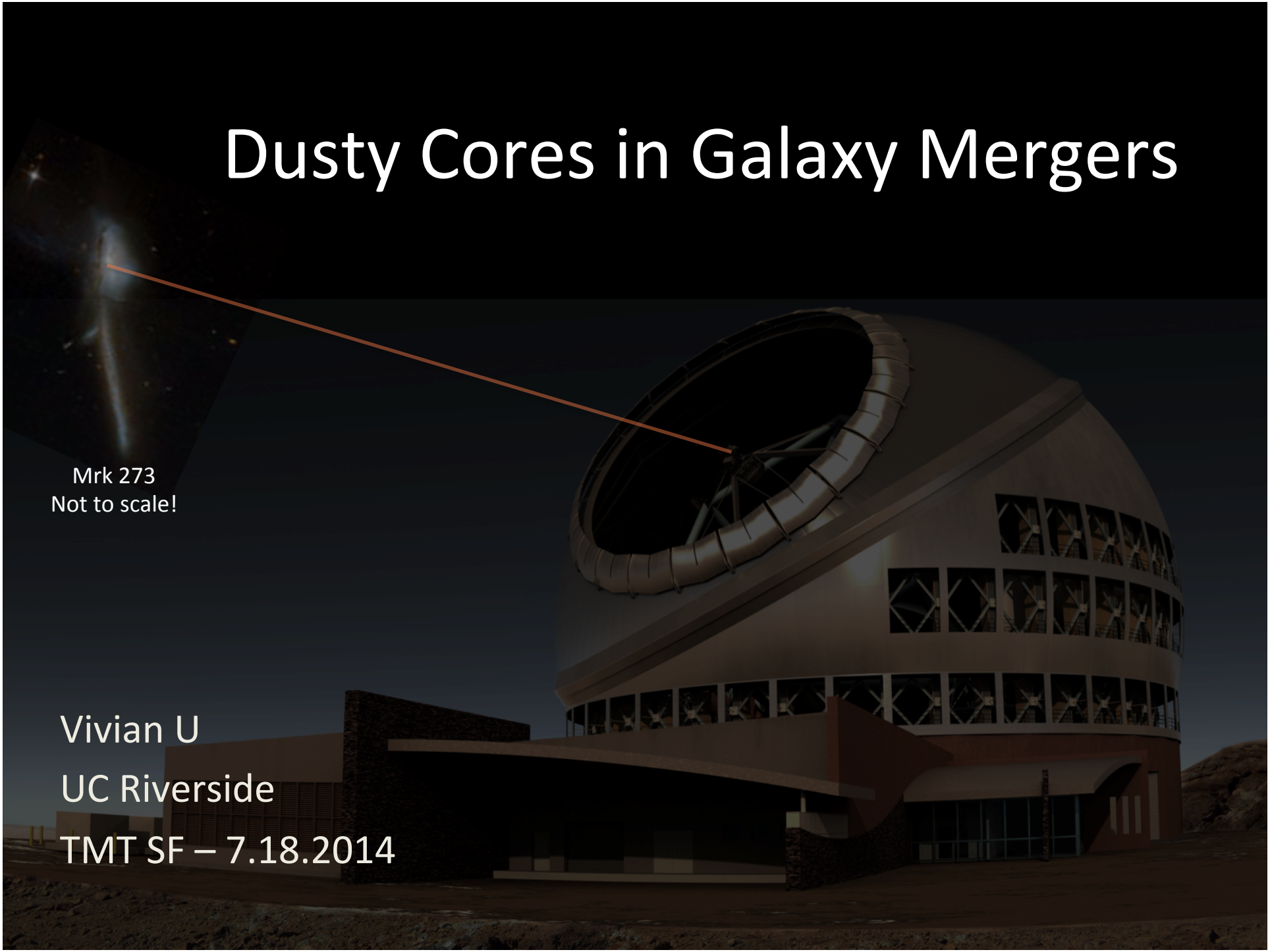
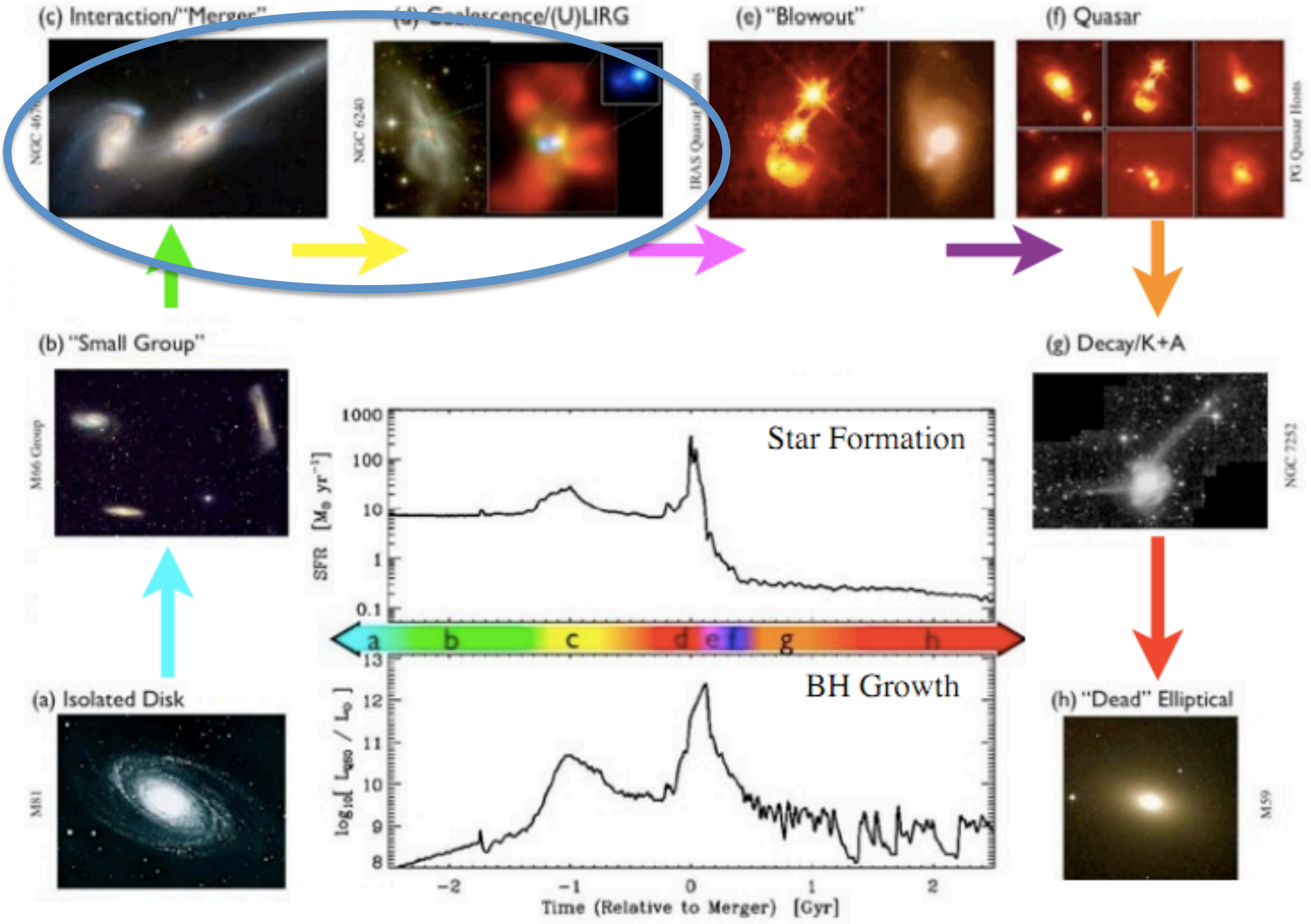
Dusty Cores in Galaxy Mergers



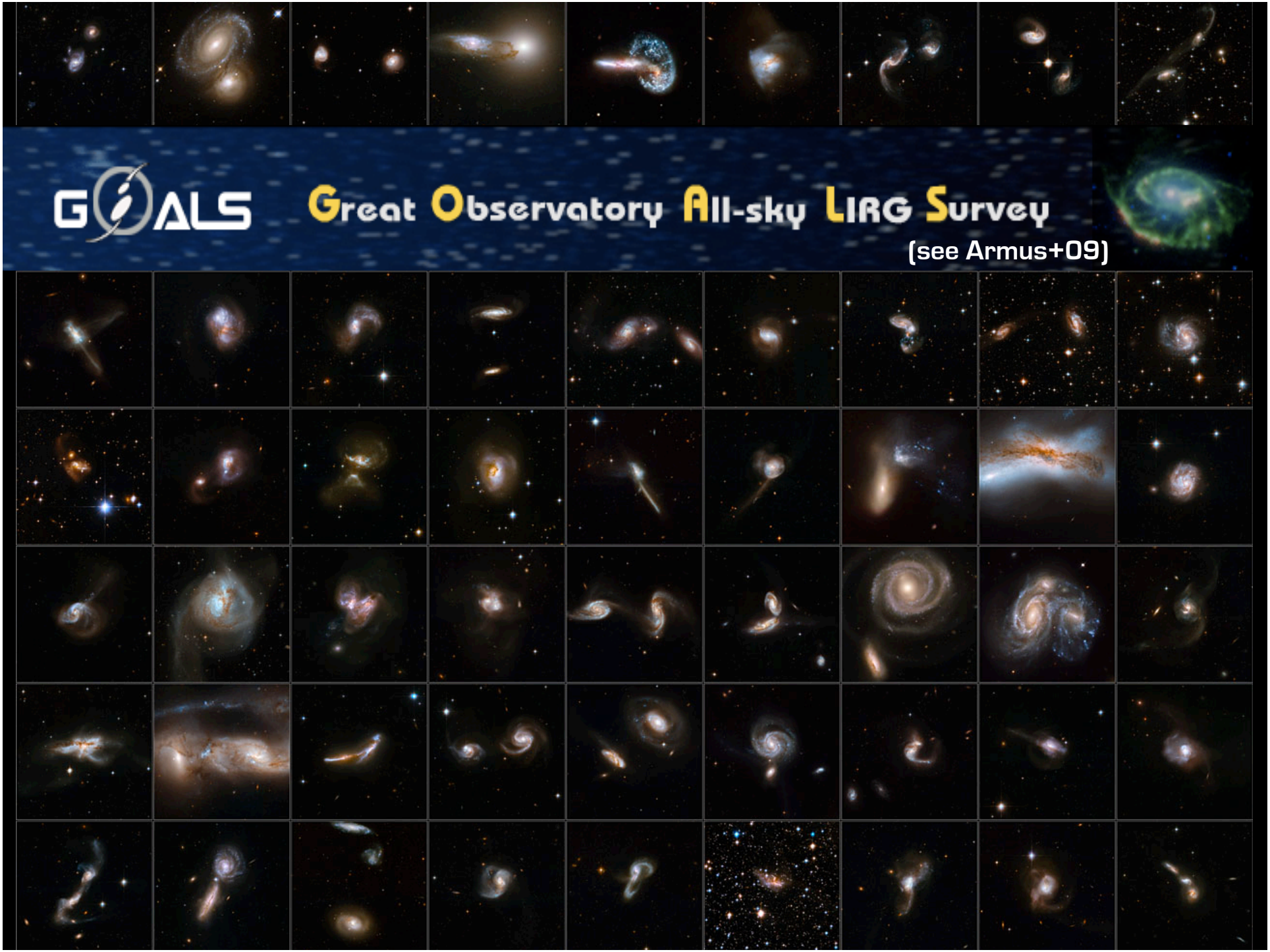
Vivian U
UC Riverside
TMT SF – 7.18.2014

Probing Galaxy Mergers with Large Mirrors

- Nuclear stellar and gas kinematics
- Black hole – host galaxy coevolution
- Outflows
- Excitation mechanisms
- The need for TMT



e.g. Sanders+88, Hopkins+08


GOALS
Great Observatory All-sky LIRG Survey
(see Armus+09)

