

## **M. Brotherton**

### *Post-Starburst Quasars*

I will discuss our investigations to find and understand post-starburst quasars, hybrid objects with accreting black holes and recent massive starbursts, and their role in the evolution of galaxies. Data from SDSS, Keck, HST, Galex, and Spitzer will be featured.

# Post-Starburst Quasars

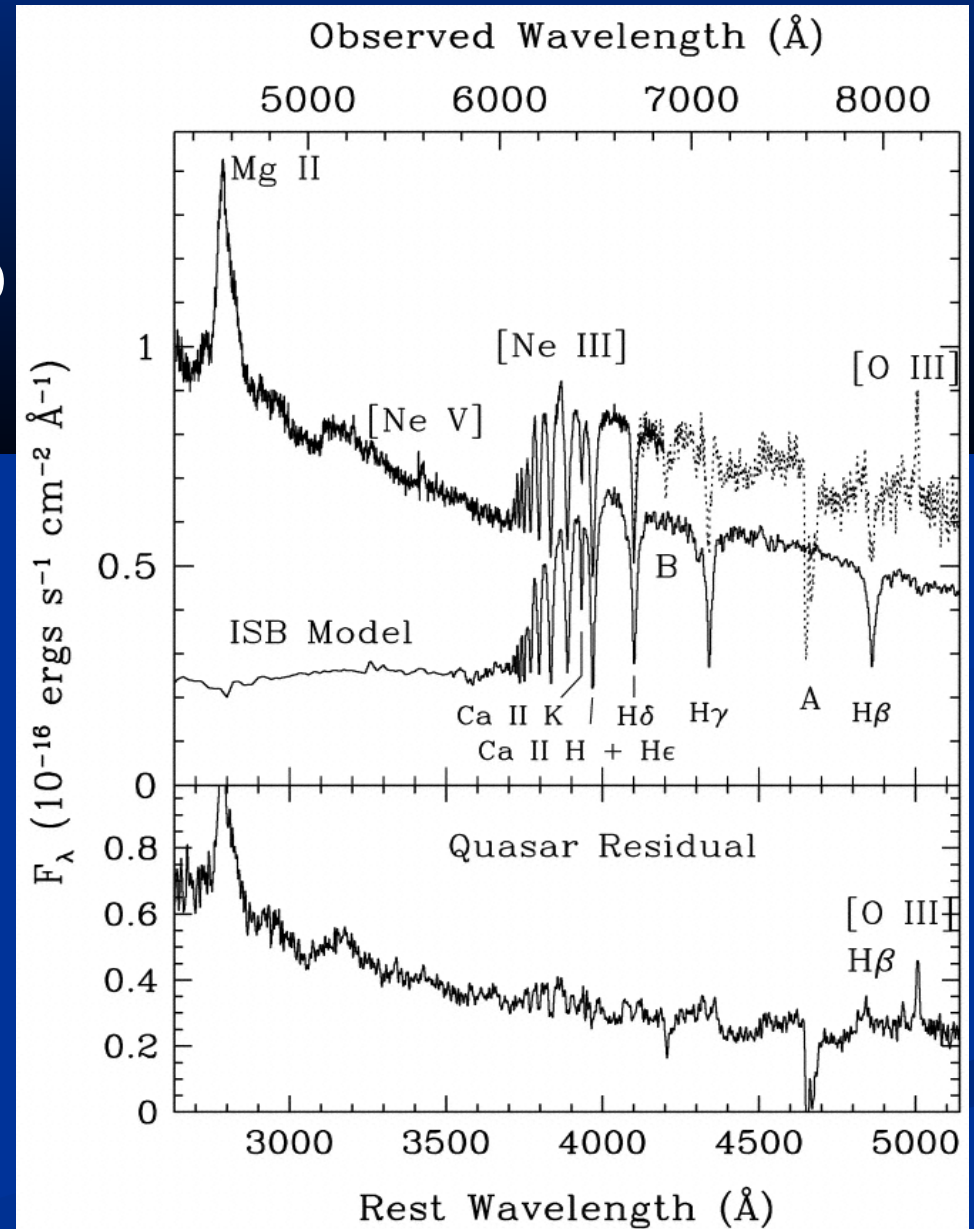
**Mike Brotherton**

**S. Cales, Z. Shang, R. Ganguly (Wyoming),  
R. Stoll (Ohio State), A. Diamond-Stanic  
(Arizona), D. Vanden Berk (Penn State), G.  
Canalizo (UC-Riverside), M. Wold (Oslo),  
T. Storchi-Bergmann & D. Sanmartin  
(UFRGS, Brazil)**

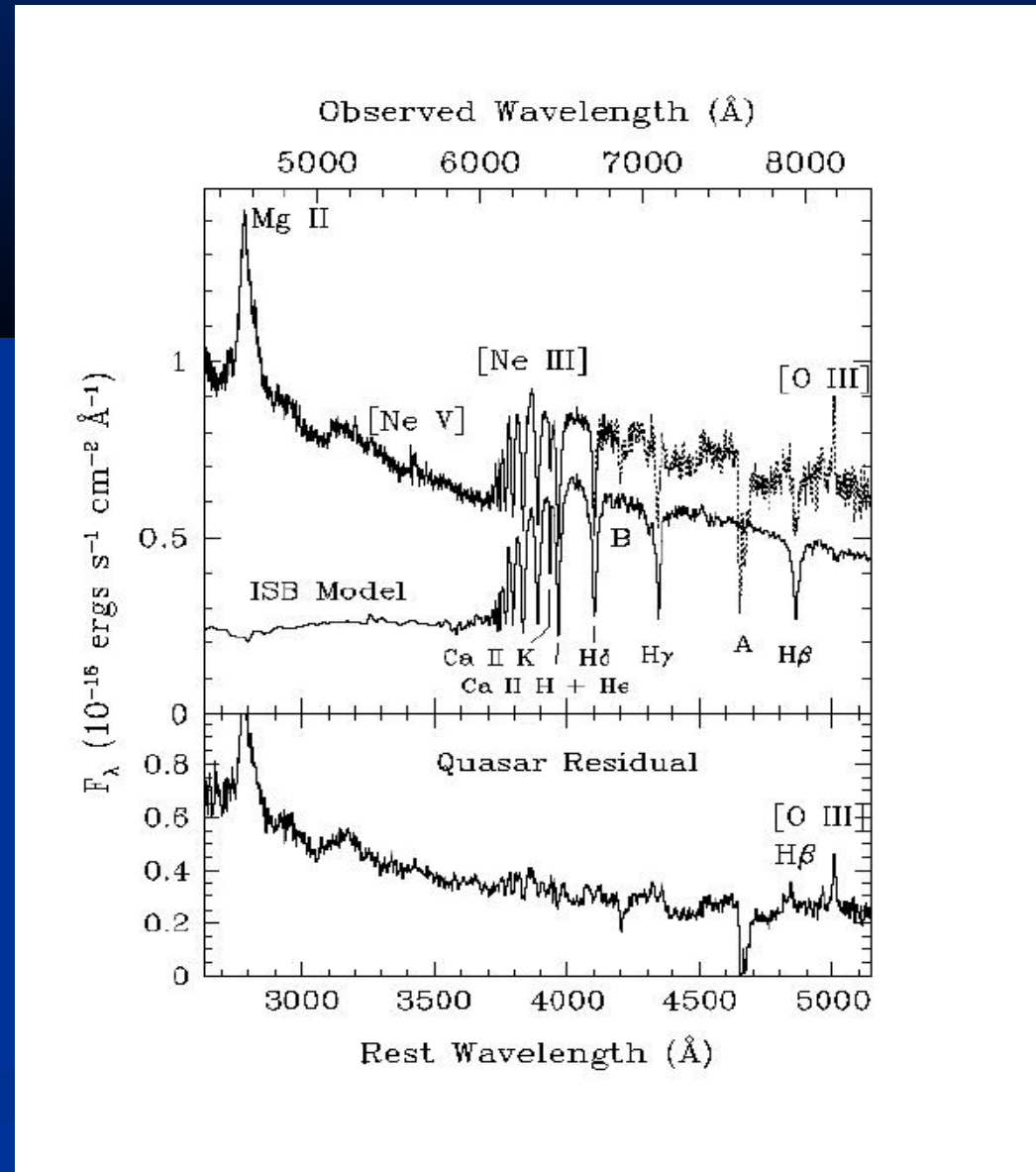
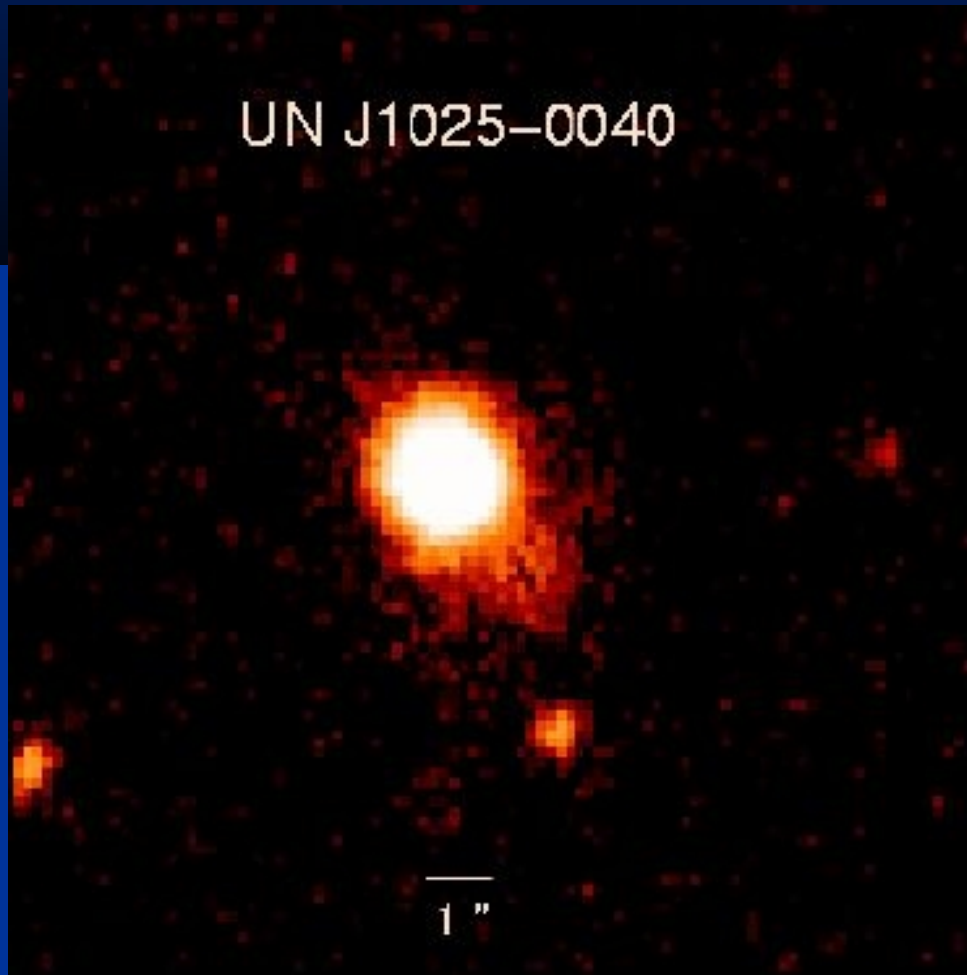
# A Post-Starburst Quasar

Prototype, UN J1025-0040  
 $Z = 0.634$

- Broad-lined AGN
- Balmer Jumps, high-order Balmer absorption lines
- Stellar Population  $\sim 400\text{Myr}$ ,  
 $\sim 10^{10} M_{\text{solar}}$



# Appears to be a post-merger system



From Brotherton et al. (1999).

