Using High-Spatial Resolution to Uncover Elusive AGN and Disentangle them from Shocks

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Elusive AGN, George Mason University

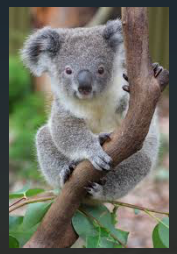
*With: **Vivian U**, Anne Medling, Thomas Bohn, Laura Sales, and KOALA team*

Main take away:

High spatial resolution studies can help us uncover elusive AGN

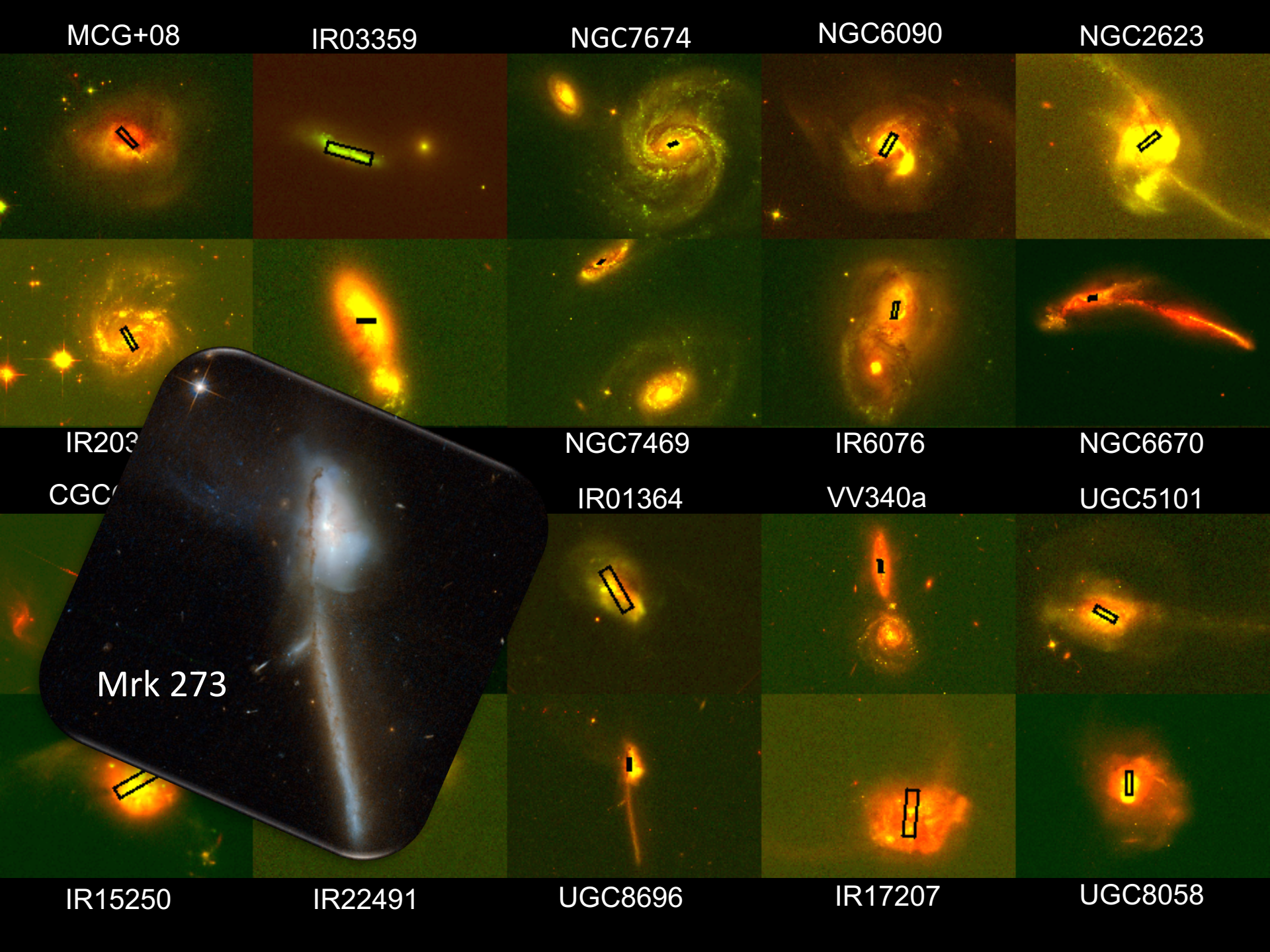
Keck OSIRIS AO LIRG Analysis (KOALA) Survey

PI: Vivian U



OSIRIS + NIRC2 + LGS AO

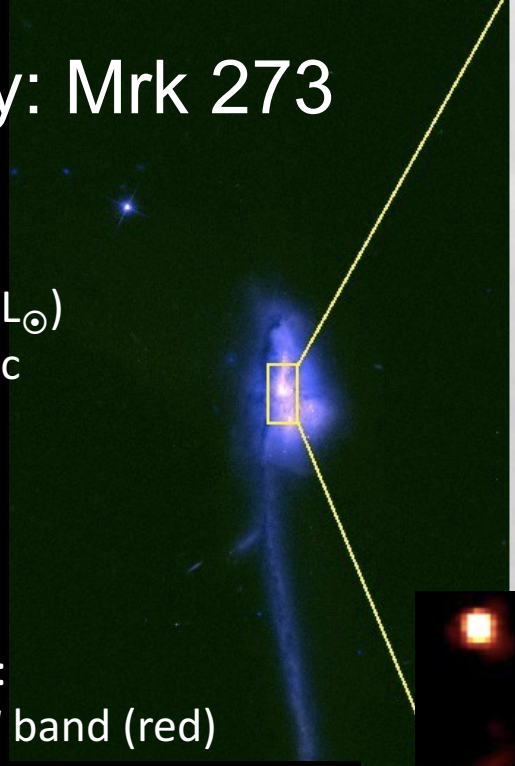
- ***K (or H) band, sampling at 0.035” and 0.1"/spaxel***
- ***Targeted ~20 (U)LIRGs at z < 0.08***
- ***20-50 pc/spaxel***

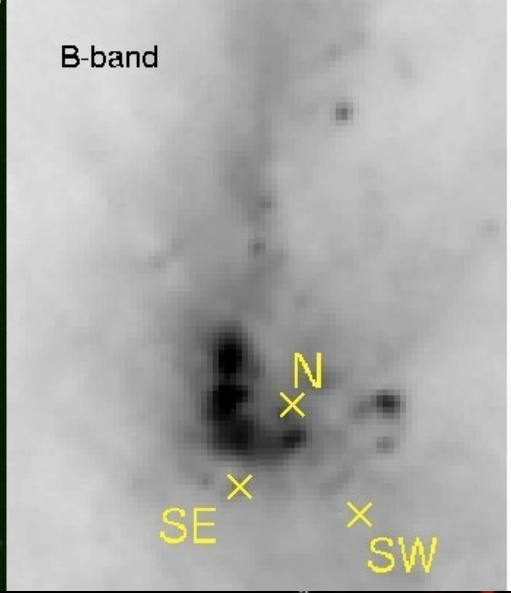

MCG+08
IR03359
NGC7674
NGC6090
NGC2623
IR203
NGC7469
IR6076
NGC6670
CGC
IR01364
VV340a
UGC5101
Mrk 273
IR15250
IR22491
UGC8696
IR17207
UGC8058

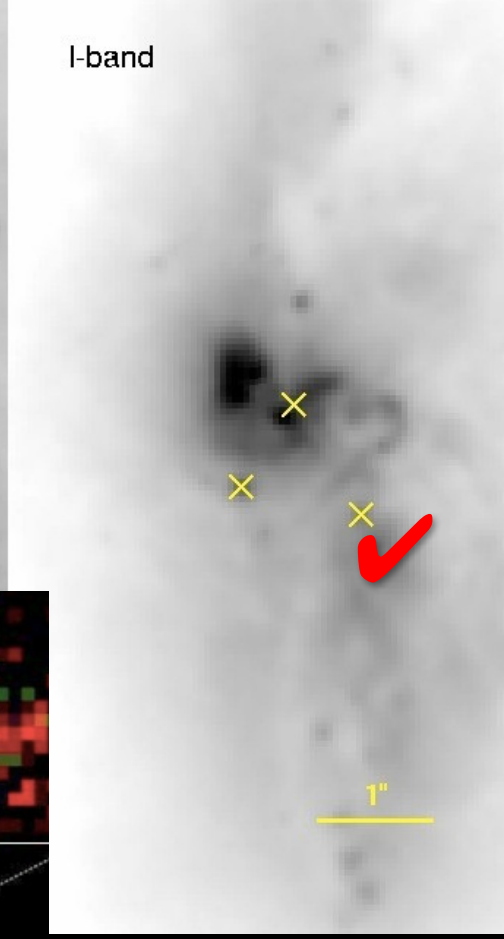
Case Study: Mrk 273

U+ 2013

ULIRG ($L_{IR} = 10^{12.21} L_{\odot}$)
z = 0.04; 1" ~ 800pc

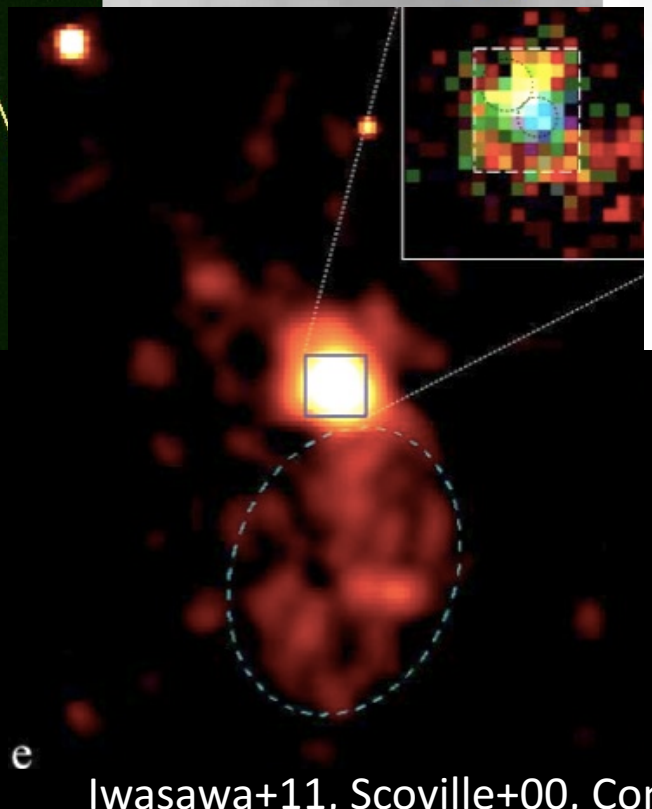






Underlying image:
I band (green) + *H* band (red)

Contours:
VLA 8.4 GHz

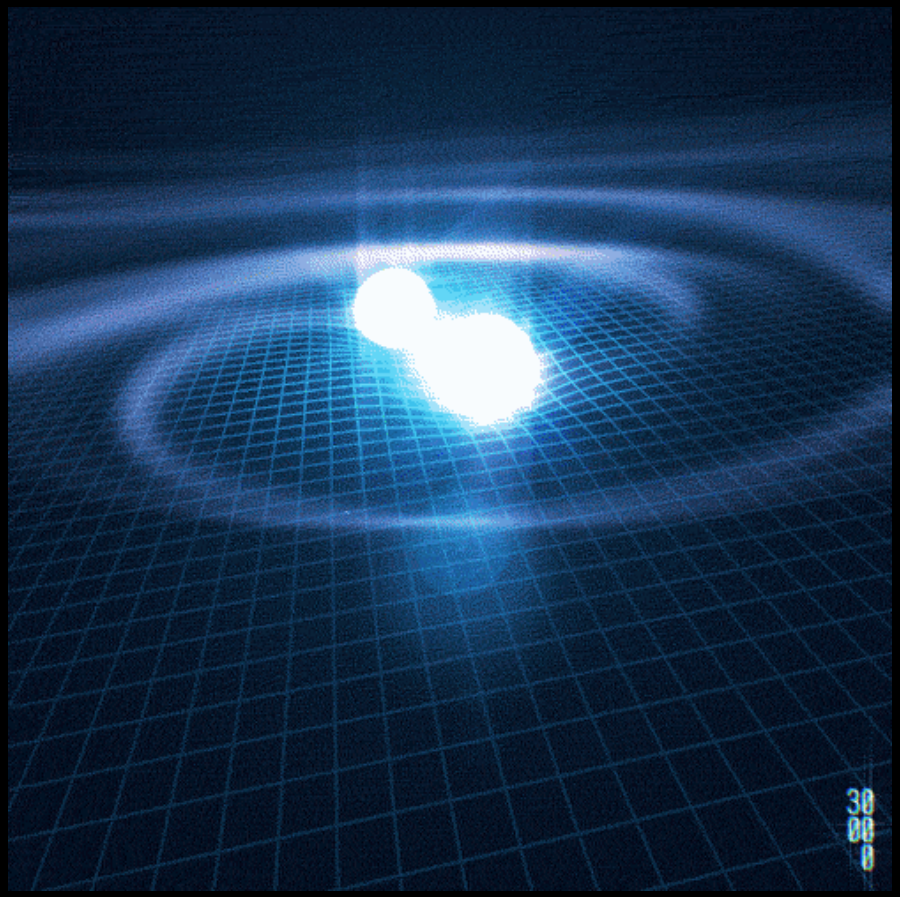


Hard X-ray (blue) +
Soft X-ray (yellow)

