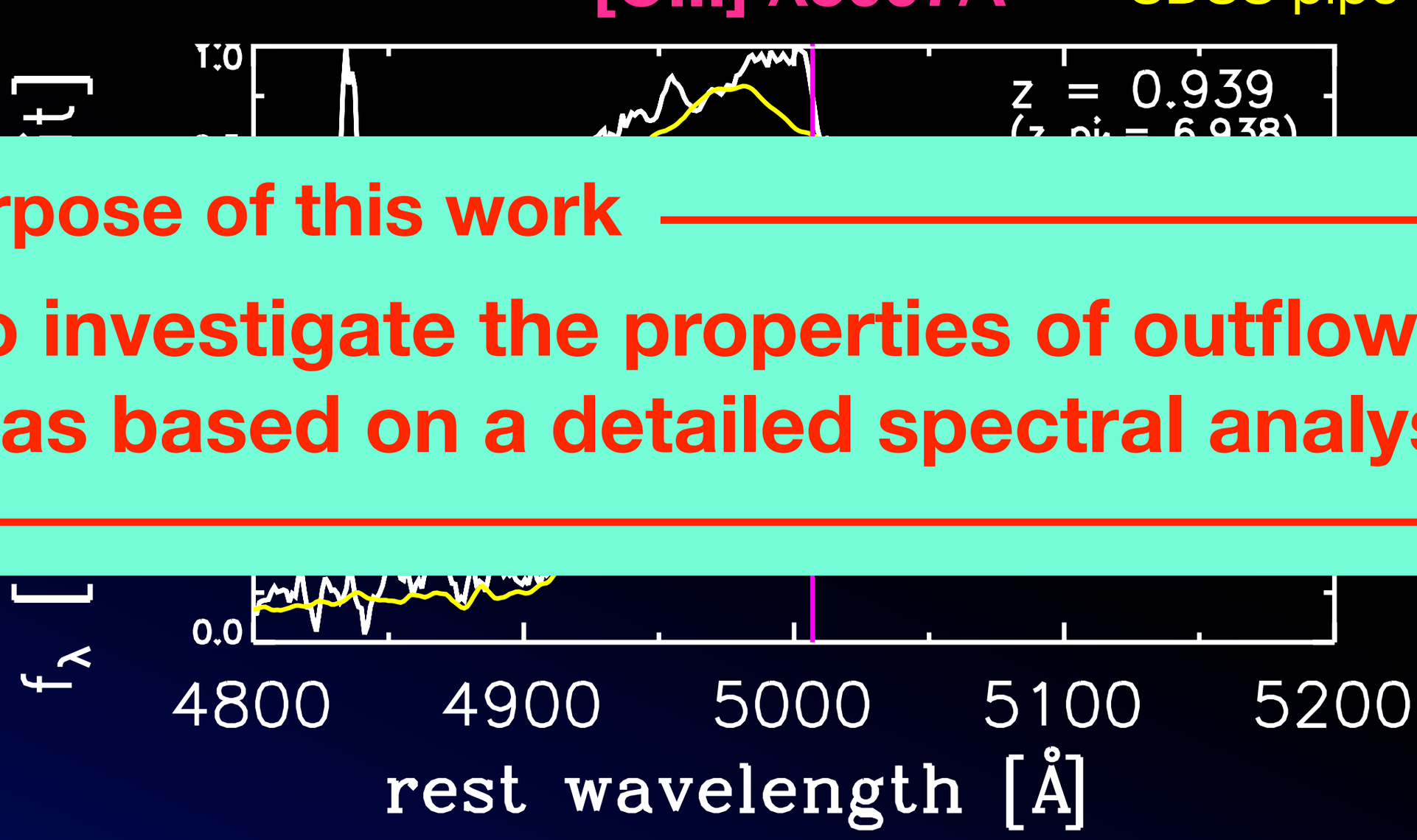


Purpose of this work

To investigate the properties of outflowing gas based on a detailed spectral analysis

We discovered IR-bright DOGs with strong ionized gas outflow

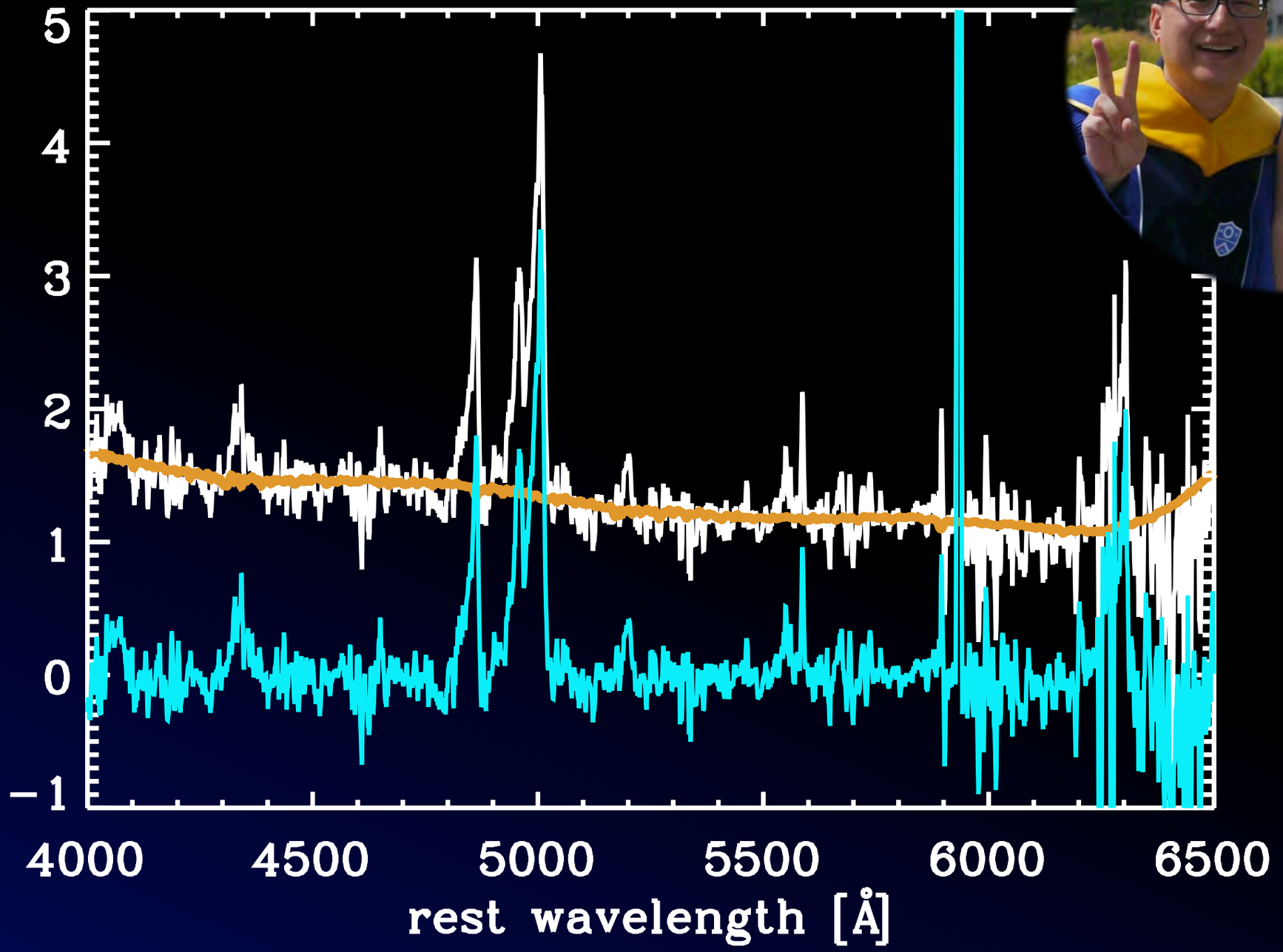
outflowing DOG!?

Data and Analysis

How do we evaluate a peculiar profile of [OIII] line?