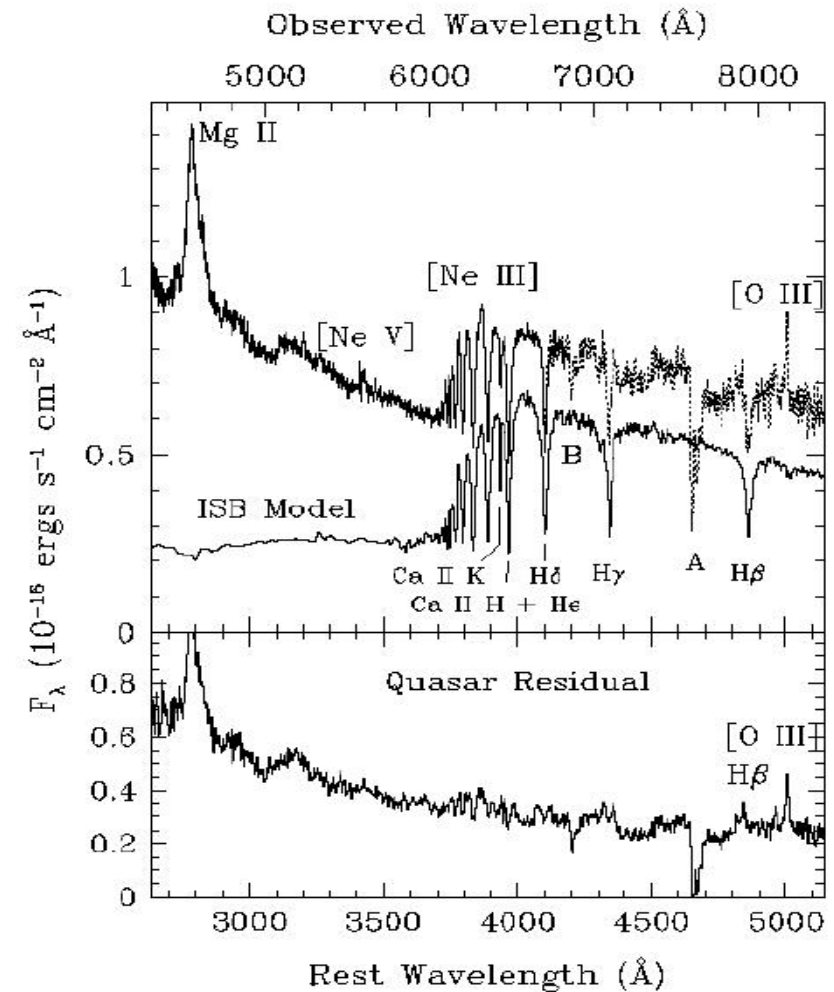


# Final Notes on PSQ Prototype

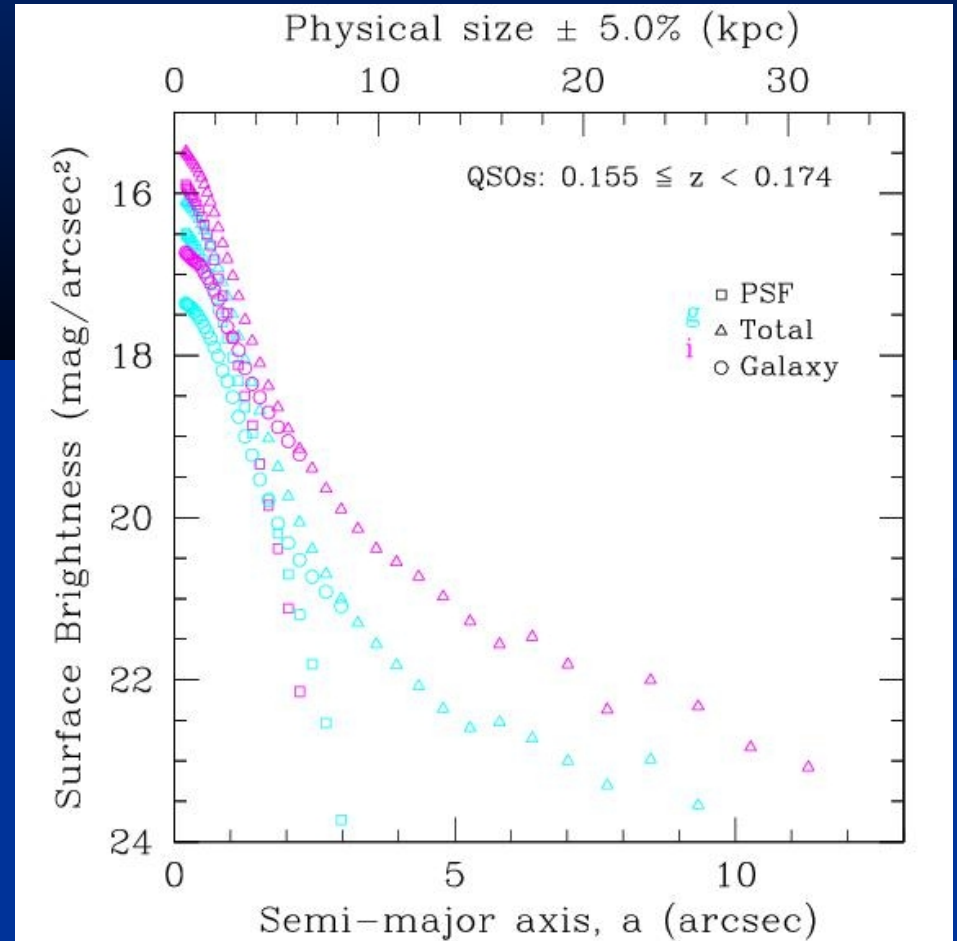
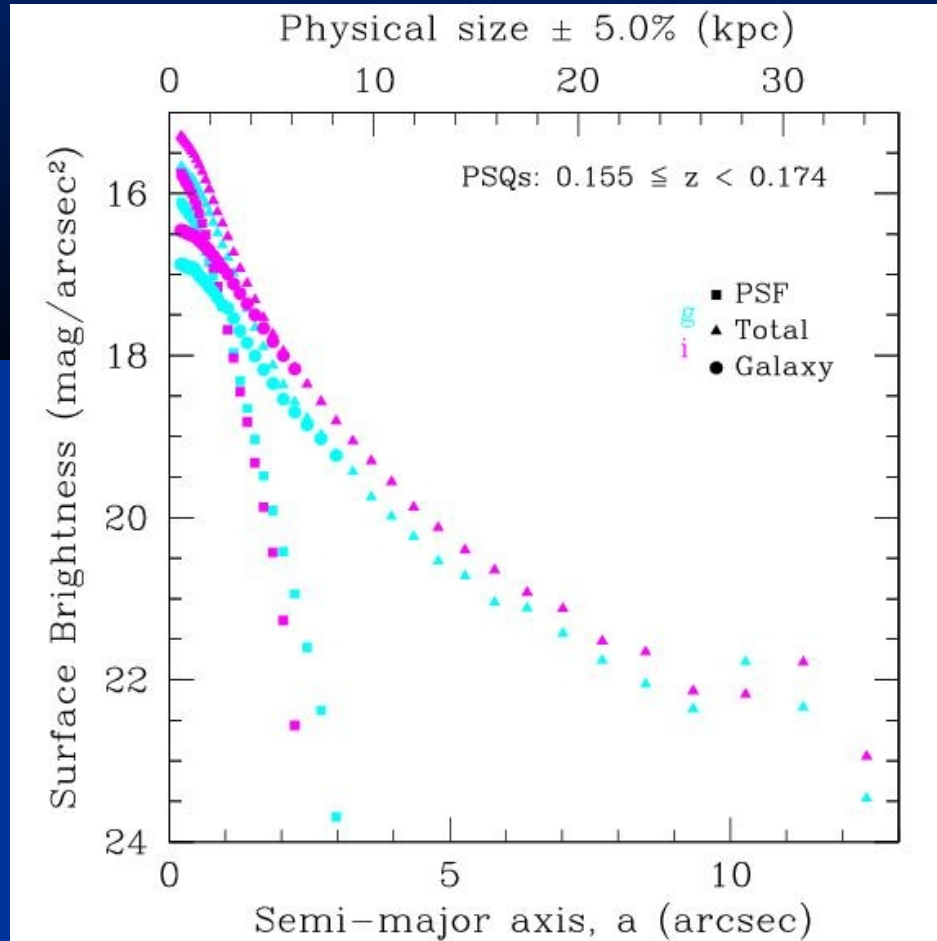
Canalizo et al. 2000 obtained spectrum of companion object, well described by a 800 Myr single burst model.

Brotherton et al. (2002) analyzed HST images and determined there was an excess of extended blue light that required young stars, 40 Myrs old or younger.

The prototype was only the first...



# SDSS Image Stacking Results



Within same redshift bins, normalizing by the “PSF Magnitude” (AGN brightness), evidence that PSQs more extended, and the fuzz is also bluer.

# New Observations

## **HST (imaging)**

Morphologies and more, sample of 29 PSQs

## **IRTF (imaging of HST sample)**

Separate stellar and AGN components in K-band

## **Spitzer (16 targets from HST sample)**

IRS spectra, SED, separate stellar and AGN in MIR

## **Keck and KPNO (HST sample+)**

Better and bluer spectra for modelling, companion spectra

## **SDSS (DR3 so far, heading toward a more physical sample)**

New sample selection, environments (companions and fuzz)

## **GALEX (DR3)**

Looking for younger starbursts through UV excess

## **Gemini IFU observations of a few low-z PSQs**

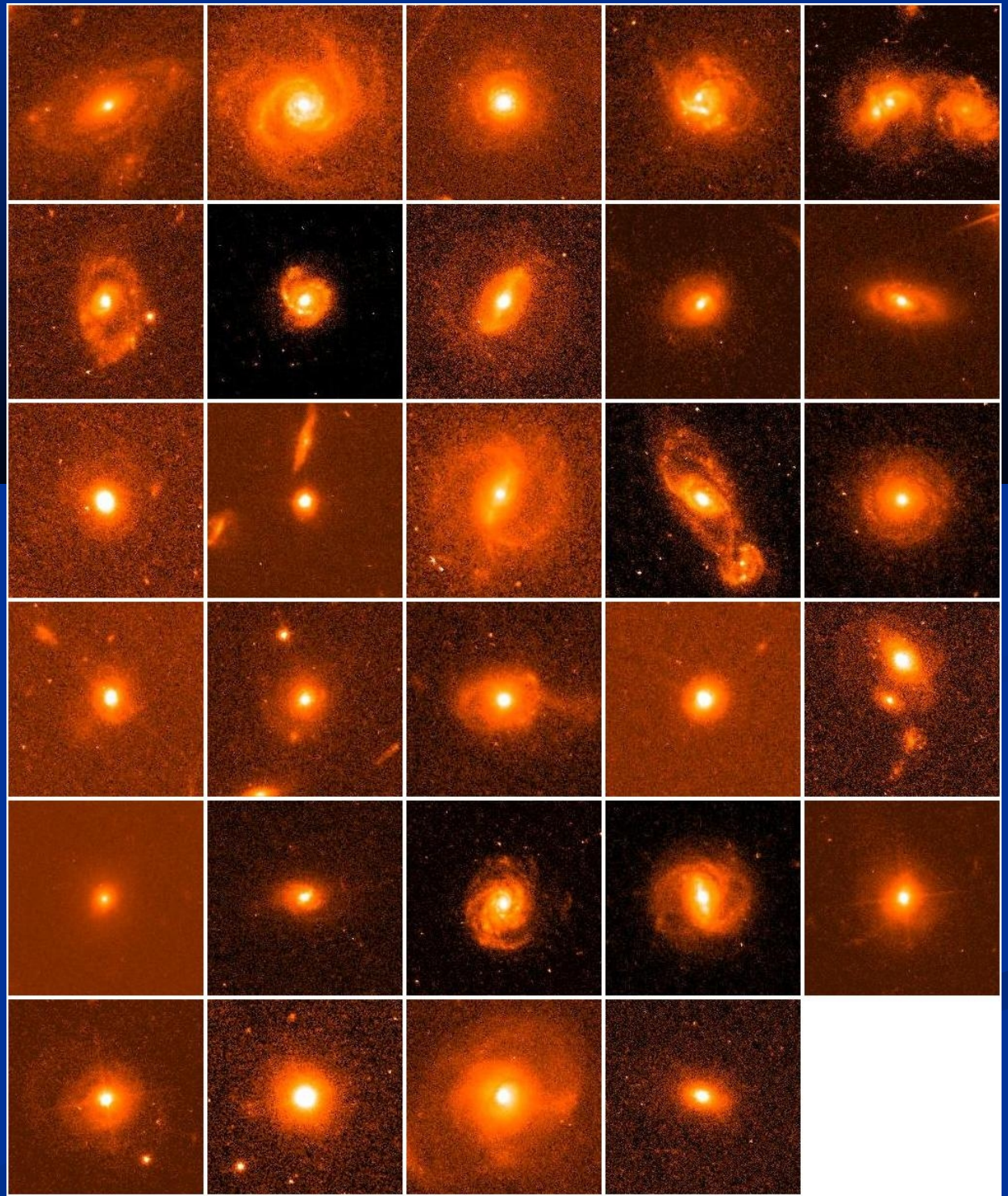
Would love stellar velocity dispersions, but VLT work on CaT failed.  
New Keck spectroscopy upcoming (with Canalizo).



# HST images Of PSQs

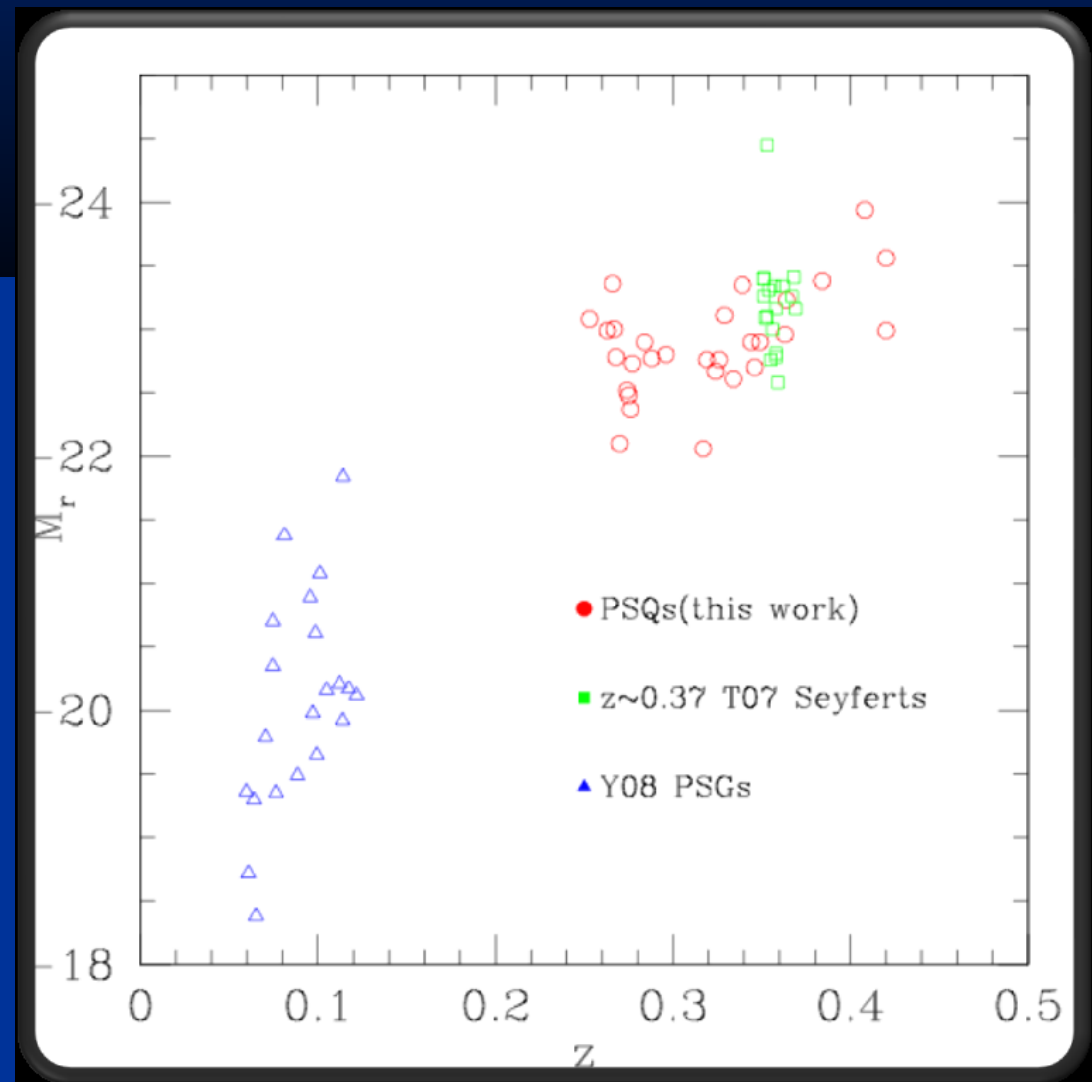
Spectroscopically chosen to be good post-starburst quasars,  $z \sim 0.3$ . ACS F606W images are 10" sides (50 kpc). Seyfert-Quasar borderline luminosities.

Many are interacting systems, companions, tidal tails, asymmetries, and evidence of recent mergers (e.g., shells). Some look normal, isolated.