Keck NIR AO Campaign

- Goals: distribution and dynamics of nuclear stars and gas, BH masses, SB vs AGN, outflows

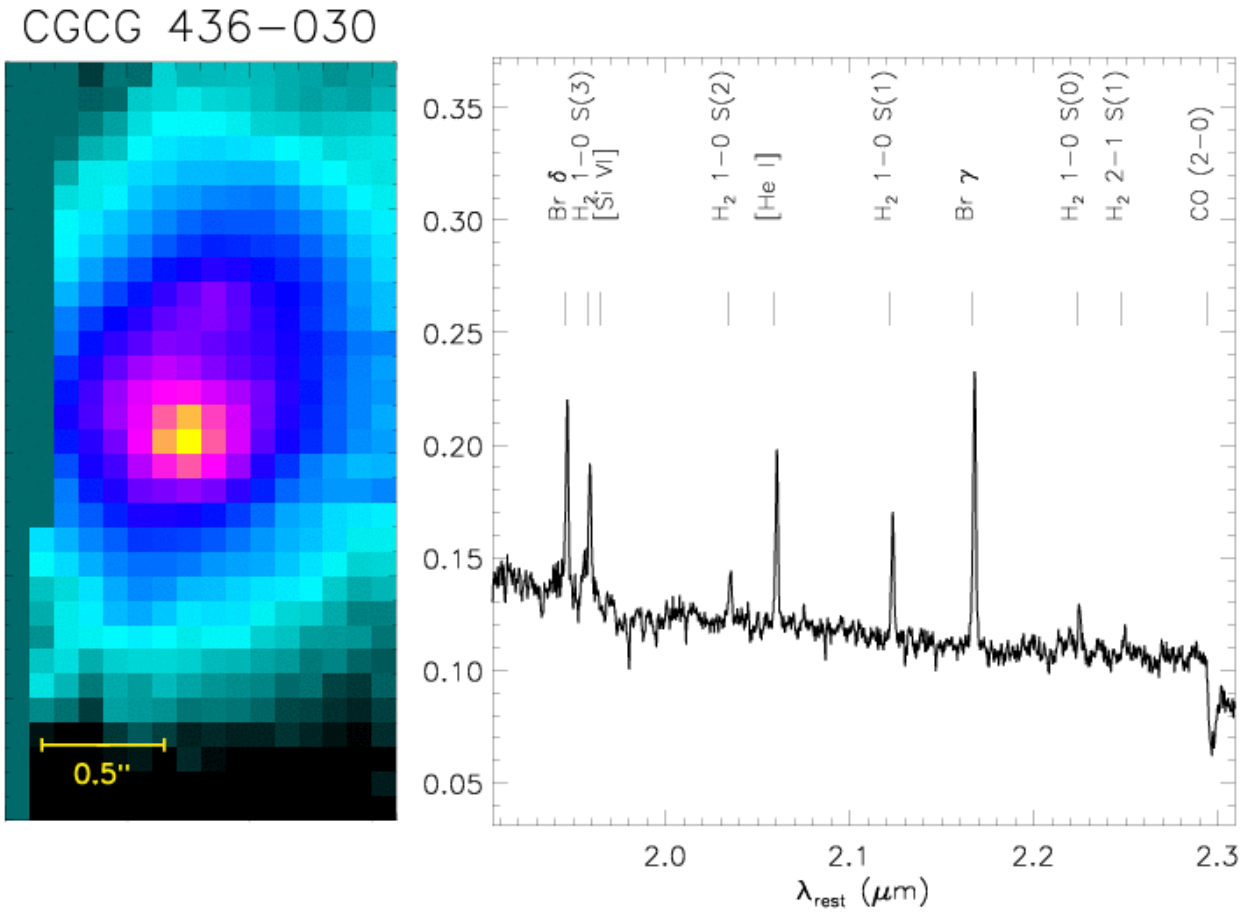
- ***Strategies:***
  - ***NIRC2 and OSIRIS, LGS AO (FWHM ~0.05")***
  - ***H or K bands, 0.01" (NIRC2) and 0.035"-0.100" (OSIRIS)***
  - ***Molecular and atomic gases, stellar dynamics: H_2, Br, He I, [Si VI], CO bandheads, etc.***

Medling (ANU), Sanders (IfA), Armus (SSC), Max (UCSC), Evans (NRAO/UVa), Iwasawa (IEEC-UB), Kewley (ANU), Mazzarella (IPAC), Surace (SSC), Inami (NOAO), Stierwalt (NRAO), Barnes (IfA), and the GOALS Team

17 (mostly late-stage) mergers at a Glance

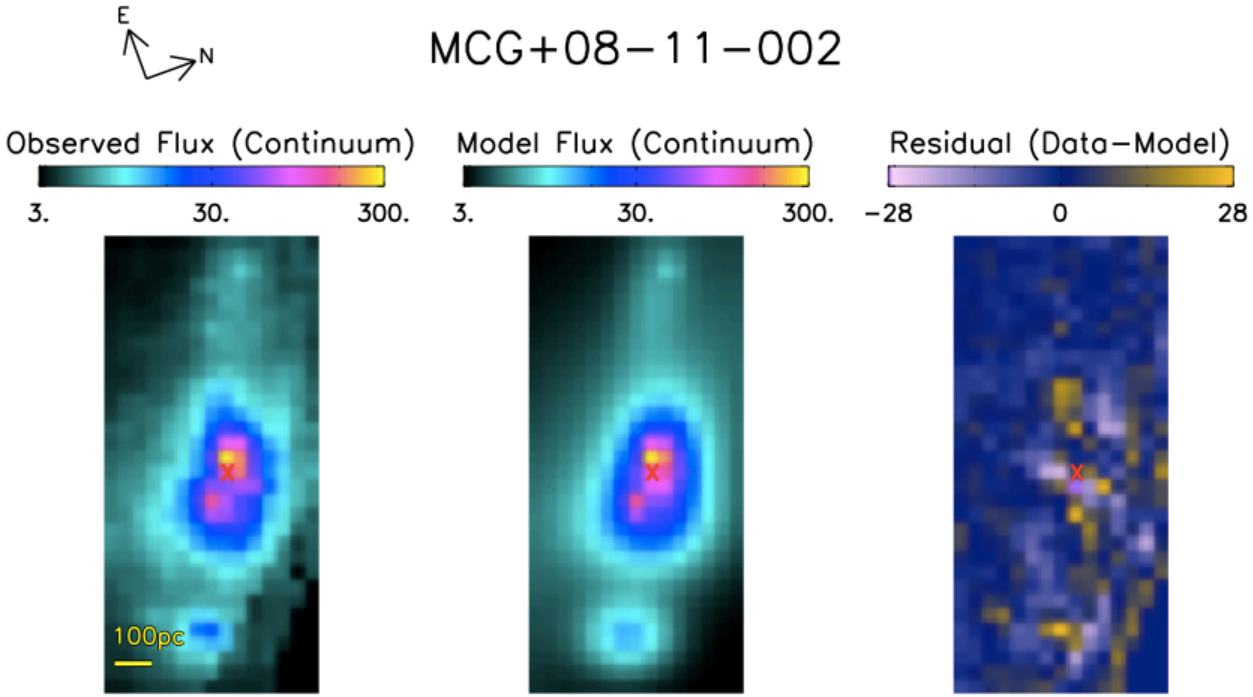
Previous IFU work on (U)LIRGs focus on large-scale gas dynamics and metallicity gradients (e.g. Westmoquette +12, Rich+11,12, Garcia-Marin+09, Piqueras Lopez+12)

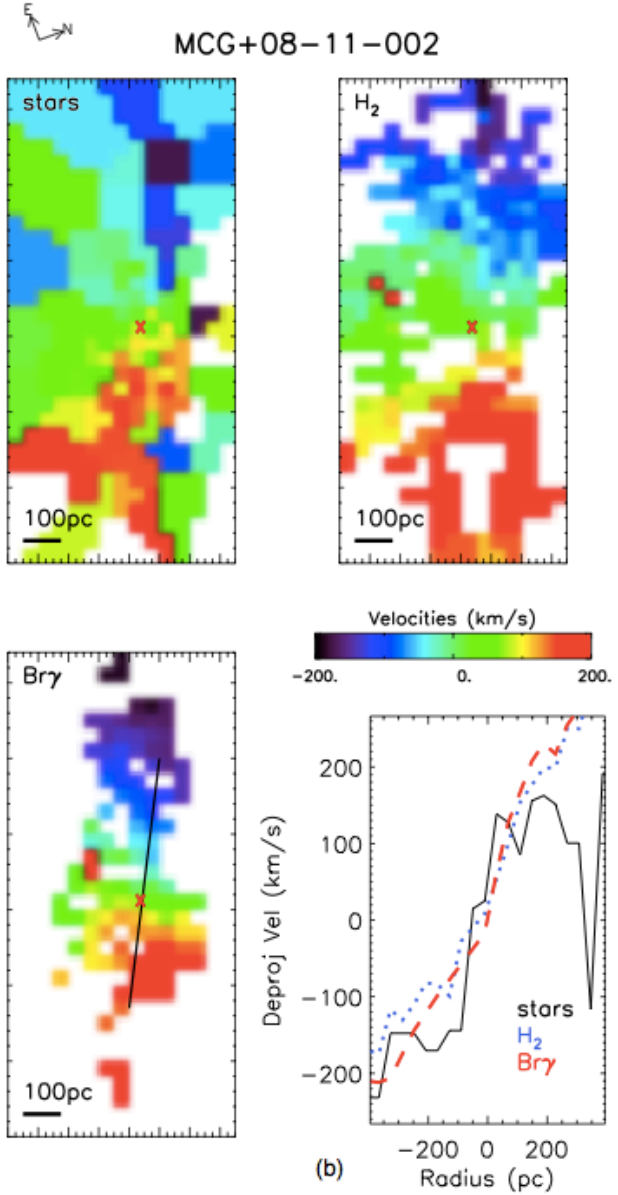
A systematic high-resolution NIR look of their dusty cores!