Spectral analysis

collaborated with
Dr. Hyun-Jin Bae



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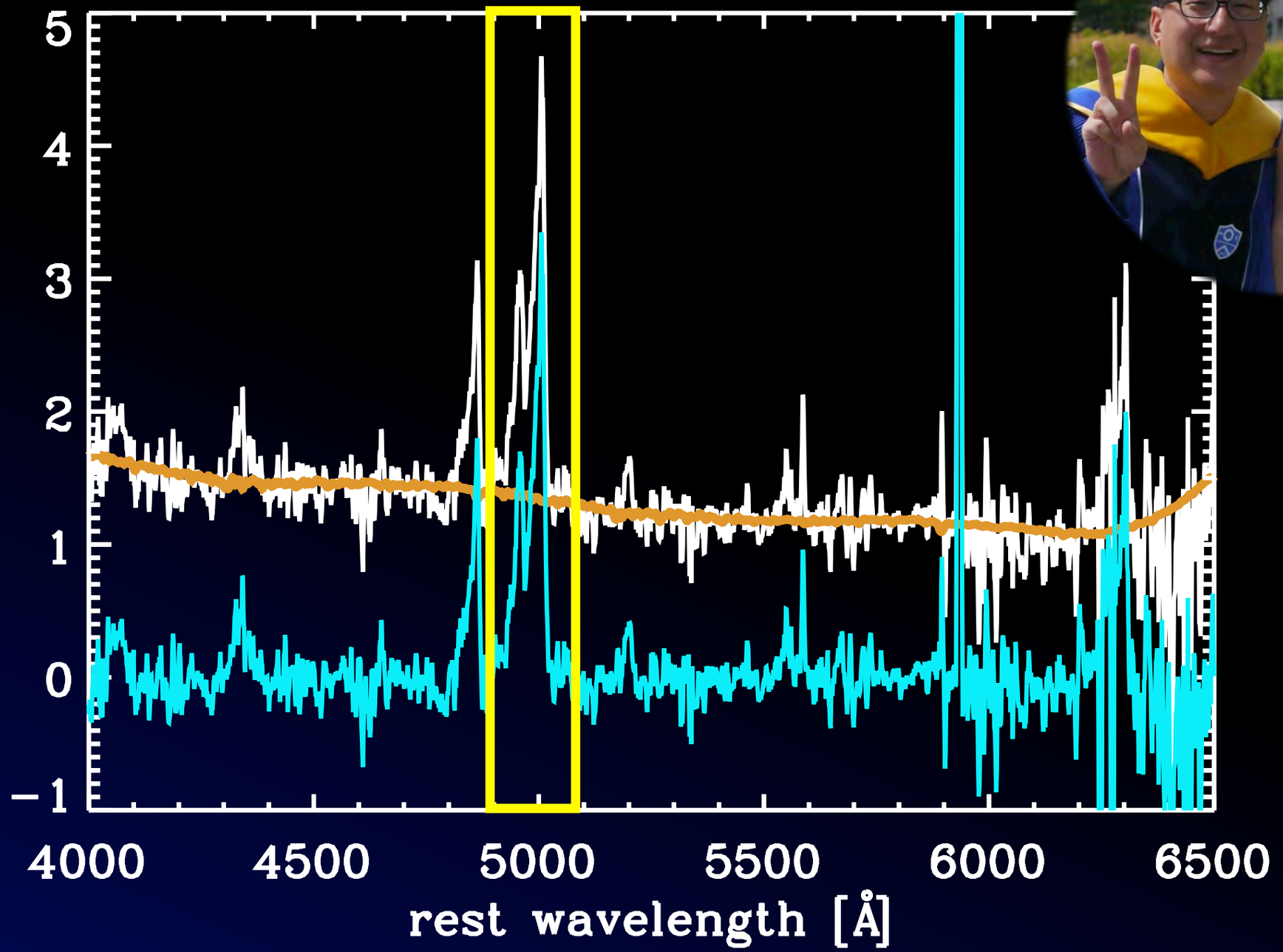
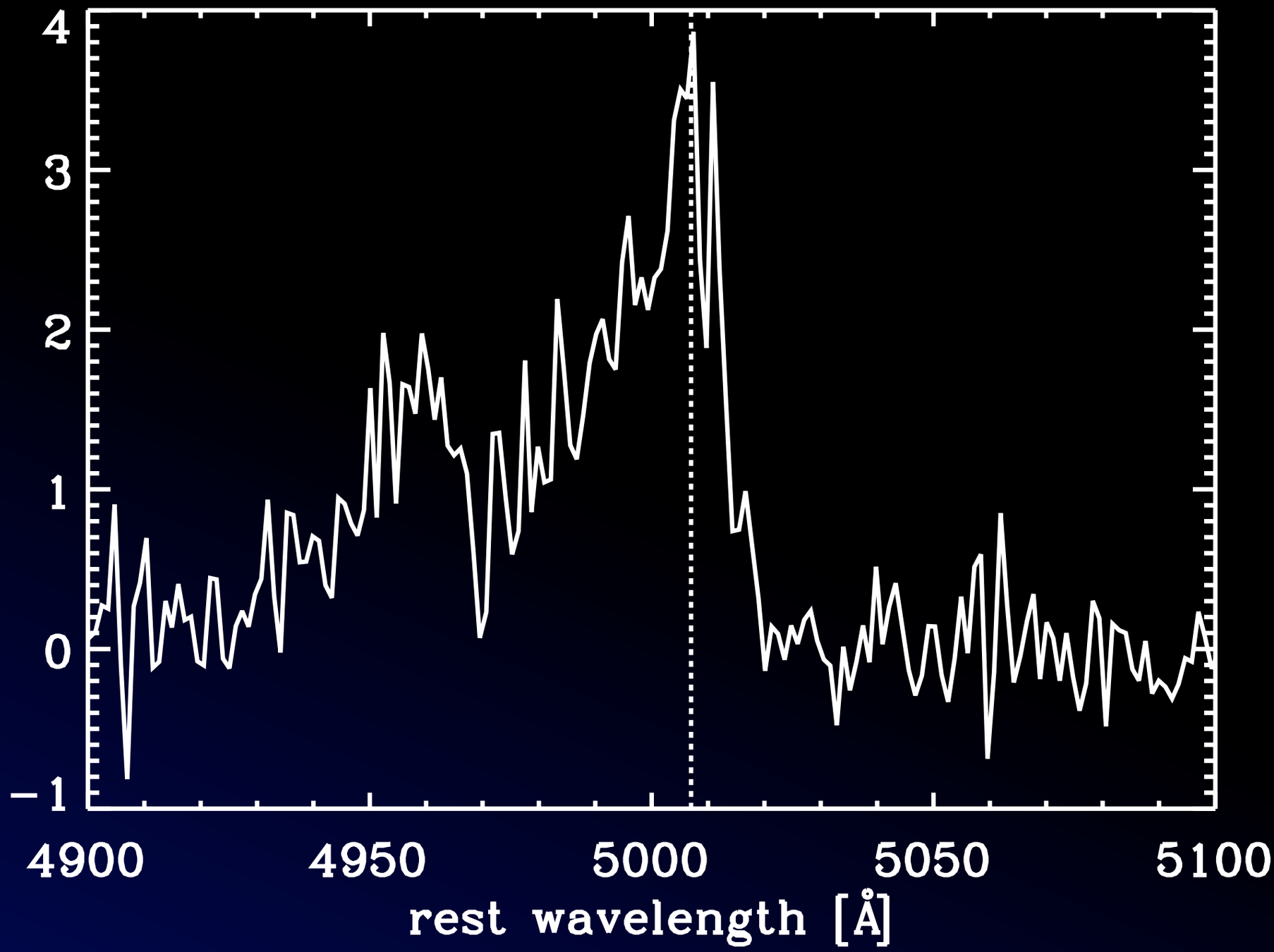
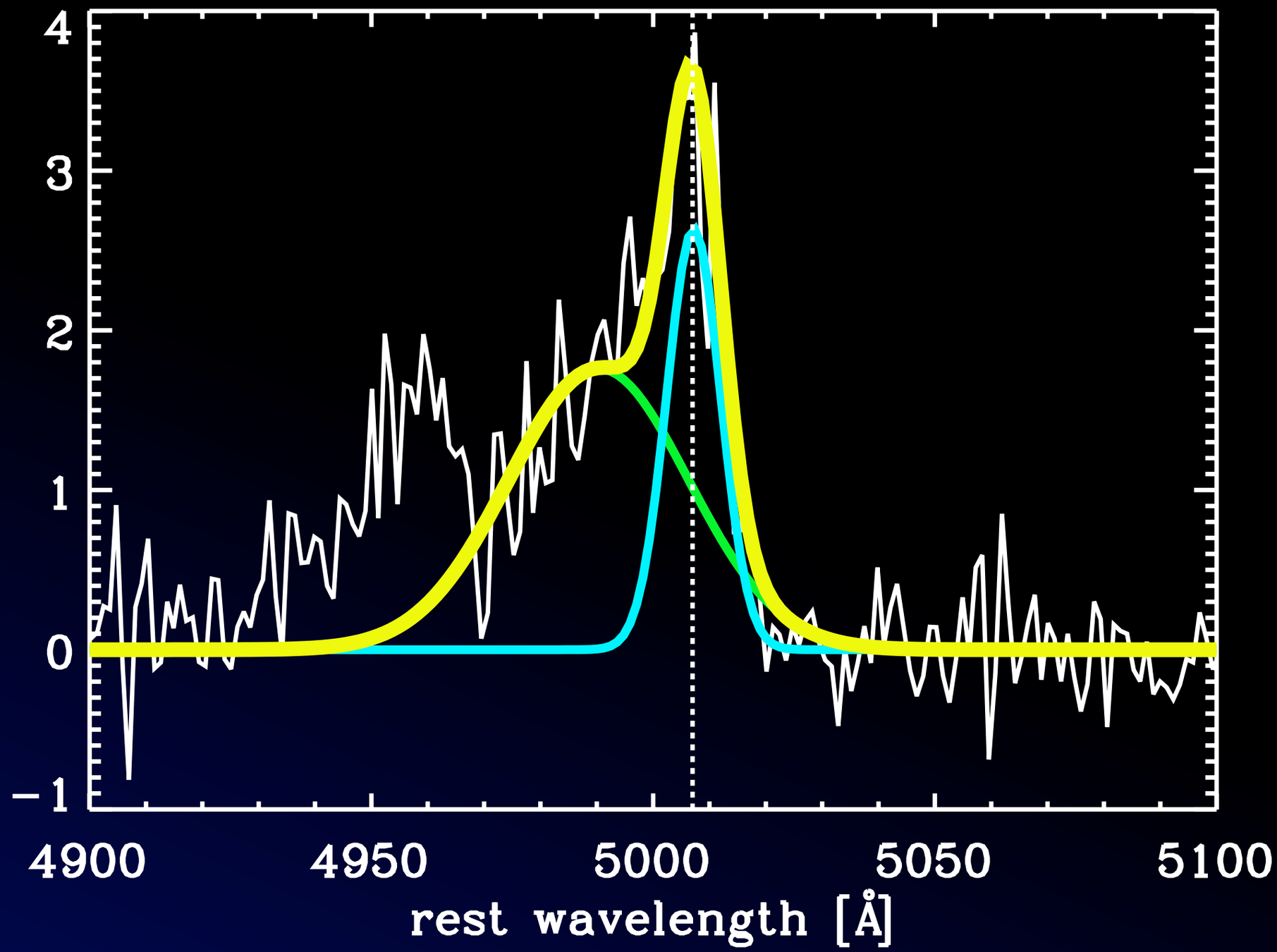


