STAR FORMATION AND NUCLEAR ACTIVITY IN LOCAL STARBURST GALAXIES: A NEAR-INFRARED PERSPECTIVE

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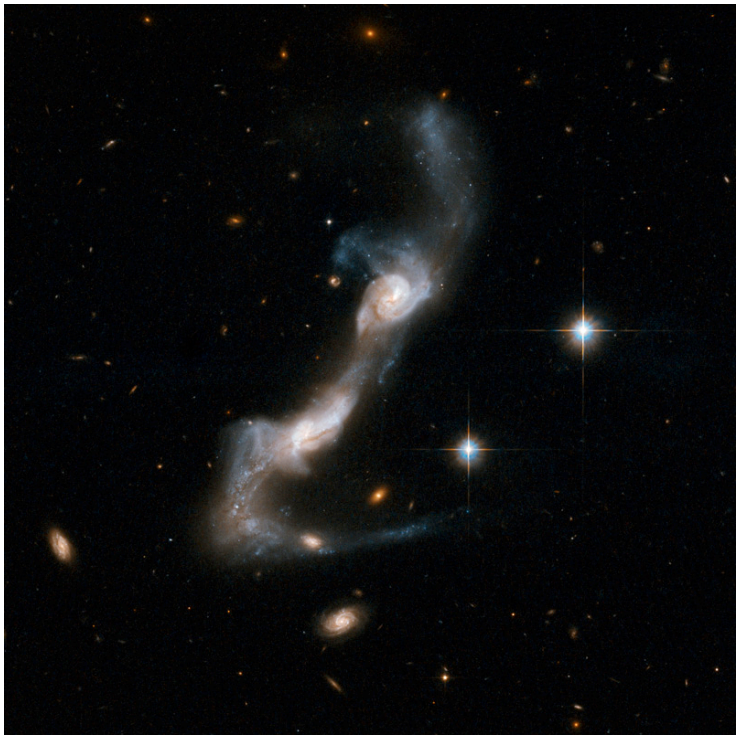
Part I: Luminous Infrared Galaxies

- Massive, gas-rich galaxy mergers
- Possess an elevated rate of star formation
- Often contain Active Galactic Nuclei
- Dominant contributor to the IR luminosity density at high redshift

$$L_{IR}\left[8-1000\,\mu m\right] \geq 10^{11} L_{SUN}$$



VV 250a

GOALS (Armus+ 2009)

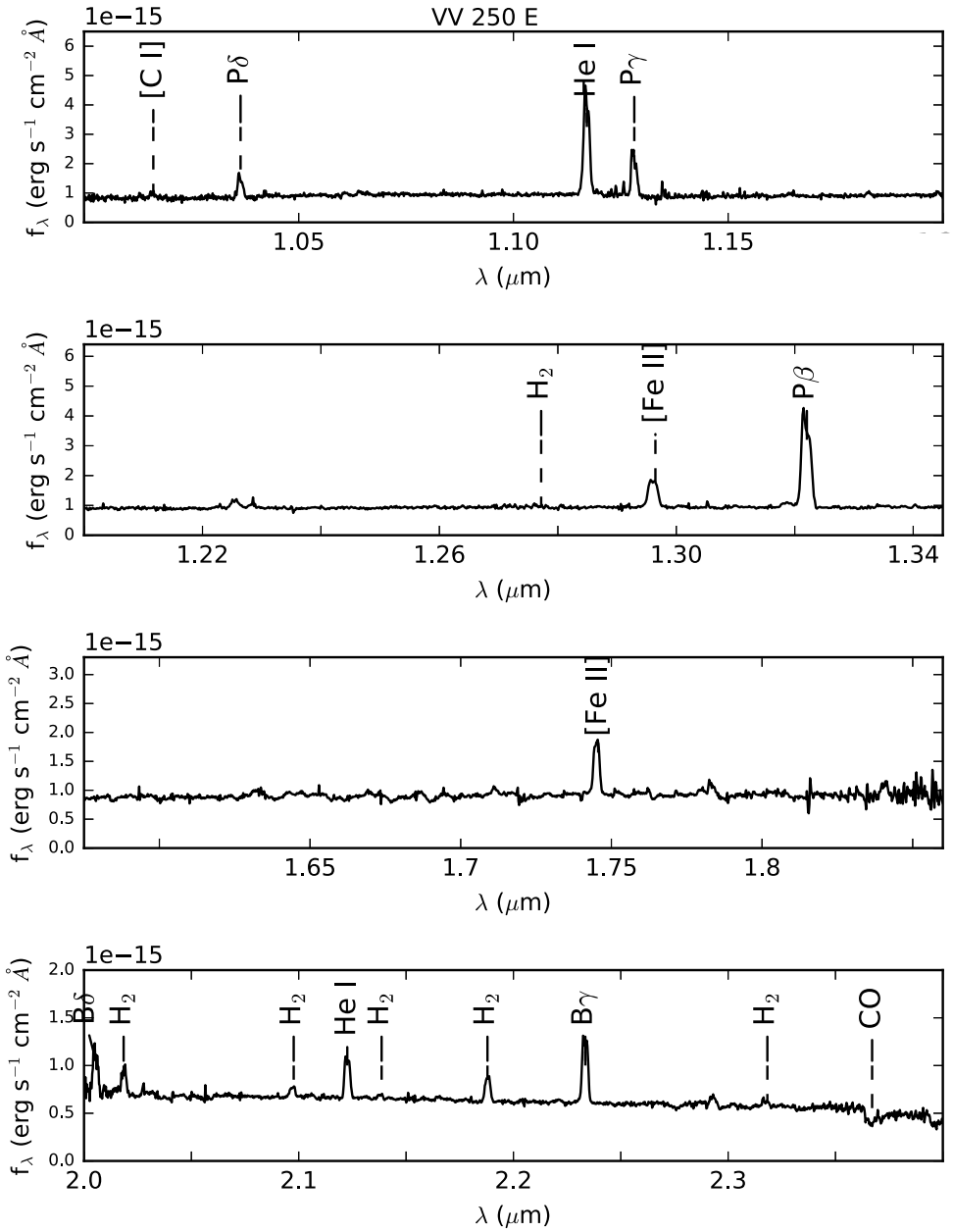
- Complete subset of RBGS (Sanders+ 2003)
- ~180 LIRGs & ~20 ULIRGS ($L_{IR} \geq 10^{12} L_{Sun}$)
- Targeted for Multiwavelength science by *Chandra, Galex, Hubble, Spitzer, Herschel,* and VLA.
- My contribution is near-infrared spectroscopy from TripleSpec

GOALS - TripleSpec

- 59 spectra in 42 LIRG systems.
- 13/59 from Apache Point Observatory.
- 46/59 from Palomar Observatory.
- 1 – 2.5 um in a single pointing.