Nuclear star and gas dynamics

- Nuclear disks are nearly ubiquitous

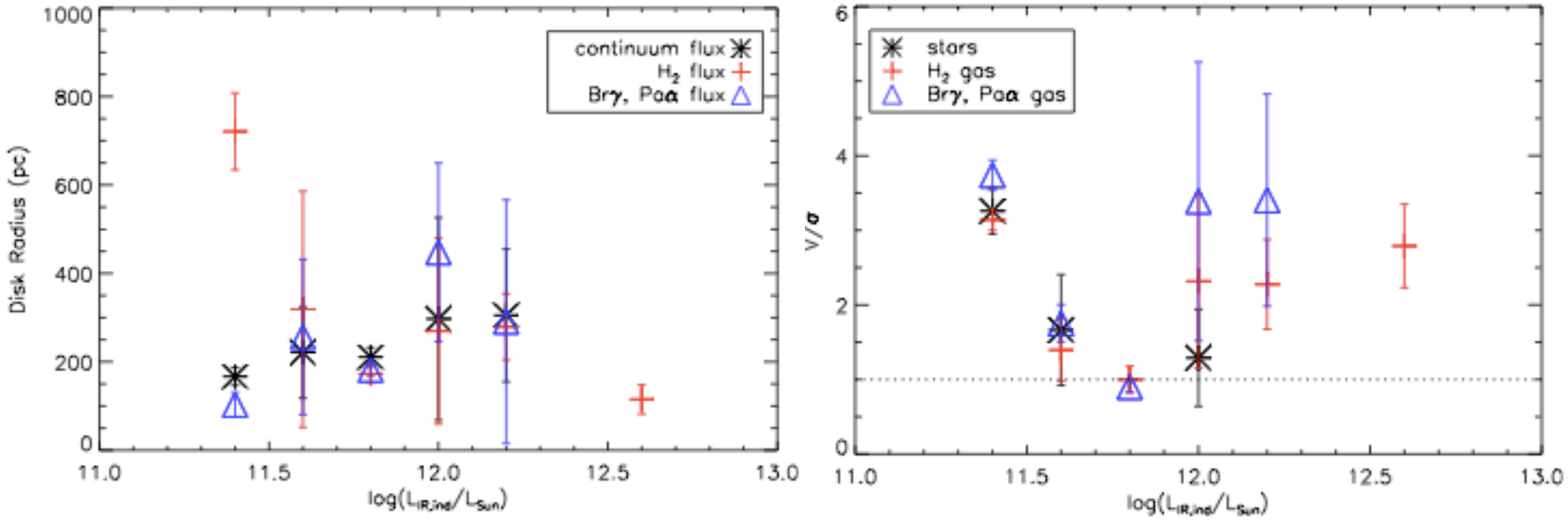




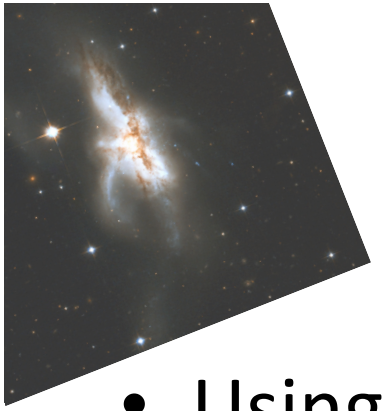
Medling, U+ 2014, ApJ, 784, 70

Nuclear star and gas dynamics

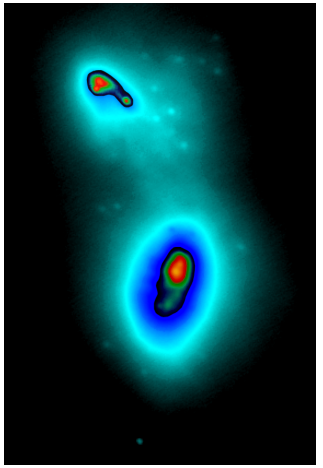
- Nuclear disks are nearly ubiquitous
- Disk sizes (r_{eff} ~ a few x 100 pc) and v/σ (1-5) compare well with simulations



Medling, U+ 2014, ApJ, 784, 70

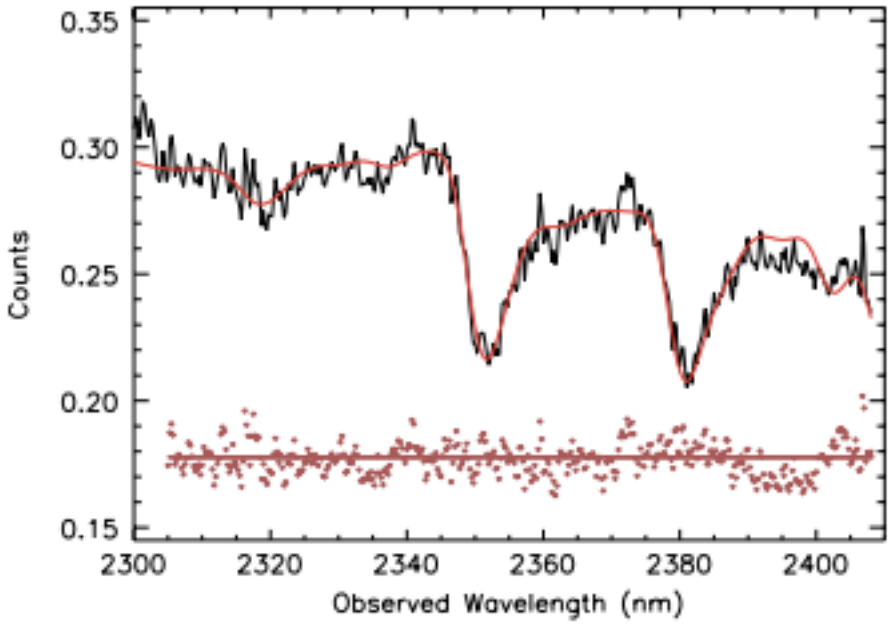


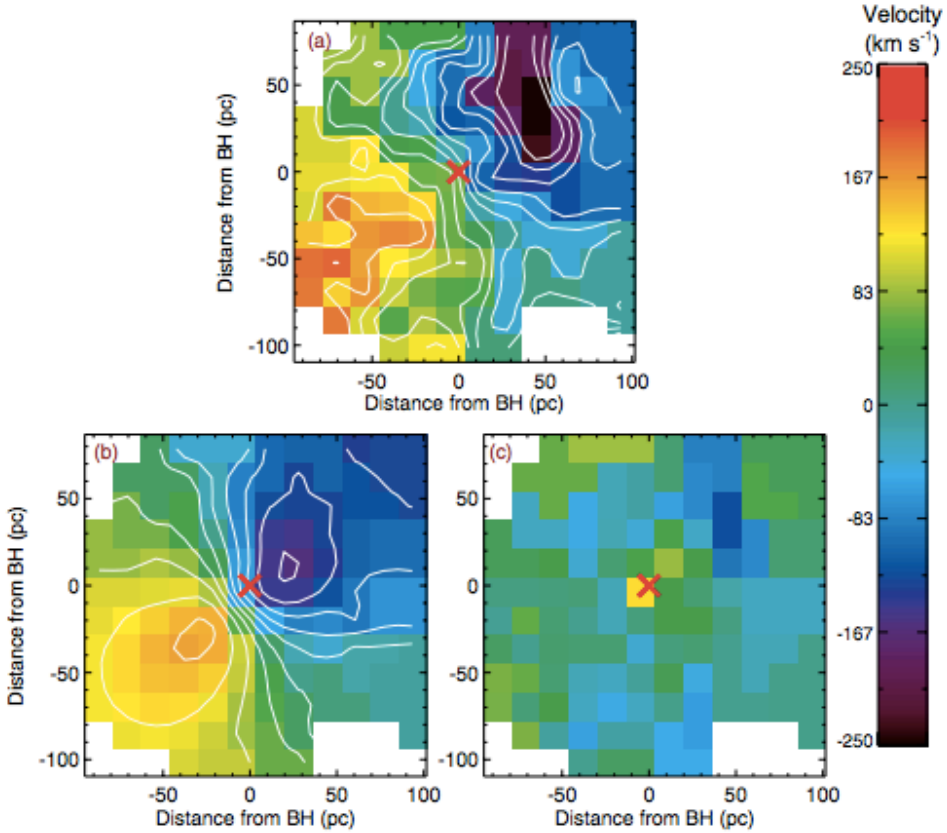
Measuring black hole masses



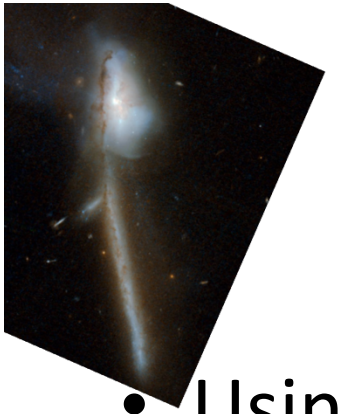
Max+ 07

- Using stellar kinematics (e.g. NGC 6240, Medling+11)

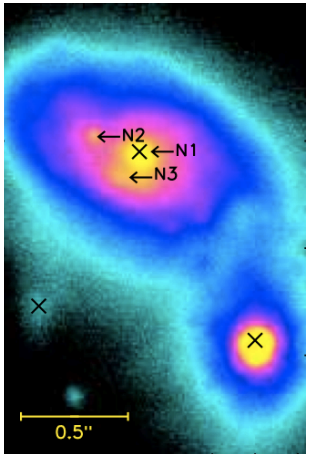




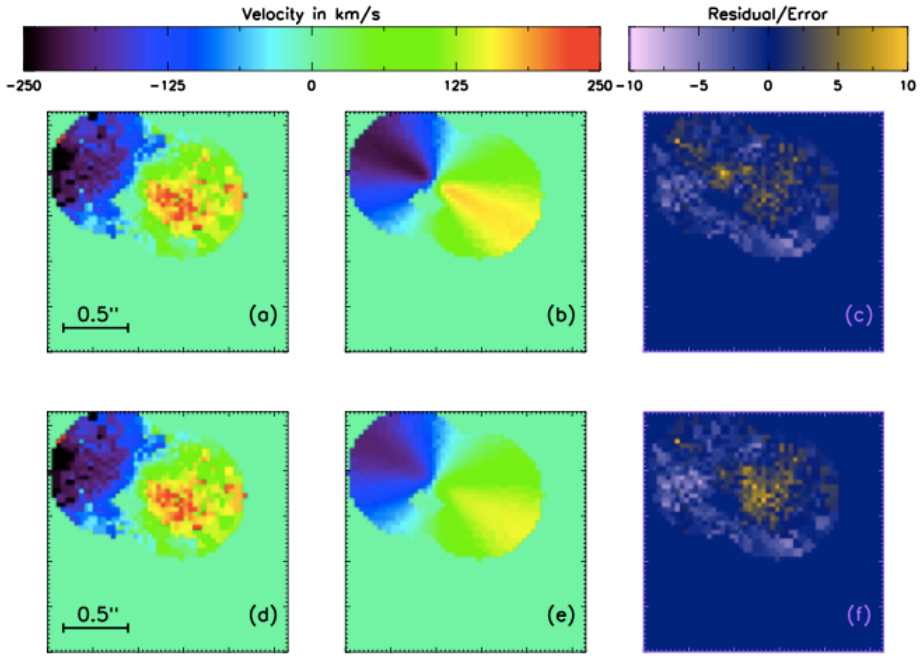
Medling+ 2011

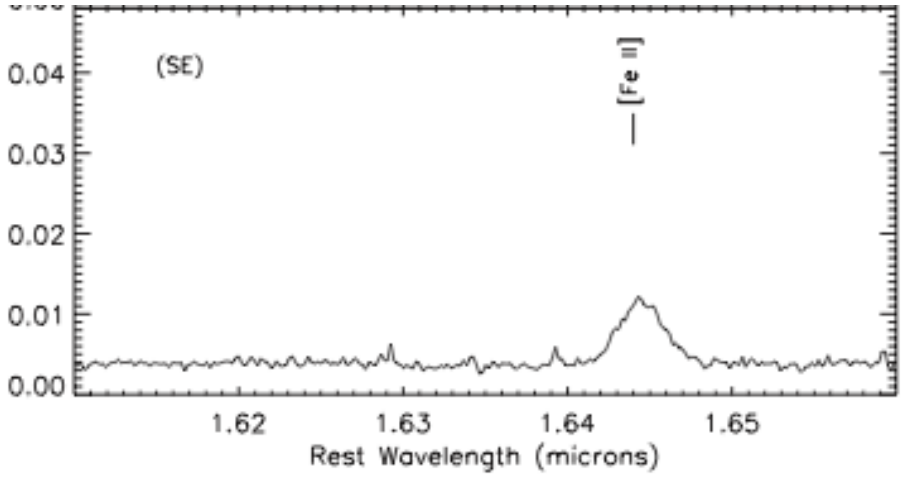


Measuring black hole masses



- Using stellar kinematics (e.g. NGC 6240, Medling+11)
- Using gas kinematics (e.g. Mrk 273, U+13)

