MEASUREMENT OF ABUNDANCES IN THE GRO J1655-40 OUTFLOW

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MOTIVATION FOR XRBS OUTFLOWS

- Measurements of outflows in X-ray could be the key to:
  - Density of the wind (Miller et al. 2008)
  - Distance from the radiation source (Miller et al. 2008)
  - Launching mechanism (Miller et al. 2006, Fukumura et al. 2021, Tomaru, Done and Mao 2023)
  - Elemental abundances inferring the progenitor (supernova)

GRO J1655-40 – A QUICK INTRODUCTION

Low mass X-ray binary

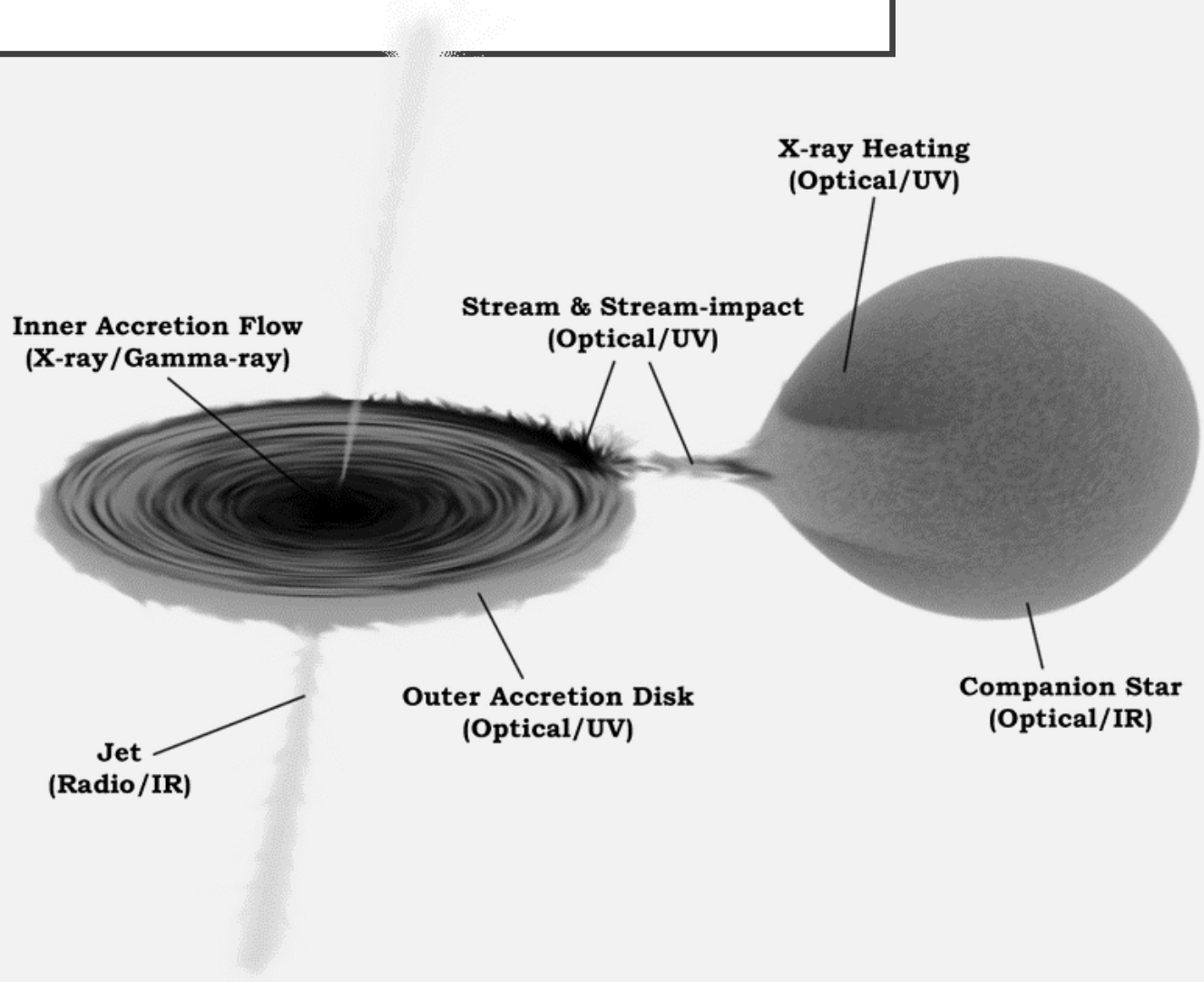
Masses of:

~6.6 $M_\odot$ stellar black hole

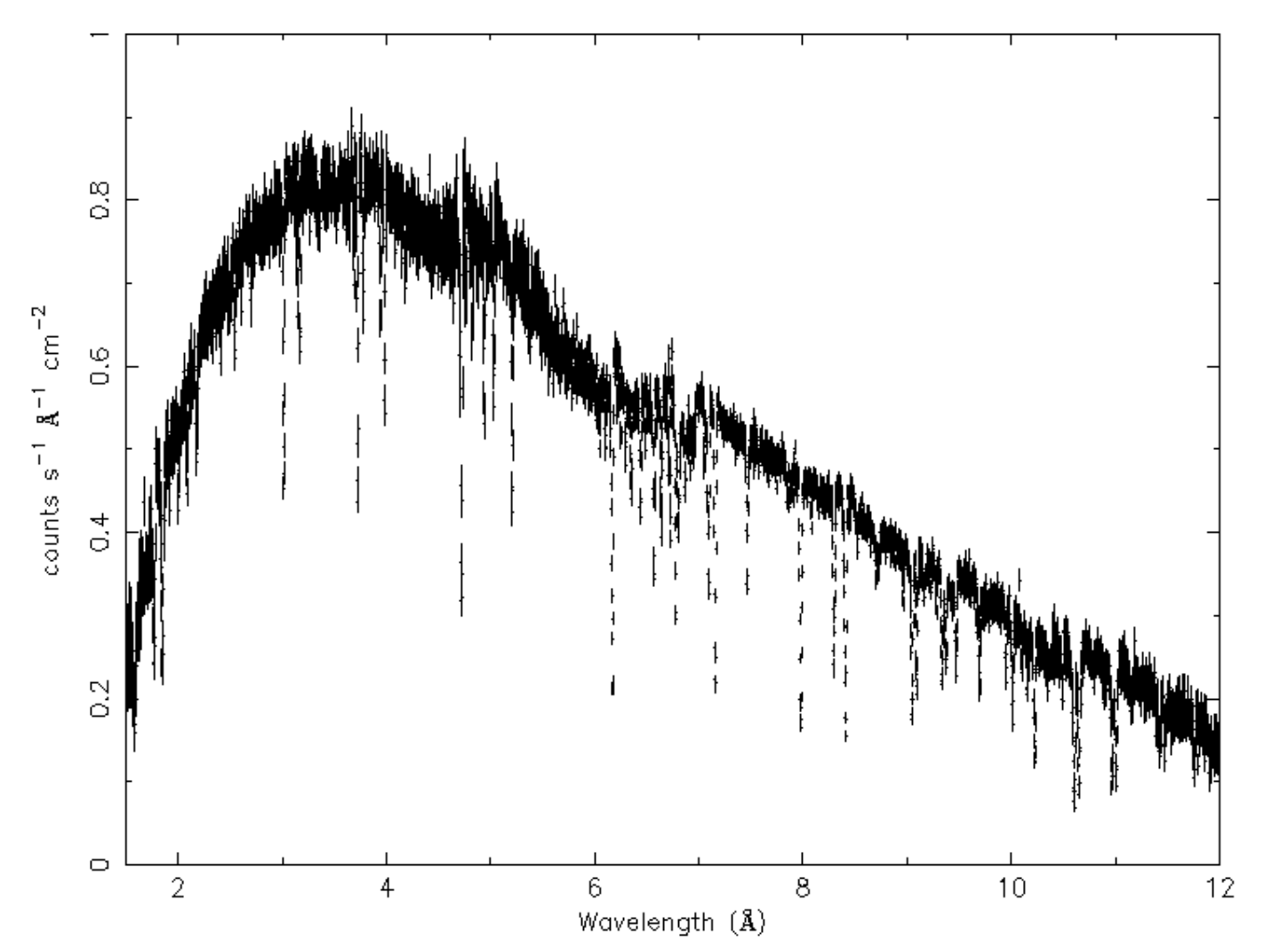
and ~2.7 $M_\odot$ F star

Orbital period of ~ 2.6 days

Separation of $\sim 10^{12}\ [cm]$



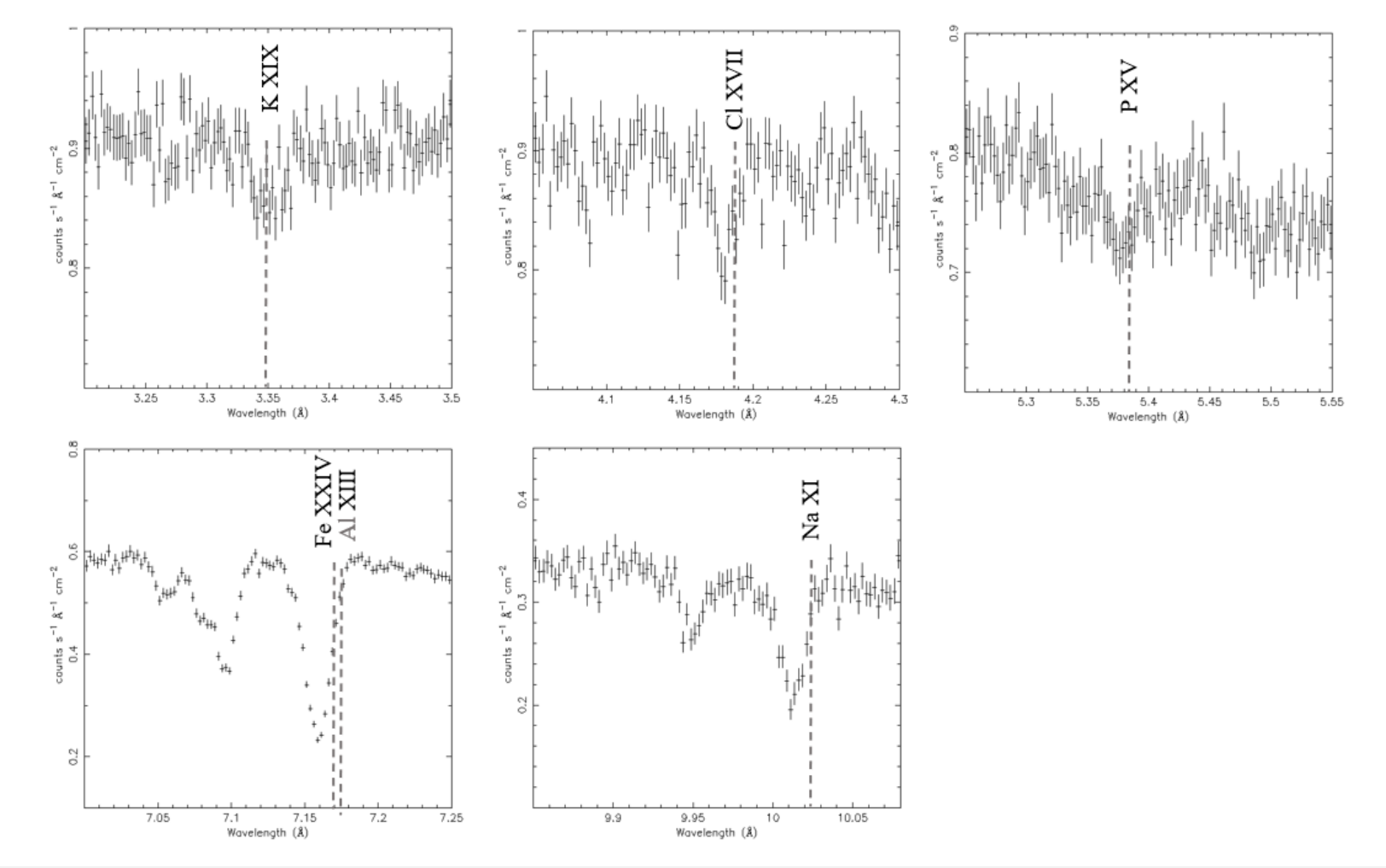
THE OUTFLOW OF GRO J1655-40



2005 outburst

Chandra/HETG, HEG

ODD-Z ELEMENTS IN THE SPECTRUM



MEASURING ELEMENTAL ABUNDANCES – SO SIMPLE..

- Ly-alpha lines from 17 elements
- We have the expression for the optical depth –