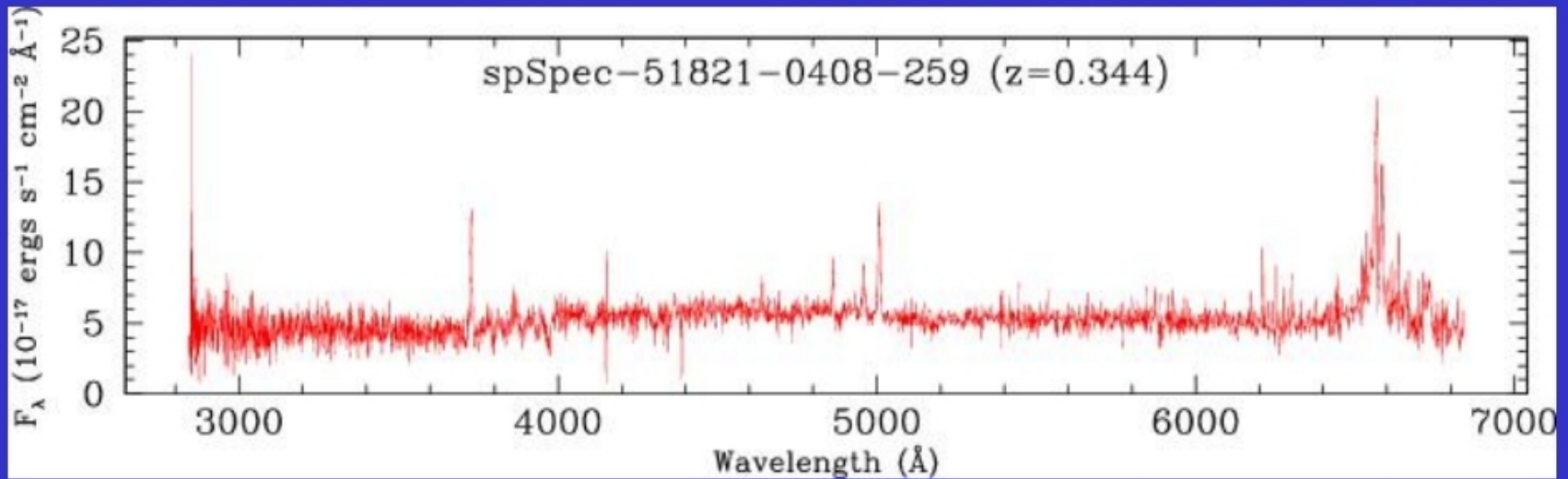
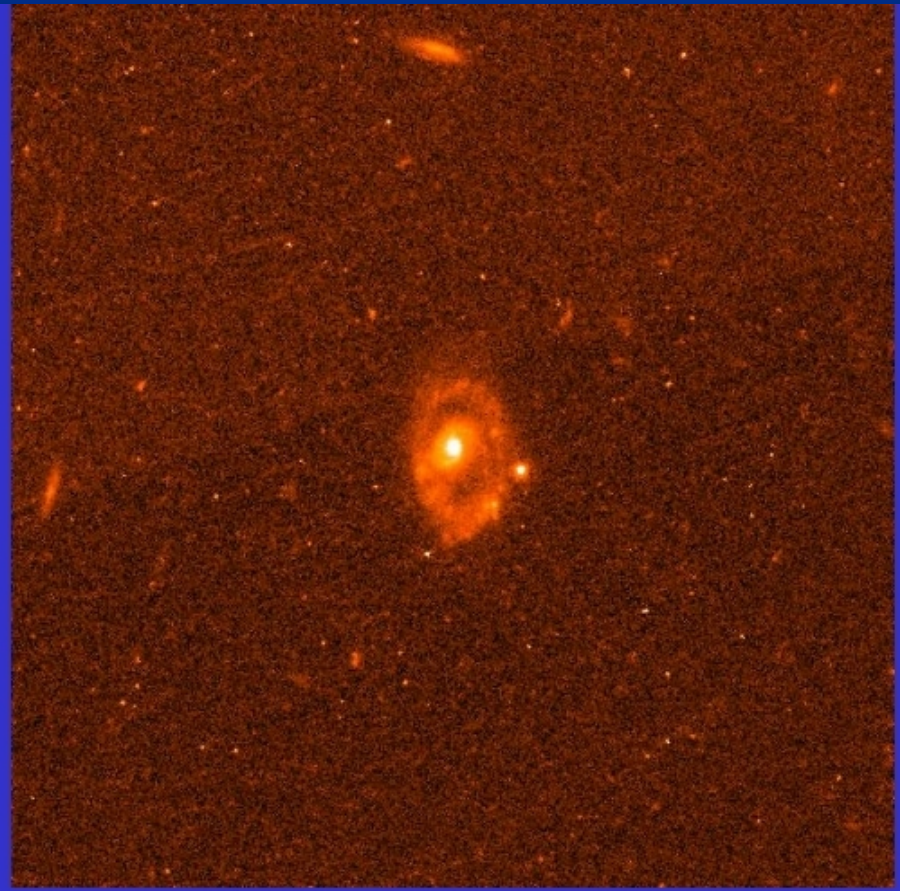
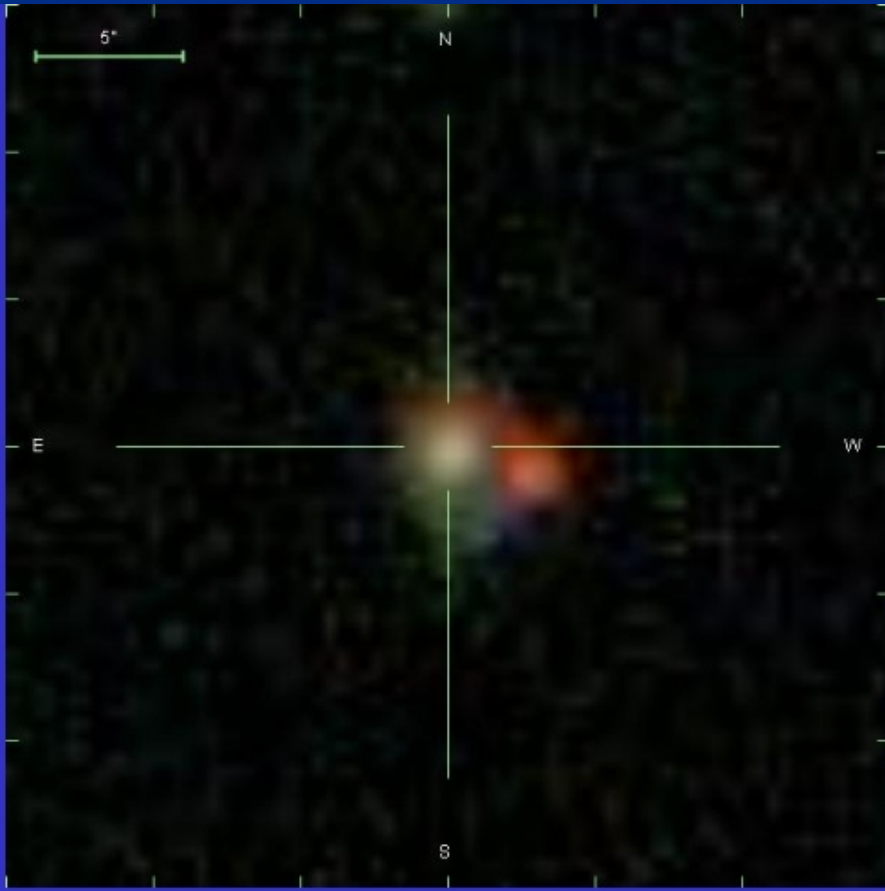


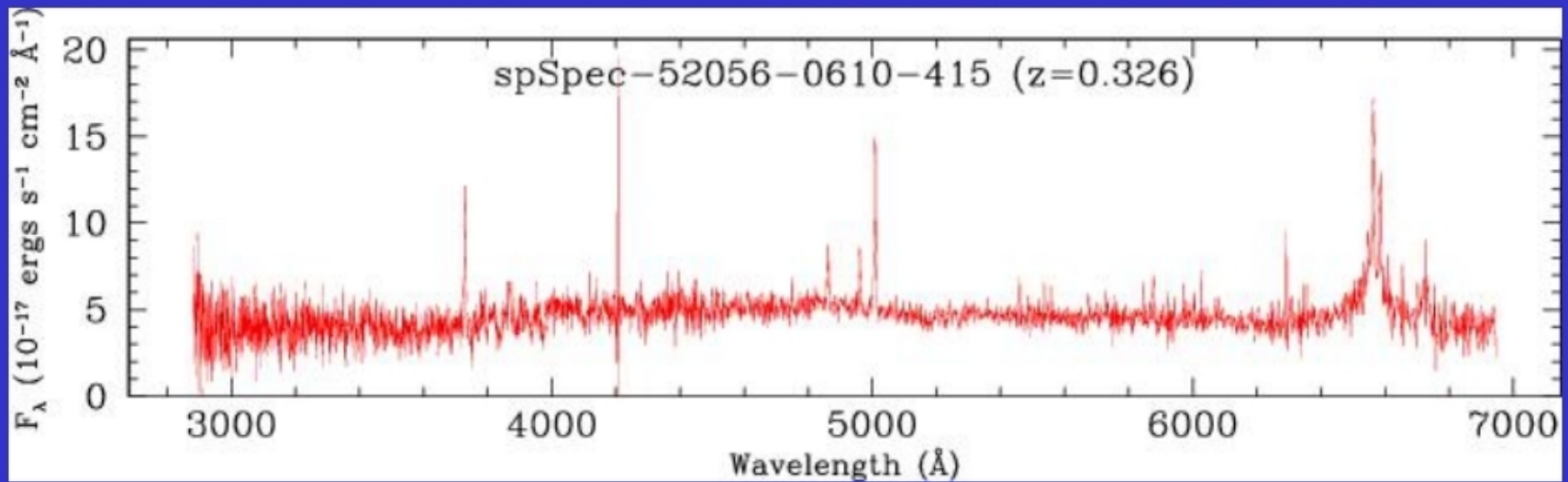
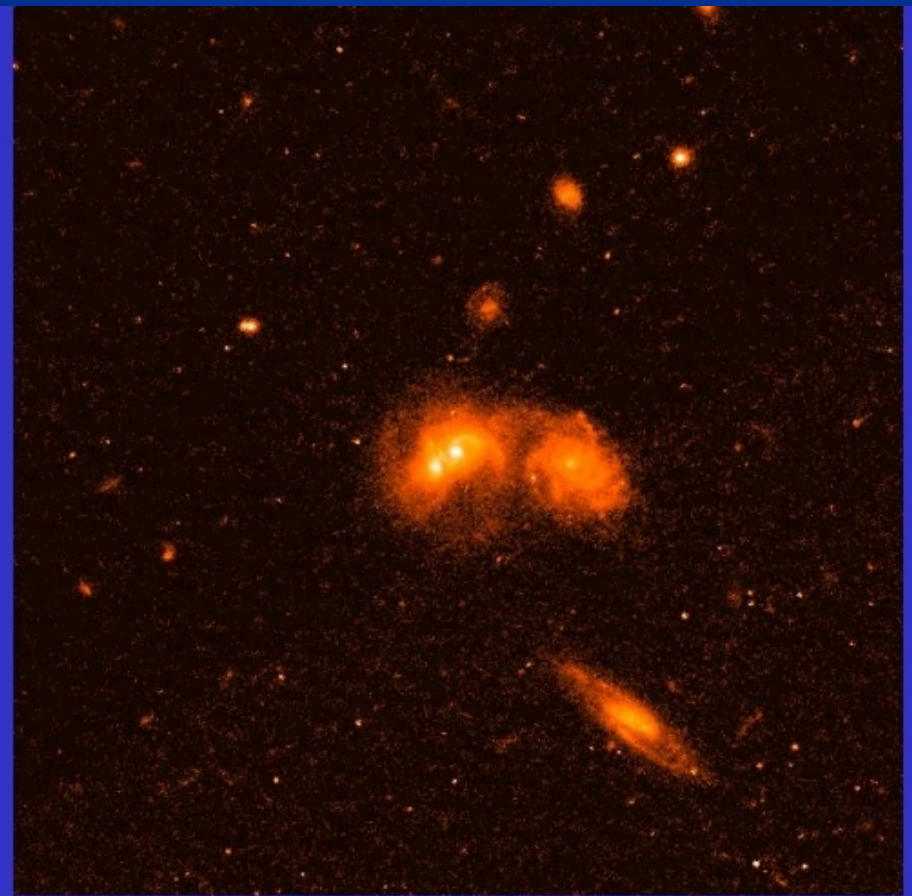
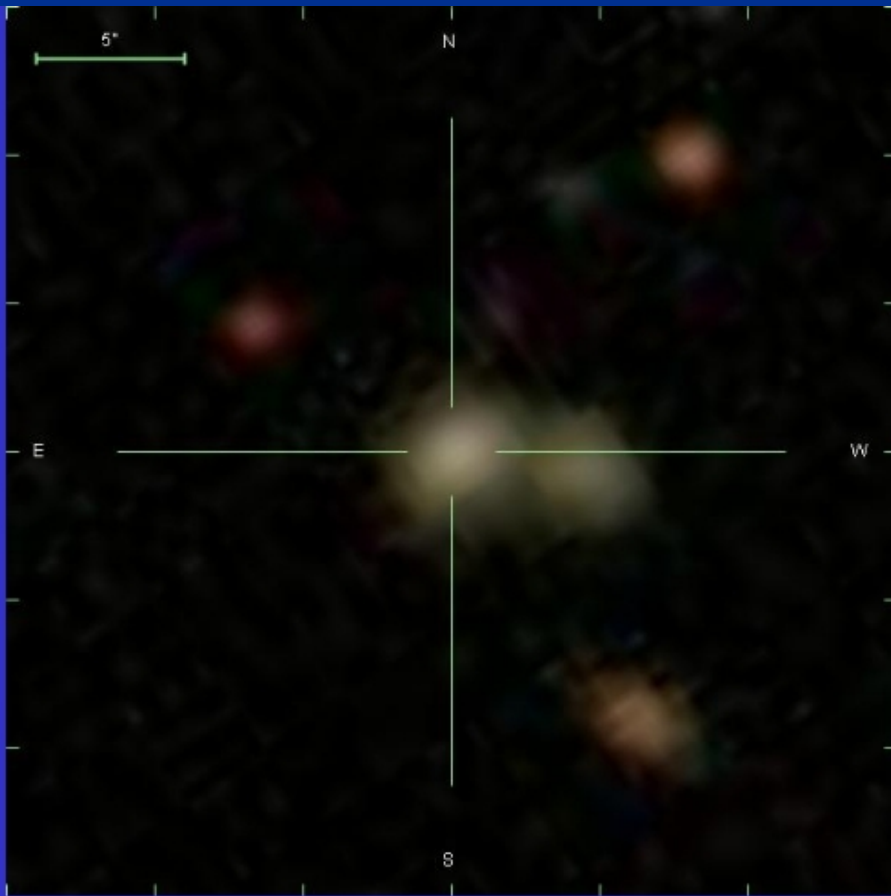
# Luminosity Comparisons

Our PSQs have very similar redshifts and luminosities to Treu et al. (2007) AGNs, but are more luminous than the lower redshift post-starburst galaxies studies with HST from Yang et al. (2008).

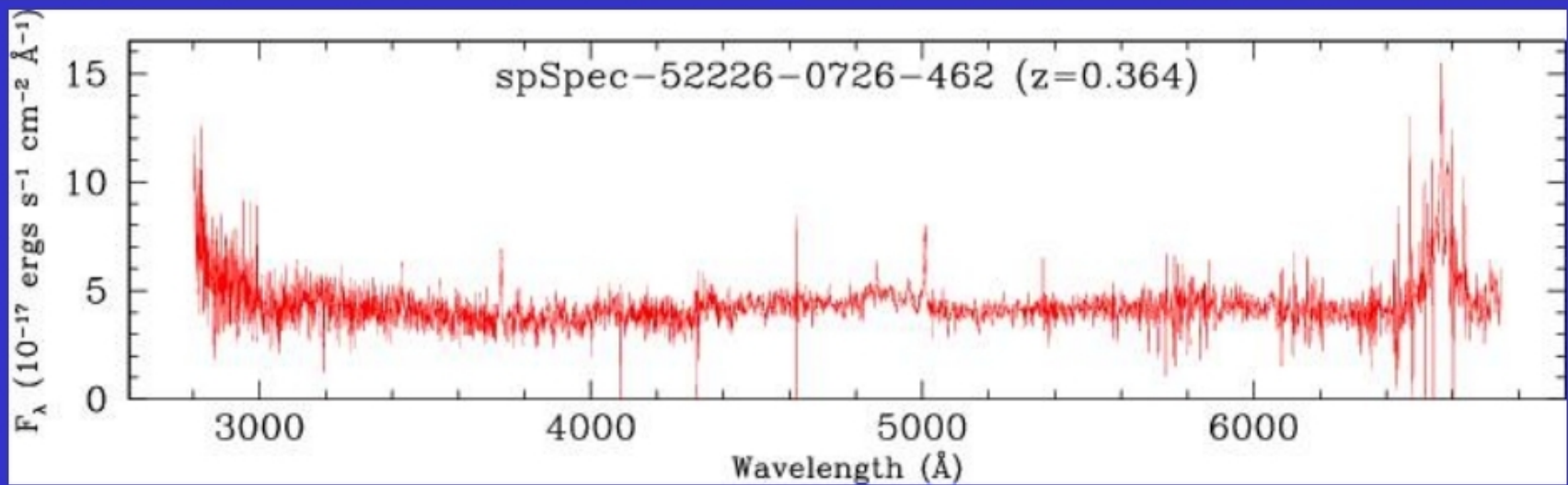
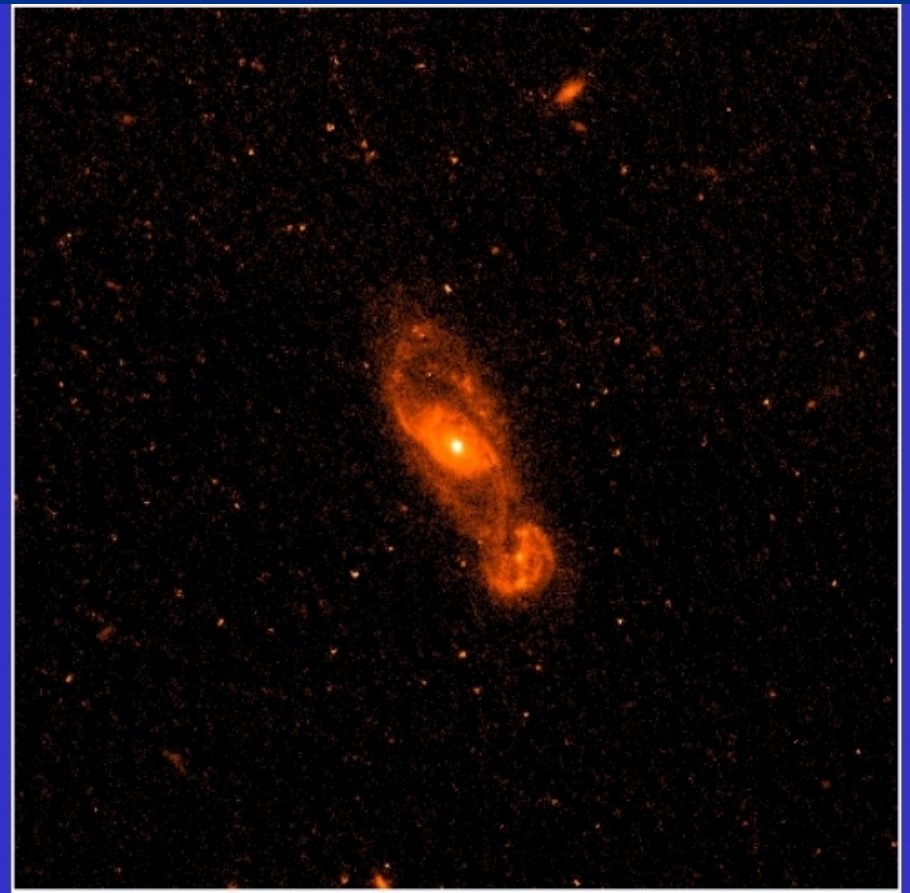
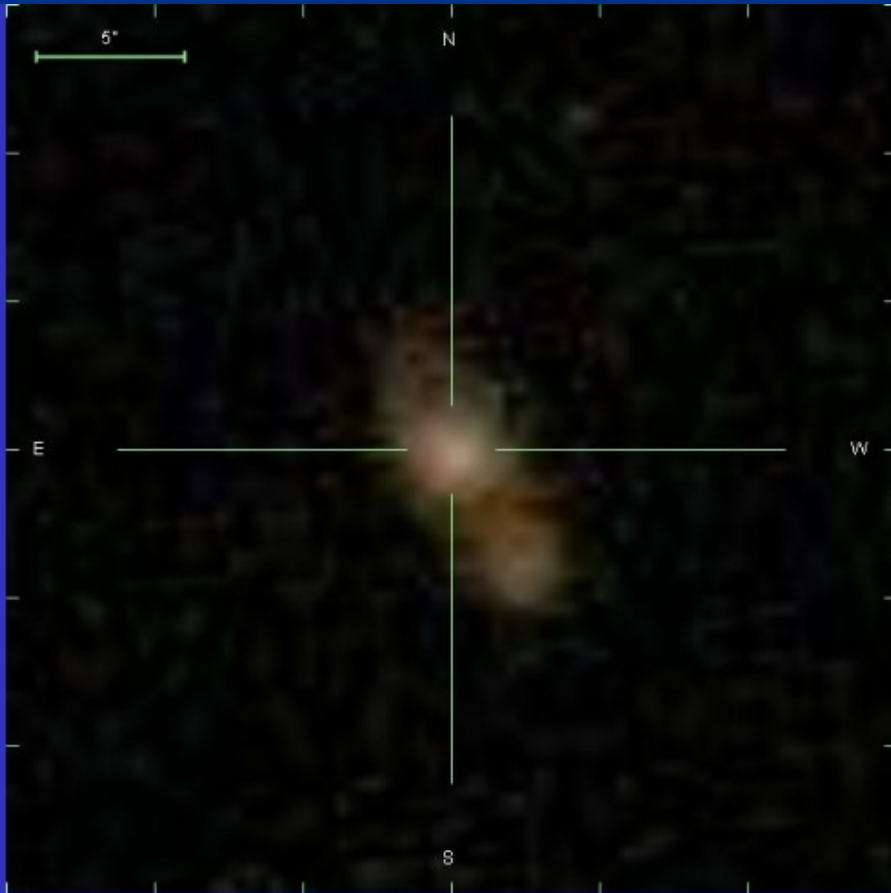




