Keck Observations of Type 2 AGNs

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Overview

- The lack of broad-line regions in **unobscured** Seyfert 2 galaxies
- Discovery of polarized, hidden double-peak Hα emission line in Sey 2 galaxies
- Laser-guide star adaptive optics (LGS-AO) near-infrared imaging of IRAS 09104+4109

Type 1 View of three Seyfert Nuclei

- X-ray observations with *ASCA*, ROSAT and Chandra
  - NGC 3147 (Terashima & Wilson 2003)
  - NGC 4698 (Georgantopoulos & Zezas 2003)
  - 1ES 1927+654 (Boller et al 2003)
- Little or no intrinsic X-ray absorption from spectral fitting
- High Hard X-ray to [O III] ratios indicate **little** obscuration
- Rapid, persistent, and strong **X-ray variability** observed over 12 year time scale in 1ES 1927+654
- Inferred nuclear optical extinction is less than ~ 1 mag.

Optical and X-ray Characteristics

Object	Type	z	m_B	$L_{[O\ III]}$ (erg s^{-1})	N_H (cm^{-2})	$f_{2\text{-}10keV}/f_{[O\ III]}$
NGC 3147	Sey2	0.0094	11.4	2×10^{40}	1.5×10^{21}	~ 41
NGC 4698	Sey2	0.0035	11.5	10^{39}	5×10^{20}	1 - 3
1ES 1927 +654	Sey2	0.017	15.4	3×10^{39}	7.3×10^{20}	~ 10^3

All are Compton-thin, consistent with little or no intrinsic absorption above Galactic column density (~ 10^{20} - 10^{21} cm^{-2}).

Where are the Broad Emission Lines?

- All indications are that we have **unobsured, direct** views of the active nuclei. Yet, they all present Seyfert type 2 optical spectra!!
- Given the type-1 view inferred from the X-ray observations, the lack of broad emission lines in these objects is puzzling, and in disagreement with the standard unification model of AGNs.
- We conduct a deep search for any weak/hidden broad emission lines in these objects

Observations

- Spectropolarimetry with the Low Resolution Imaging Spectrograph (LRIS):
  - long, 1” wide slit
  - NGC 3147: 60 min
  - NGC 4698: 200 min, 2 epochs
  - 1ES 1927+654: 240 min, 2 epochs
- Direct Near-IR Spectroscopy with the Near-Infrared Spectrometer (NIRSPEC):
  - NGC 4698:
    - long, 0.76” wide slit
    - J band, 48 min
  - 1ES 1927+654:
    - long, 0.57” wide slit
    - J band, 32 min
    - K band, 48 min

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10 x deeper than previous surveys

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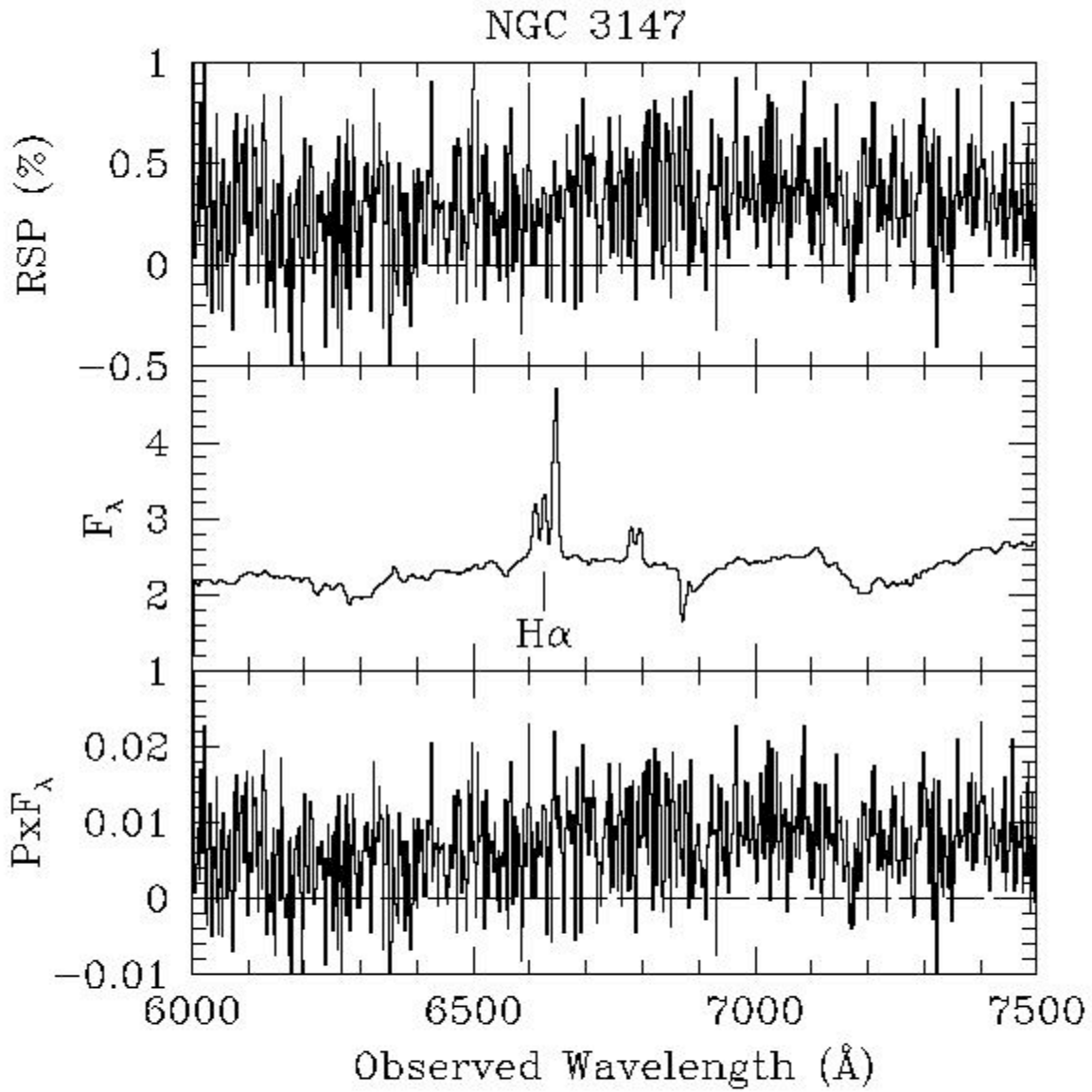
Spectropolarimetric Results

In each case, a small amount of polarization is detected but no polarized broad lines indicative of a hidden broad-line region are seen in the polarized flux spectra.

Object	P (%)	Θ (deg)
NGC 3147	0.31 ± 0.01	159 ± 1
NGC 4698	0.18 ± 0.01	64 ± 5
1ES 1927+654	0.32 ± 0.02	100 ± 2