Spectral analysis



Spectral analysis



Spectral analysis

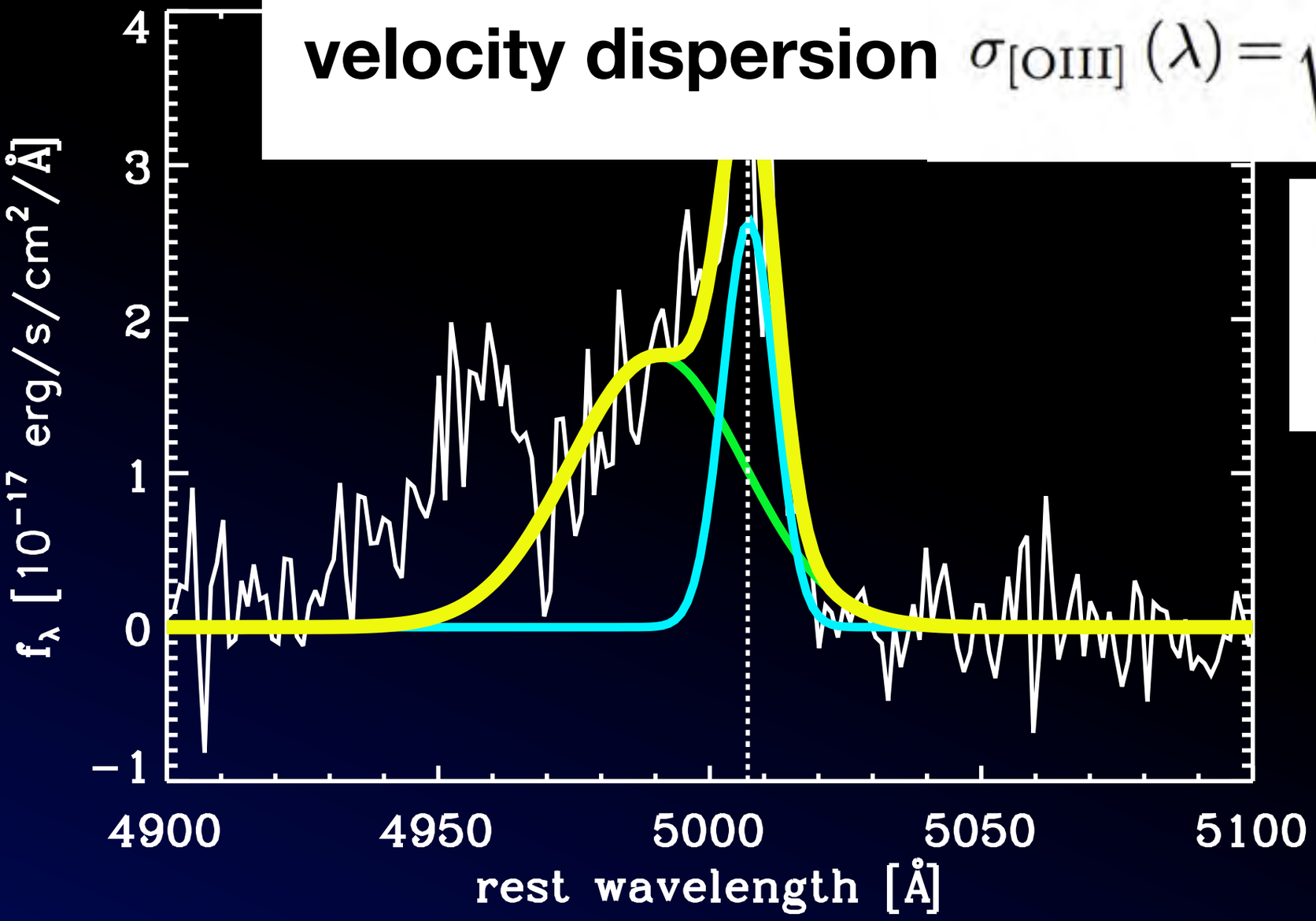
velocity offset

$$v_{[\mathrm{OIII}]}(\lambda) = \frac{(\lambda_0 - \lambda_{\mathrm{rest}})c}{\lambda_{\mathrm{rest}}} - v_{\mathrm{sys}}(\lambda)$$

velocity dispersion

$$\sigma_{[\mathrm{OIII}]}(\lambda) = \sqrt{\frac{\int \lambda^2 f(\lambda)\,\mathrm{d}\lambda}{\int f(\lambda)\,\mathrm{d}\lambda} - \lambda_0^2}$$

$$\lambda_0 = \frac{\int \lambda f(\lambda)\,\mathrm{d}\lambda}{\int f(\lambda)\,\mathrm{d}\lambda}$$



We discovered IR-bright DOGs with strong ionized gas outflow

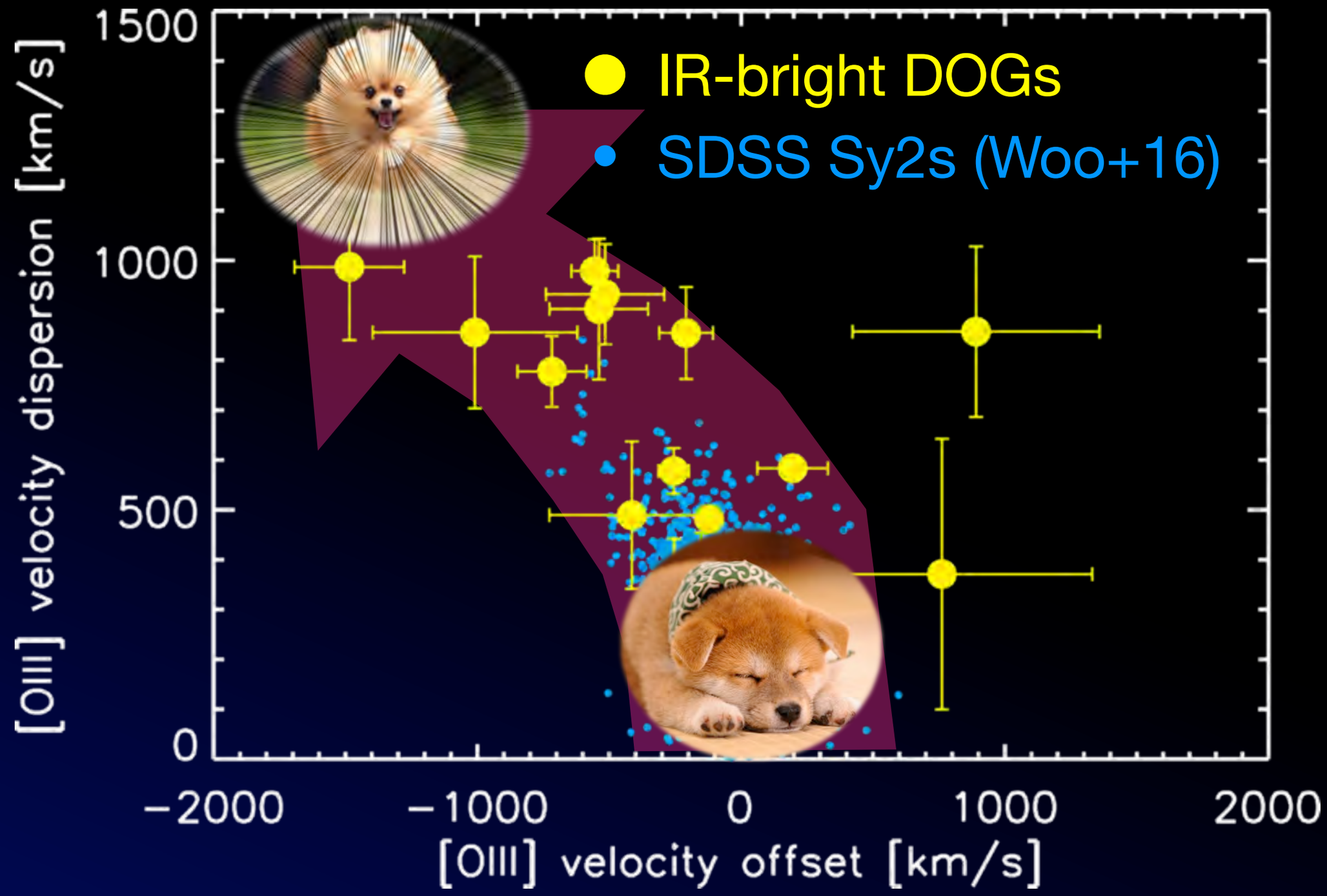
Results and Discussions

Comparison of outflow strength between IR-bright DOGs and Sy2s

What determines the outflow strength?

How about other lines such as [OII]λ3727?