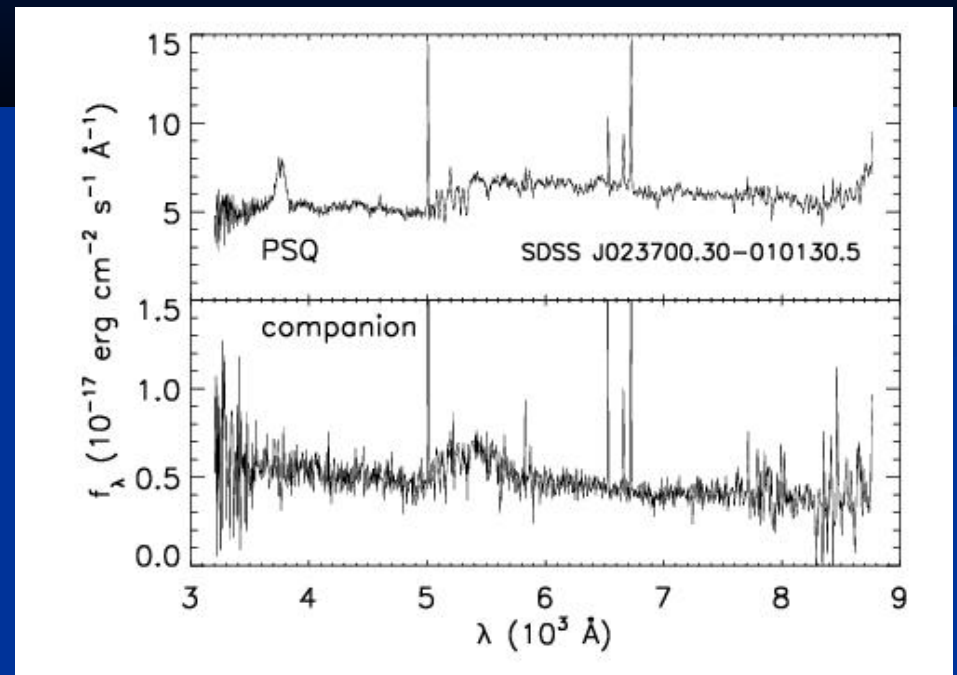
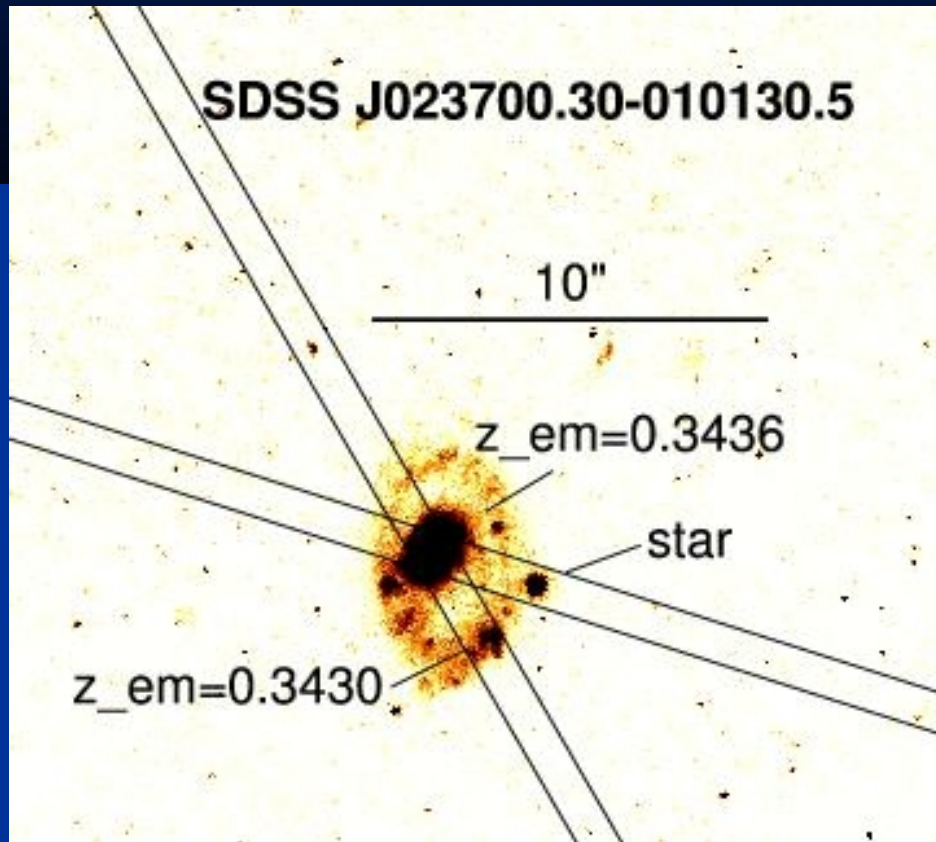




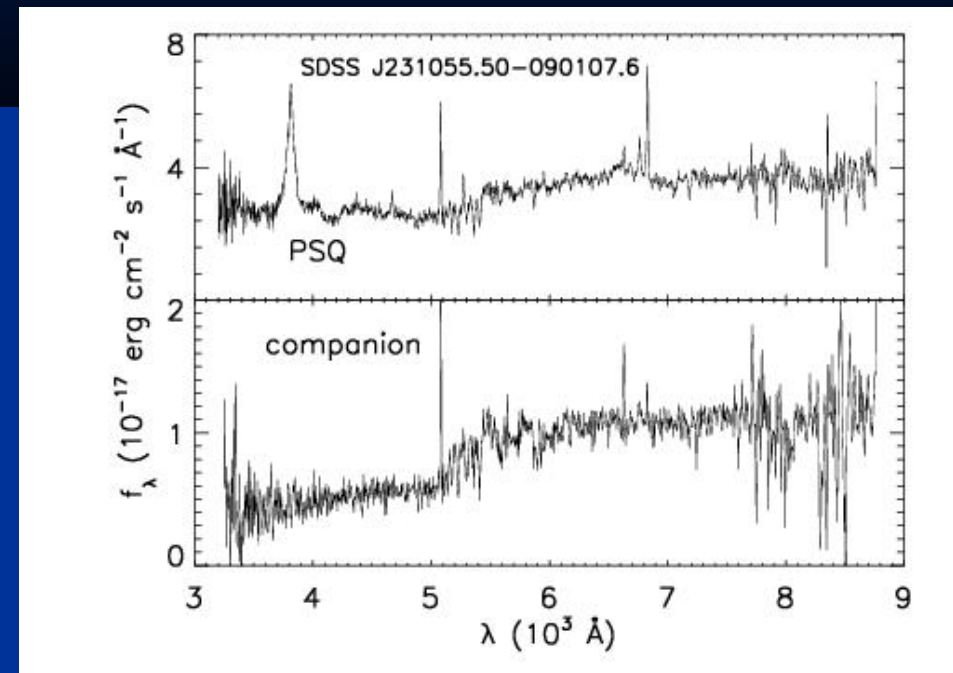
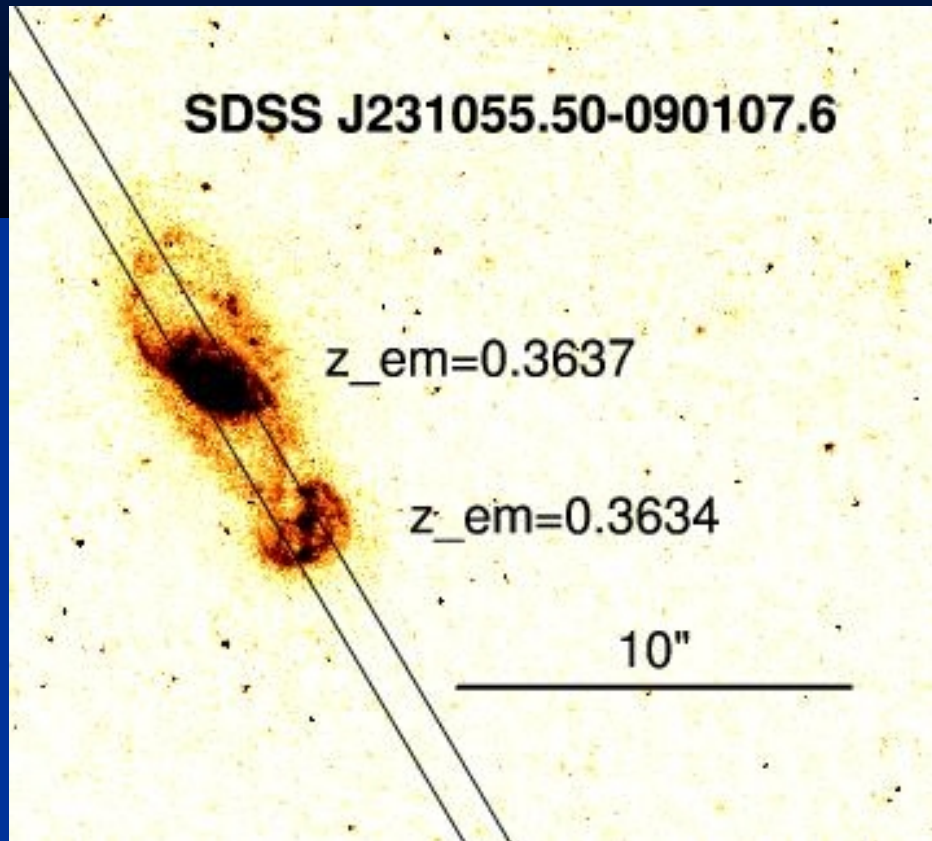




# Keck Spectroscopy of Companions

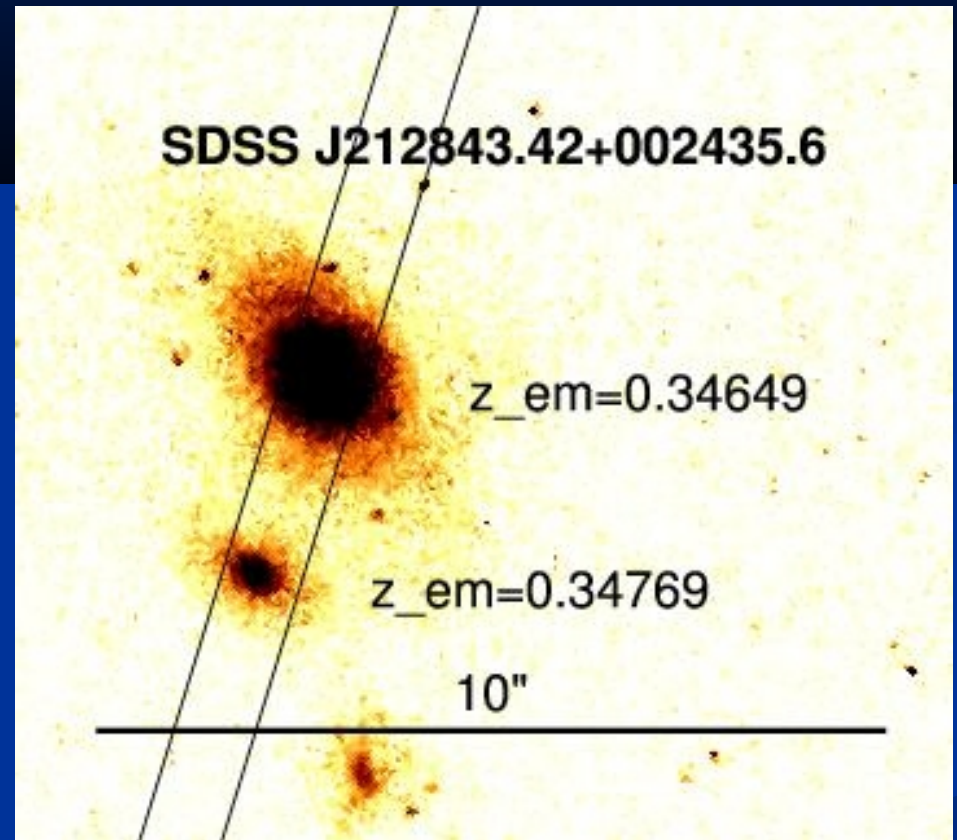
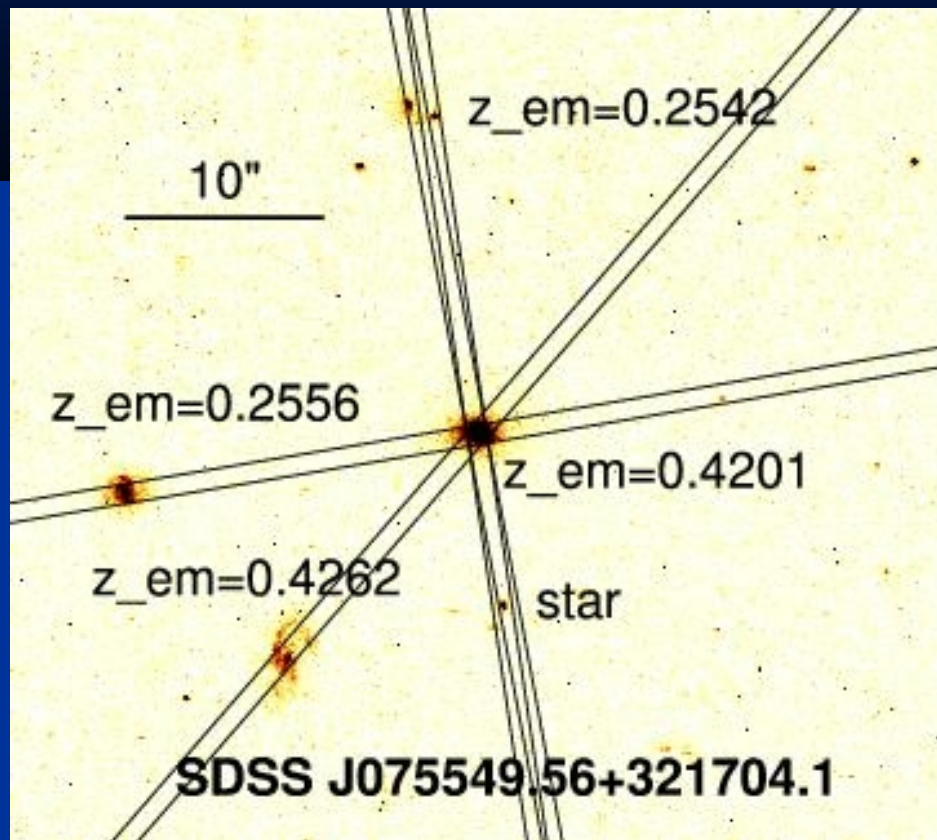


