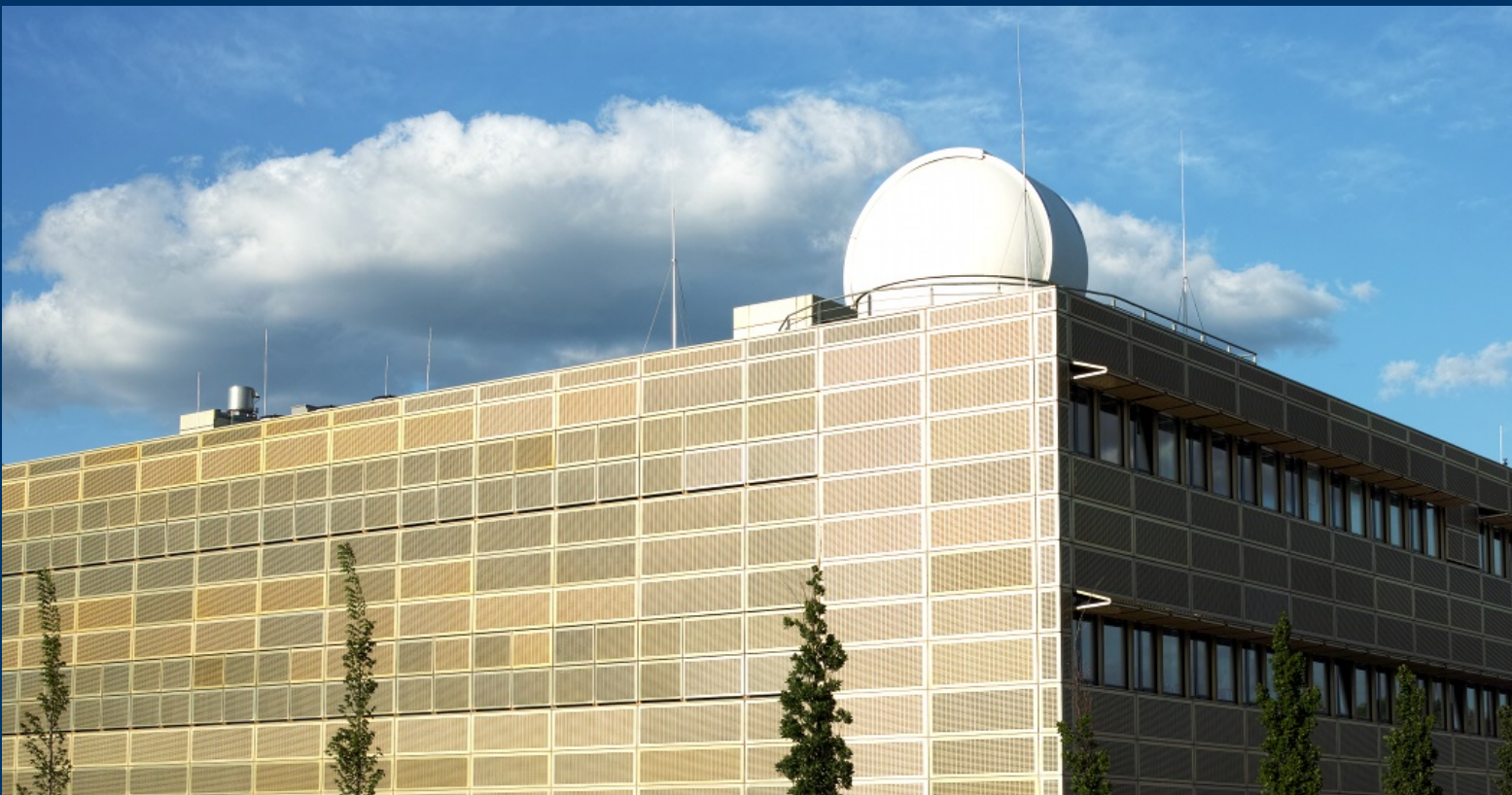


Current and future limits of QSO analysis

Martin Wendt
10.07.2013

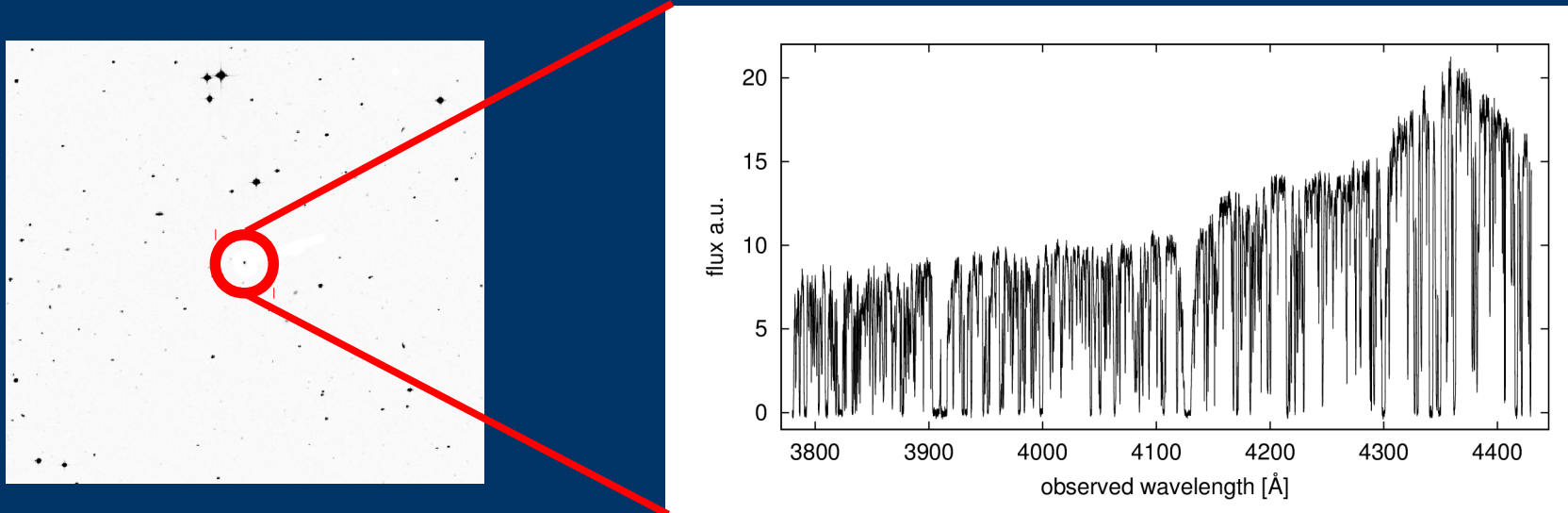


University of Potsdam

“Varying fundamental constants and dynamical dark energy”
08.07.2013 – 13.07.2013, Sexten

Current and future limits of QSO analysis

Martin Wendt
10.07.2013



QSO 0347-383

“Varying fundamental constants and dynamical dark energy”

08.07.2013 – 13.07.2013, Sexten

Current and future limits of QSO analysis

Why QSO 0347 and why $\Delta\mu/\mu$?

Current and future limits of QSO analysis

Why $\Delta\mu/\mu$?

PRL 96, 151101 (2006)

PHYSICAL REVIEW LETTERS

week ending
21 APRIL 2006

Indication of a Cosmological Variation of the Proton-Electron Mass Ratio Based on Laboratory Measurement and Reanalysis of H₂ Spectra

E. Reinhold,¹ R. Buning,¹ U. Hollenstein,^{1,2} A. Ivanchik,³ P. Petitjean,^{4,5} and W. Ubachs^{1,*}

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³*Ioffe Physical Technical Institut, Polytekhnicheskaya 26, 194021 Saint Petersburg, Russia*

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⁵*LERMA, Observatoire de Paris, 61 avenue de l'Observatoire, F-75014 Paris, France*

(Received 13 May 2005; revised manuscript received 6 October 2005; published 17 April 2006)

Based on highly accurate laboratory measurements of Lyman bands of H₂ and an updated representation of the structure of the ground $X^1\Sigma_g^+$ and excited $B^1\Sigma_u^+$ and $C^1\Pi_u$ states, a new set of sensitivity coefficients K_i is derived for all lines in the H₂ spectrum, representing the dependence of their transition wavelengths on a possible variation of the proton-electron mass ratio $\mu = m_p/m_e$. Included are local perturbation effects between B and C levels and adiabatic corrections. The new wavelengths and K_i factors are used to compare with a recent set of highly accurate H₂ spectral lines observed in the Q 0347-383 and Q 0405-443 quasars, yielding a fractional change in the mass ratio of $\Delta\mu/\mu = (2.4 \pm 0.6) \times 10^{-5}$ for a weighted fit and $\Delta\mu/\mu = (2.0 \pm 0.6) \times 10^{-5}$ for an unweighted fit. This result indicates, at a 3.5σ confidence level, that μ could have decreased in the past 12 Gyr.

(Reinhold et al. 2006)

Current and future limits of QSO analysis

Why $\Delta\mu/\mu$?

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Indication of a Cosmological Variation of the Proton-Electron Mass Ratio Based on Laboratory Measurement and Reanalysis of H₂ Spectra

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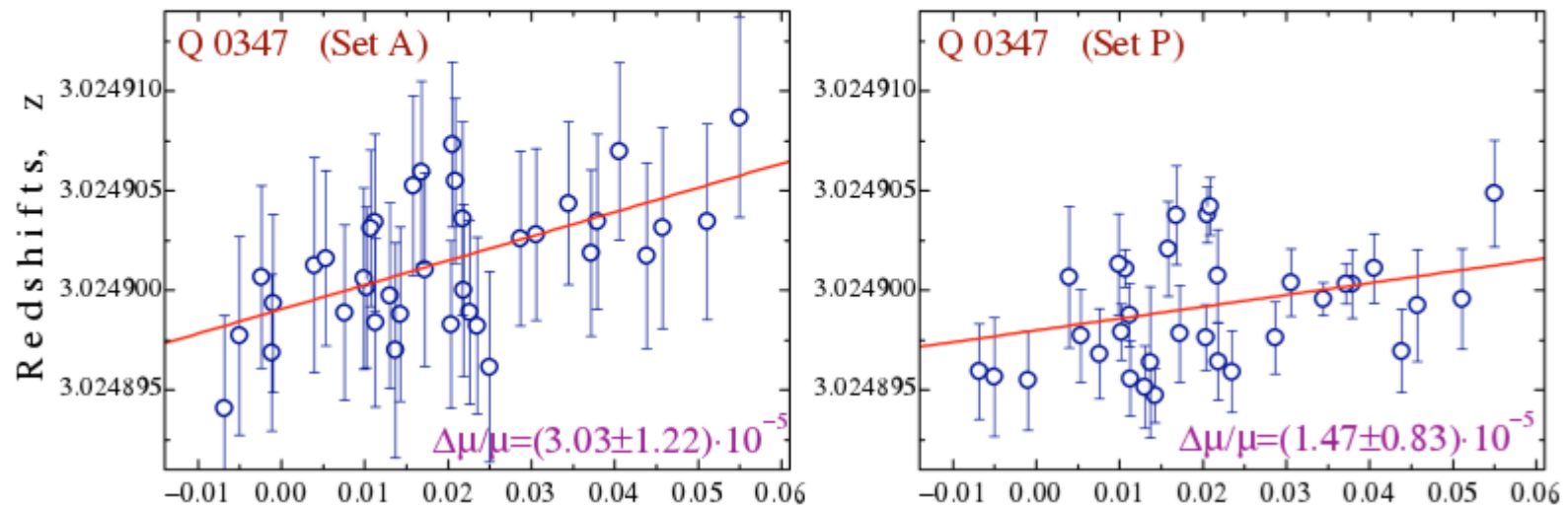
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(Reinhold et al. 2006)

Current and future limits of QSO analysis

Striking new laboratory data.
Former line positions.