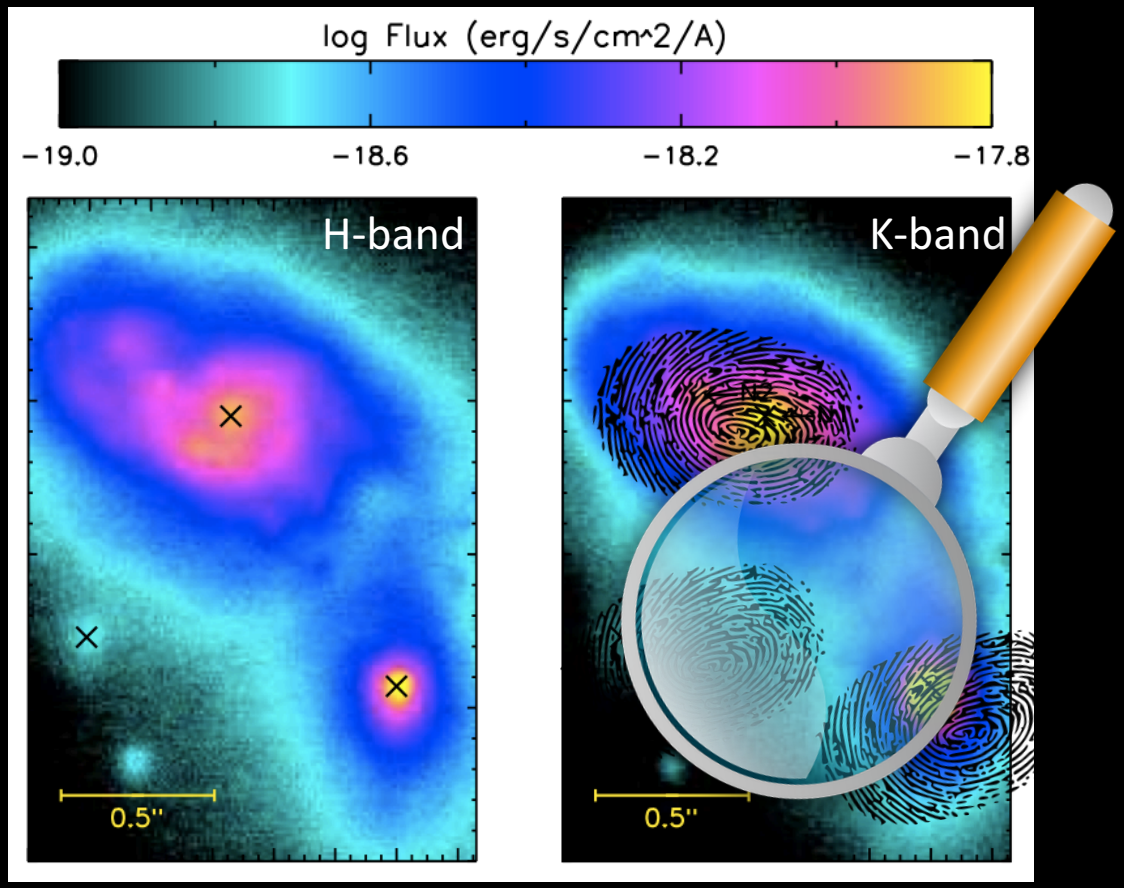
Iwasawa+11, Scoville+00, Condon+91, etc.

Is there a second (elusive) AGN in Mrk 273?

(cf. talks by Sara Ellison, Anca Constantin, Andy Goulding, and Laura Blecha)

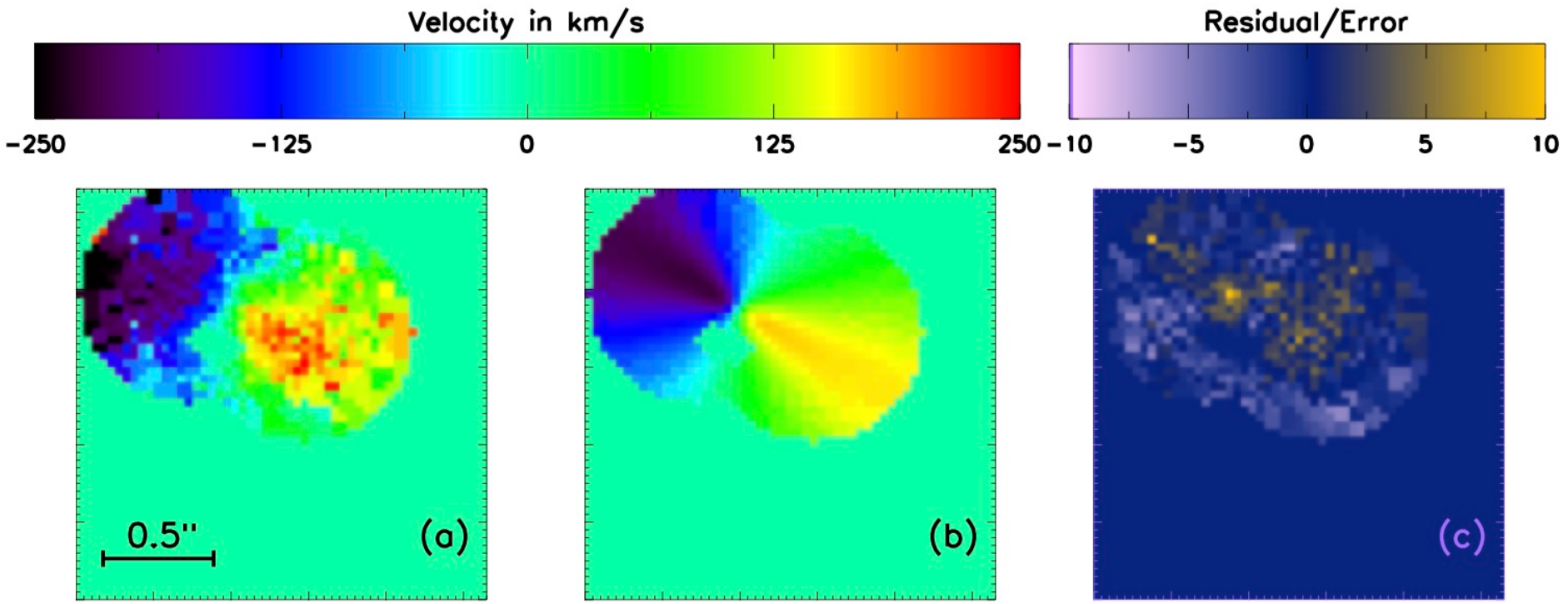


NIRC2 LGS AO images (0.01"/px, or 8pc/px)



NIR lines give us clues to the nature of the three sources

Clue #1: There is a very massive object in clump N!

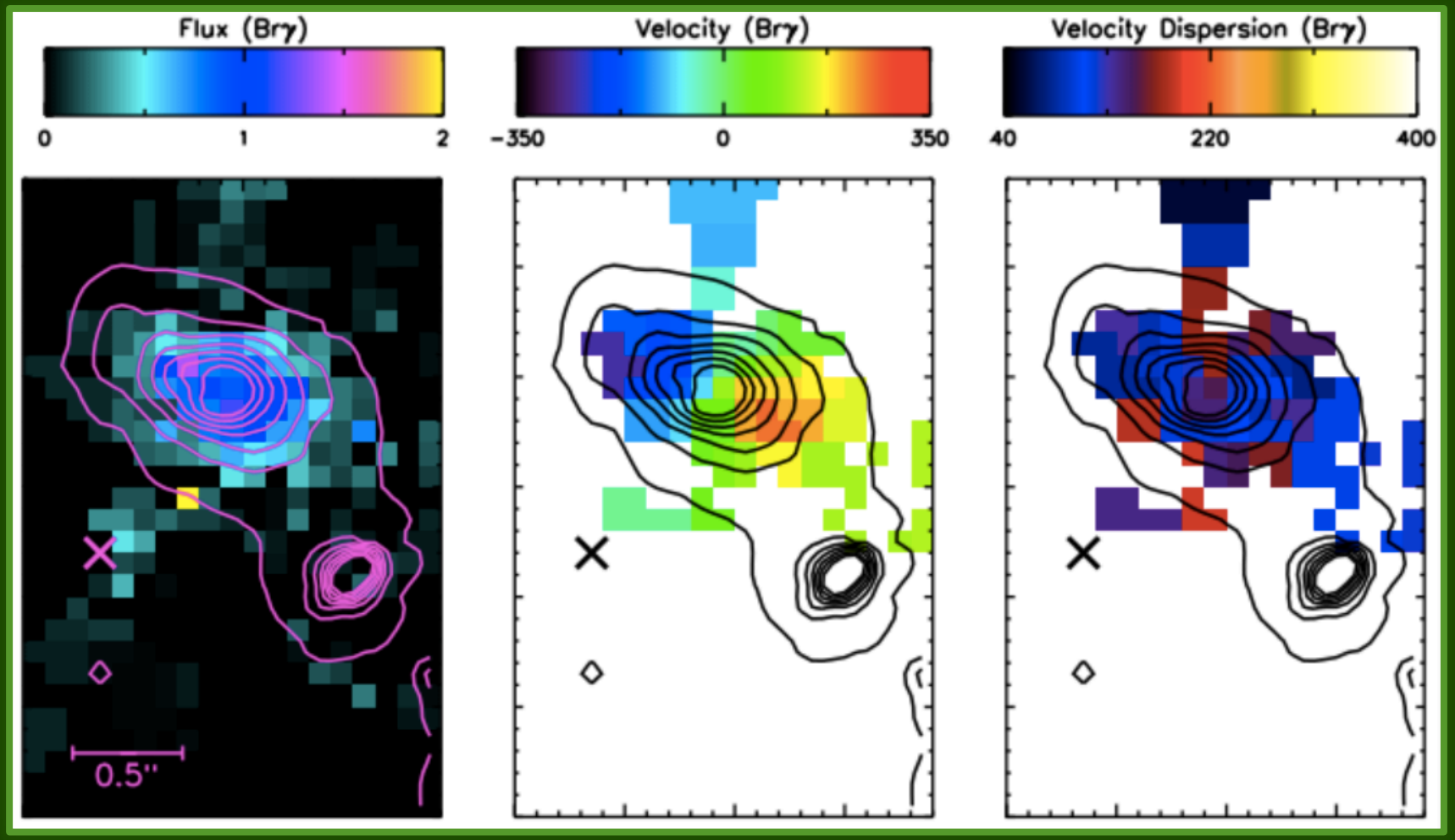


Keplerian disk model of [Fe II] gas shows there is a mass of $1.04 \pm 0.1 \times 10^9\ M_\odot$ enclosed within 26 pc -> SMBH!

