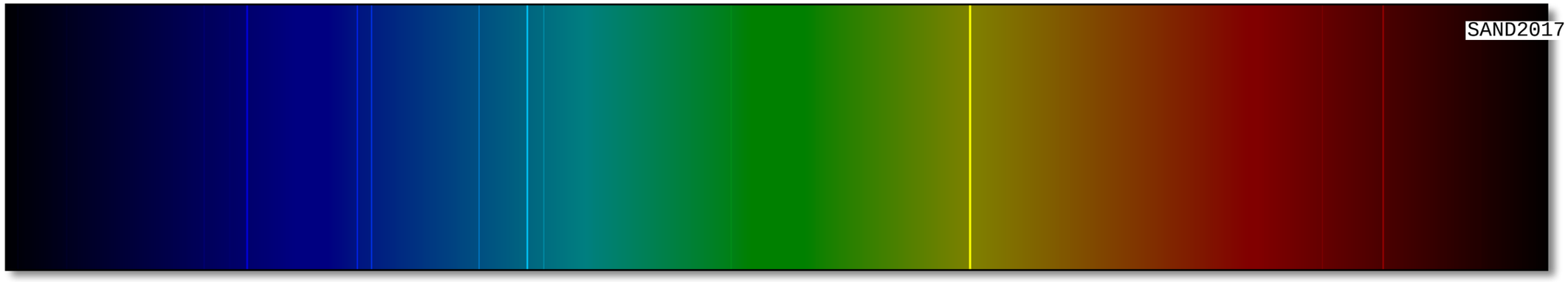

Helium at White Dwarf Photosphere conditions: line shifts and widths

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07/18/2017

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Stellar evolution in a nutshell