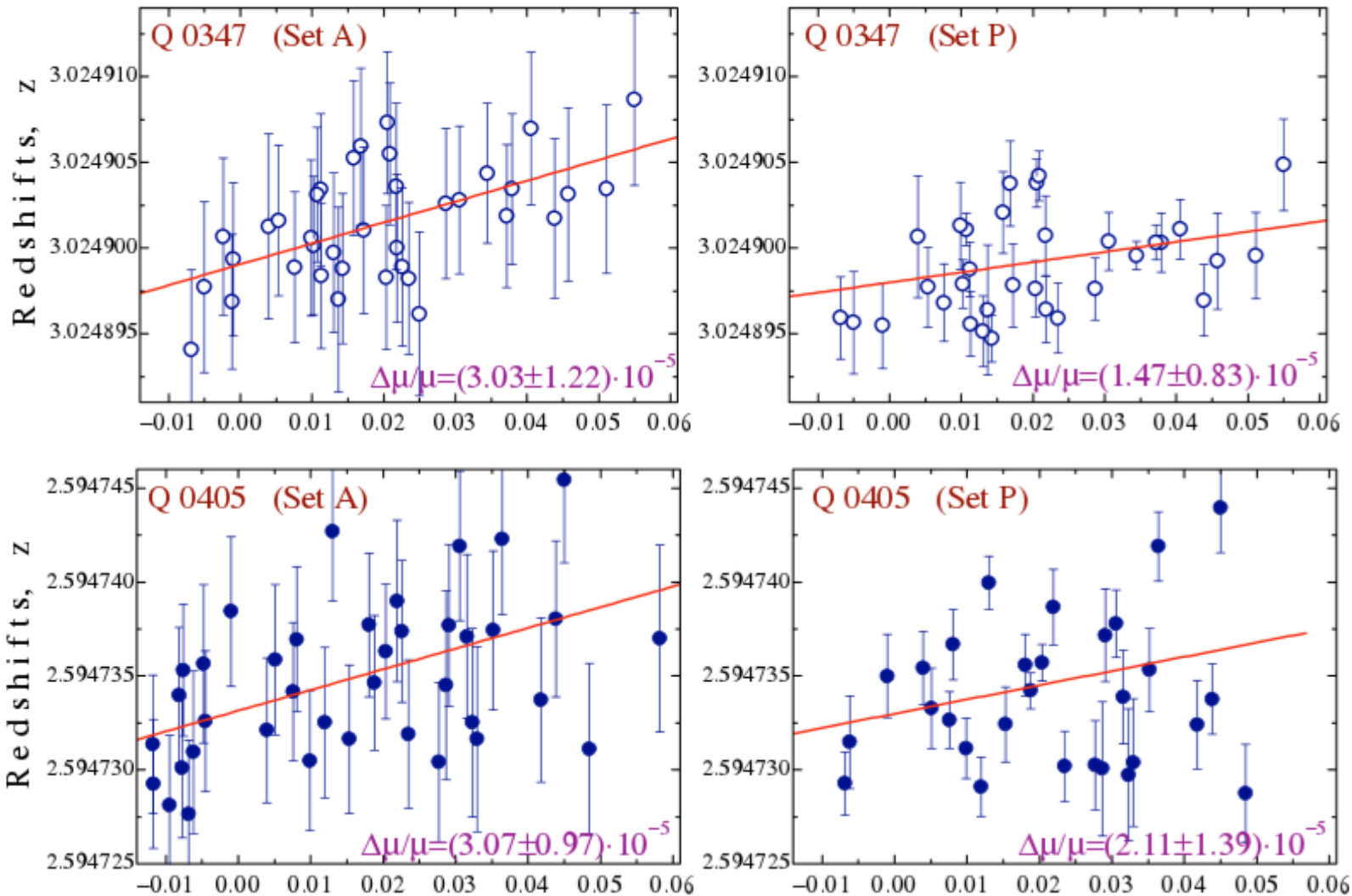
A. Ivanchik et al.: A new constraint on the time dependence of the proton-to-electron mass ratio



(Ivanchik et al. 2005)

Current and future limits of QSO analysis

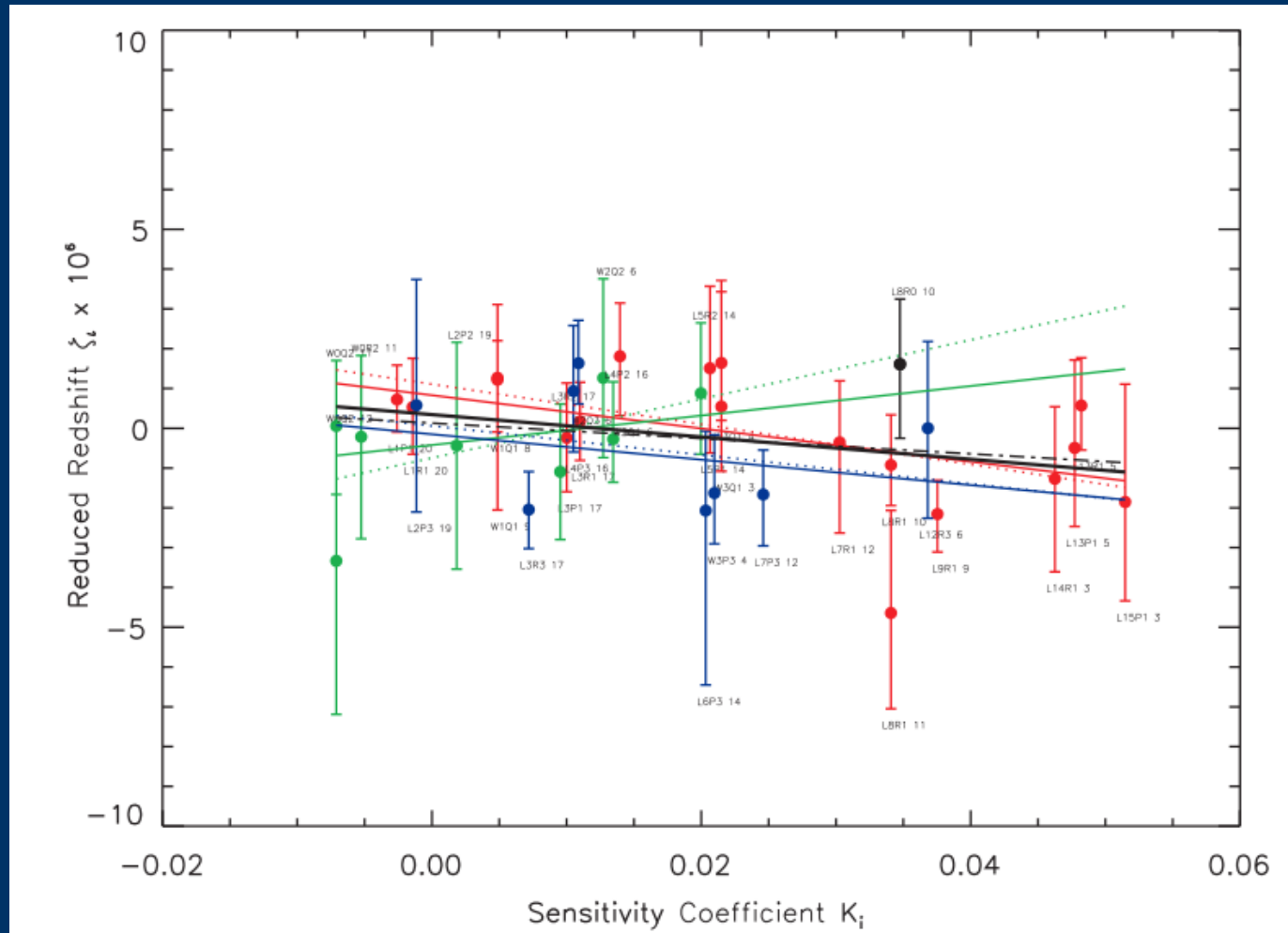
A. Ivanchik et al.: A new constraint on the time dependence of the proton-to-electron mass ratio



(Ivanchik et al. 2005)

Current and future limits of QSO analysis

QSO 0347-393 revisited many times over.