(cf. Dave Sanders' talk)

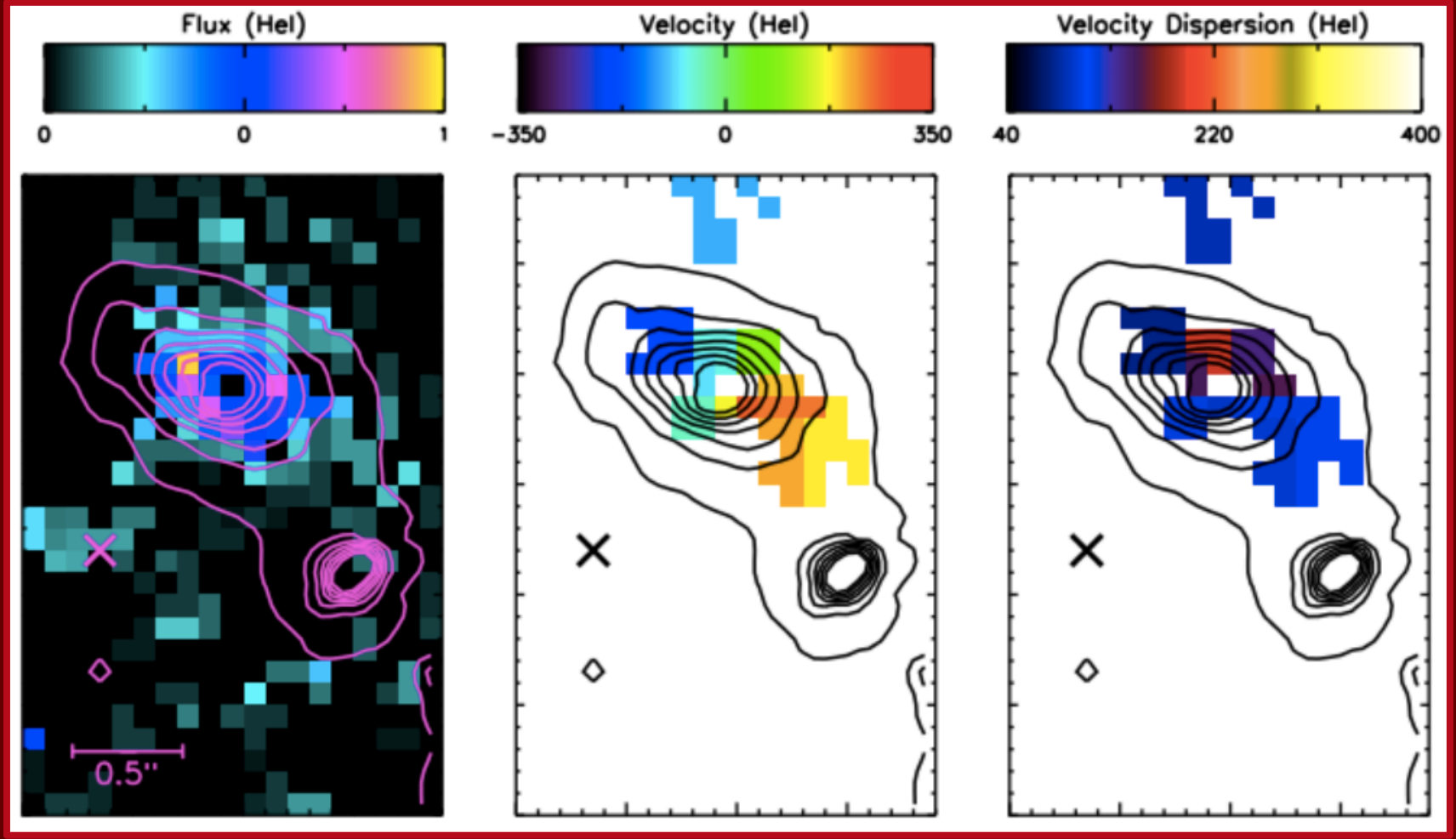
Clue #2: Suppressed Brγ and He I near the center of N – ionized by obscured AGN?

Br γ

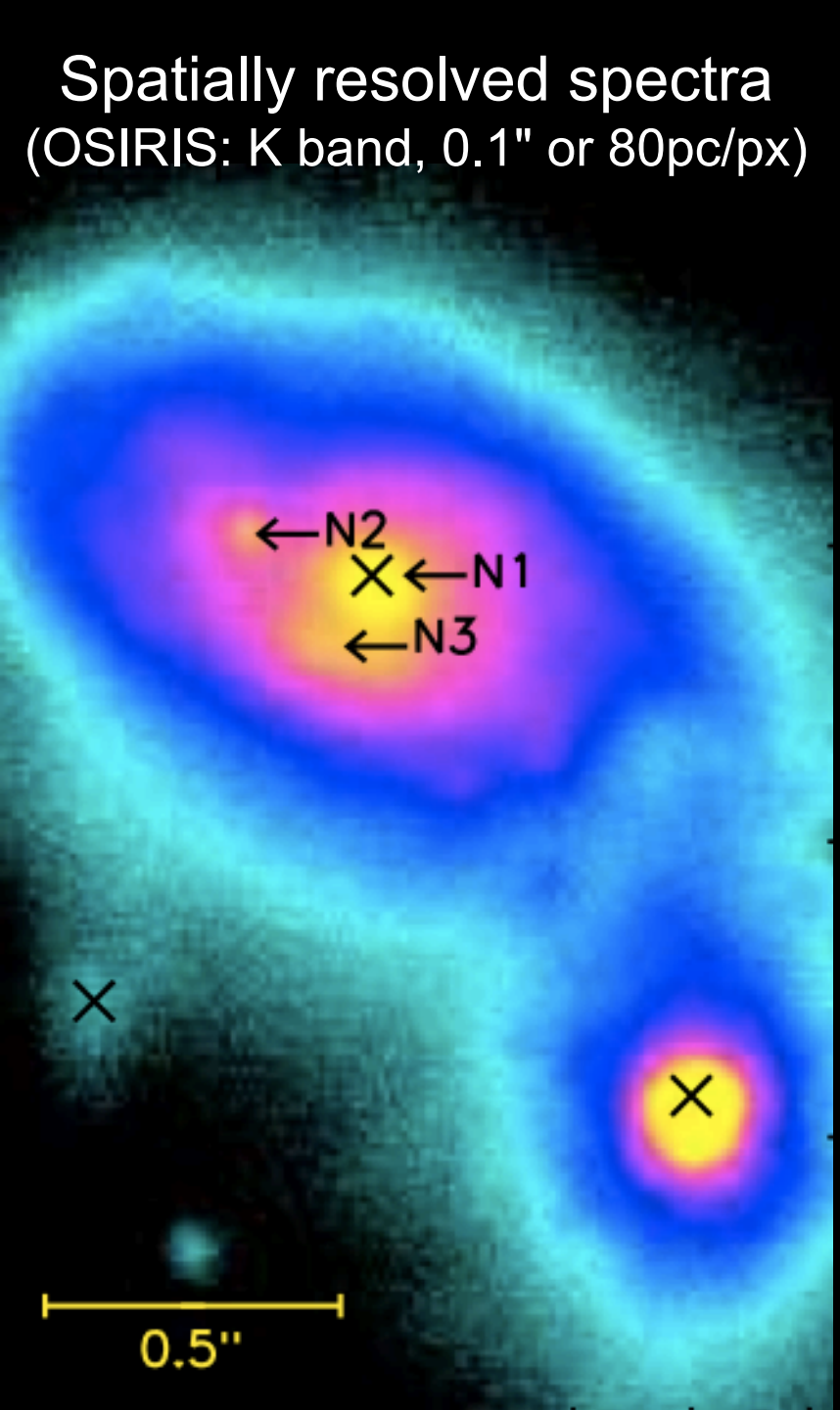


Clue #2: Suppressed Brγ and He I near the center of N – ionized by obscured AGN?

He I



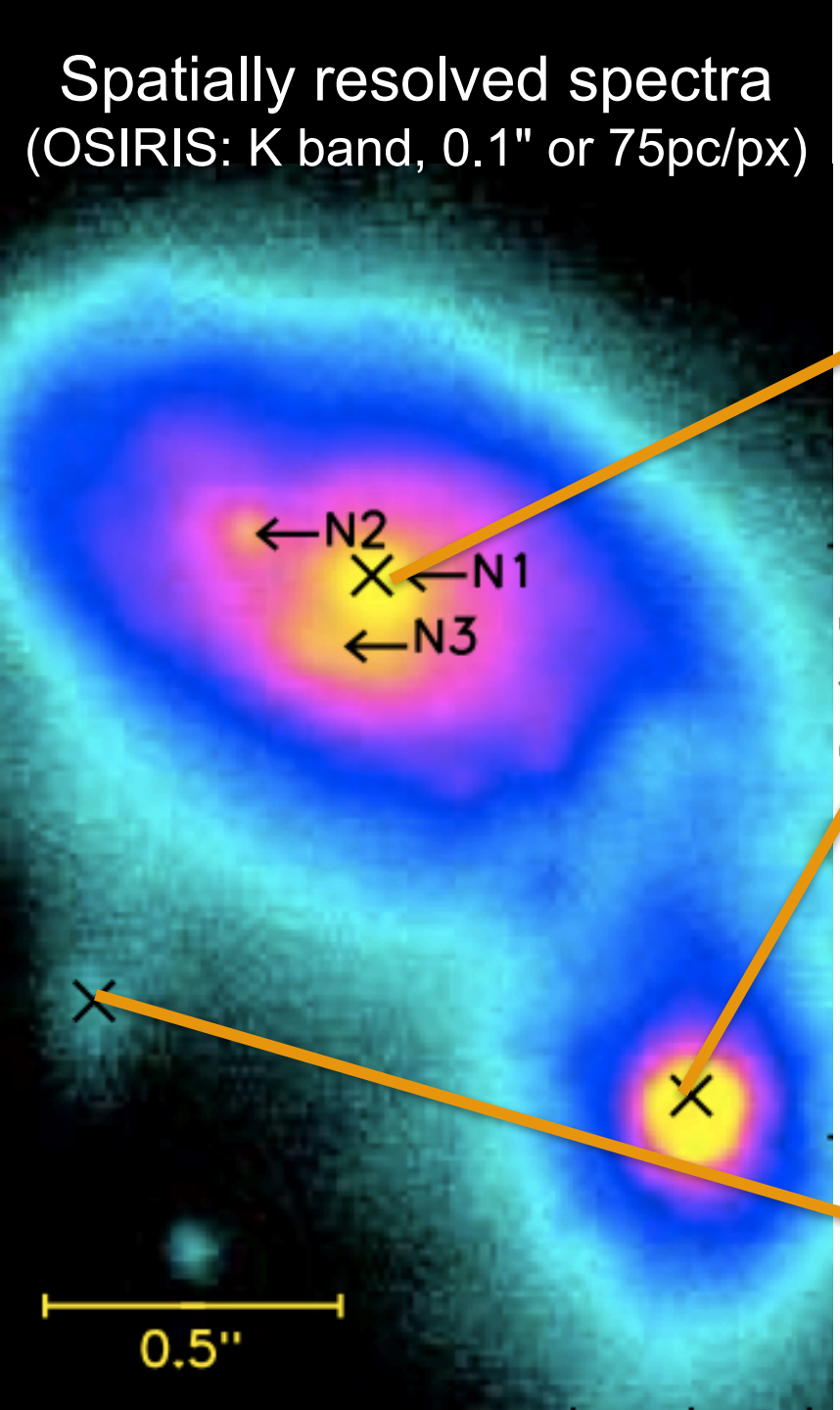
Spatially resolved spectra
(OSIRIS: K band, 0.1" or 80pc/px)

