Variability of mini-BAL and BAL outflows in Quasars

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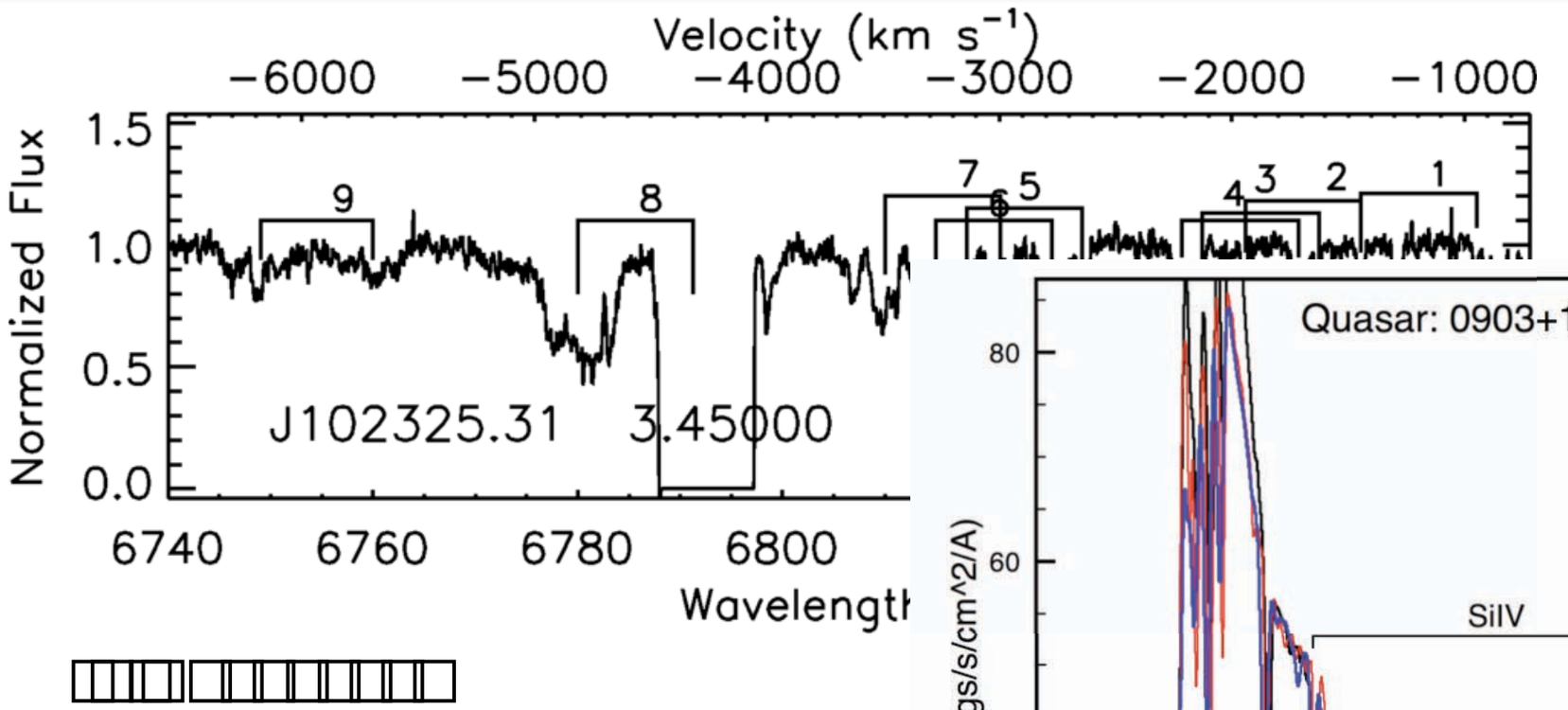
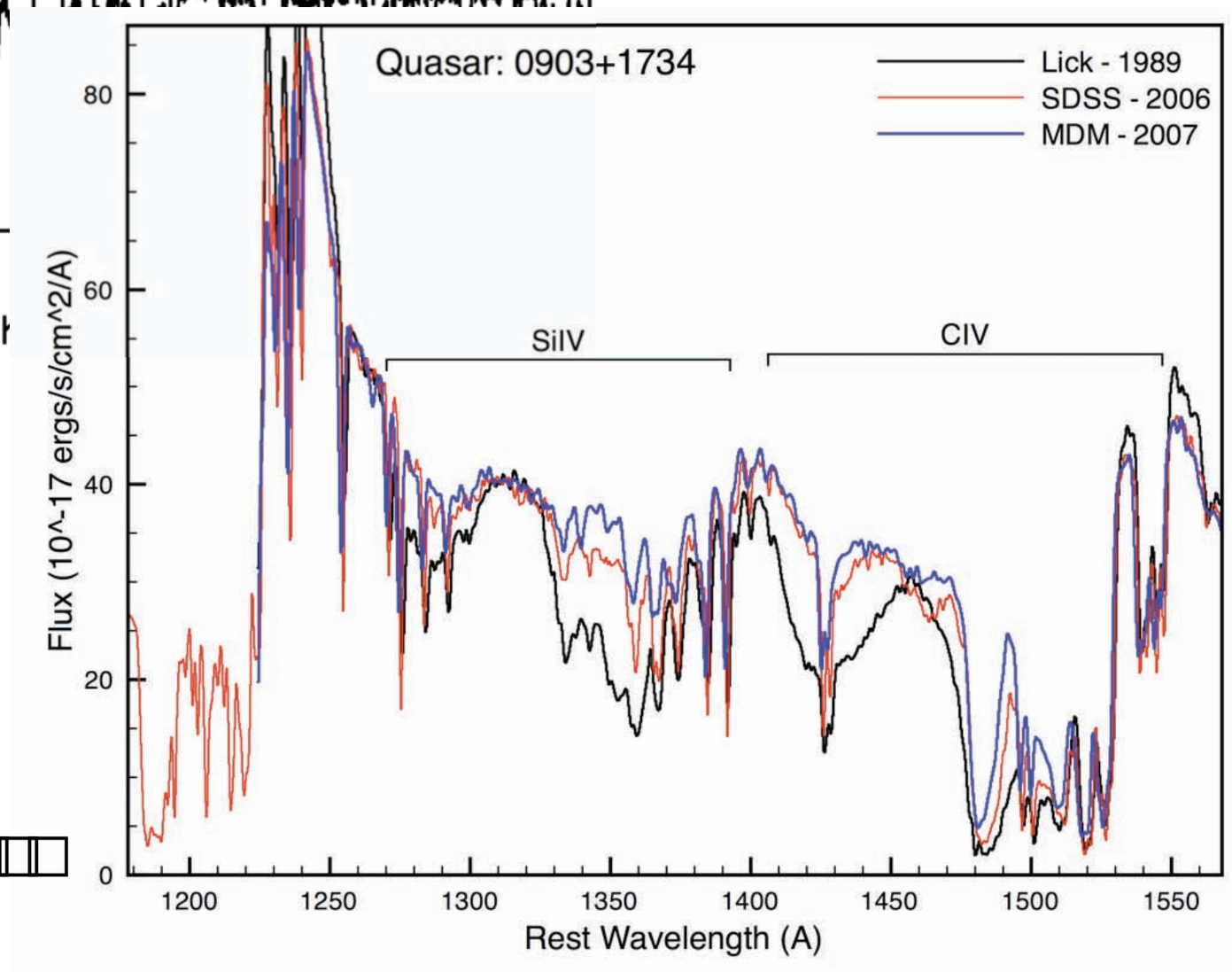
Some collaborators:

Daniel Capellupo (Univ. of Florida)
Jane Charlton (Penn State Univ.)
George Chartas (C. of Charleston)
Michael Eraclous (Penn State Univ.)
Fred Hamann (Univ. of Florida)
Michael Murphy (Swinburne Inst.)
Daniel Nestor (UCLA)
Daniel Proga (Univ. Nevada)
Joseph Shields (Ohio University)

Already presented:
BALs and NALs





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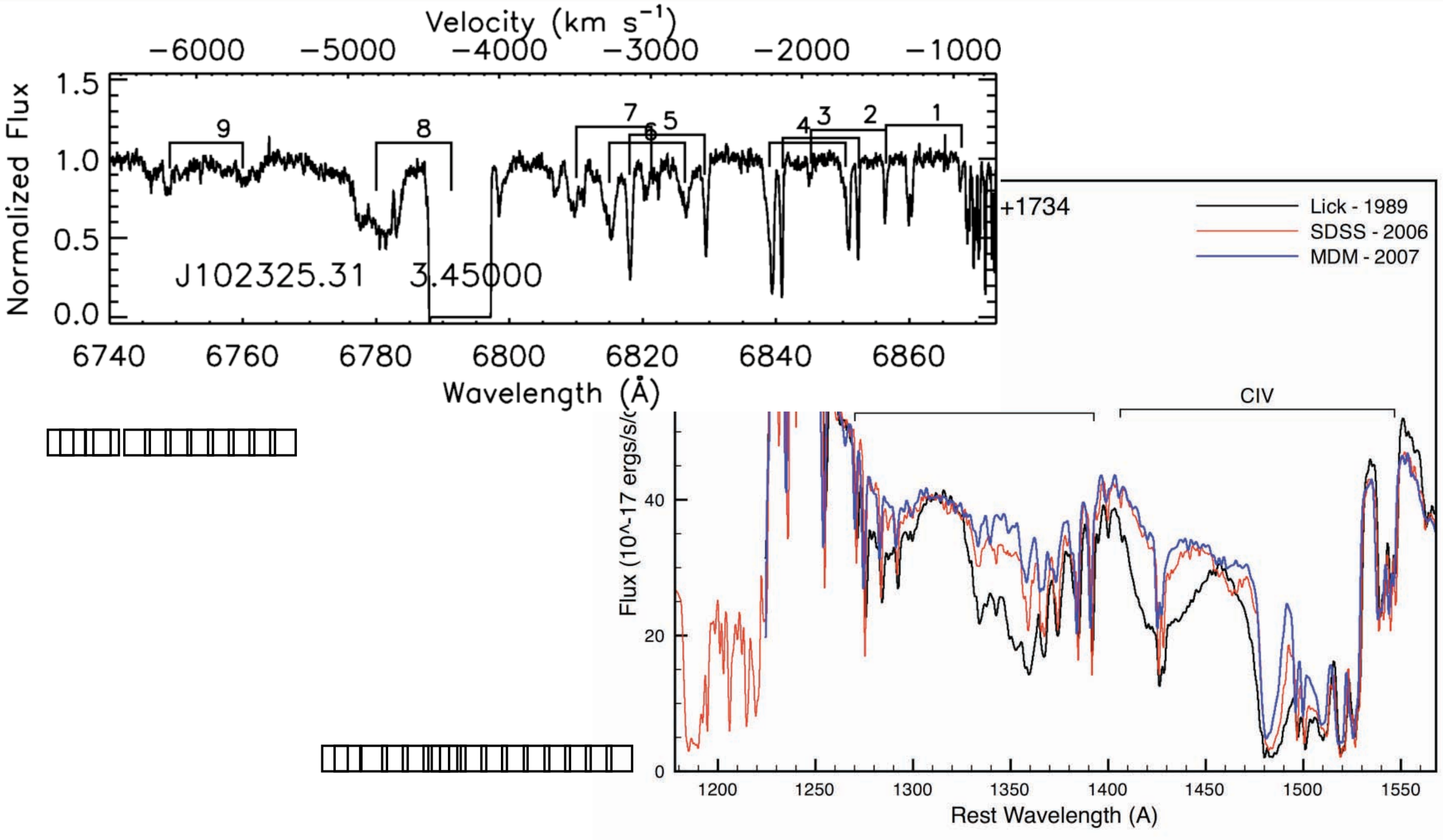
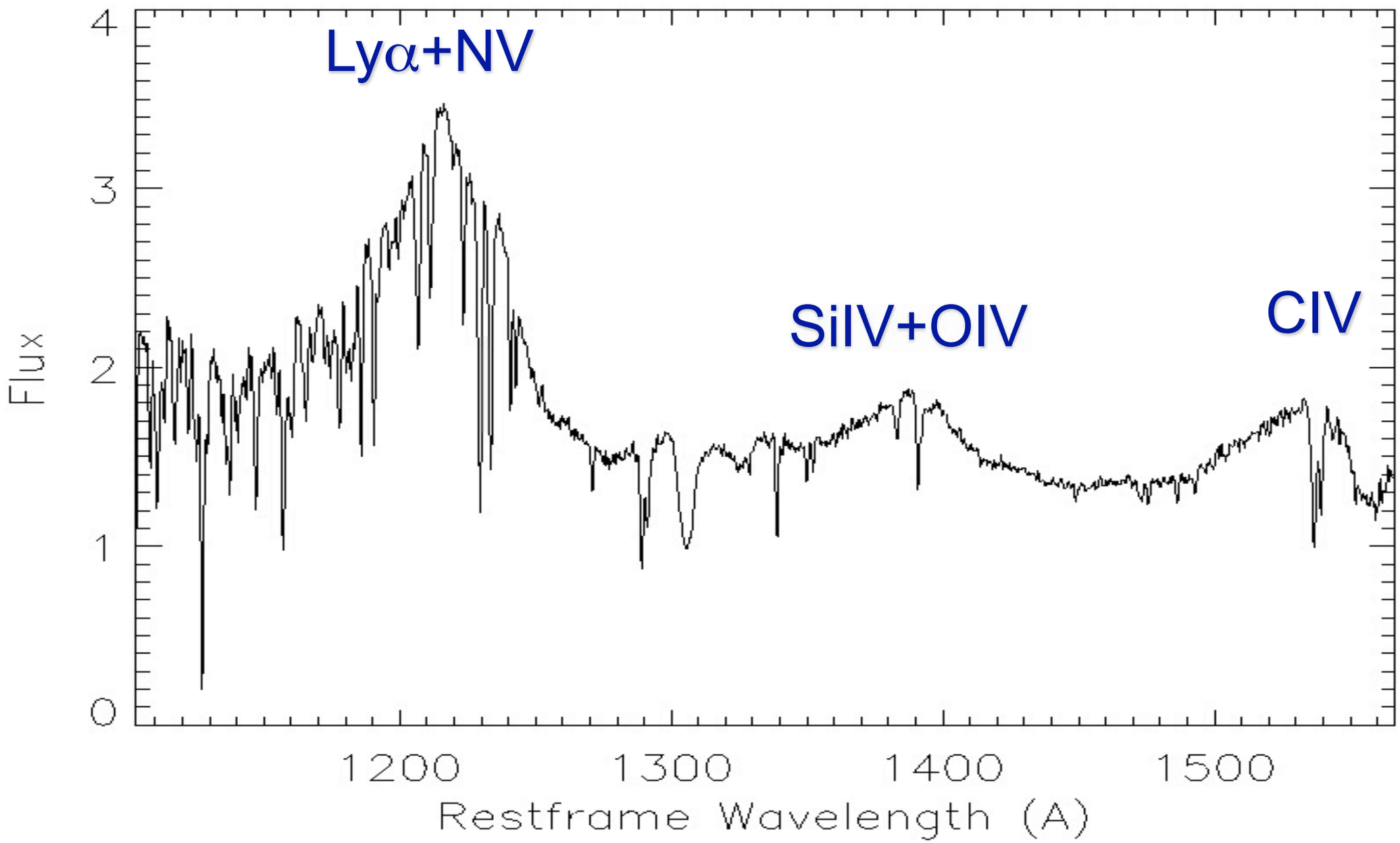


High Velocity Outflow and mini-BAL



(Hamann+1997)

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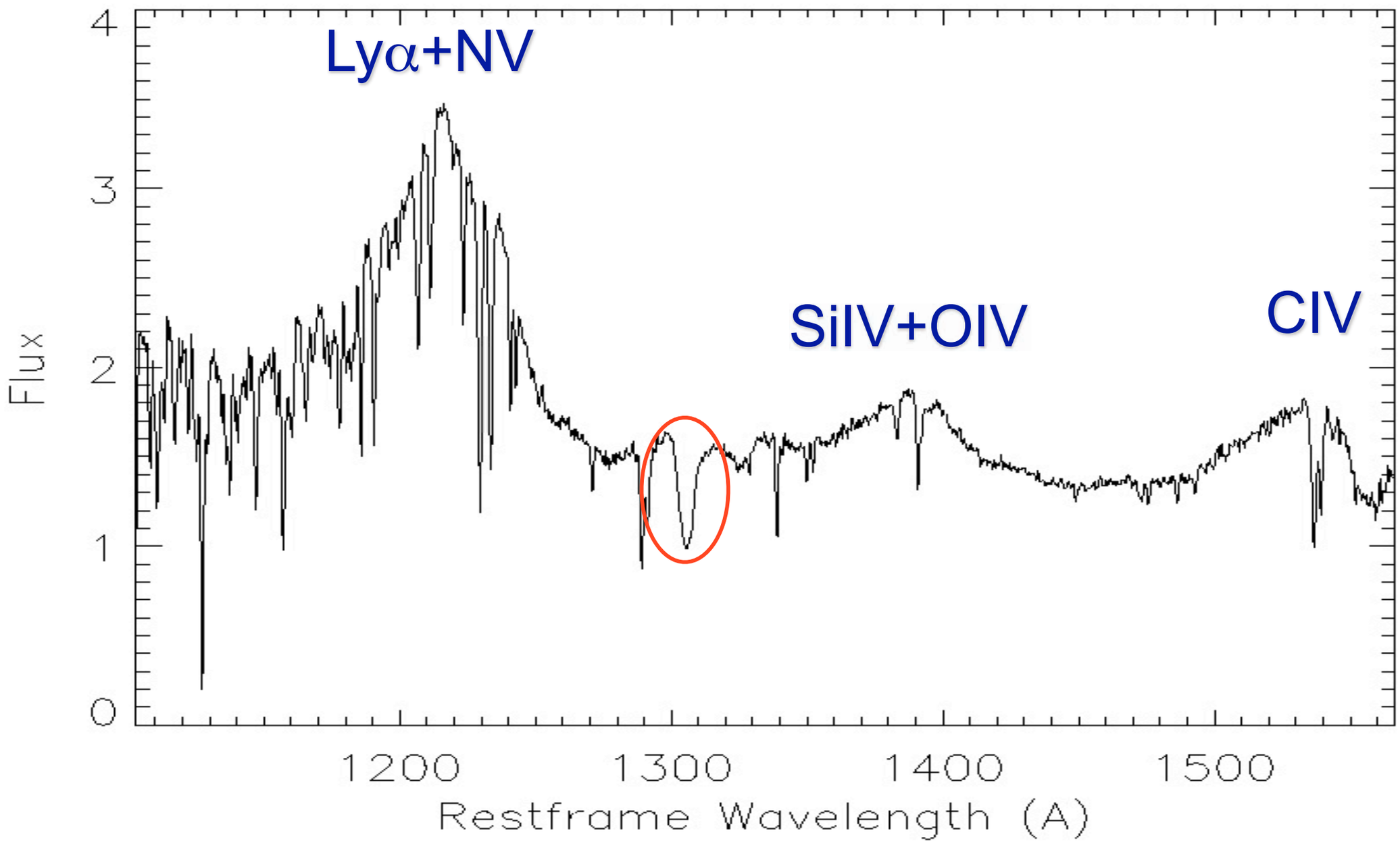