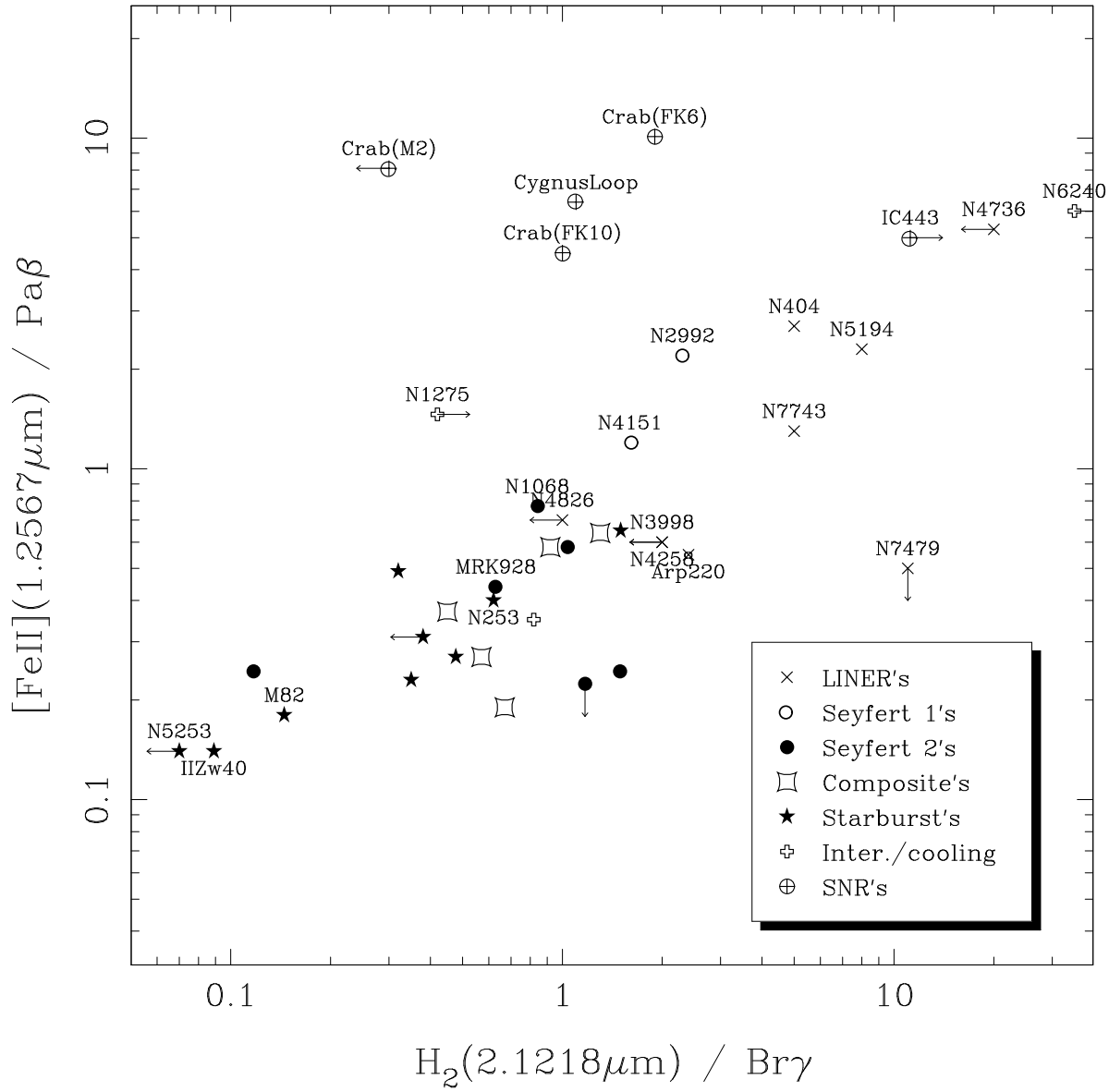
Science Drivers

- **Gas Excitation:** Diagnosis of Shock or Photoionization emission via ratios of emission lines.
- **Hidden AGN:** Broad Line Regions (BLRs) or Coronal Lines not visible due to dust extinction in optical observations?
- **Gas Kinematics:** Evidence of rotation (= dynamical mass estimate) or nuclear outflows?



Data

- Dominated by strong narrow emission from Paschen and Brackett recombination lines, [S III], He I, [Fe II],
- K band contains many lines of warm H_2
- Often strong absorption features from the evolved stellar population



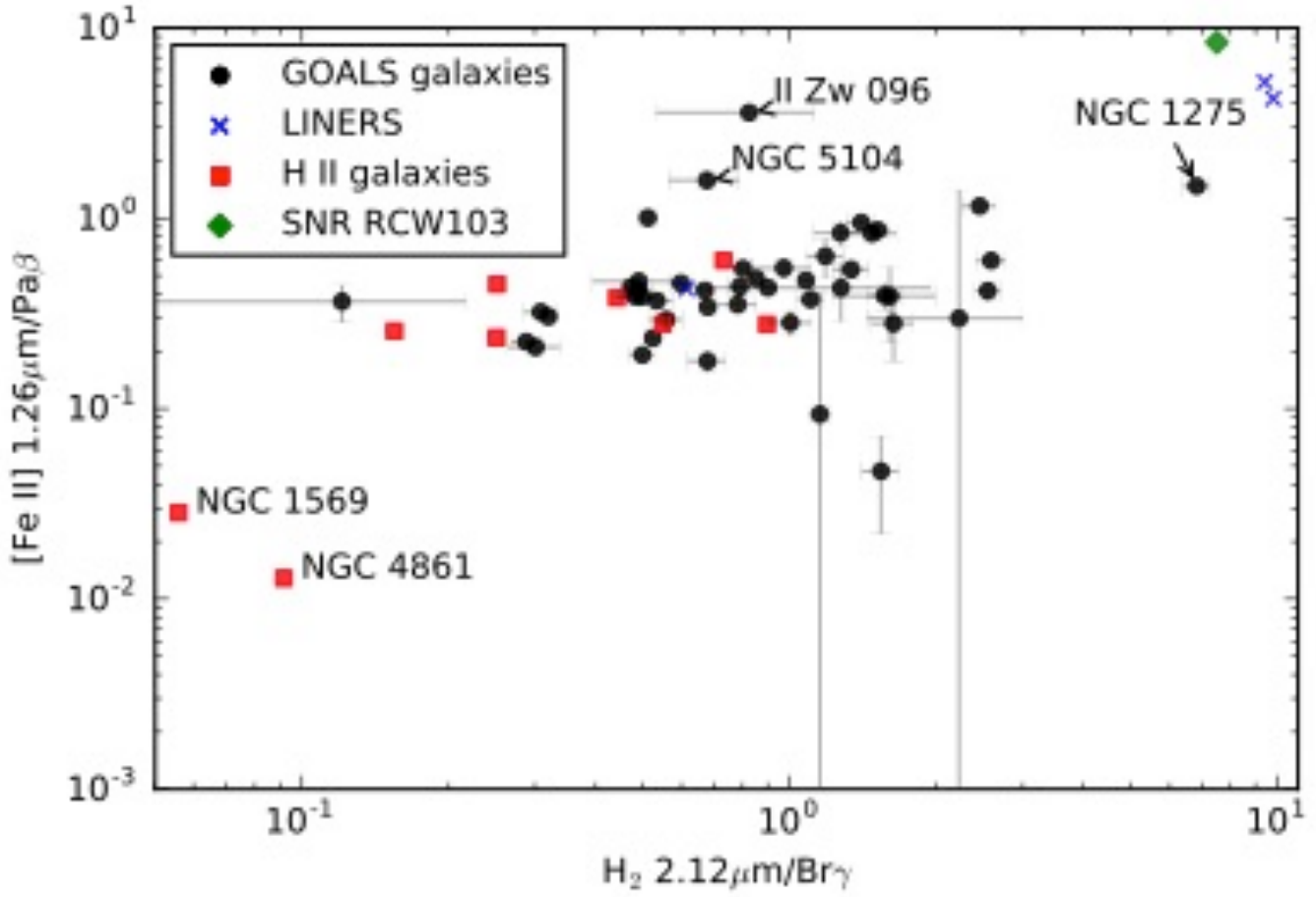
NIR Diagram (Larkin+ 1998)