# Keck Spectroscopy of Companions

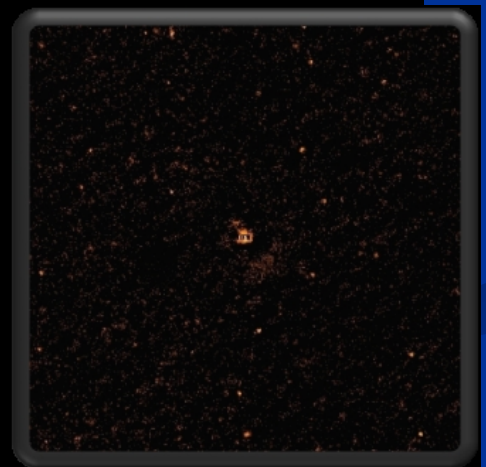
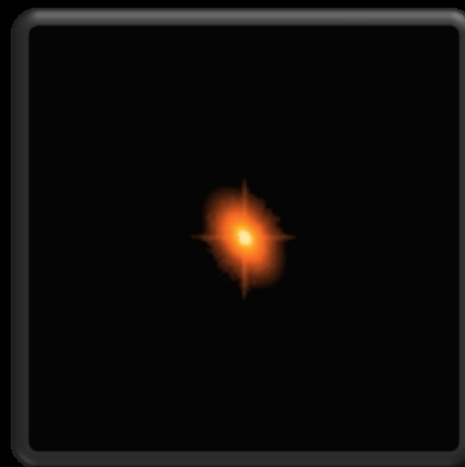
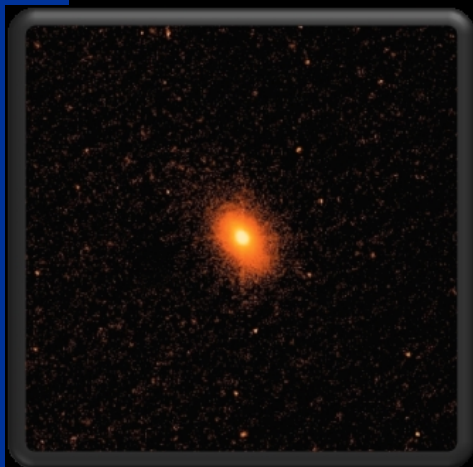
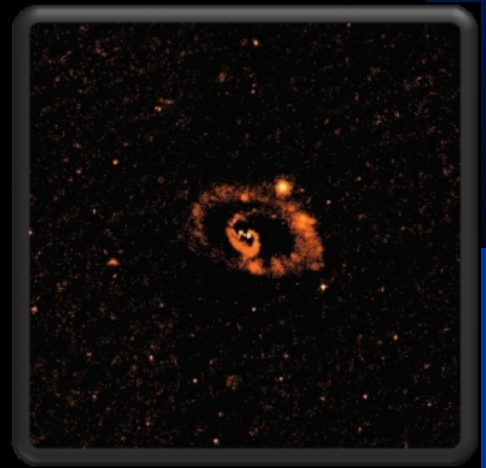
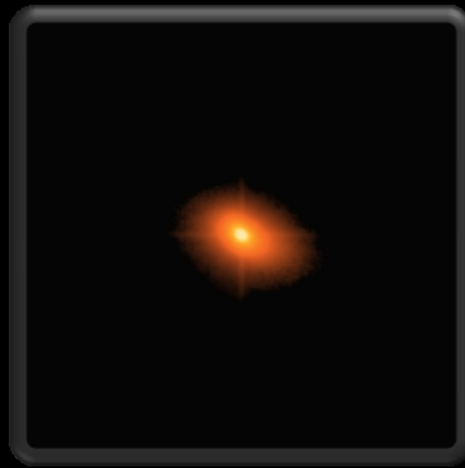
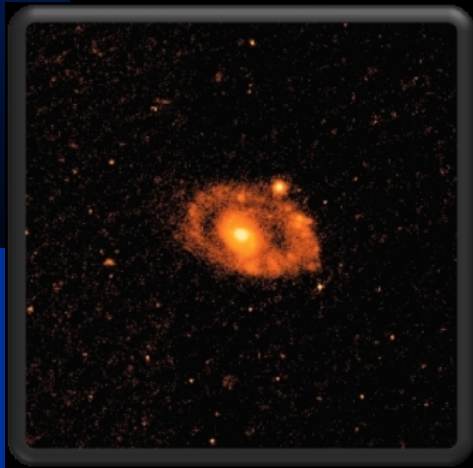