NGC 3147



P (%)	Θ (deg)
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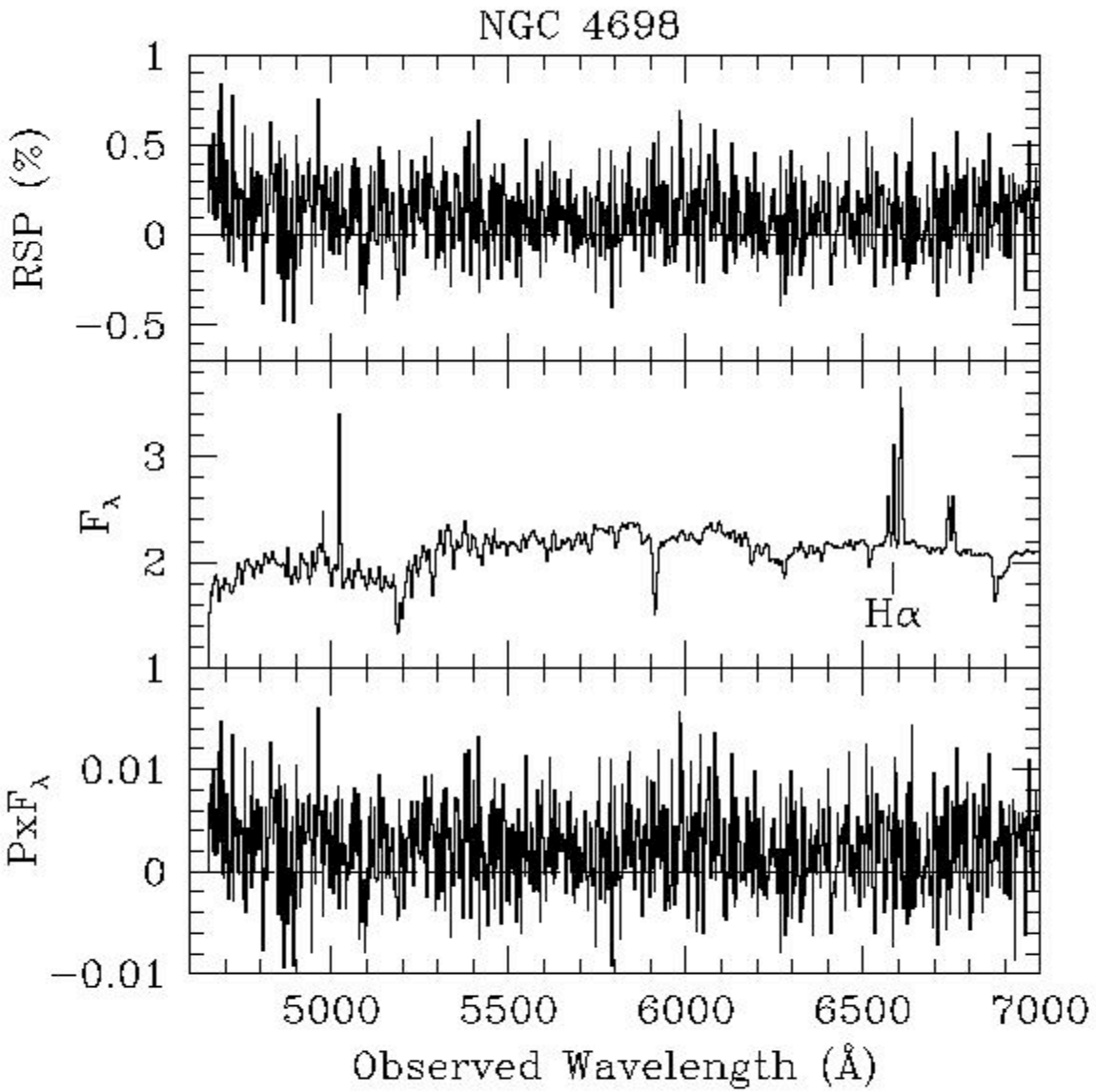
NGC 4698



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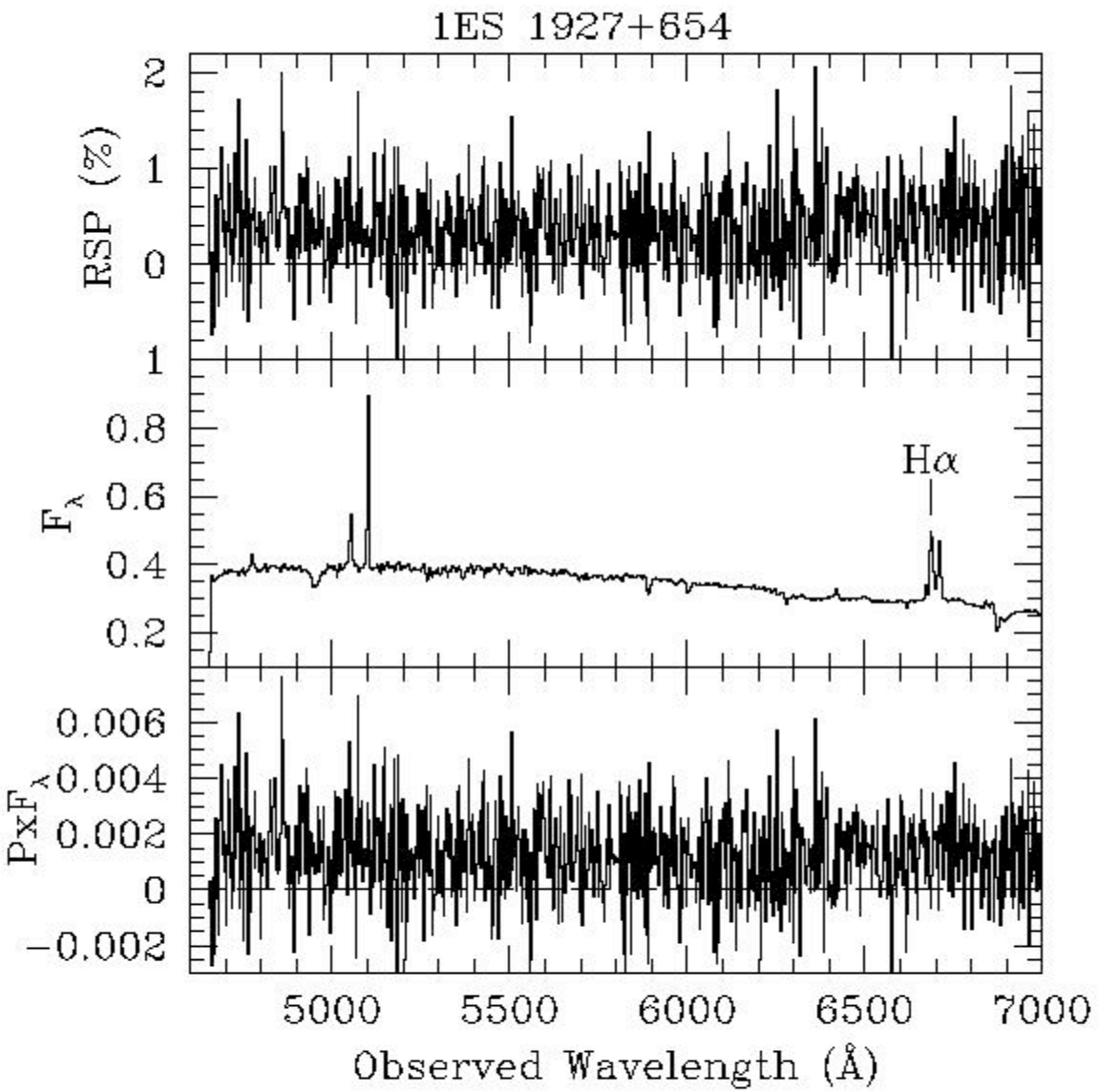
1ES 1927+654