[Fe II] traces extended shocks because Fe is typically found in solid phase.

H_2 is also excited in extended partially ionized zones created by shocks. (However it may also be excited via UV fluorescence from hot young stars.)

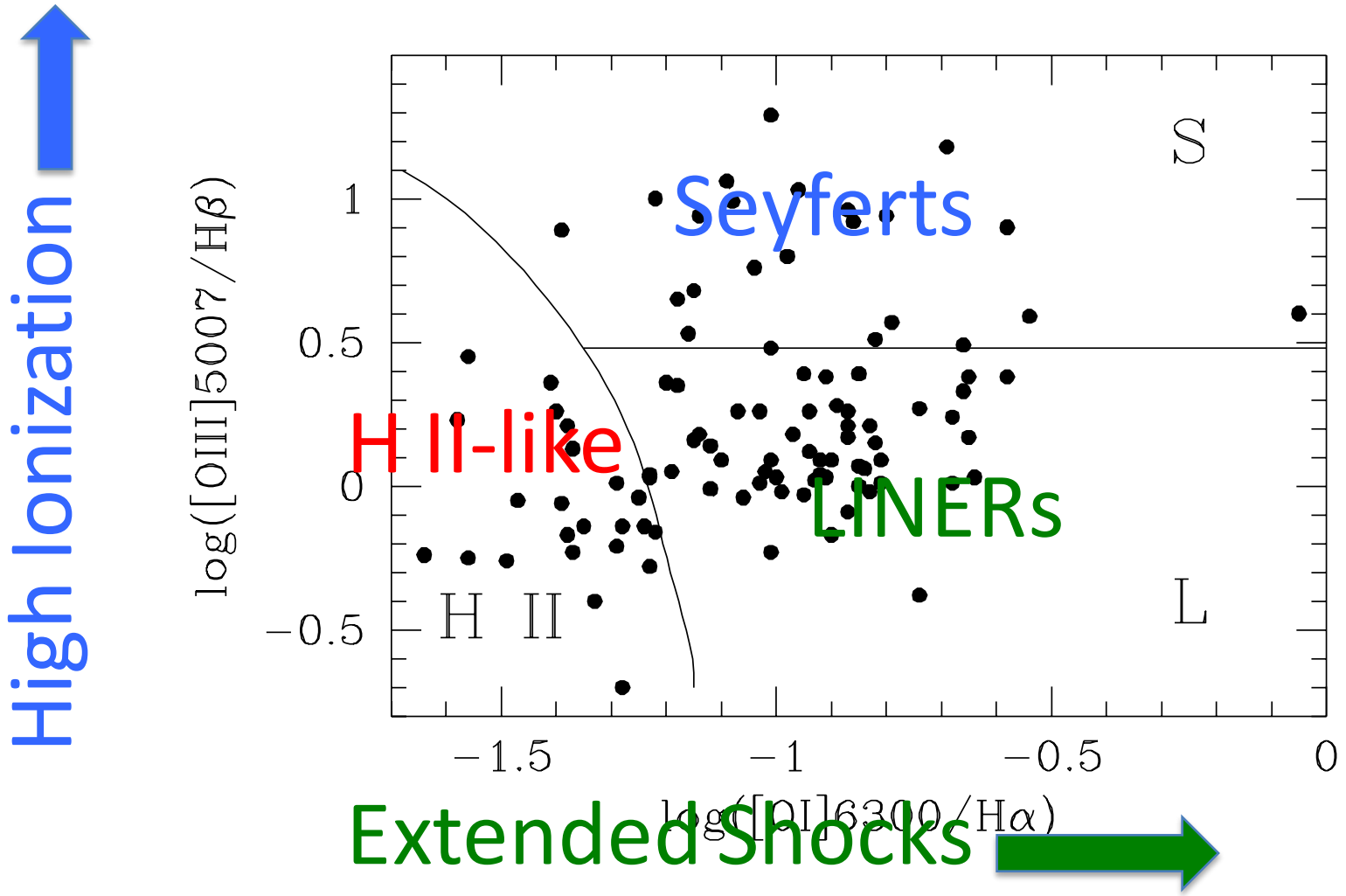
NIR Diagnostics

Empirical comparison to low luminosity (i.e., not very dusty) galaxies (star forming and LINERs) and a supernova remnant.