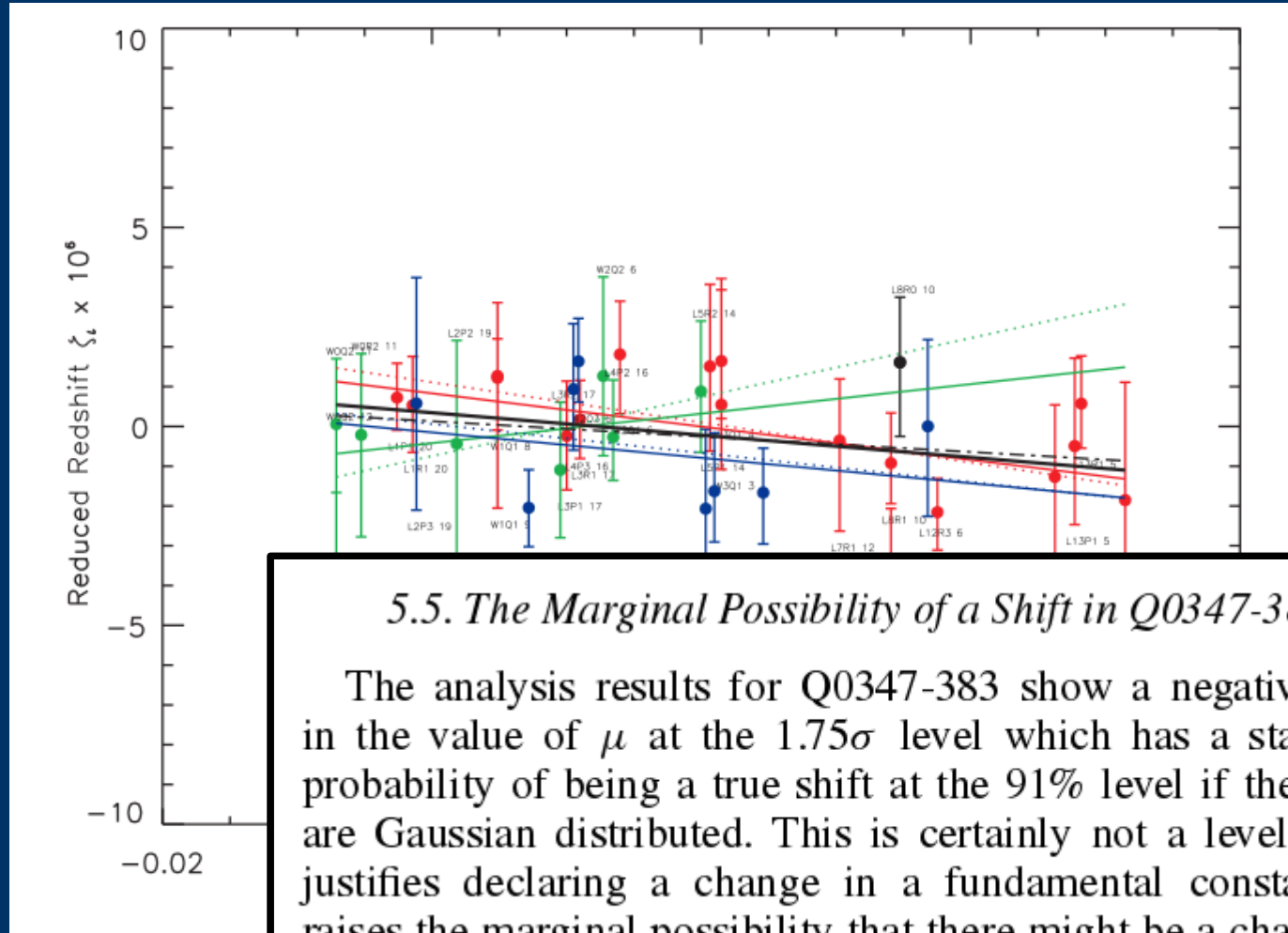


(Thompson et al. 2009)

Last result based on the identical data.

Current and future limits of QSO analysis

QSO 0347-393 revisited many times over.



5.5. The Marginal Possibility of a Shift in Q0347-383

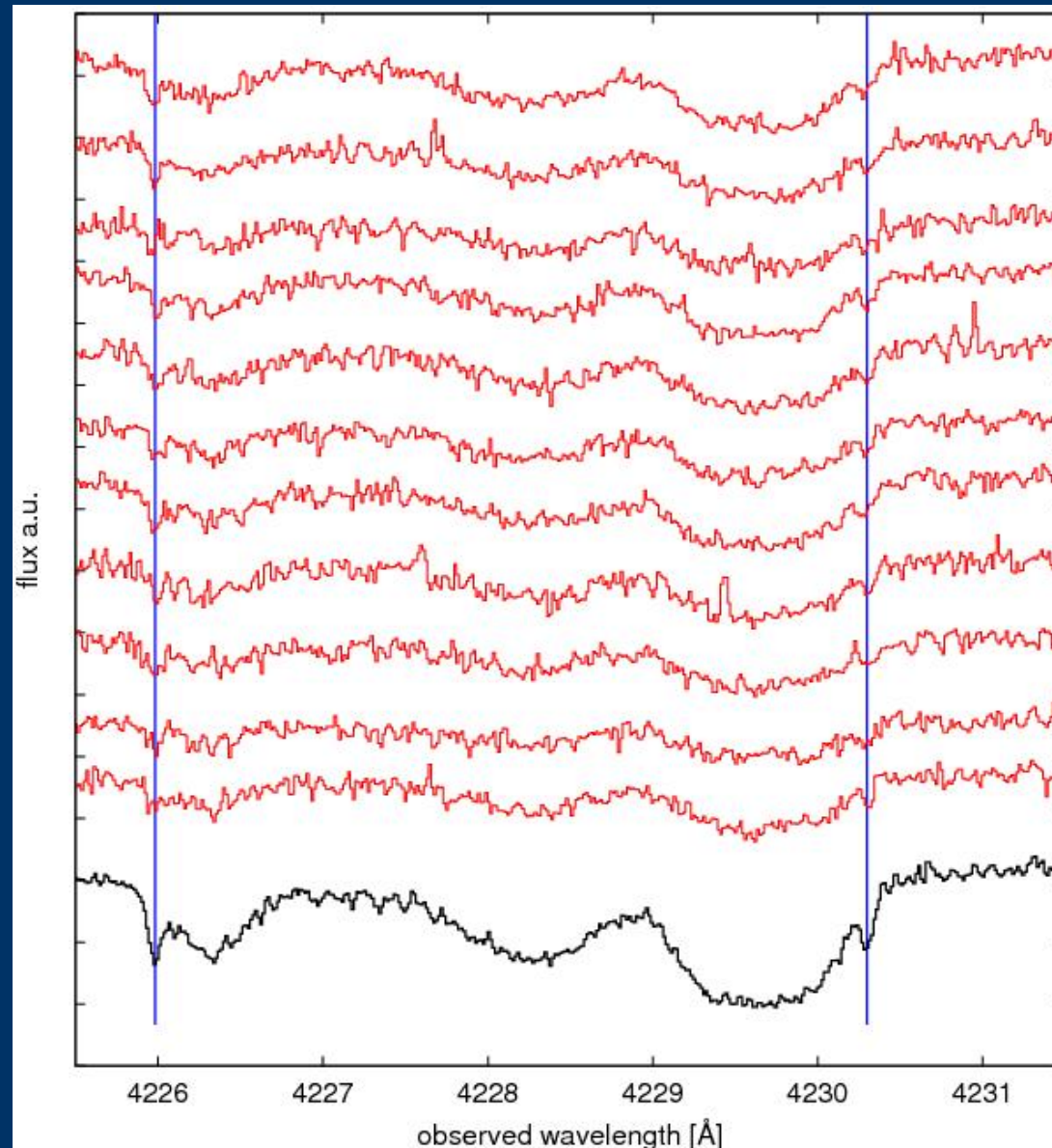
The analysis results for Q0347-383 show a negative shift in the value of μ at the 1.75σ level which has a statistical probability of being a true shift at the 91% level if the errors are Gaussian distributed. This is certainly not a level which justifies declaring a change in a fundamental constant but raises the marginal possibility that there might be a change. In

(Thompson et al. 2009)

Last result based on the identical data.

Current and future limits of QSO analysis

New data of QSO 0347 taken in 2009.



(Wendt & Molaro 2012)

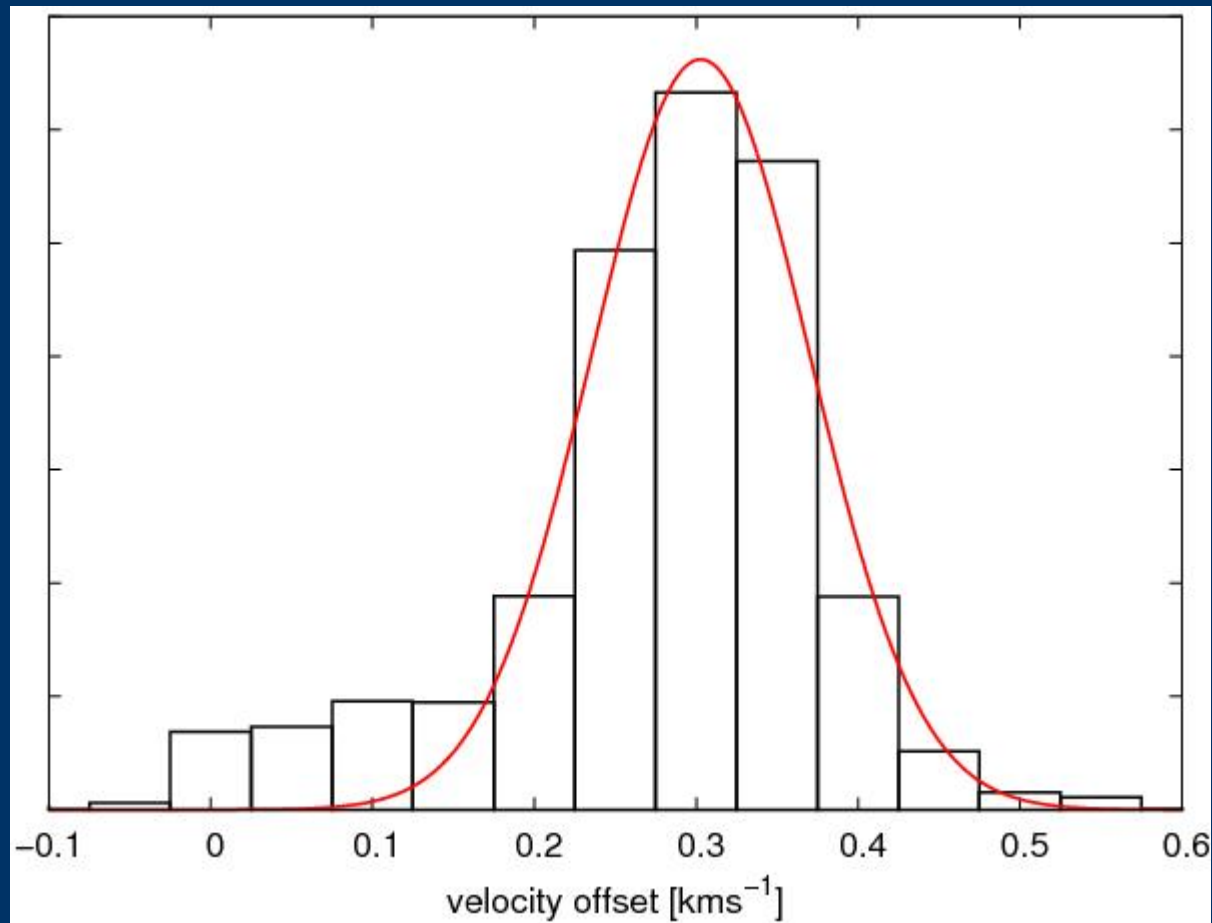
Current and future limits of QSO analysis

Changes for the new data:

- attached calibration frames
- improved pipeline / ThAr line lists
- no 2x2 binning, $R \sim 66.000$
- Temperature drift ~ 0.2 K, < 50 m/s (0.3 K)
- dealing with individual exposures

Current and future limits of QSO analysis

Consideration of mechanical drifts between exposures.