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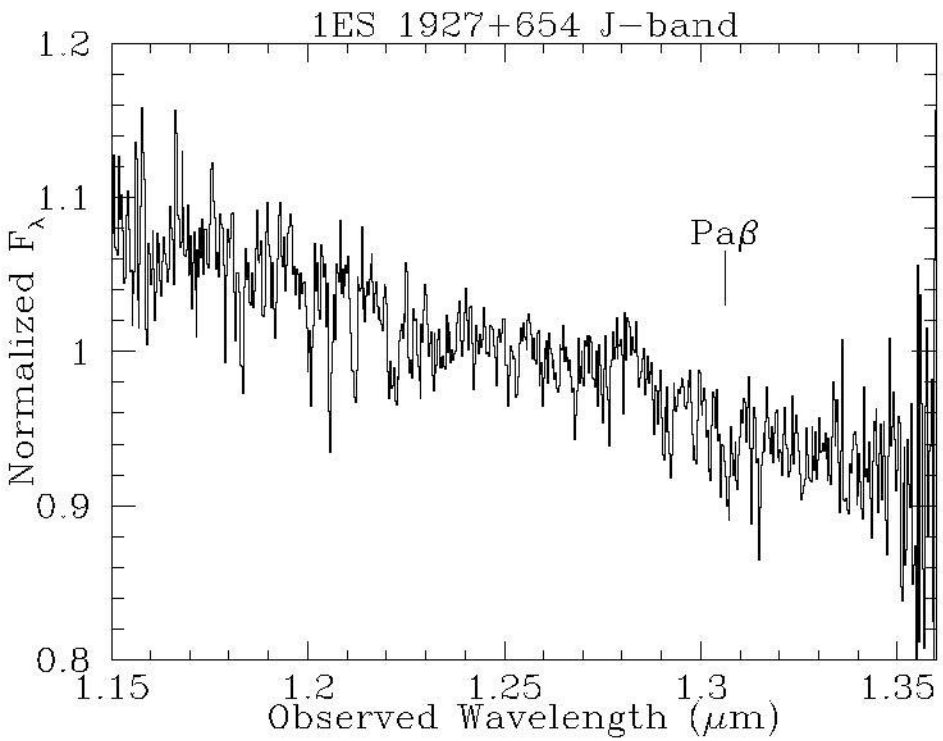
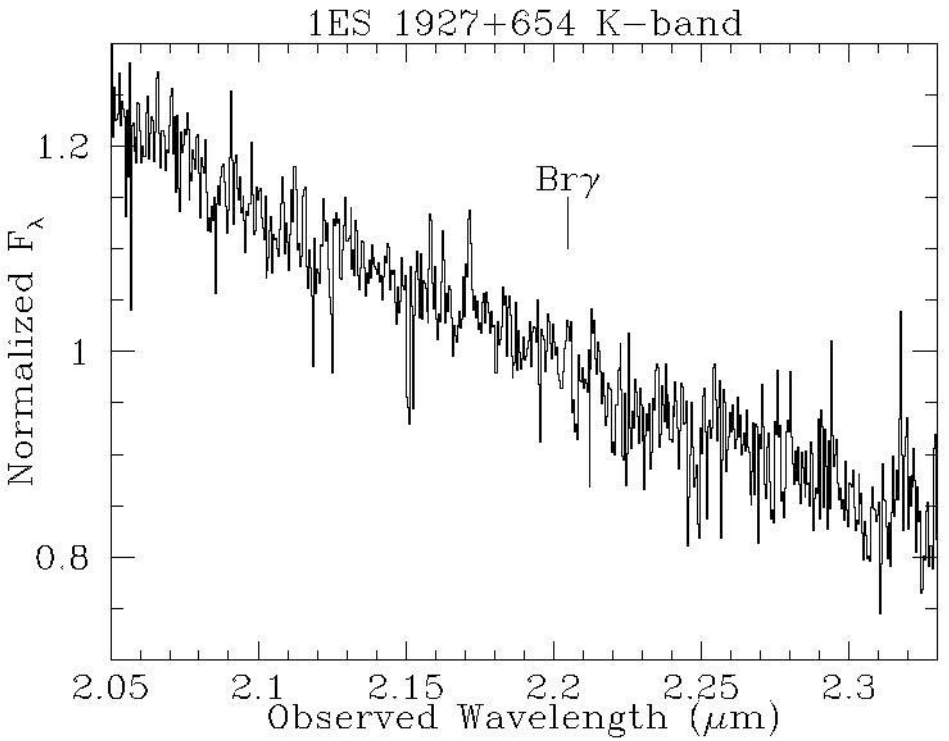
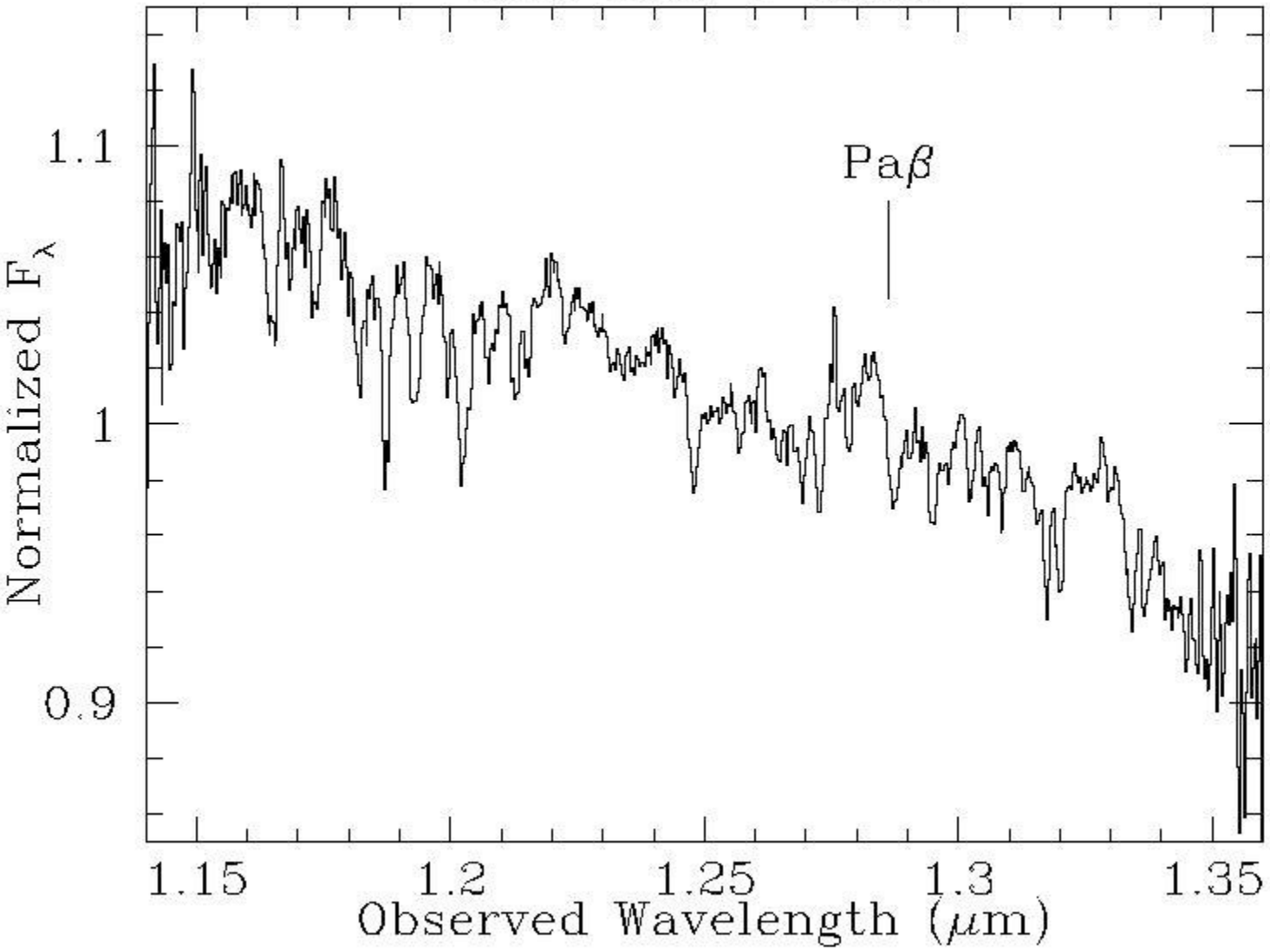
Near-Infrared Spectroscopic Results





We do not detect any significant emission in Paβ or Brγ. No direct broad emission lines are detected.

