Recent Results in Reverberation Mapping

Bradley M. Peterson, Gisella De Rosa,
and Gerard A. Kriss

"The Inner Regions of Quasars" 13 September 2014

Current Themes in RM
– Context –

- RM lags measured for ~50 sources
  - Nearly all at low *z*, mostly Balmer lines, bias toward high Eddington ratio objects
- High-fidelity velocity-resolved results are finally beginning to emerge

Pancoast, Horne (this session)

Current Themes in RM

1) More efficient RM
   - RM development necessarily carried out on small telescopes
     - Brighter, low-*z* objects, laboriously observed
   - To better characterize quasars, need to go to higher *z*
     - Fainter objects, but higher surface density
       - Multiobject spectroscopy, bigger telescopes
     - Need to calibrate rest-UV lines to establish *R*-*L*

R-L for C IV is probably an overstated concern. Microlensing provides independent confirmation

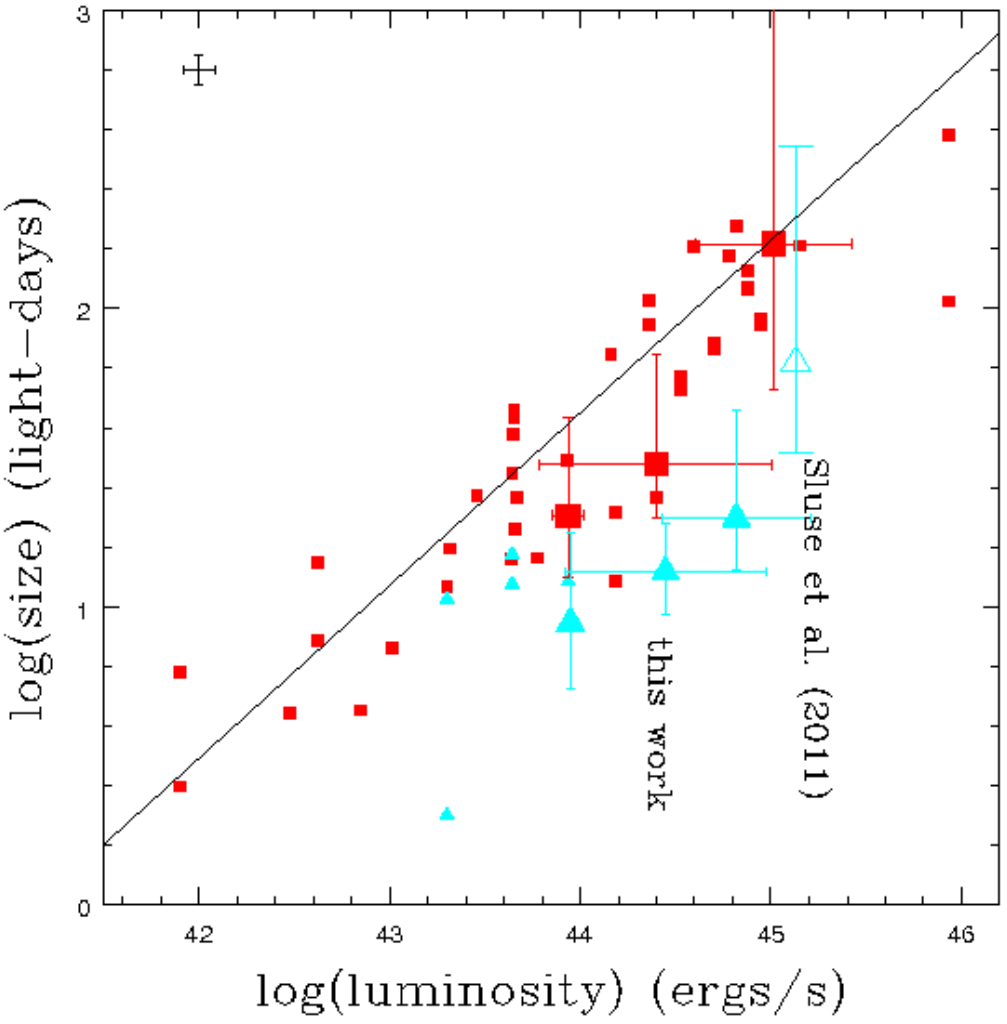
Lawrence (this session)

RM measurements, low ionization lines

Microlensing, Low-ionization lines

RM measurements, high-ionization lines

Microlensing, high-ionization lines



Guerras+ 2013, ApJ, 764:160

Current Themes in RM

2) “Better” RM

- Higher-quality data, better sampled, broader wavelength range
  - Probe quasar structure in more detail
  - Establish “ground truth” for lower-quality data
  - Establish limitations for more suboptimal data

    “How much information is lost by using the optical continuum as a surrogate for the ionizing continuum?”

AGN Space Telescope and Optical Reverberation Mapping Program (AGN STORM)

- Anchored by daily *HST* COS observations of NGC 5548 (Cycle 21)
  - 2014 February 2 through July 27
  - 170/179 observations successful, single 2-day gap
  - Spectra cover 1153 −1796 Å (Lyα through He II 1640)
- Target selection:
  - Luminosity suited to daily cadence and one *HST* cycle
  - Obtain a high *S/N* COS spectrum in one orbit
  - Well-characterized, “reliably” variable source
  - Relatively weak absorption in resonance lines

However, note Kriss talk (earlier today)

AGN STORM Supporting Observations

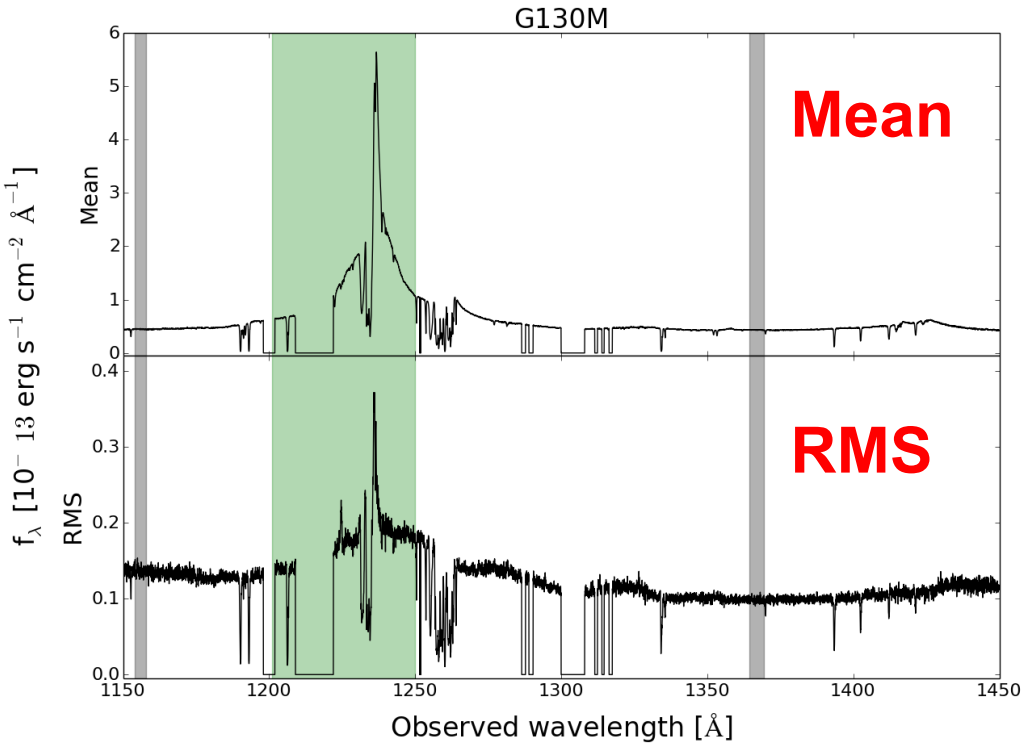
- *SWIFT*
  - Hard/soft X-rays, NUV/optical photometry
  - ~2 visits/day for 4 months (2/3 of *HST* program)
- *Chandra*
  - 4 visits, one every 60 days
- Ground-based spectroscopy