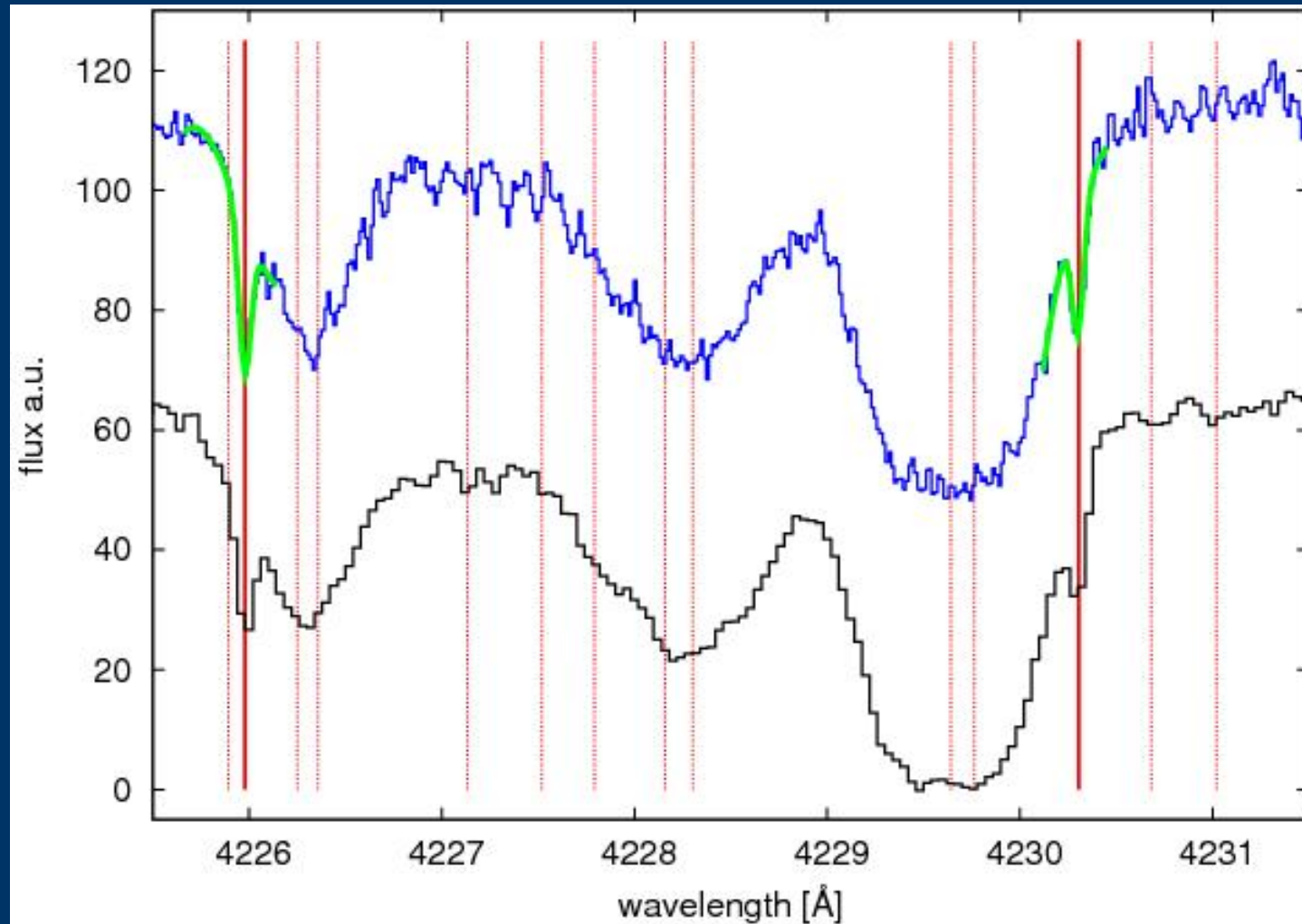


(Wendt & Molaro 2012)

Bootstrap over fit of 48 lines in a single spectrum.

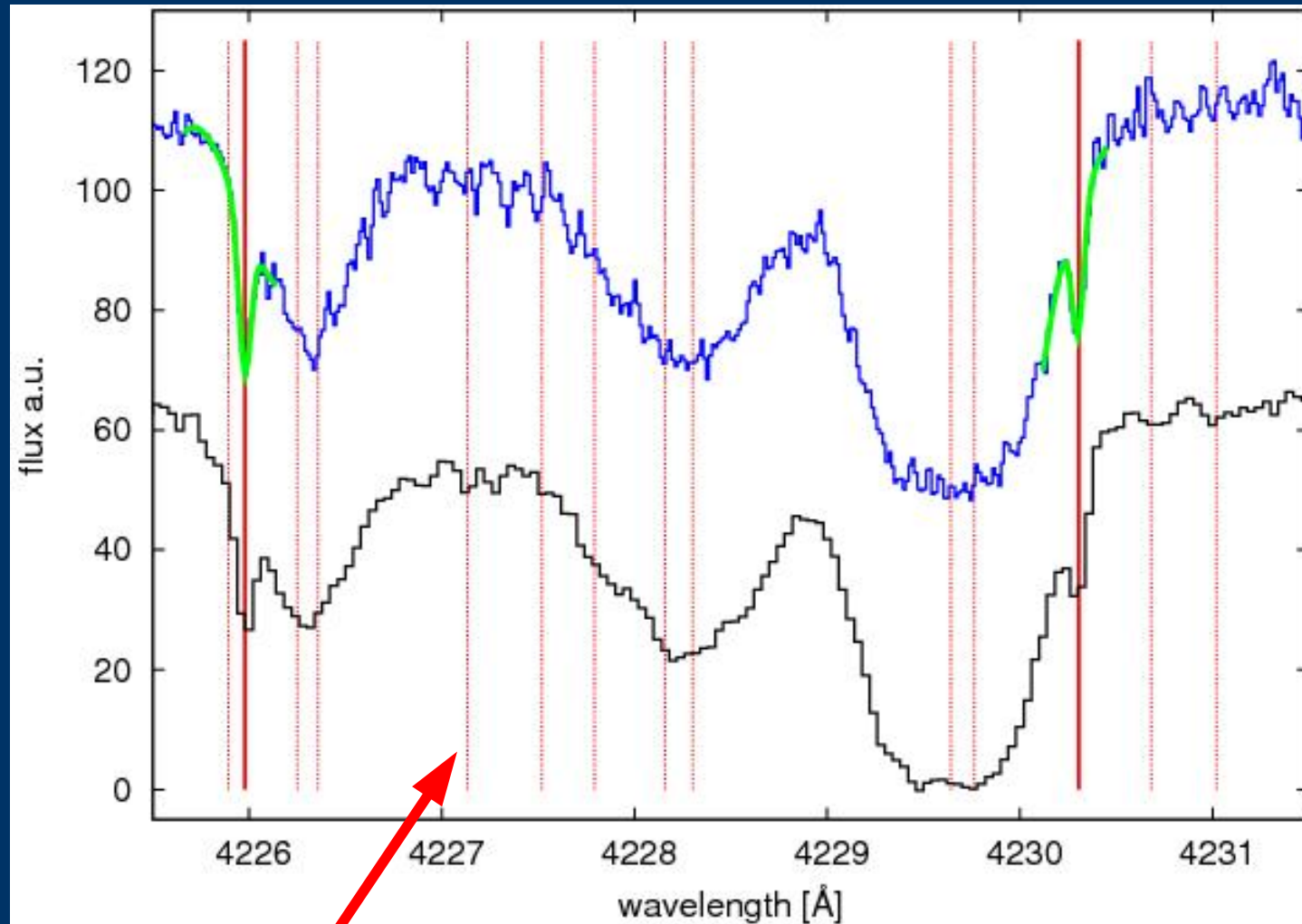
Current and future limits of QSO analysis

Comparison of former data set versus the 2009 data.



Current and future limits of QSO analysis

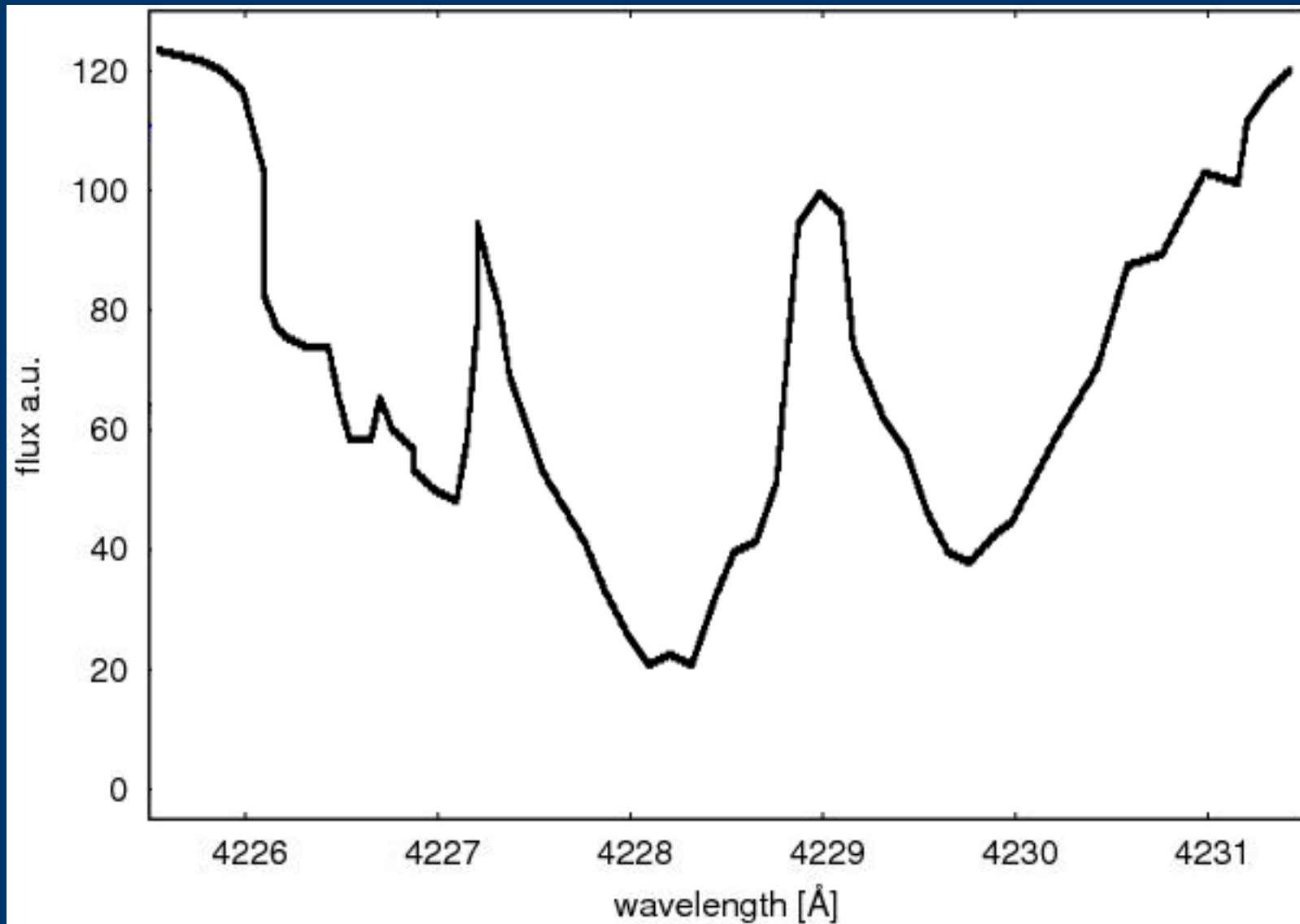
Comparison of former data set versus the 2009 data.