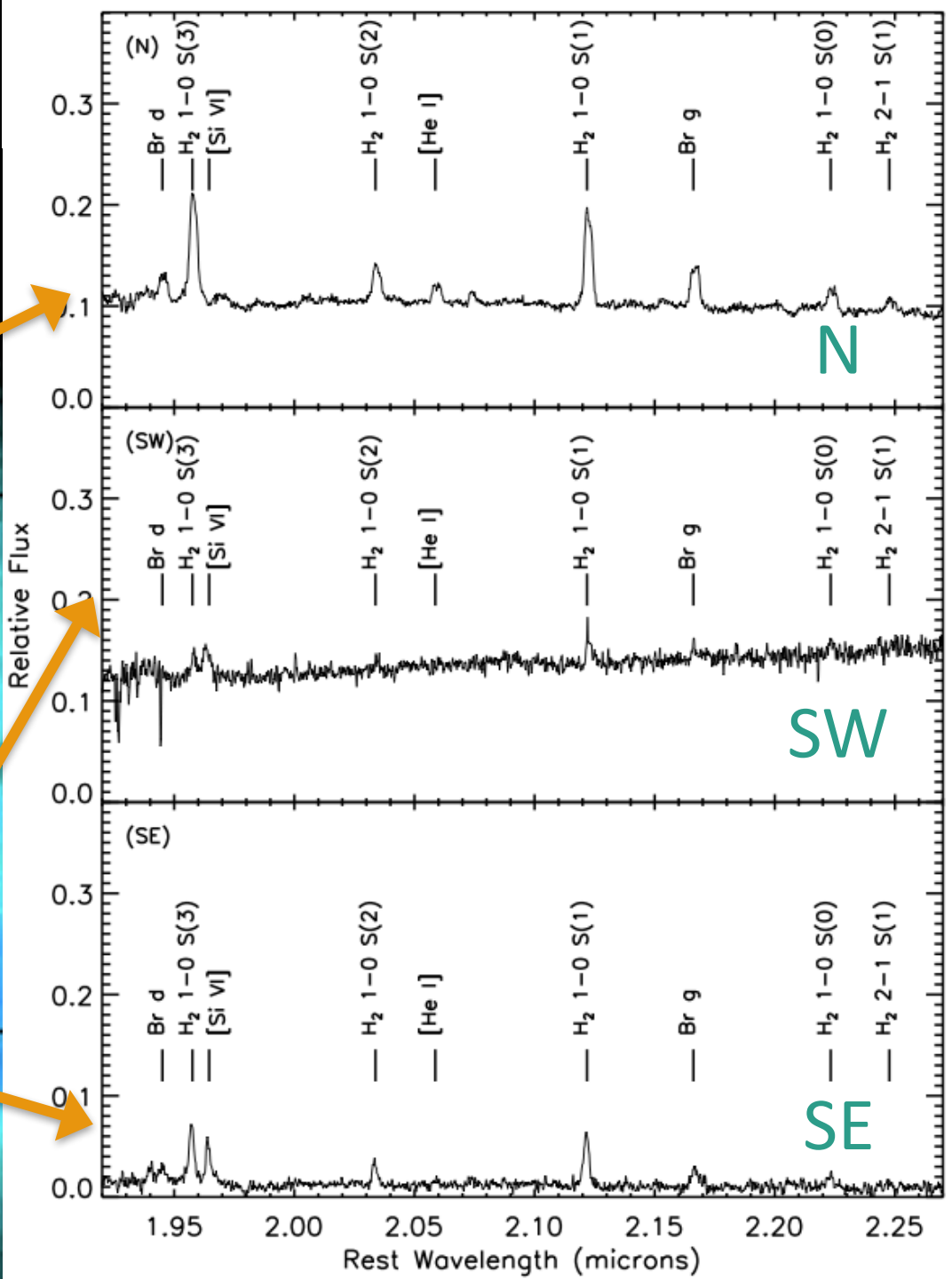


Clue #3: [Si VI] is detected in SE and SW, but not in N… hmm….

(cf. Anca Constantin's talk)

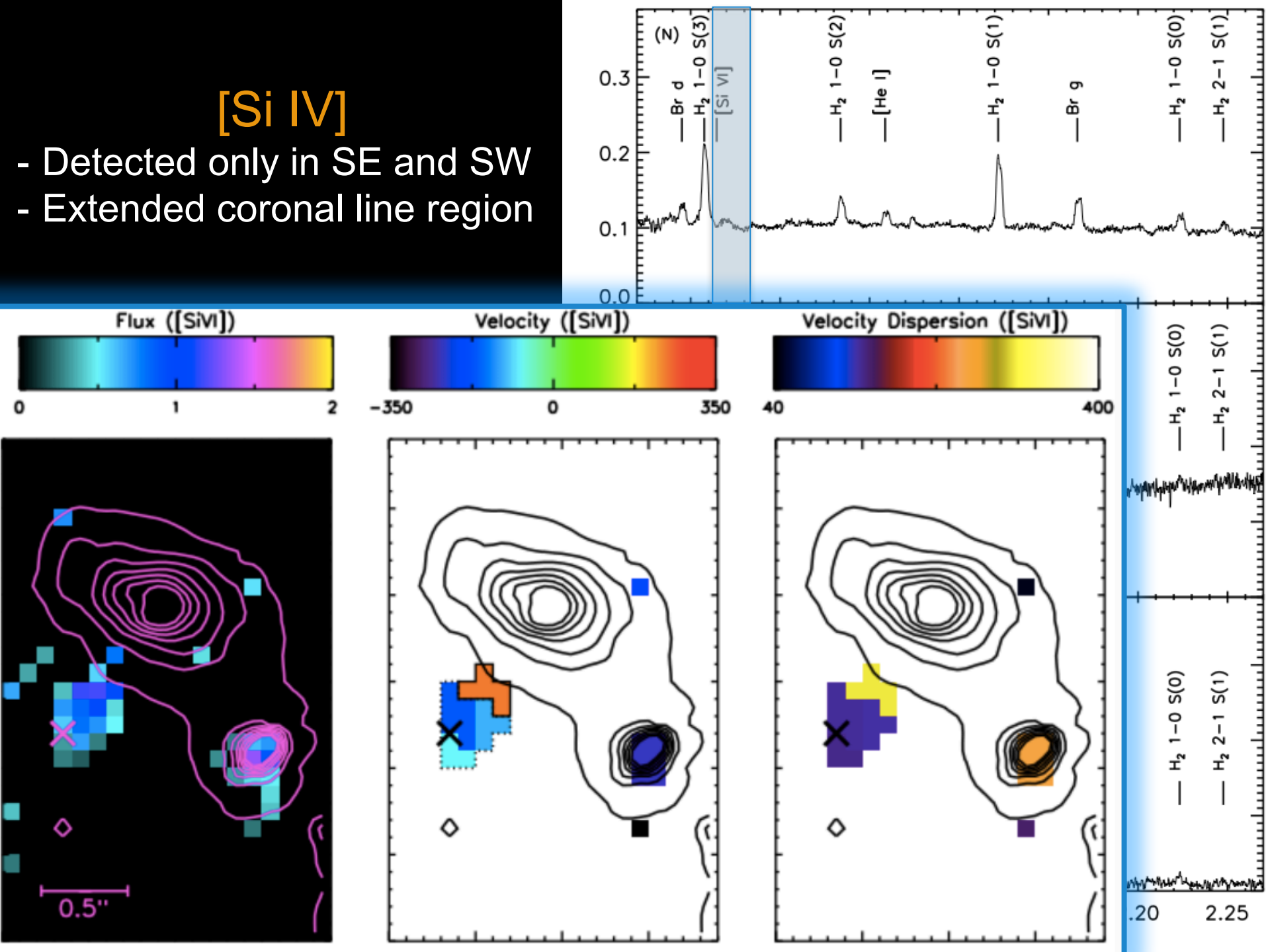
Spatially resolved spectra
(OSIRIS: K band, 0.1" or 75pc/px)



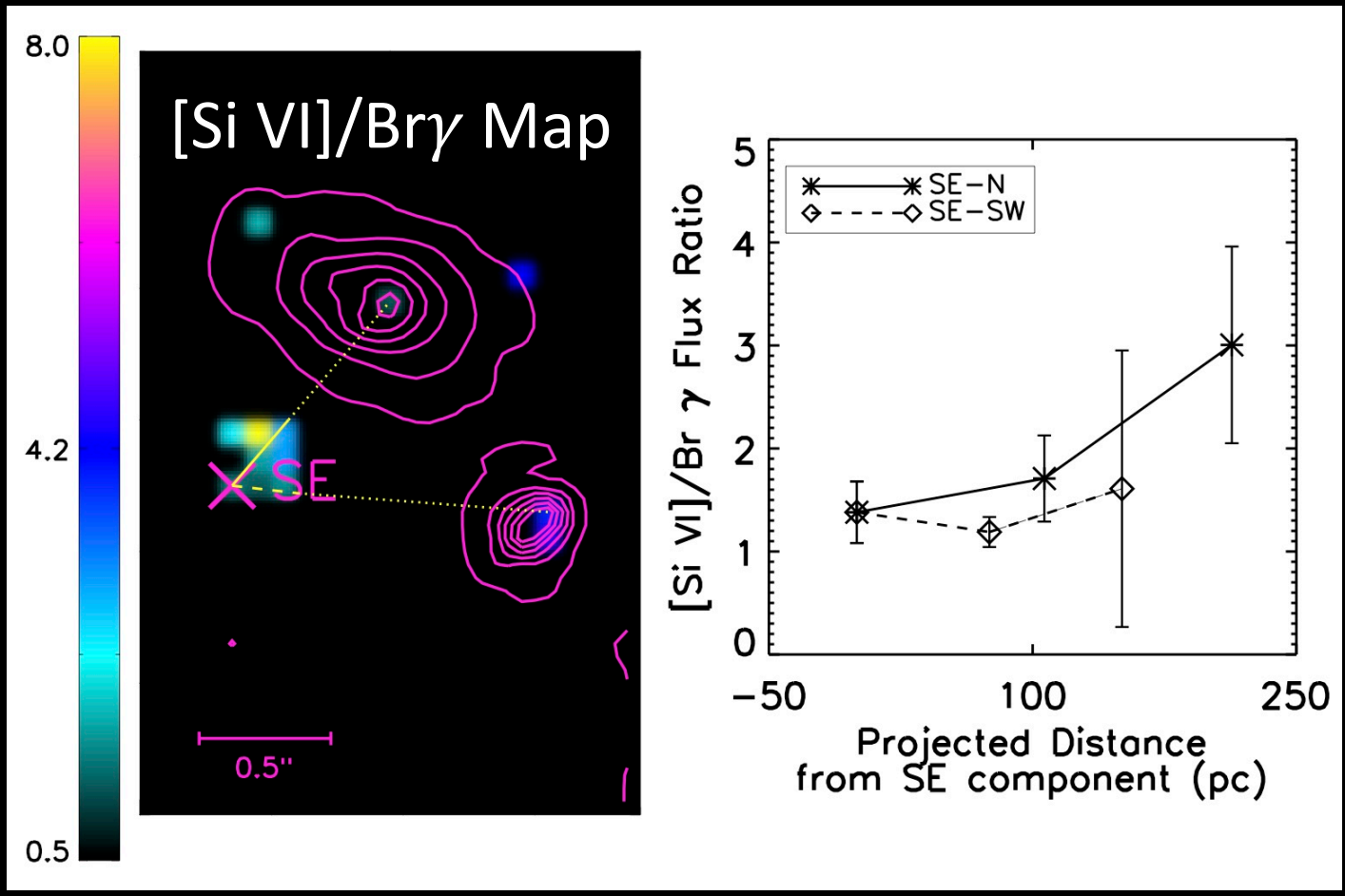


[Si IV]

- Detected only in SE and SW
- Extended coronal line region



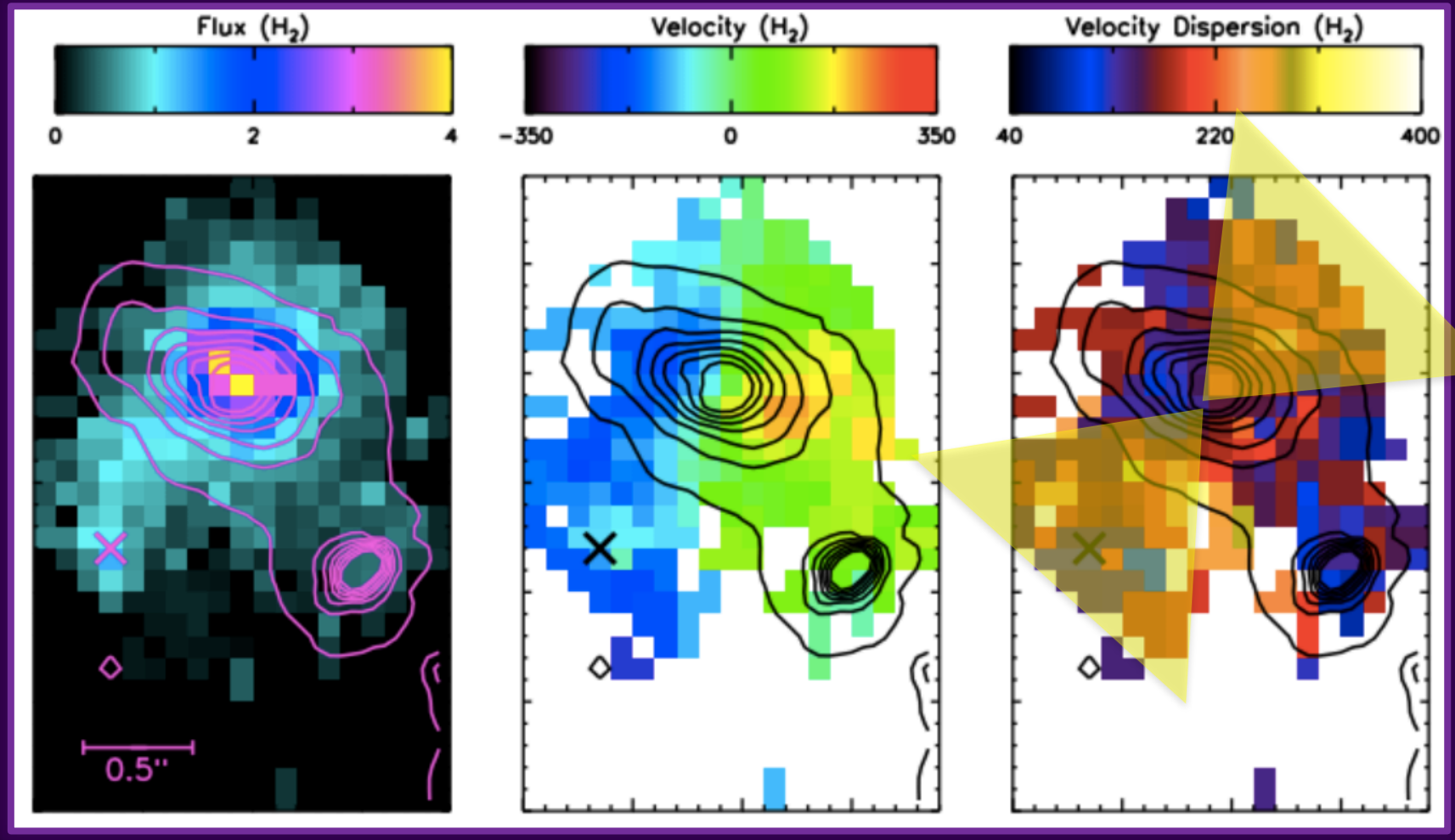
Clue #4: Gradient in [Si VI]/Brγ decreasing toward SE suggests photoionization from AGN in N