  >6 observatories, January through August
- Ground-based imaging

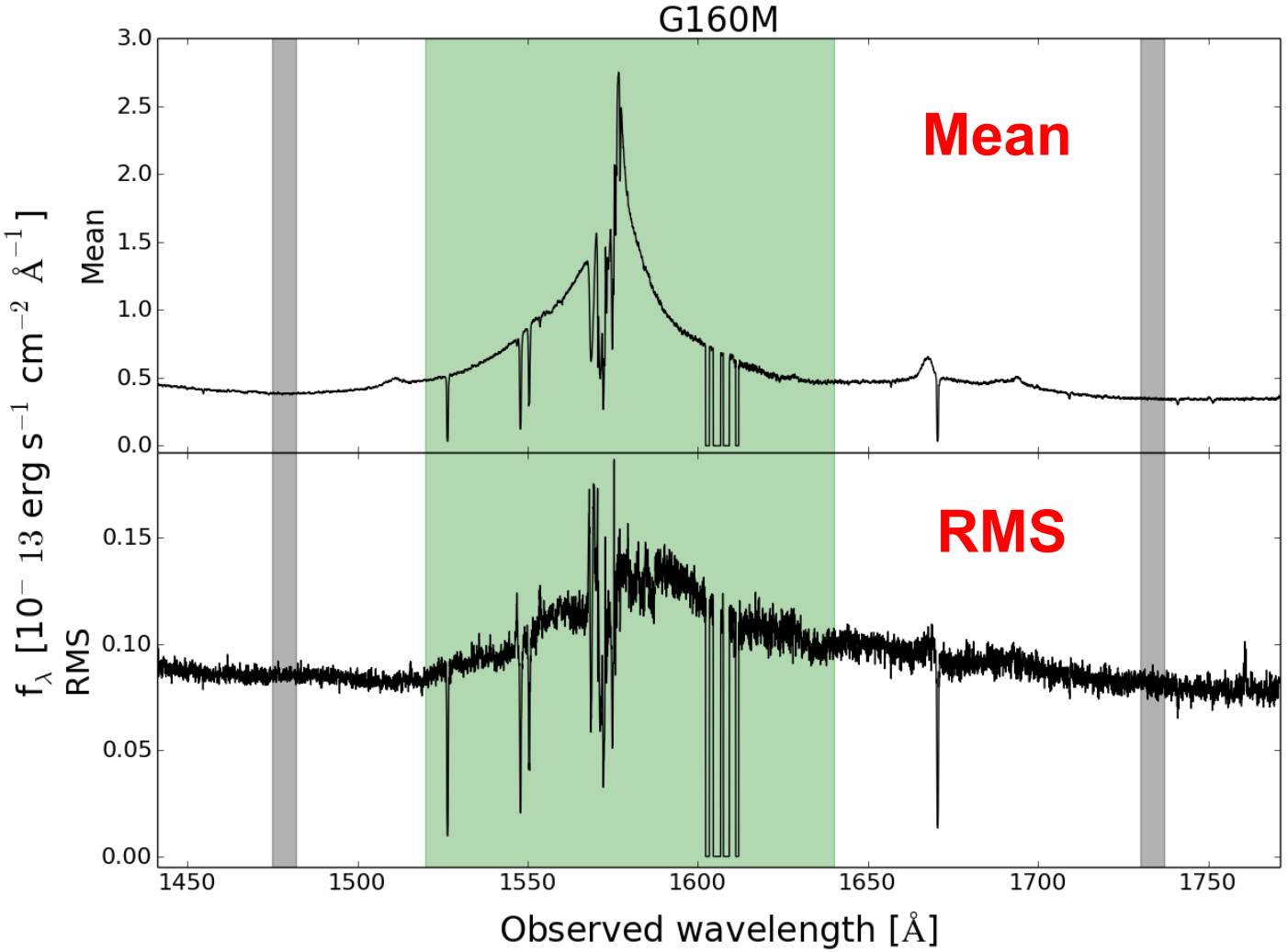
  >12 observatories, NUV through NIR

AGN STORM Early Results

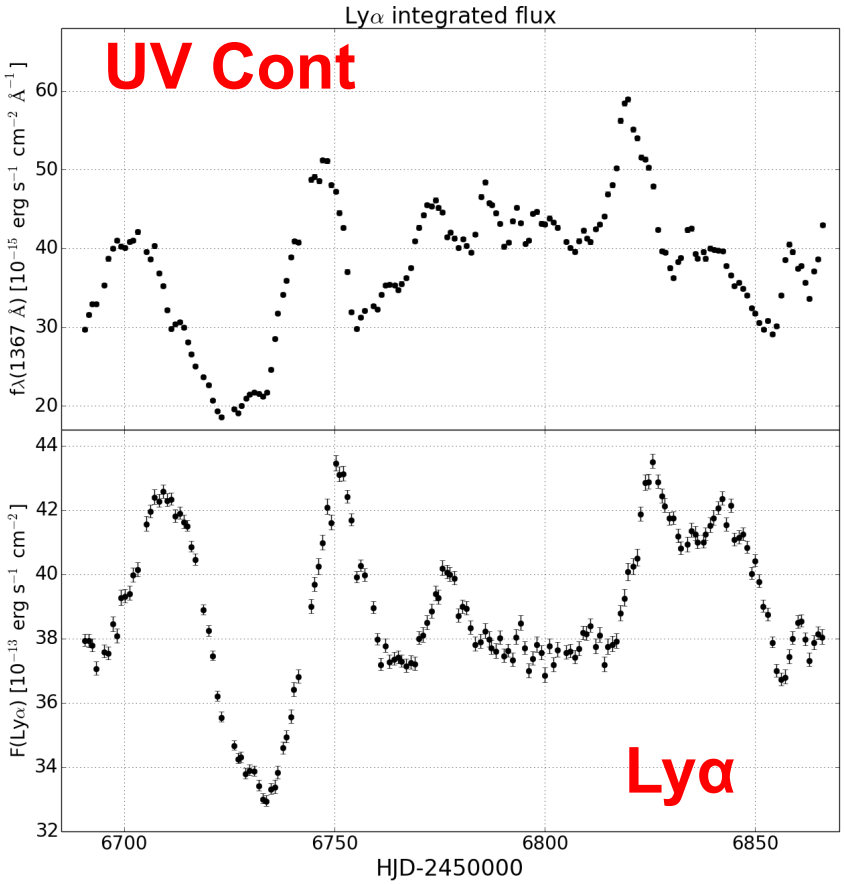
- Continuum window: gray band (1367 Å)
- Lyα total flux in green
  - Geocoronal lines and bad pixels masked
    - Bad pixels "move," depending on placement of spectrum on detector