Multicomponent structure of *King et al. 2008*.

Current and future limits of QSO analysis

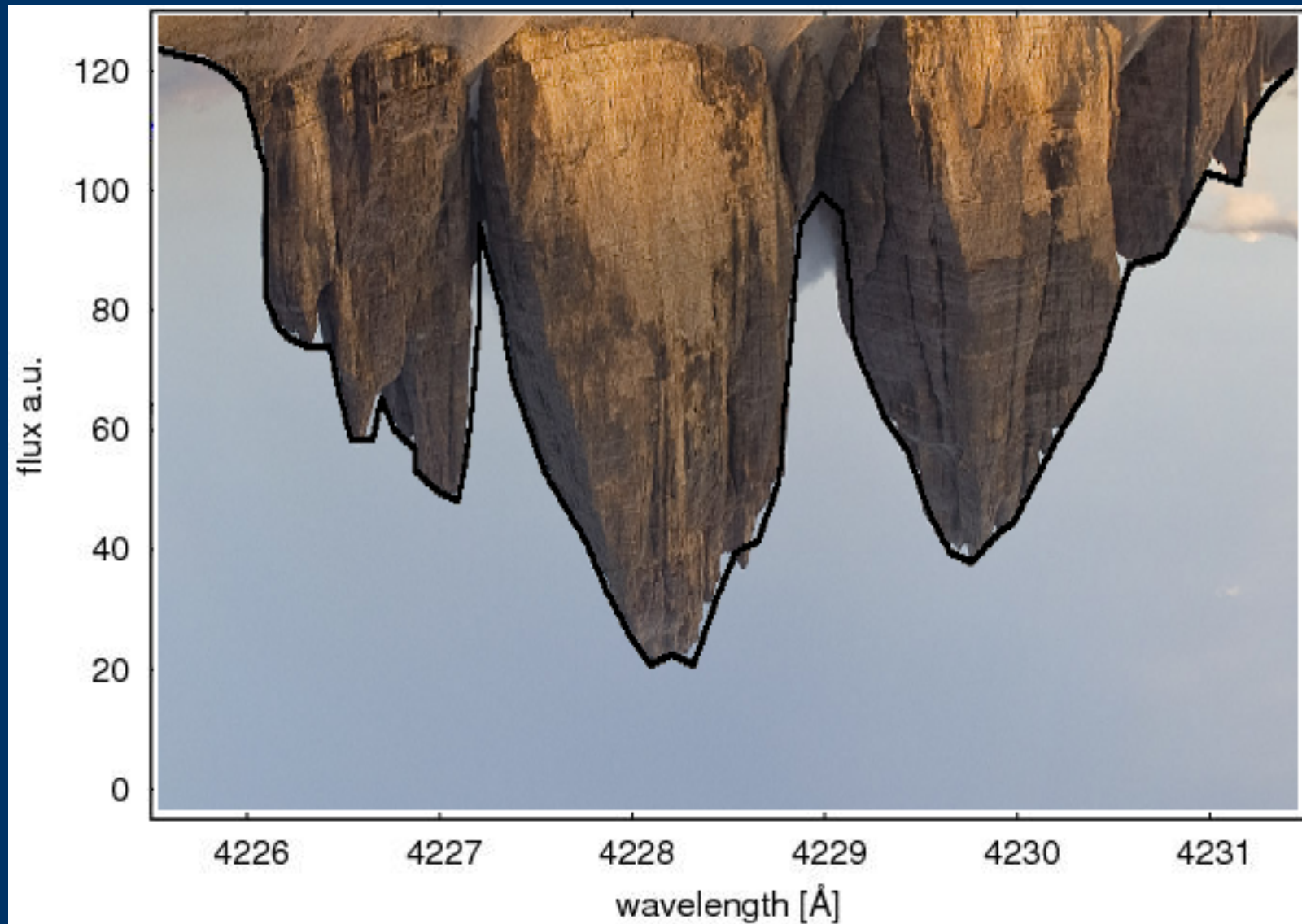
General limit of physical interpretation



How many and which components to fit?

Current and future limits of QSO analysis

General limit of physical interpretation



How many and which components to fit?

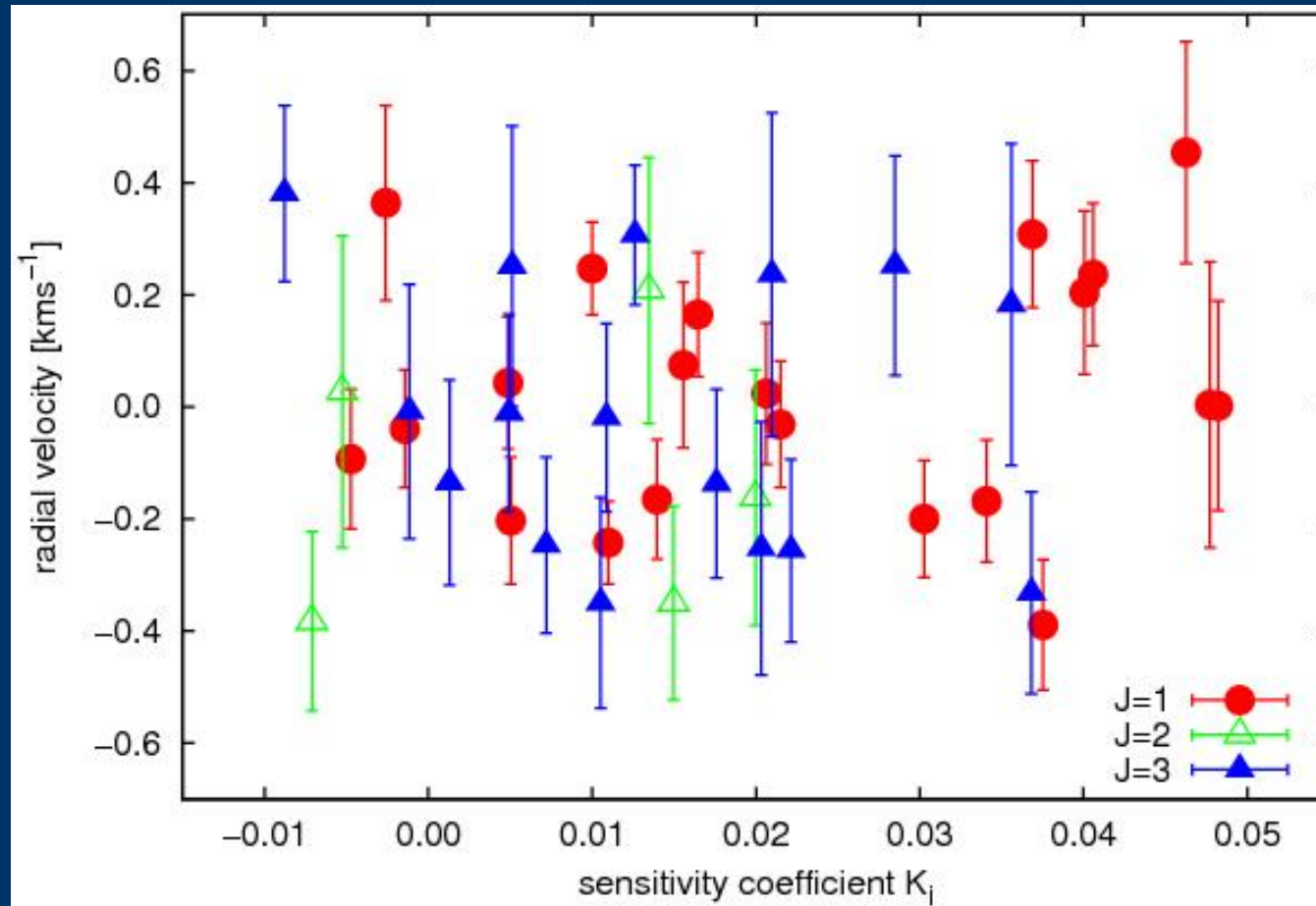
Current and future limits of QSO analysis

General limit of physical interpretation



How many and which components to fit?