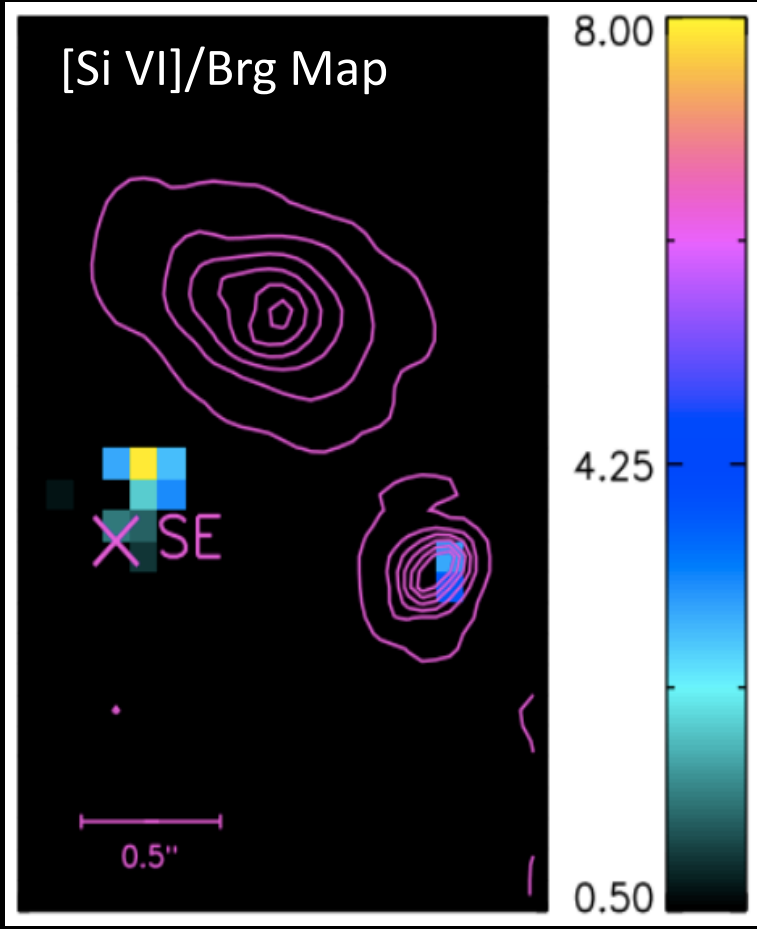
CLOUDY models confirm AGN located at N could produce these ratios

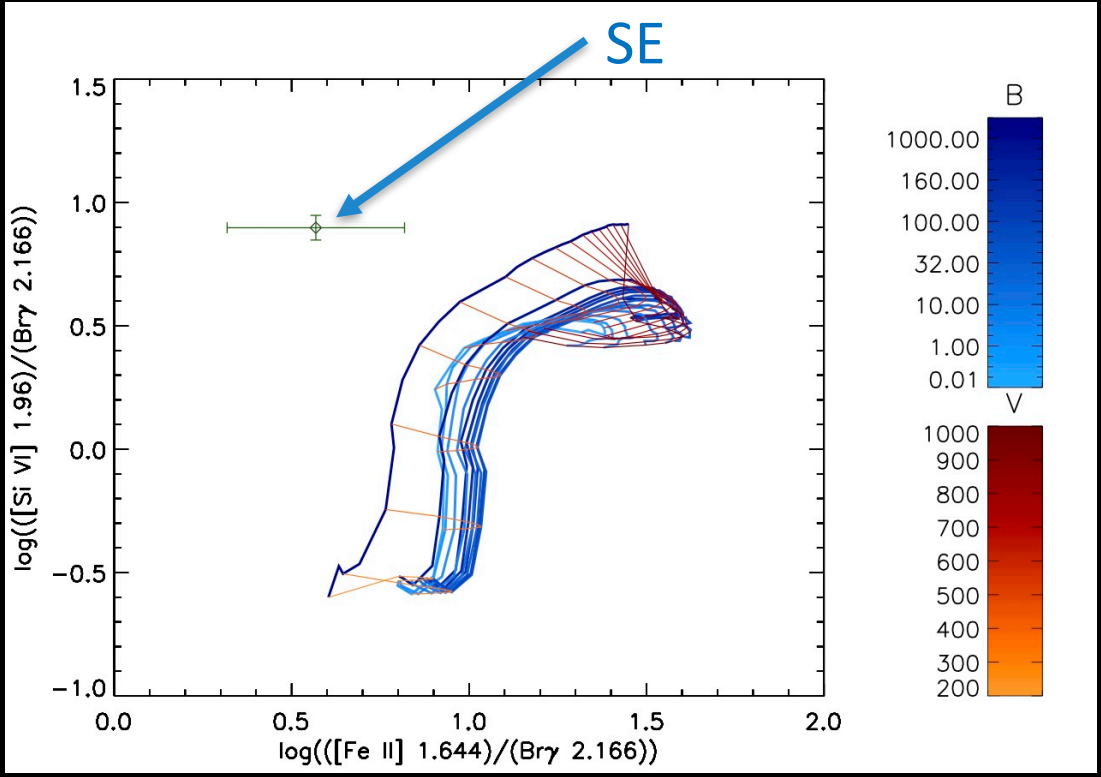
Bonus: We see biconical molecular outflows from N and directed toward SE

Increased velocity dispersion for H_2 along the minor axis



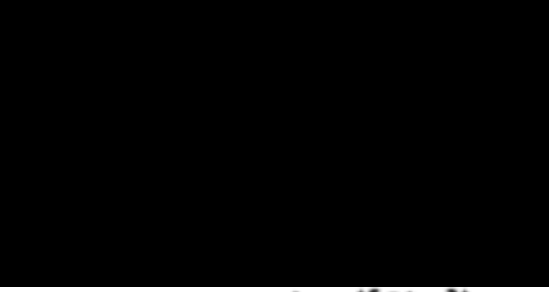
Shock or AGN?

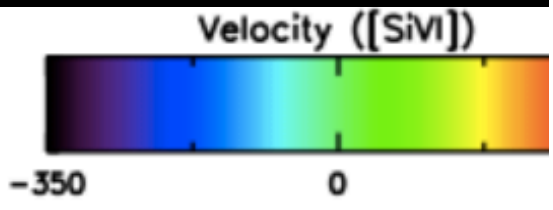


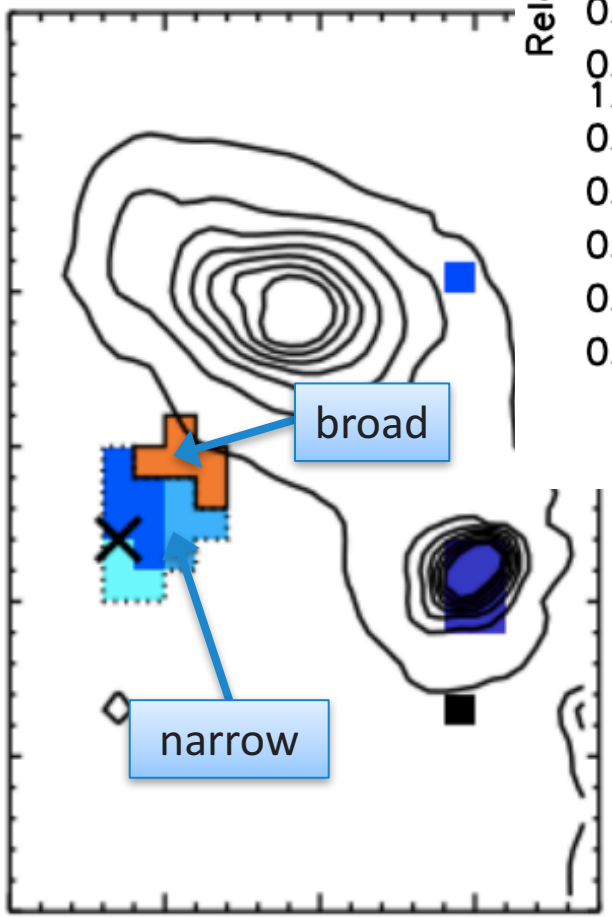


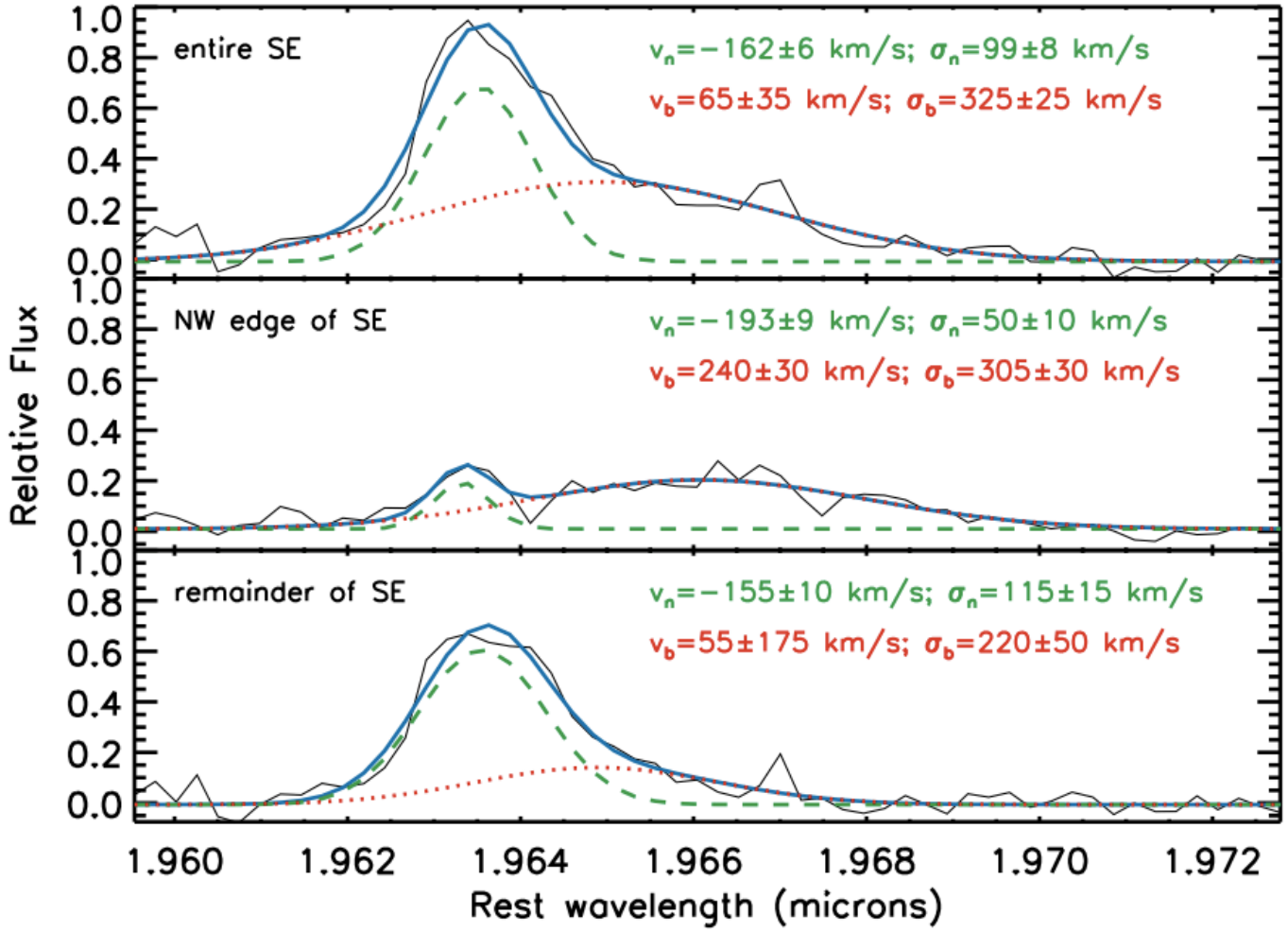
Models using SHOCKPLOT (Allen+2008)