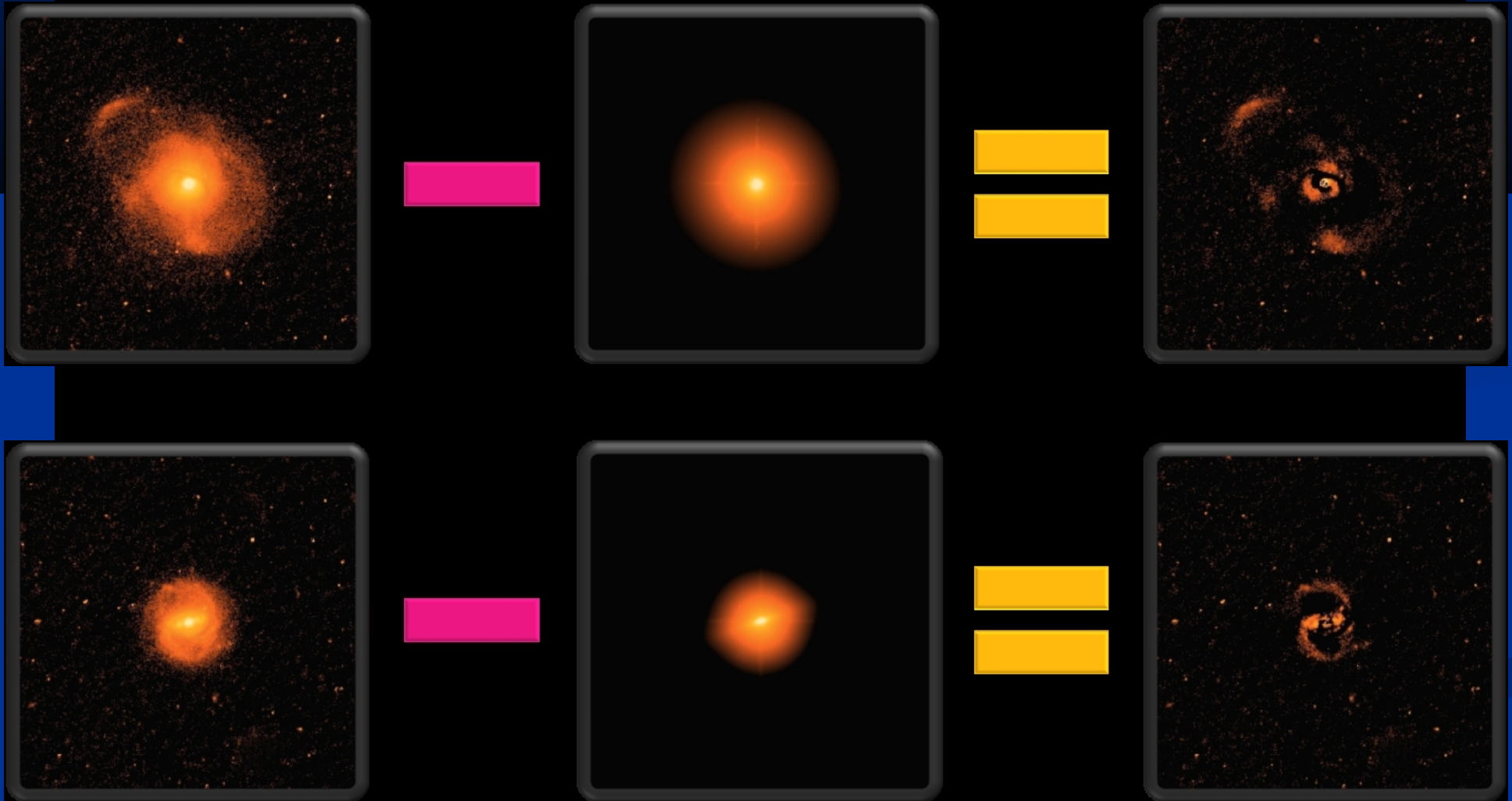
# Keck Spectroscopy of Companions



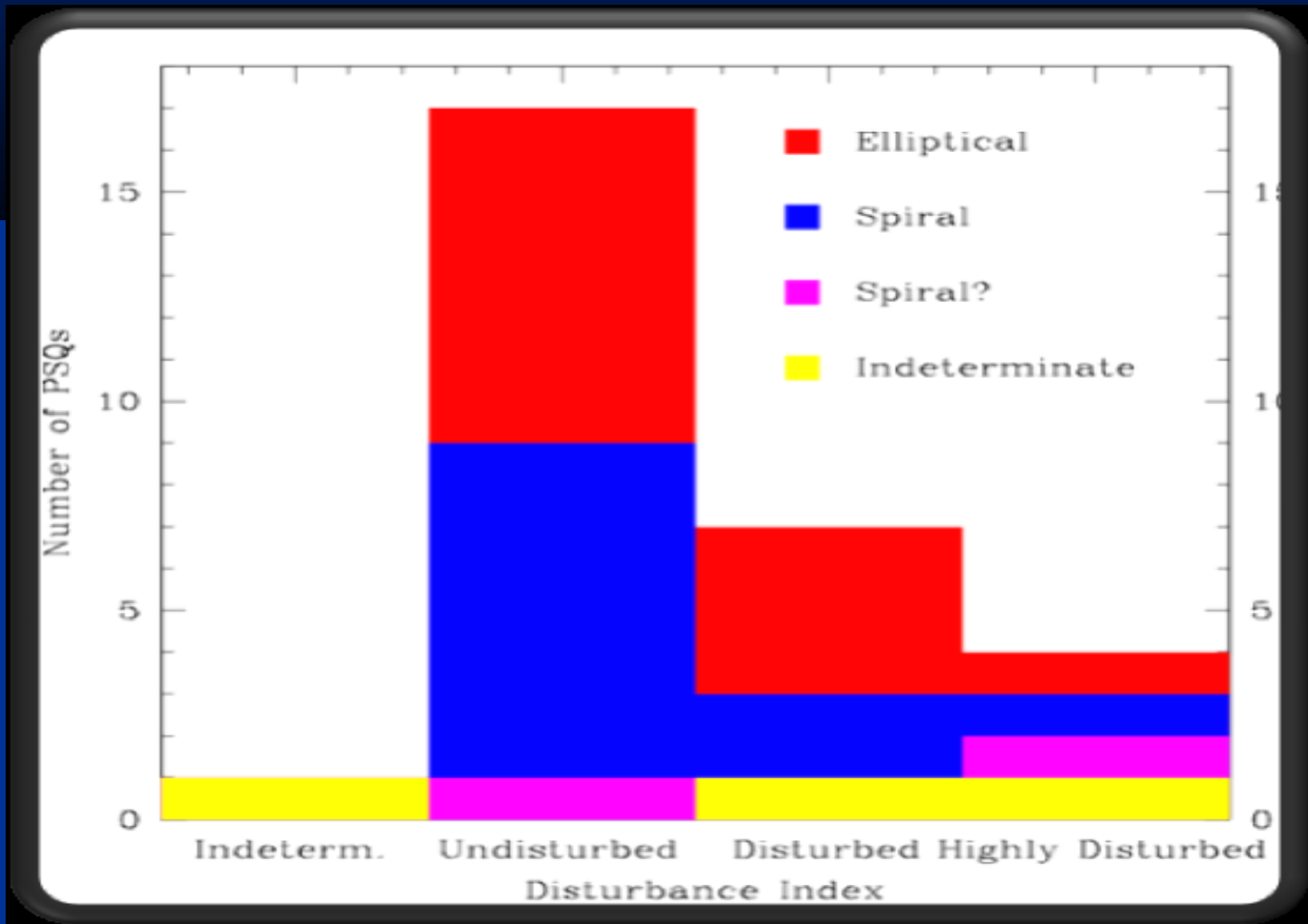
# Subtraction



# Subtraction

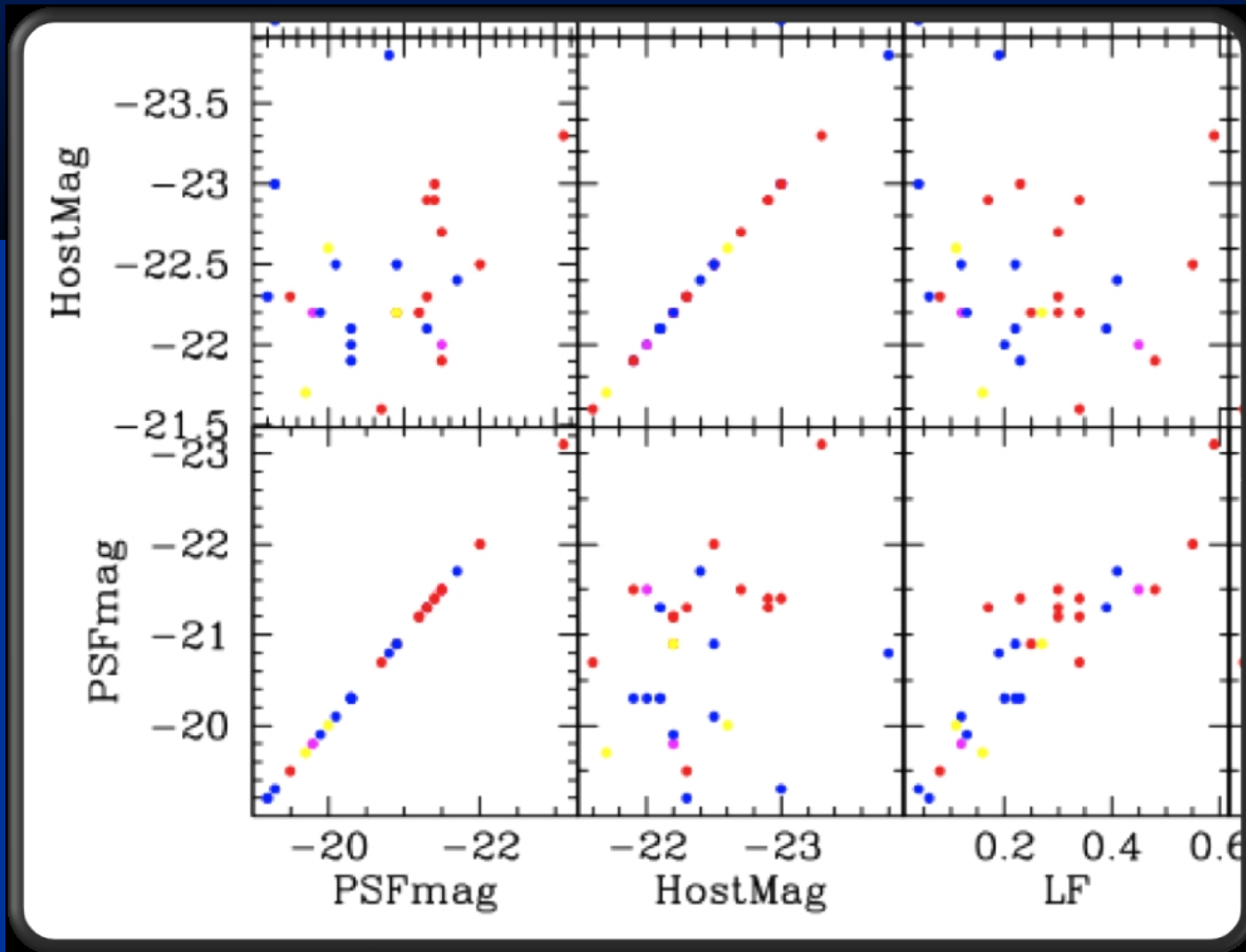


# Morphology





# Host vs PSF Abs Mag

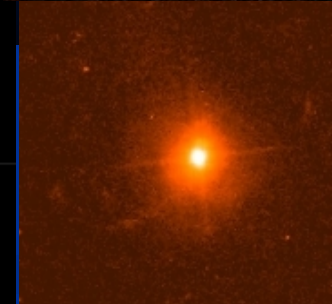
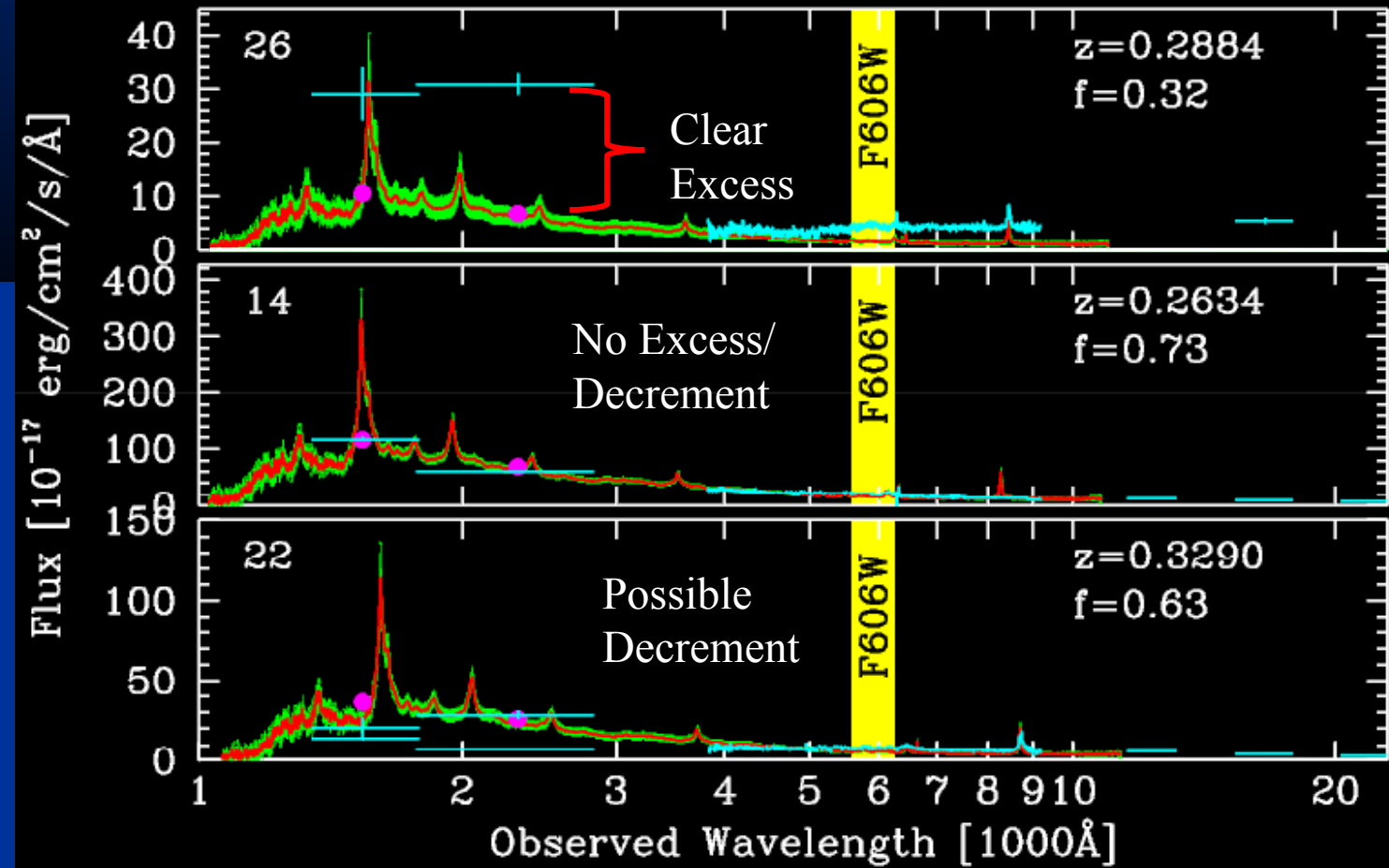


# PSQs: GaleX Results

GALEX

SDSS/HST

2MASS

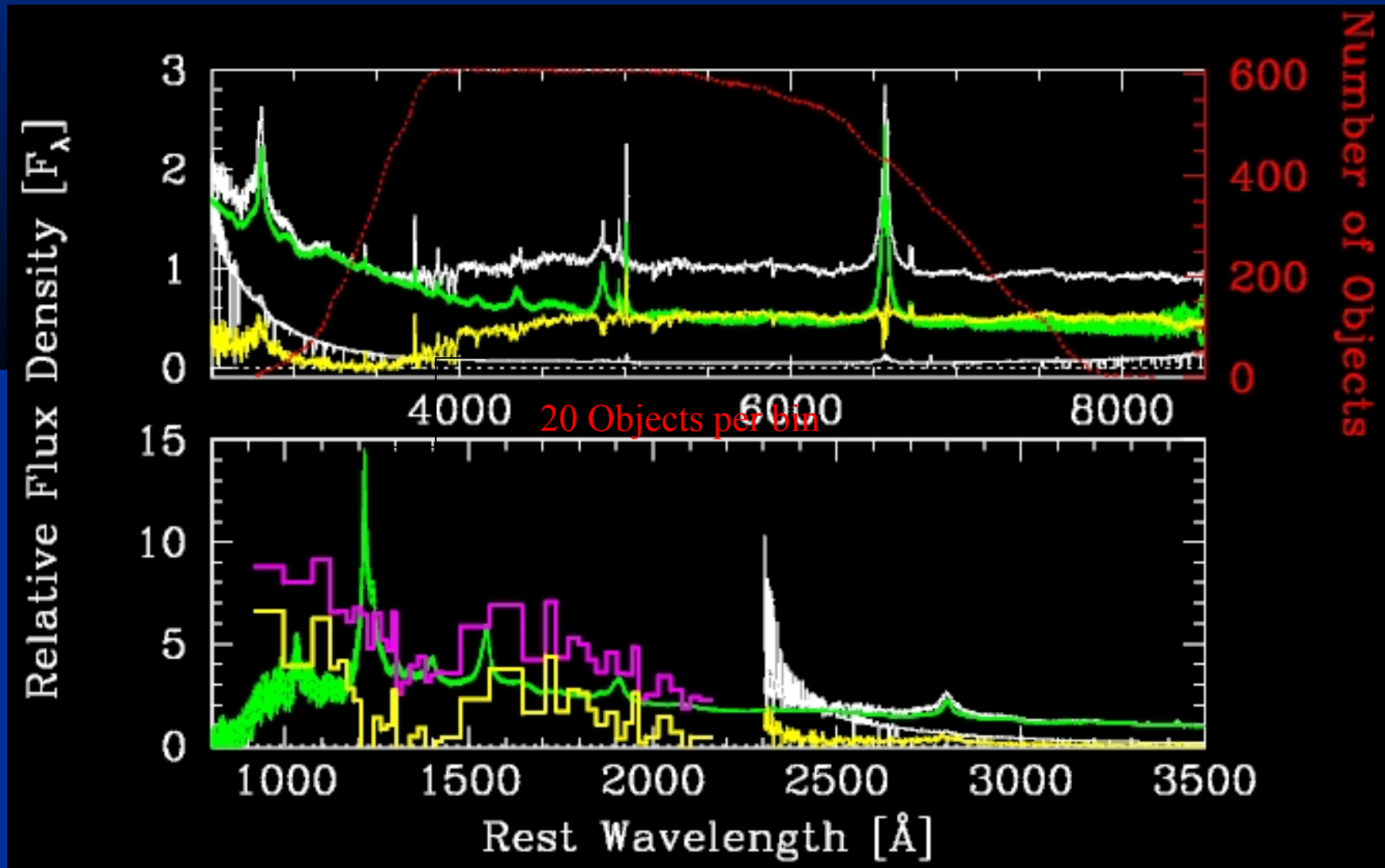


Cyan = data red = scaled SDSS QSO composite green = 3 $\sigma$  uncertainty magenta = predicted GALEX photometry  $f$ =QSO/total light fraction in HST band

# Post-Starburst Quasars: Still star-forming or blowhards?

- Figure 3 shows some examples of our objects. We have overlaid the composite QSO SDSS spectrum, scaled to match the estimated QSO flux in the HST/ACS-F606W band.
- Yes....
  - 56% of objects show a UV excess, an indication of ongoing star-formation.
  - 8% of objects possibly show a UV decrement, an indication of either an outflow, or dust.
- ...and no (36% of objects are consistent with only UV flux from the QSO)

# The Composite PSQ Spectrum



White: Composite SDSS spectrum of PSQs

Green: Composite SDSS spectrum of QSOs (Vanden Berk et al. 2001)

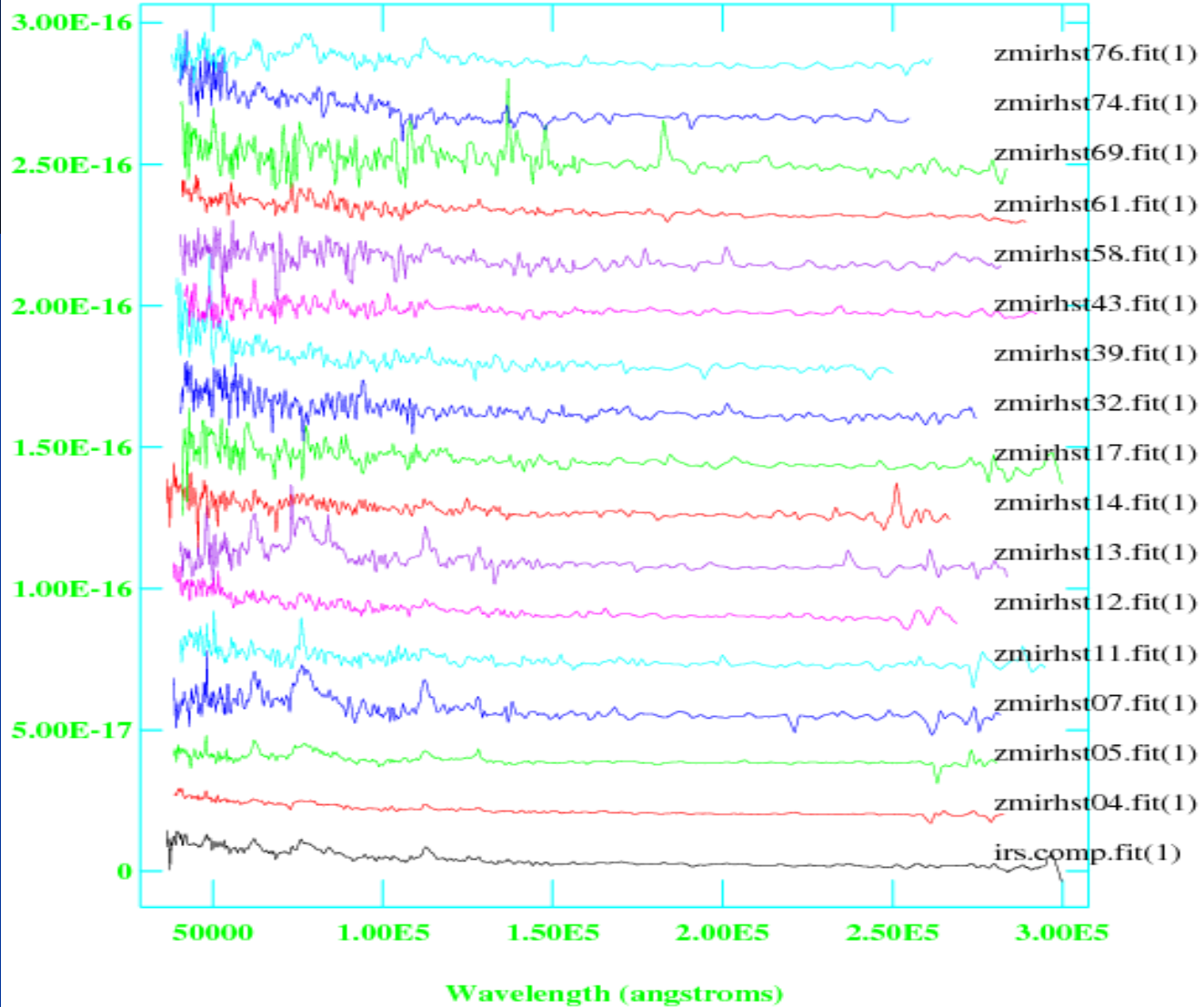
Magenta: Composite GALEX pseudo-spectrum of PSQs

Yellow: Residual flux (PSQ composite – QSO composite)