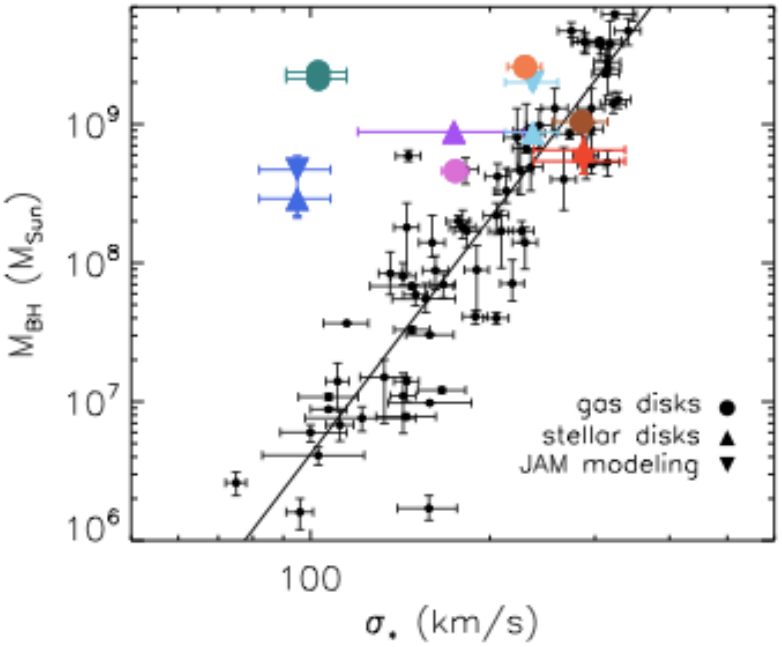


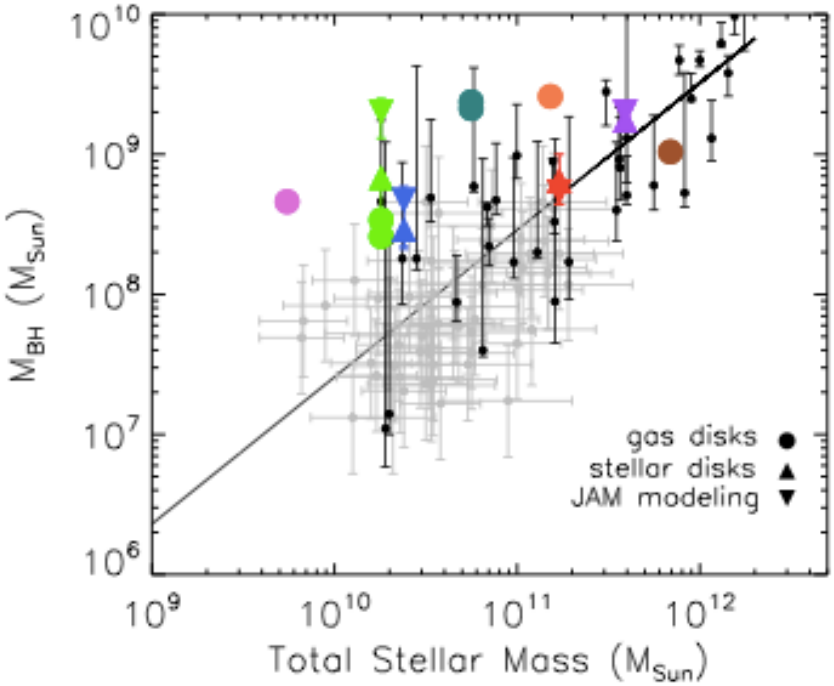


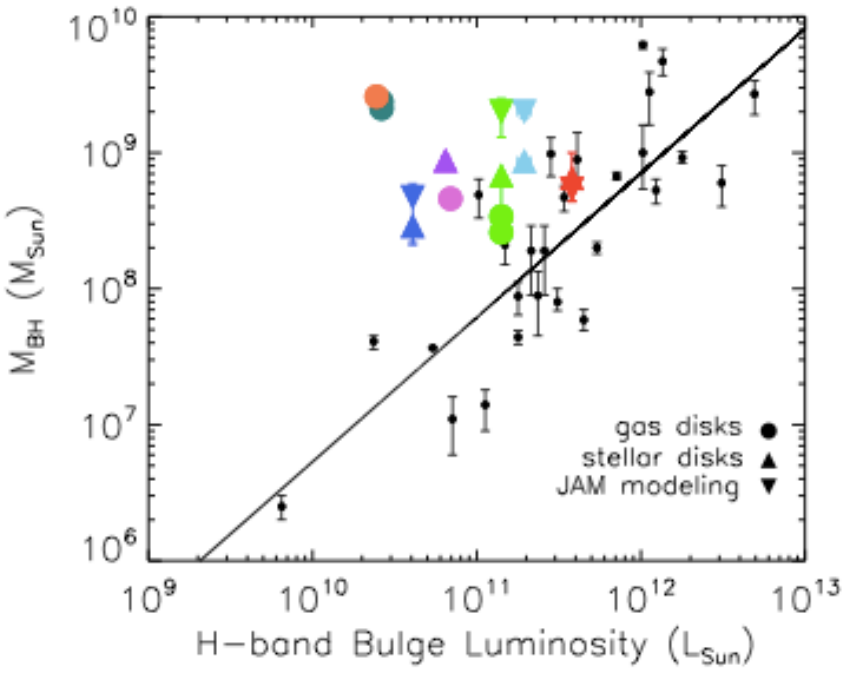
U+ 2013, ApJ, 775, 115

BH Scaling Relations

- Galaxy mergers lie *above* the various scaling relations! (Medling, U+ in prep.)