Only fast shocks in the densest material, if at all, could reproduce the observed line ratios





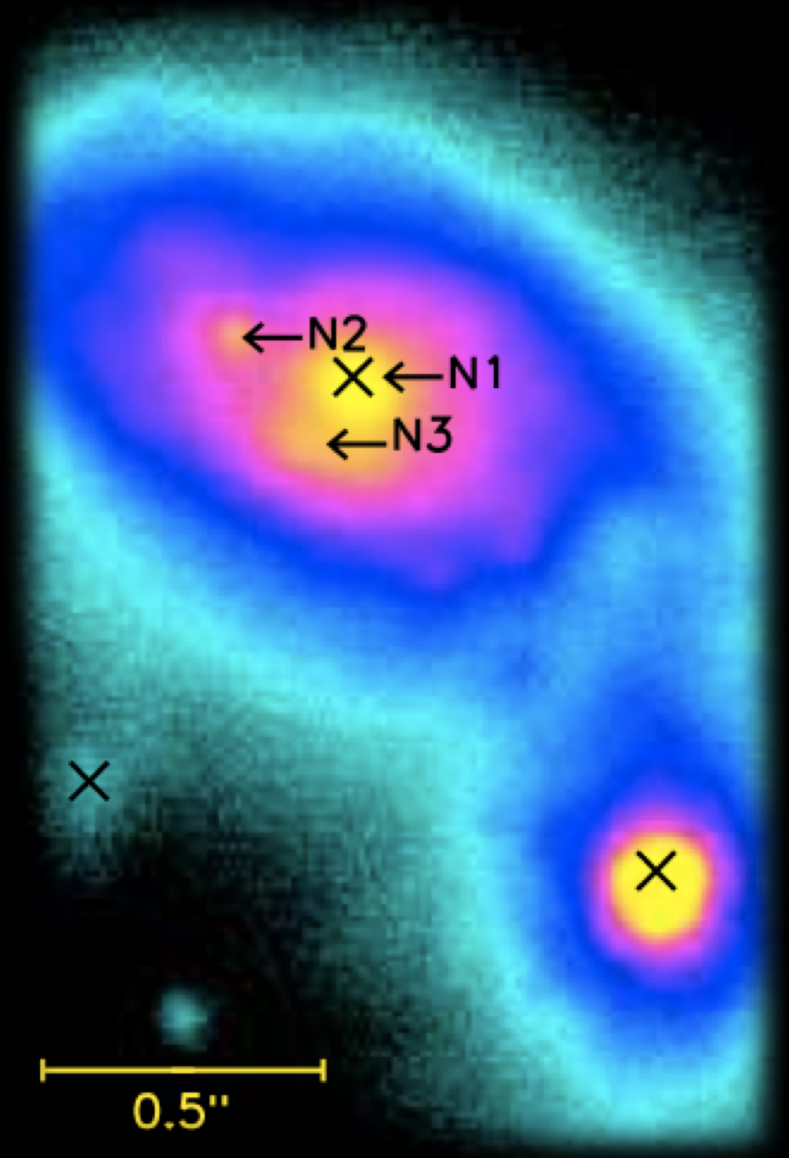




[Si VI] line in the SE

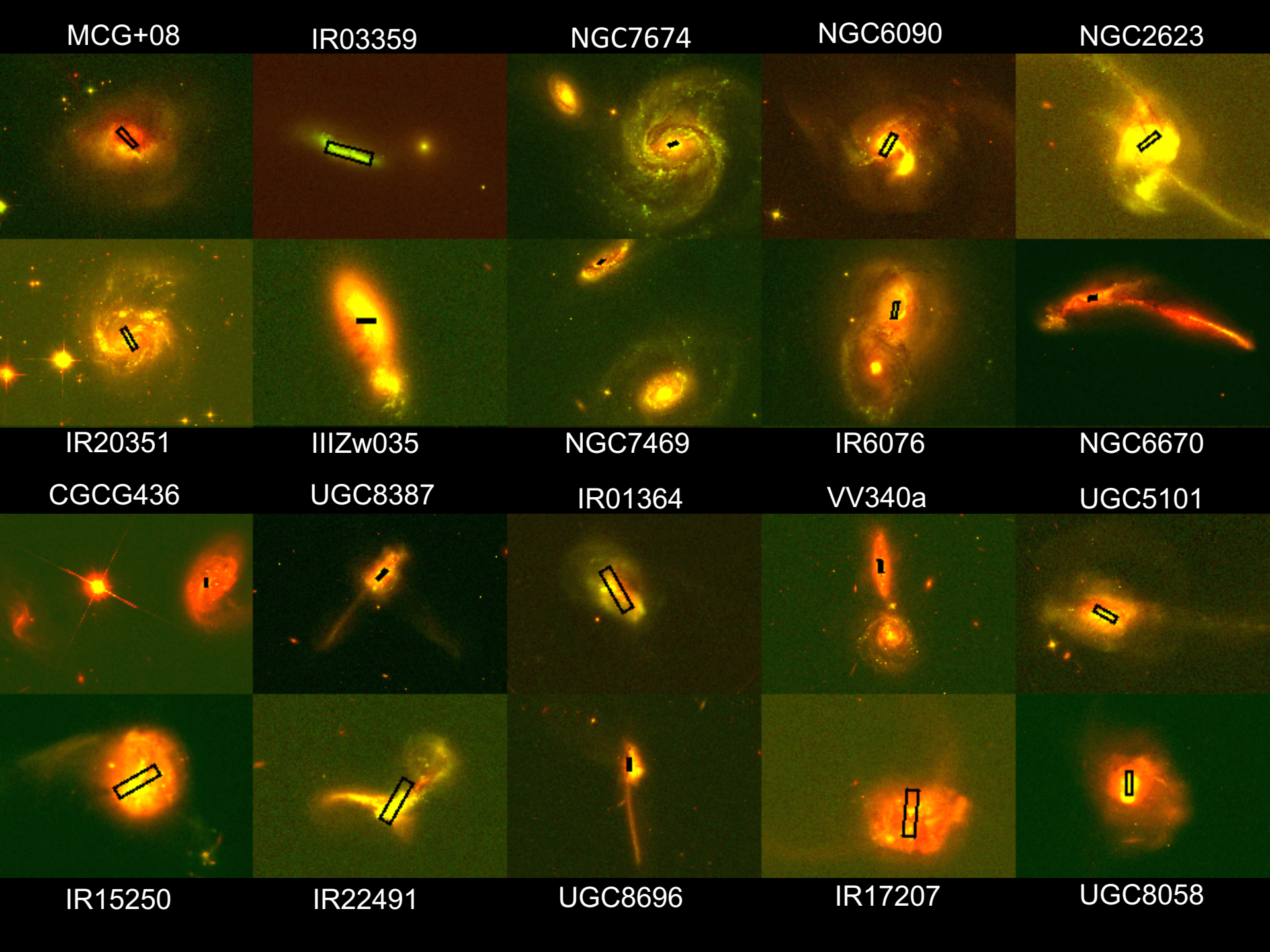
Two kinematic components
(broad and narrow)

Summary for Mrk 273

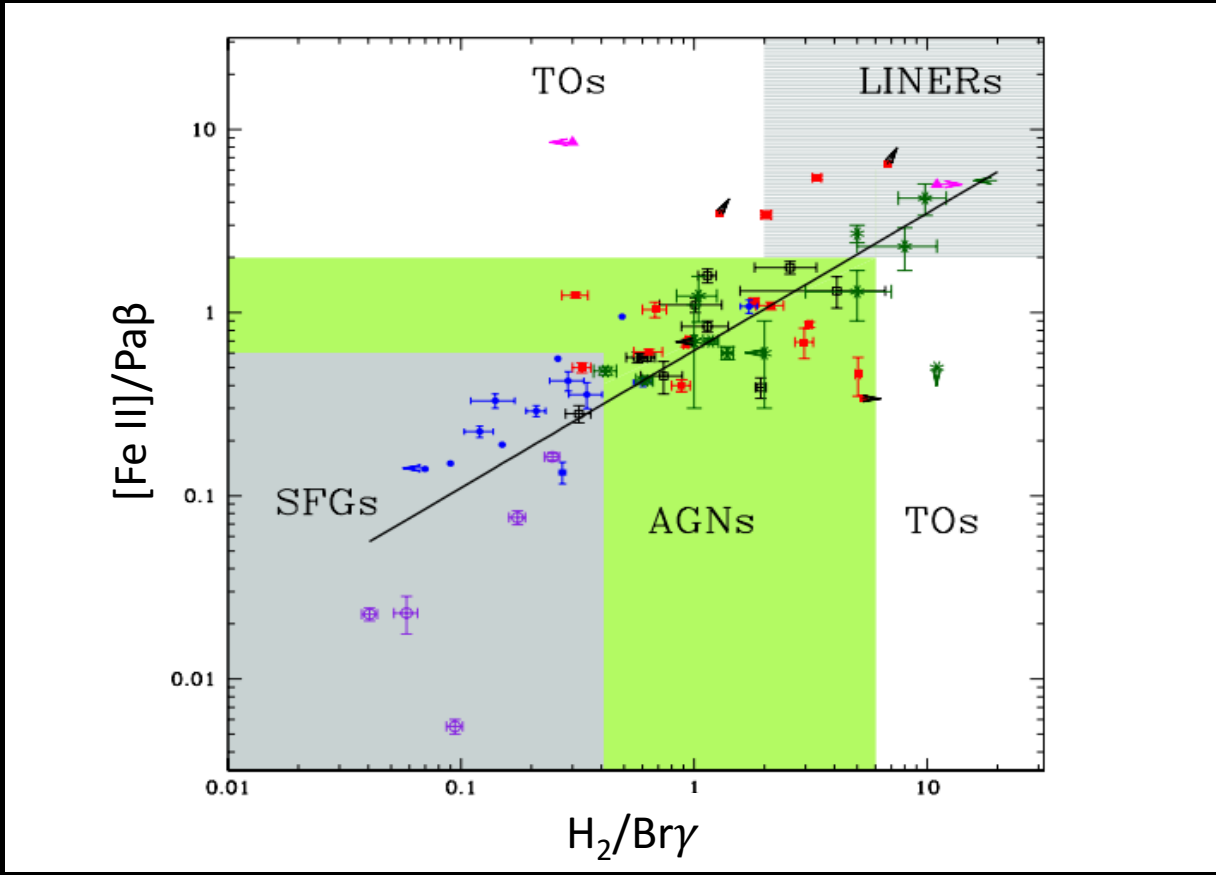


- SW: Hard X-ray AGN
- N: SMBH, obscured AGN
- SE: clump of gas or tidal feature, photoionized by obscured AGN in N and shock-heated by outflows from AGN
- Bridge: outflow