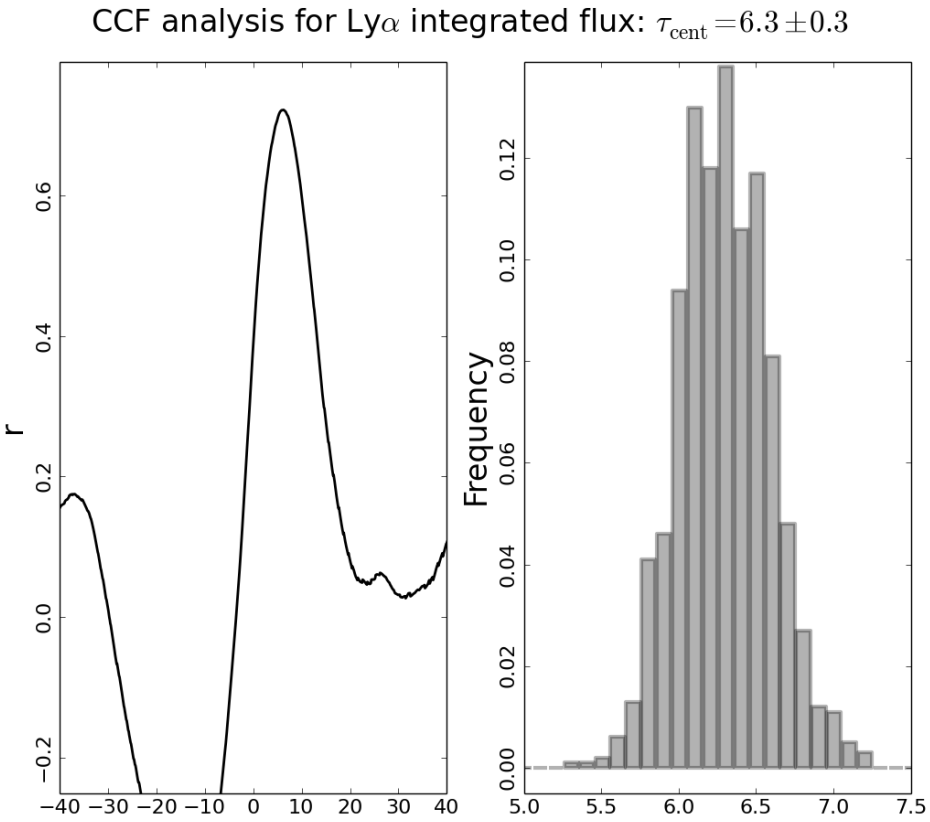


AGN STORM Early Results



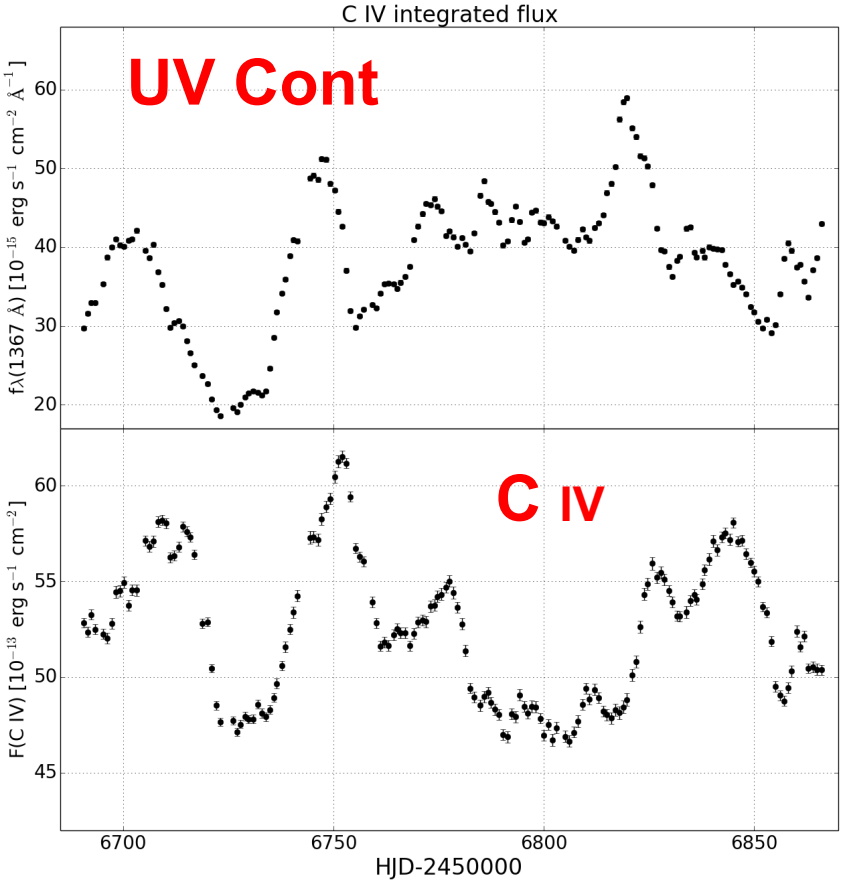
AGN STORM Early Results

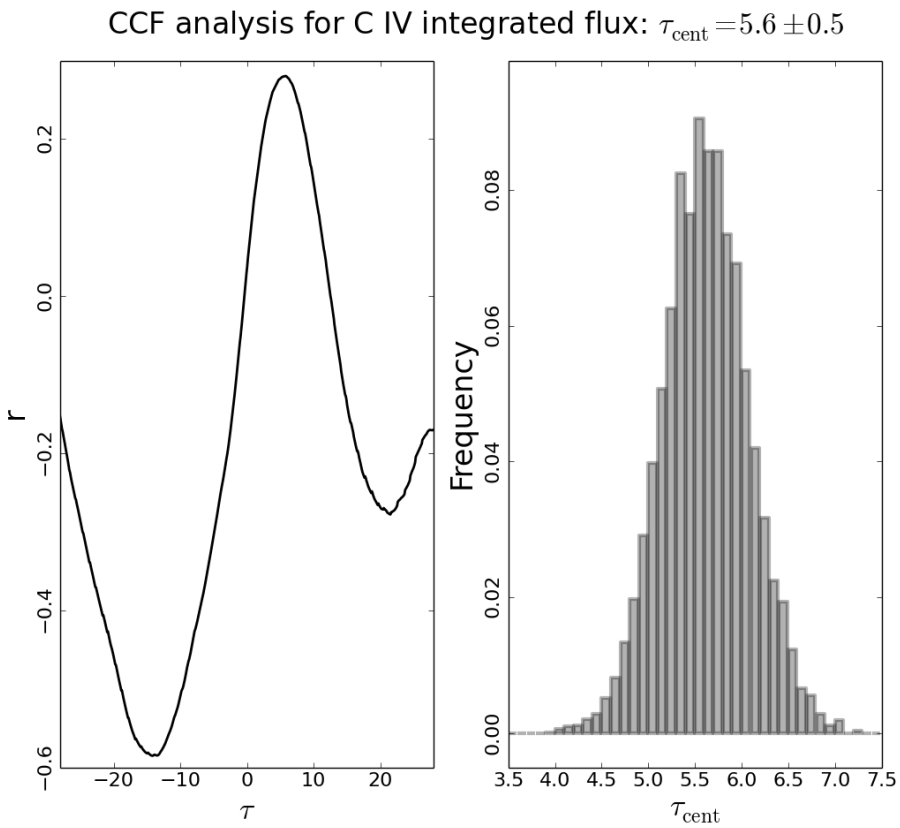




AGN STORM I – De Rosa et al., in prep.