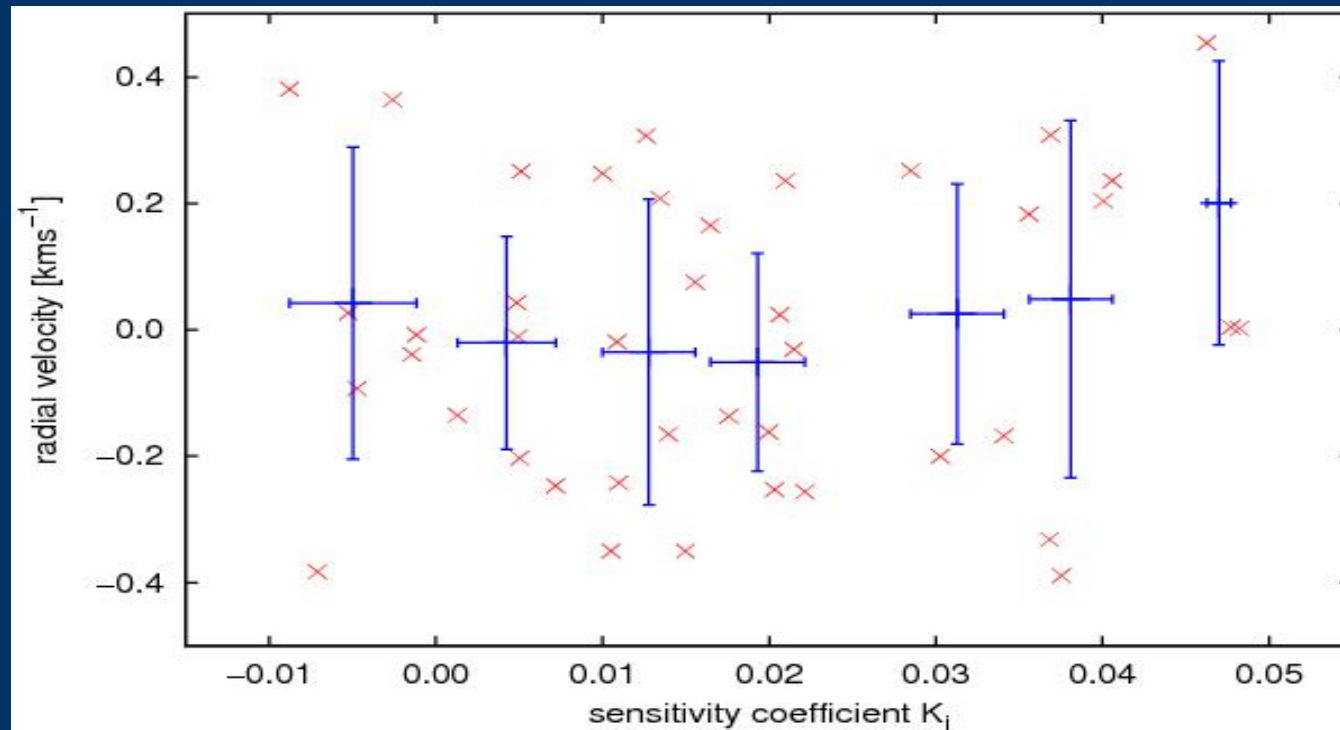
Current and future limits of QSO analysis



(Wendt & Molaro 2012)

All observed H2 lines.

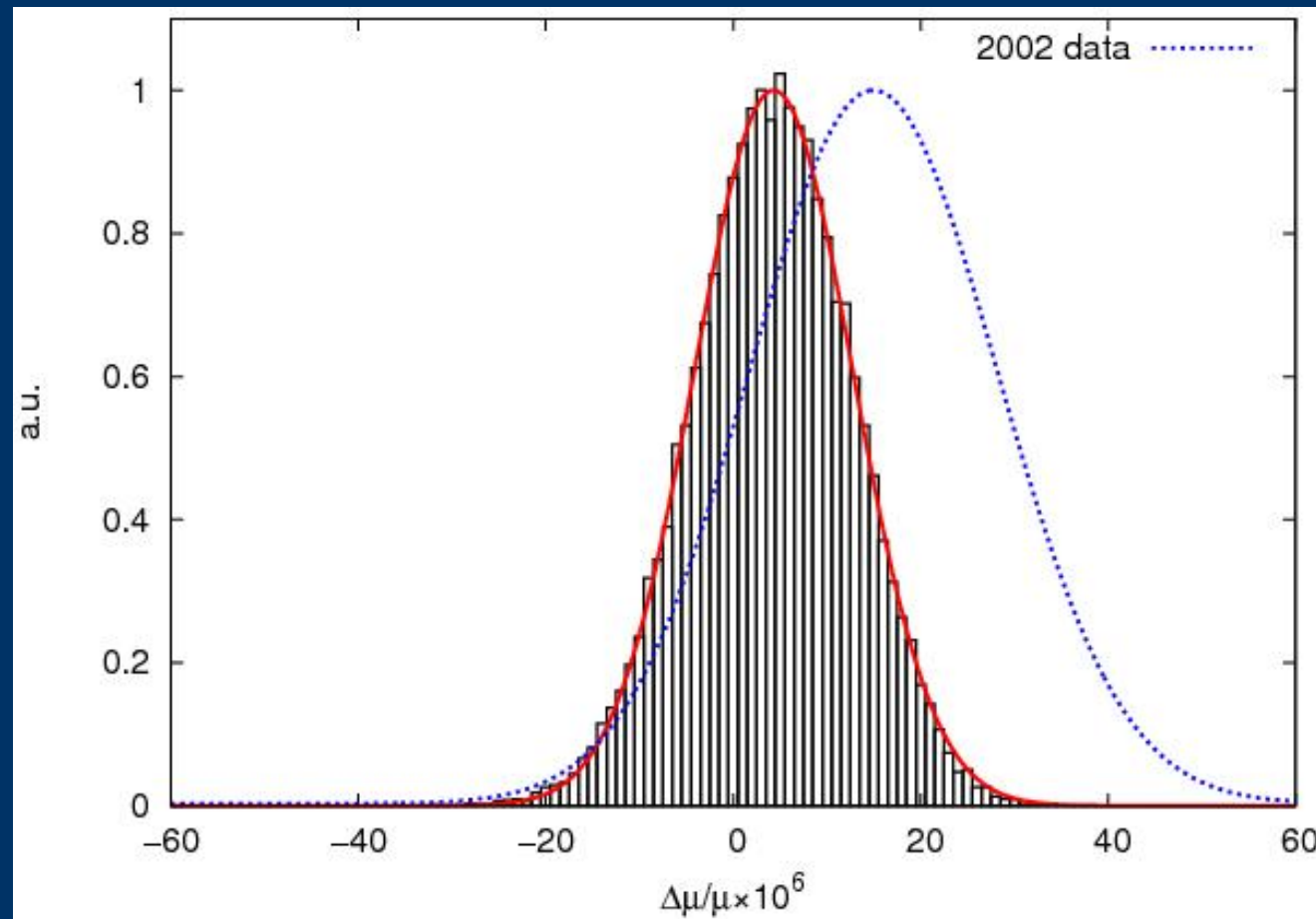
Current and future limits of QSO analysis



(Wendt & Molaro 2012)

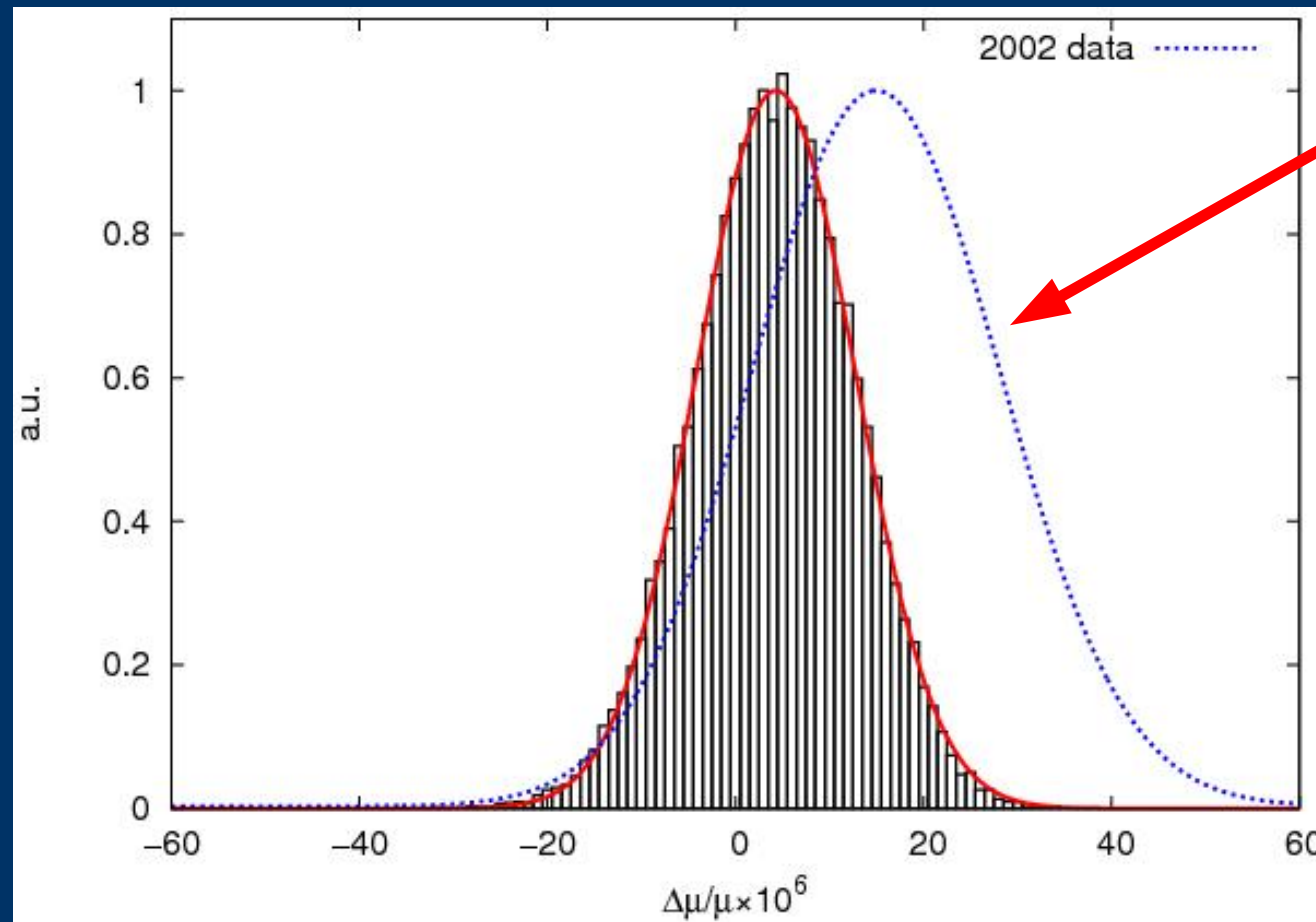
Binned data with stat. Error bars.

Current and future limits of QSO analysis



Bootstrap analysis, normal distribution.

Current and future limits of QSO analysis



Own
result
on former
data.

Bootstrap analysis, normal distribution.

Current and future limits of QSO analysis

Final results on QSO 0347...

Unweighted fit:

$$\Delta\mu/\mu = (4.2 \pm 7.7) \times 10^{-6}$$

Fit to the bootstrap distribution:

$$\Delta\mu/\mu = (4.3 \pm 7.2) \times 10^{-6}$$

Current and future limits of QSO analysis

Final results on QSO 0347...