… Dual AGN system

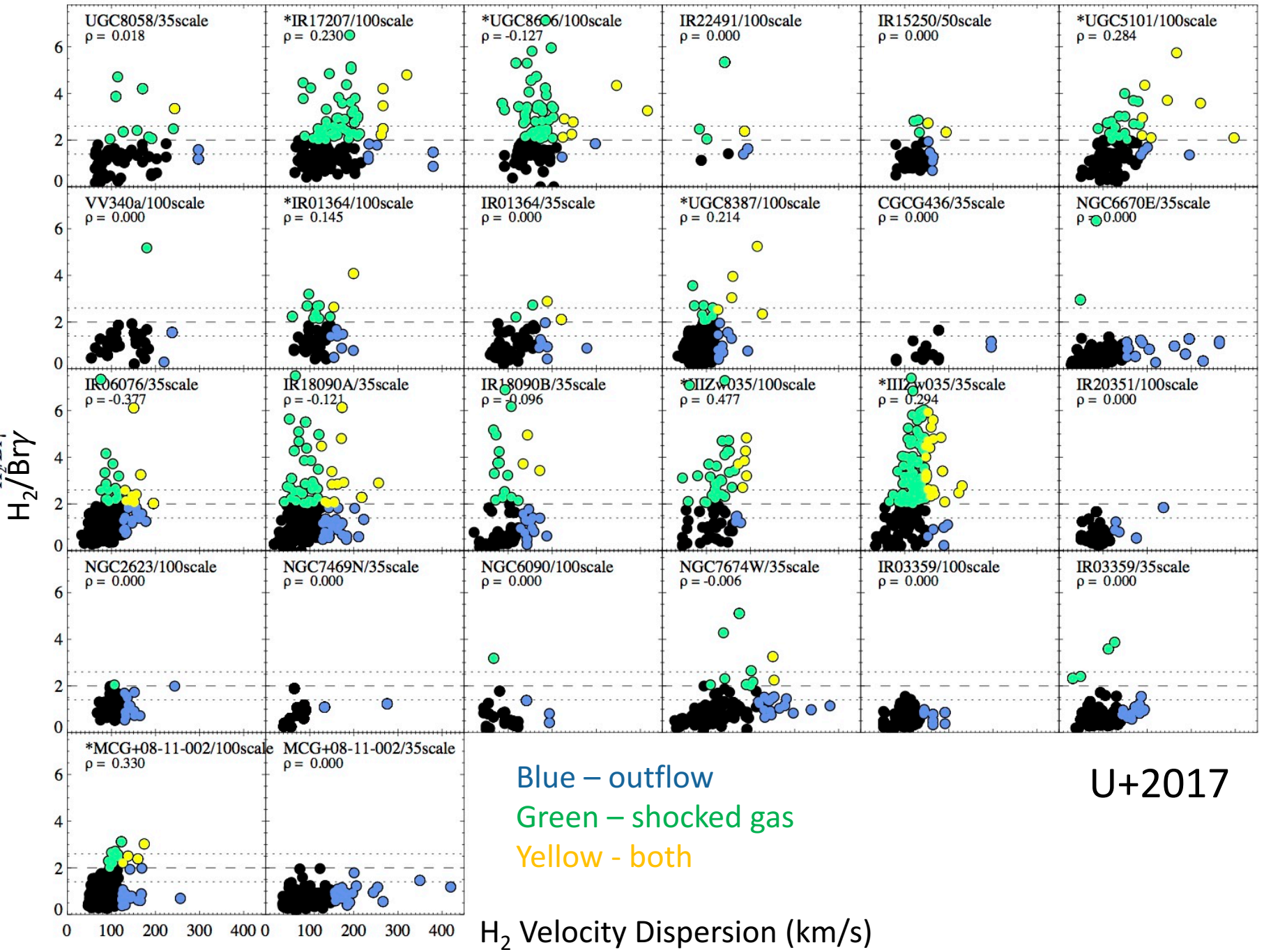

MCG+08
IR03359
NGC7674
NGC6090
NGC2623
IR20351
IIIZw035
NGC7469
IR6076
NGC6670
CGCG436
UGC8387
IR01364
VV340a
UGC5101
IR15250
IR22491
UGC8696
IR17207
UGC8058

- $H_2/Br\gamma$ quantifies the relative contributions from UV vs. X-ray radiation or shocks.
- $H_2/Br\gamma > 2$ indicates regions dominated by shocks.



Riffel+13
Medling+2015

(cf. Anca Constantin's talk)

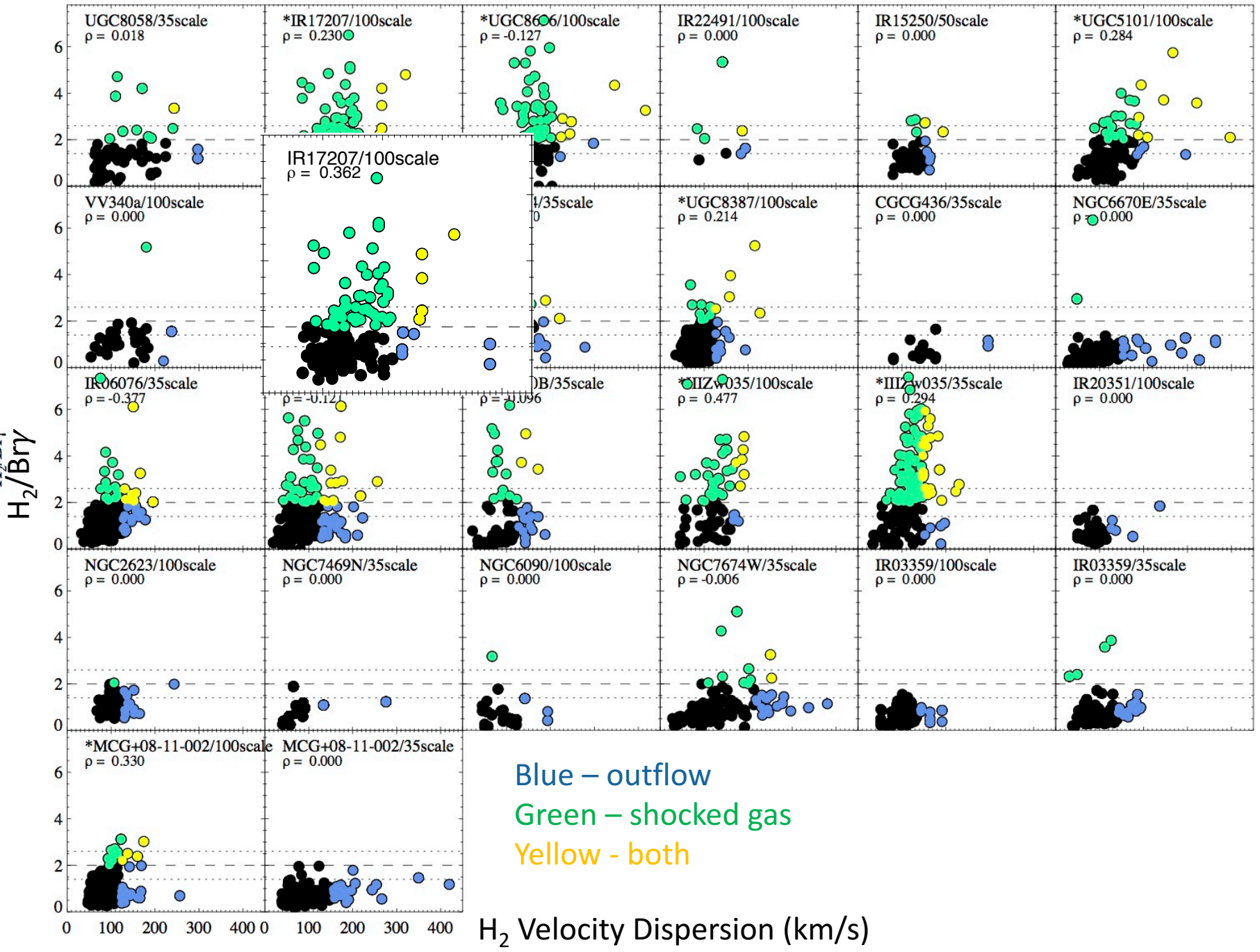


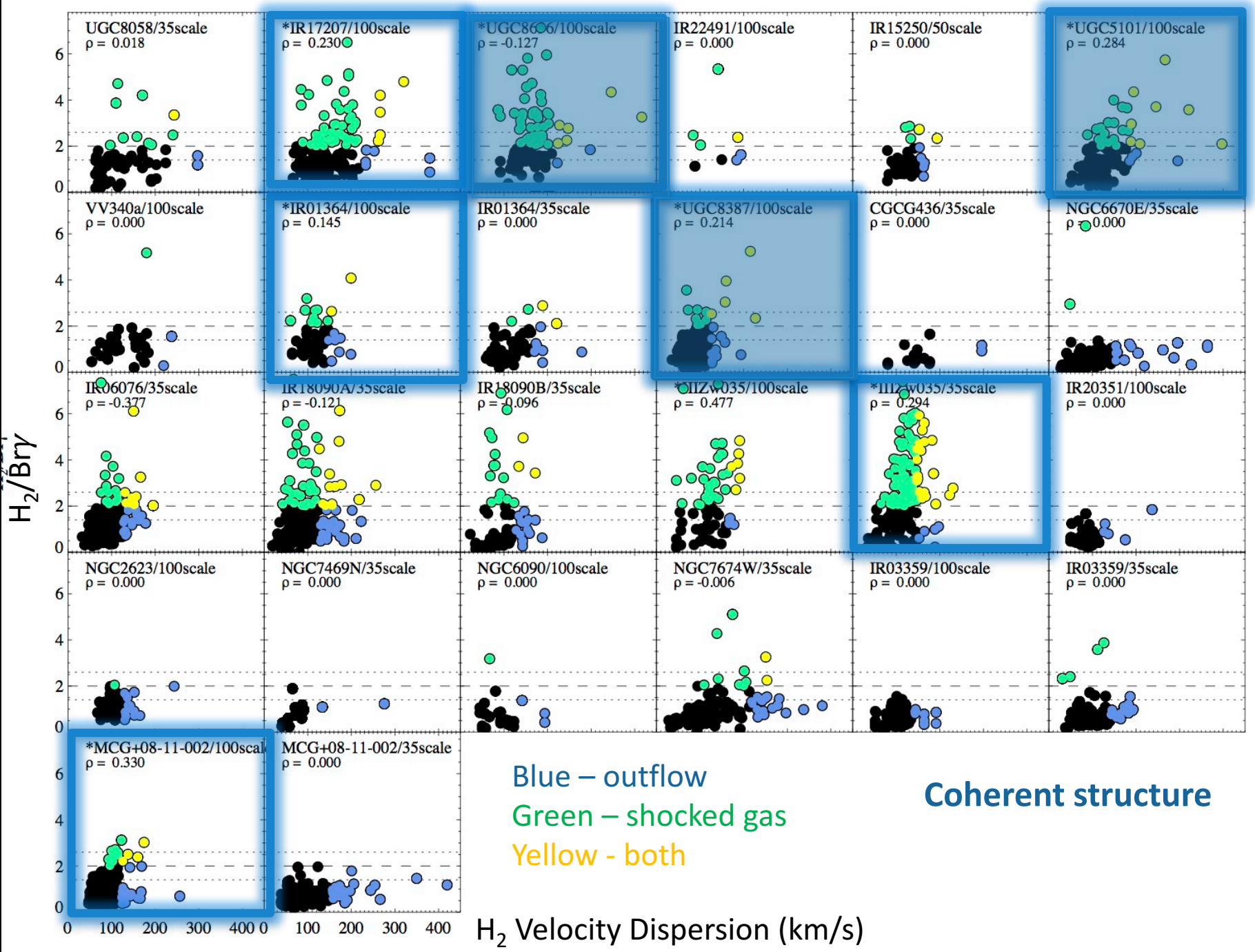
Blue – outflow

Green – shocked gas

Yellow - both

U+2017


UGC8058/35scale
ρ = 0.018
*IR17207/100scale
ρ = 0.230
*UGC8696/100scale
ρ = -0.127
IR22491/100scale
ρ = 0.000
IR15250/50scale
ρ = 0.000
*UGC5101/100scale
ρ = 0.284
IR17207/100scale
ρ = 0.362
VV340a/100scale
ρ = 0.000
*UGC8387/100scale
ρ = 0.214
CGCG436/35scale
ρ = 0.000
NGC6670E/35scale
ρ = 0.000
IR06076/35scale
ρ = -0.377
*IIZw035/100scale
ρ = 0.477
*IIZw035/35scale
ρ = 0.294
IR20351/100scale
ρ = 0.000
NGC2623/100scale
ρ = 0.000
NGC7469N/35scale
ρ = 0.000
NGC6090/100scale
ρ = 0.000
NGC7674W/35scale
ρ = -0.006
IR03359/100scale
ρ = 0.000
IR03359/35scale
ρ = 0.000
*MCG+08-11-002/100scale
ρ = 0.330
MCG+08-11-002/35scale
ρ = 0.000
H2/Brγ
H2 Velocity Dispersion (km/s)
Blue – outflow
Green – shocked gas
Yellow - both