Velocity offset — Velocity Dispersion diagram



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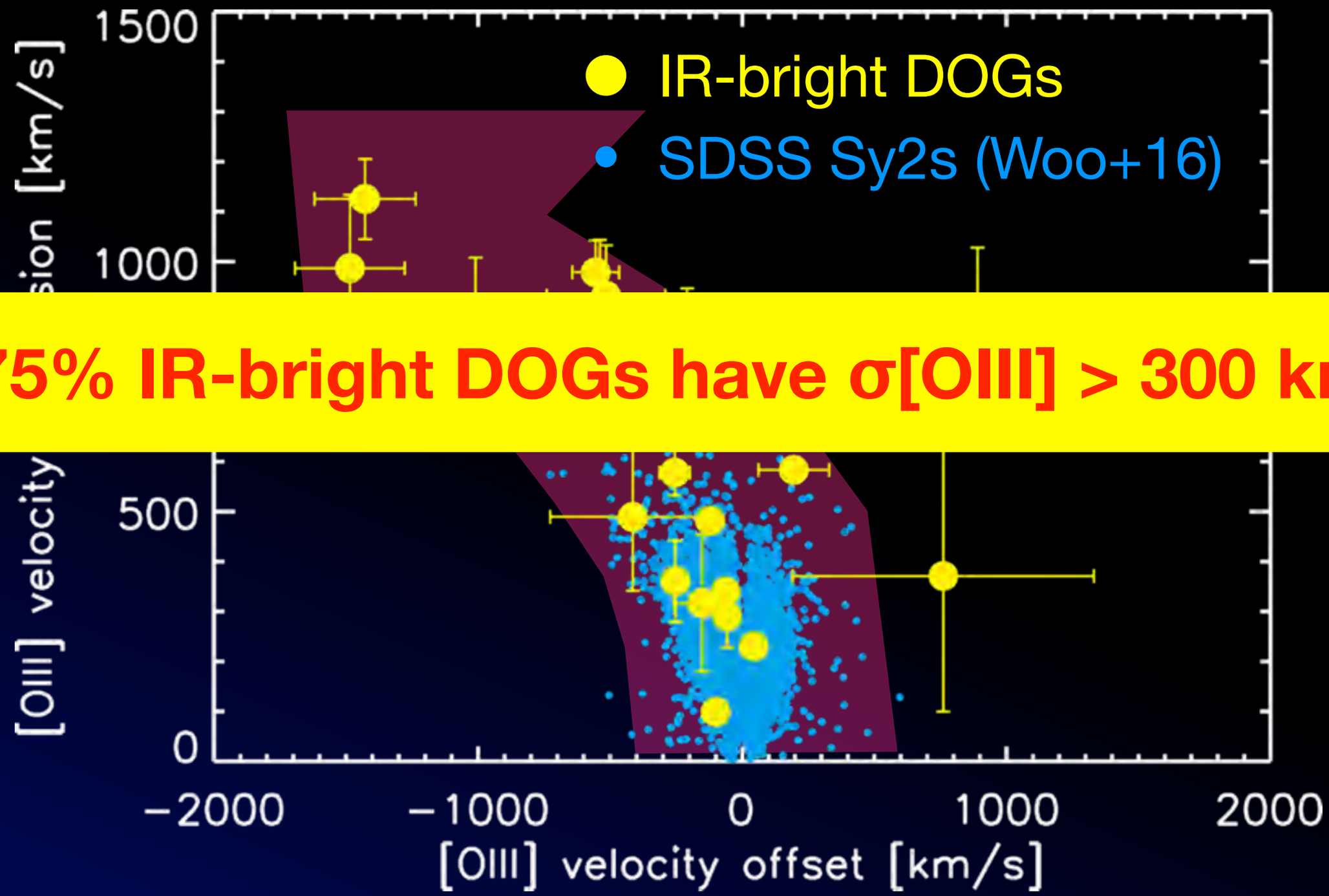
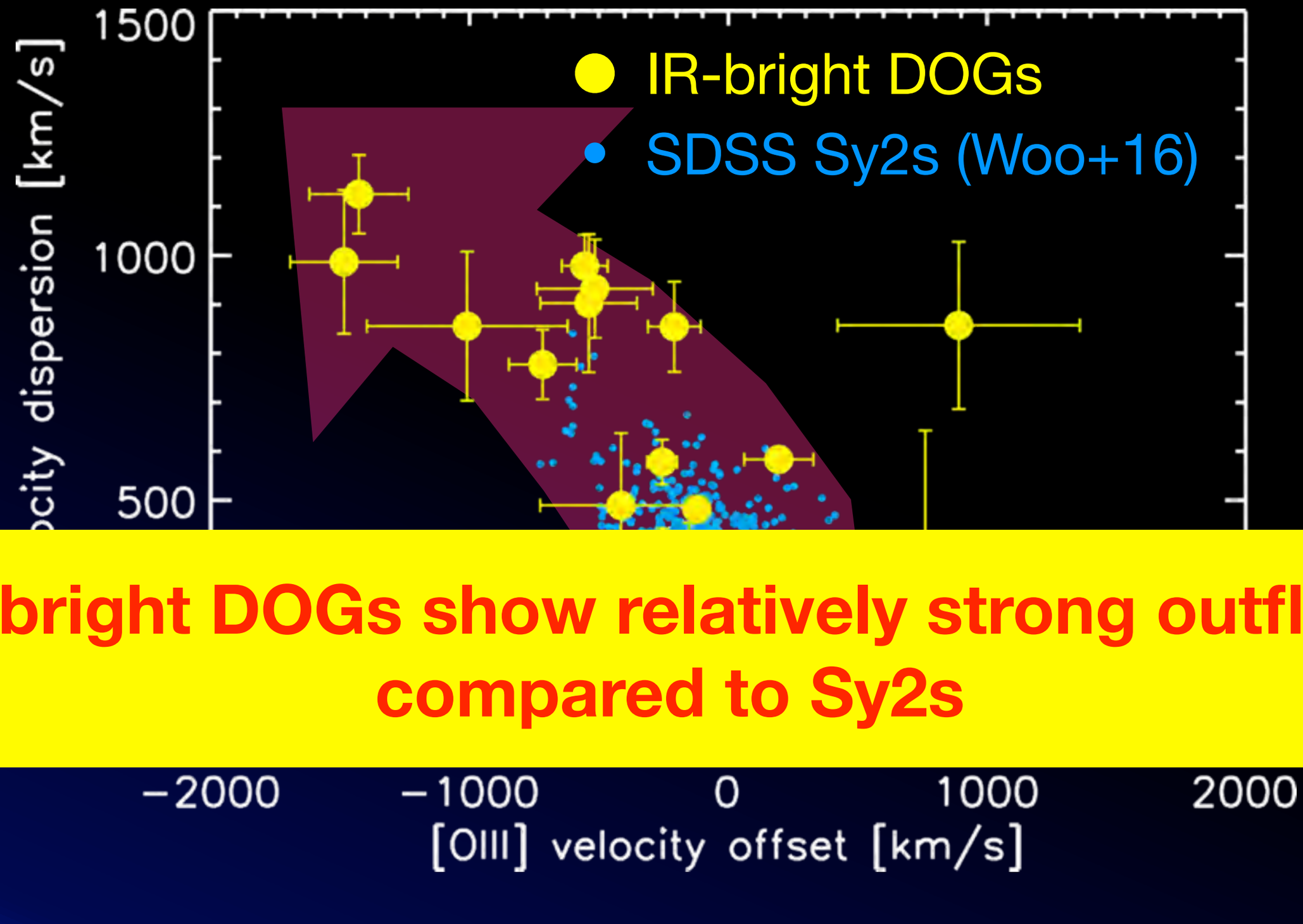


~75% IR-bright DOGs have σ[OIII] > 300 km/s

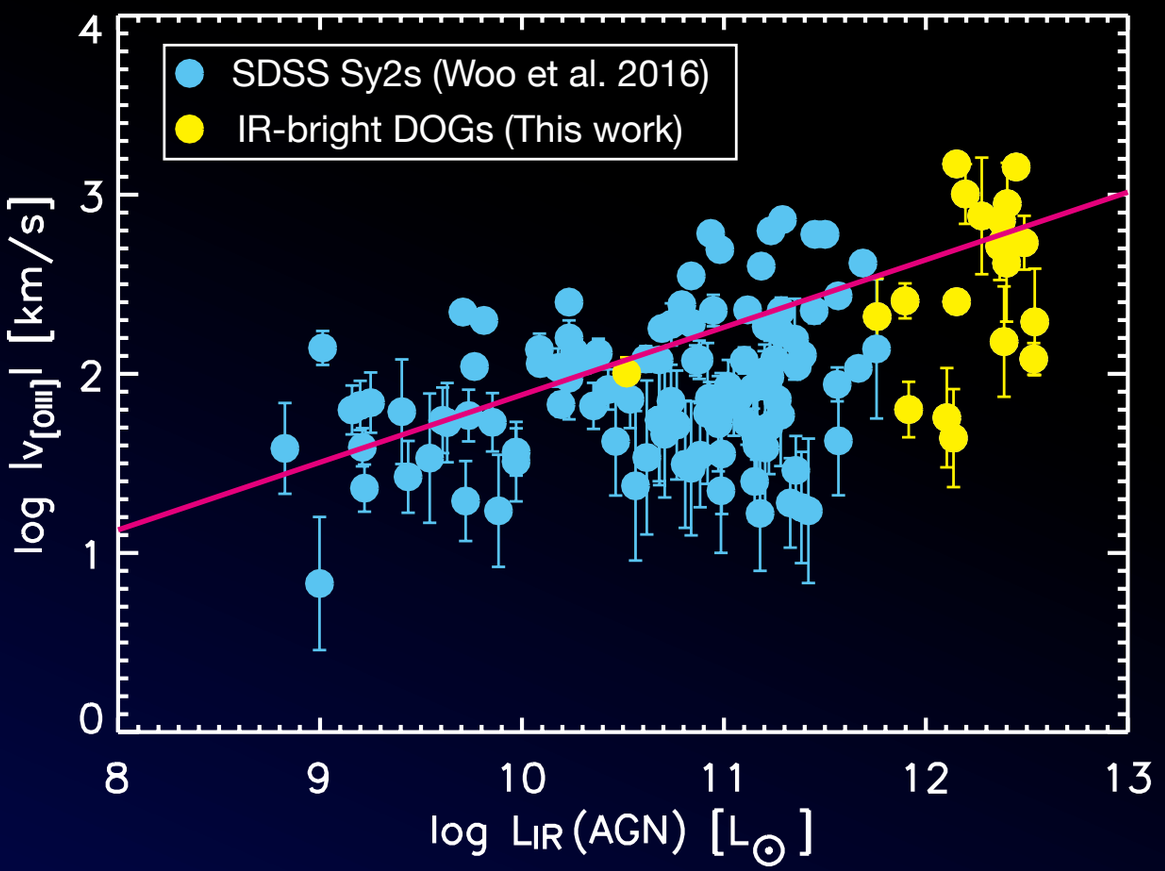
Velocity offset — Velocity Dispersion diagram



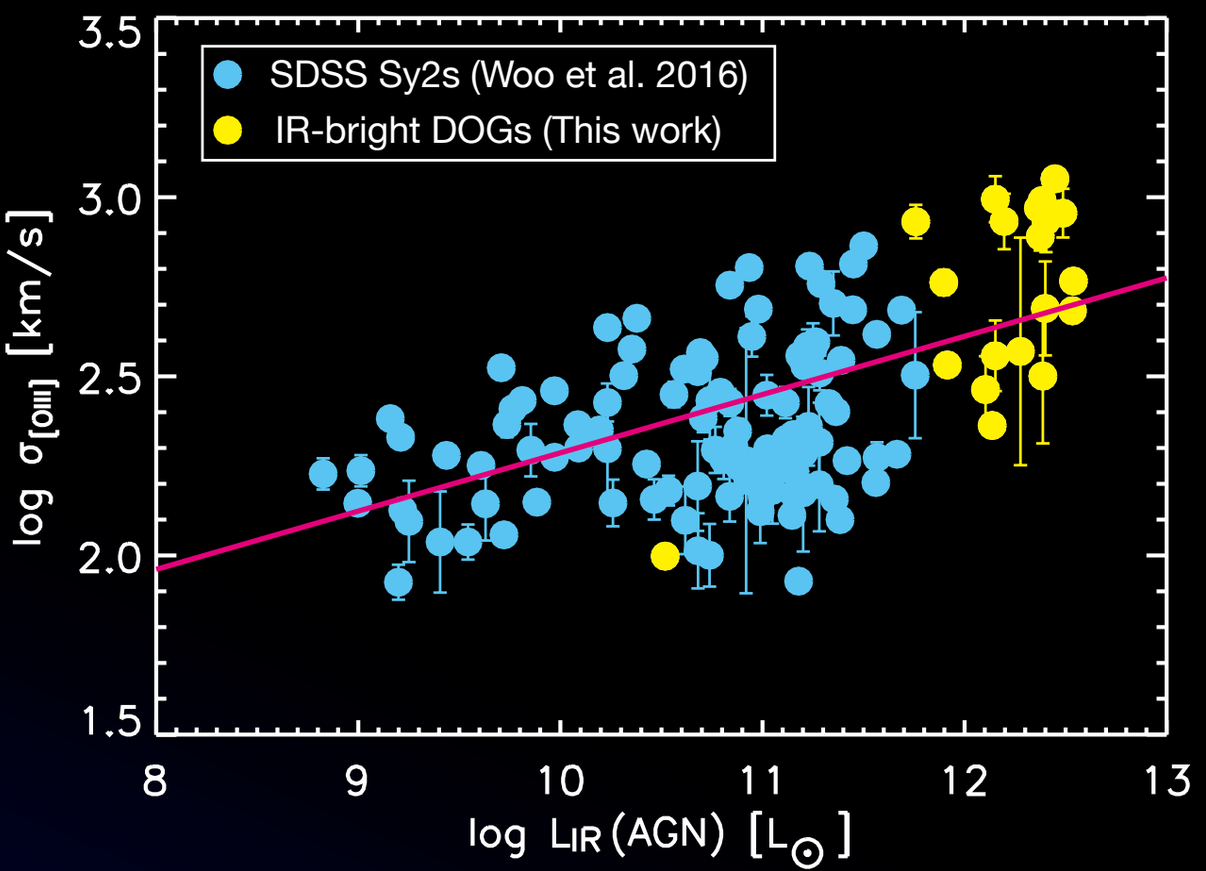
IR-bright DOGs show relatively strong outflows compared to Sy2s