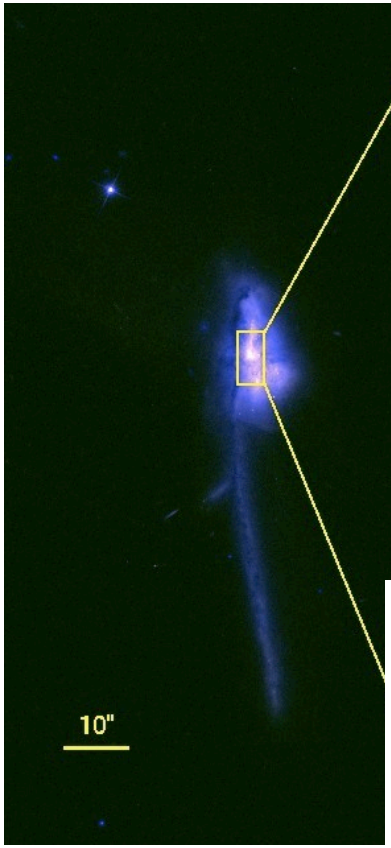


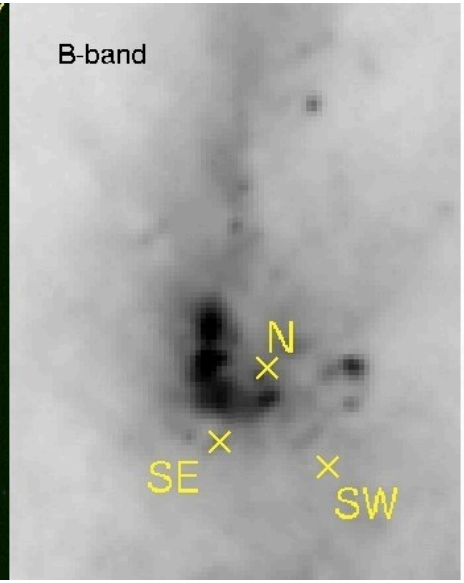


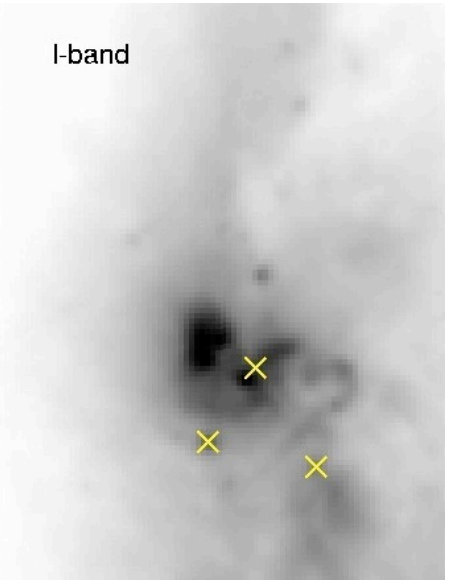


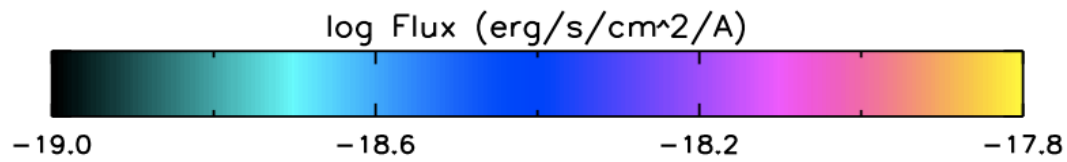
Outflows

- Case study: Mrk 273

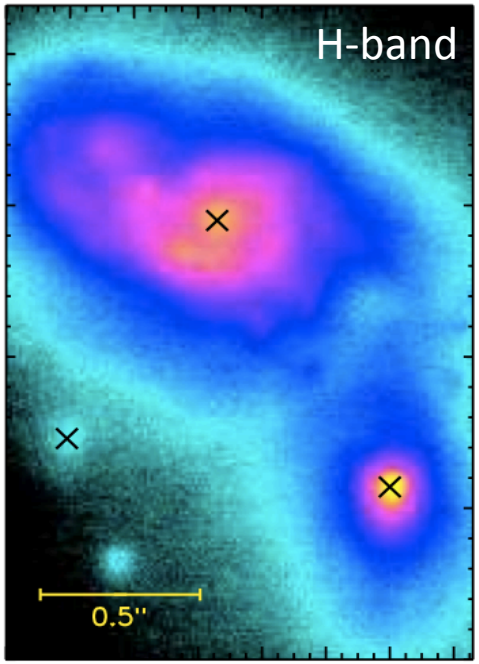


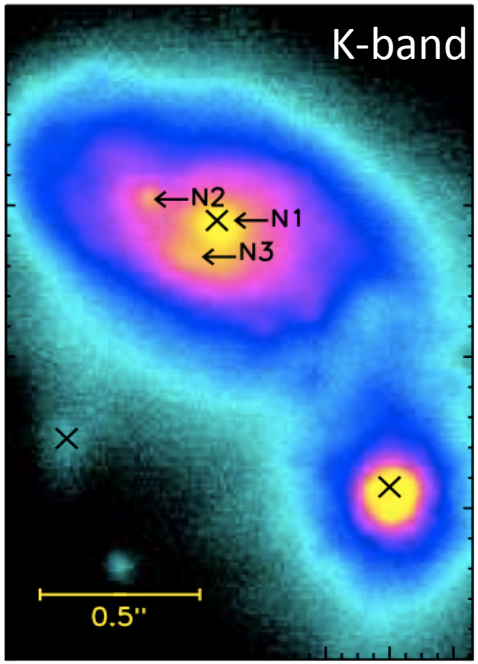






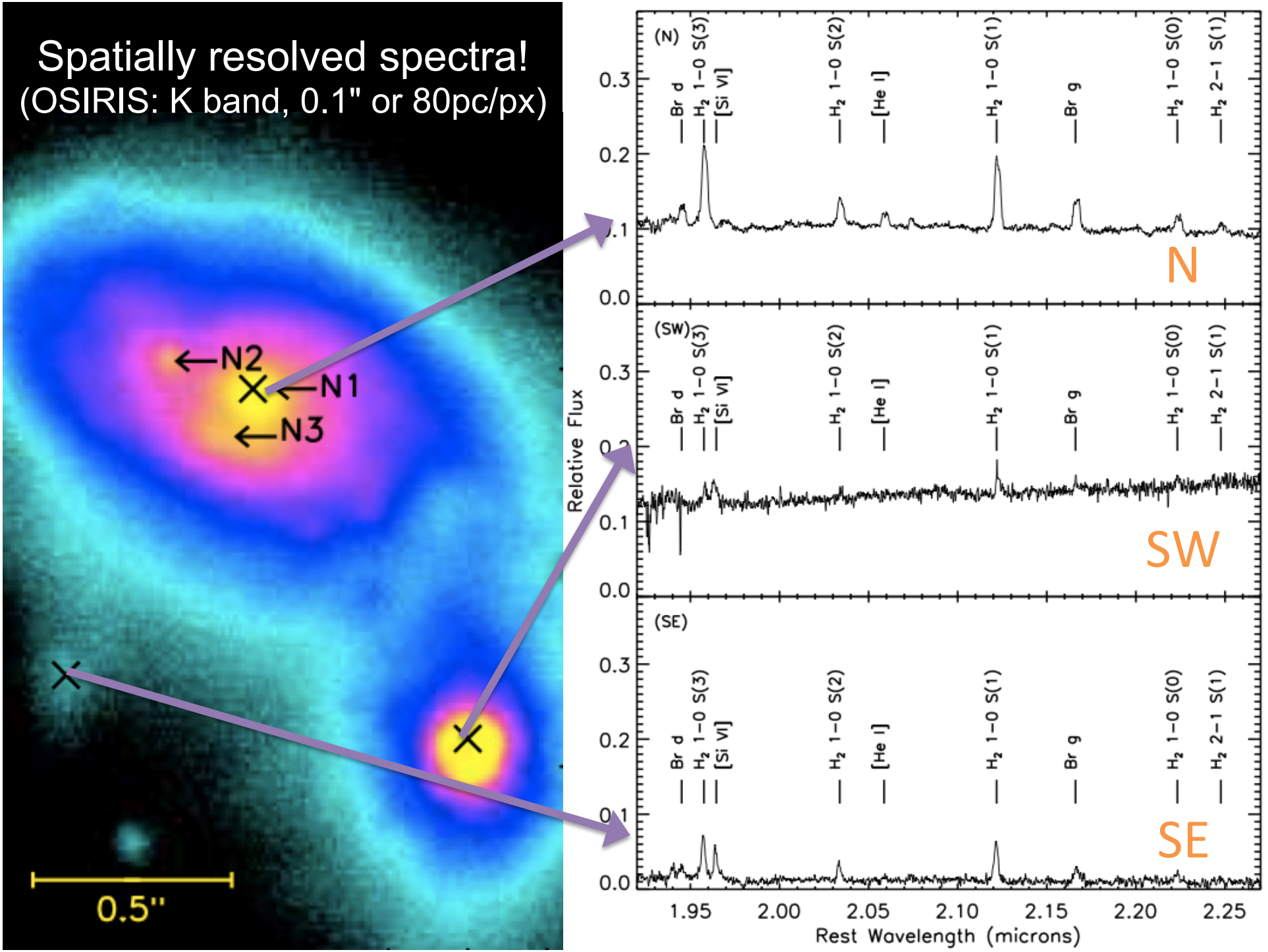
Above: HST ACS B and I bands





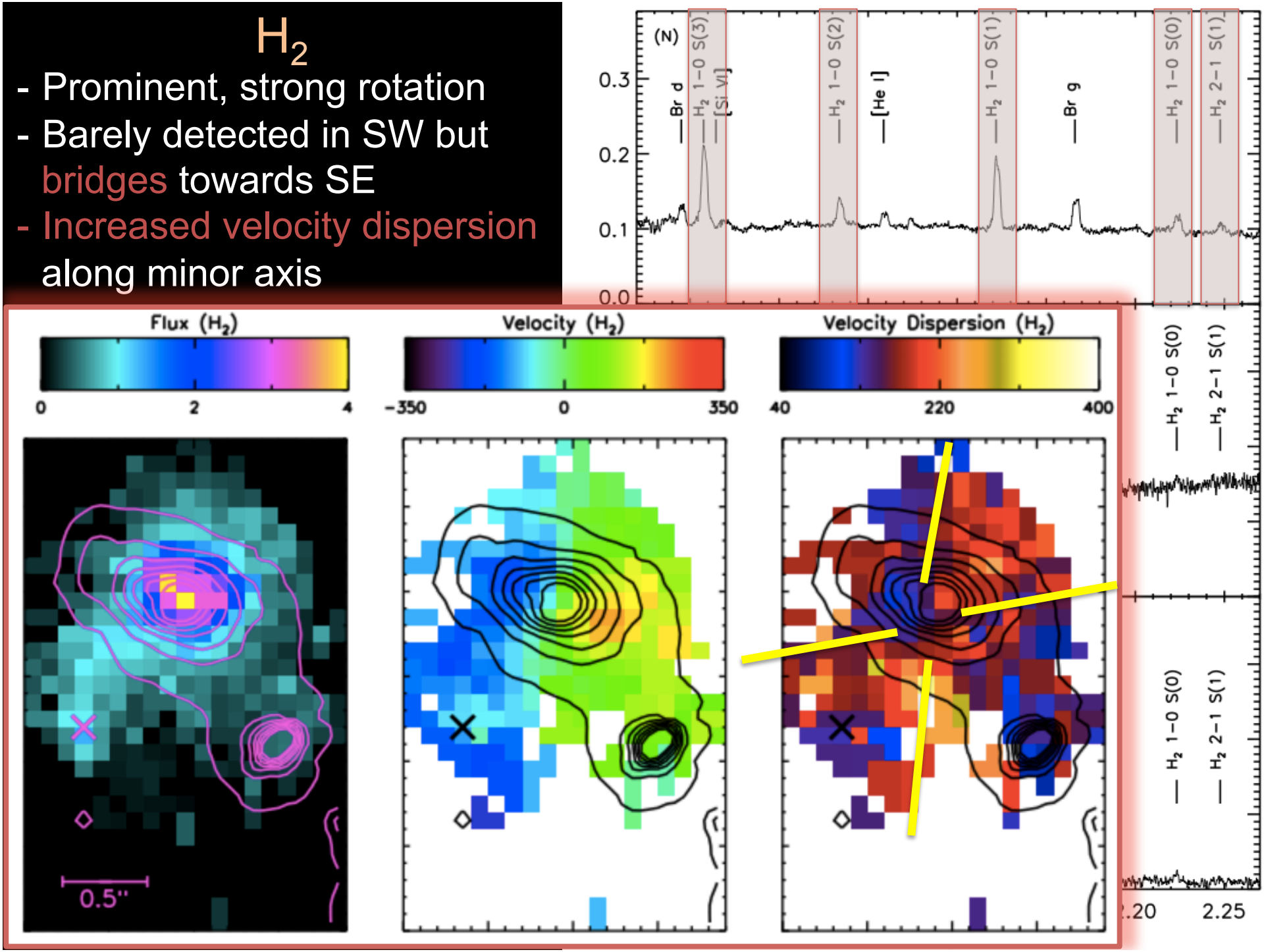
Right: Keck NIRC2+AO H and K bands (0.01"/px, or 8pc/px)

U+ 2013, ApJ, 775, 115


Spatially resolved spectra!
(OSIRIS: K band, 0.1" or 80pc/px)
N2
N1
N3
0.5"
(N)
(SW)
(SE)
Br d
H2 1−0 S(3)
[Si VI]
H2 1−0 S(2)
[He I]
H2 1−0 S(1)
Br g
H2 1−0 S(0)
H2 2−1 S(1)
N
SW
SE
Relative Flux
0.0
0.1
0.2
0.3
1.95
2.00
2.05
2.10
2.15
2.20
2.25
Rest Wavelength (microns)

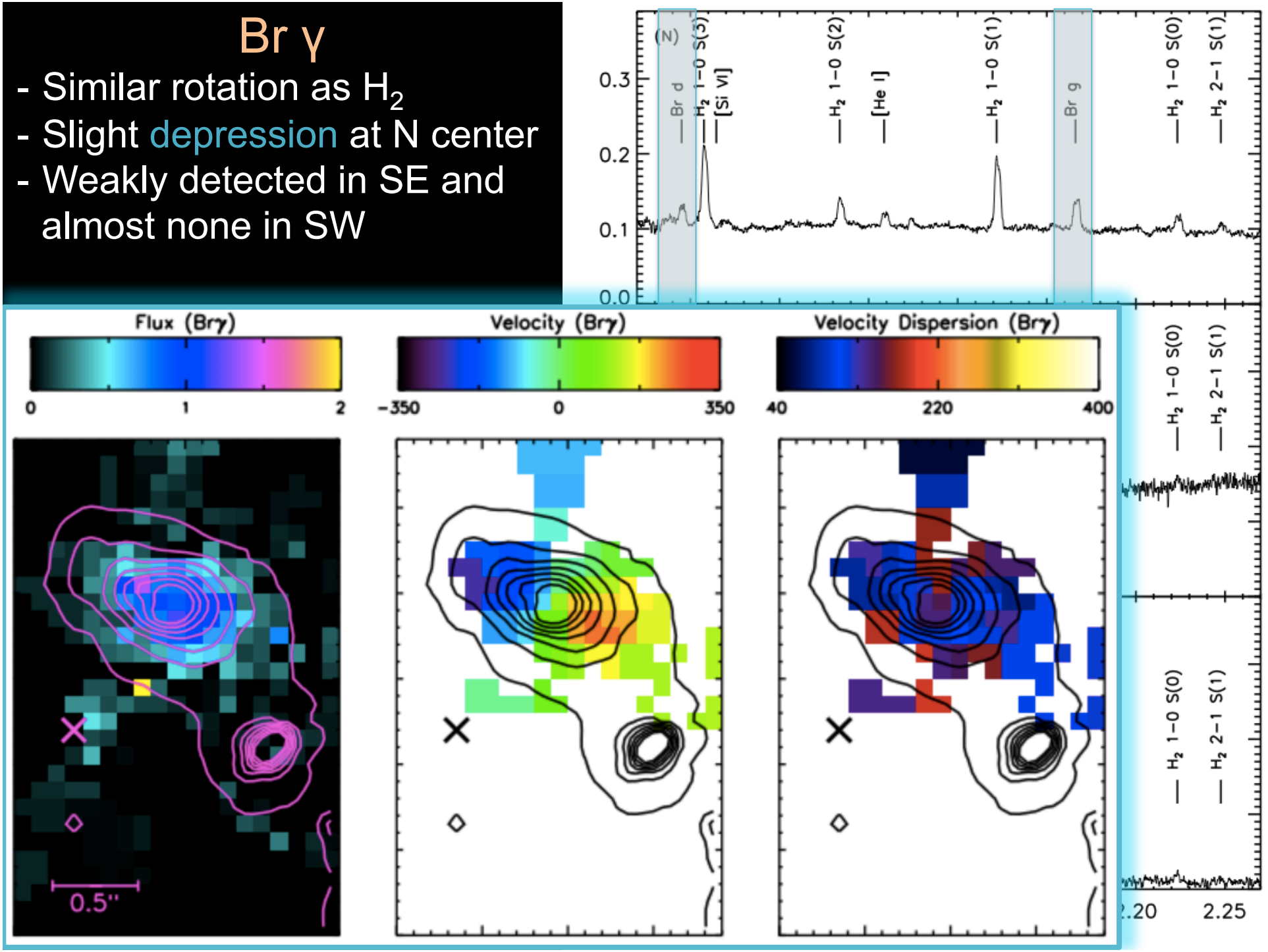
H_2

- Prominent, strong rotation
- Barely detected in SW but bridges towards SE
- Increased velocity dispersion along minor axis