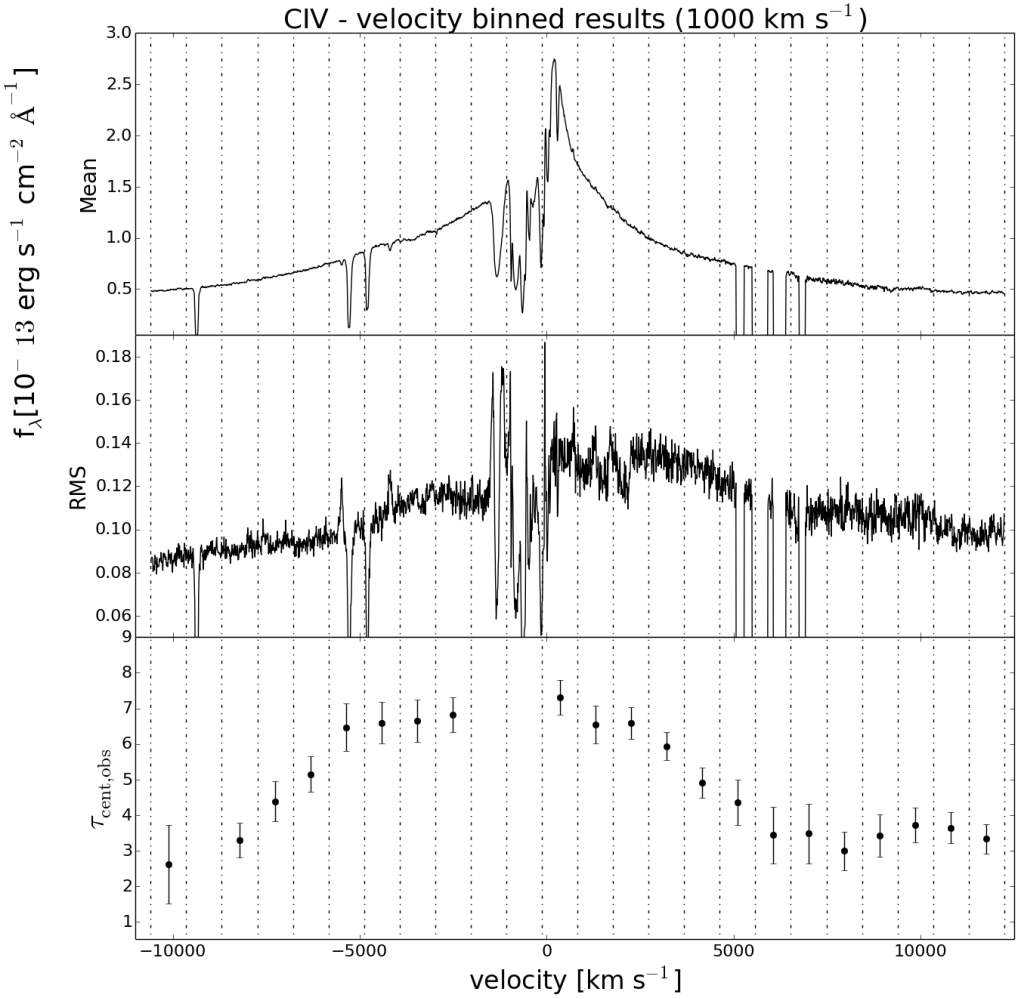
AGN STORM Early Results





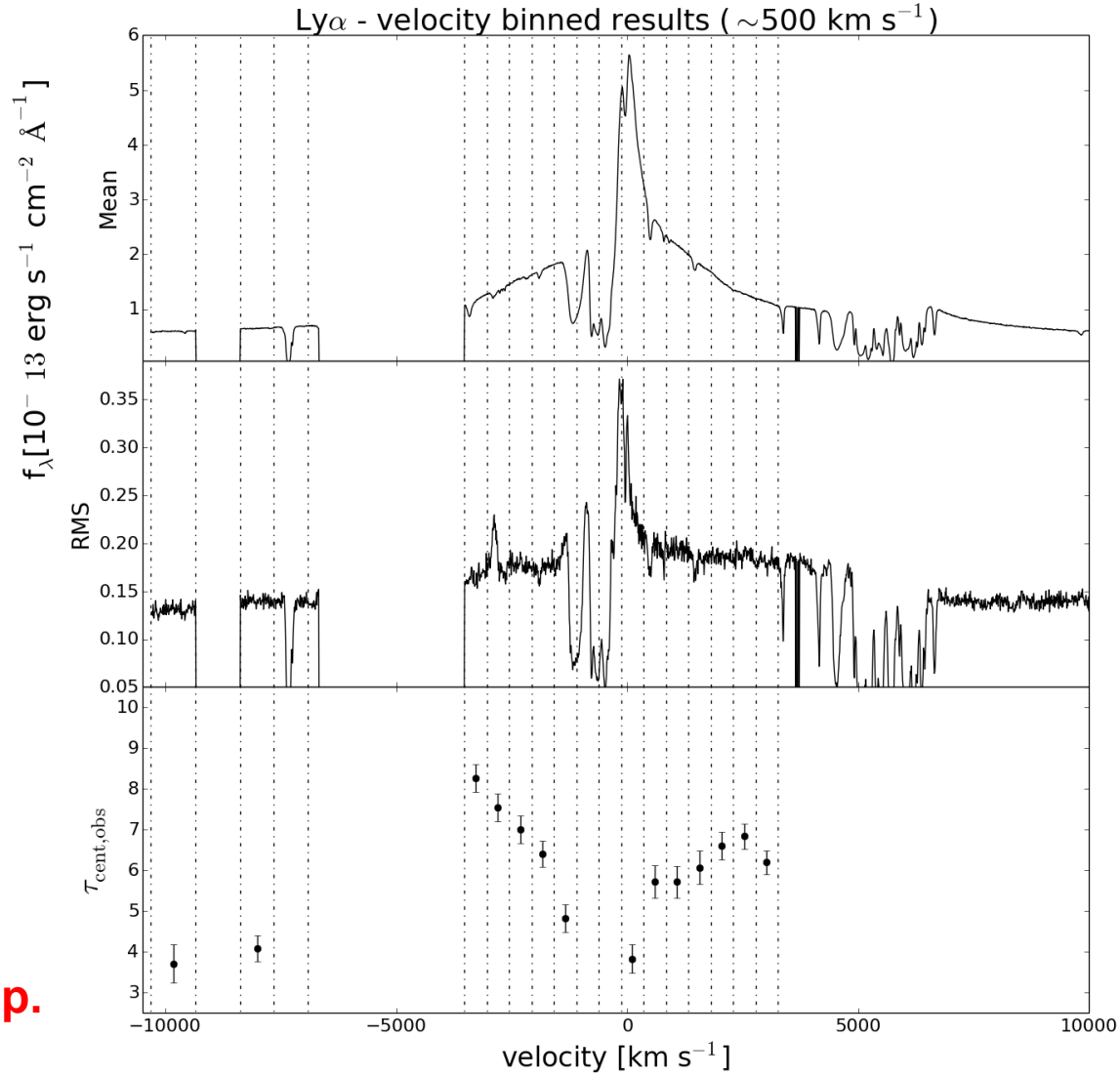
AGN STORM I – De Rosa et al., in prep.

AGN STORM – Early Results



AGN STORM I – De Rosa et al., in prep.