LIR (AGN) vs. outflow strength

$v_{[OIII]}$ vs. L_{IR} (AGN)



$\sigma_{[OIII]}$ vs. L_{IR} (AGN)



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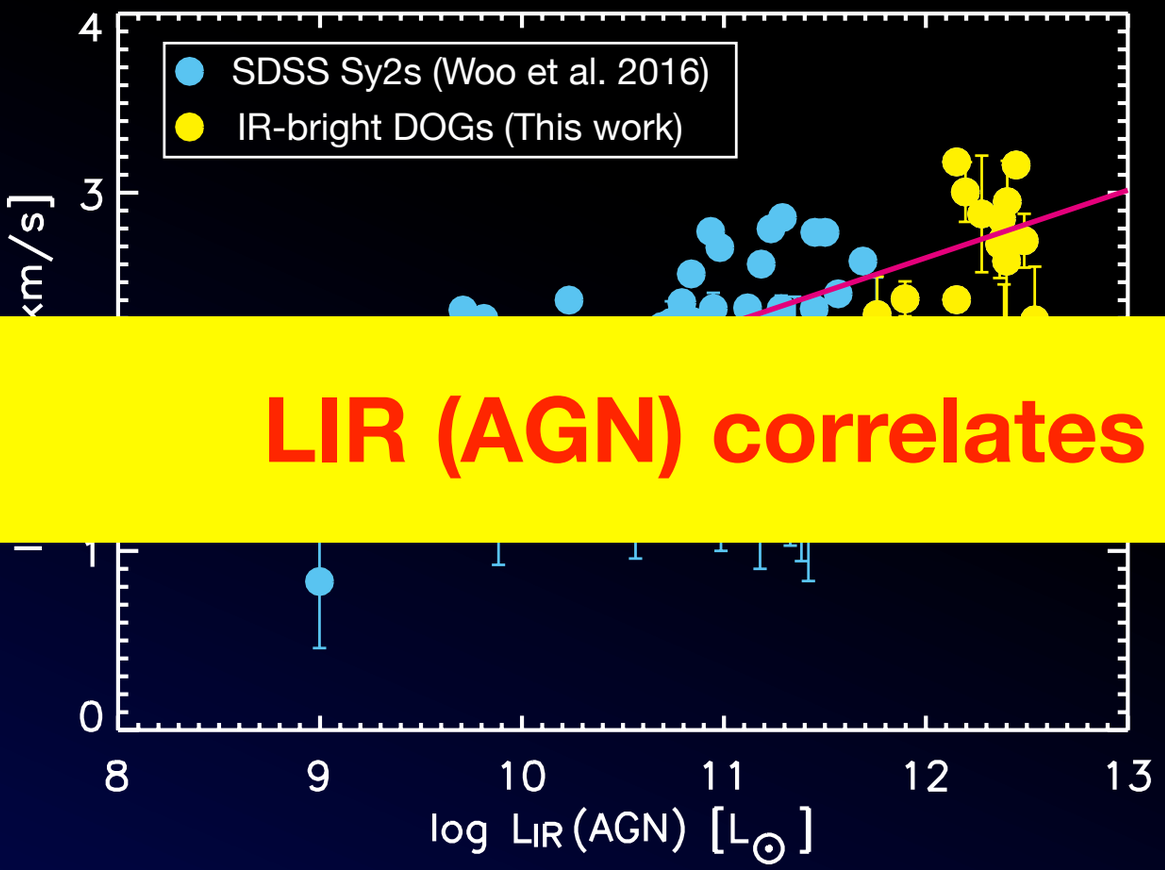

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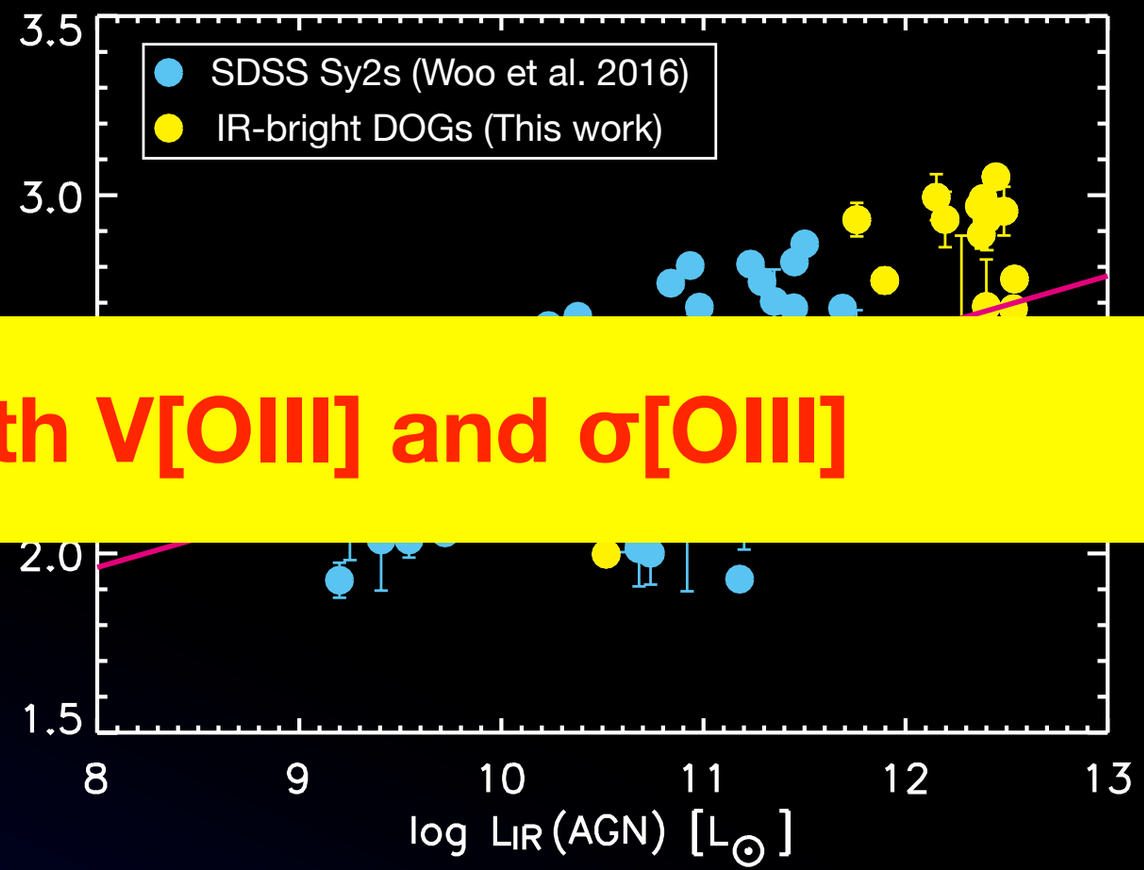
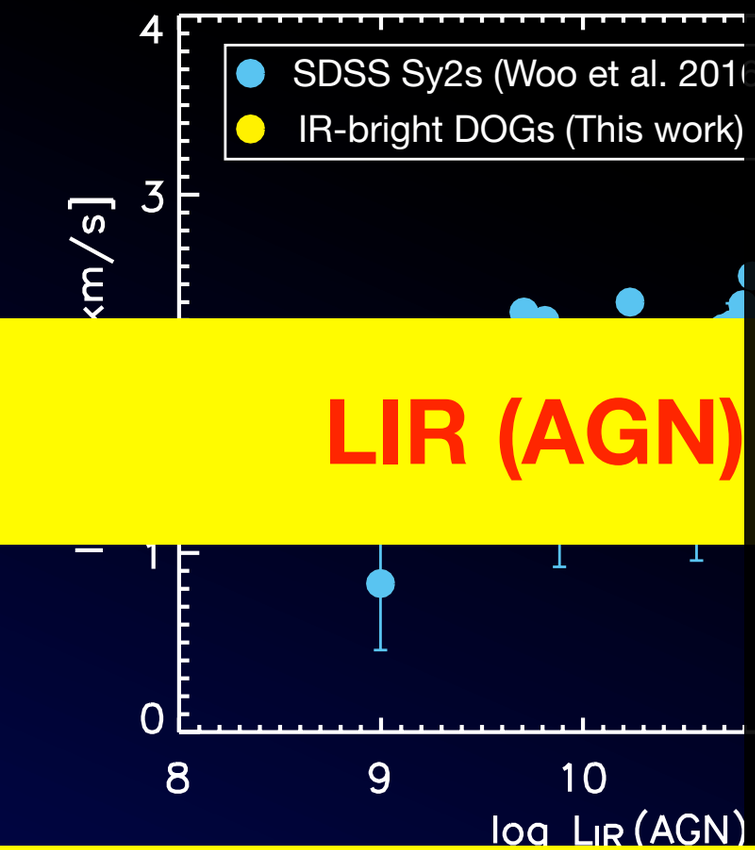


LIR (AGN) correlates with V[OIII] and σ[OIII]