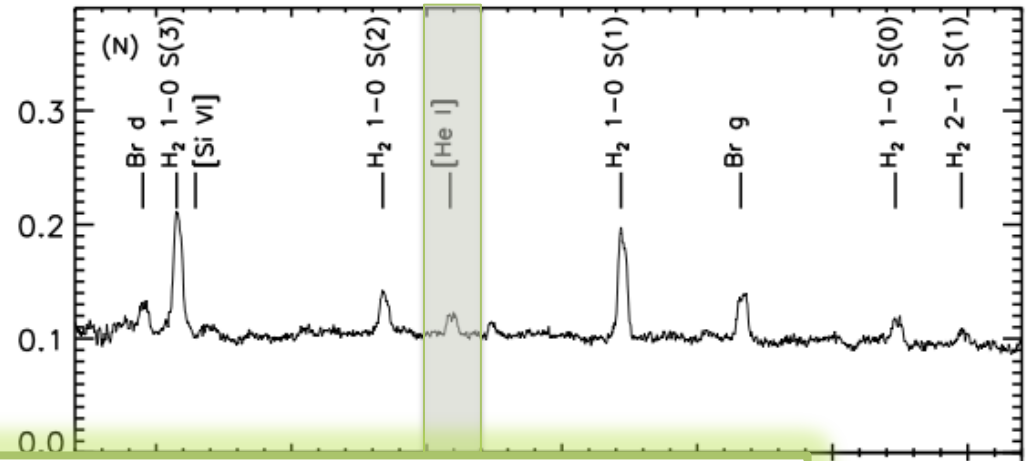
Br γ

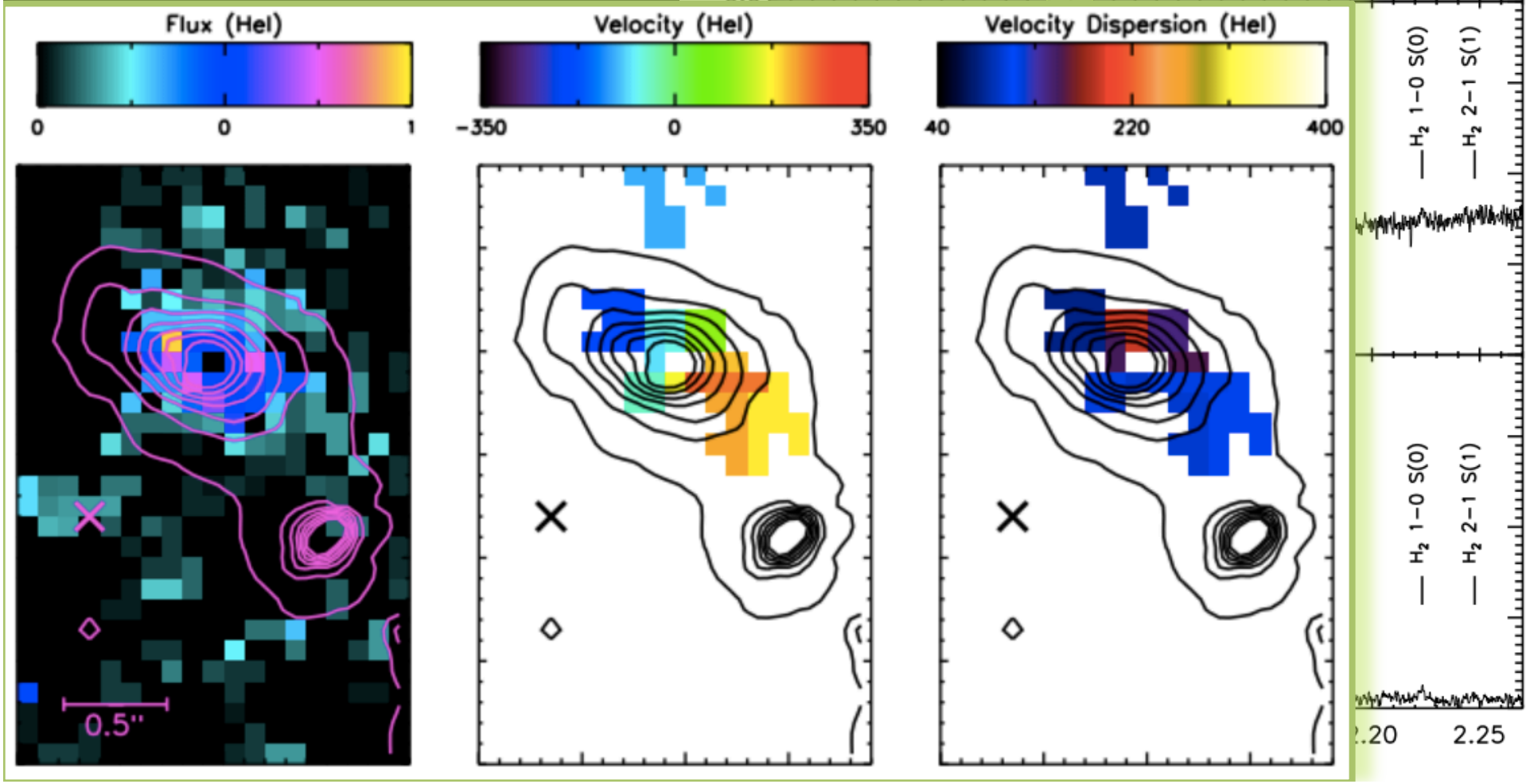
- Similar rotation as H_2
- Slight depression at N center
- Weakly detected in SE and almost none in SW



[He I]

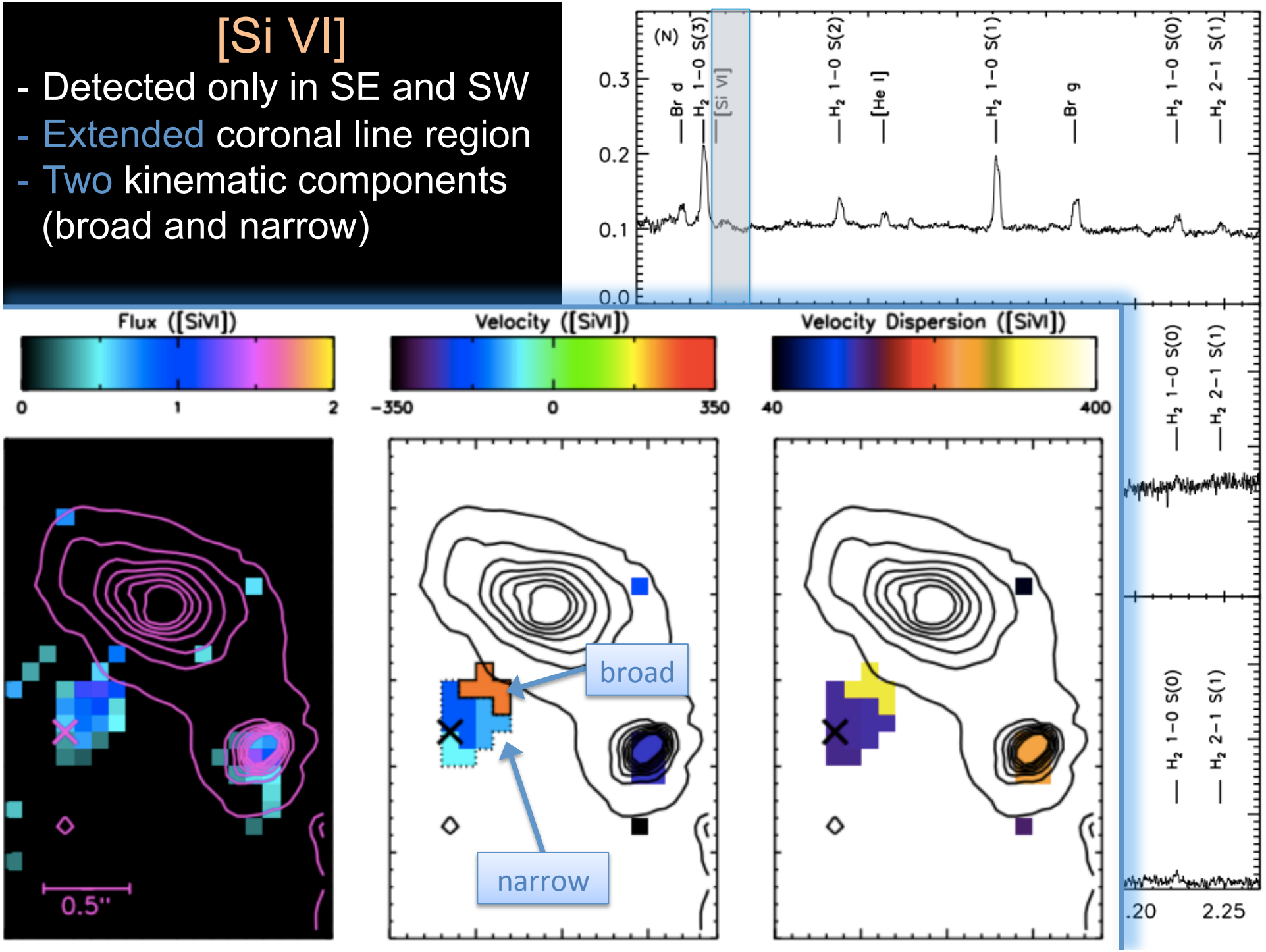
- Similar kinematics as Br γ
- More pronounced depression at N center
- Weakly detected in SE and