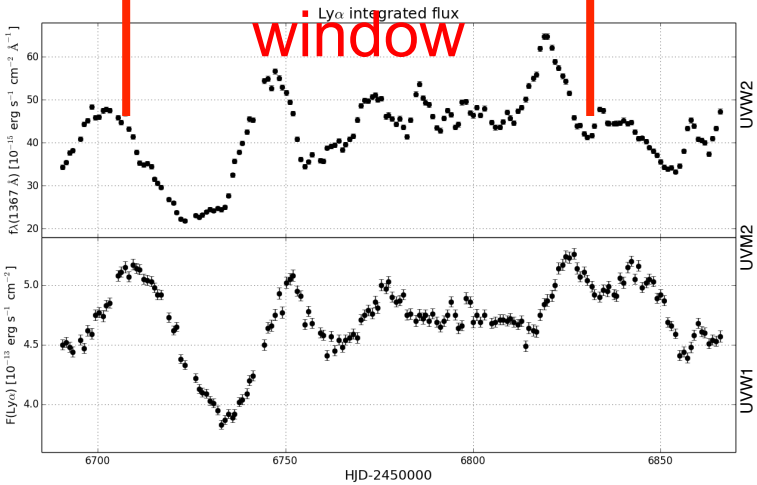
AGN STORM – Early Results



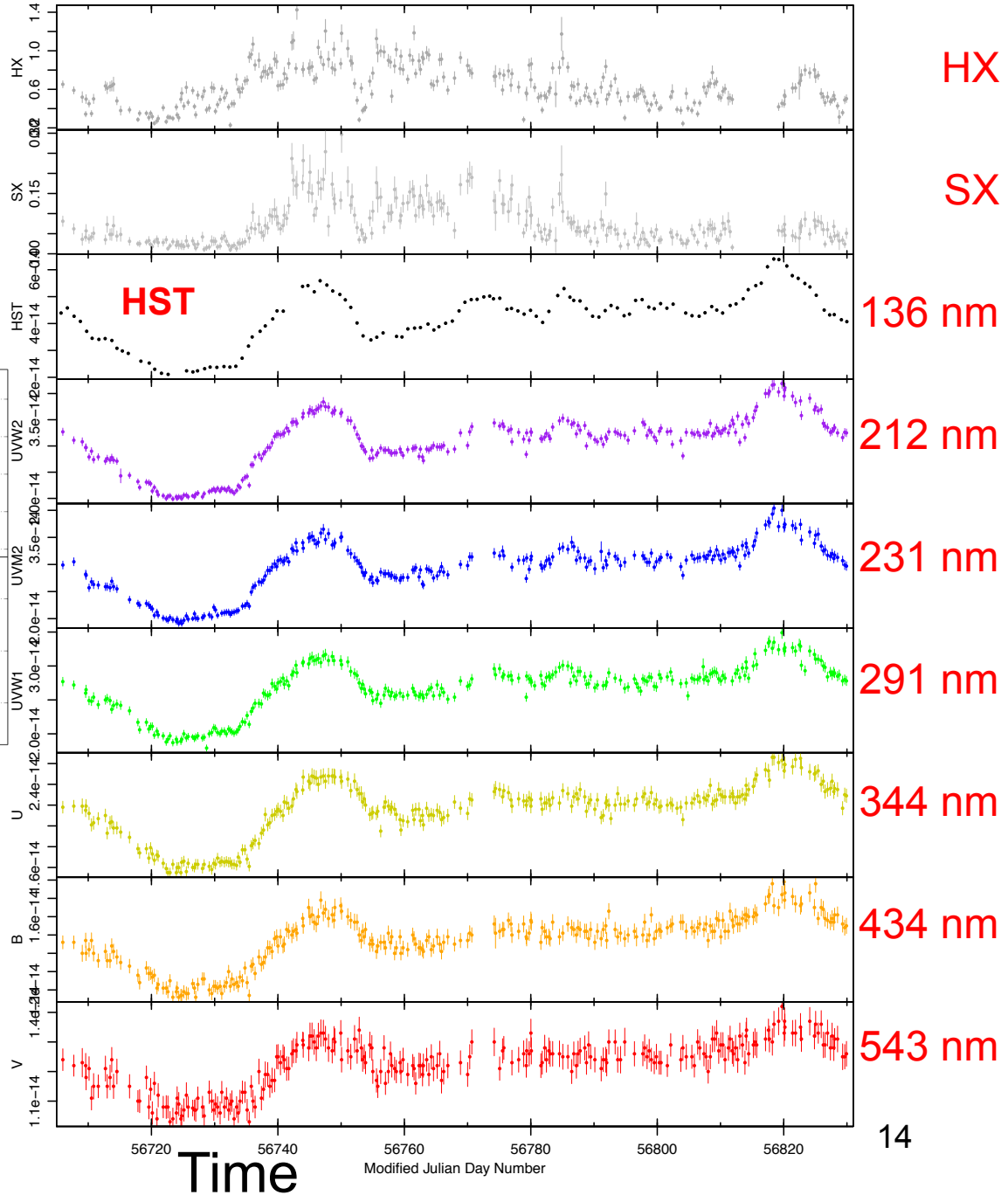
AGN STORM I –
De Rosa et al., in prep.

AGN STORM Early Results

SWIFT window



AGN STORM II – Edelson et al., in prep.