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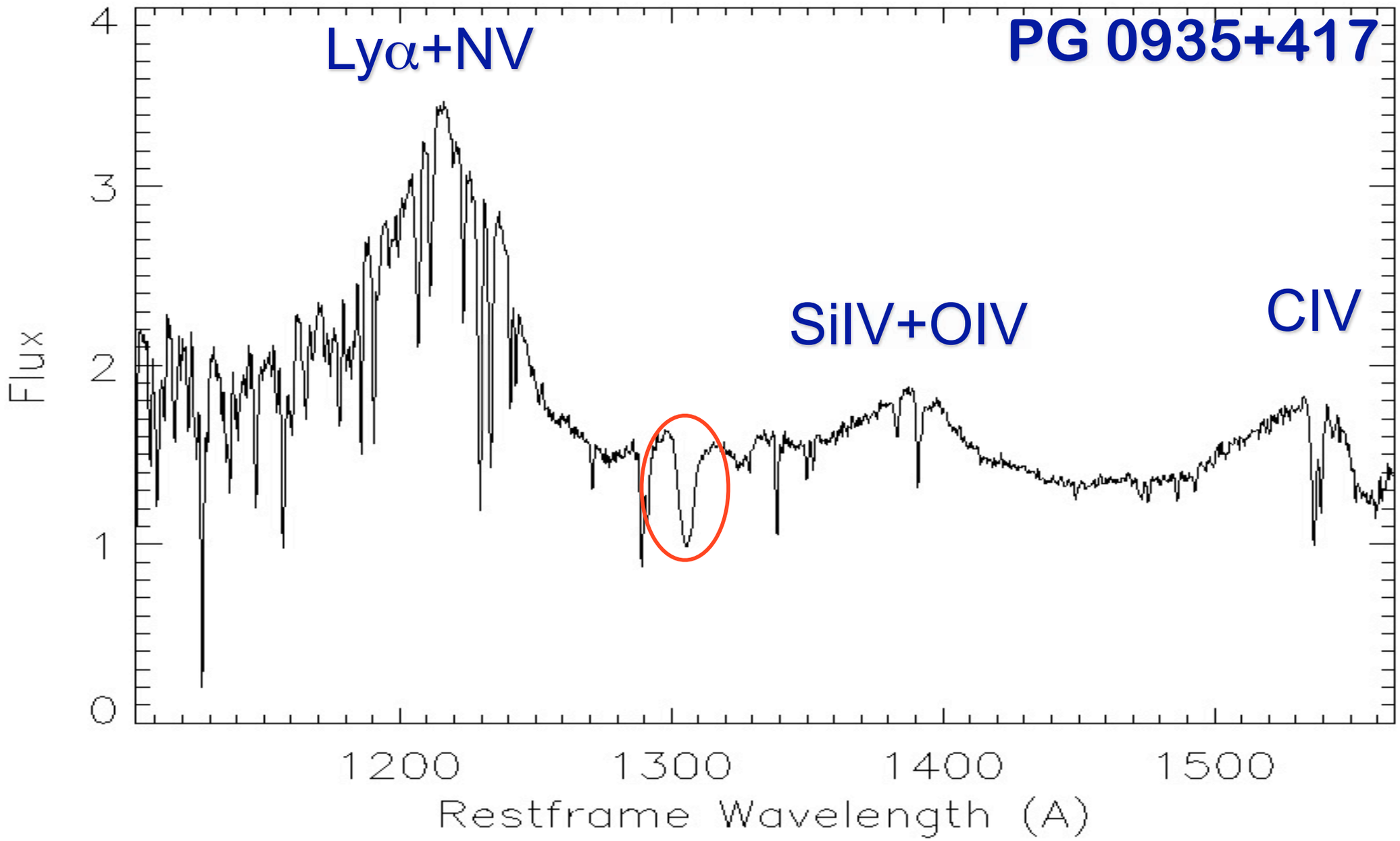
Study case of PG0935+417



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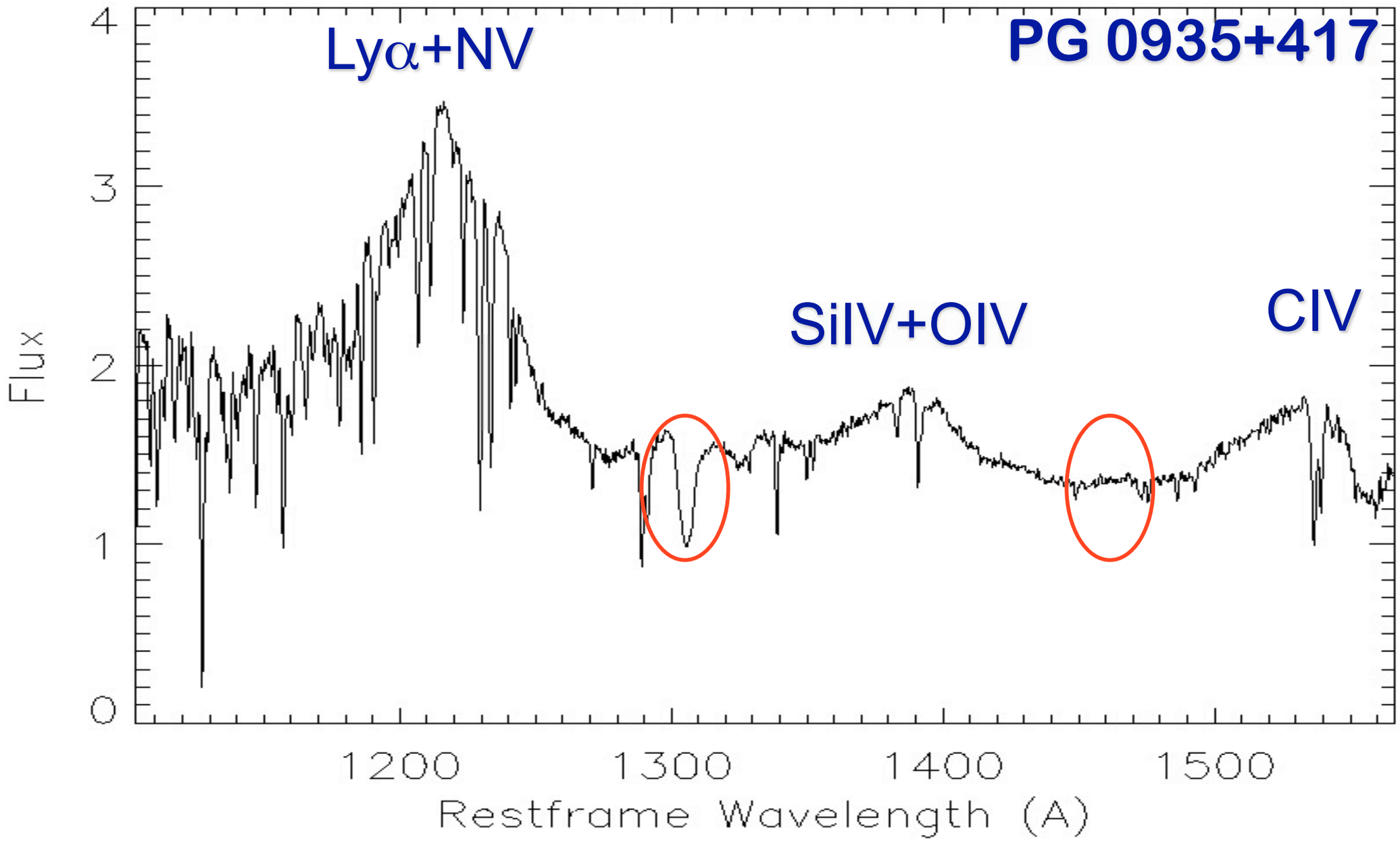

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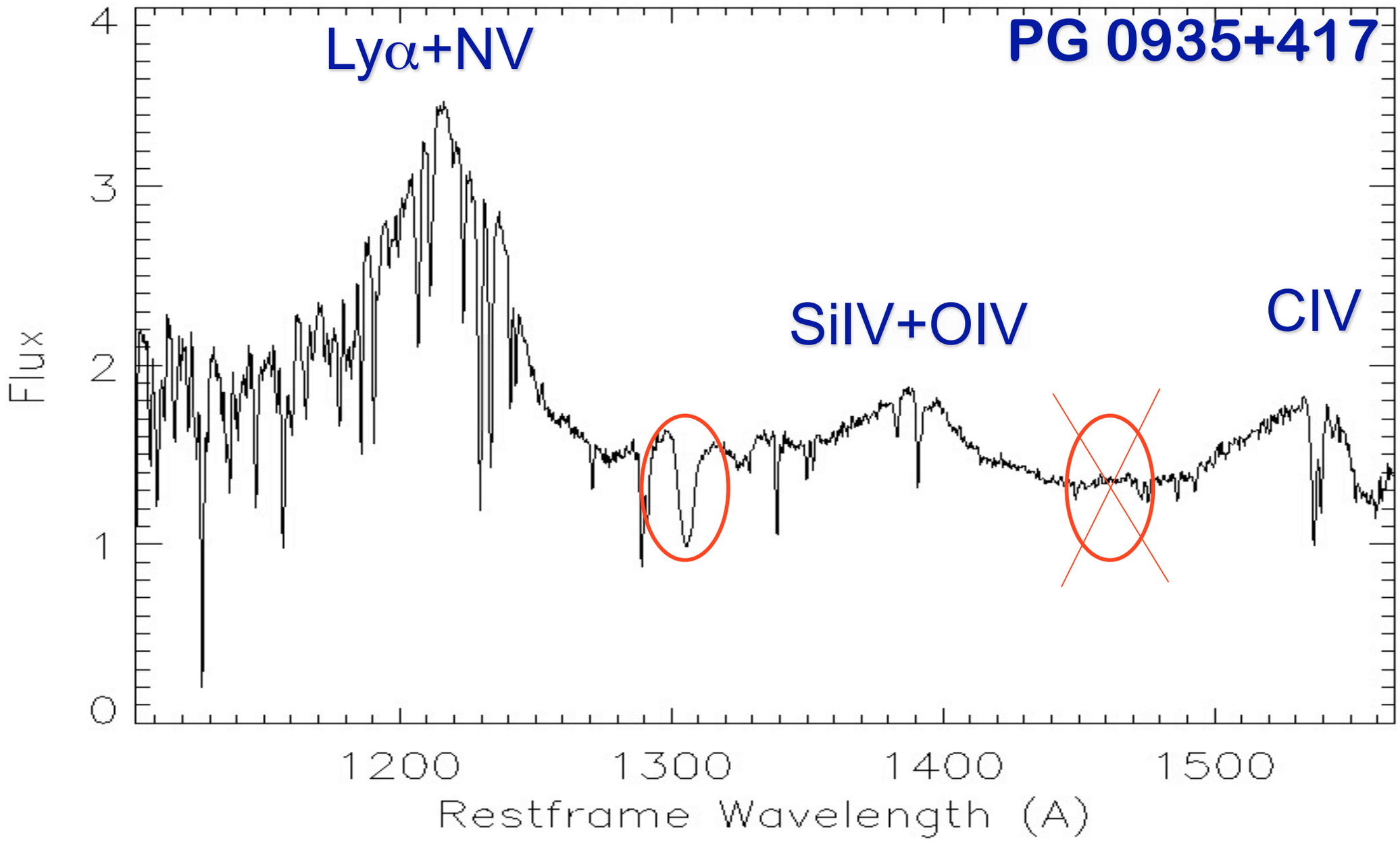

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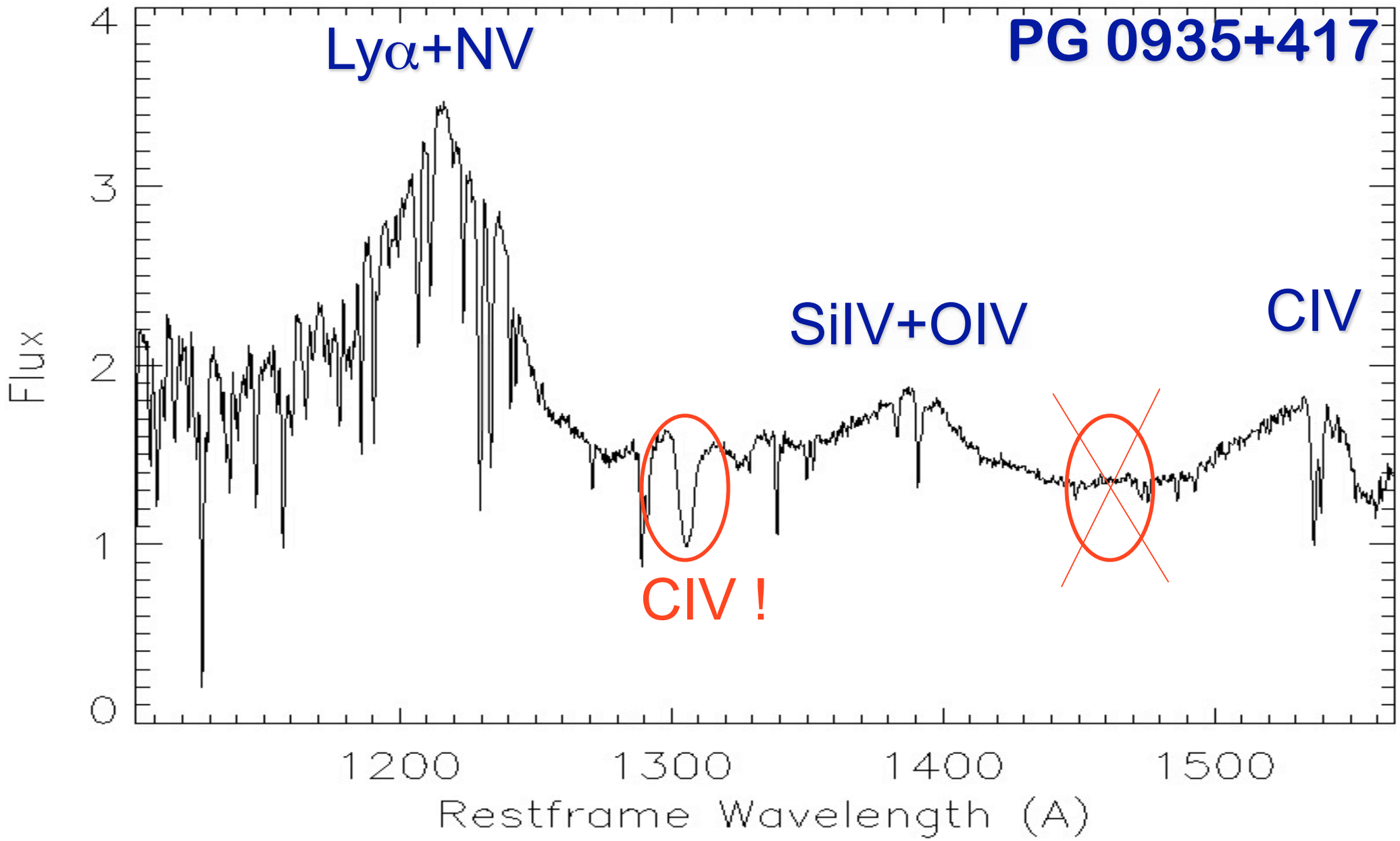

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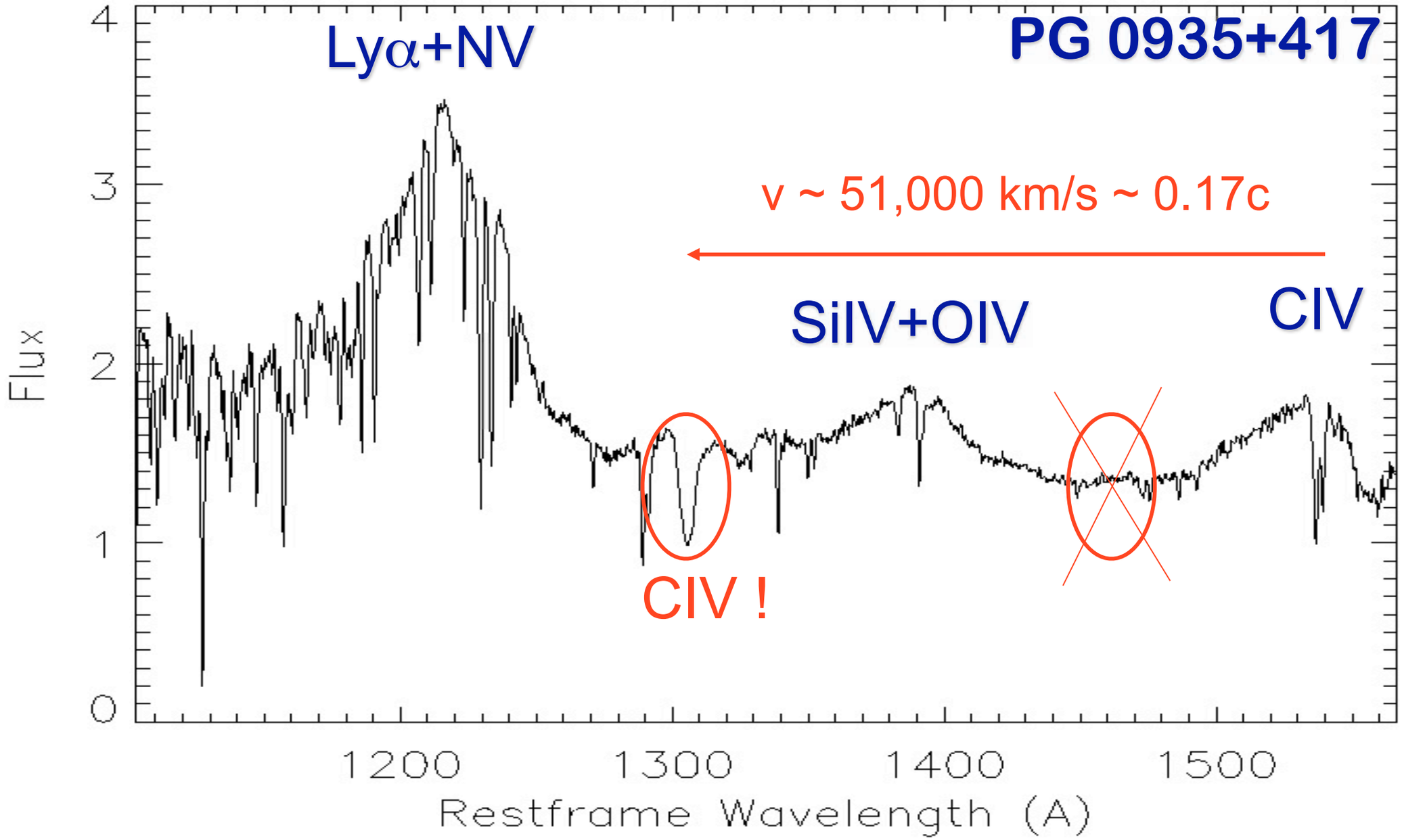

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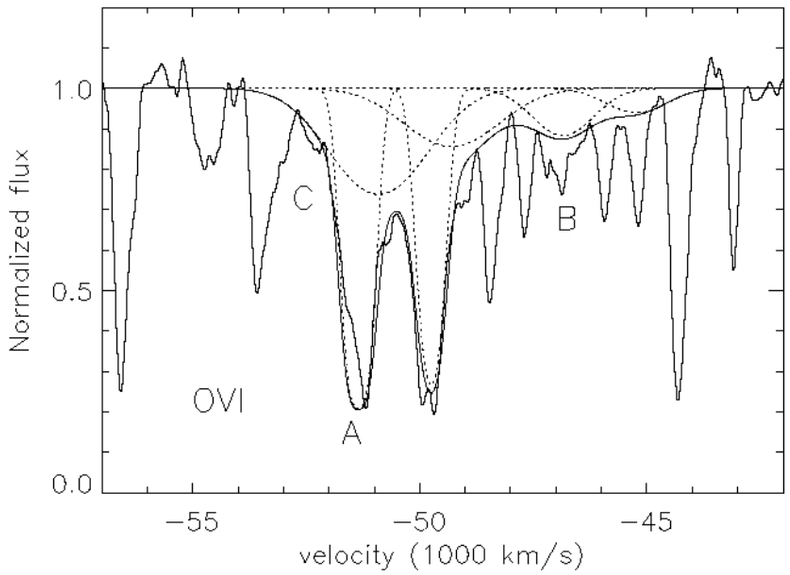

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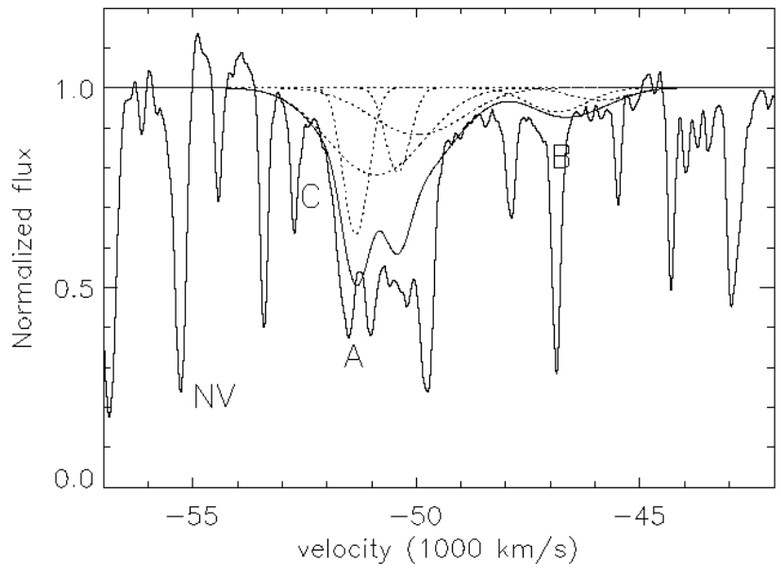