$$\tau = \sigma \mathrm{N}_{ion} = \sigma N_H f_{ion} A_Z$$

- Considering the expression for σ –

$$\sigma = \frac{\pi e^2}{m_e c} f_{ij} \phi(\nu)$$

- For all Ly-α lines $f_{ij} \sim 0.4$

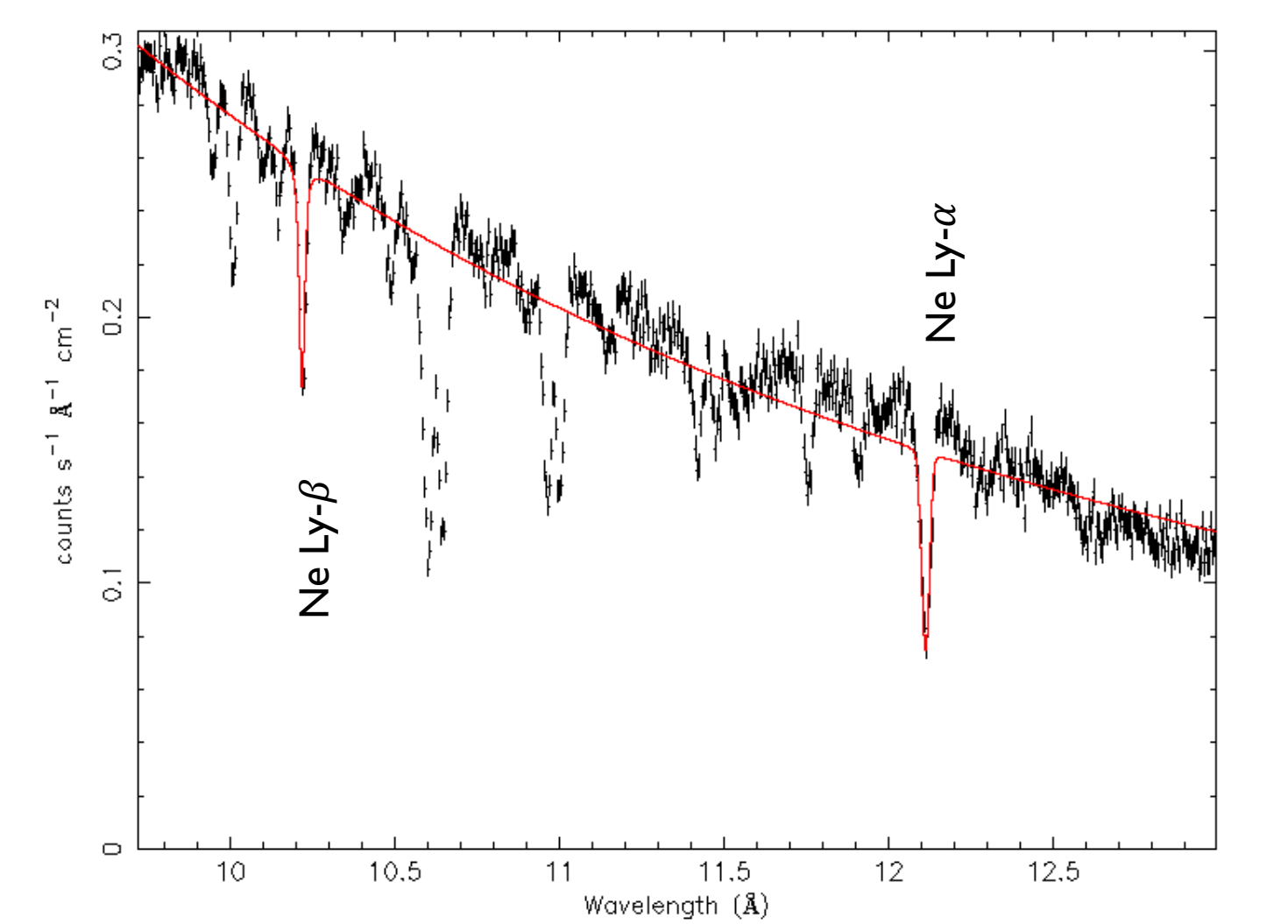
.. UNTIL IT FAILS

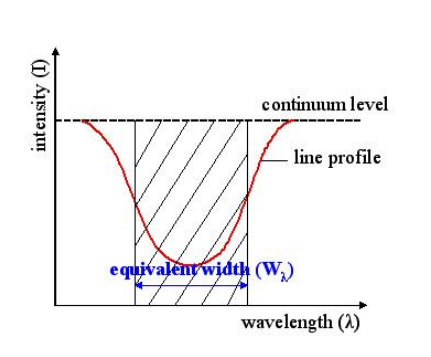
$$\sigma = \frac{\pi e^2}{m_e c} f_{ij} \phi(\nu)$$