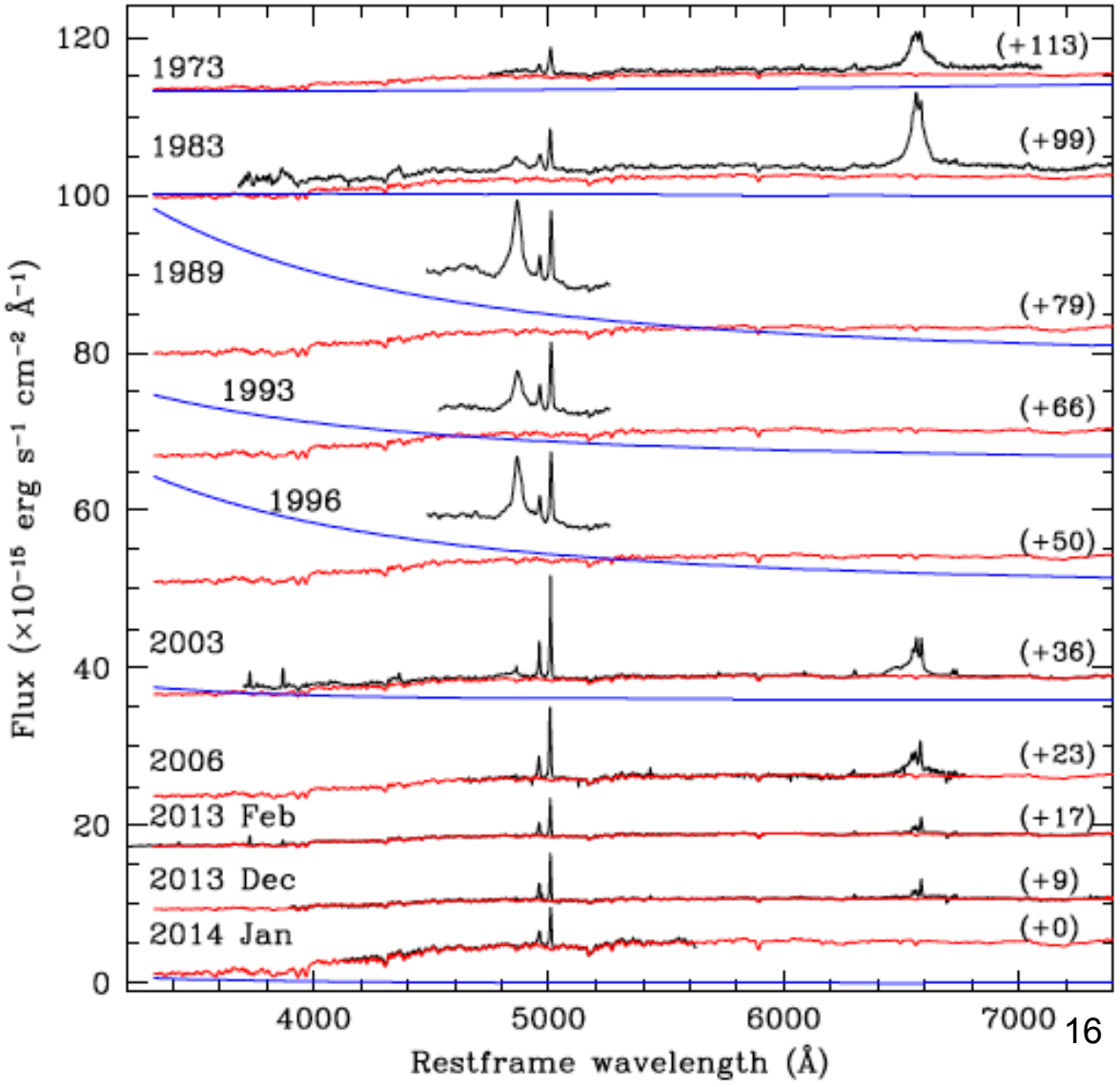


Long-Term Monitoring

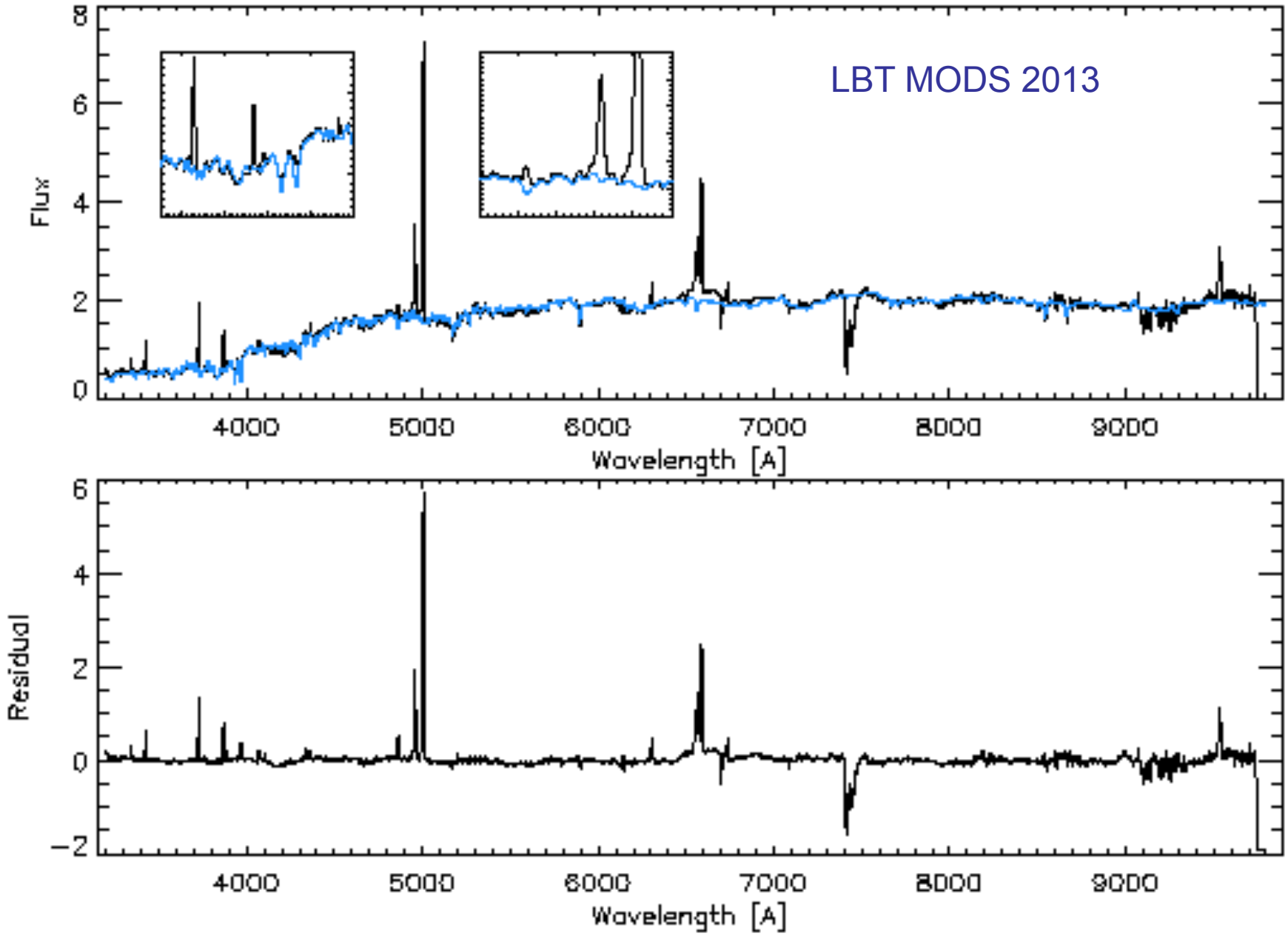
- Long-term monitoring has revealed some interesting results:
  - Fading of Mrk 590 by factor of ~100
    - Seyfert 1/2 or 2/1 transitions seen in the past
    - Event distinguished by time and wavelength coverage and magnitude of effect
  - Narrow-line flux variability in NGC 5548
    - On timescales of years, shorter than usually supposed

Kraemer knew something like this would happen!

Mrk 590: A Retired Seyfert 1?



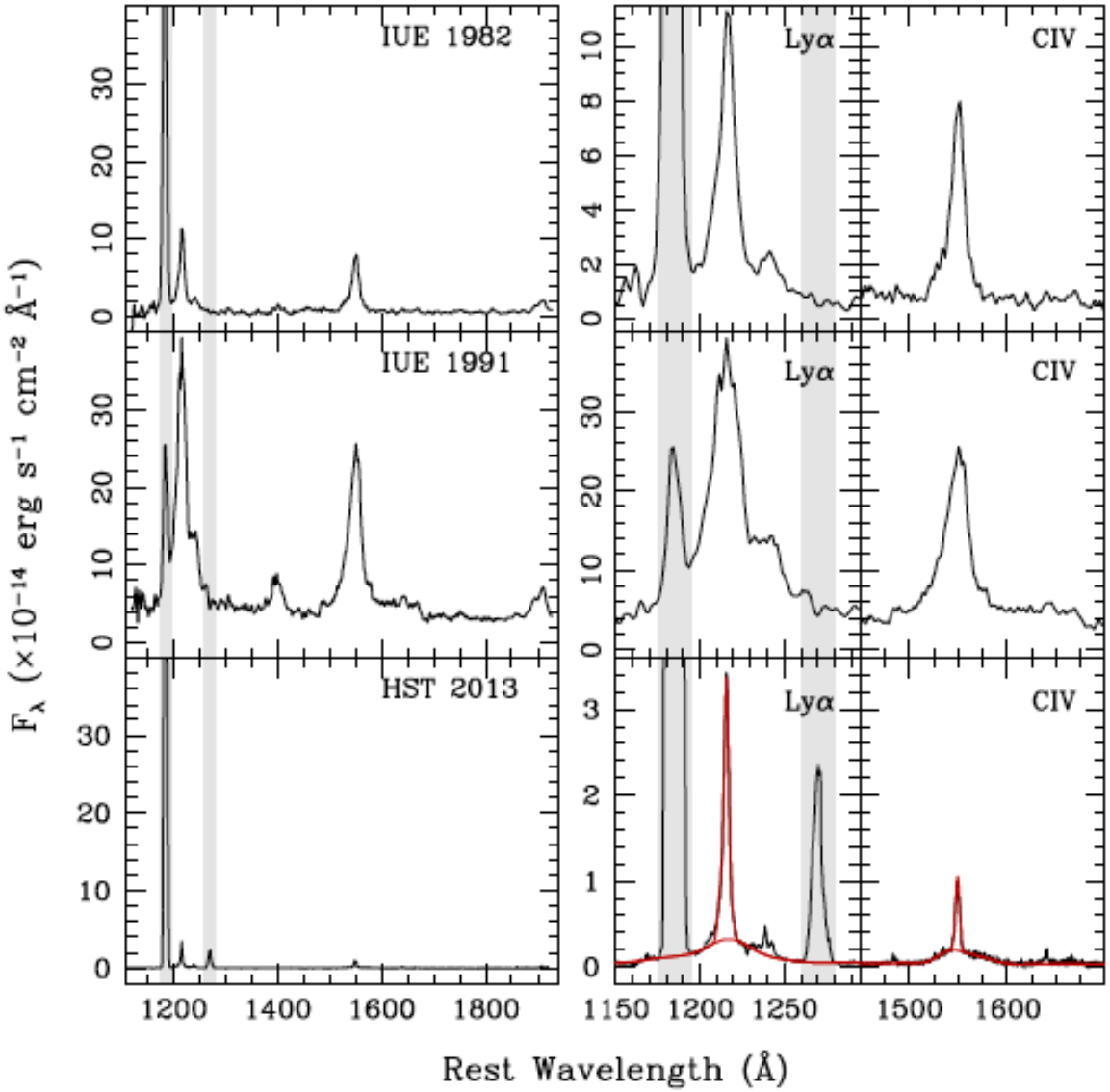
Denney et al. 2014


LBT MODS 2013
Flux
Wavelength [A]
Residual
Wavelength [A]