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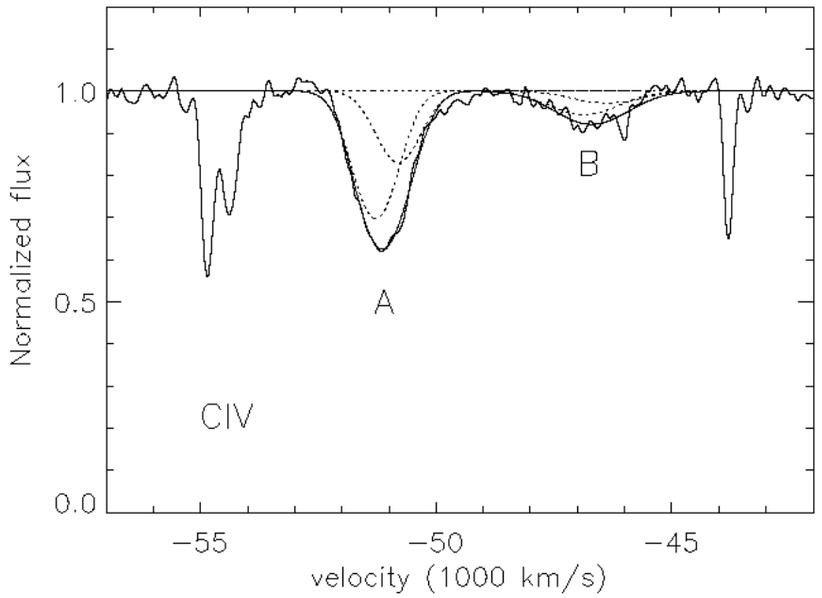

(Rodriguez Hidalgo+2011)

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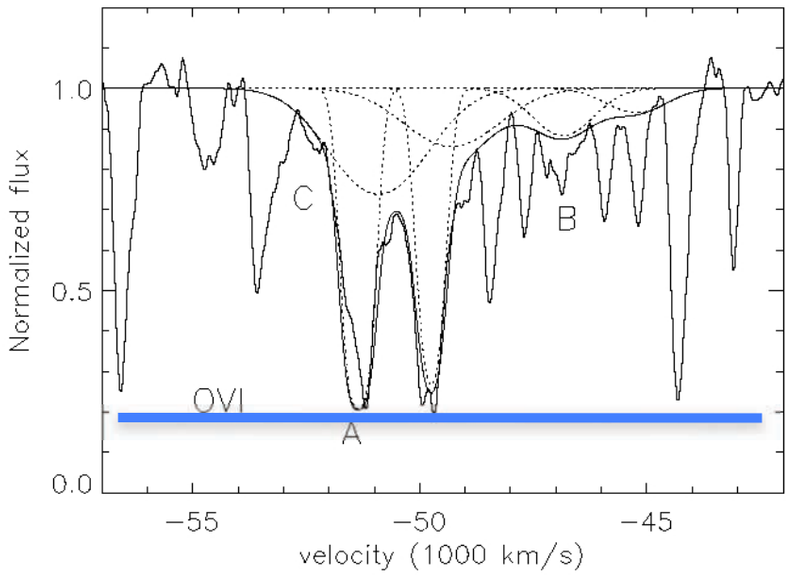

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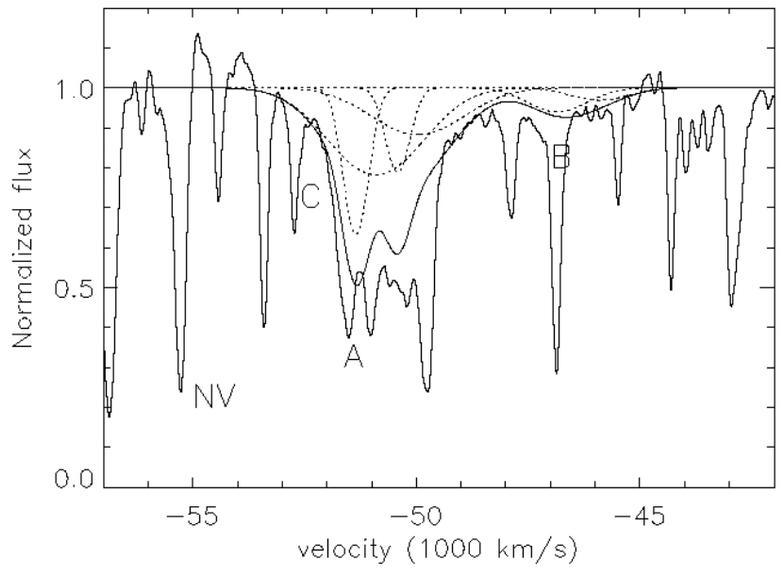

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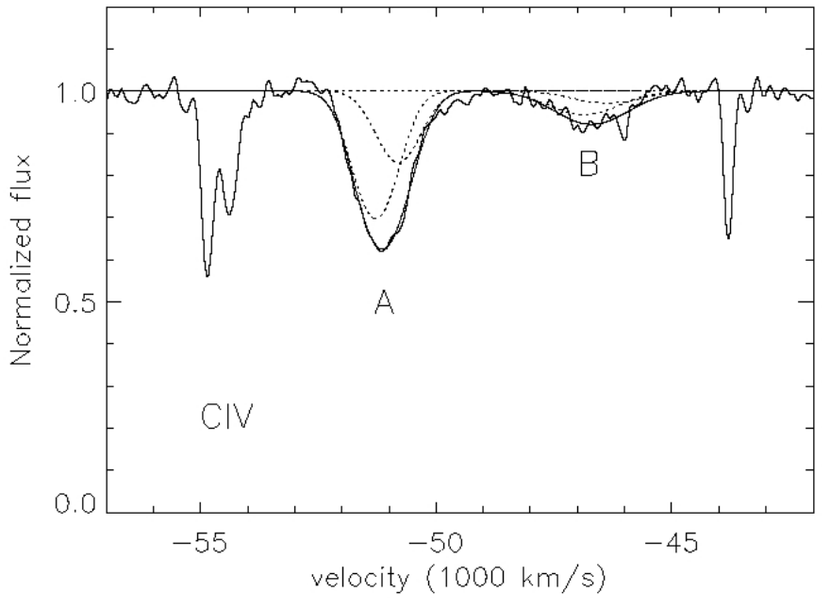

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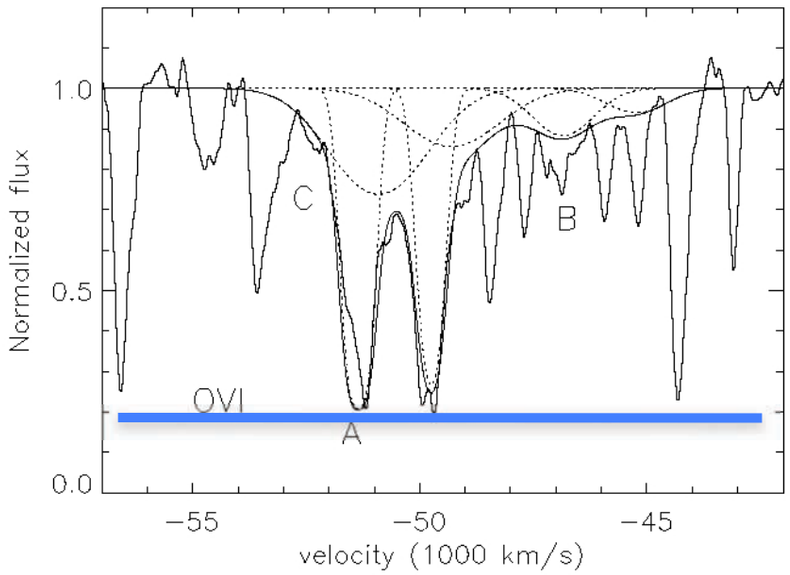

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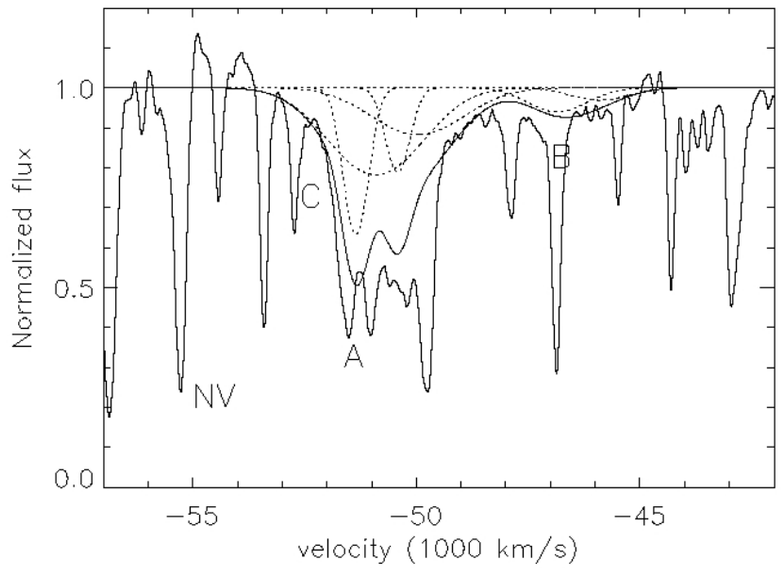

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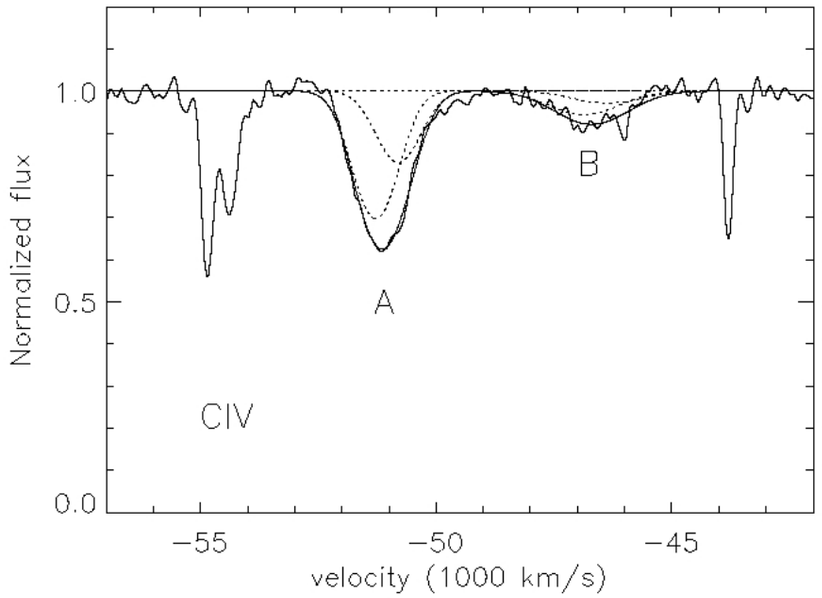

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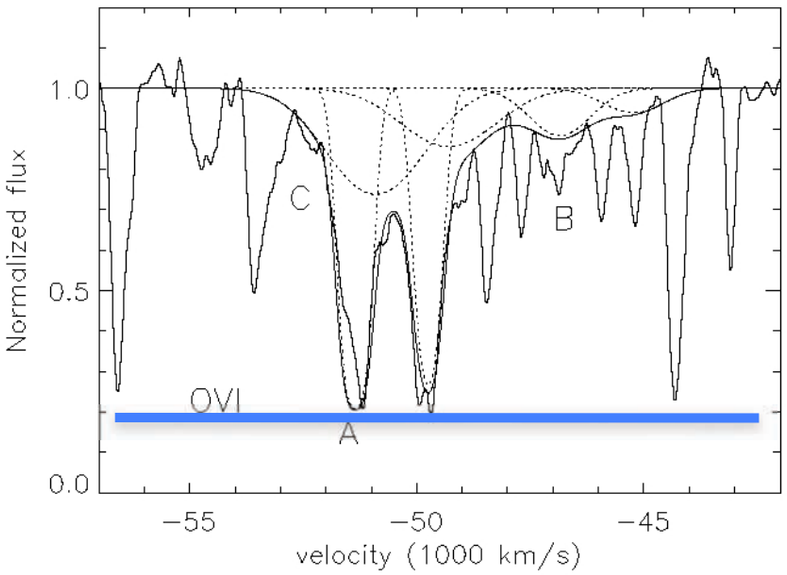

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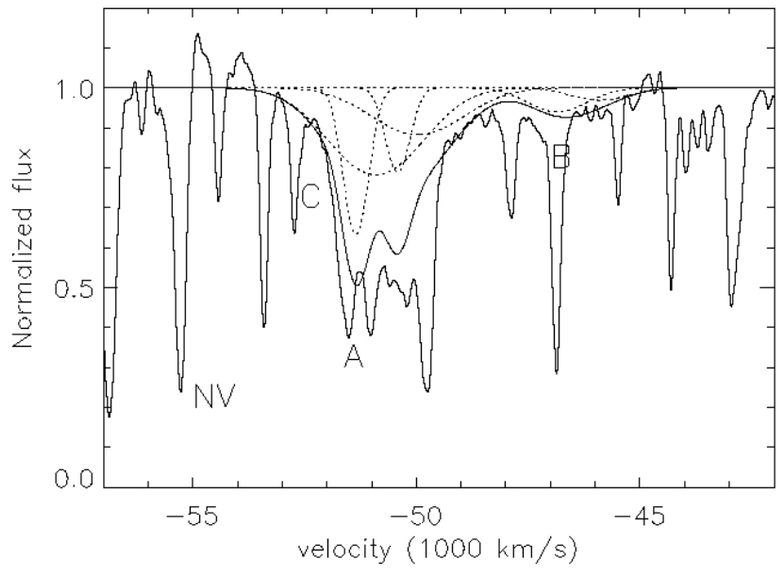

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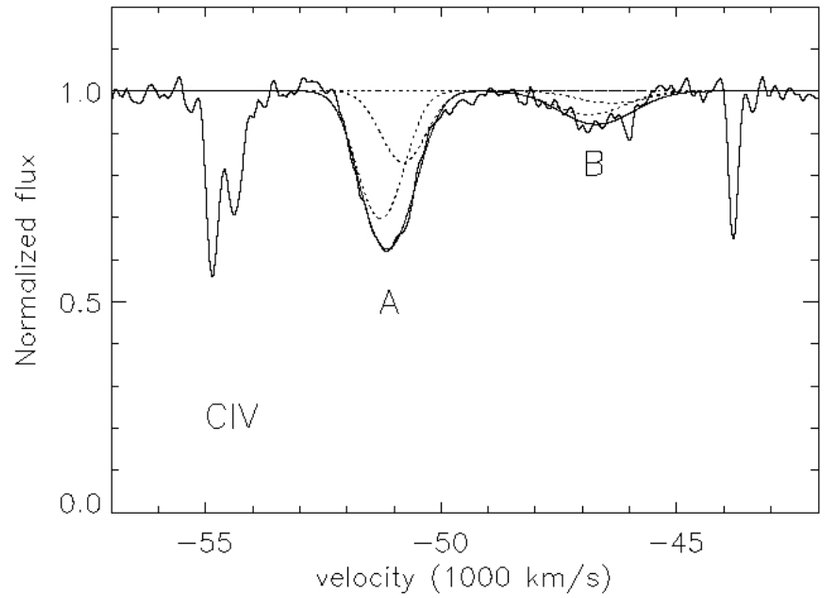

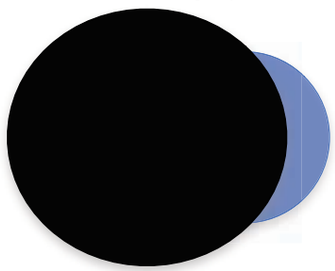

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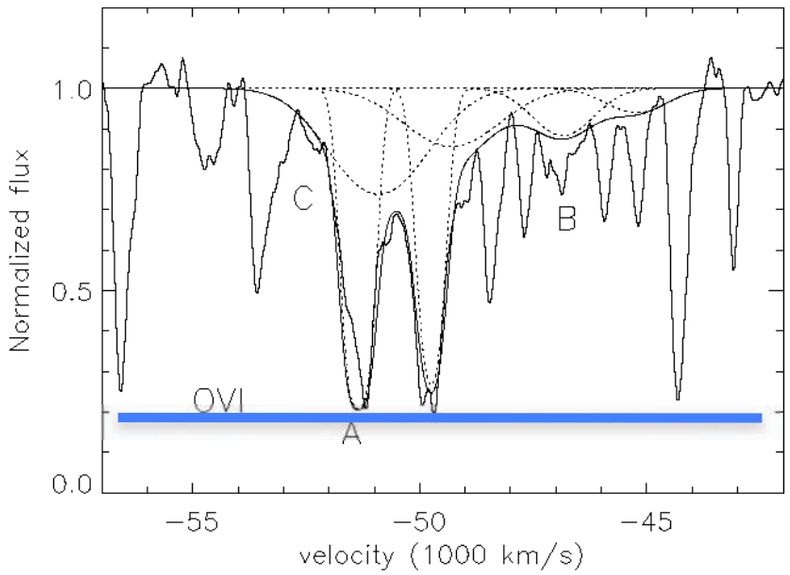

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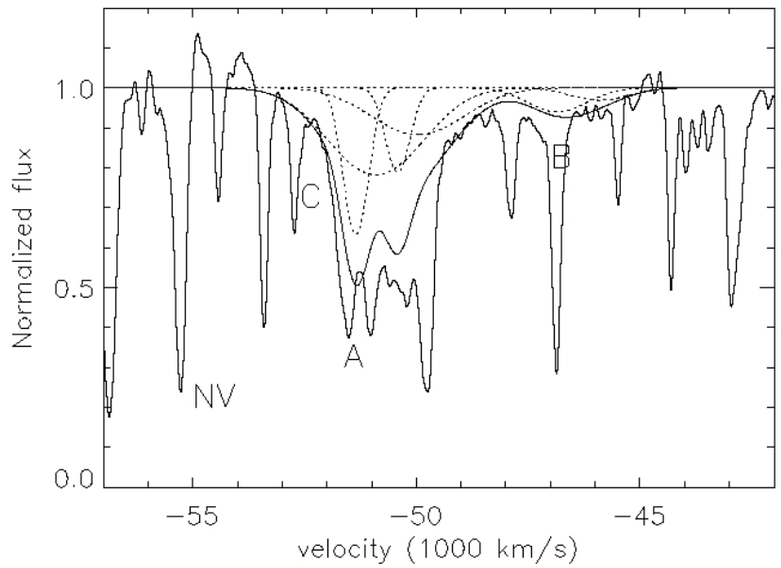