Blue – outflow

Green – shocked gas

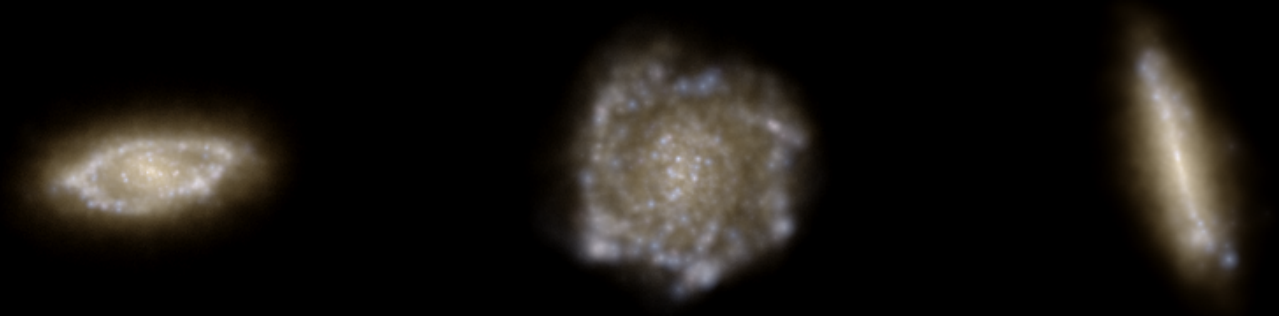
Yellow - both

Coherent structure

Summary from KOALA survey (U+2017):

- Outflows are present in nearly every object
- Shocks are commonly found in LIRGS and ULIRGs (> 50%)
- About half of AGN show shocked outflows, often in biconical shape
- Shocked outflows with coherent structure can be present in objects with no detected AGN. Either
  - They are powered by central starbursts
  - They betray the presence of very elusive AGN

AGN in Bulgeless Galaxies



Thomas Bohn

- The study of the BH population in bulgeless galaxies sheds light on alternative growth mechanisms for BHs that are not strictly connected to mergers
- Another way to look at “fossil record” of BH seeds (cf. Jon Trump’s talk)
- Comparison to Illustris simulations (cf. Colin DeGraf’s talk) allow us to trace back the growth history of these objects

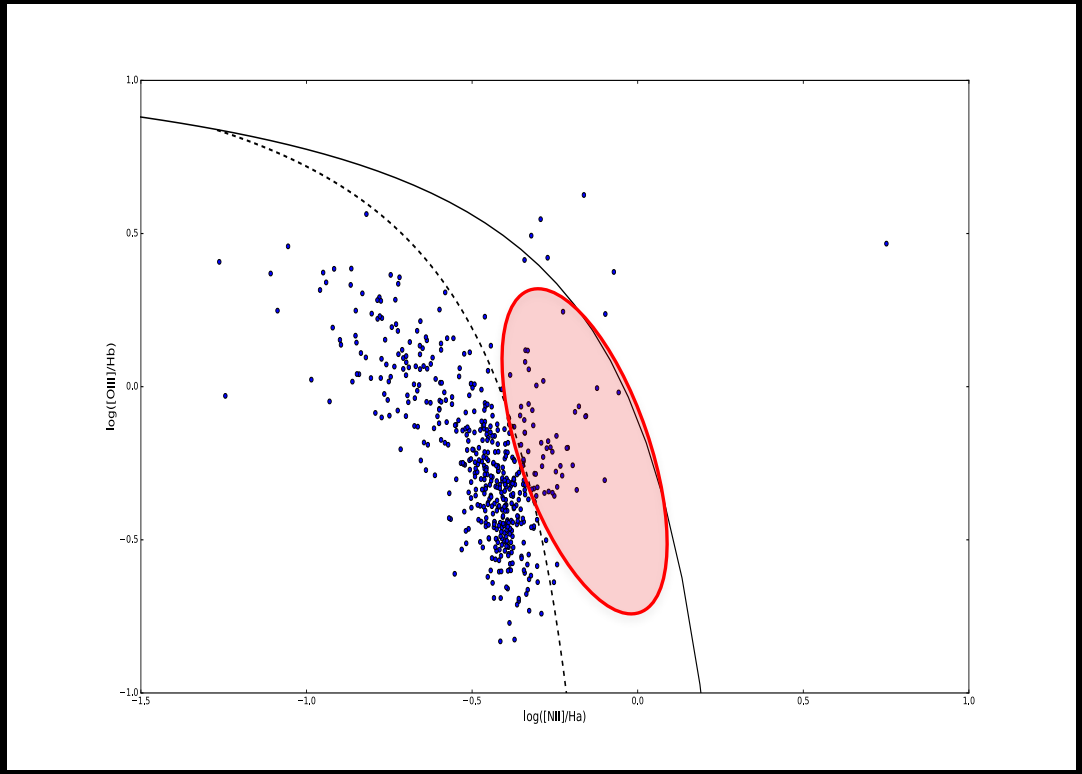
Bulgeless galaxies potentially hosting AGN

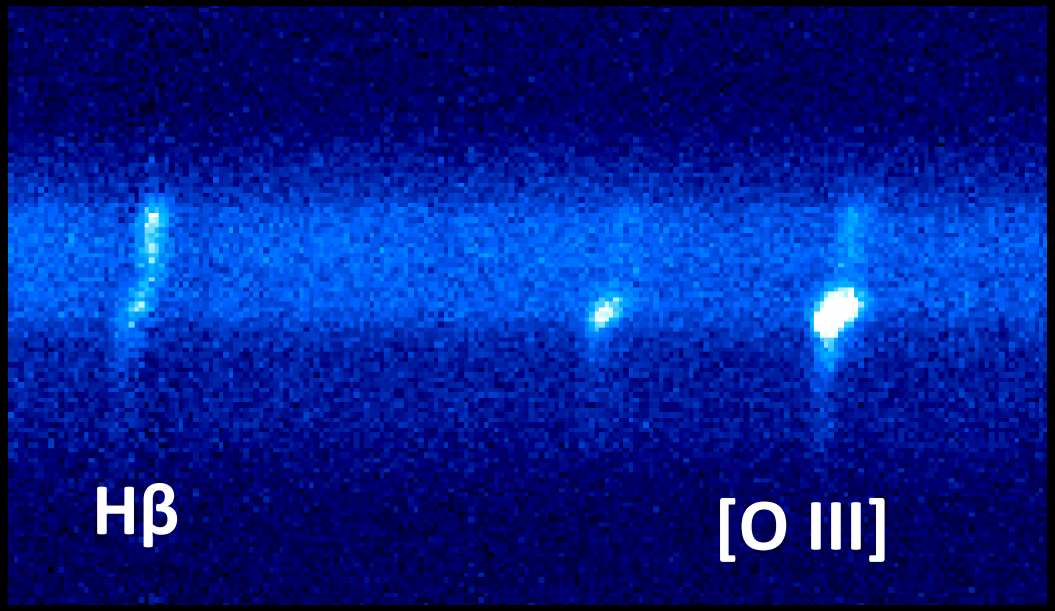
Following Satyapal+2014, we selected galaxies:

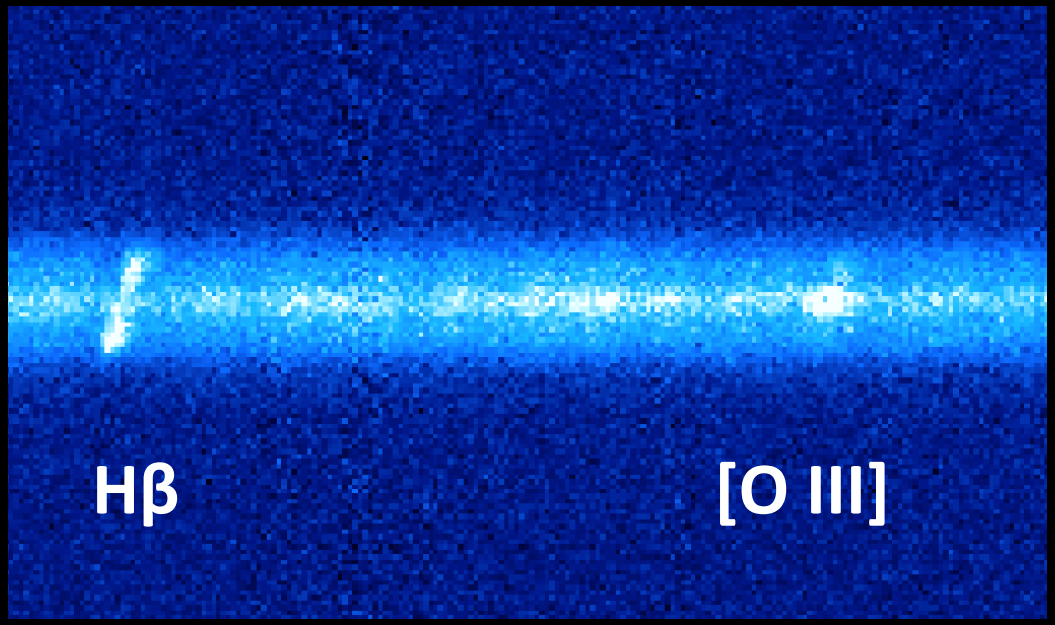
- $z < 0.05$
- B/T = 0 (Simard+2011)
- BPT composite or AGN

Two problems (at least):

- Host subtraction
  (cf. Ingyin Zaw's talk)
- Shocks







Lick 3-meter spatially resolved spectroscopy:

solution to host dilution in some cases

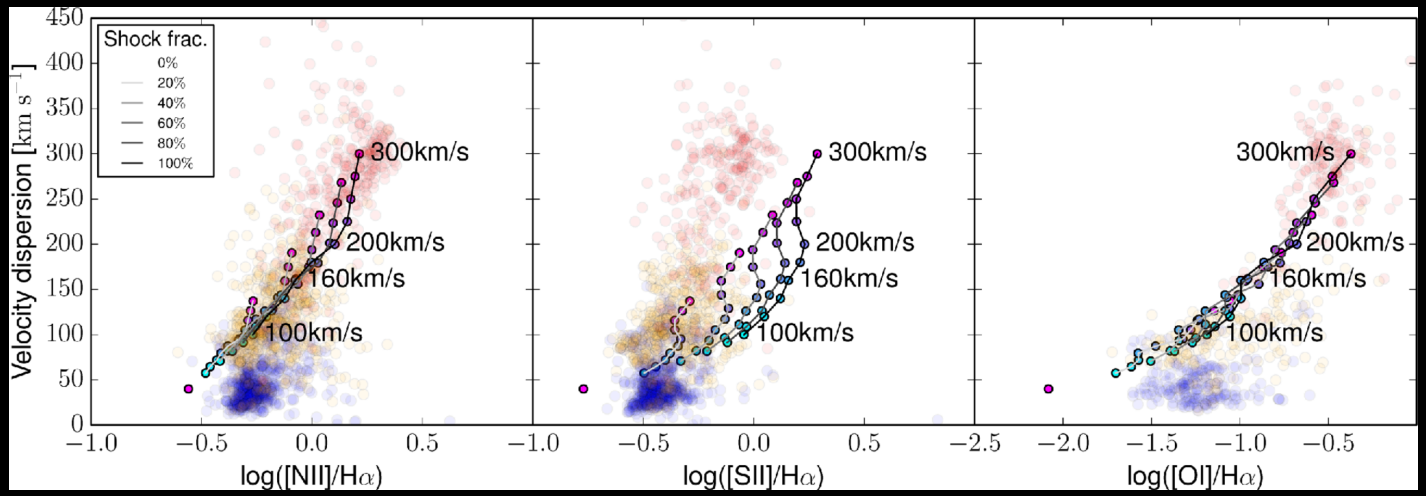
Will follow up with NIR observations

Summary:

High spatial resolution studies can help us uncover elusive AGN

- Sometimes even a modest improvement in spatial resolution can make all the difference!

- There is observational evidence that shock velocity is correlated with velocity dispersion (Ho+2015)



Ho+2015