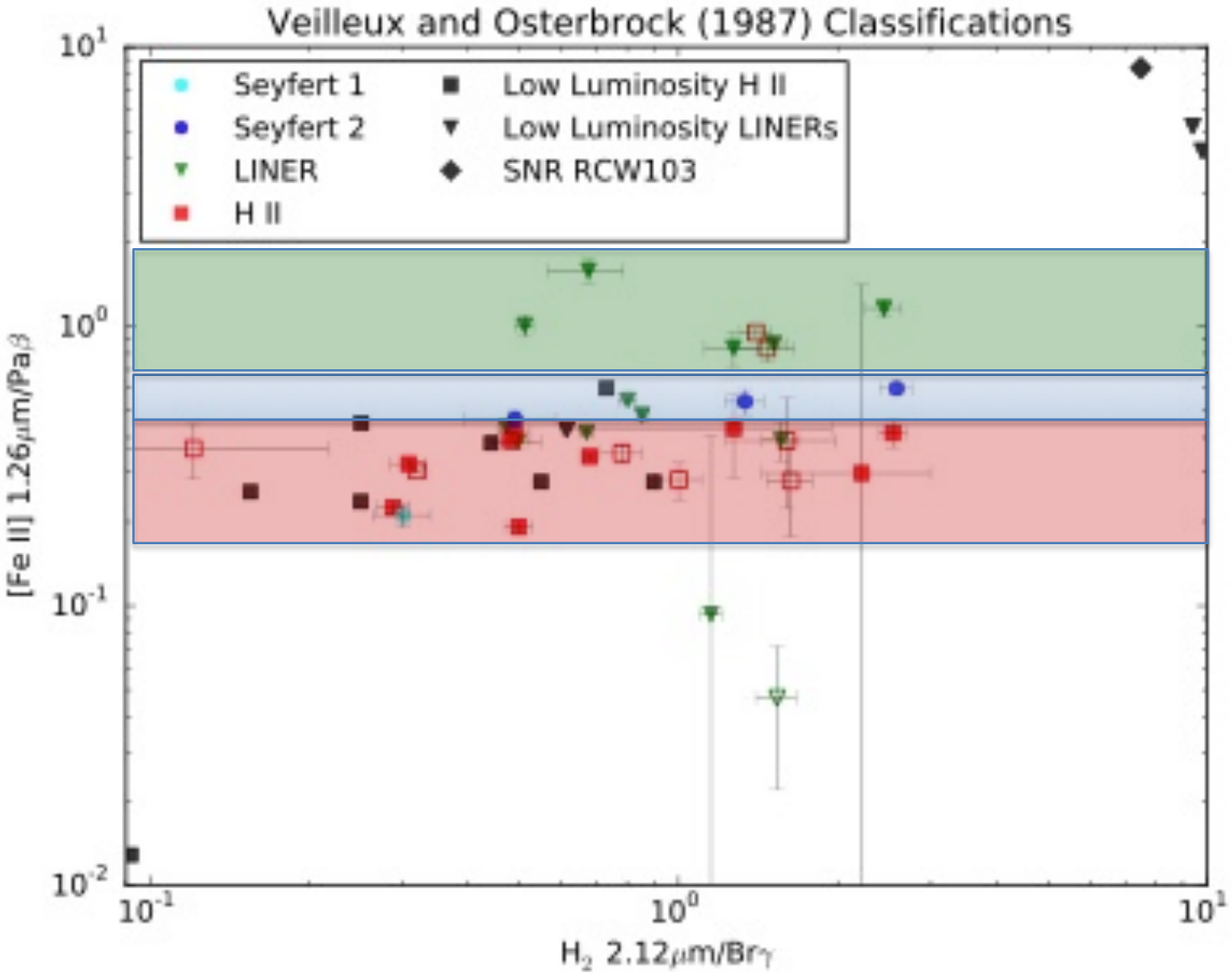


Optical Diagnostic Diagram

Veilleux, Kim, & Sanders (1999)