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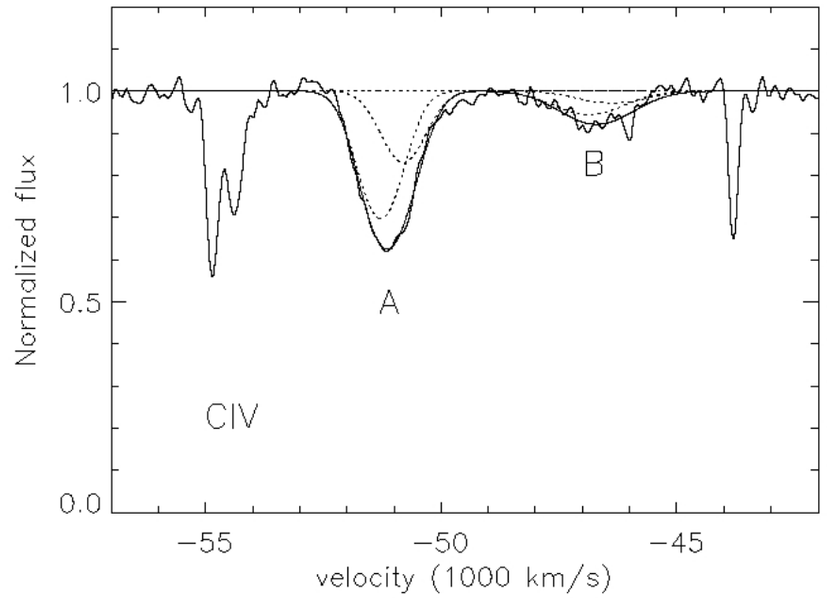
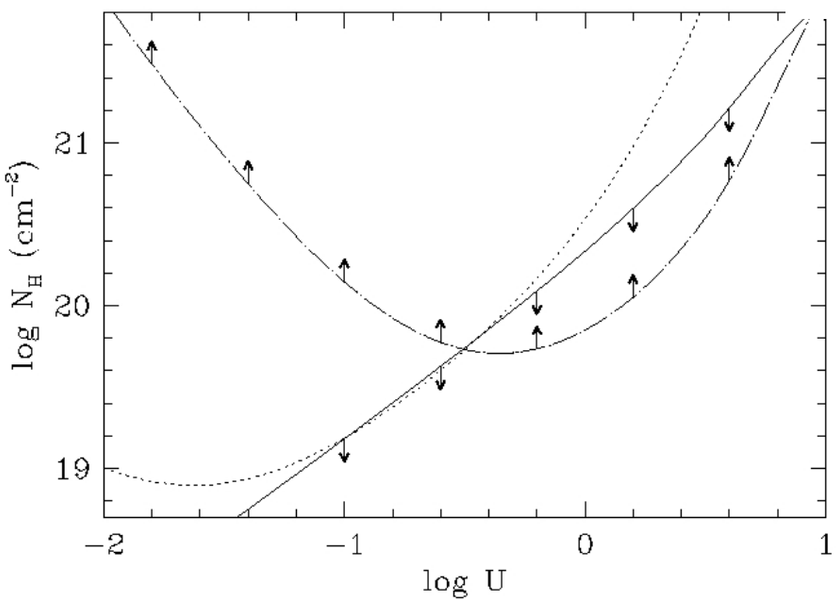




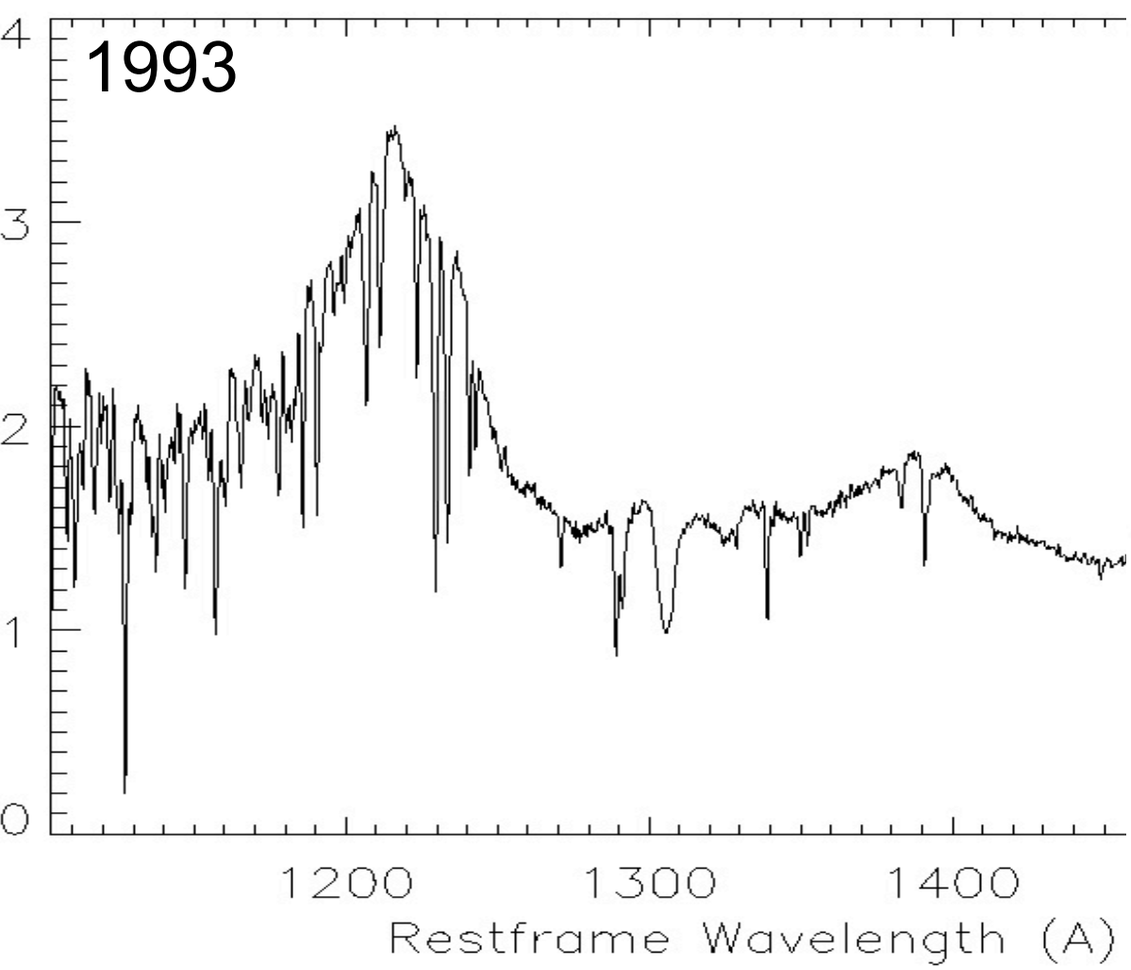
(Rodriguez Hidalgo+2011)

Cf=0.8

Total Column Density: $N_H \sim 5 \times 10^{19}$ cm^{-2}

Ionization: log $U \sim -0.5$

Study case of PG0935+417



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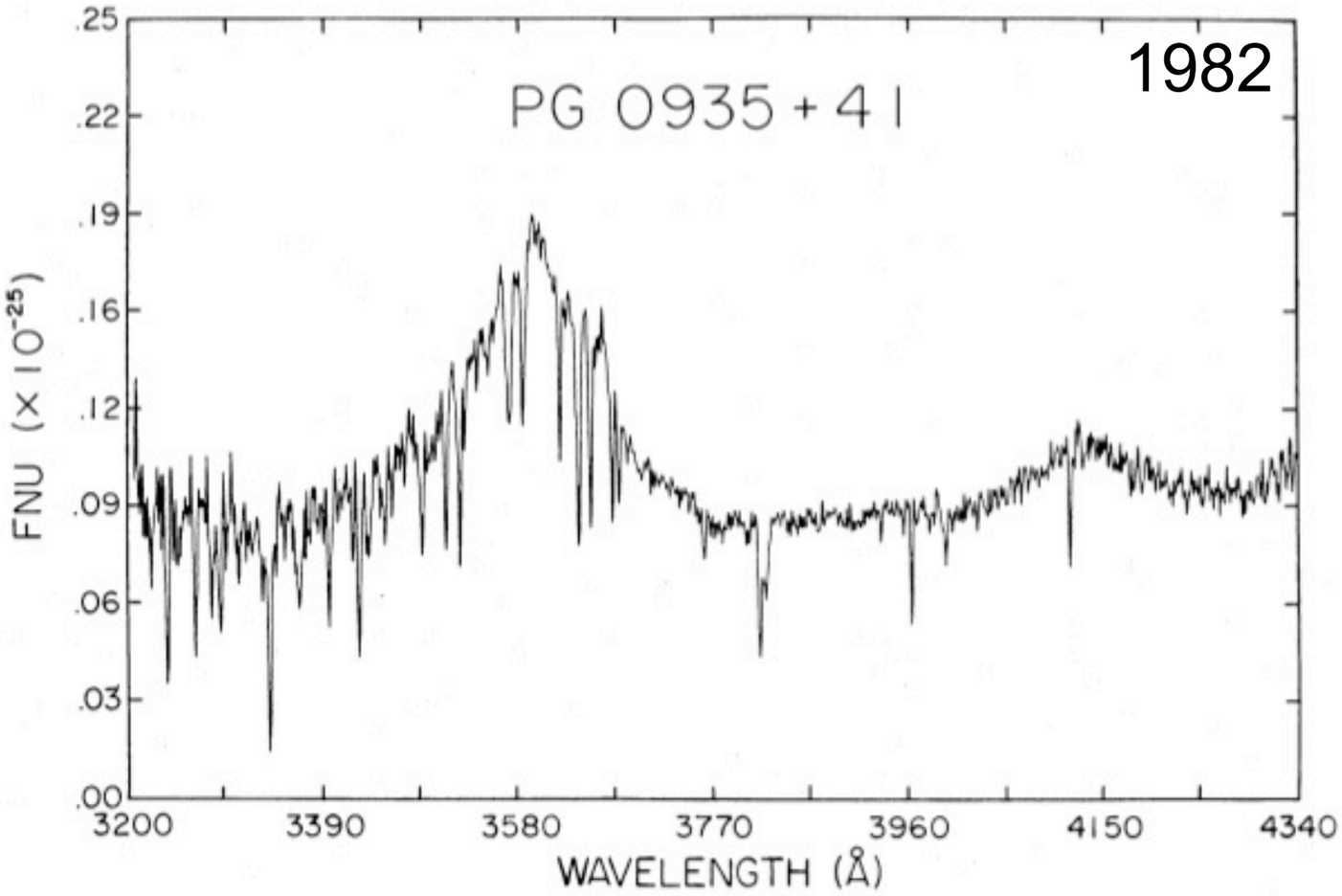

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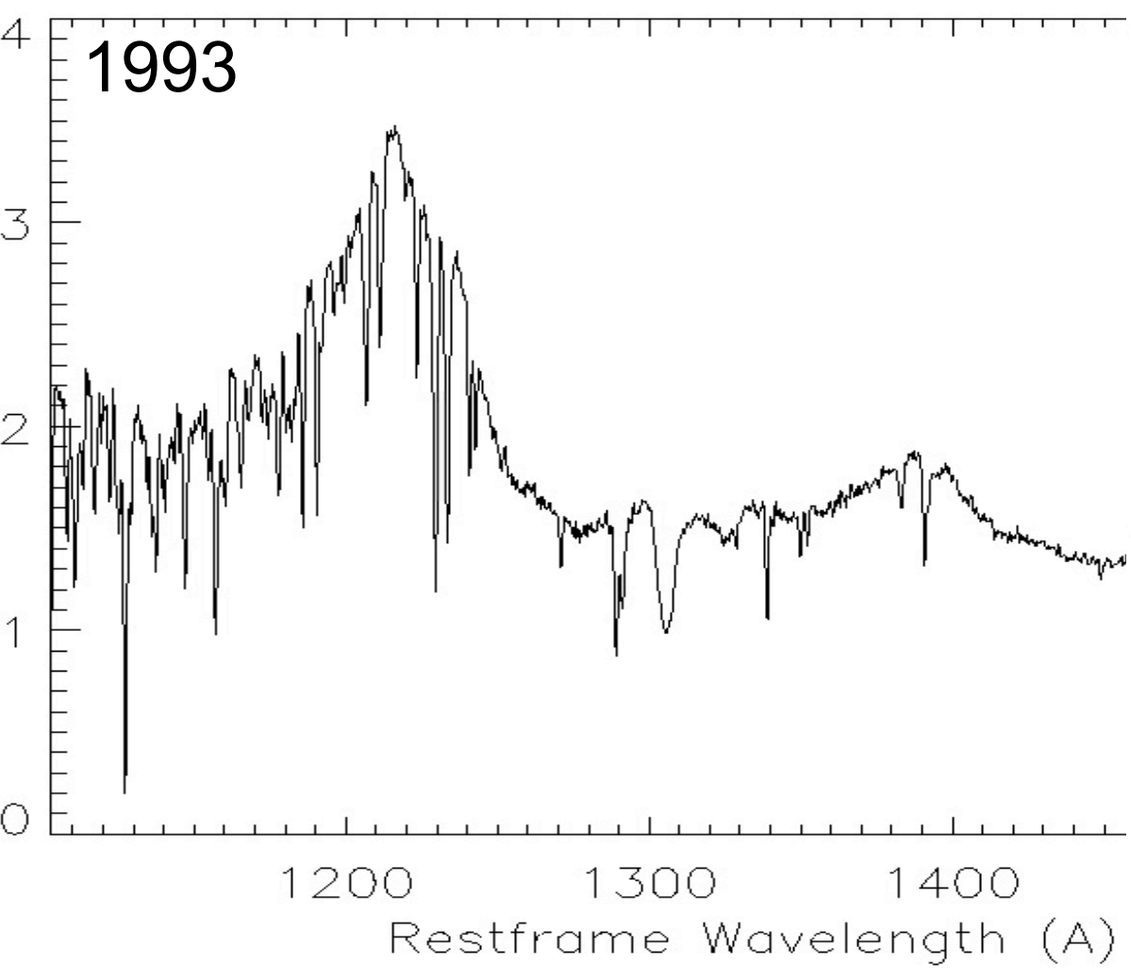

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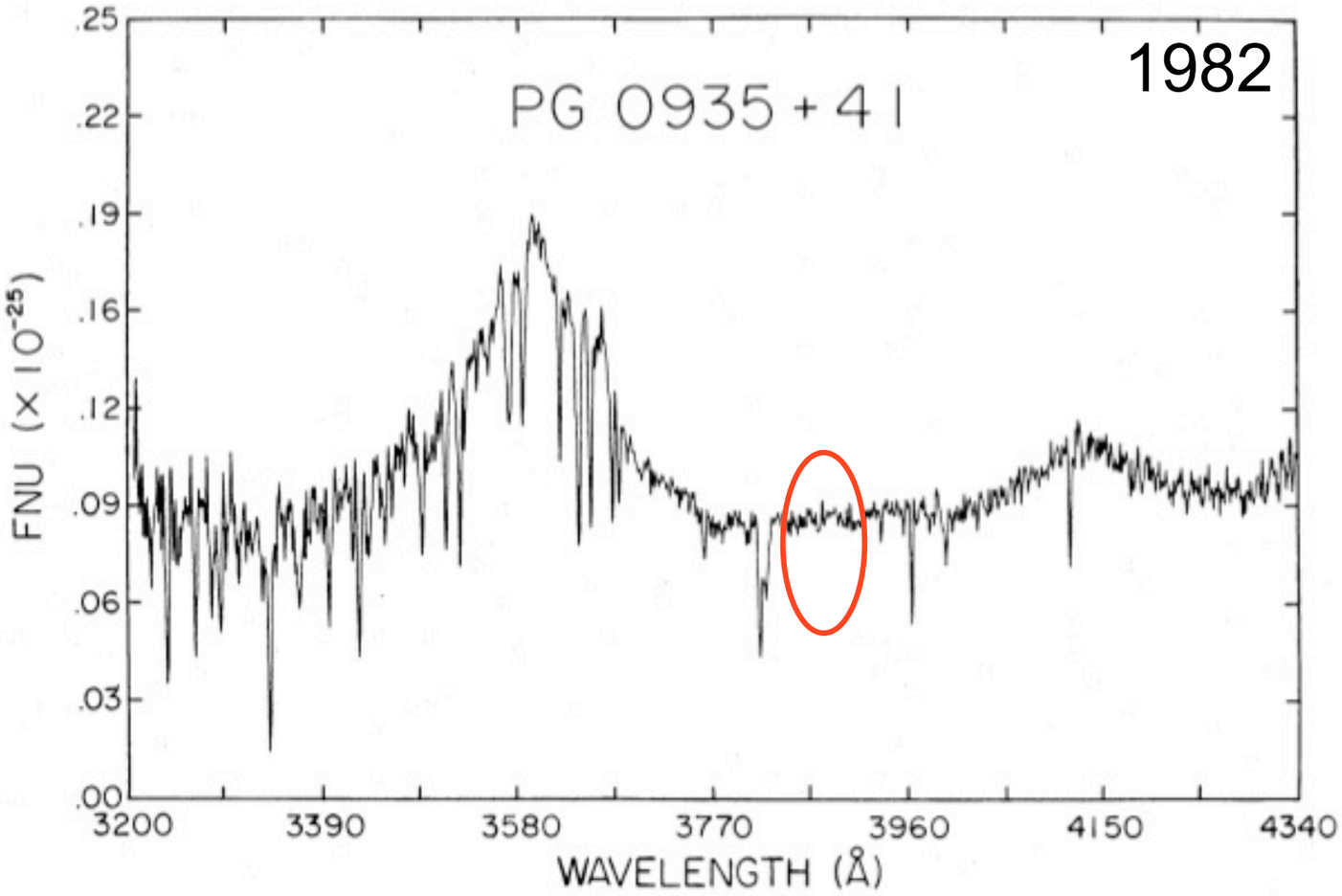

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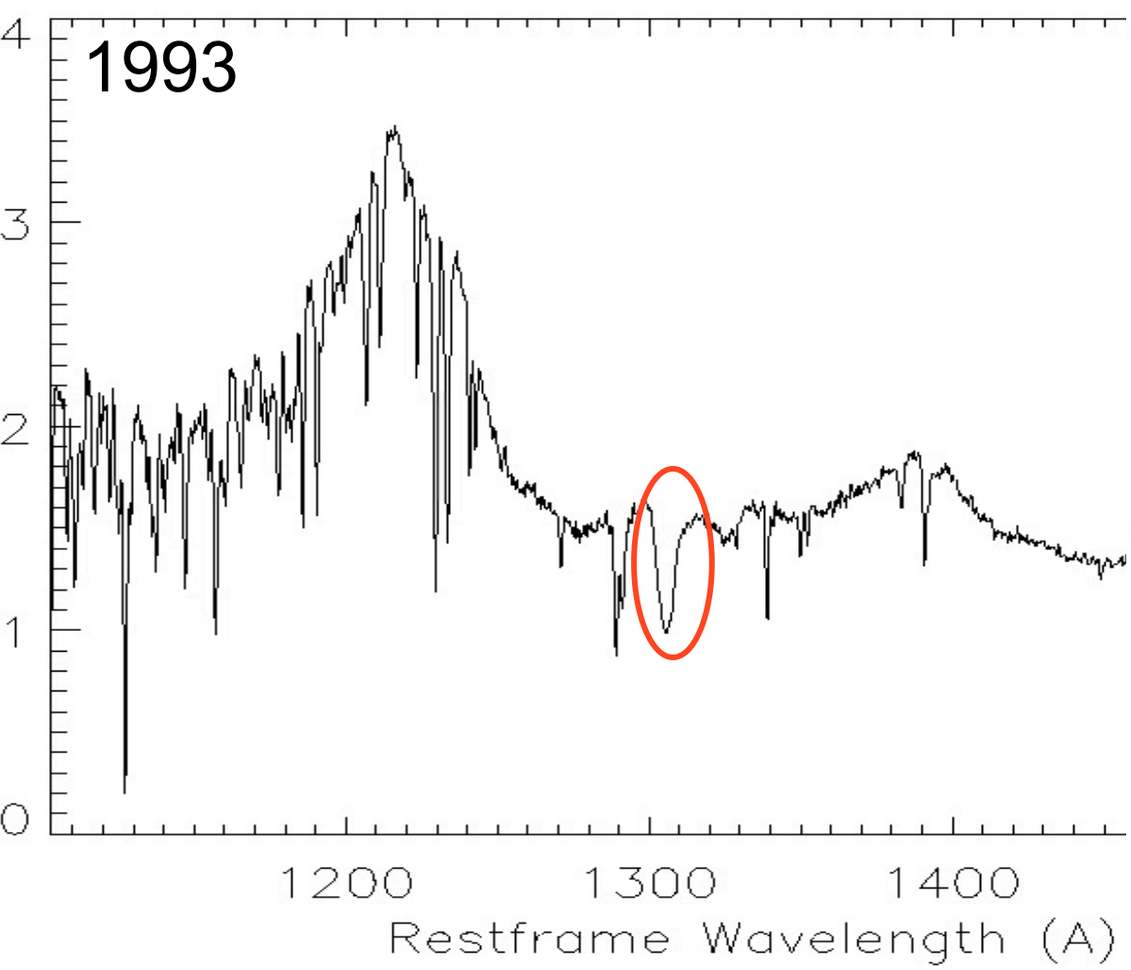