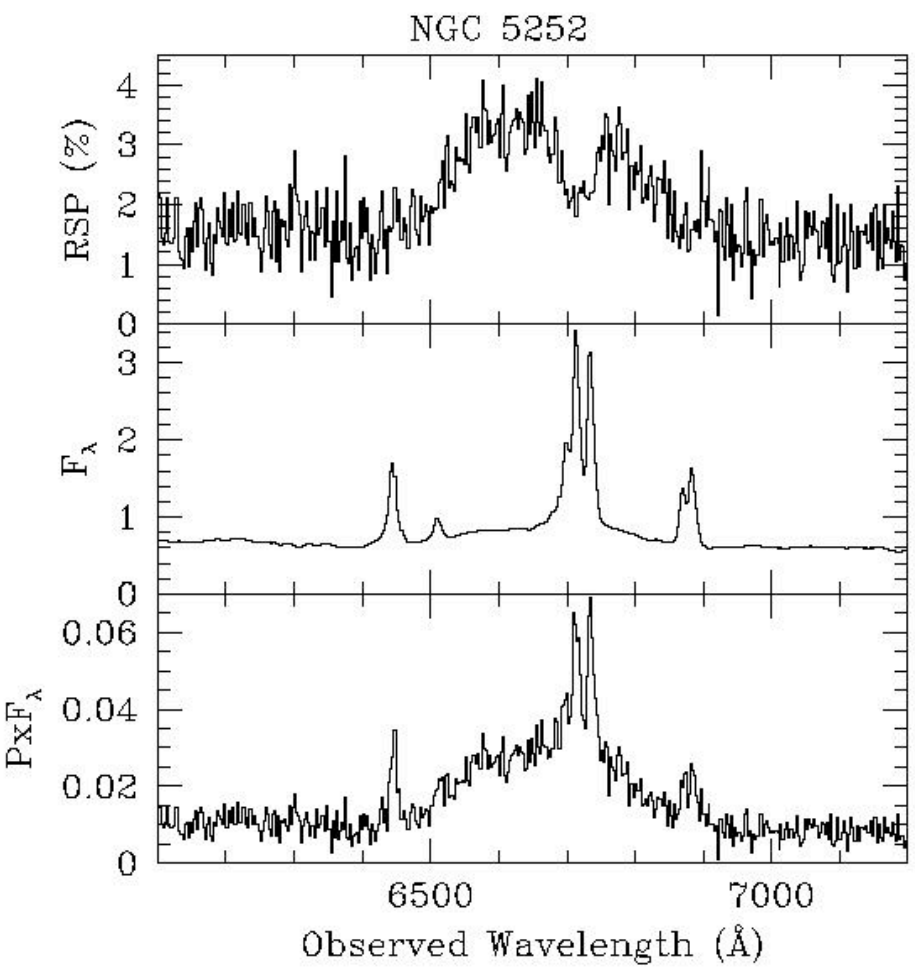
NGC 4698 J band

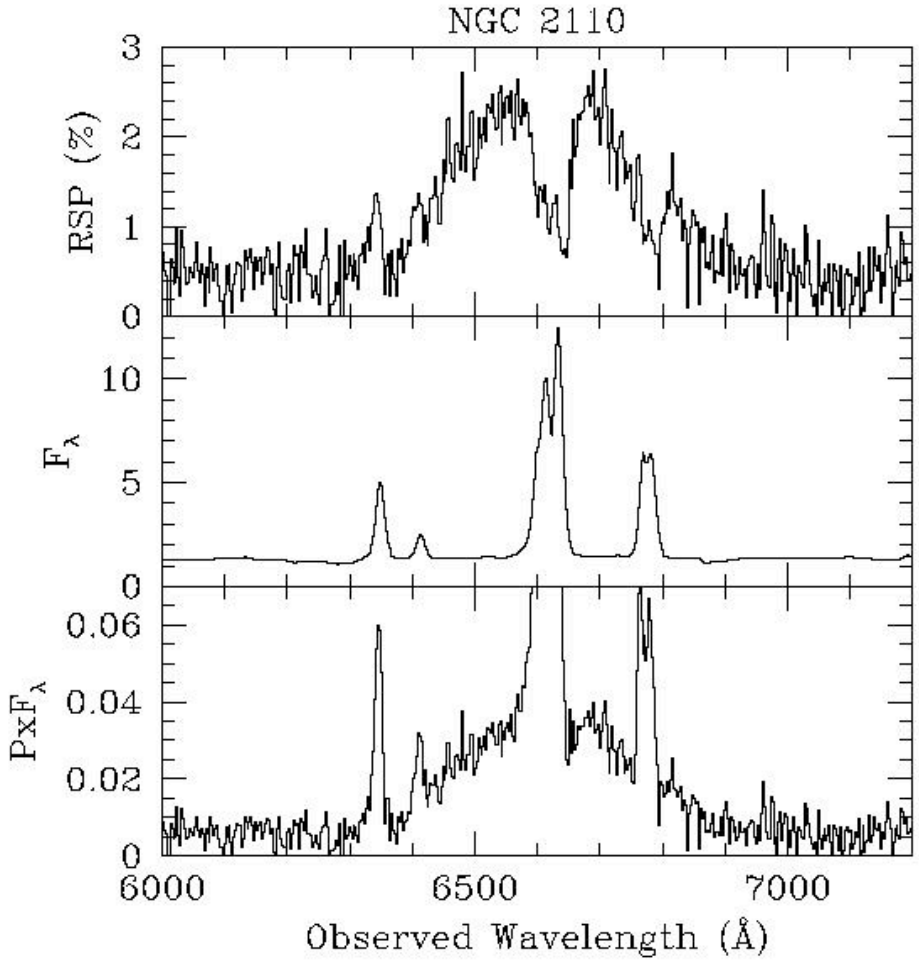


Summary

- NGC 3147, NGC 4698 and 1ES 1927+654 have an unusual combination of properties:
  - X-ray spectra show variability and little absorption indicative of a type-1 (direct) view
  - optical spectra show only narrow emission lines, typical of a type-2 (obscured) view of the nucleus.
- A deep search for hidden BLR using Keck LRIS spectropolarimetry and NIRSPEC direct spectroscopy does not reveal any broad emission lines.
- If typical broad lines were present, the BLR non-detections would indicate $A_V \sim 10 - 26$, inconsistent with X-ray observations.
- The obscuration is due to different material for X-ray and optical light, or that the BLR in these objects are unusually weak or absent.
- L_bol/L_Edd consistent with Nicastro (2000)

Hidden Double-Peakers Revealed





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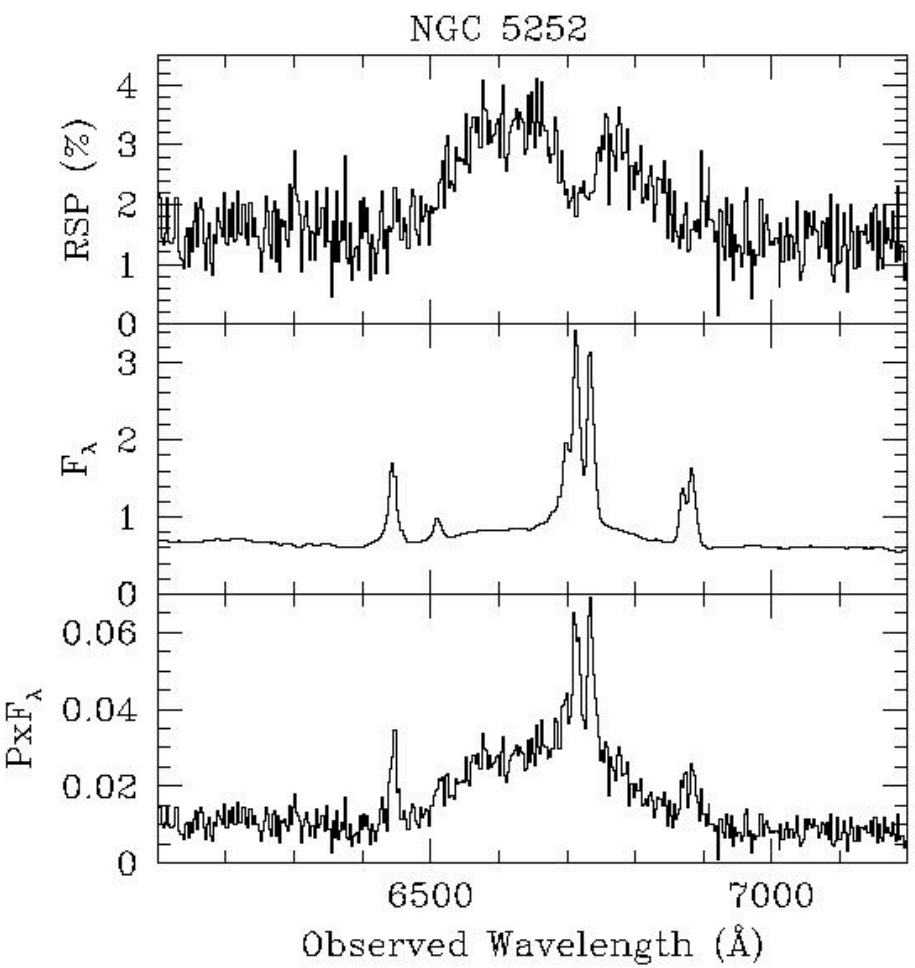