$$f_{ij} -$$

$$\frac{\beta}{\alpha} = \frac{0.079}{0.41} \sim 0.2$$

$$\frac{EW_\beta}{EW_\alpha} \approx 0.9$$

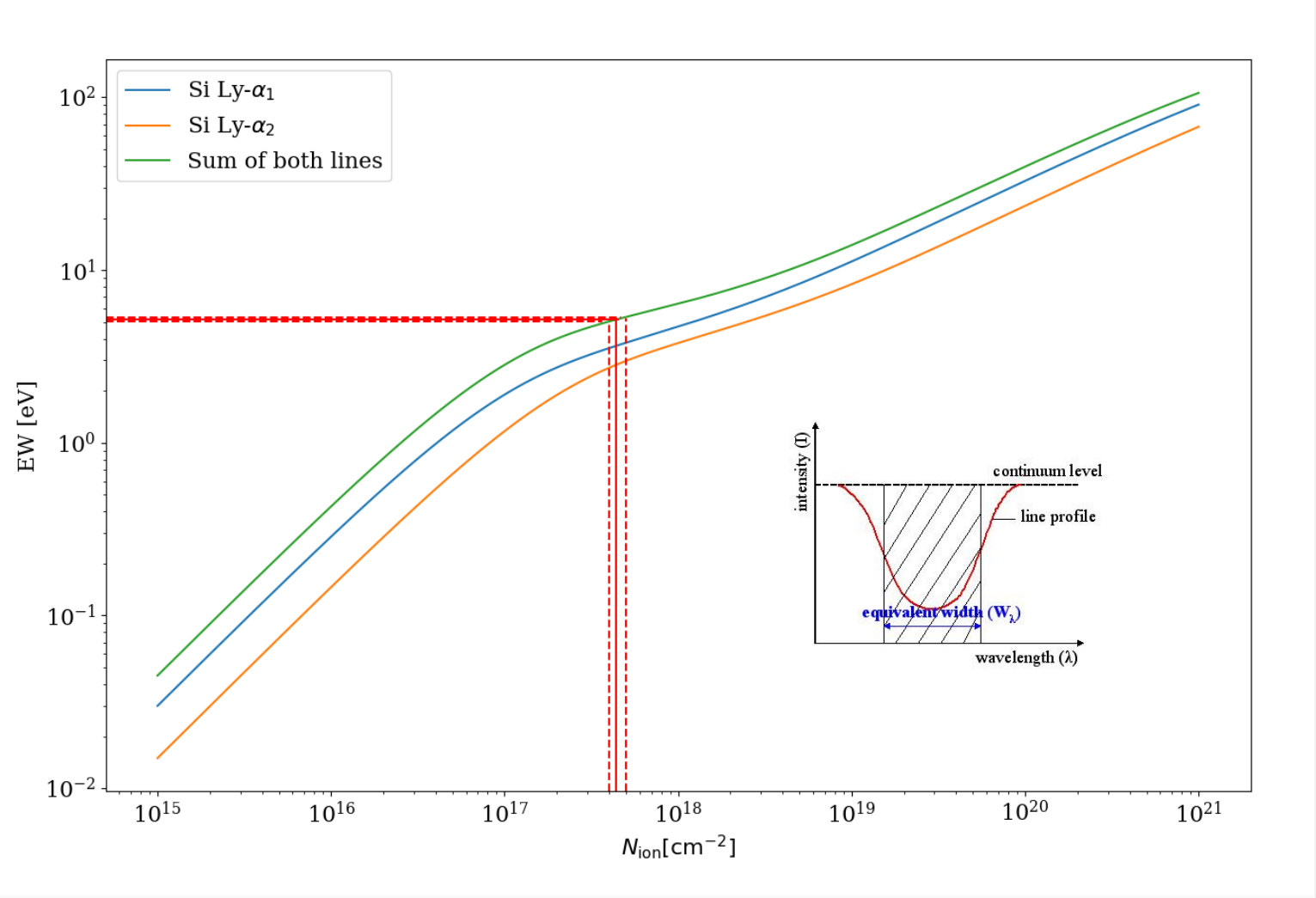




$$EW = \int (1 - e^{-\sigma N_{ion}}) d\nu$$

CURVE OF GROWTH ANALYSIS

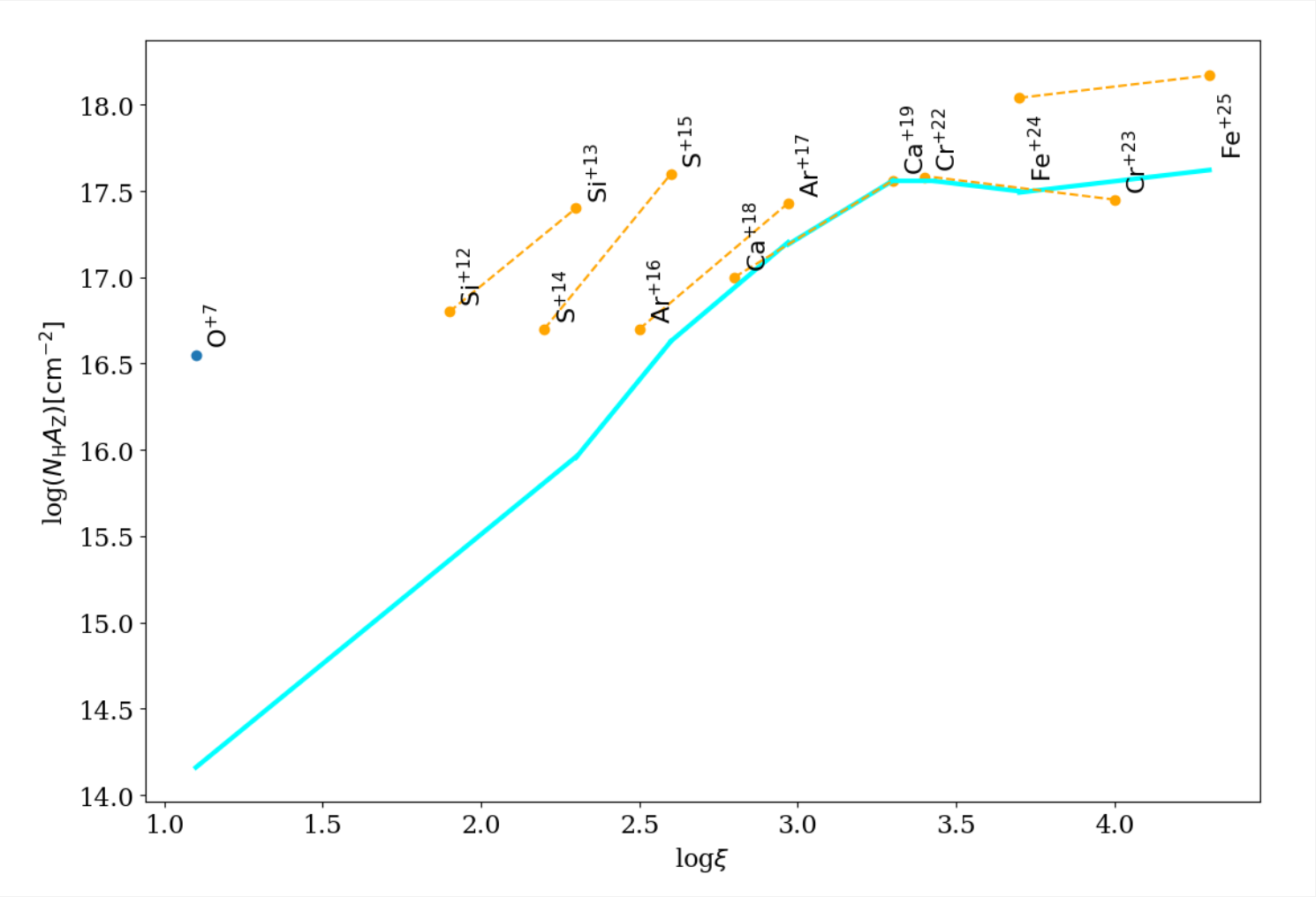
$$EW = \int (1 - e^{-\sigma N_{ion}}) dv$$