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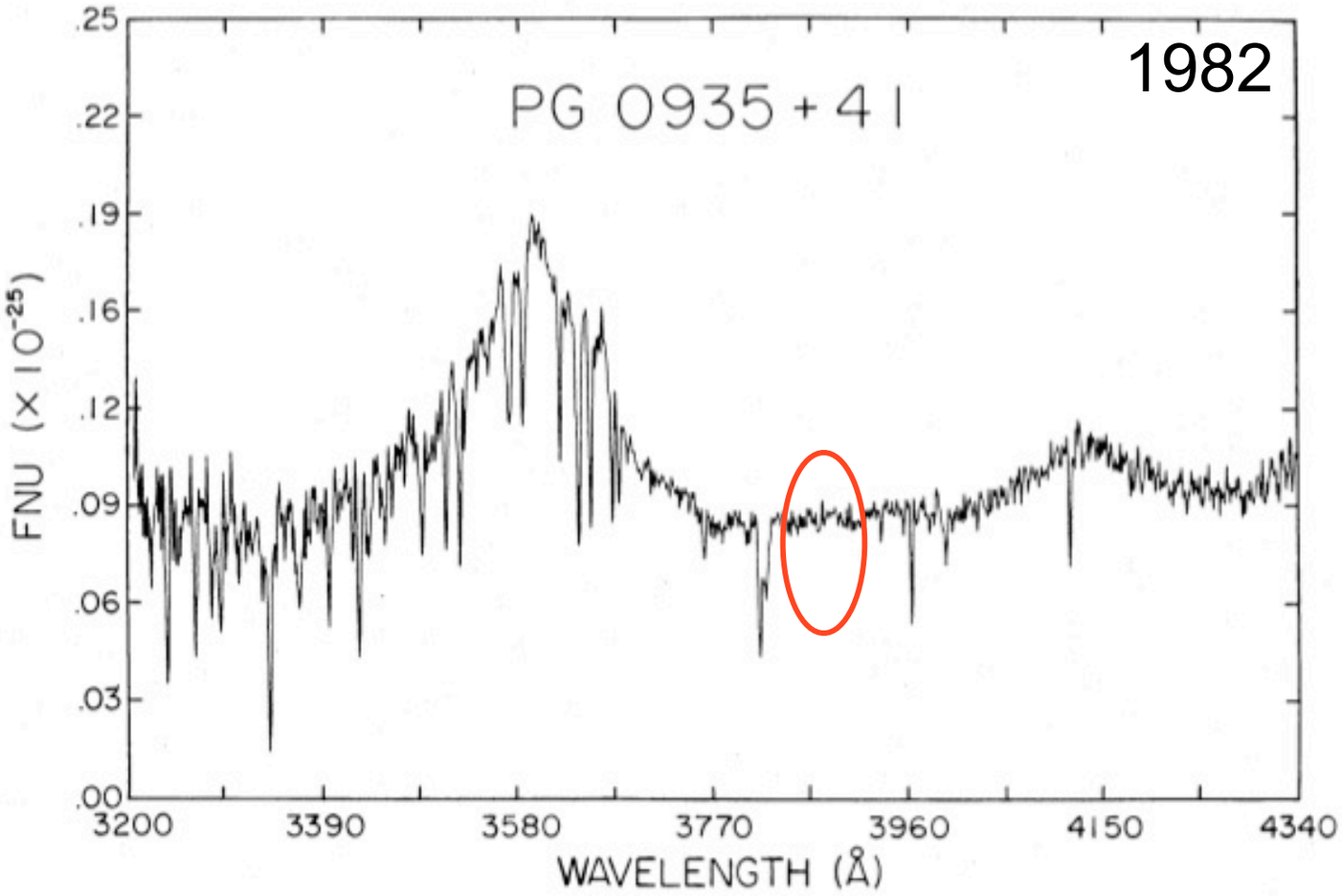

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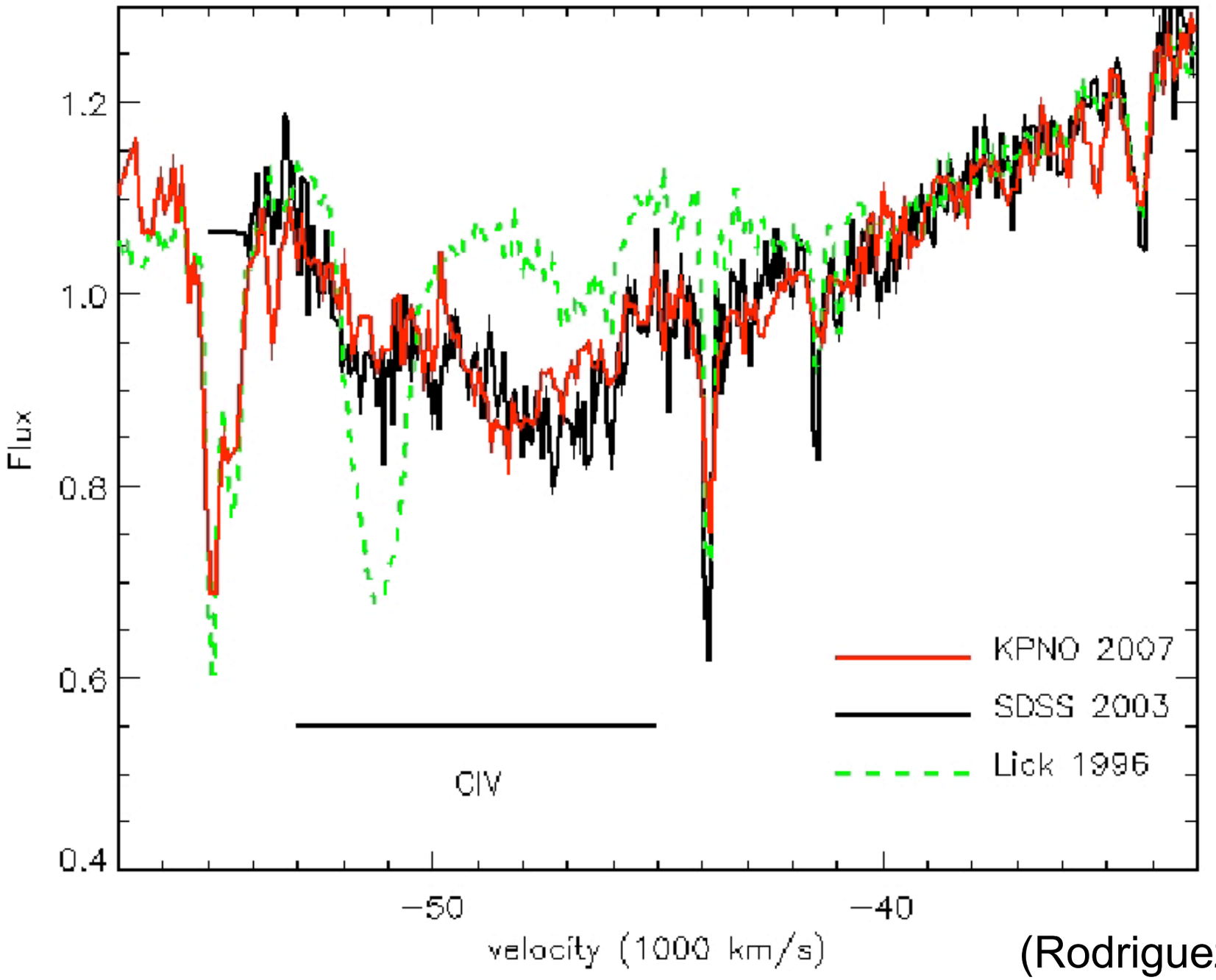

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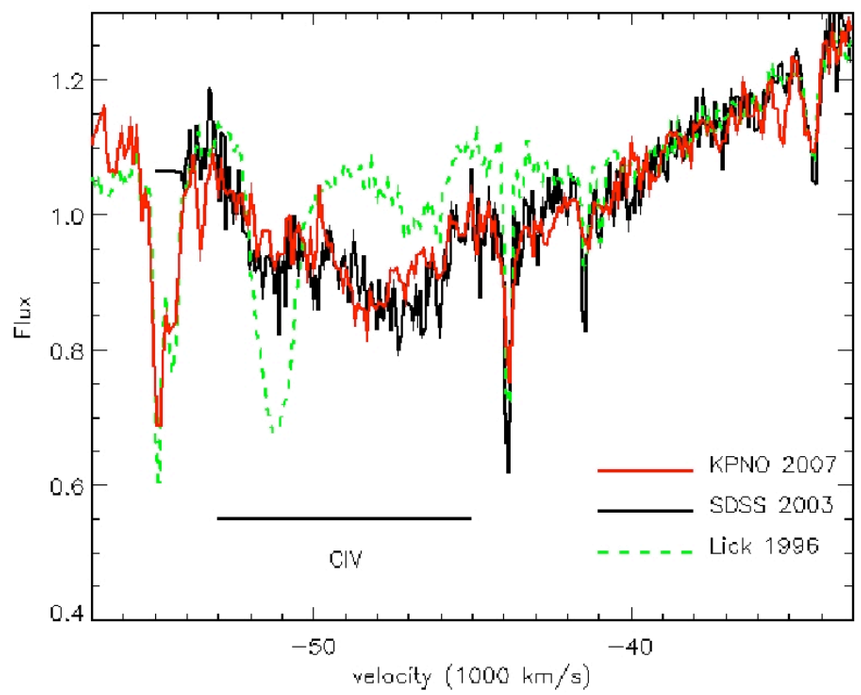


- outflowing material

- velocity range is variable in (-45,000 km/s, -53,000 km/s)

- no acceleration/deceleration

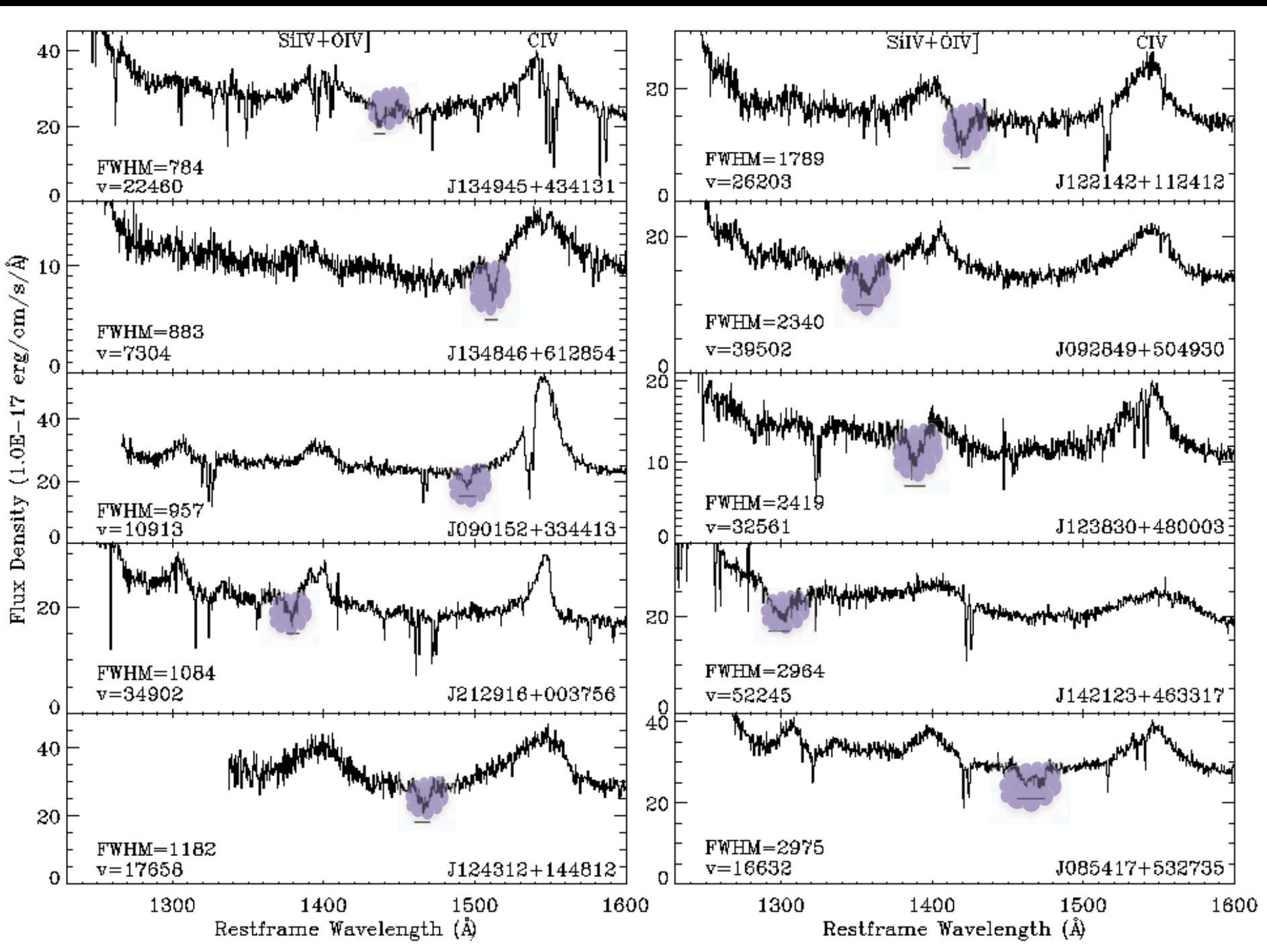
- complex & highly variable

- timescales ~1 year in the quasar rest-frame, matching results of variability in models (i.e., Daniel Proga's)

- how frequent are cases such as this one?

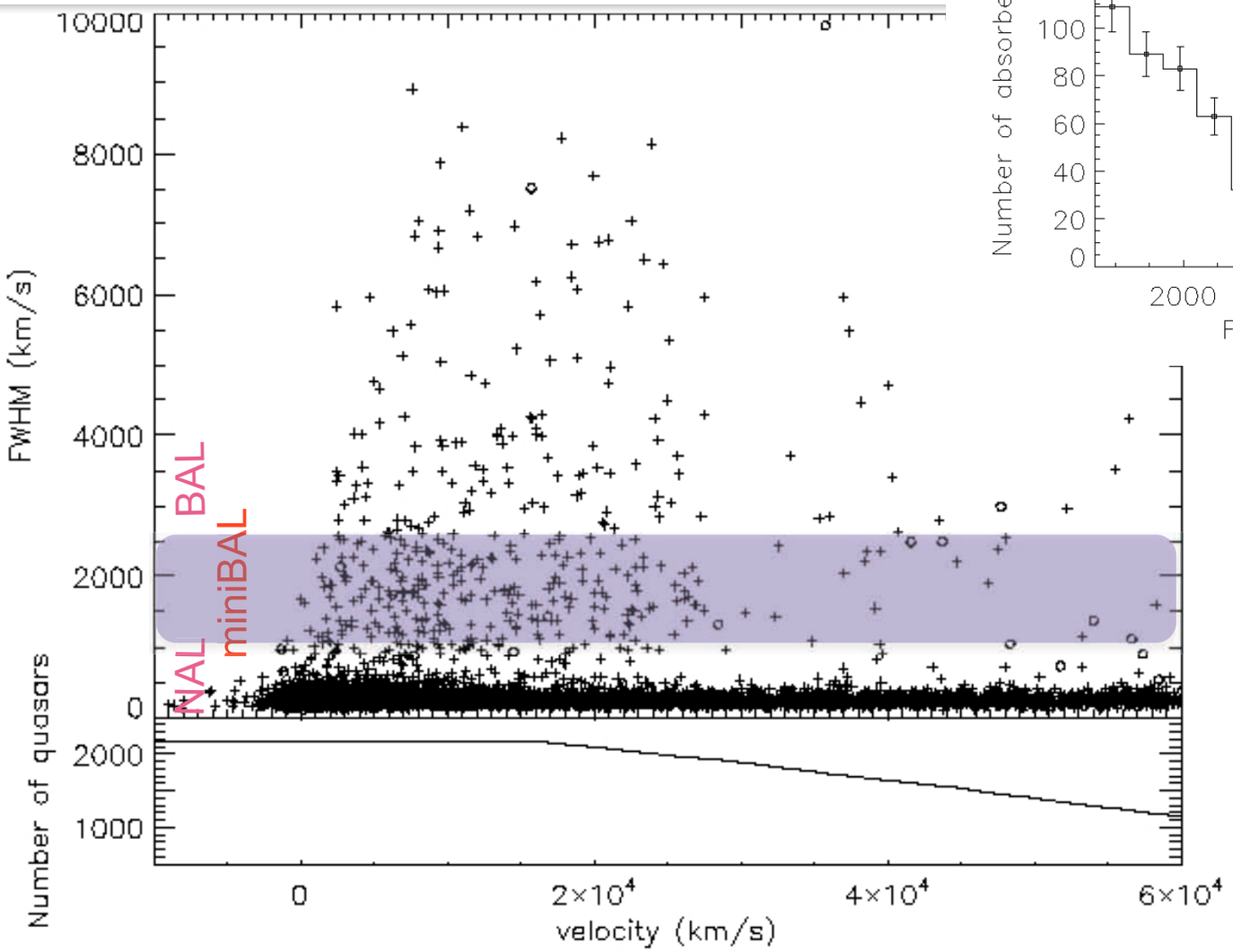
(Rodriguez Hidalgo+2011)

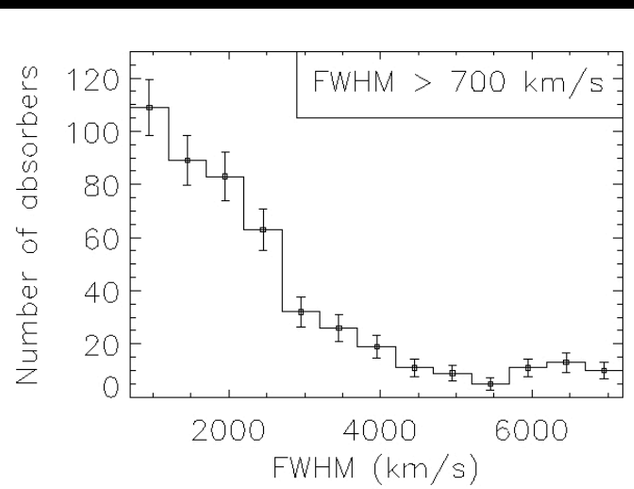
SDSS Mini-BAL Survey



(Rodriguez Hidalgo+in prep)

CIV absorbers found





- **SDSS Quasar spectra (R ~ 150 km/s; spectral coverage 3820-9200 A)**
- **To see CIV λλ1548,1550 absorbers: z_{em} > 1.8**
- **We examine the 2200 spectra with best signal-to-noise**
- **We look for every blue-shifted CIV absorber and measure z_{abs}, v, FWHM, REW, Balnicity Index, Absorption Index**

(Rodriguez Hidalgo+in prep)