Optical Classifications

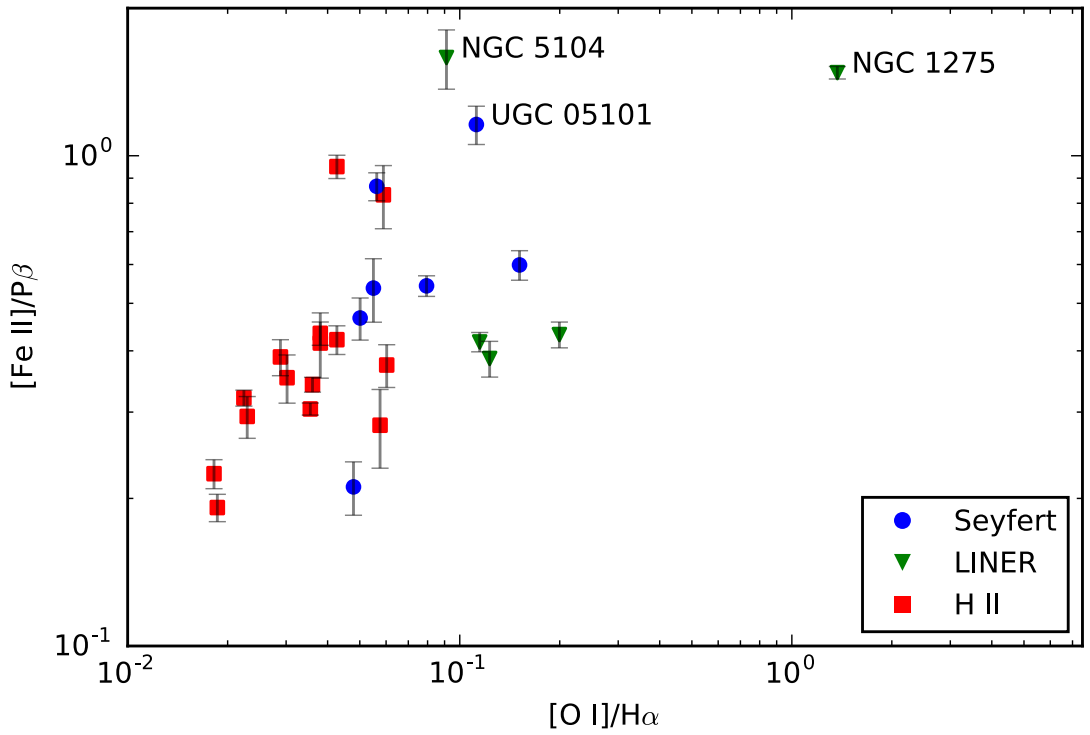


LINERS: Higher [Fe II]/PaB

Seyferts: Intermediate

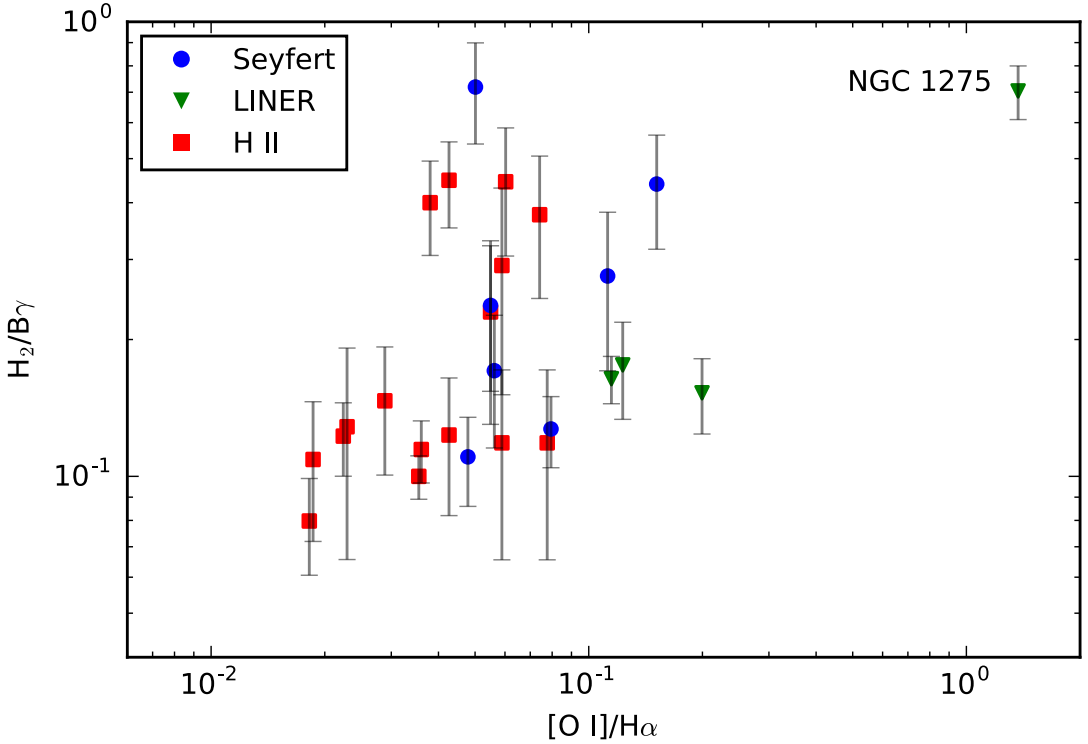
H II-like:Lower [Fe II]/PaB

Optical ([O I]/Hα) vs. Near-IR ([Fe II]/Pβ)



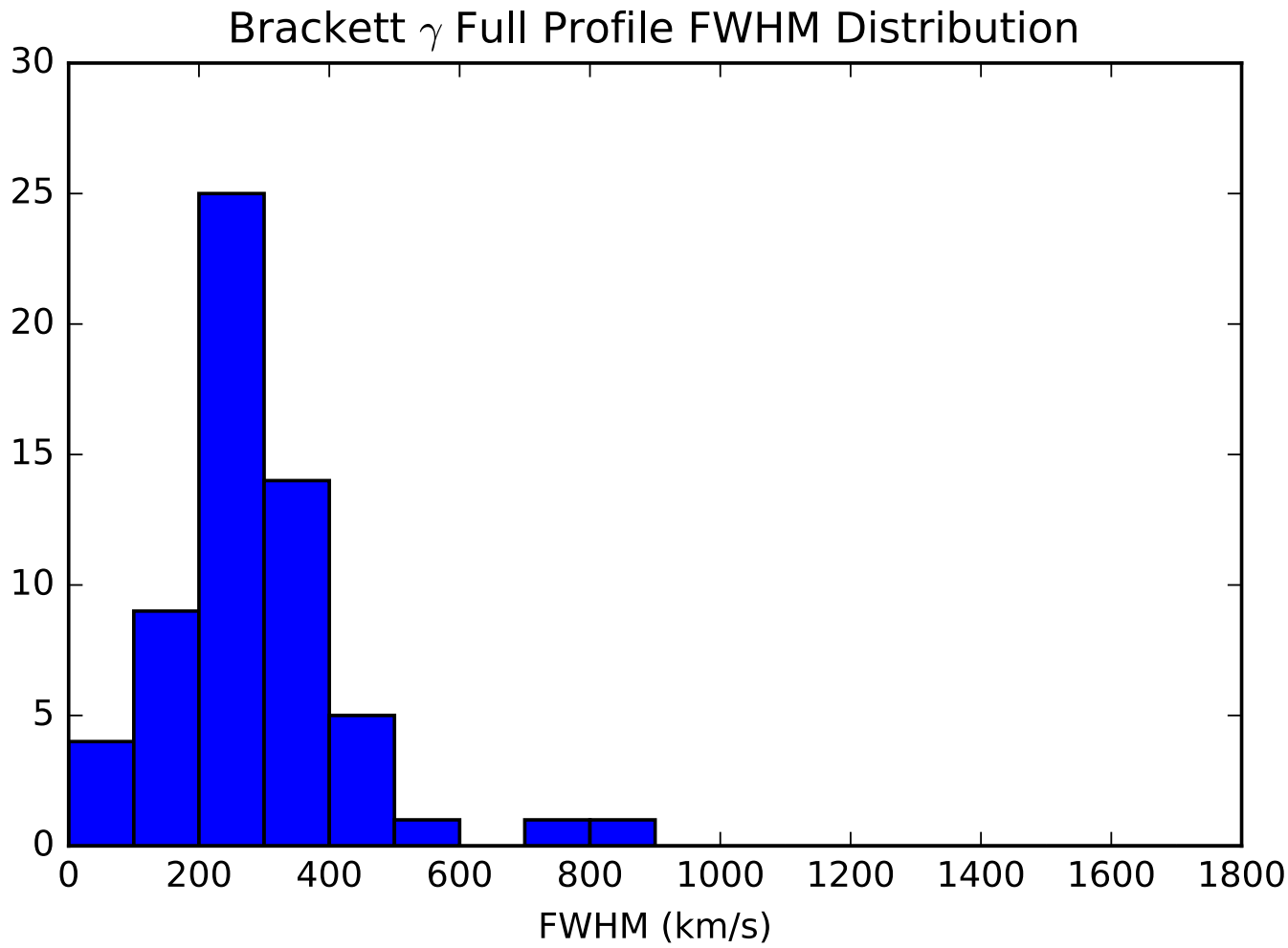
- Direct comparison shows rough correlation.
- Expected as strength of low ionization lines depends on extended partially ionized zones created by shocks or X-Rays.

Optical ([O I]/Hα) vs. Near-IR (H_2/Bγ)



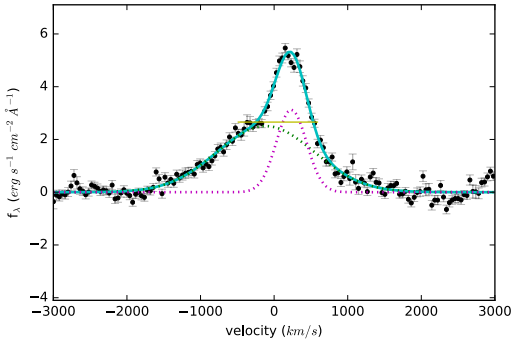
- As suggested by the Near-IR diagnostic diagram, the correlation between H_2/Bγ and [O I]/Hα is less direct.