LIR (AGN) vs. outflow strength



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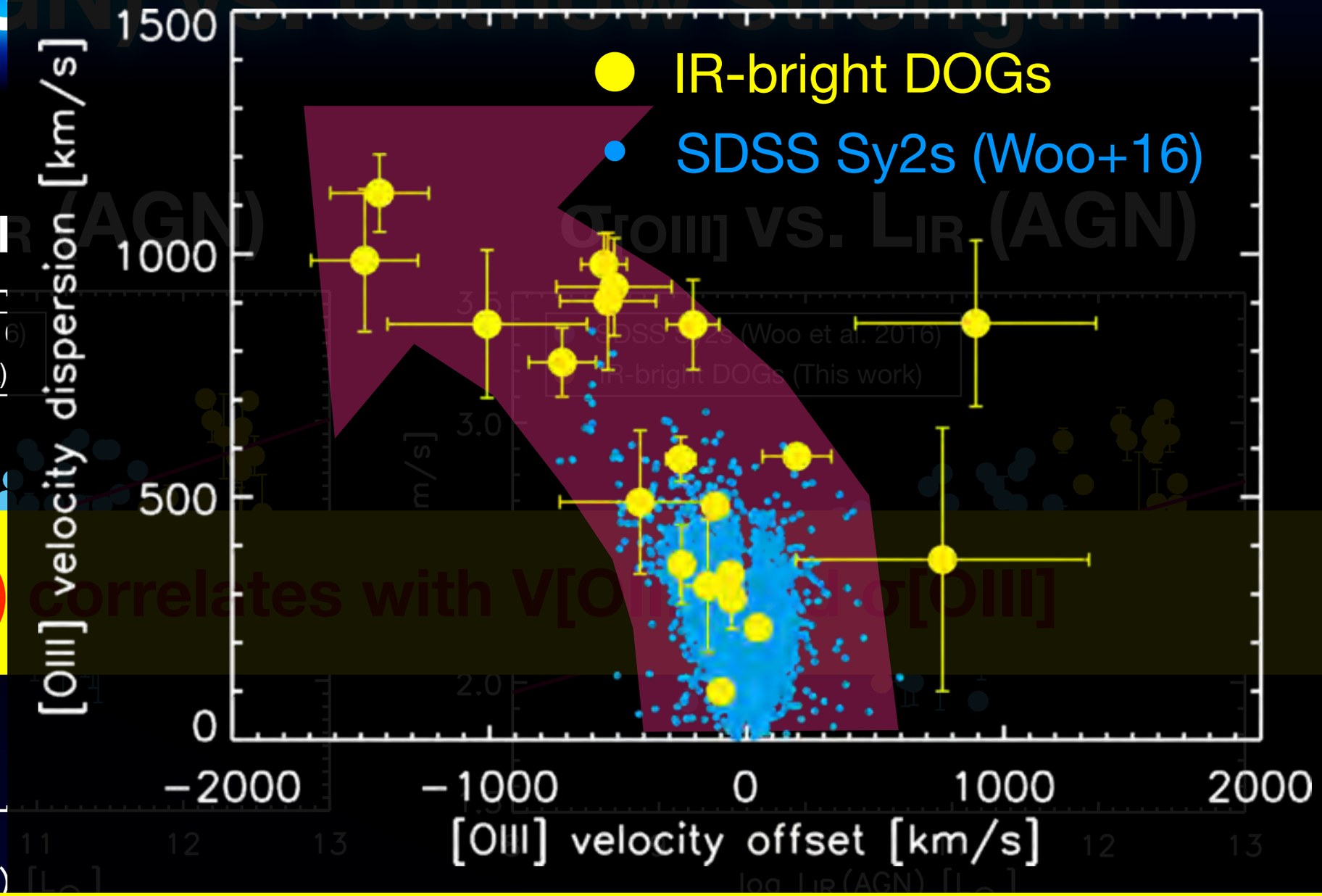
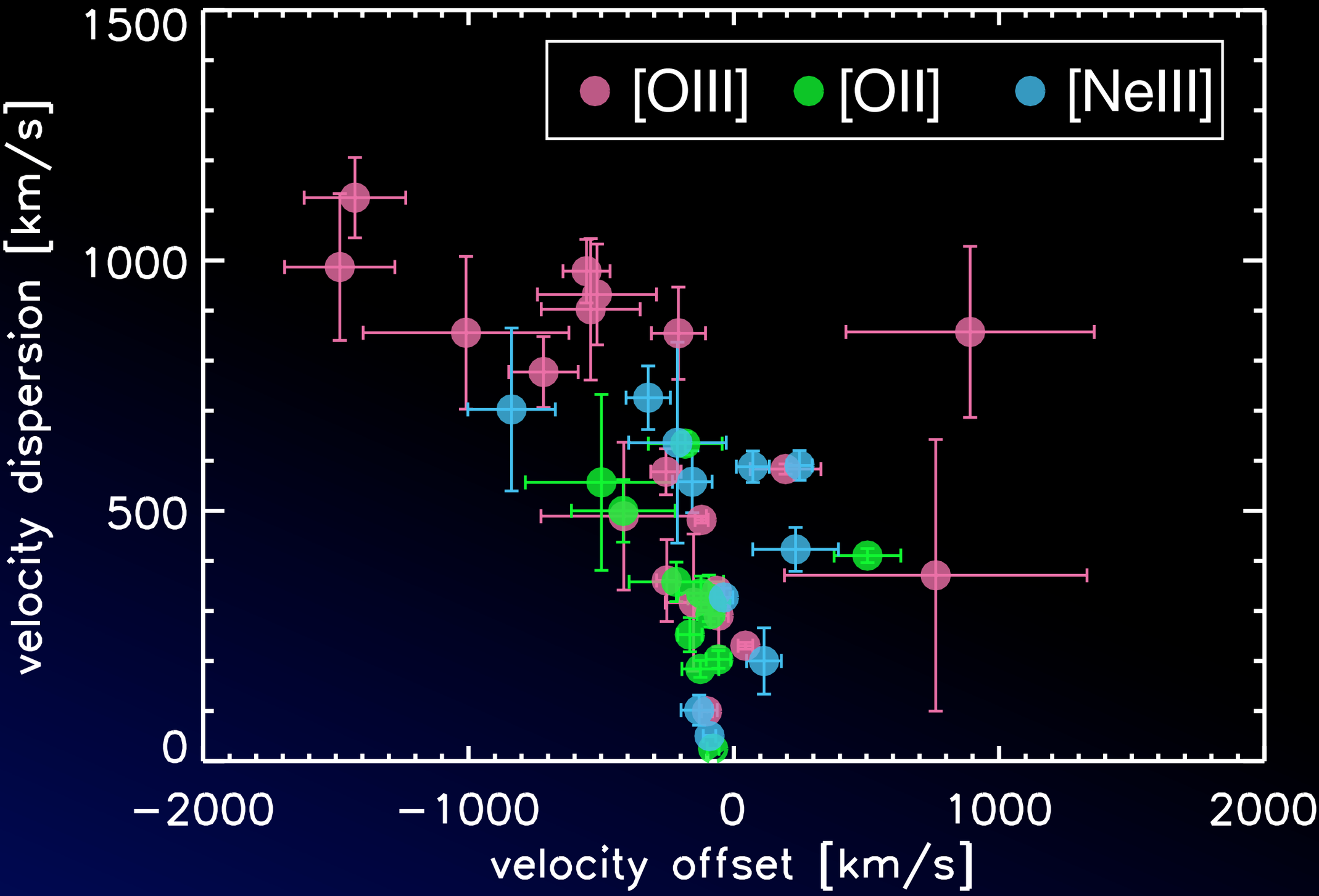


The systematic offset on the VVD is due to the difference in LIR(AGN)