5320 absorption systems measured

Variability Monitoring Program

Mini-BALs' variability barely studied before, handful of cases

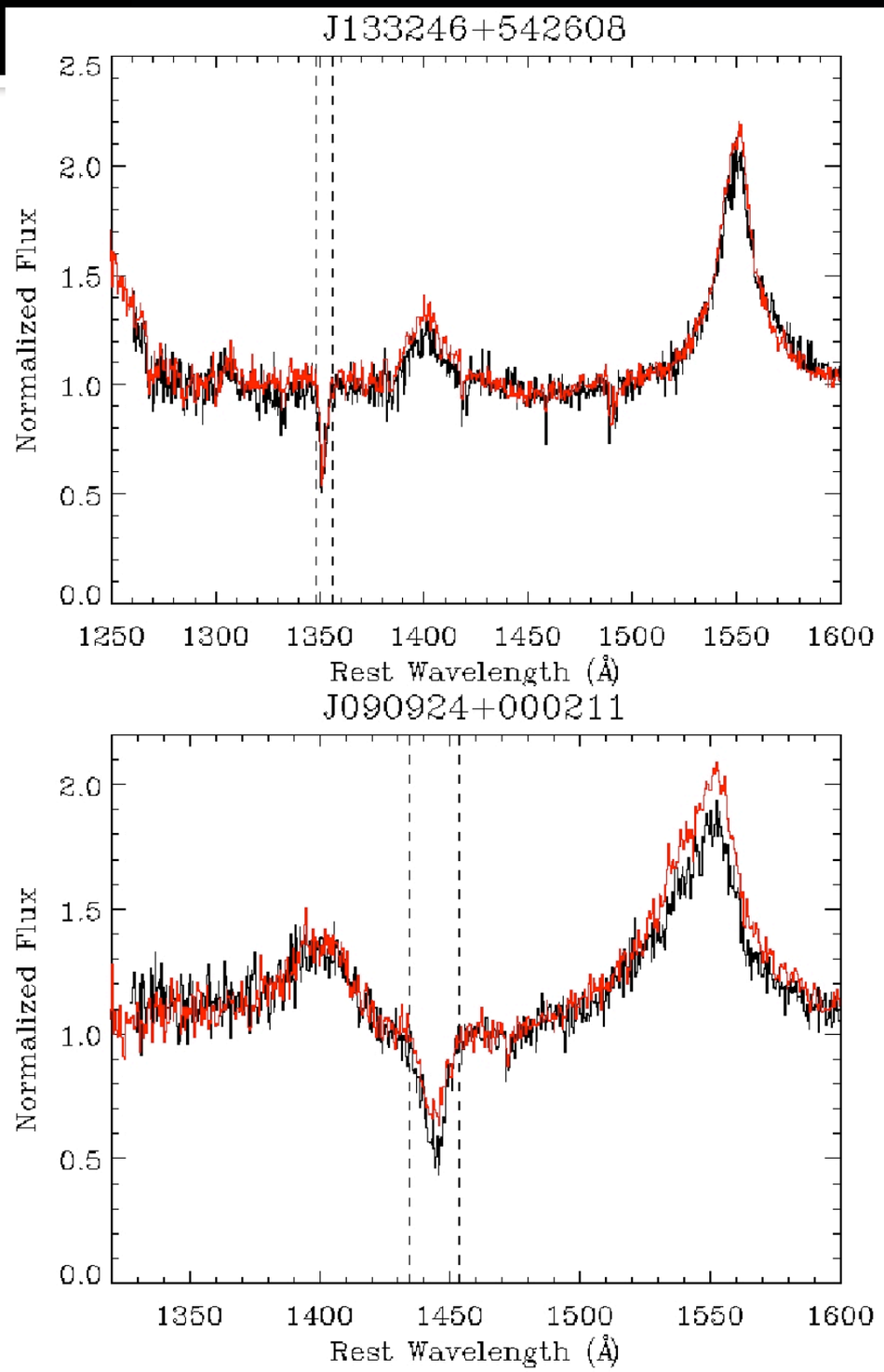
- KPNO 2.1m : R~200 km s^{-1}, λ~3600-6200 A (collaboration with Daniel Nestor & Daniel Capellupo)

- MDM 2.4m : R~230 km s^{-1} , f.e., λ~3600-5200 A (collaboration with Joseph Shields)

- Report of two observations of 26 quasars SDSS + (KPNO or MDM)

- 39 CIV absorption systems including mini-BALs, BALs and NALs in the same spectra

Variability Study: some results



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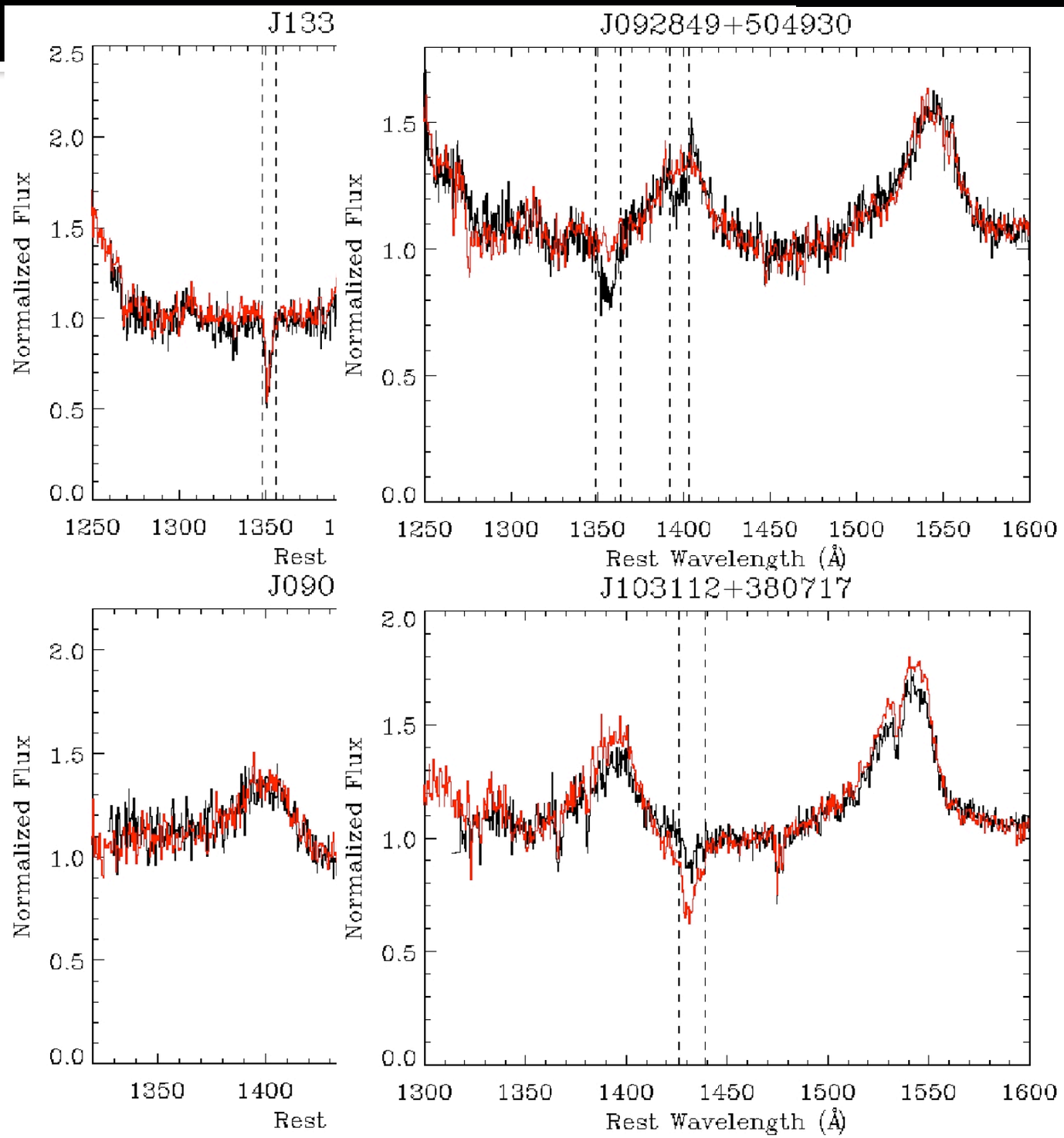

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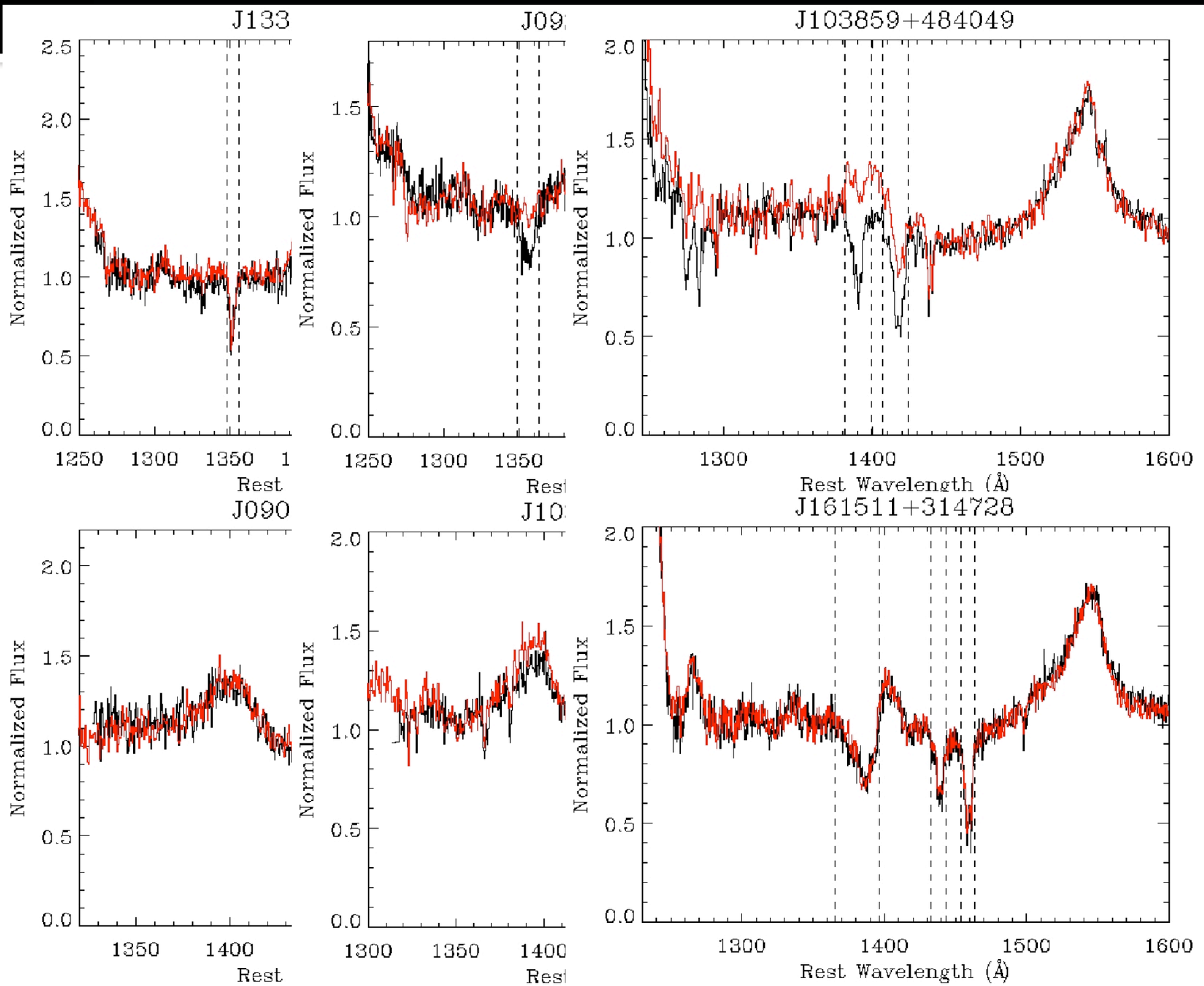

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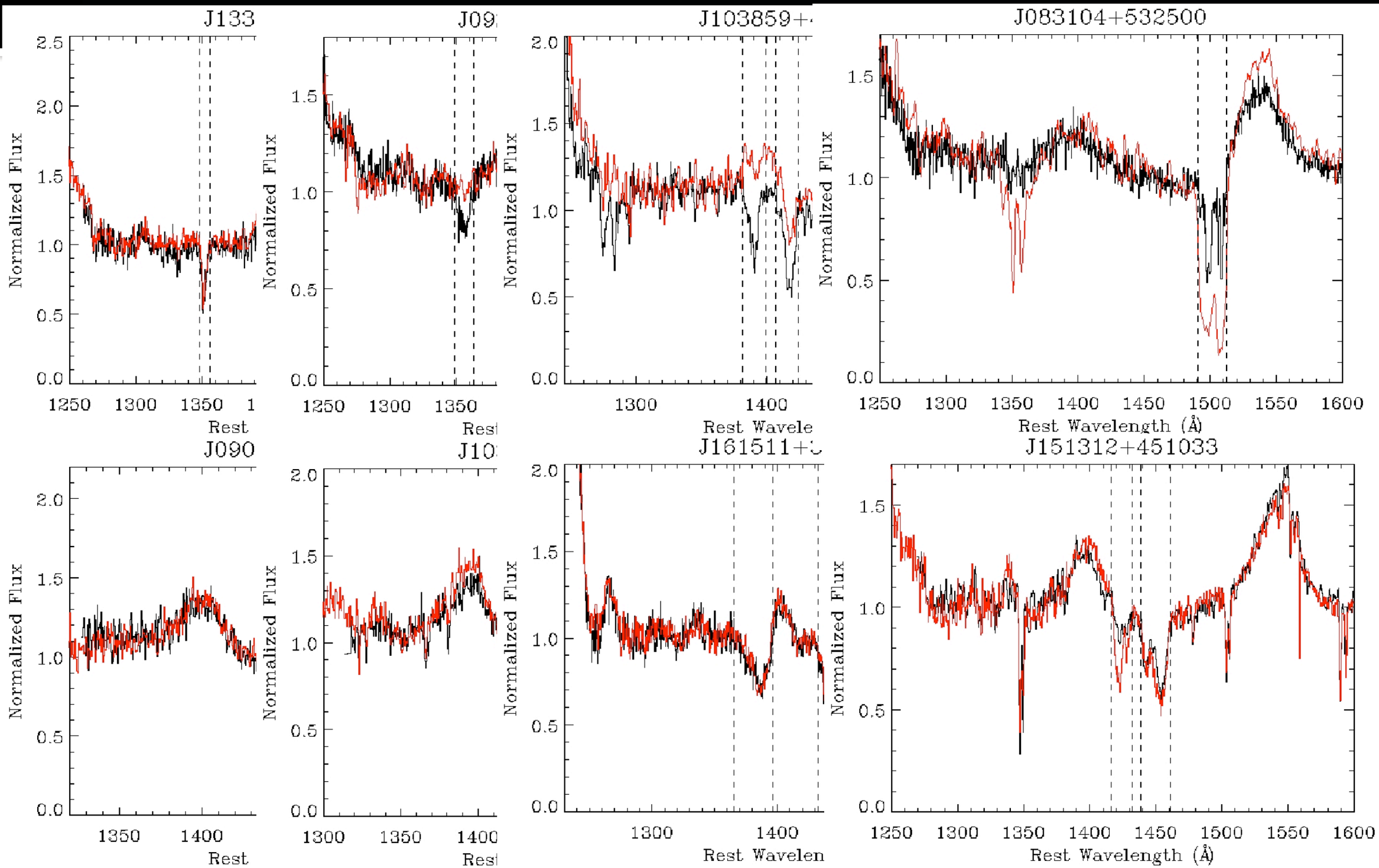

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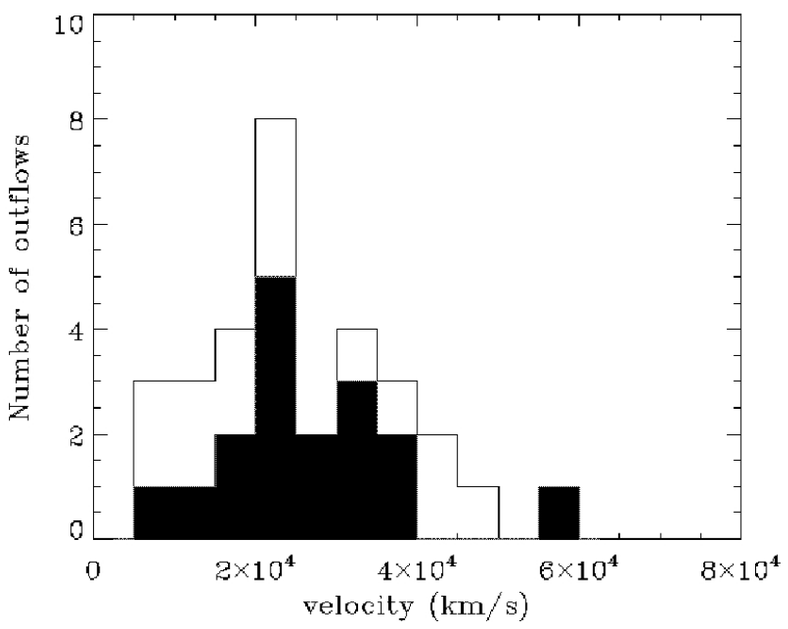
- 57% of the quasar spectra included an absorption trough that varied

- 49% out of the 39 studied CIV absorption lines in our sample vary over a range of
  Δt = 0.9 - 3.3 years in the rest-frame

- No trend with velocity



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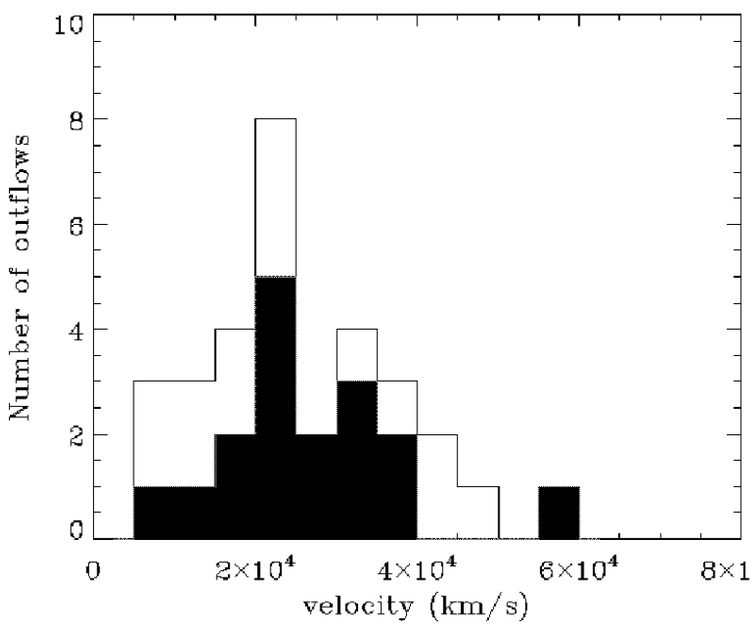