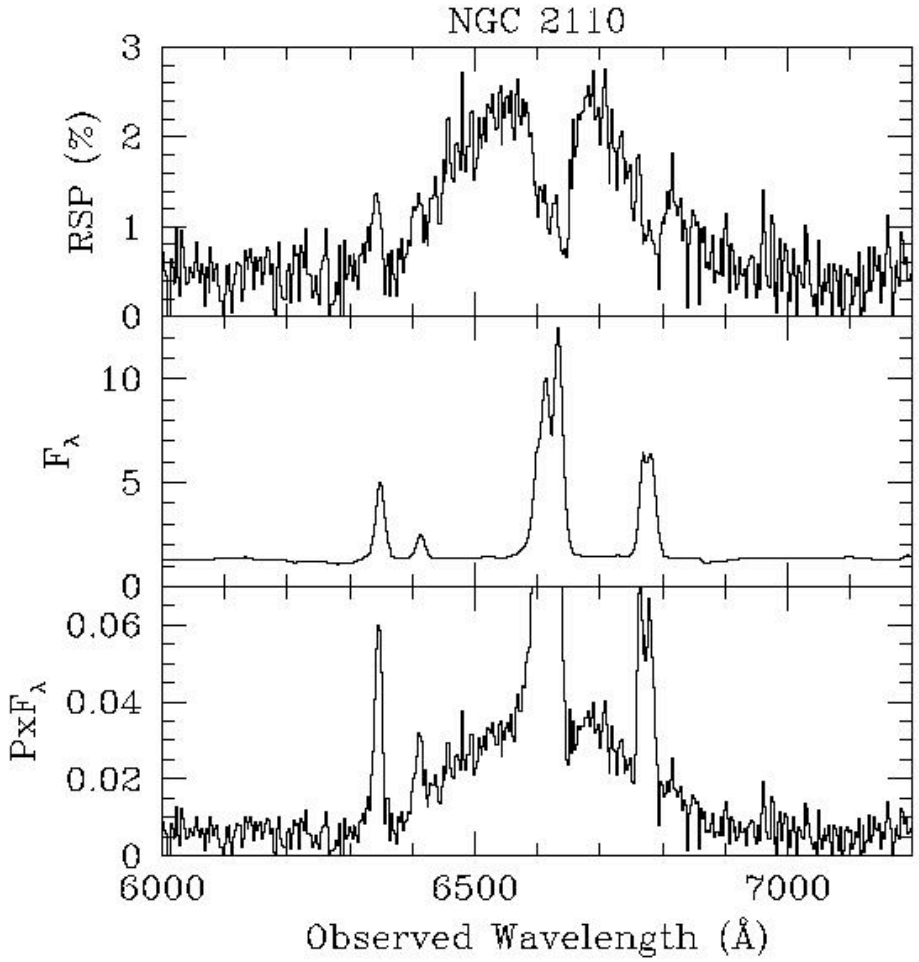

FWHM ~ 12,000 km/s

FWZI ~ 24,000 km/s

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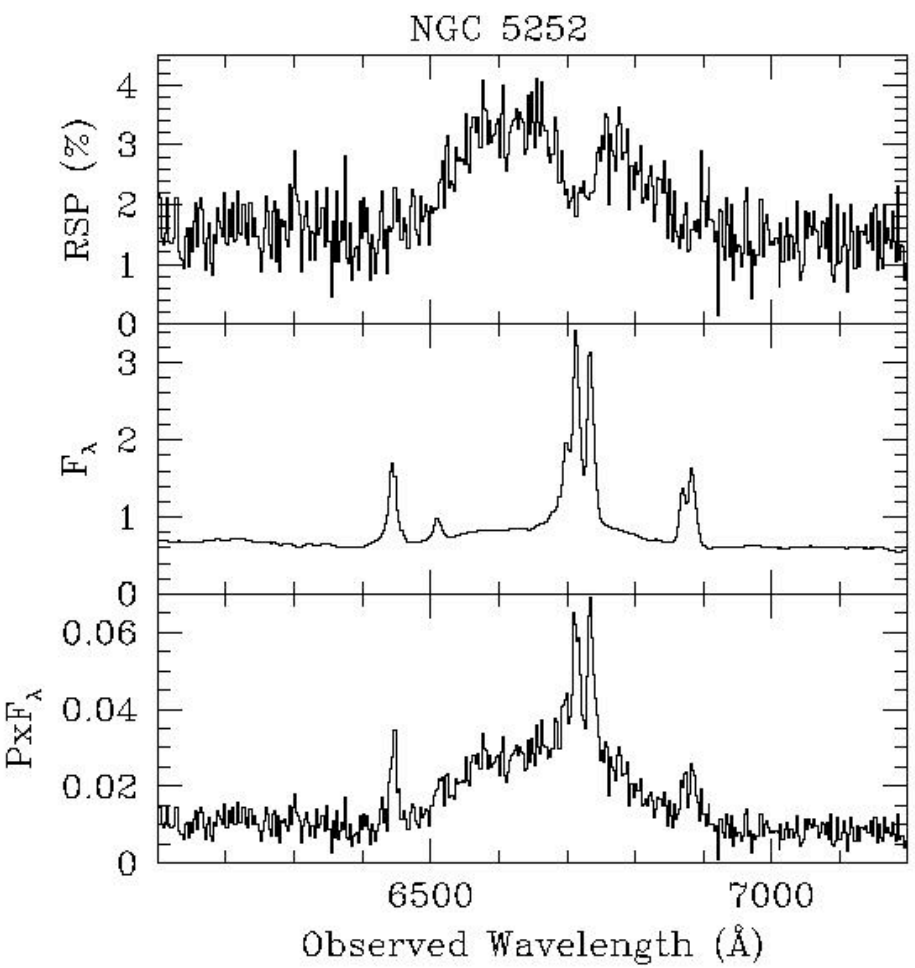

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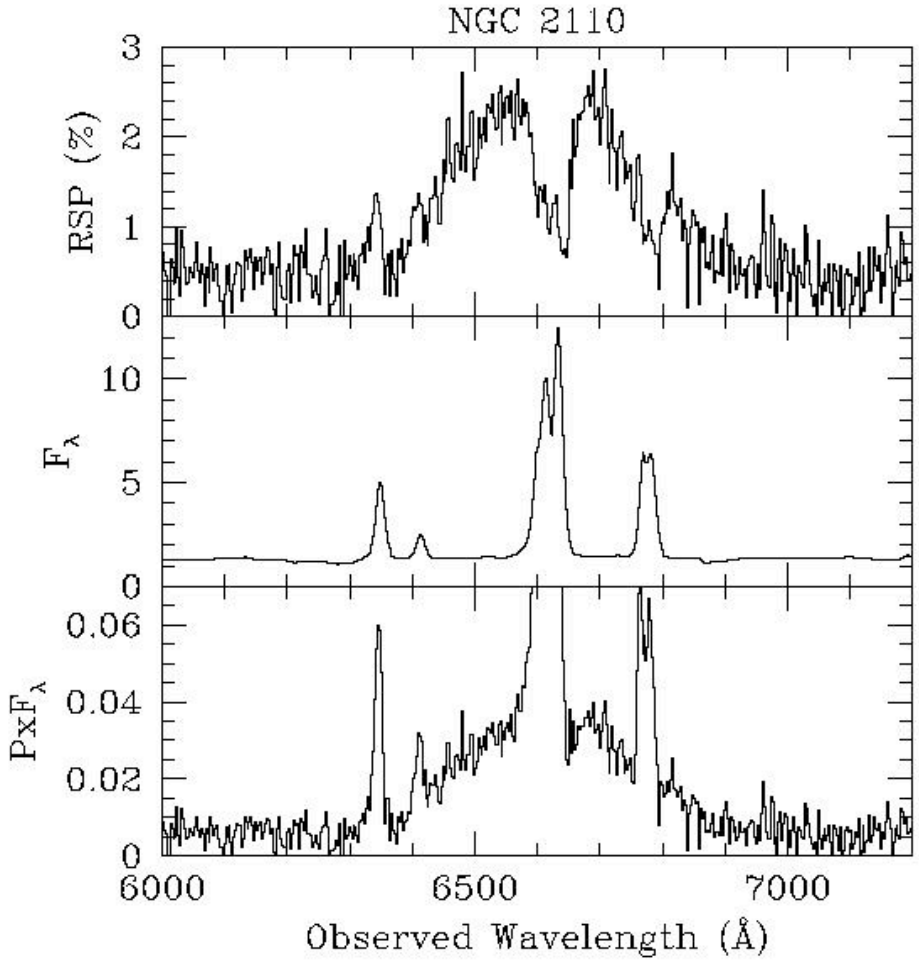
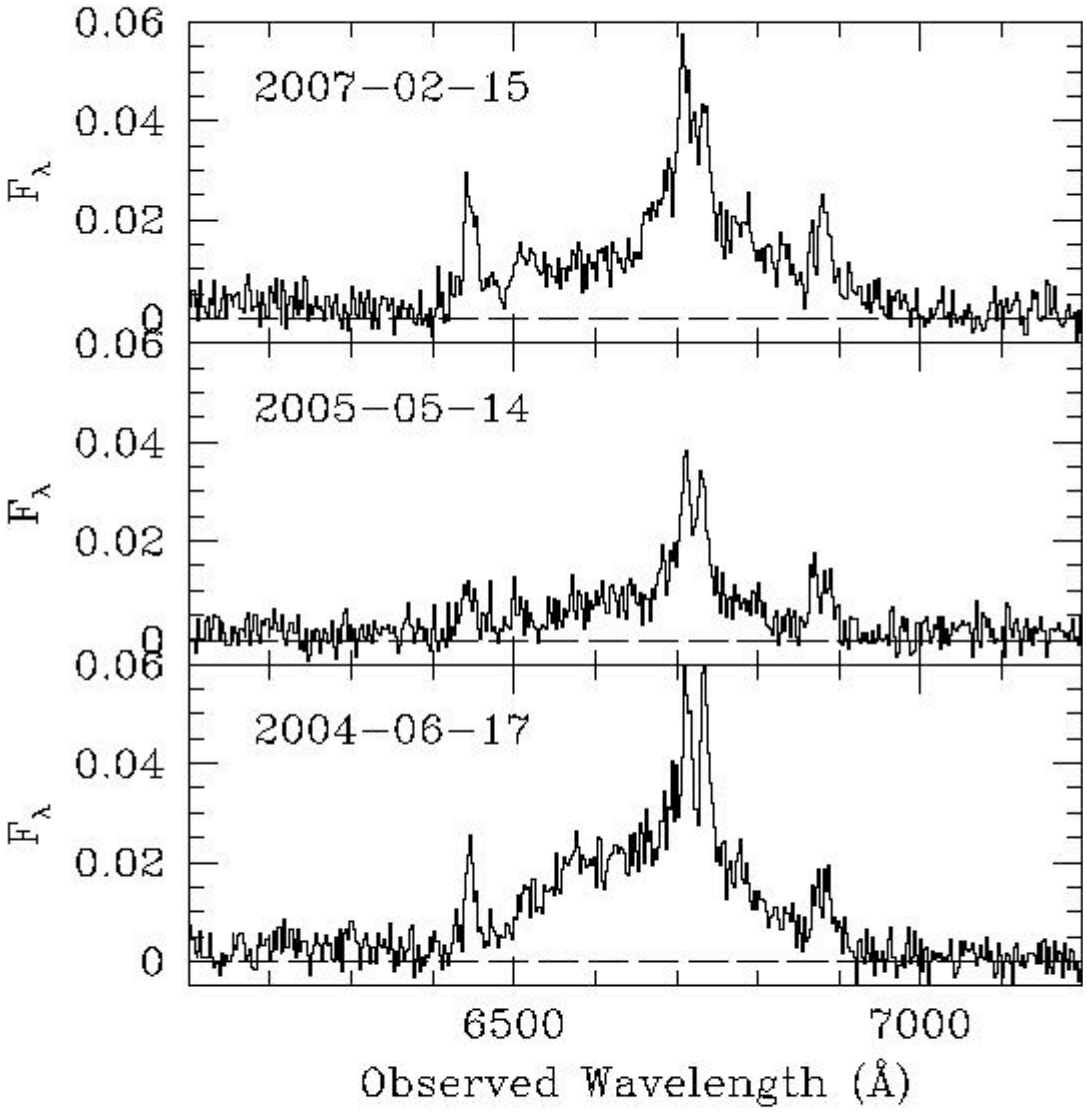