# Spitzer IRS Spectra

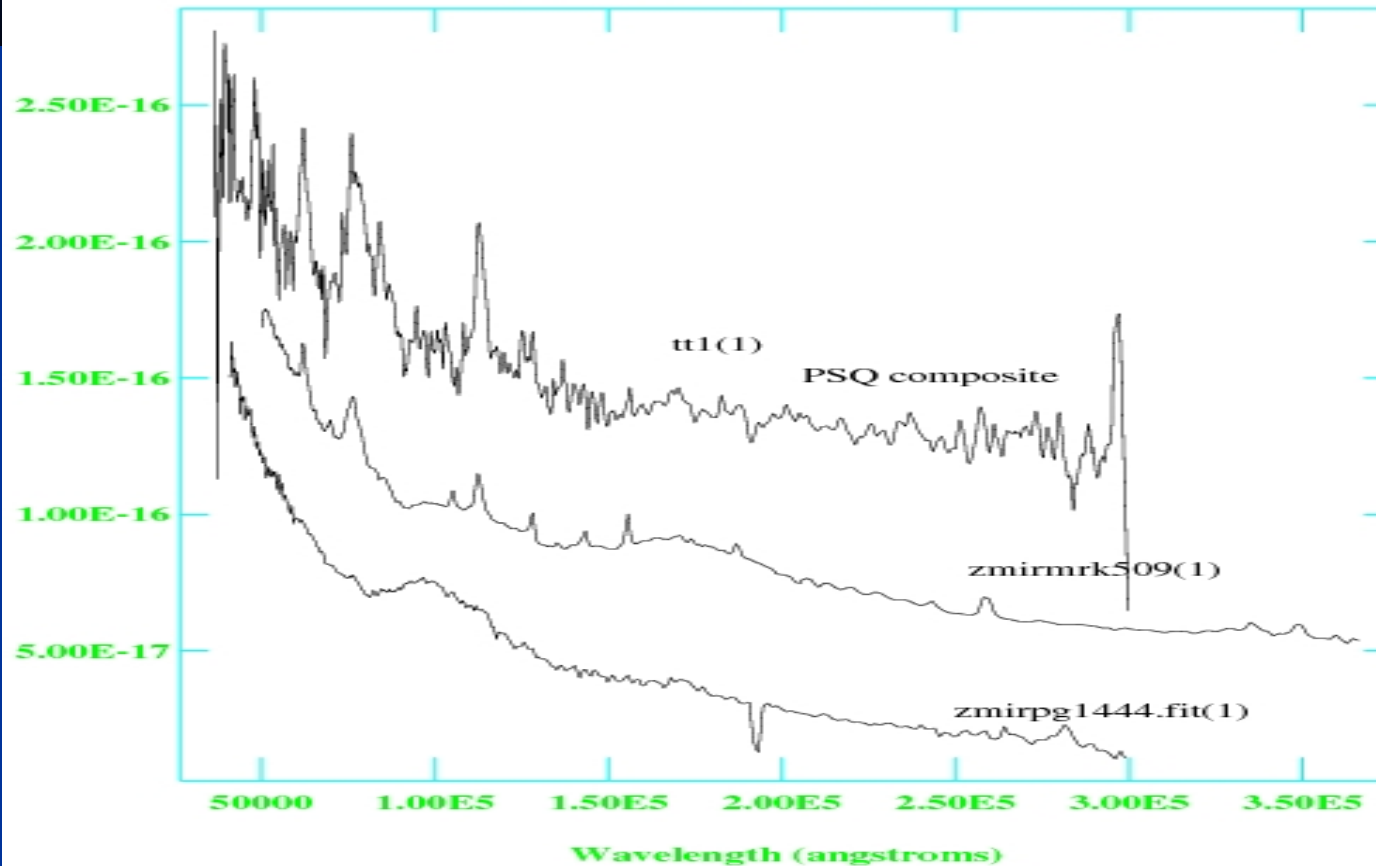
NOAO/IRAF V2.14EXPORT shang@pca.uwyo.edu Tue 21:49:32 07-Oct-2008

Separation step = 1.766090E-17



# Spitzer IRS Spectra Composite/Comparison

NOAO/IRAF V2.14EXPORT shang@pca.uwyo.edu Mon 22:29:14 06-Oct-2008  
Separation step = 3.614354E-17

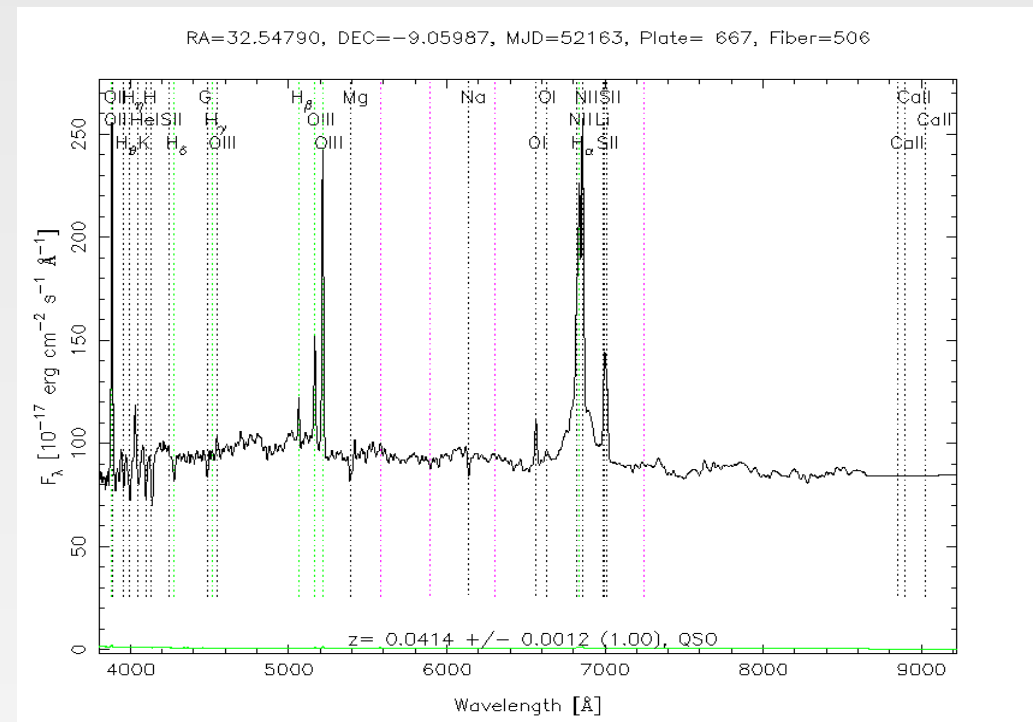
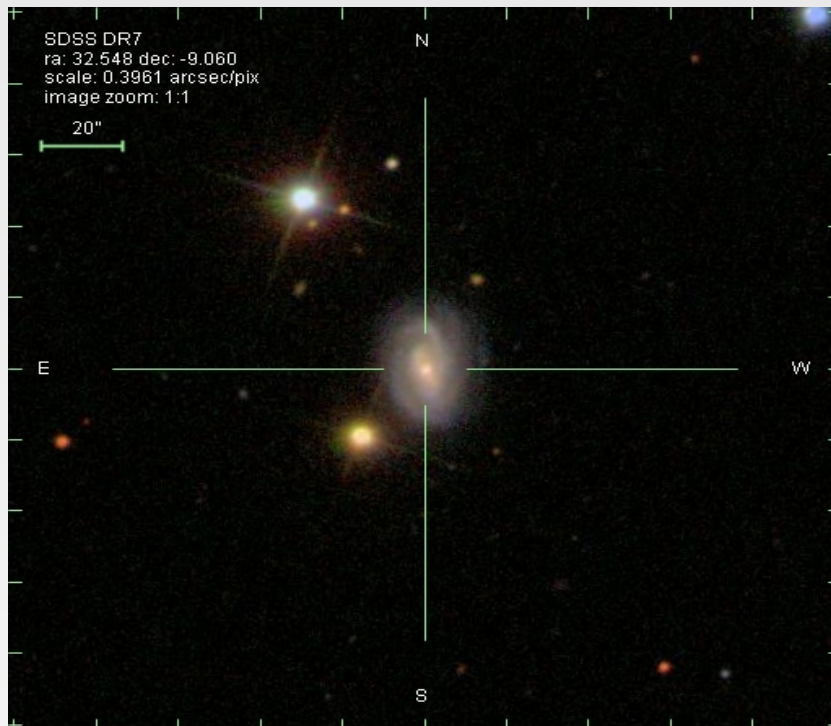




# Gemini IFU Observation with GMOS

→ [SDSS J0210-0903](#)

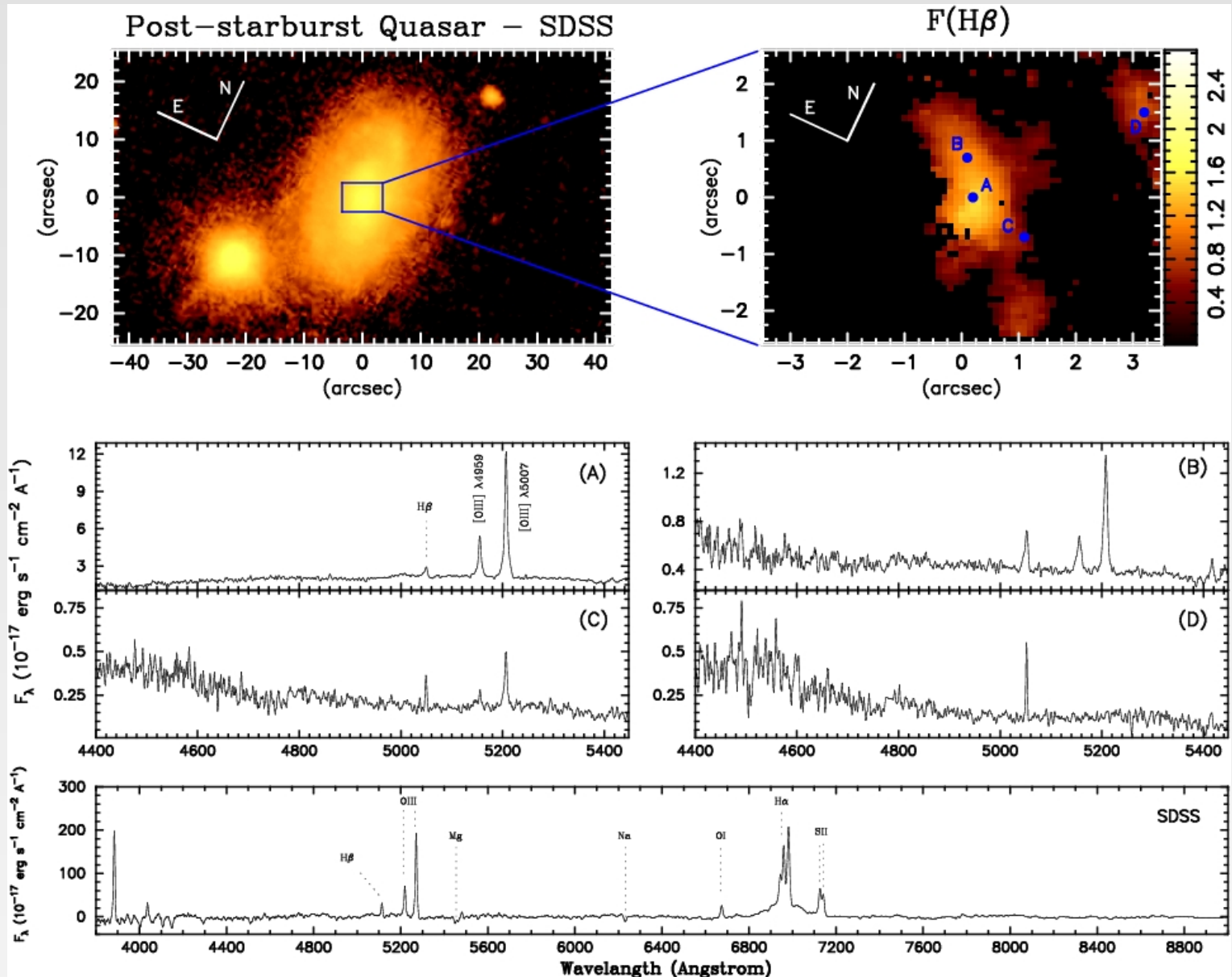
- One of the closest and brightest PSQs;
- $z \sim 0.04$ ;
- $7 \times 5 \text{ arcsec}^2 \rightarrow 0.8 \text{ kpc / arcsec} \rightarrow 5.6 \times 4.0 \text{ kpc}^2$
- Broad H $\alpha$  and H $\beta$  emission;
- Clear signs of post-starburst population. Barred spiral.





# Observations of central 7x5 arcsec

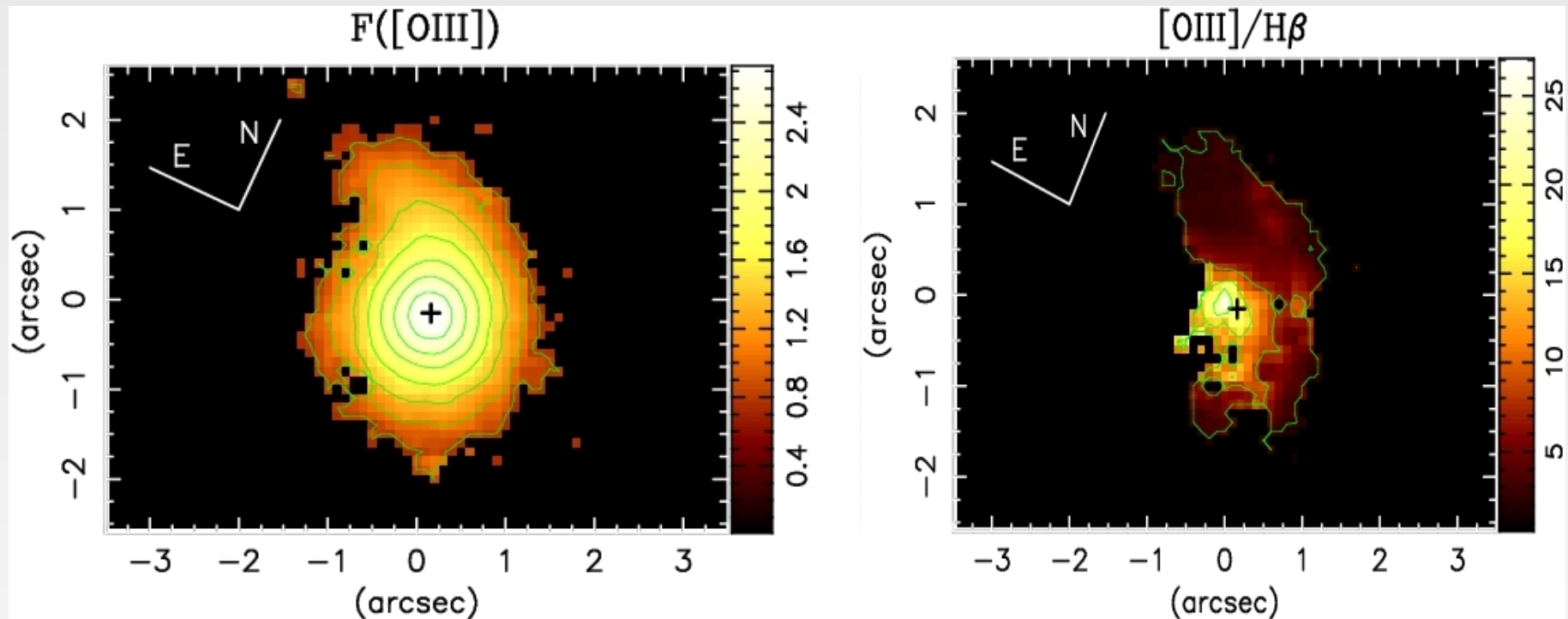
→ SDSS J0210-0903



# IFU Results

→ Line fluxes and ratios

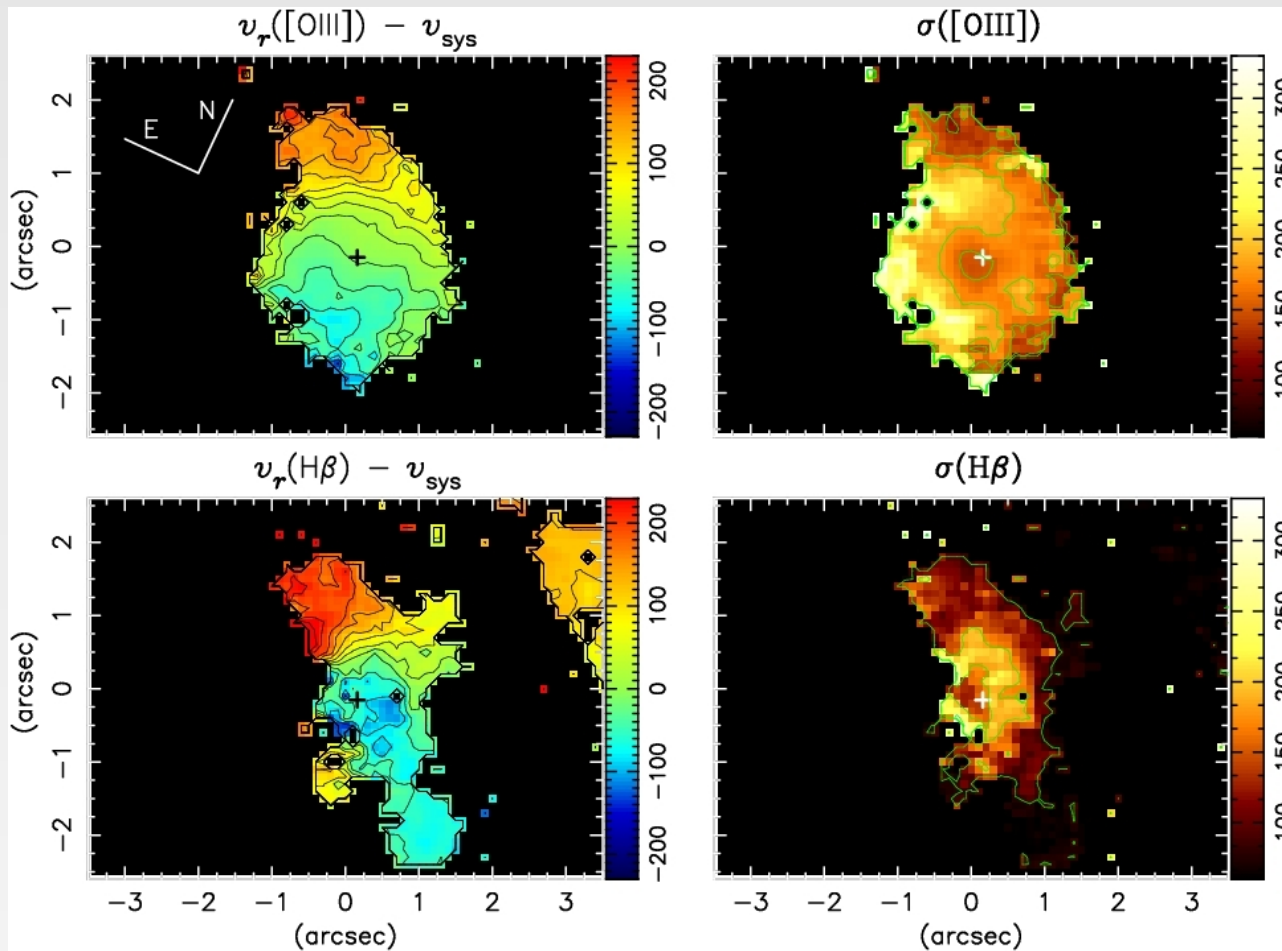
- ✓ The emission from  $[\text{OIII}]\lambda 5007$  peaked on nucleus;
- ✓ The extension to the NE has LINER-like ratio, star forming region?