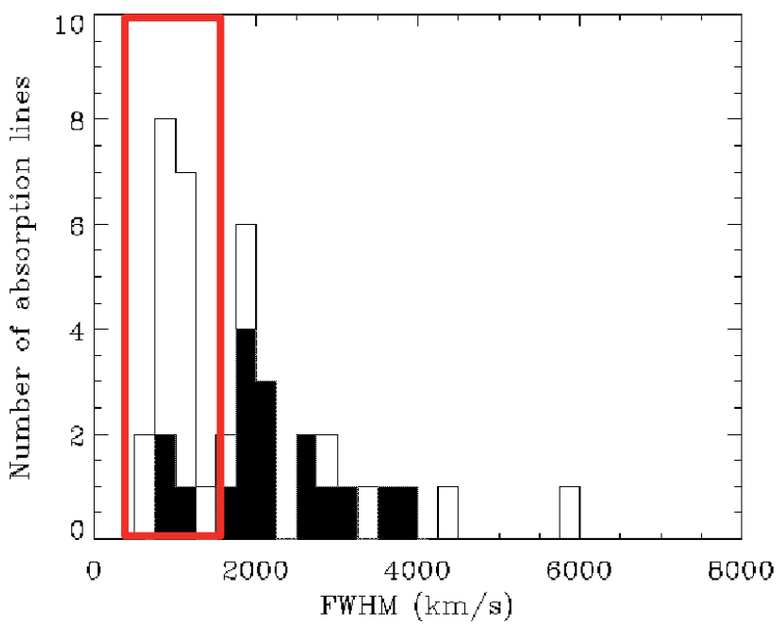

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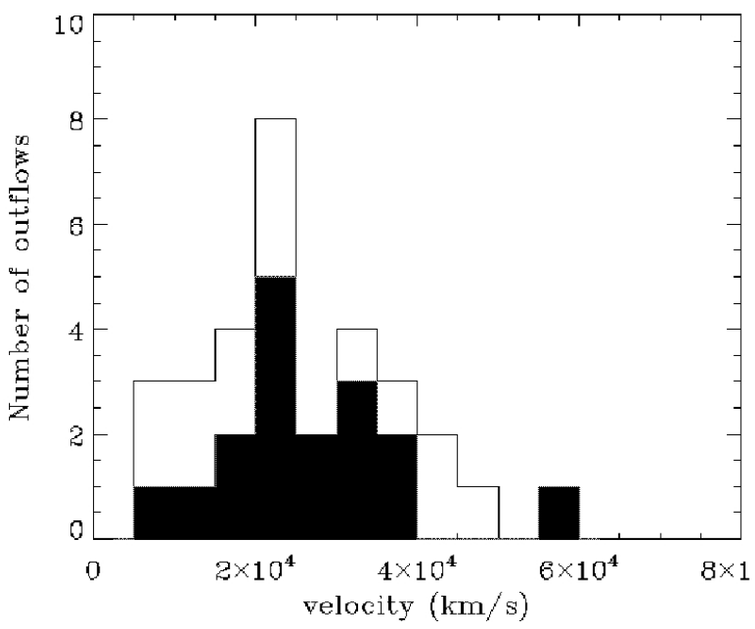
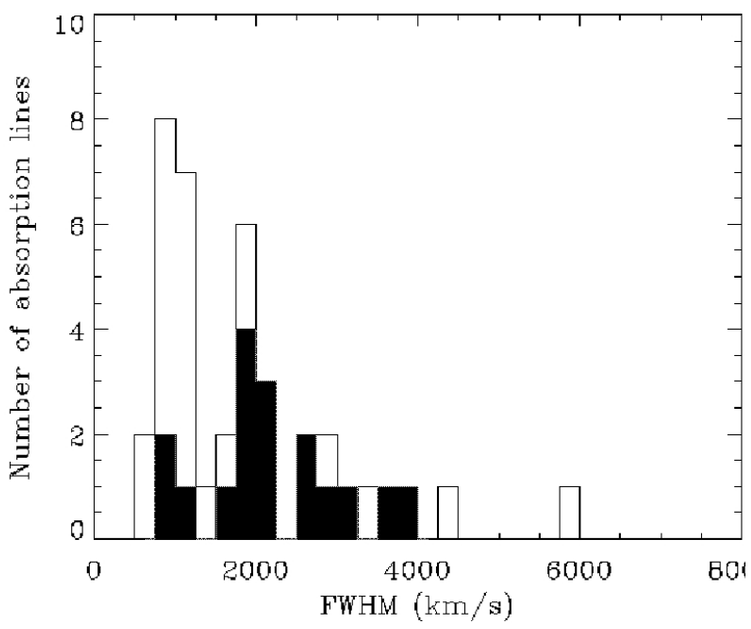
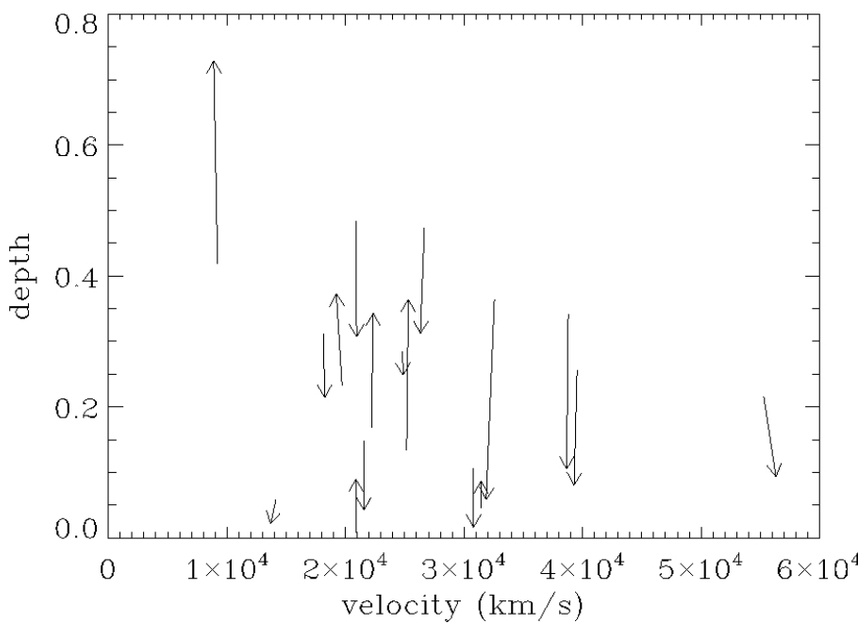
- The narrow systems vary less

- No acceleration/deceleration clear in any case, but variability is complex







Variability Monitoring Program

Location, location, location... what's causing the variability? (PG0935+417)

a) changes in the ionizing flux?

t_{var} ~ 1 yr > $\tau_{rec} \sim \frac{1}{\alpha_r n_e}$ ⇒ $n_e \sim n_H \geq 1.1 \times 10^{-4}$ cm^{-3} ⇒ $U = \frac{L}{n_H r^2}$ ⇒ $r \leq 1.2$ kpc

so better constraints on the t_{var} will lead to better constraints in distances (keep on giving us observing time, please)

b) motion of clouds across the line of sight?

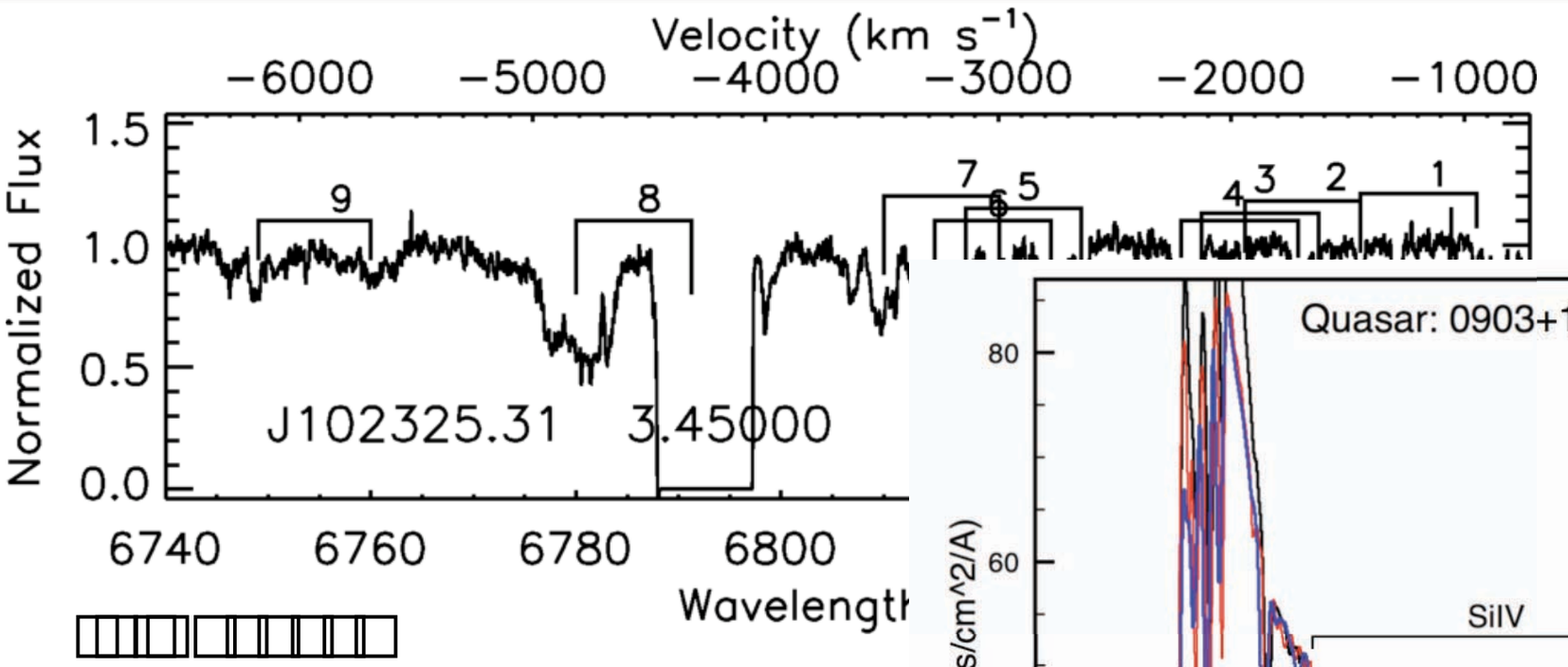
$D_{1300} \sim 0.02$ pc ⇒ $v_{trans} \sim 10{,}000$ km s^{-1} ⇒ $r \leq 0.9$ pc

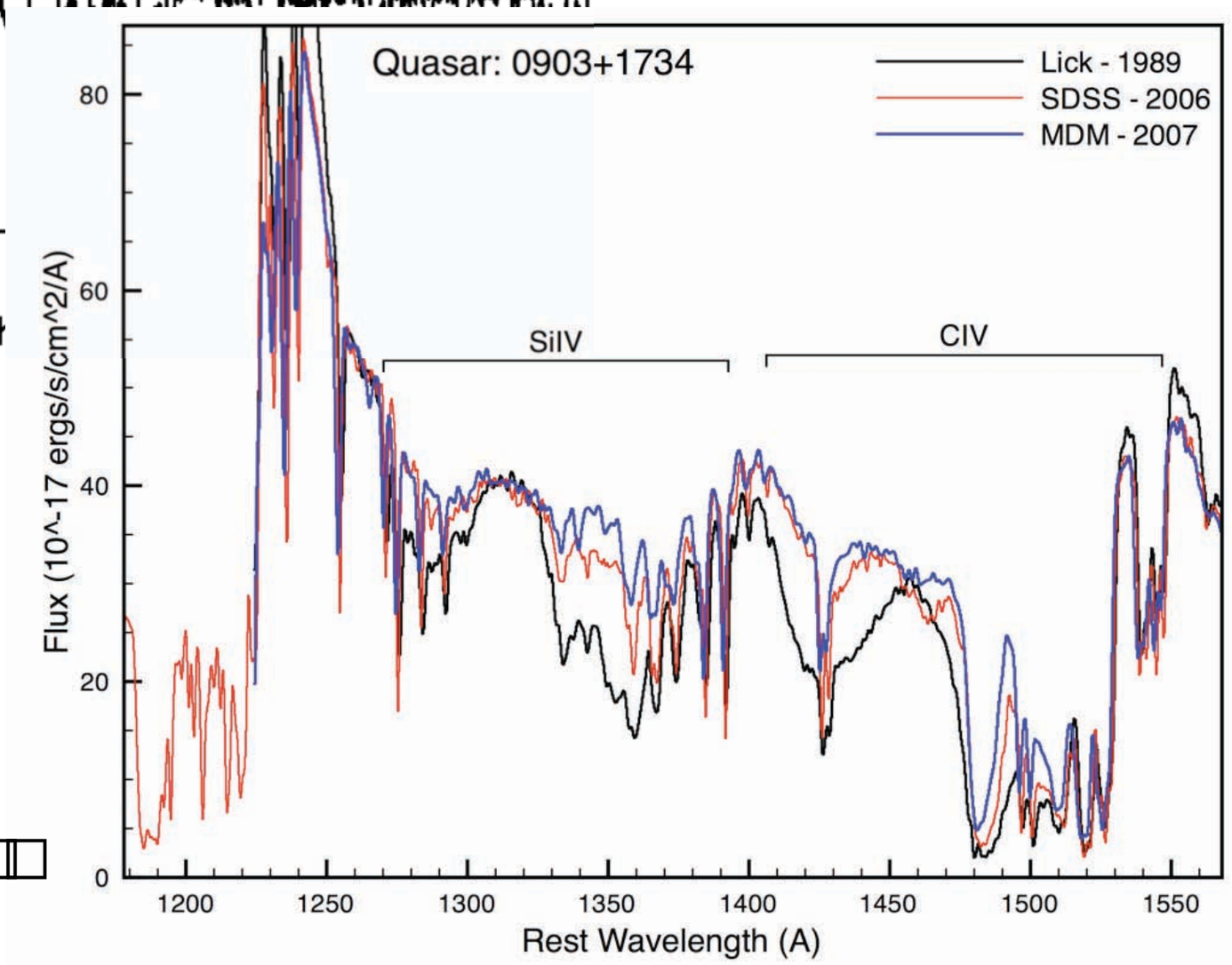
57% of quasars show some variability in at least 1 abs. profile

65% of BALQSOs change between 2 observations (Capellupo+11)

Evolution: mini-BALs are turning into BALs and mini-BALs into BALs!

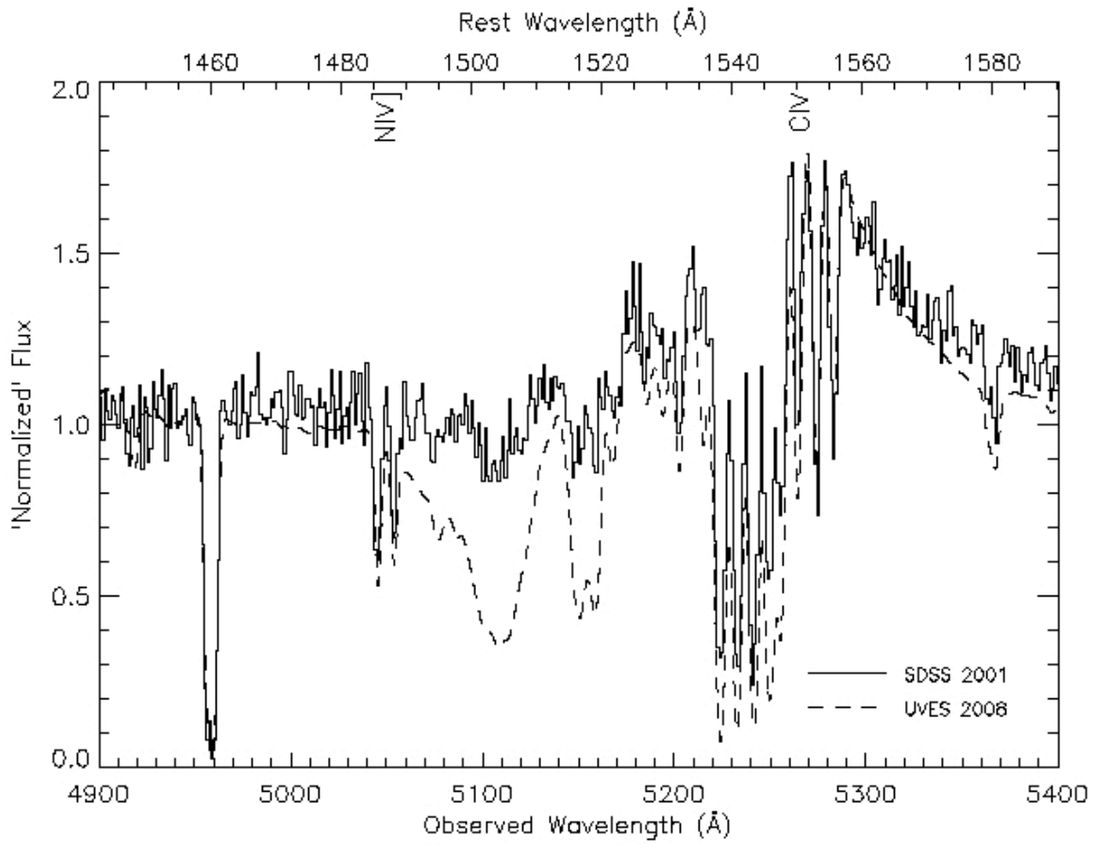
Already presented:
BALs and NALs

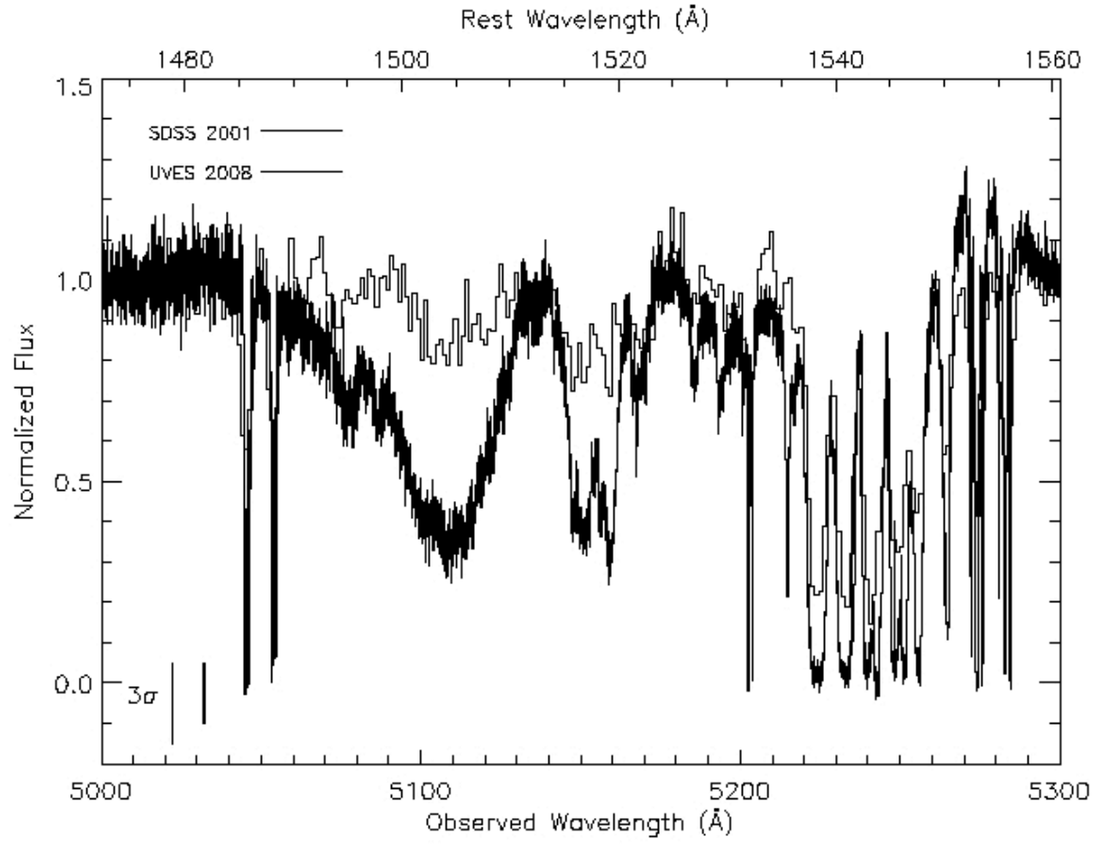




Variability Monitoring Program

Cross-correlation of our SDSS sample to VLT/UVES archival spectra.