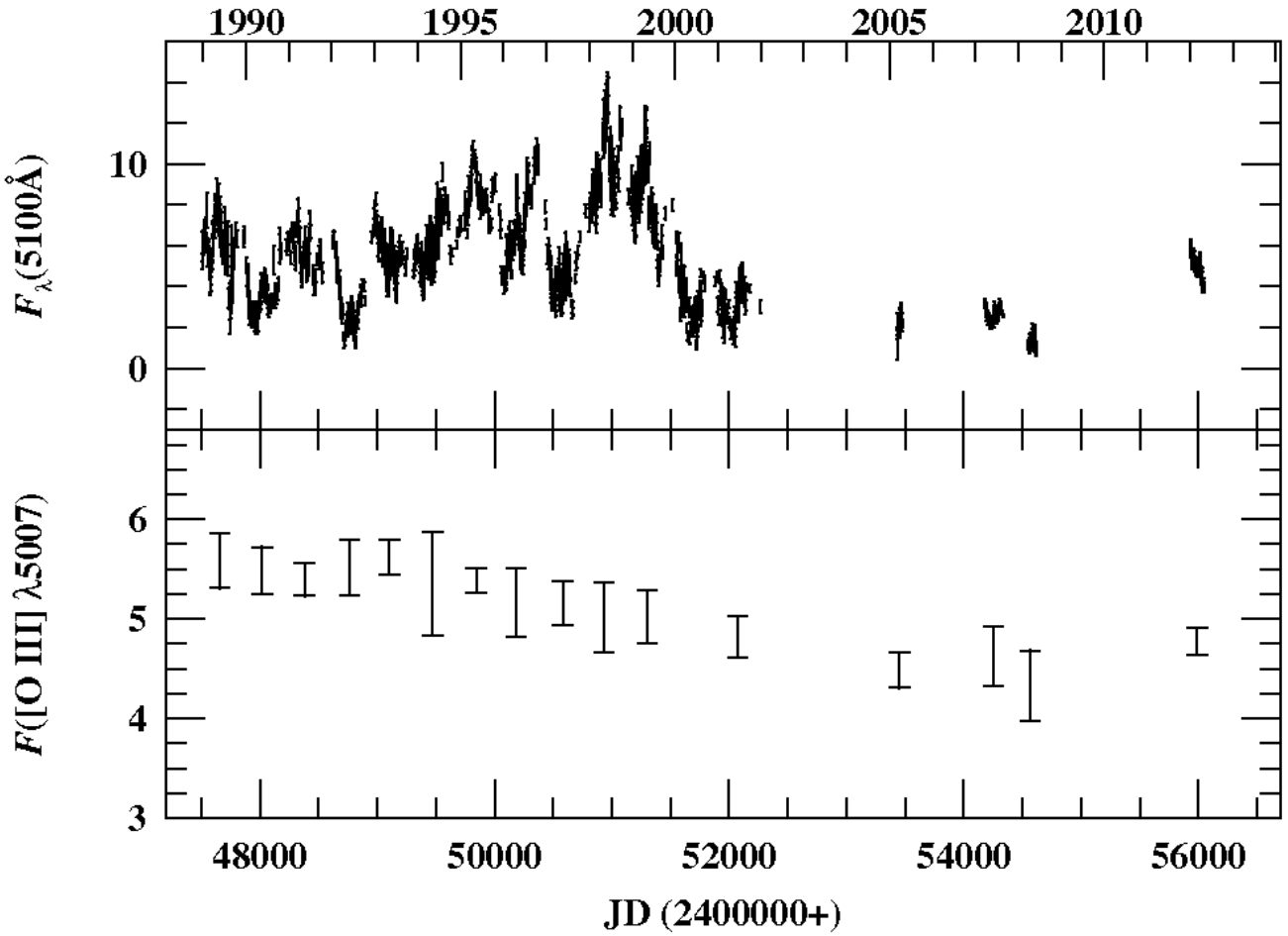
Mrk 590 UV Variability

UV spectrum obtained with *HST* COS DD time.

Unambiguous detection of UV narrow lines in a (former?) Seyfert 1 spectrum.



Narrow Emission-Line Variability in NGC 5548



Peterson+ 2013 ApJ, 779:109

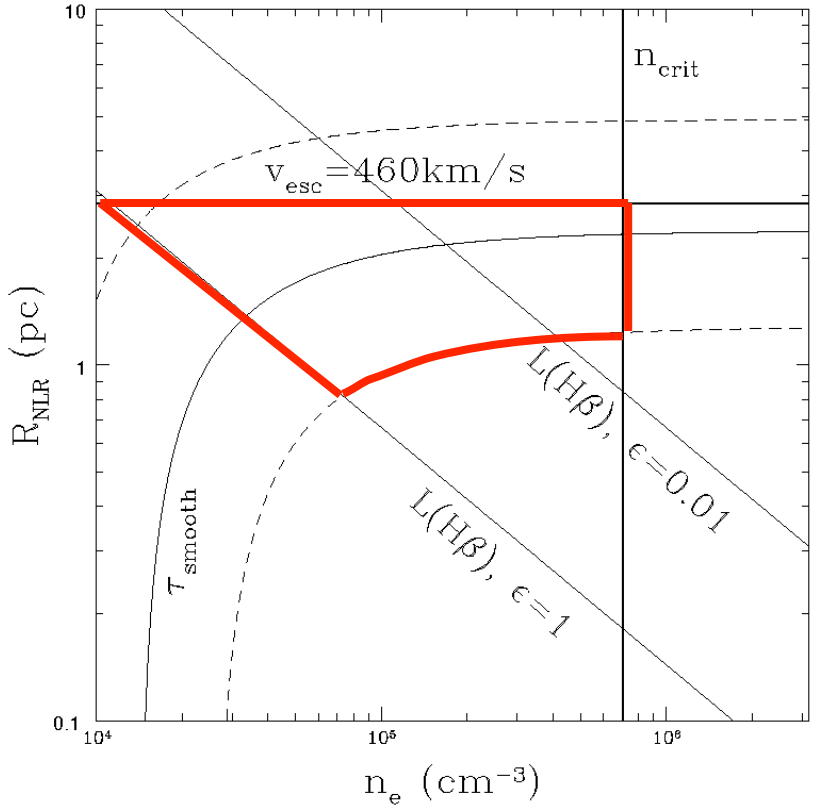
Narrow Emission-Line Variability in NGC 5548

$$\tau_{\rm smooth} = \left(\frac{2R_{\rm NLR}}{c} \right) + \left(\frac{1}{n_e \alpha_{\rm B}} \right)$$

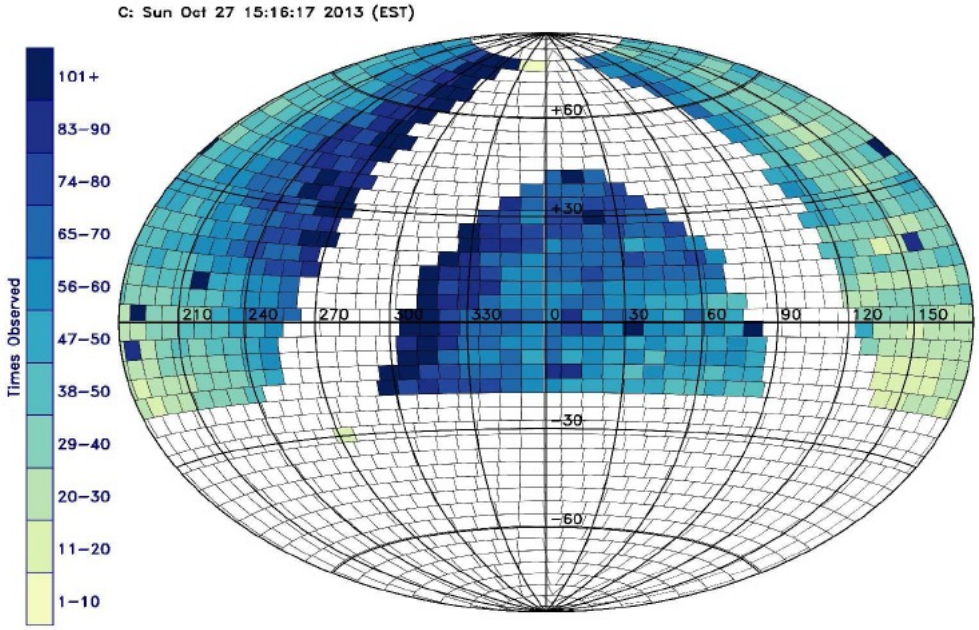
Light-travel time

Recombination timescale

- Size of narrow-line region constrained to 1-3 pc
- Density ~ 10^5 cm^{-3}
- Second credible detection of [O III] variability (3C 390.3 by Zheng+ 1995), but first to measure $R_{\rm NLR}$