No Strong Broad Recombination Lines

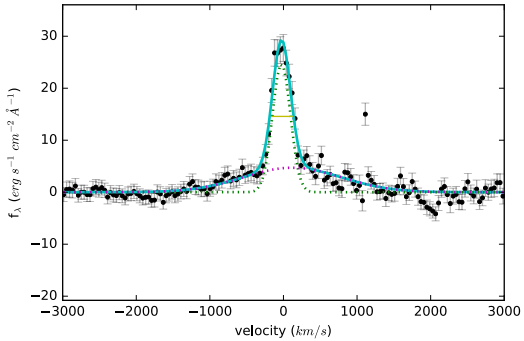


Broad Component Fits (Pβ)

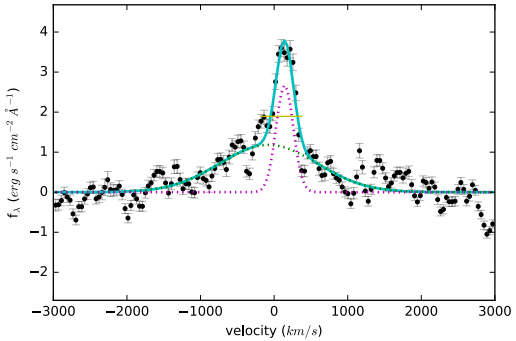
NGC 1275



NGC 7469

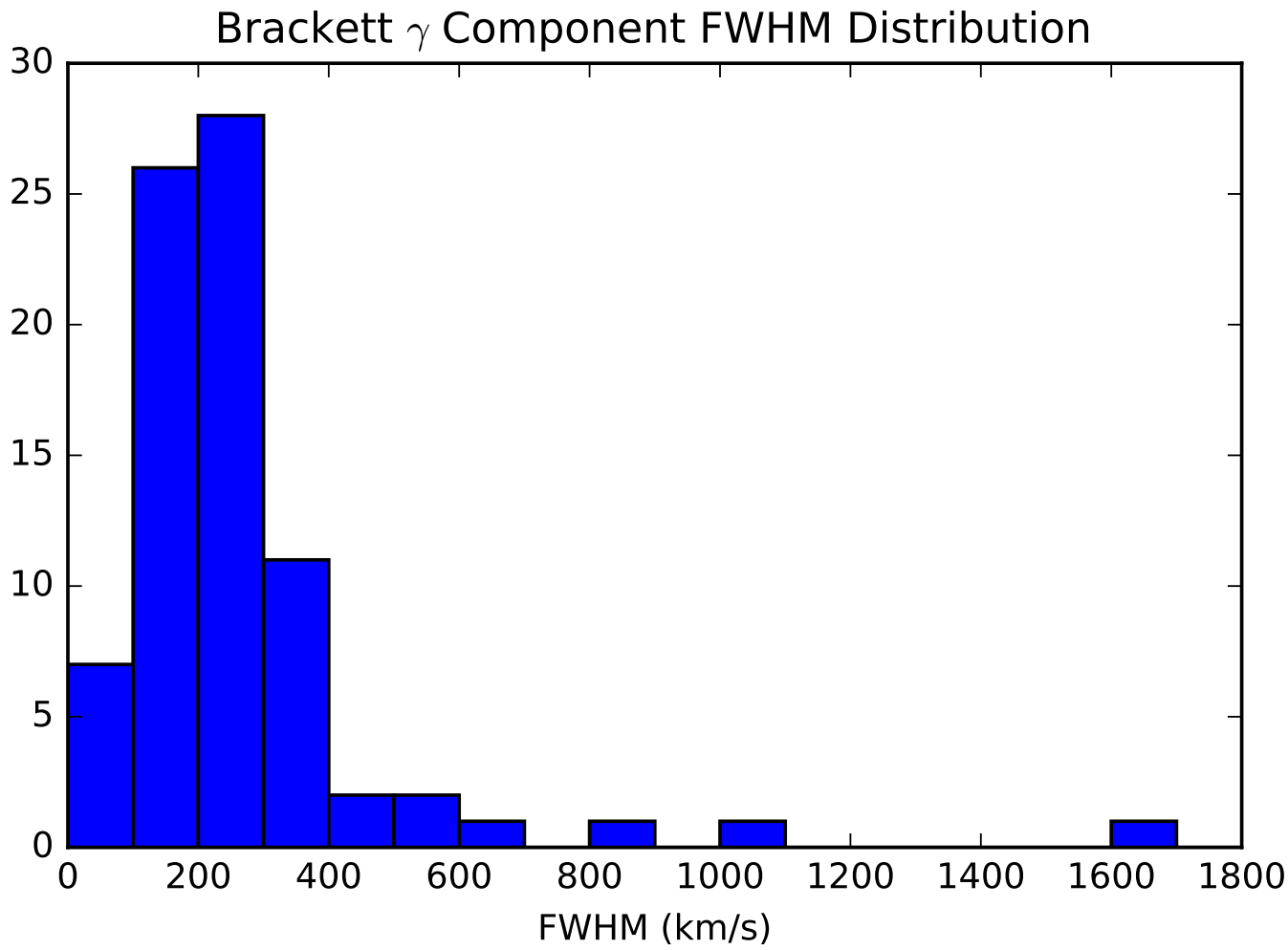


NGC 7674

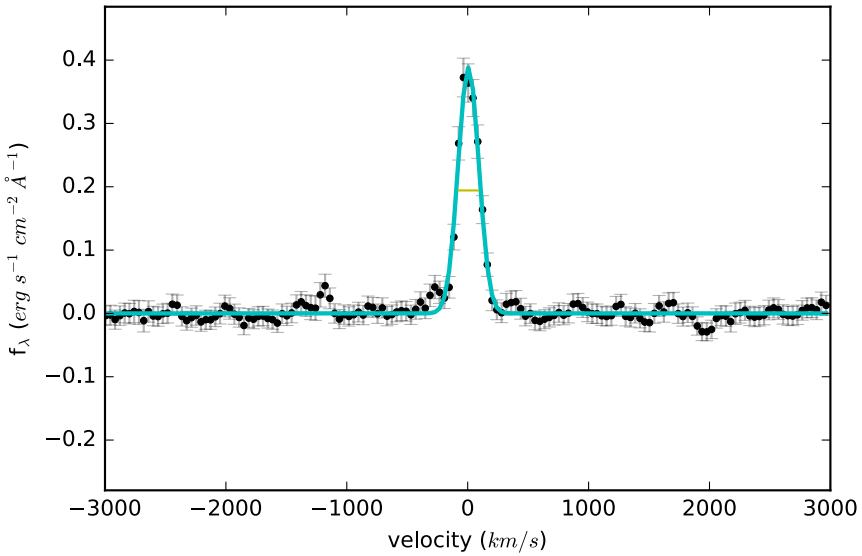


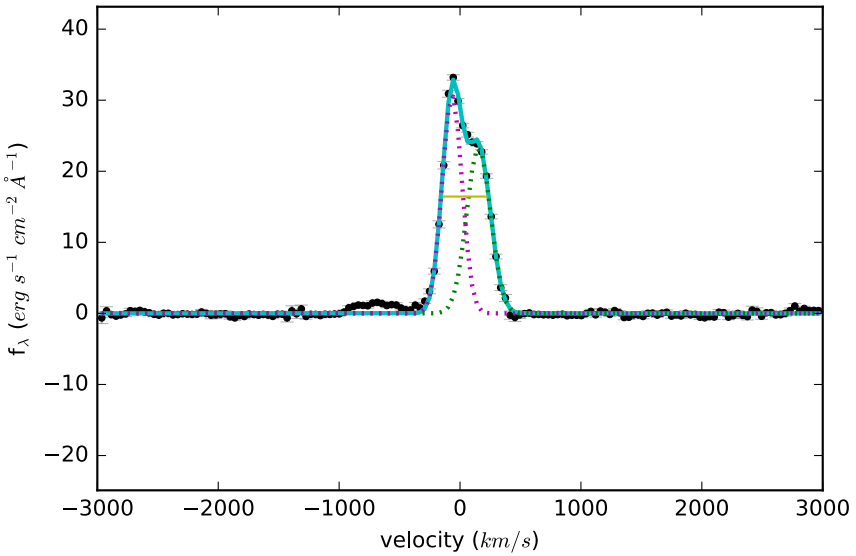
3 of the 10 optical Seyferts in the sample show an indication