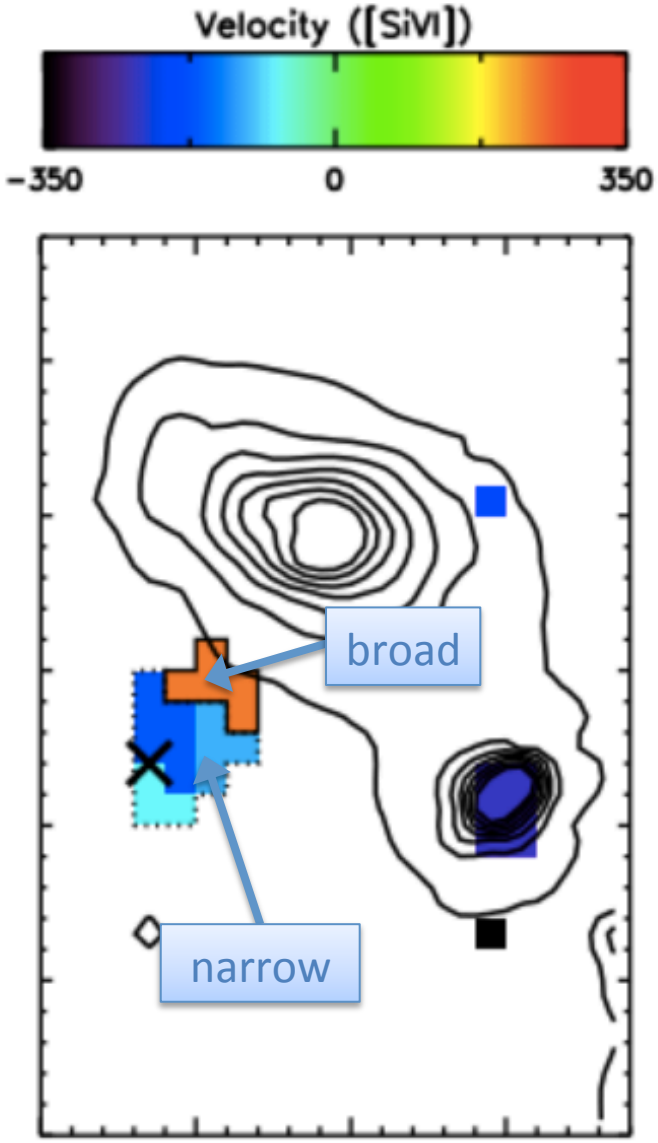


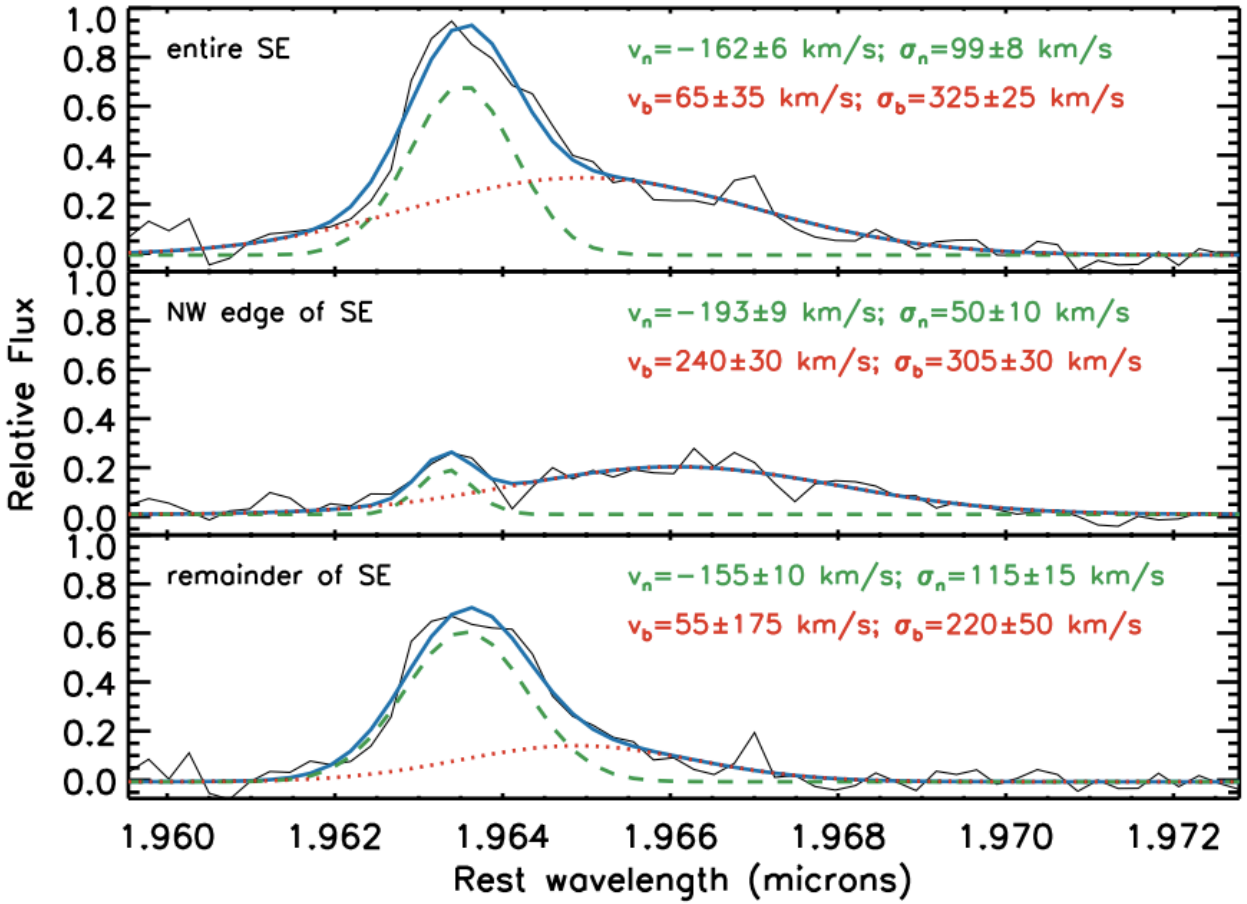


[Si VI]

- Detected only in SE and SW
- Extended coronal line region
- Two kinematic components (broad and narrow)



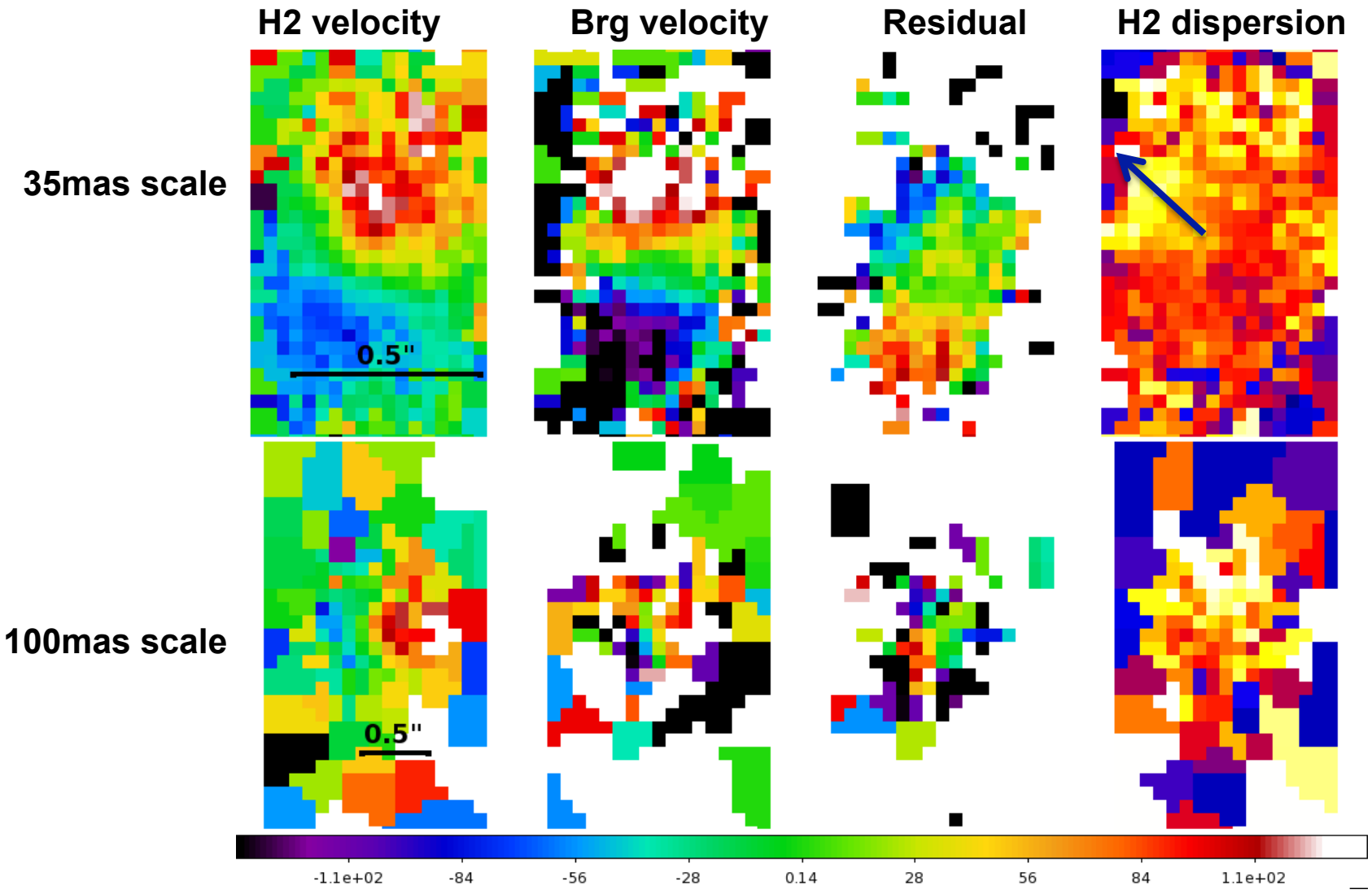




[Si VI] line traces extended CLR, which are associated with outflows in Seyfert galaxies (see also Muller-Sanchez+11)

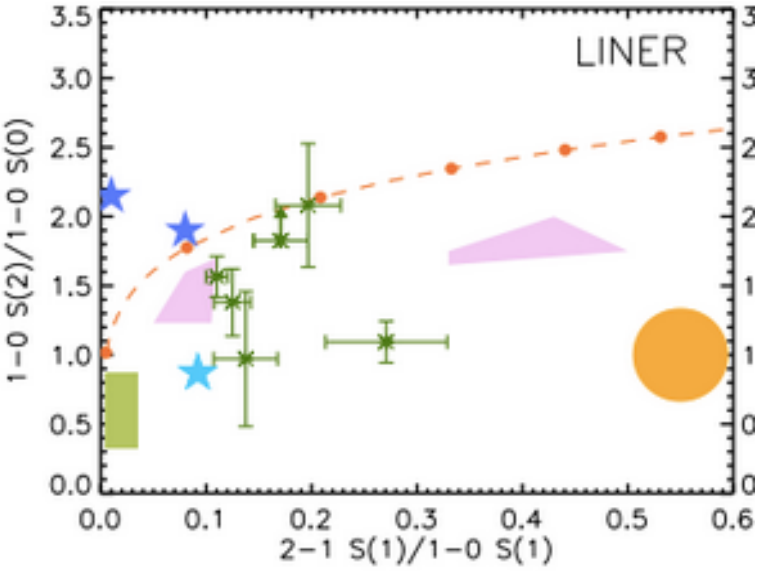
Ionized vs. Molecular Gas Kinematics

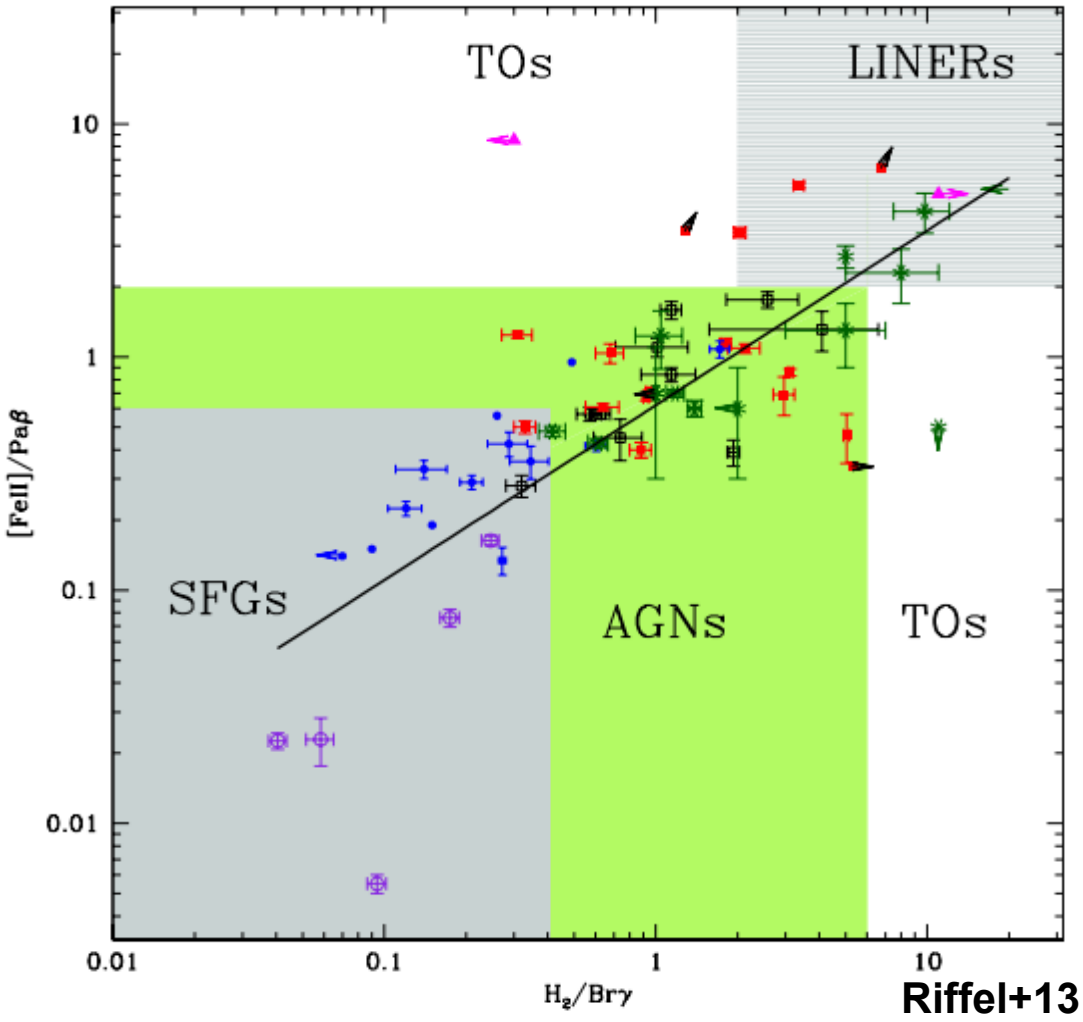
- Example: III Zw 035 (U+ in prep.)