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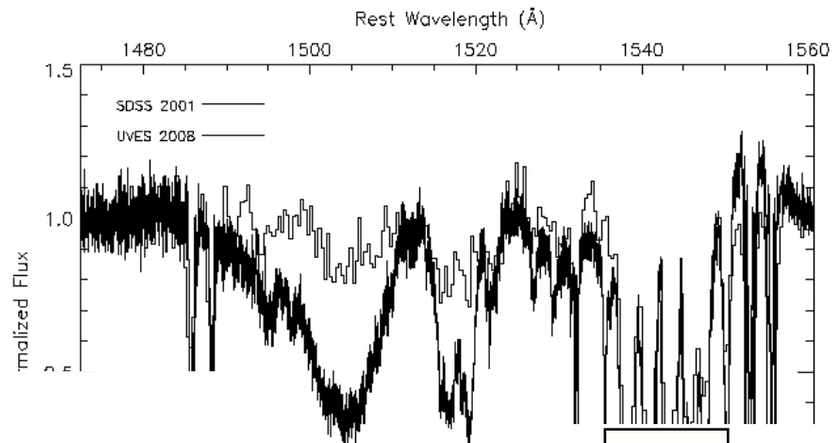
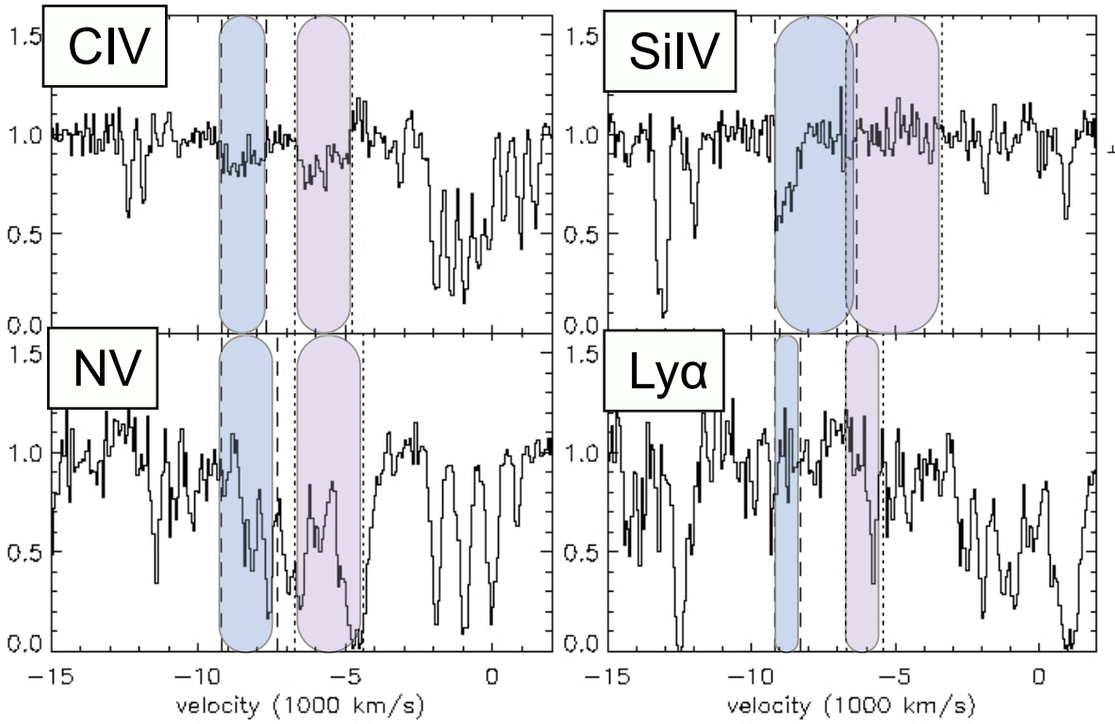
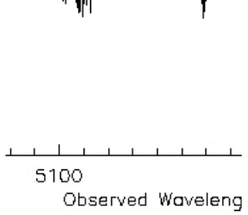
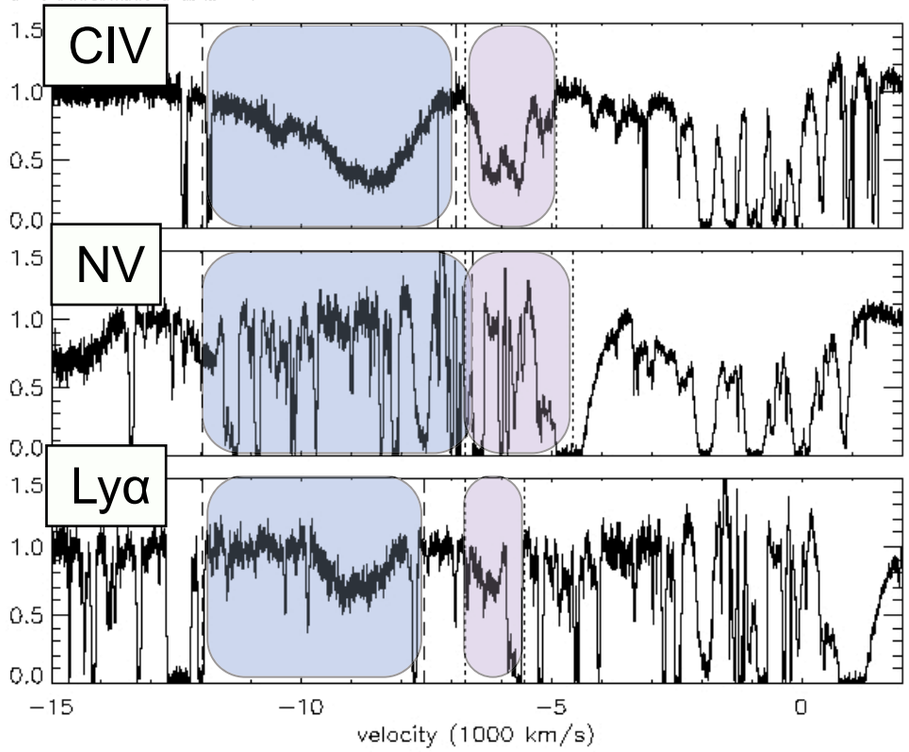


SDSS





VLT/UVES



Conclusions

- High velocity outflows and mini-BALs are another part of the outflow phenomena

- Variability is complex, emergences, disappearances, increasing/decreasing depths, but no clear acceleration or deceleration

- Constraints do not allow for distinction between causes for the variability so far, but we need close monitoring

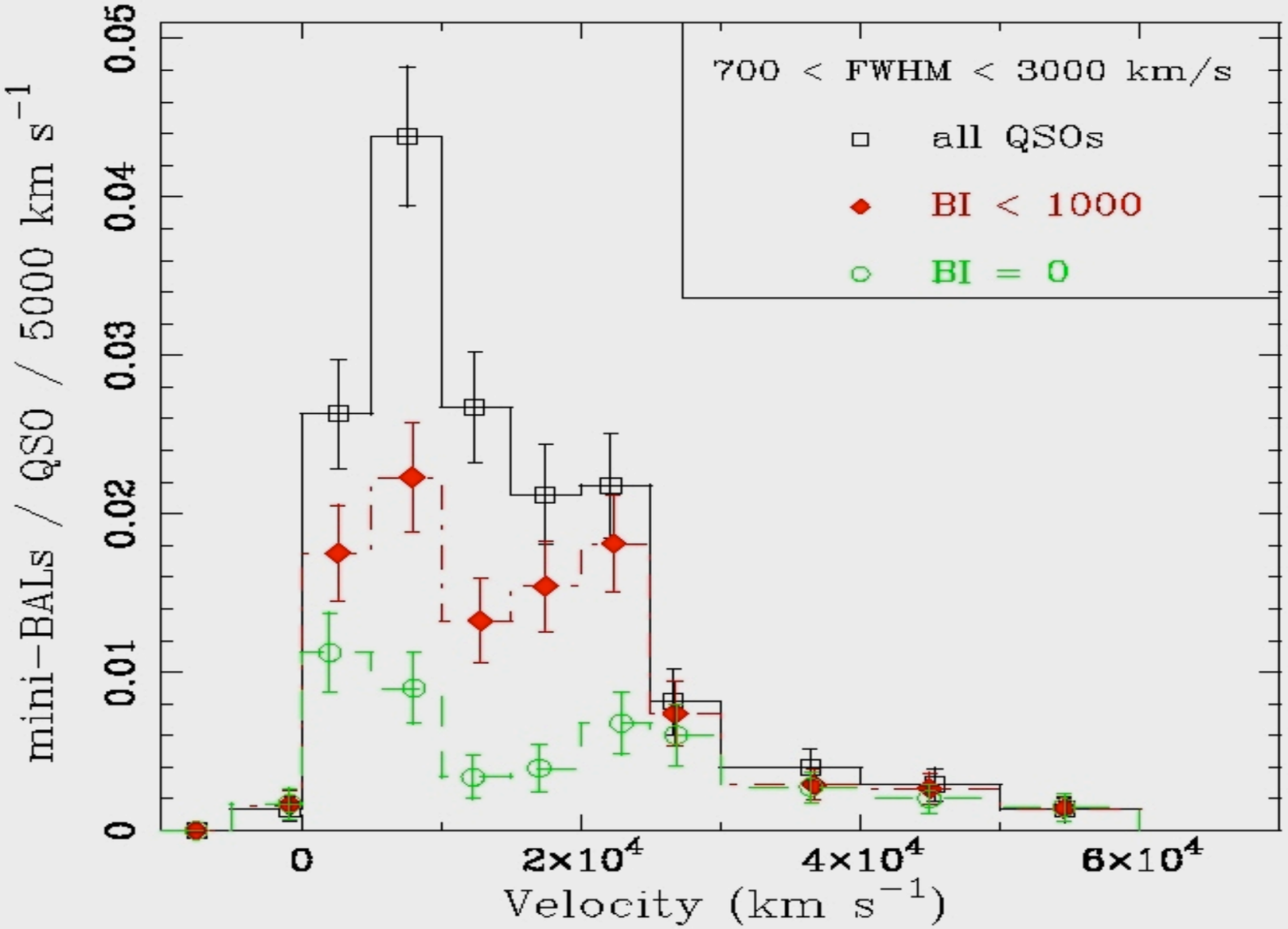
- No trends found with velocity

- Narrow systems seems to vary less frequently

- Evolution: BALs become mini-BALs and mini-BALs become BALs.

Thank you!

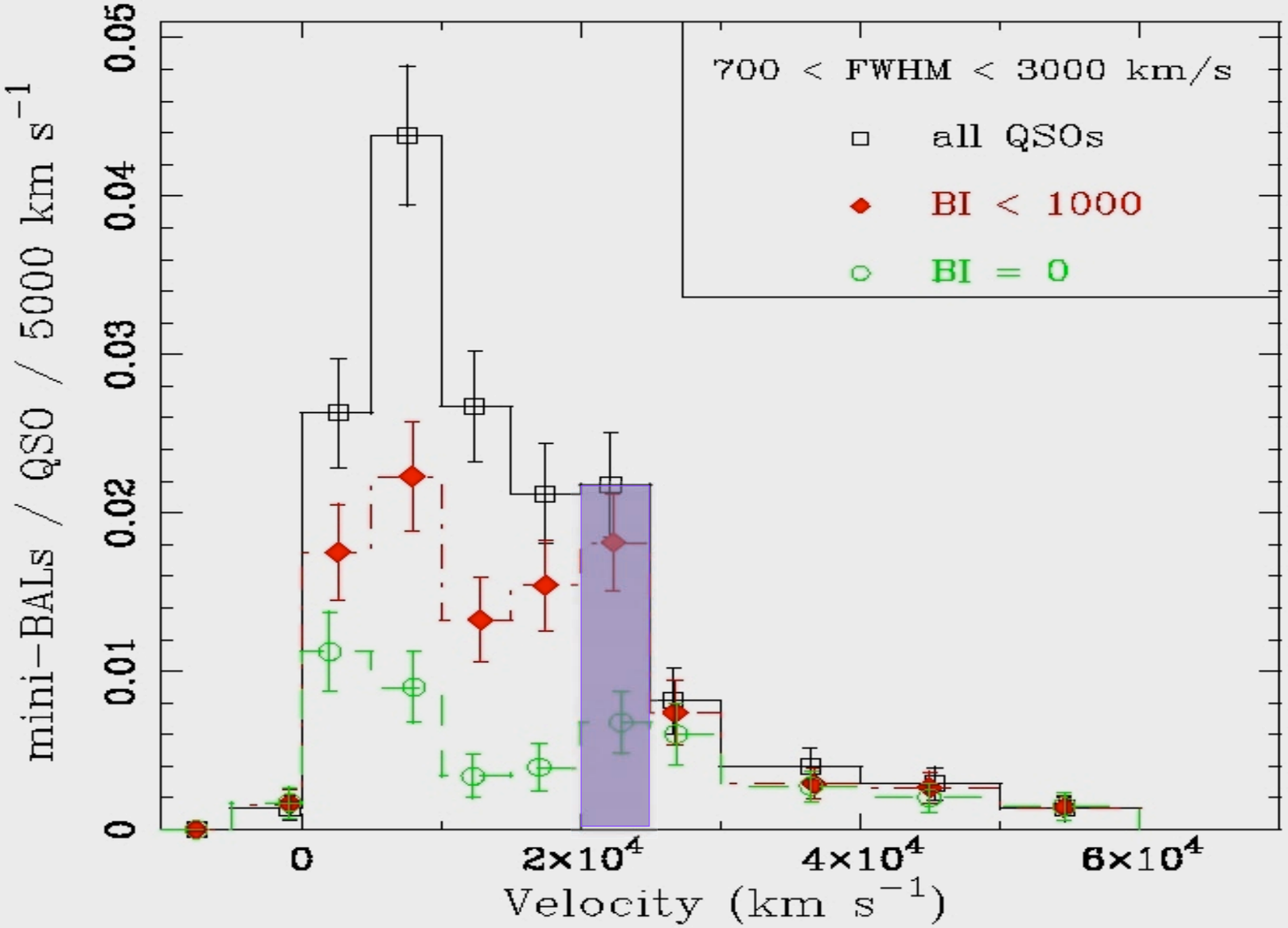
Mini-BALs found



We find:

- mini-BALs are present in 11.4% of quasars
- BALs are present in 10.7% (similar as previous studies: Reichard et al. 2003, Trump et al. 2006)
- 2.9% of quasars include outflows at v>25000 km/s
- BALs and mini-BALs coexist in some spectra

Mini-BALs found



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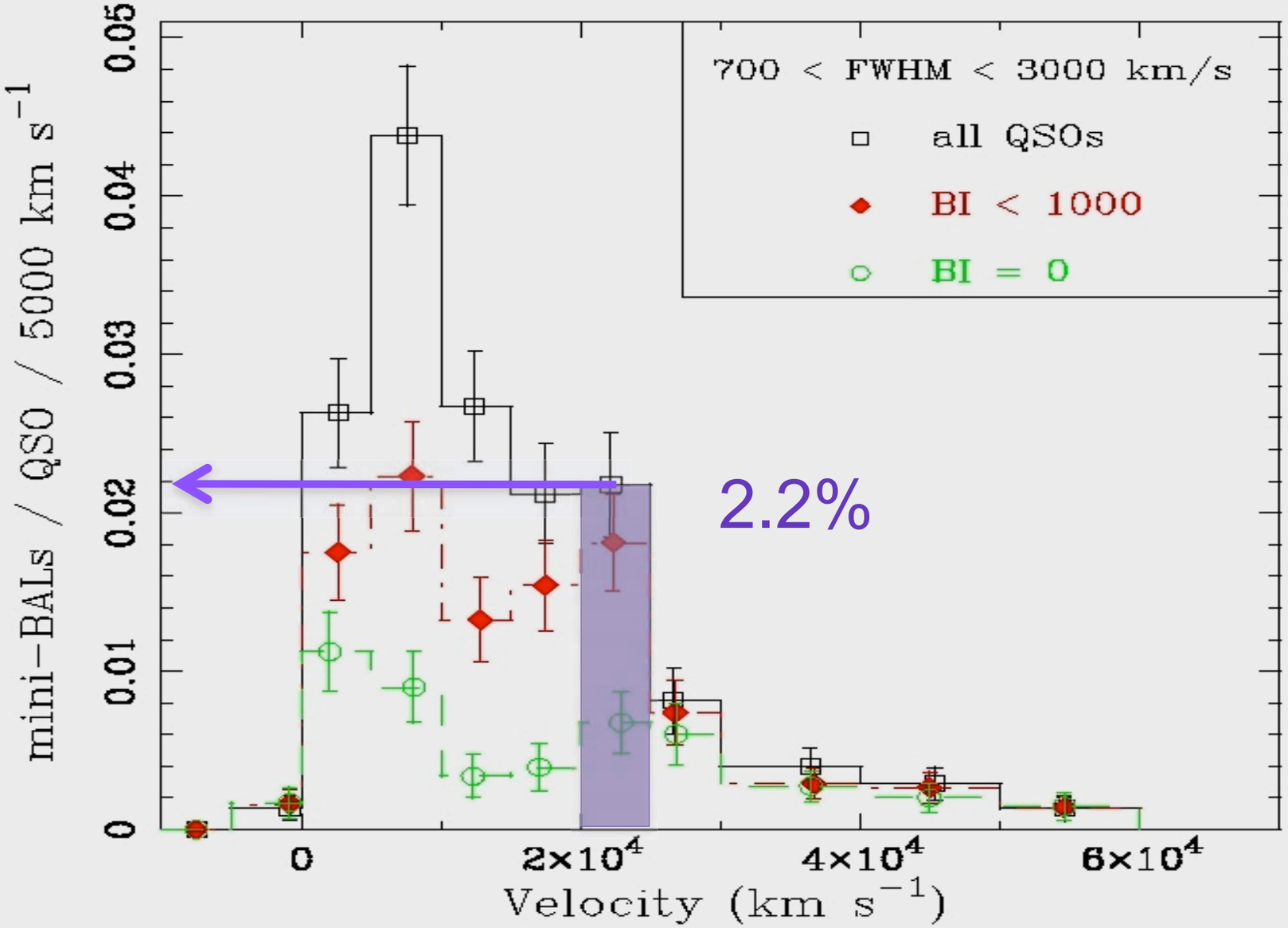

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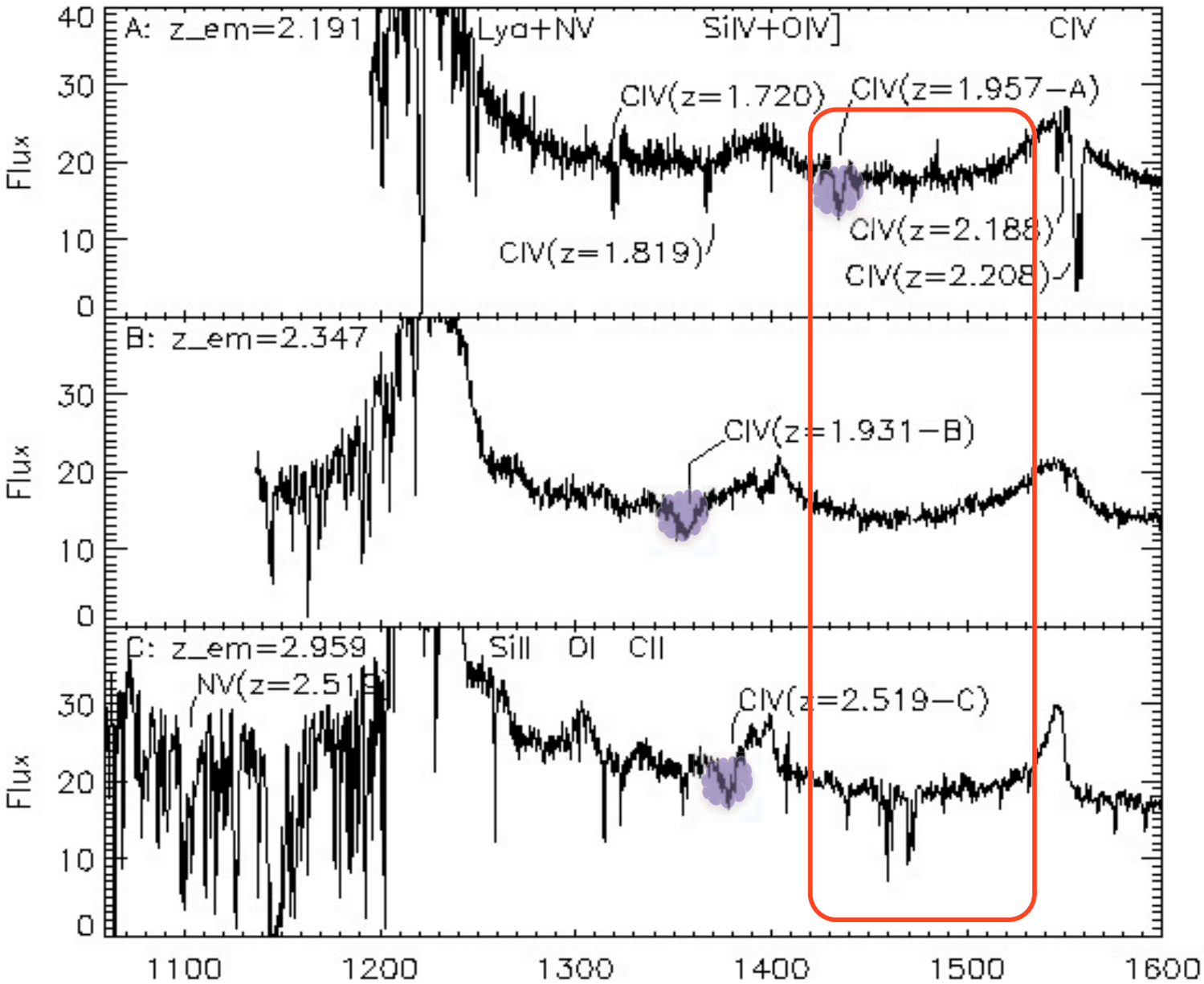
BALs



Balnicity Index (BI)