Unweighted fit:

$$\Delta\mu/\mu = (4.2 \pm 7.7) \times 10^{-6}$$

Fit to the bootstrap distribution:

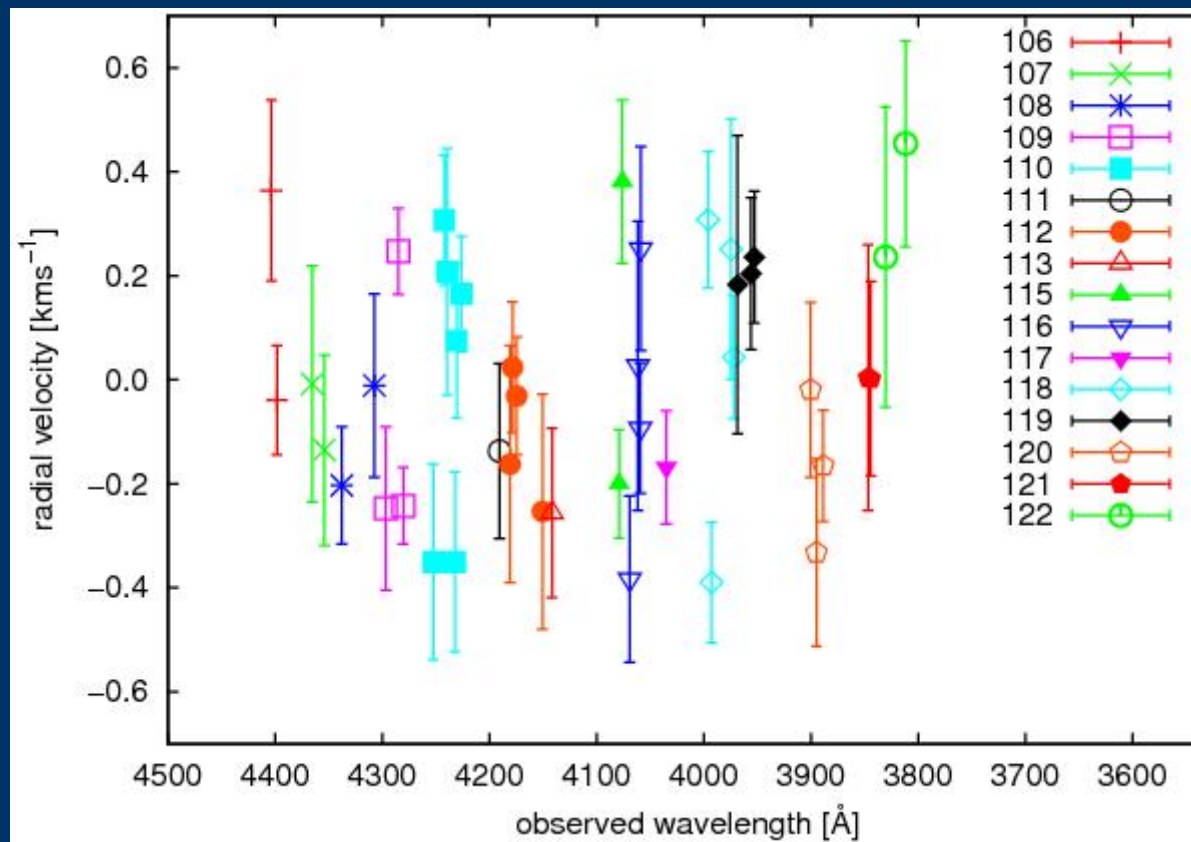
$$\Delta\mu/\mu = (4.3 \pm 7.2) \times 10^{-6}$$

statistical error of ~ 150 m/s

systematic error of ~ 150 m/s

Current and future limits of QSO analysis

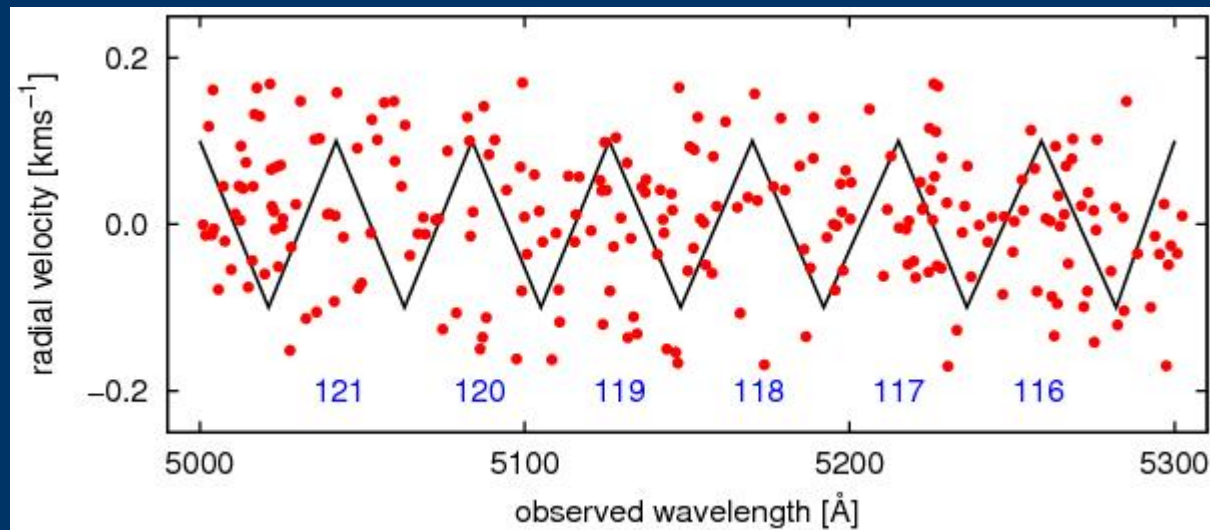
Hunt for systematics.



Individual orders.

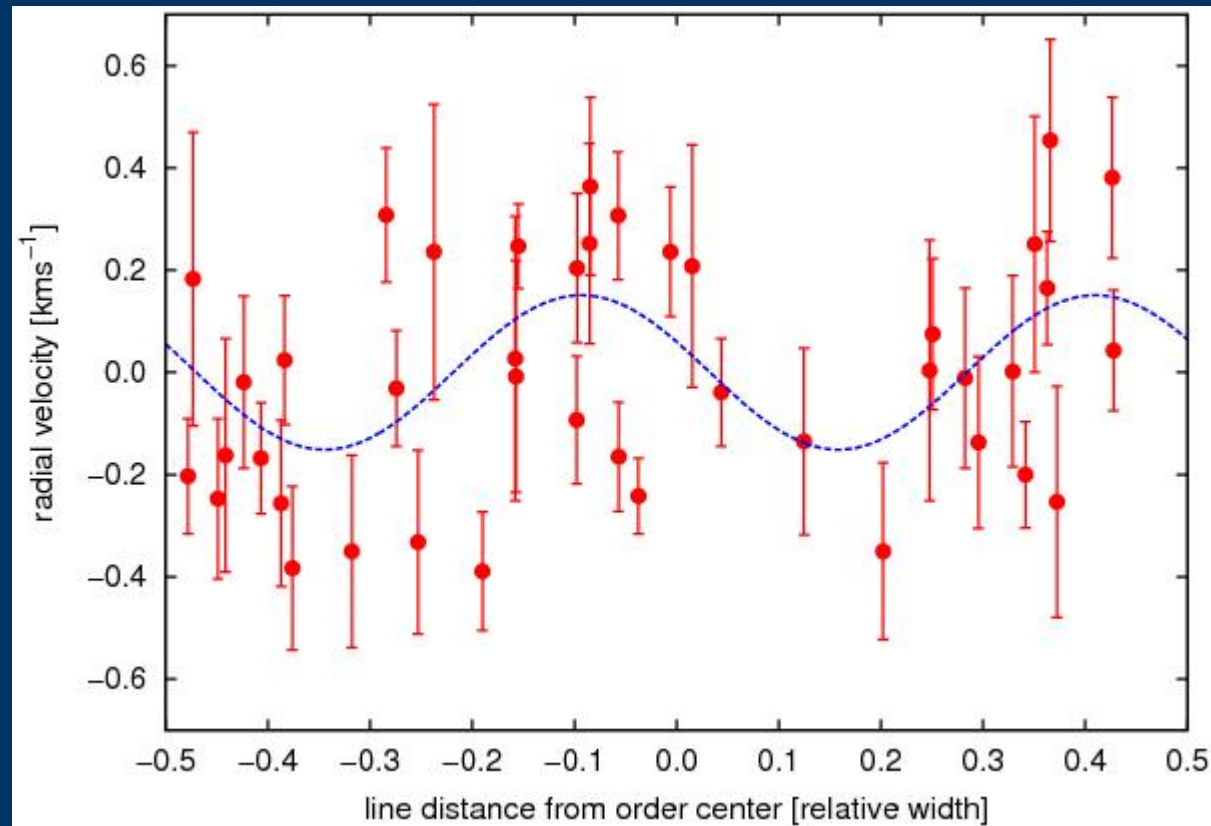
Current and future limits of QSO analysis

Evaluation of UVES calibration.



Offsets of 238 solar photospheric lines.
Comparison with *Whitmore et al. 2010*.