VVD diagram for other lines



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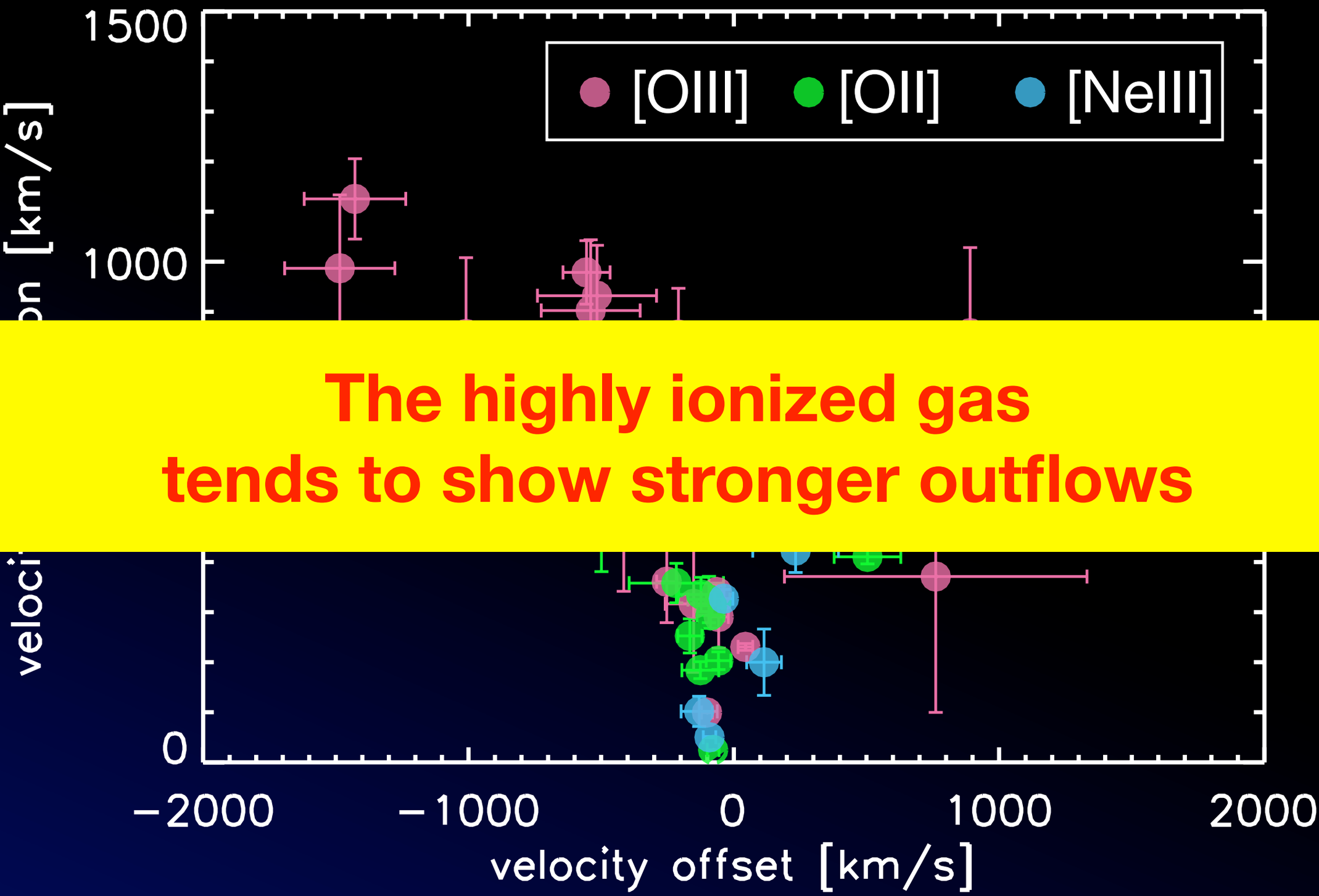
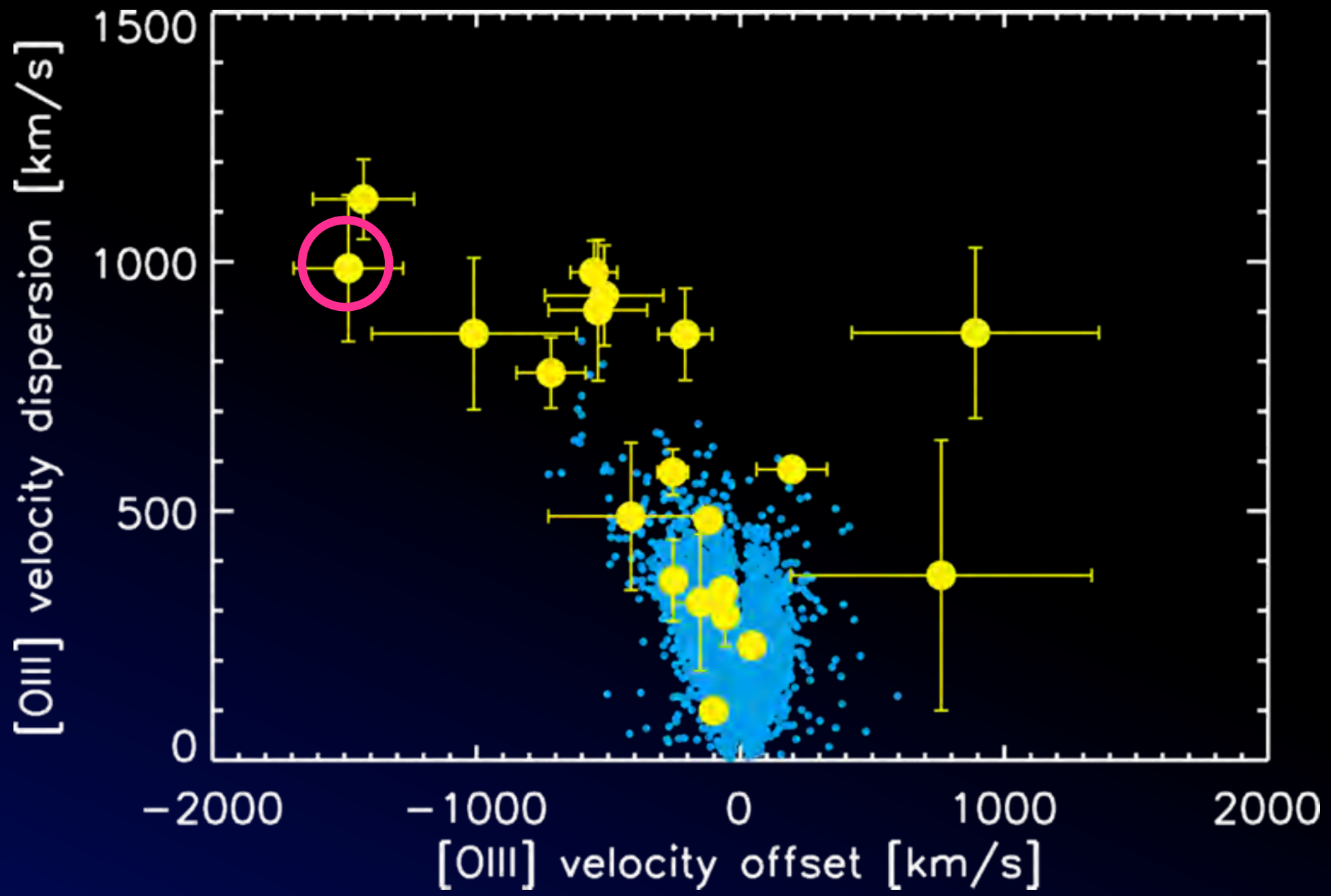


The highly ionized gas tends to show stronger outflows

How about a molecular gas?

Toba et al. 2017d, ApJ, accepted (arXiv:1711.10091)



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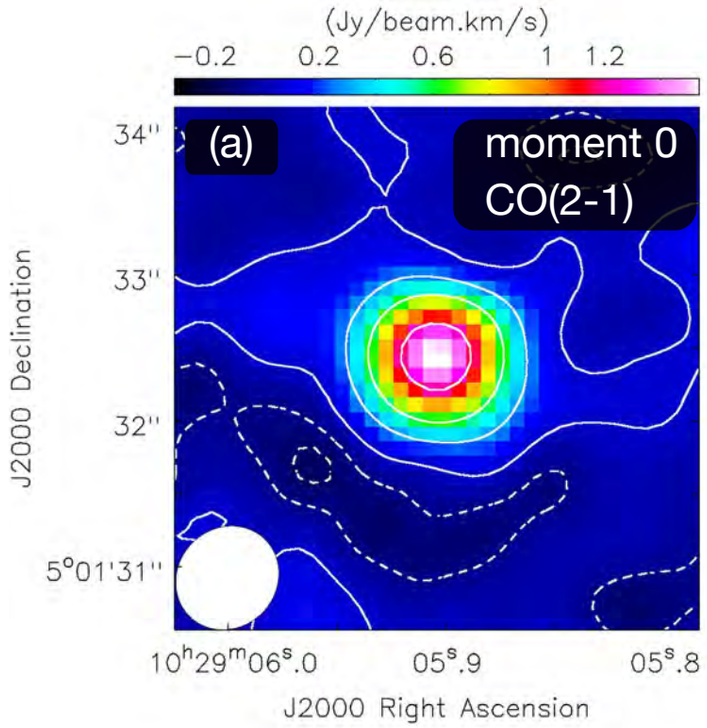
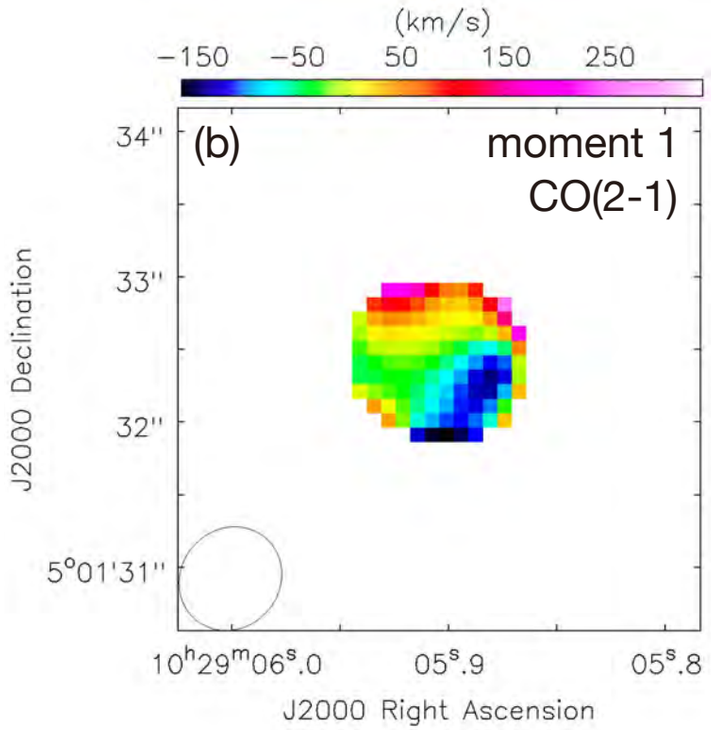
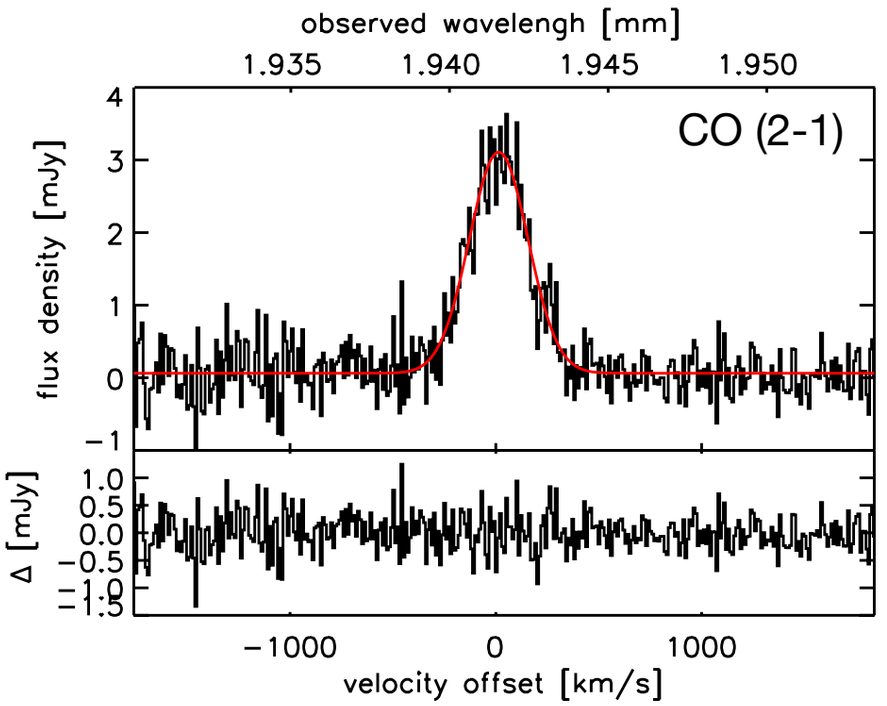
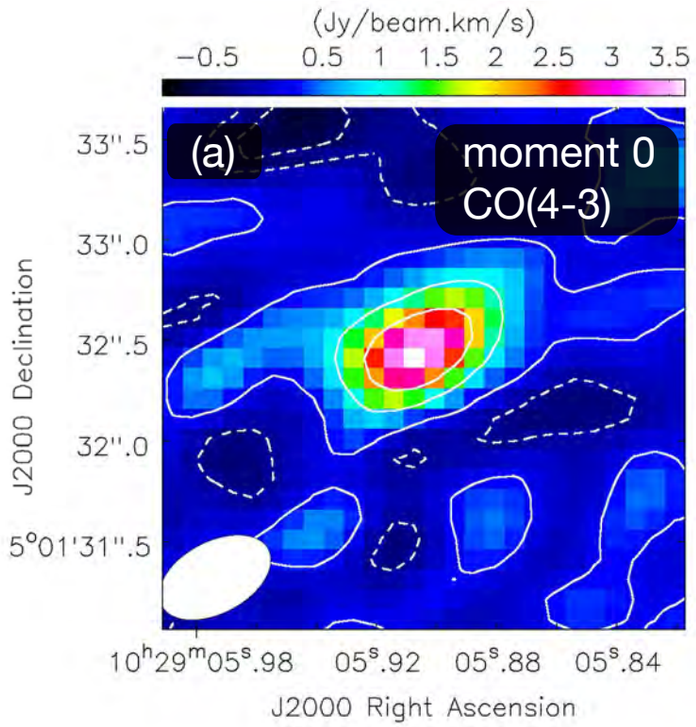
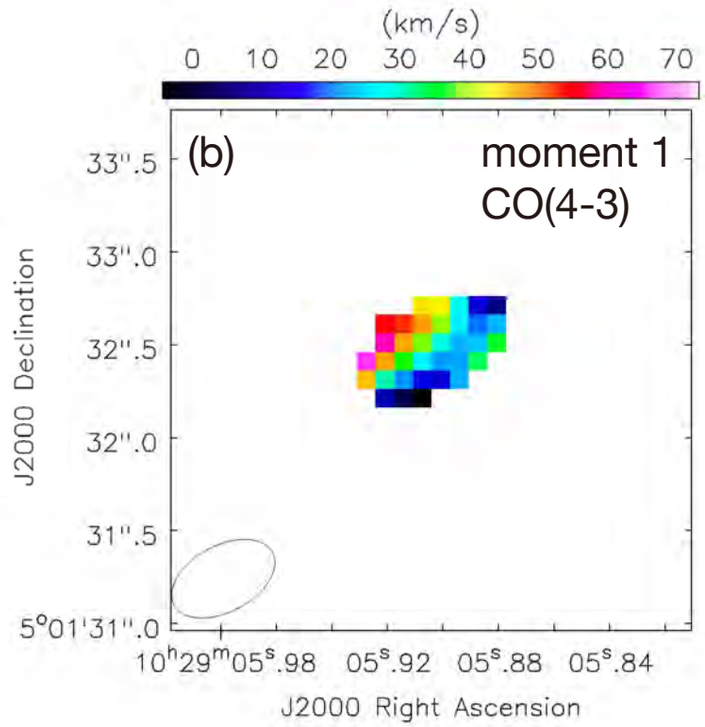
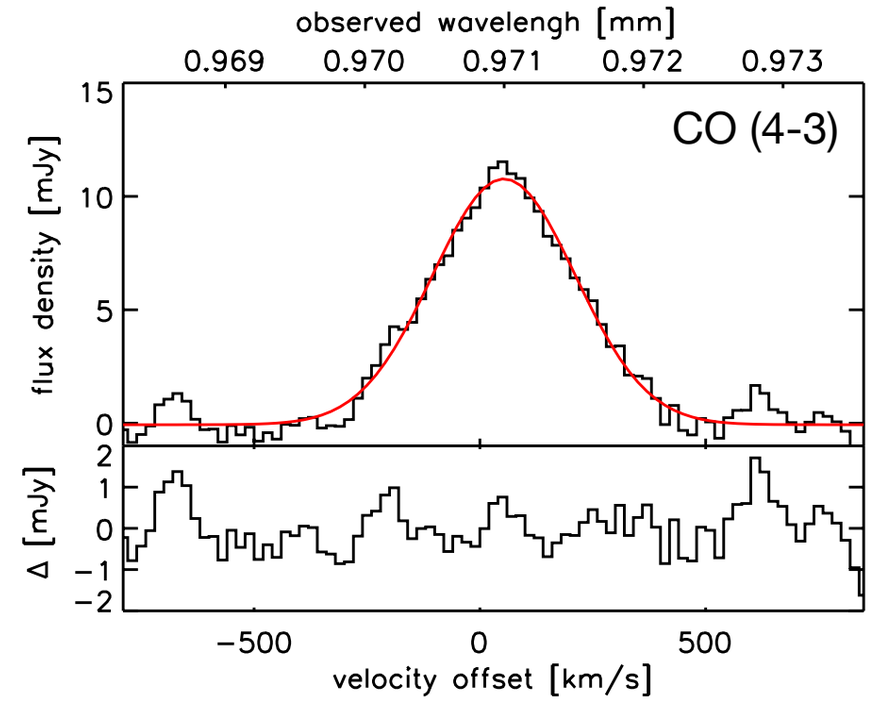