FWHM ~ 17,000 km/s

FWZI ~ 32,000 km/s

NGC 5252: Hidden Hα Profile Variability



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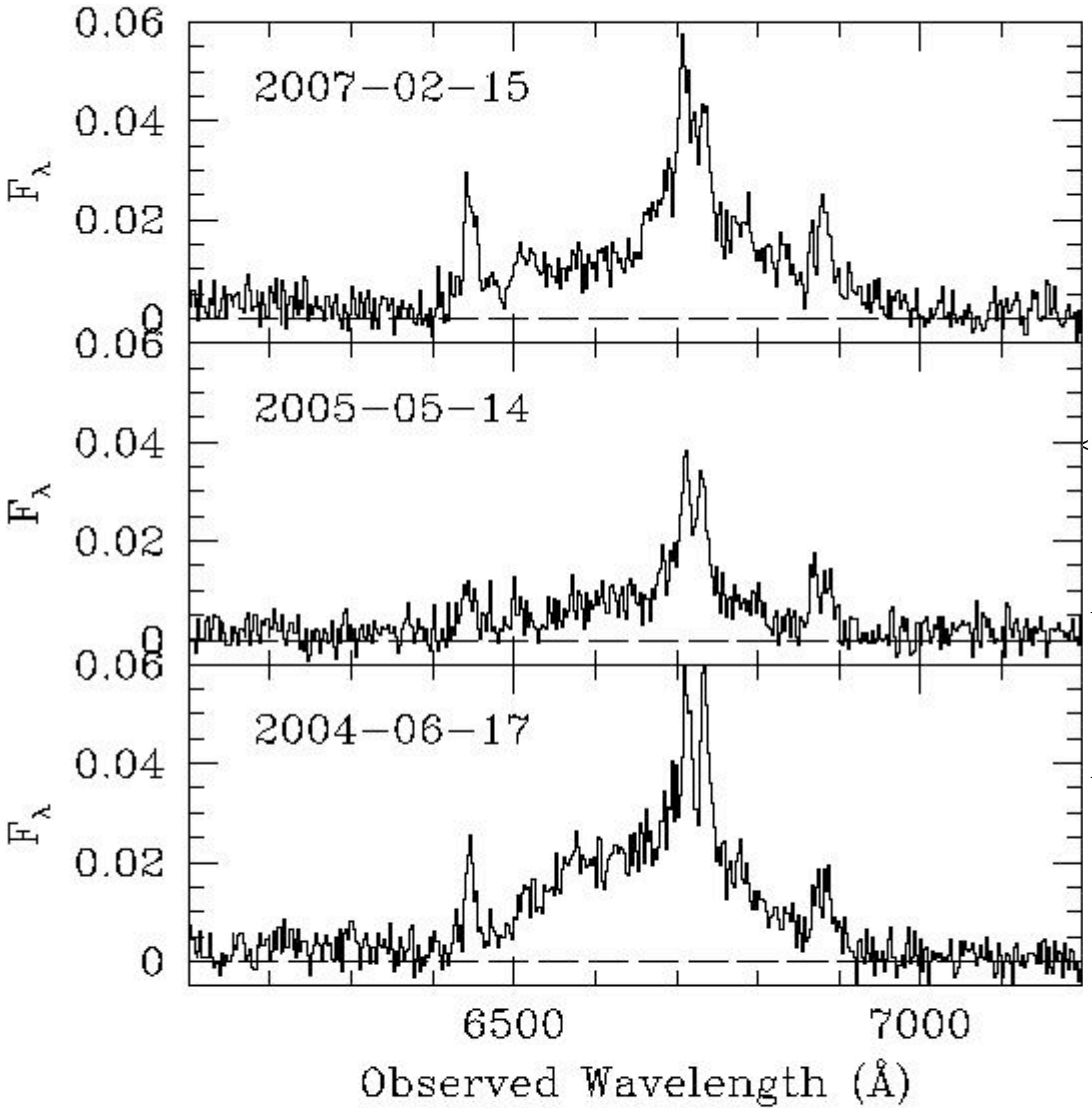
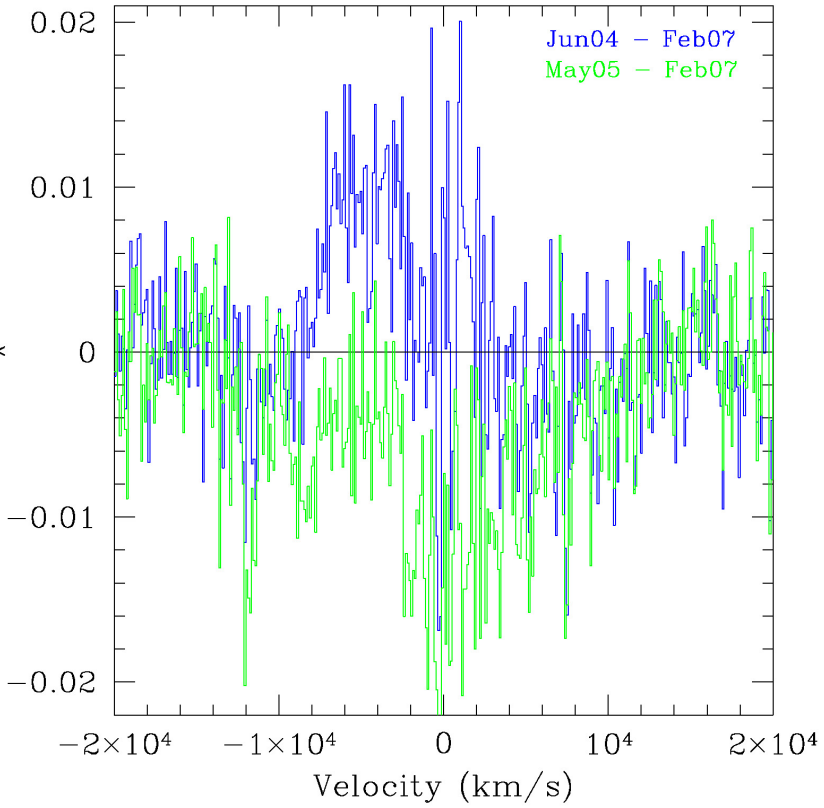
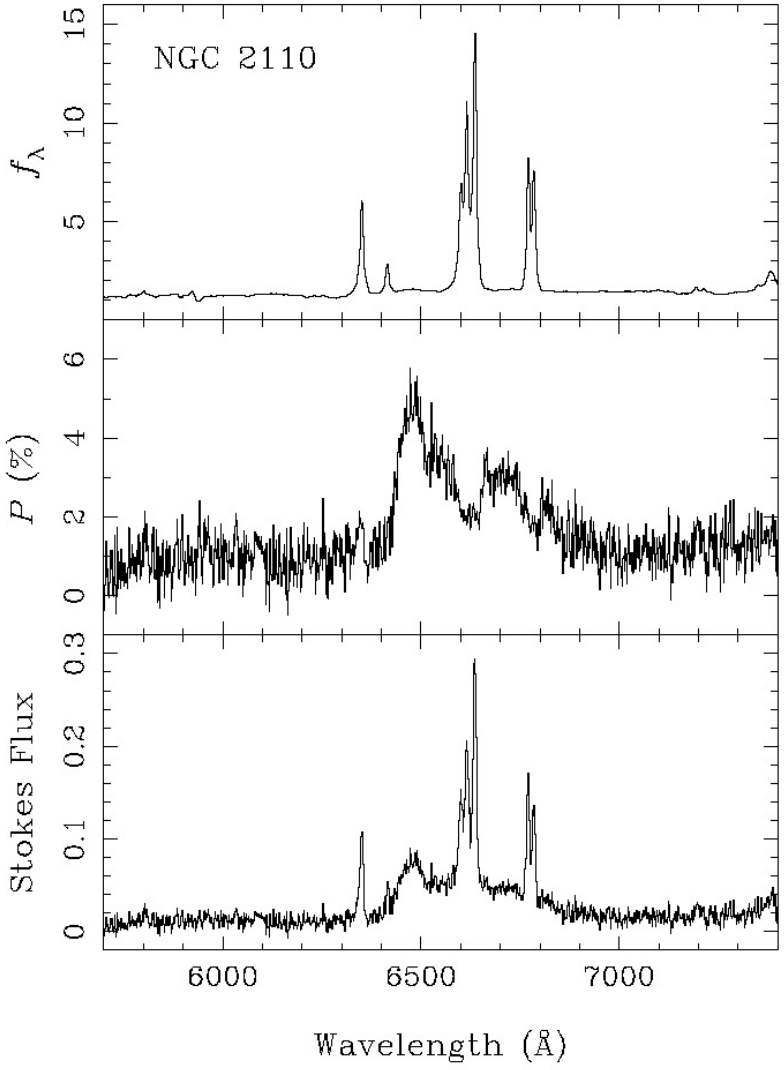