# Results

## → Gas Kinematics

- ✓ There is the suggestion of rotation, although the sigma is large.
- ✓ The extension/Hbeta has different kinematics suggestive of a flow.

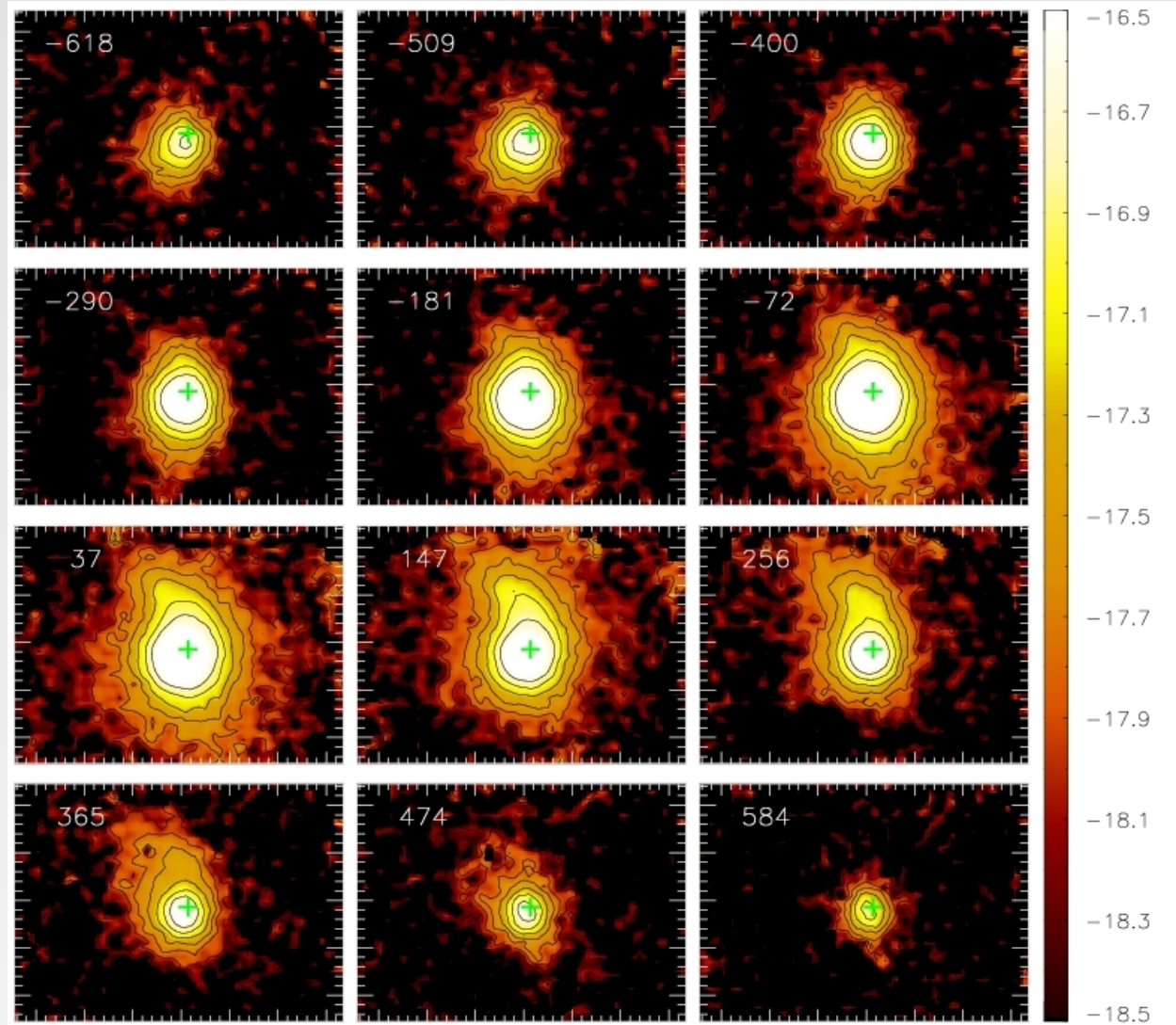


# Results

→ Gas Kinematics

✓ 'Channel Maps'

✓ [OIII]  $\lambda$ 5007

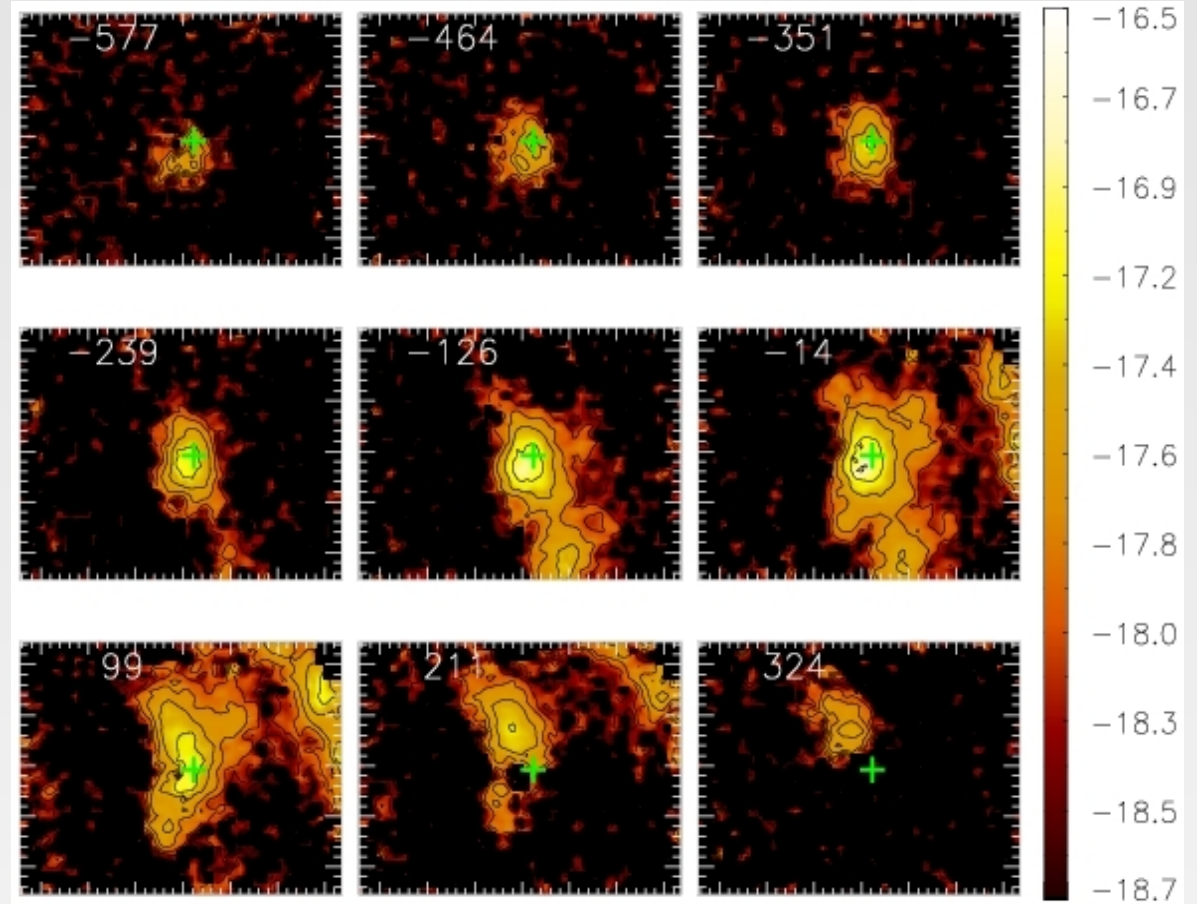


# Results

→ Gas Kinematics

✓ "Channel Maps"

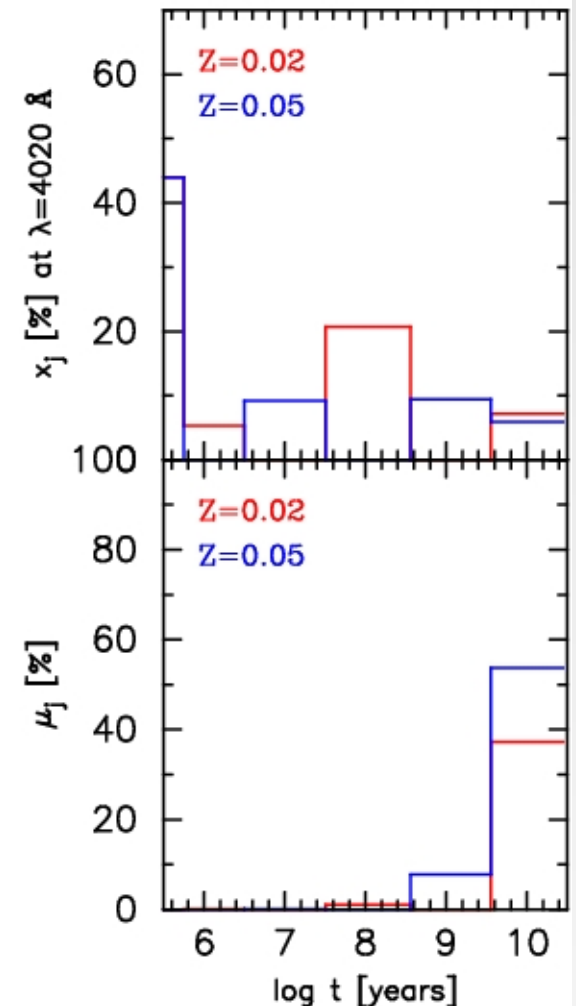
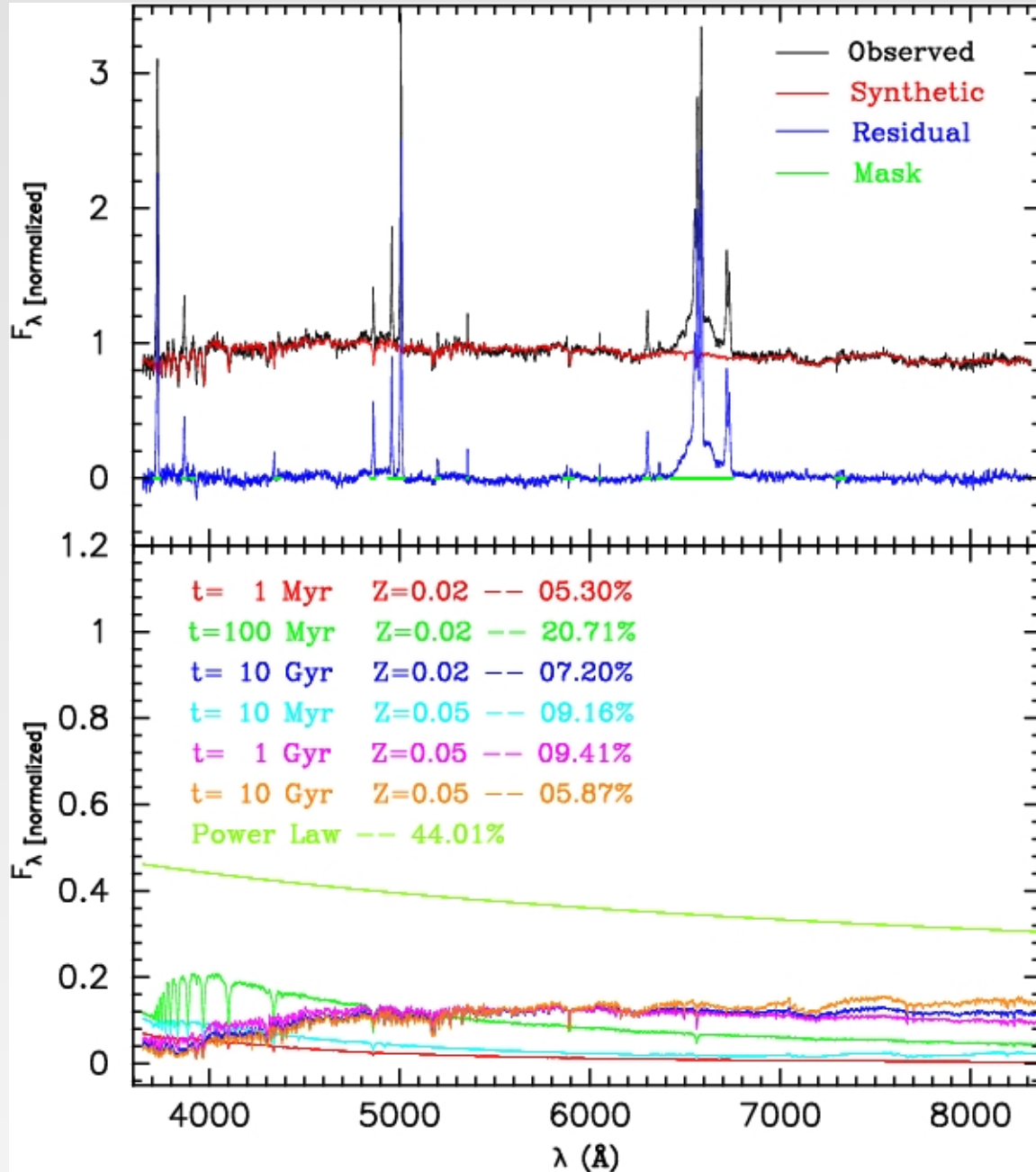
✓  $H\beta$





# Starlight Spectral Synthesis

SDSS spectrum



# Summary

- Several percent of low- $z$  SDSS quasars ( $\sim 1000+$ ) have detectable post-starburst stellar populations.
- These show blue extended fuzz, and have a slight excess of nearby companions.
- HST imaging shows 45% spirals (often barred) and 45% ellipticals with signs of being merger products. These are at the Seyfert/QSO border.
- GALEX UV data suggests over half of these SDSS PSQs may have ongoing or recent star formation.
- Spitzer spectra show PAHs at some level. More work to be done here.
- Gemini IFU observations are being made for a few.
- Big upcoming challenge: spectral modeling.