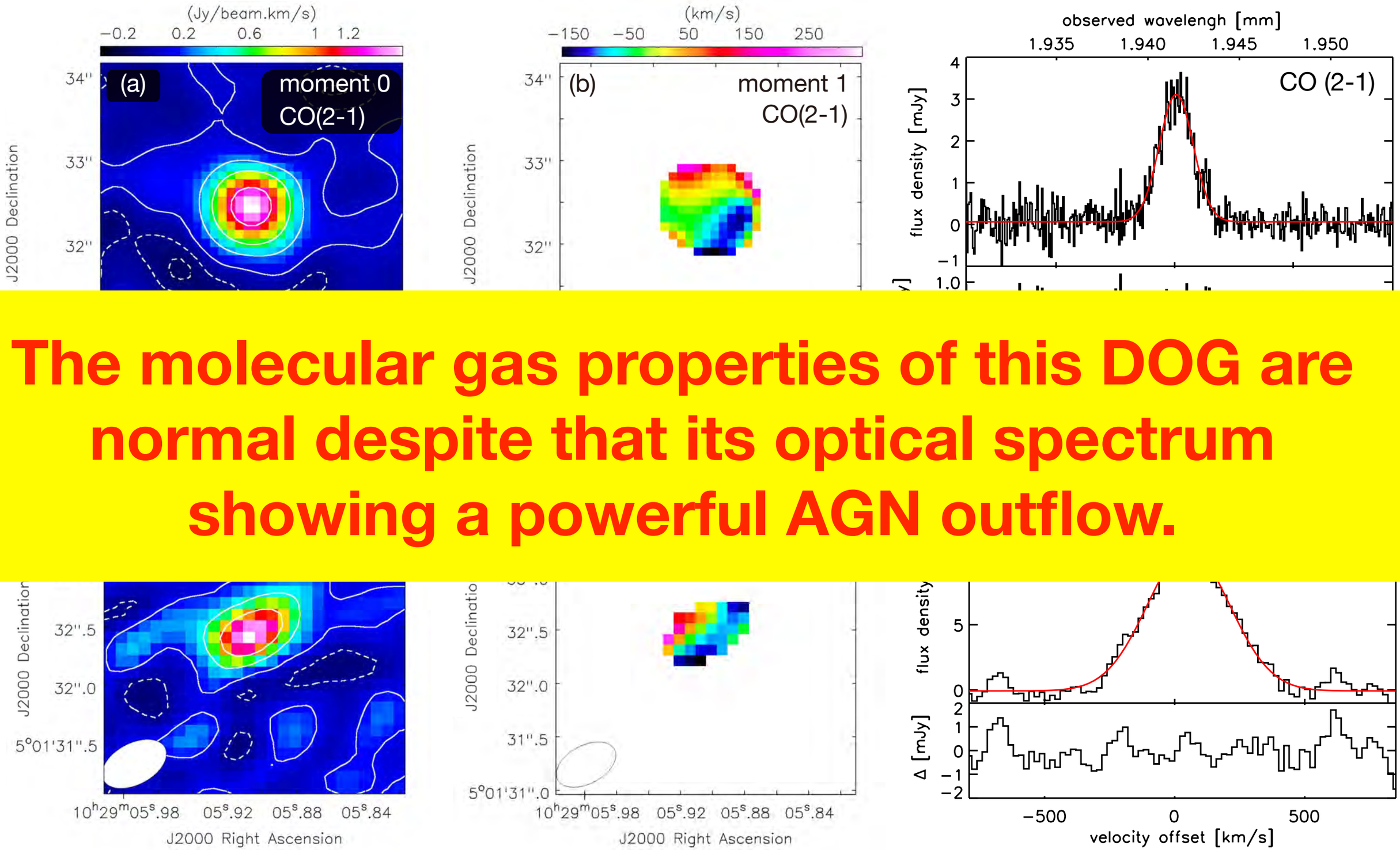








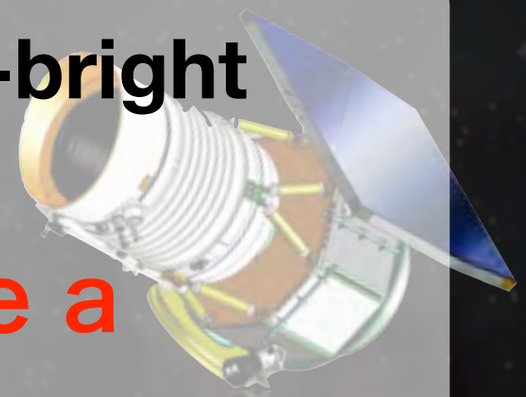
How about a molecular gas?



The molecular gas properties of this DOG are normal despite that its optical spectrum showing a powerful AGN outflow.

Summary

We investigated ionized gas properties of 32 IR-bright DOGs selected with SDSS and WISE



- 24/32 (75%) IR-bright DOGs have a strong [OIII] outflow
- IR-bright DOGs show relatively strong outflows compared to Sy2s due to the difference in LIR(AGN)
- The highly ionized gas tends to show stronger outflows

I ♥ DOGs