of faint broad recombination lines, absent in the H_2 line.

Three Broad Components



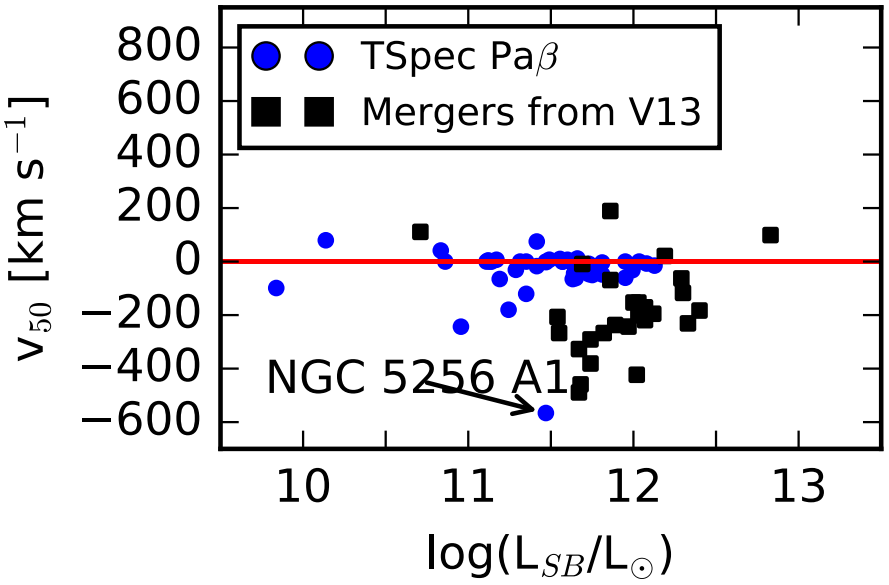
Kinematics

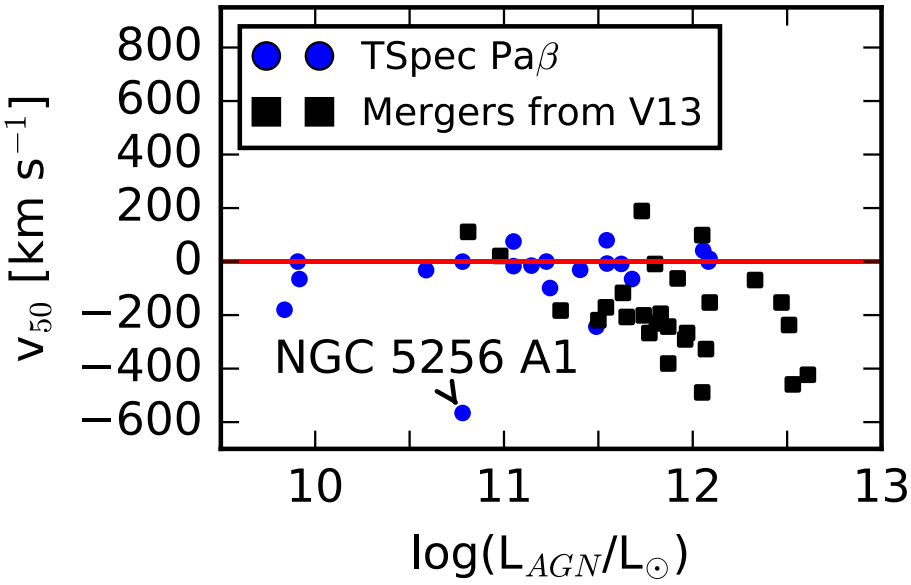




- Gaussian fits show 22(27) single(double) component fits to Pa β, 36(19) for Br γ, 41(14) for H_2 S(1) 1-0.

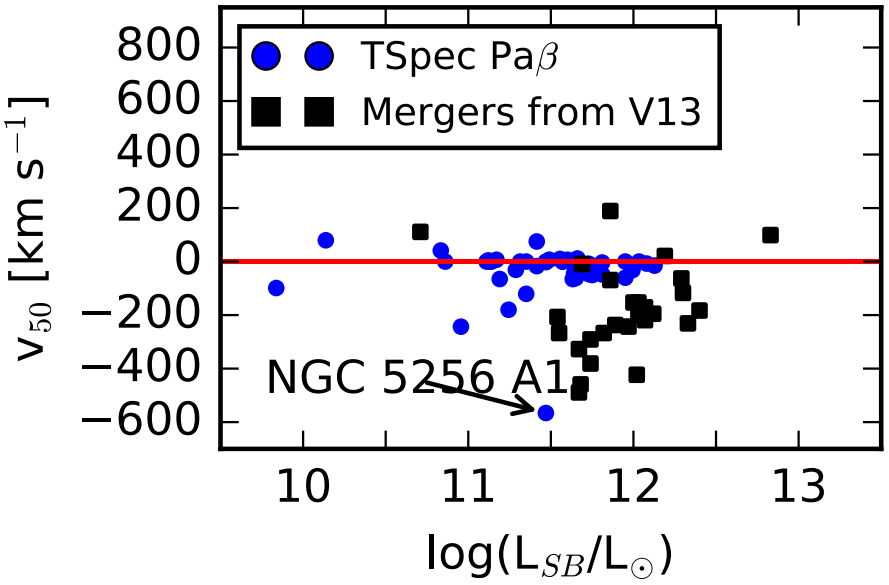
Blueshifted components (outflows)