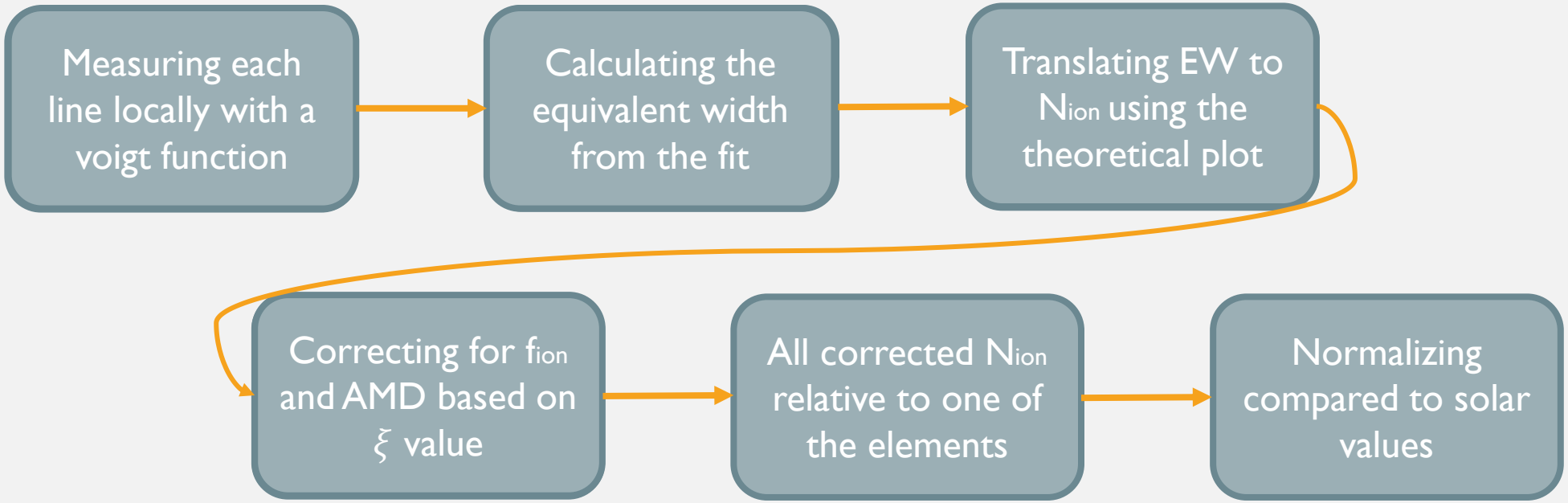
N_H IS A COMPLICATED FUNCTION OF ξ

$$A_Z \propto \frac{\tau}{N_H(\xi)}$$

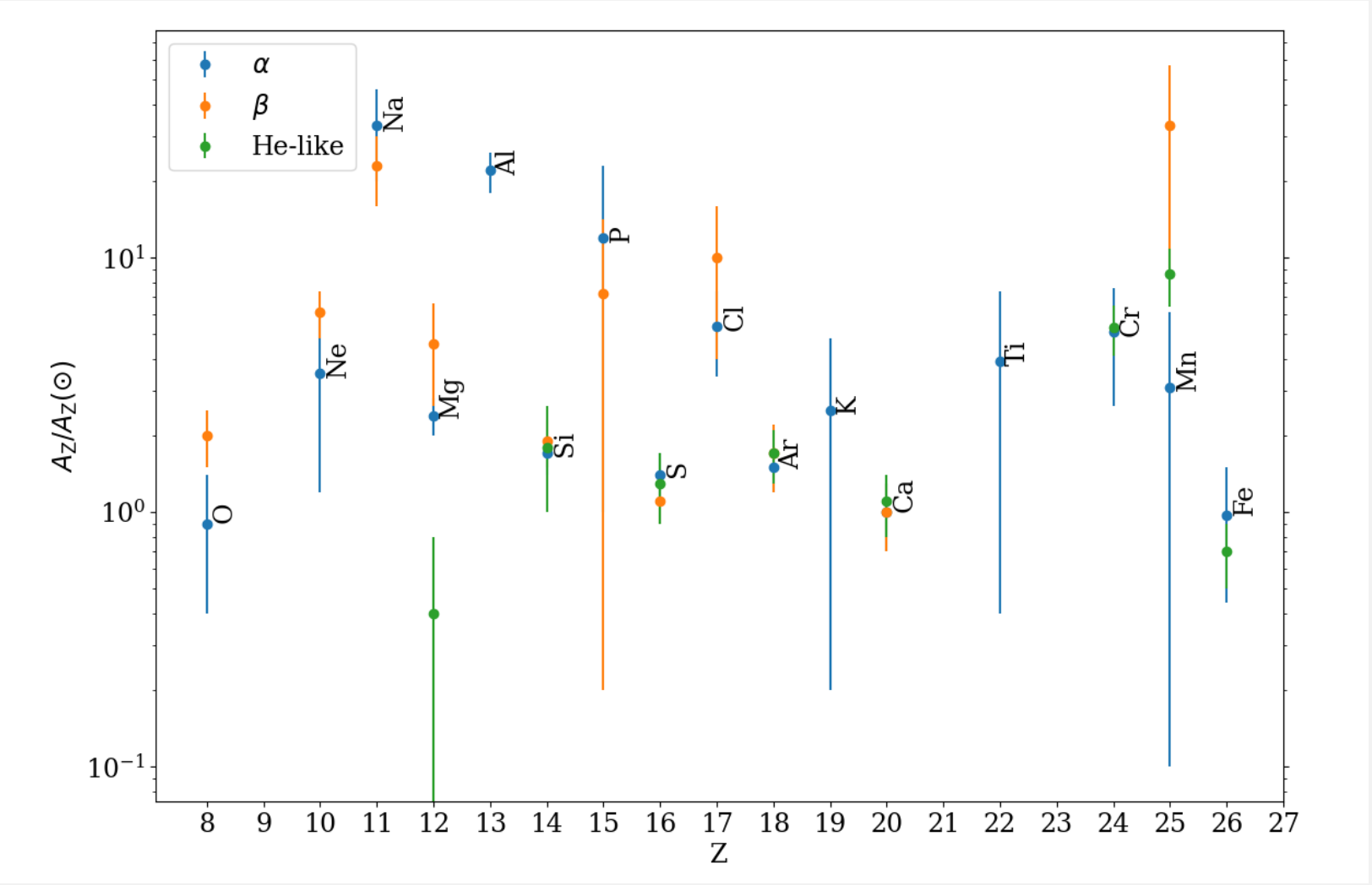
ξ - ionization parameter



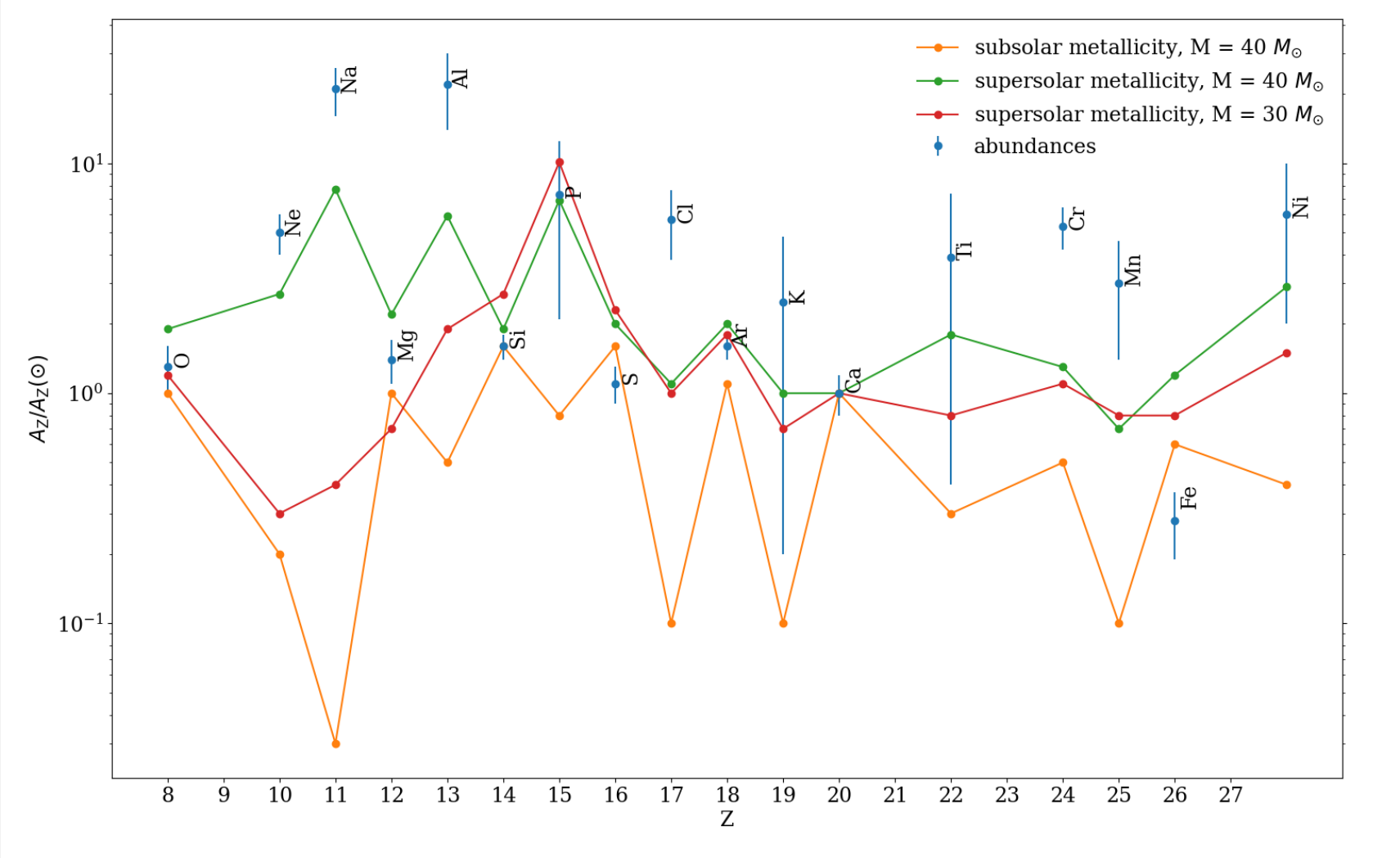
SUMMARIZING THE METHOD



RESULTS – CONSISTENCY CHECK

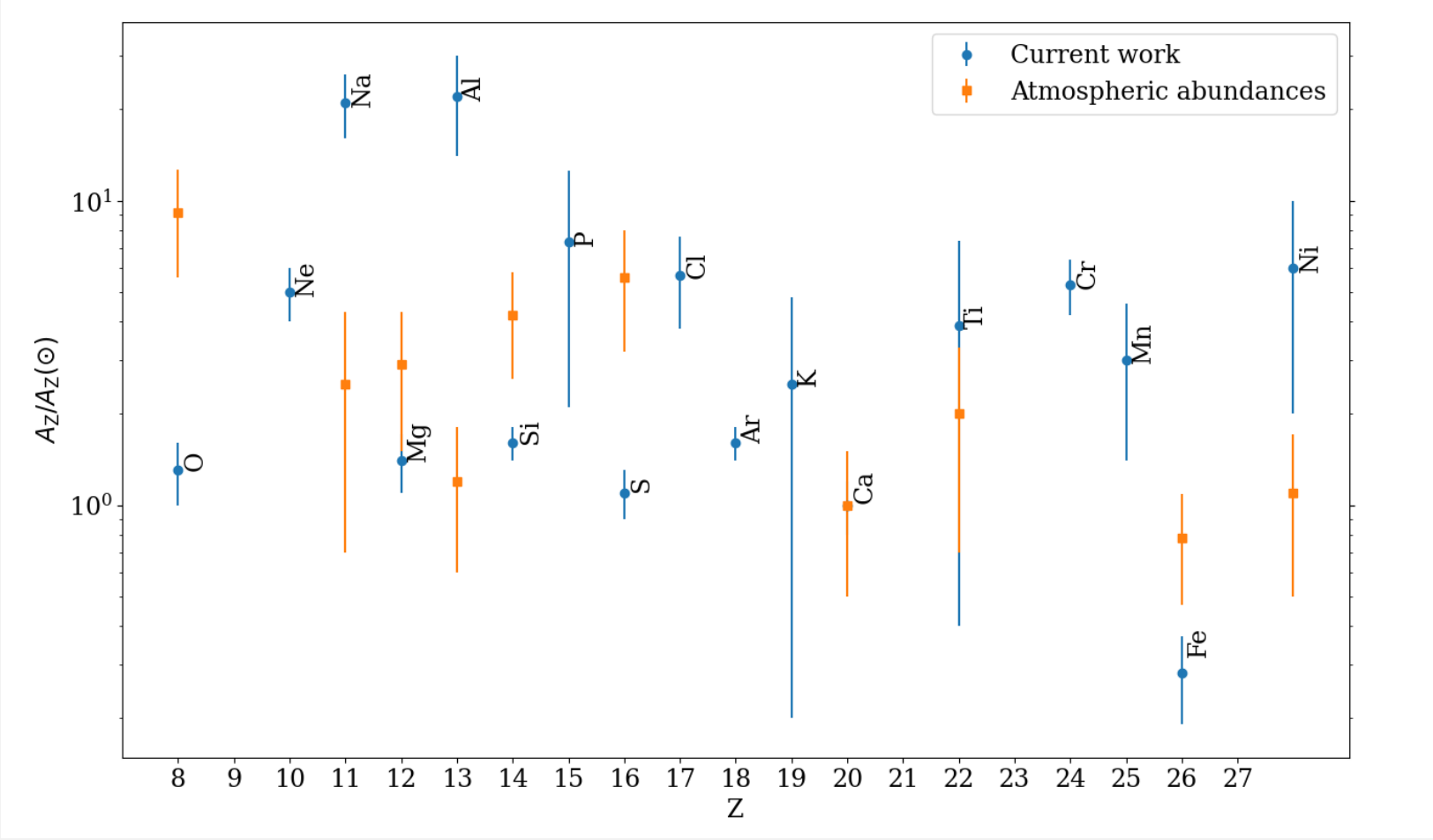


ANOMALOUS HIGH ODD-Z ELEMENTS..



Nomoto et al. 2006

DISCREPANCIES WITH THE COMPANION



Companion measurements from Hernandez, Rebolo, and Israelian (2008)

REMAINING QUESTIONS

- Width of the lines – keeping velocity as a free parameter?
- Ions forming at the peak – need for a better approximation?
- Origin of the wind and full picture of the system
- Age of the system – no supernova remnant, but remains of the same material?

CONCLUSIONS

- Independent measurements, not model related, of 17 different elements
- Some are rare elements, not usually observed – P, Cl, K, Cr, Mn
- Decent agreement with models of type II SN from a high metallicity progenitor