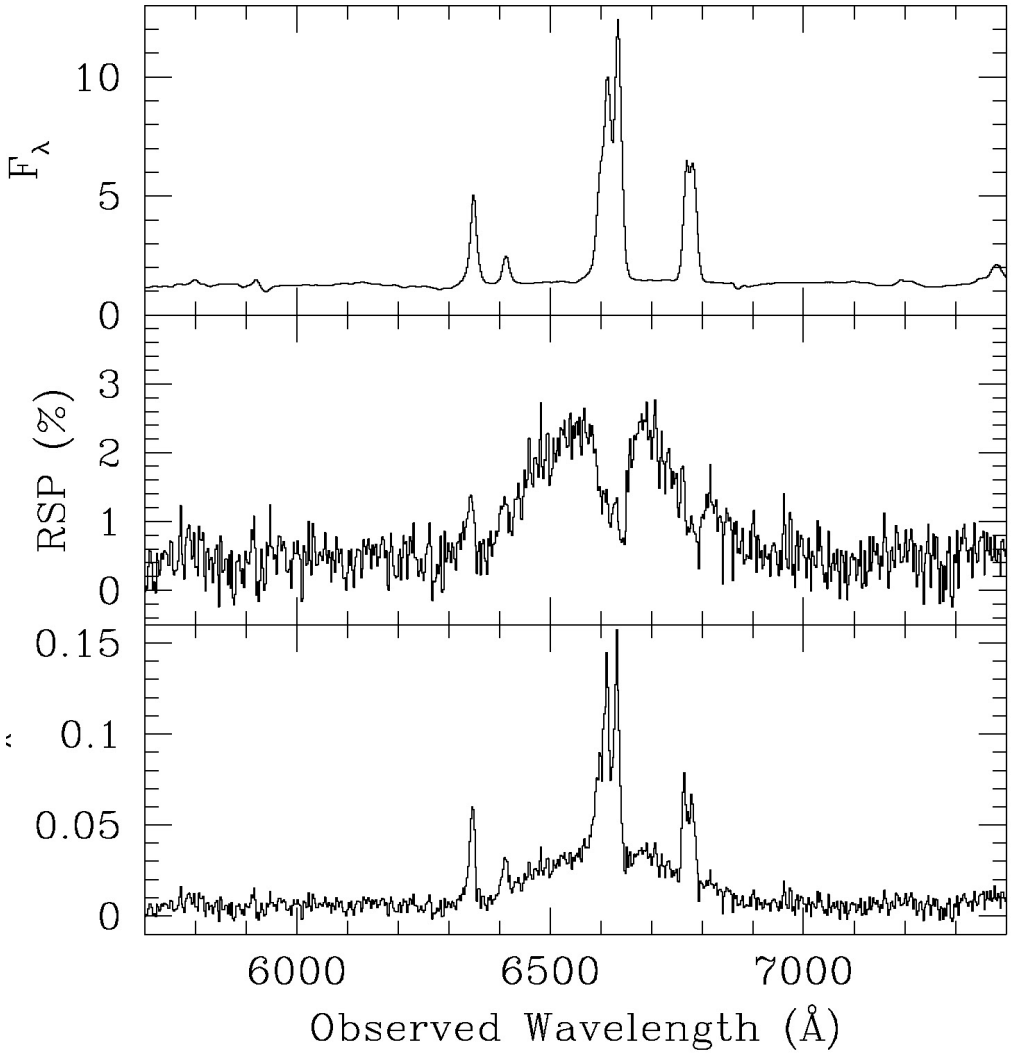


NGC 2110: Hidden Hα Profile Variability

Moran et al: ~2005



February 2007



Conclusions

- NGC 5252 and NGC 2110 are type-2 counterparts to the extremely broad-line "double peaked emitters"
  - Very strong low-ionization lines
  - Strong starlight continuum
  - Variability of double-peak Hα
  - NGC 5252 has been dubbed a "LINER undercover"
- Profile changes in the polarized, hidden, double-peaked Hα
  - Scatterers are very compact, with size scales of order ~ few light months
  - Scatterers see emitting disk over very narrow range of viewing angles
- Possible to detect very broad emission lines in polarized light

IRAS 09104+4109

- One of the most luminous Ultraluminous Infrared Galaxies (ULIRGs); z = 0.442
- Isolated, central cD galaxy in a rich cluster
- Hidden, misdirected quasar at center
  - Highly polarized ~ 20%
  - Broad Balmer lines in polarized flux spectra
  - Natural coronagraph: study quasar host environment