Excitation mechanisms

- Diagnostics for starbursts vs AGNs, shocks, etc.
- H2 line ratios





Riffel+13

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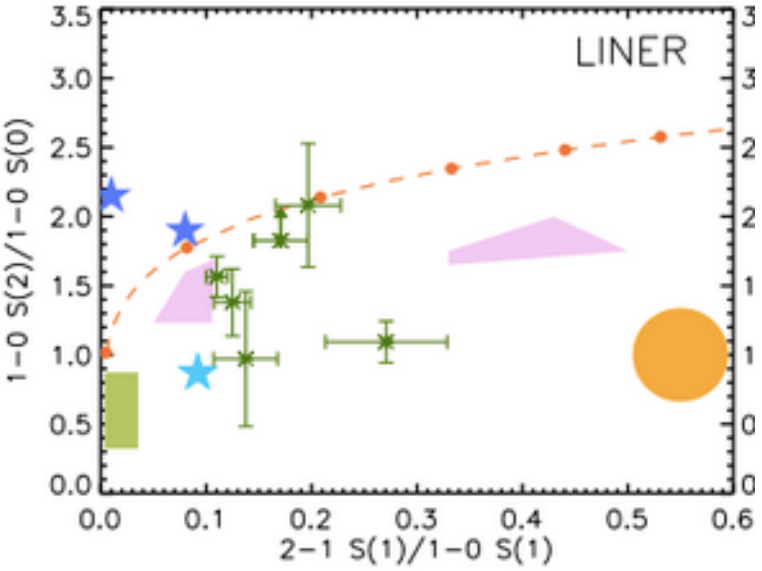
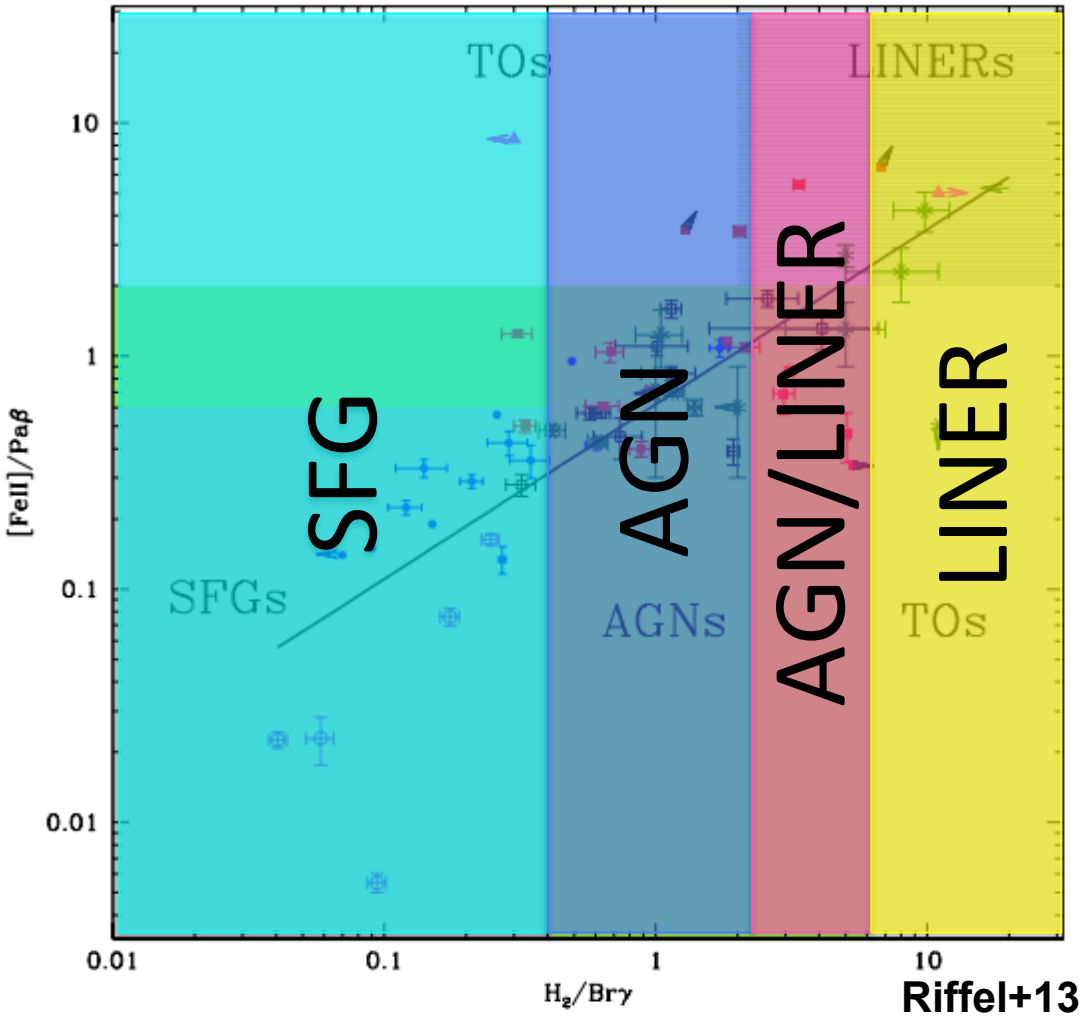
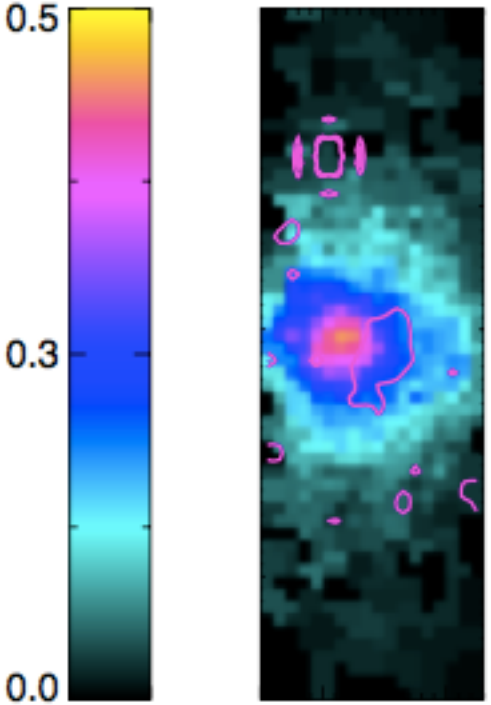


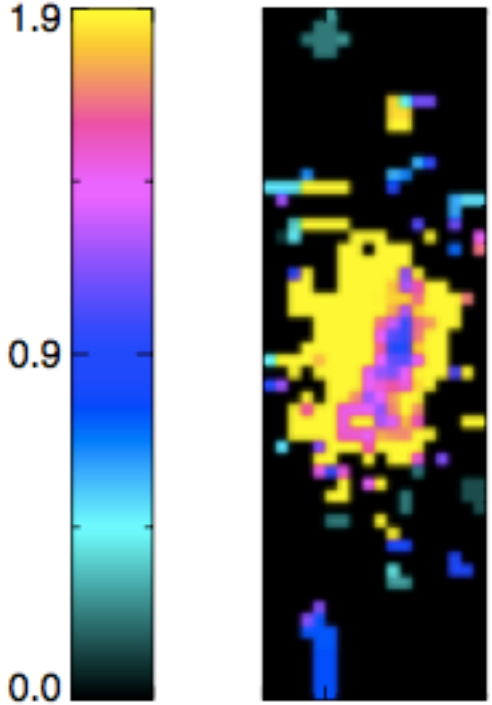


Riffel+13

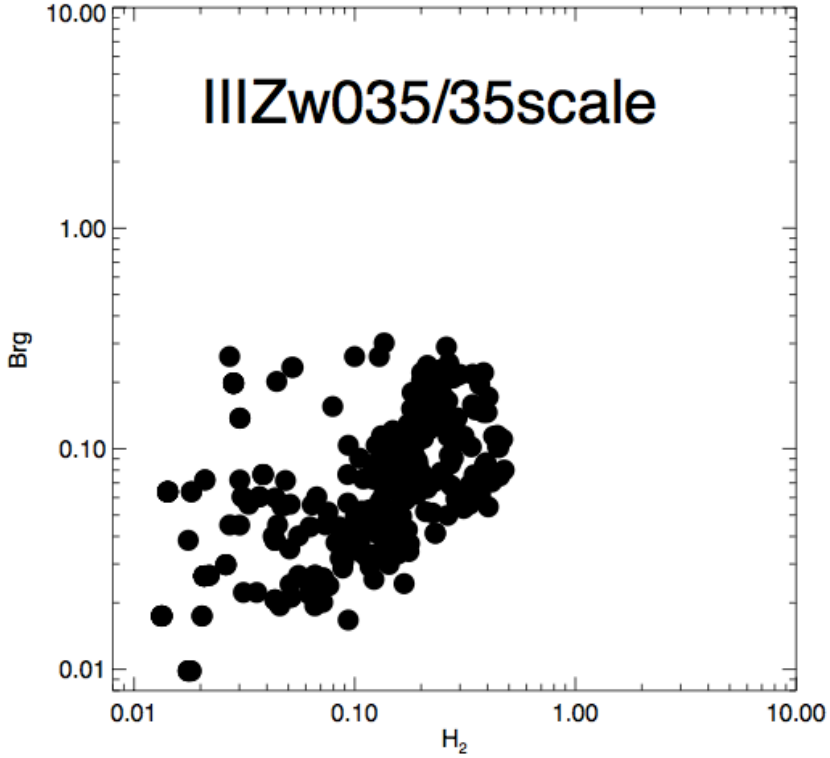
NIR Line Diagnostics: H_2/Brg



Brg contours overlaid on H2 flux map



H2/Brg map



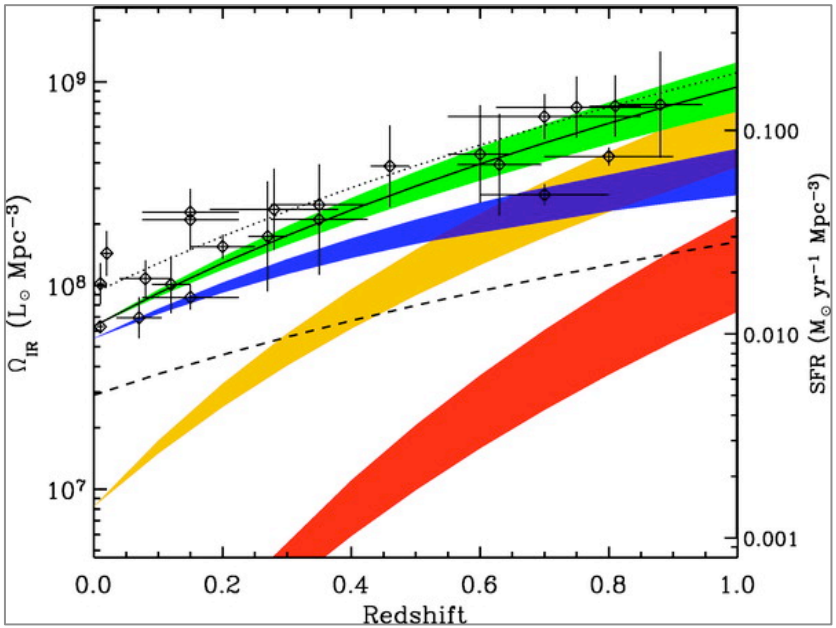
pixel to pixel plot

U+ in prep.

Ask not what TMT can do for you, but what you ***want*** TMT to do for you…

Ask not what TMT can do for you, but what you ***want*** TMT to do for you…

- With much(!) enhanced sensitivity and spatial resolution:
  - Push to higher redshift (more (U)LIRGs)
  - More efficient
- More lenient AO restrictions



Le Floc'h et al. (2005)

Total

LIRGs

Low-lum

ULIRGs

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- Tracing gas down to starburst/AGN – localize the power source

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- Tracing gas down to starburst/AGN – localize the power source
- Binary AGNs in mergers – how and when in a merger both AGNs get triggered
- Nature of obscured CT AGNs – synergy with X-ray or radio telescopes
- Detecting outflows in highly ionized gas in CLRs – “smoking gun” AGN signature (target sources with molecular outflows found by ALMA)

…and what you can do [to prepare] for TMT

- Need high spatial resolution models from the theorists
- Develop detailed near-IR line diagnostics
- Prepare for *discovery science*!