Current and future limits of QSO analysis

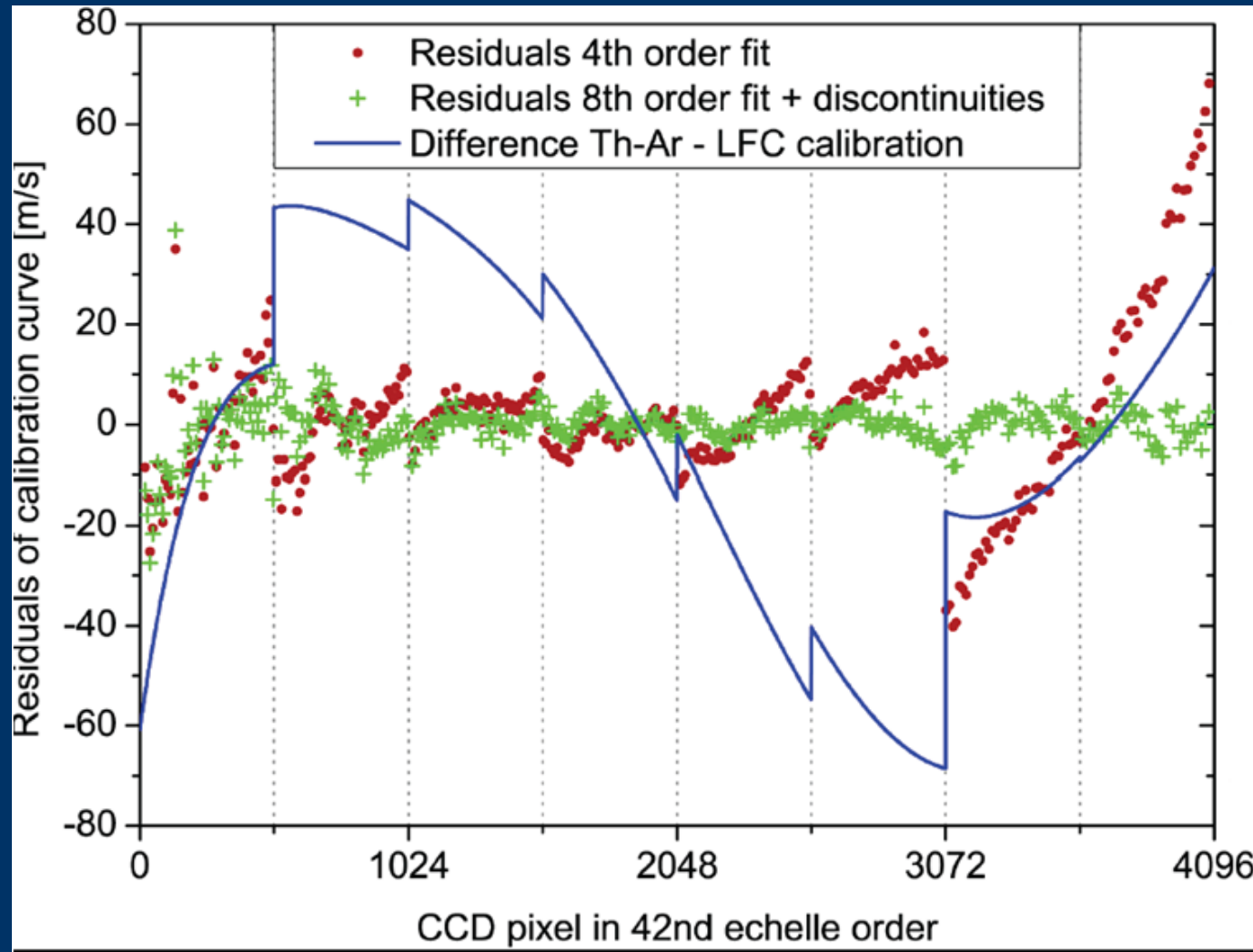


(Wendt & Molaro 2012)

Line positions on the CCDs.

Current and future limits of QSO analysis

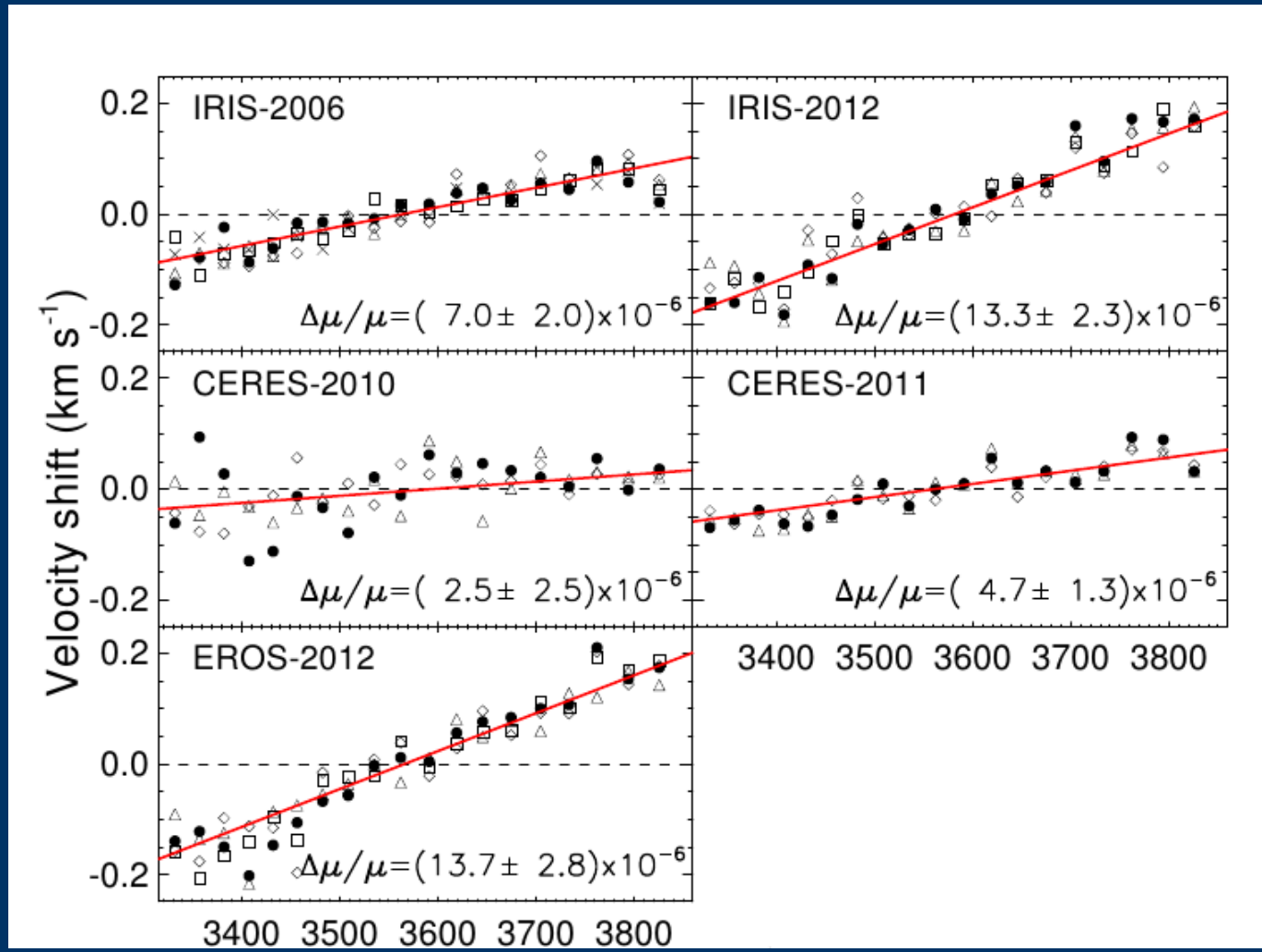
Similar effect seen for HARPS.



(Wilken et al. 2010)

Current and future limits of QSO analysis

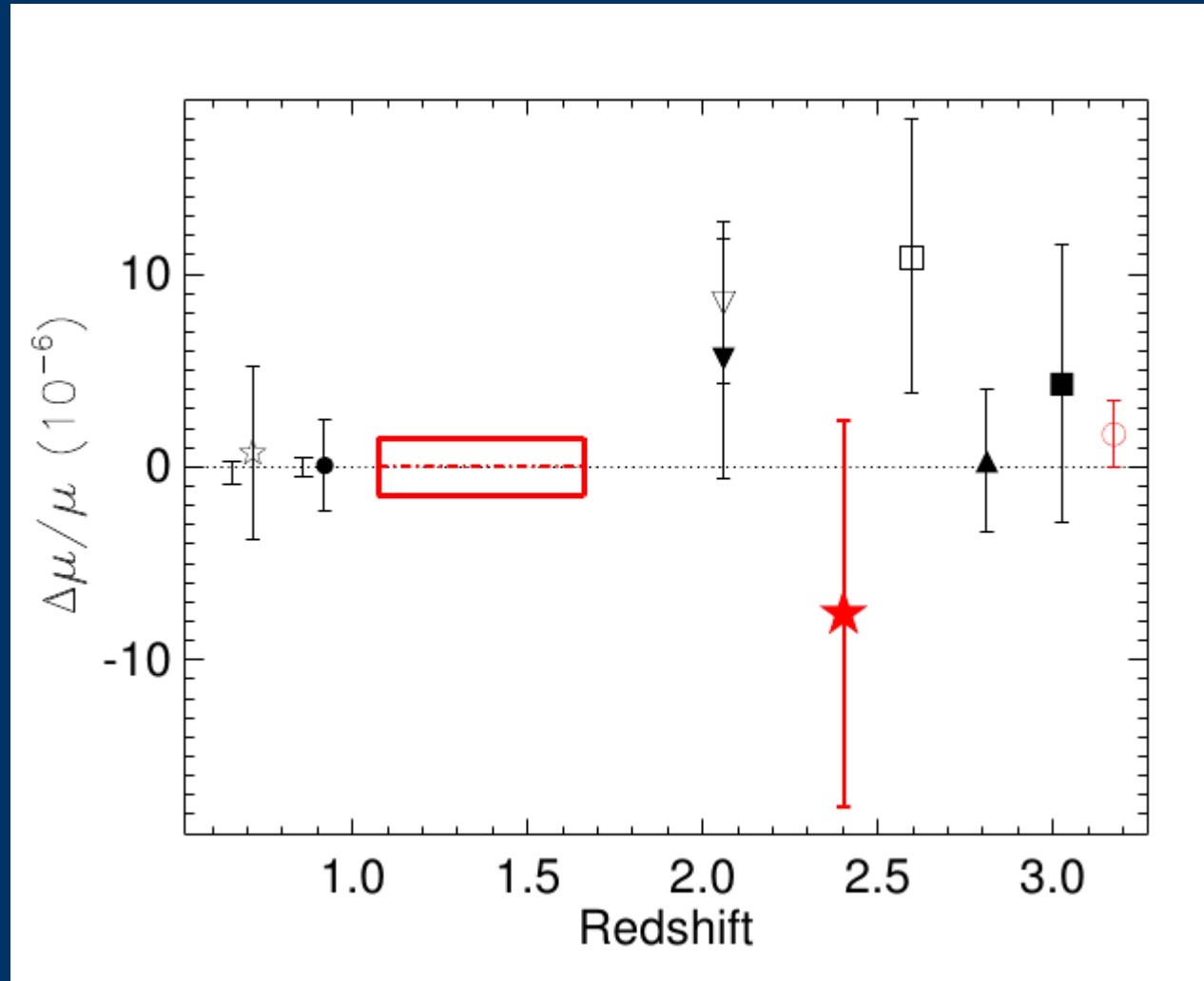
Drifts of solar lines in asteroid spectra.



(Rahmani et al. 2013, submitted)

Current and future limits of QSO analysis

Status quo of $\Delta\mu/\mu$.



(Rahmani et al. 2013, submitted)

Current and future limits of QSO analysis

Analysis of LP data for $\Delta\mu/\mu$ and possible changes in the finestructure constant continues.

“It is impossible for a man to learn what he thinks he already knows.”

- Epictetus

Thank you.