IRAS 09104+4109

IRAS 09104+4109

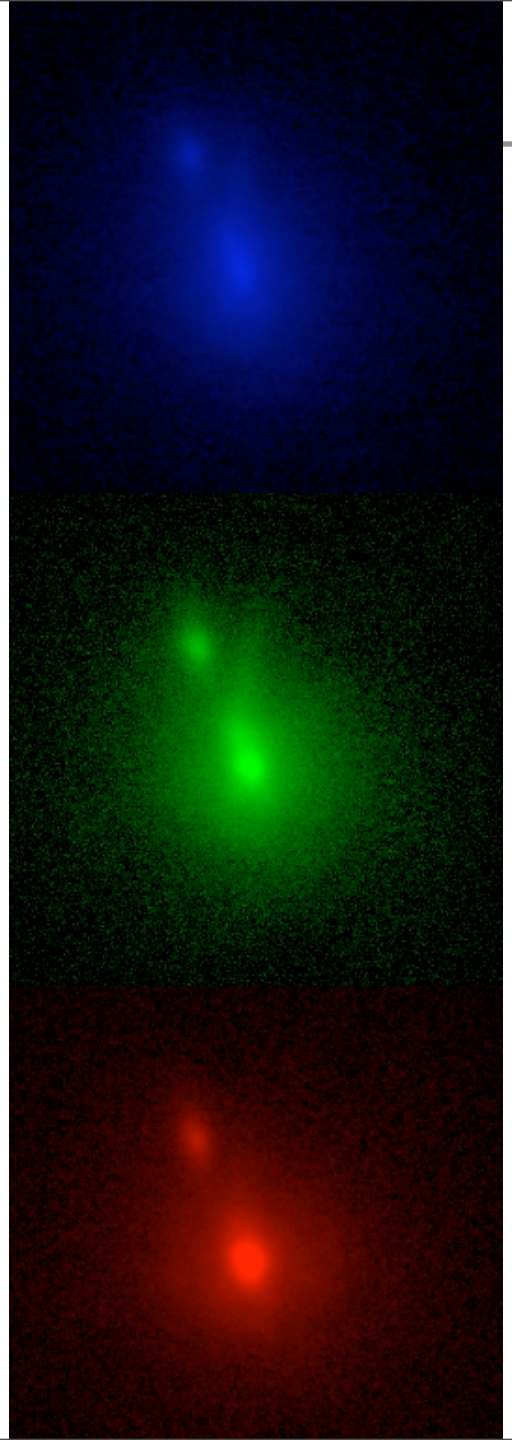
2006-11-17 LGS-AO

- NIRC2 narrow camera: 10 mas/pix
- J: 42 min, H: 30 min, Kp: 30 min
- Observing Conditions & Performance:
  - Seeing: 0.5" in K, photometric
  - Nucleus used as TT Ref (R ~18)
  - PSF: 0.075" FWHM
  - Strehl estimate: ~ 20%

J

H

K



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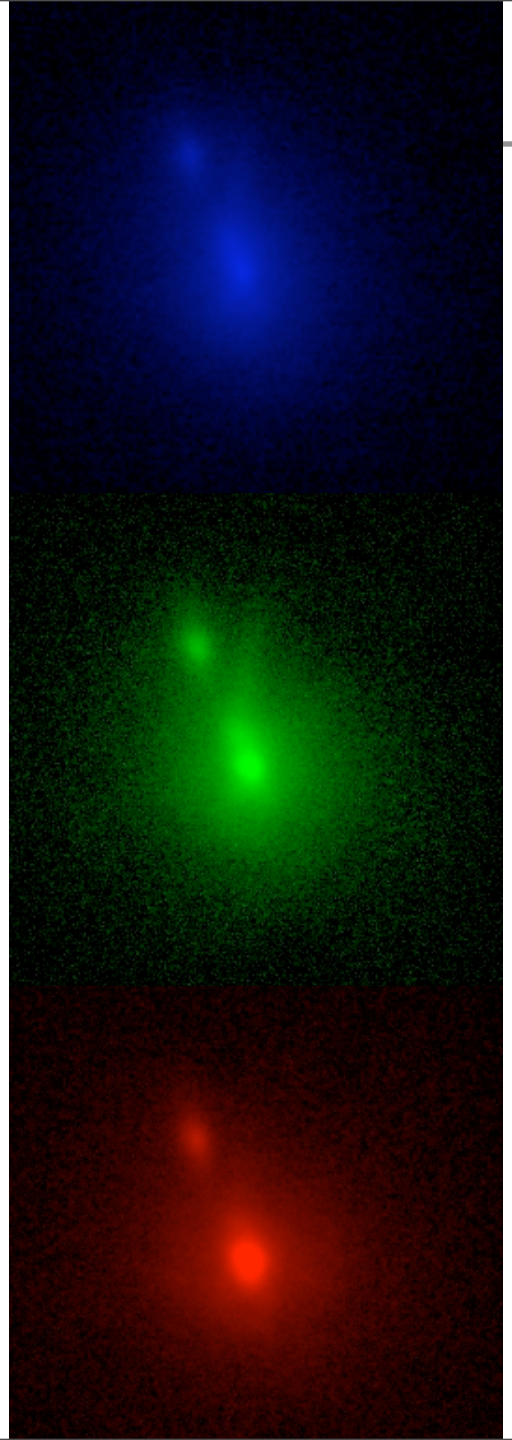
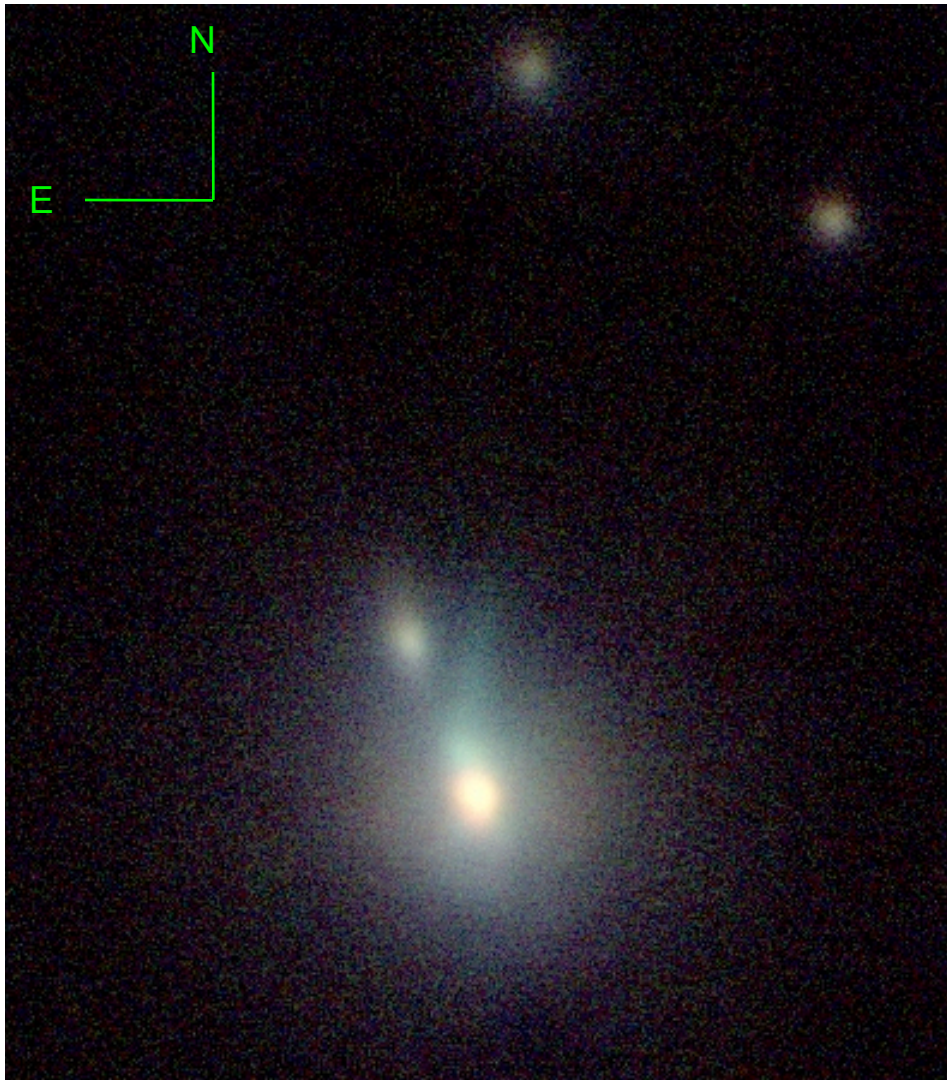


NIRC2

0.5”



HST, WFPC2

F622W, F814W

Keck, NIRC2

J, H, K

0.5”