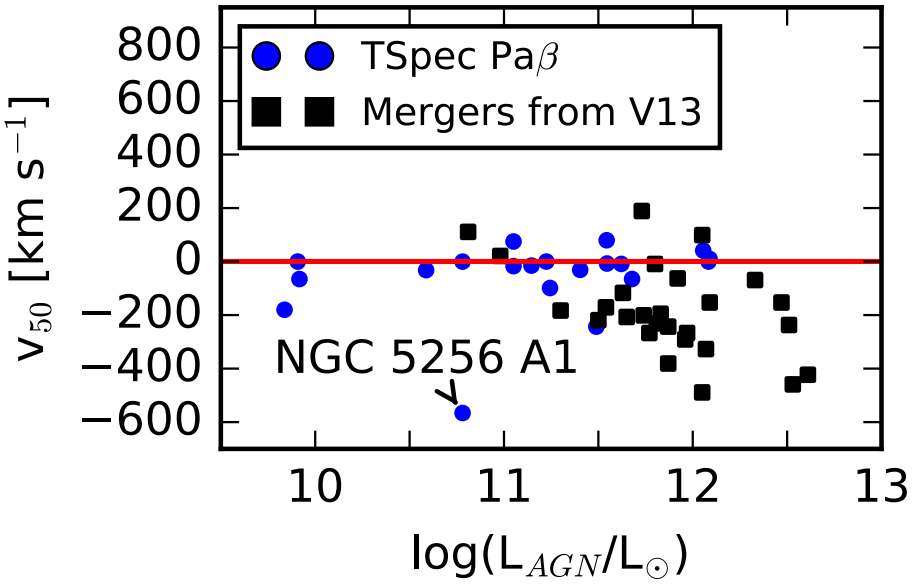




- Of the ensemble of detections of Paschen β, five sources show evidence for outflows in excess of ~ 100 km/s.
  - NGC 1275, NGC 5104, NGC 5256, UGC 12150, IC 5298
- Each object has a Seyfert or LINER optical classification.
- Comparison to OH 119 μm a la Veilleux+ 2013.

Blueshifted components (outflows)





- Only NGC 5256 has an outflow velocity comparable to the highest v measured in OH 119 um by Veilleux+ 2013.

NGC 5256

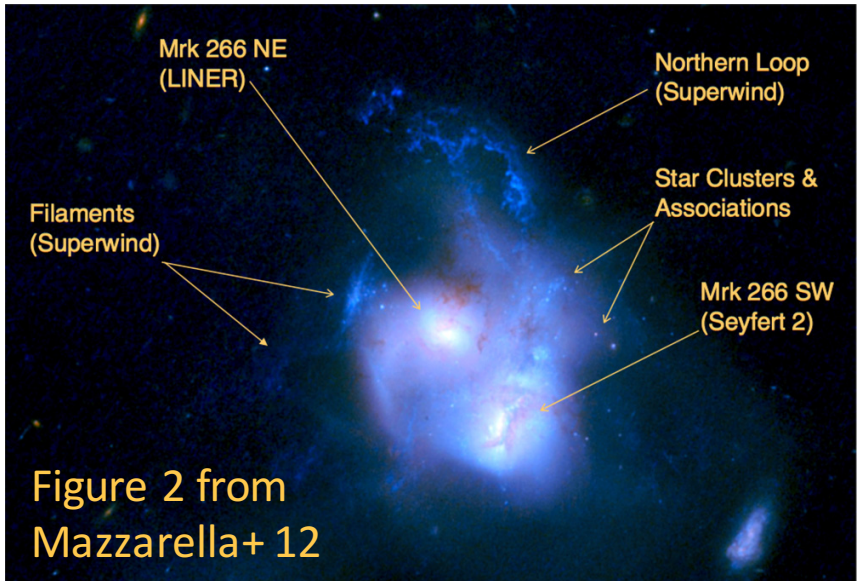


Figure 2 from Mazzarella+ 12

Outflow driven bubble seen in Xray, Radio, and Optical!

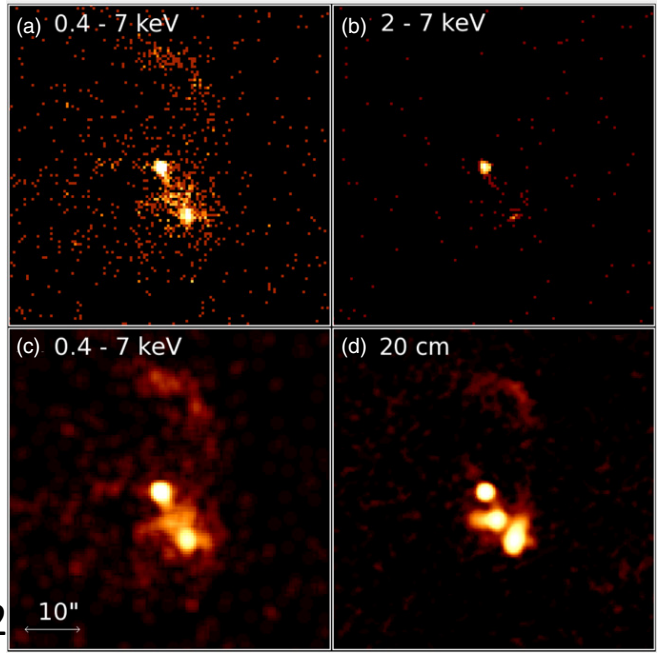


Figure 3 from Mazzarella+ 12

Summary

- 42 low redshifts LIRGs were surveyed with near-IR spectrograph TripleSpec.
- [Fe II]/Paβ vs. H2/Brγ ratios of this sample overlaps with normal star-forming galaxies and the optical diagnostic classification (Veilleux & Osterbrock 1987, Veilleux+ 1999) correlates with the value of the [Fe II]/Paβ ratio, with higher values being associated with LINERs.
- Consistent with the correlation to optical classifications, [Fe II]/Paβ values of the sample, rather than H2/Brγ, correlate more closely with [O I]/Hα, [N II]/Hα, and [S II]/Hα.
- Five of the 42 LIRGs surveyed show evidence of outflows in Paβ with velocities > 100 km/s. Outflow velocities are significantly less than what is seen OH 119 μm– perhaps a result of the ability of the far-infrared line to probe regions closer to the obscured energy source.