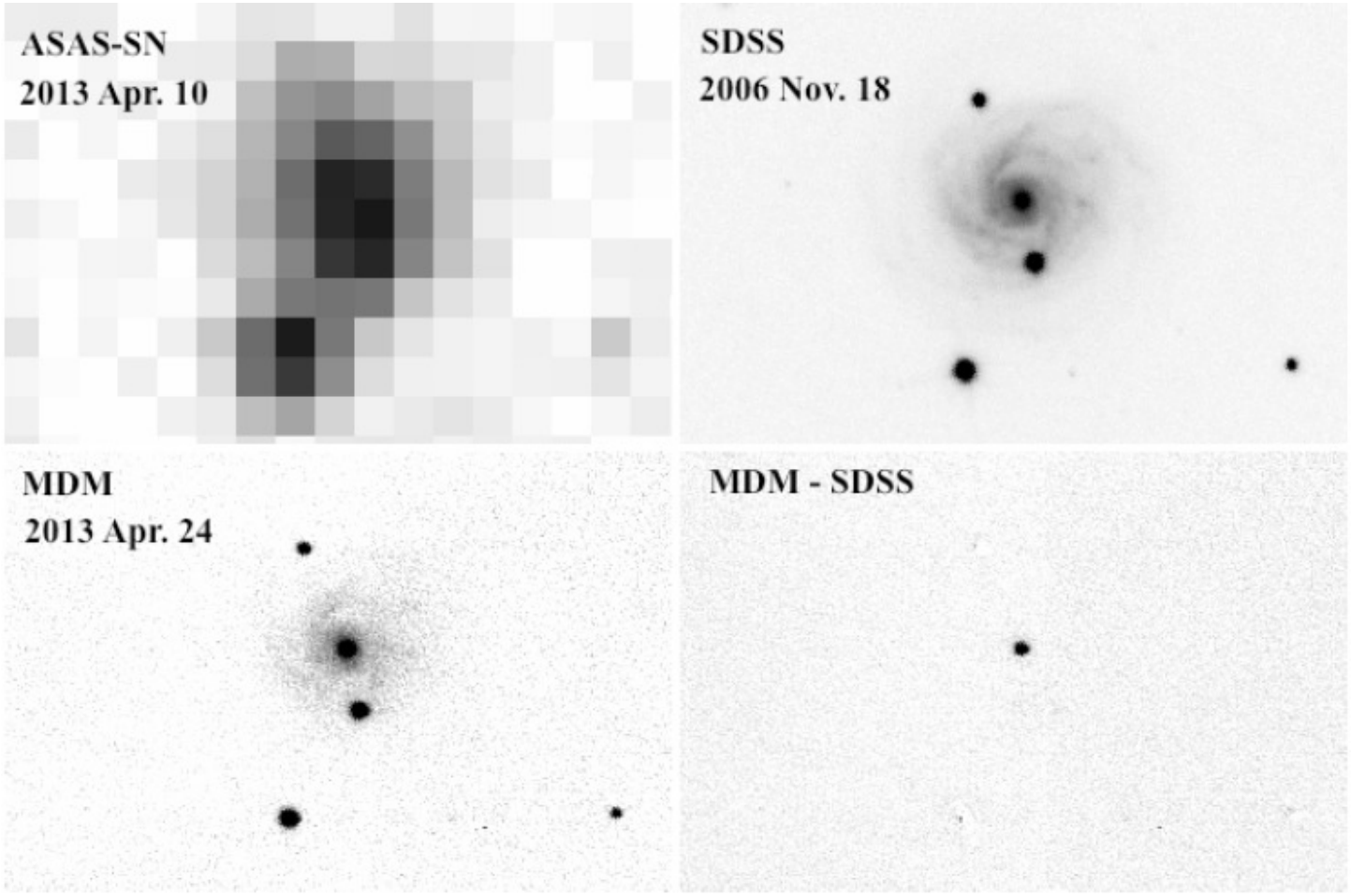
Scanning the Sky with the All-Sky Automated Survey for Supernovae (ASAS-SN)

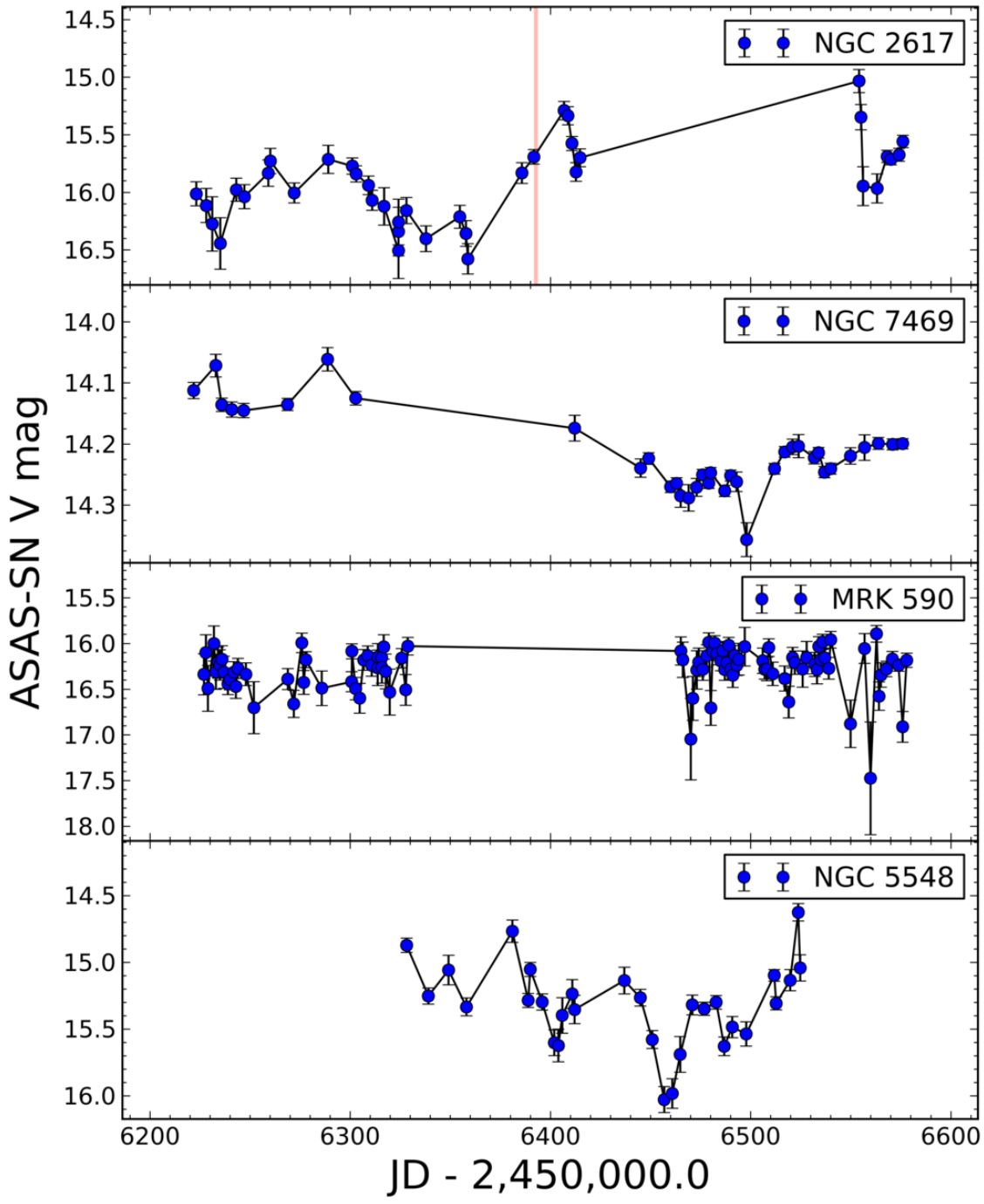


Four 14 cm telescopes.
$4.5^{o} \times 4.5^{o}$ FOV

ASAS SN

NGC 2617





ASAS-SN AGN light curves