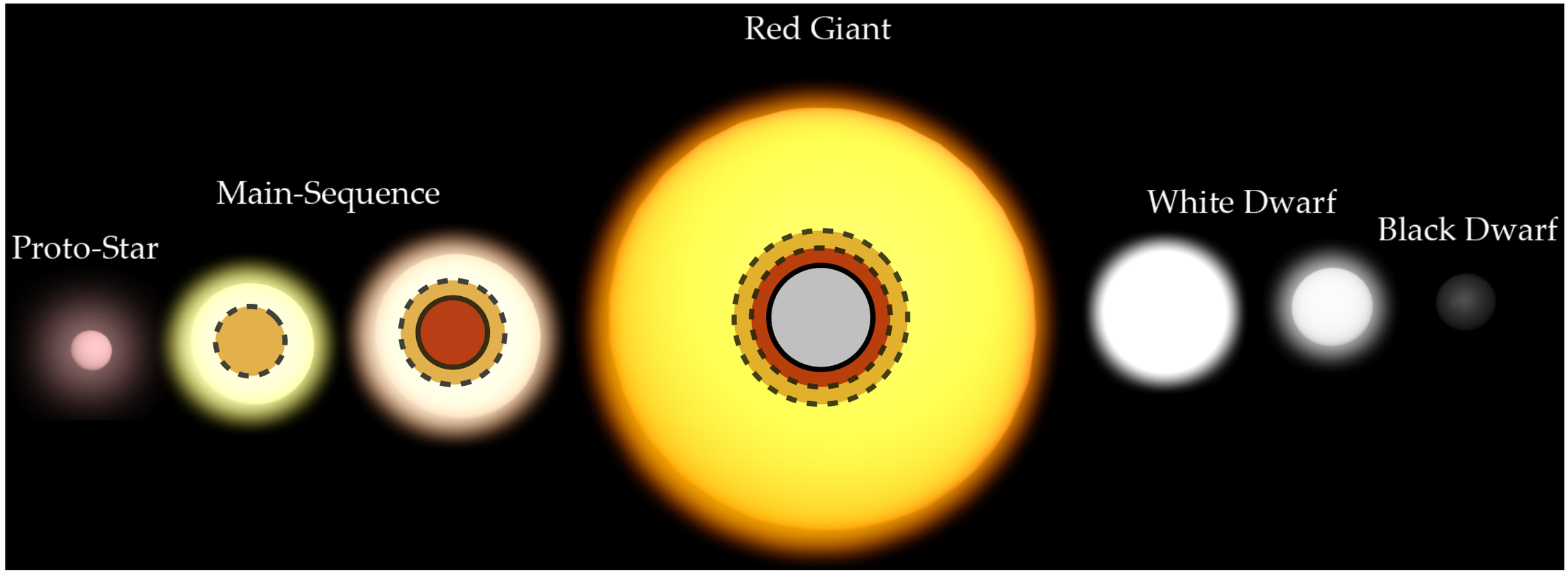


Image credit: WillGtl

Fusion

Inert

H

He

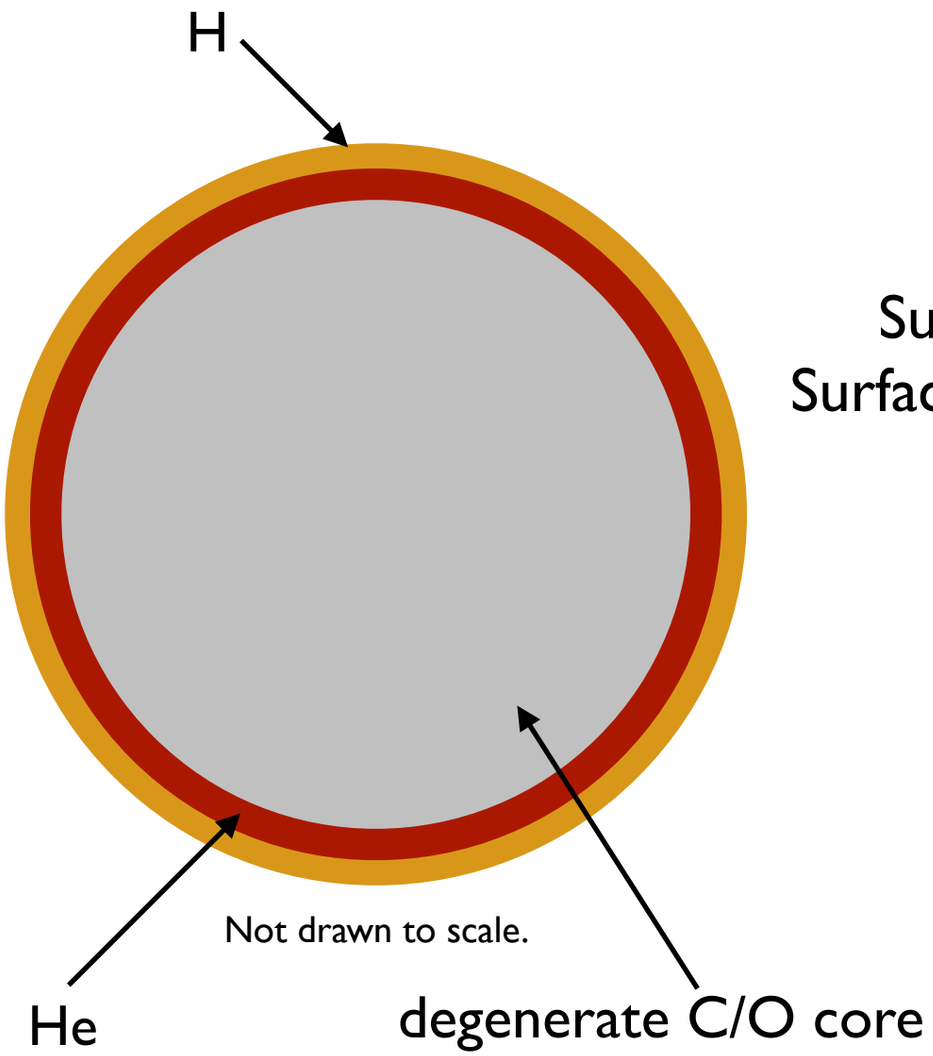
C/O

Main sequence: H-burning core

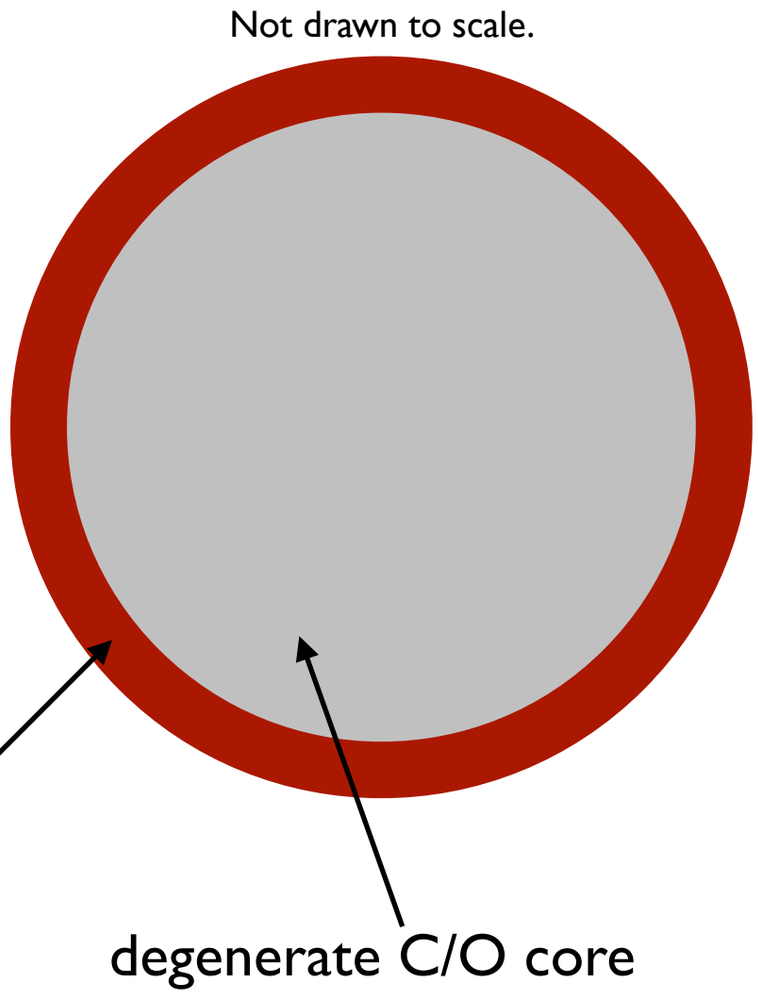
Red Giant: He-burning core

White Dwarf: Inert C/O core

Stellar evolution in a nutshell



Typical WD parameters:
Surface temperature: 10,000 K
Surface gravity: 10^8 cm/s^2 (~10^{17} cm^{-3})
Radius: r_{earth}
Mass: ~2/3 M_{sun}



Hydrogen-dominated (DA) WD

~80% of all WDs

Helium-dominated (DB) WD

~20% of all WDs

Stellar evolution in a nutshell

Total lifetime: ~11 Gyr

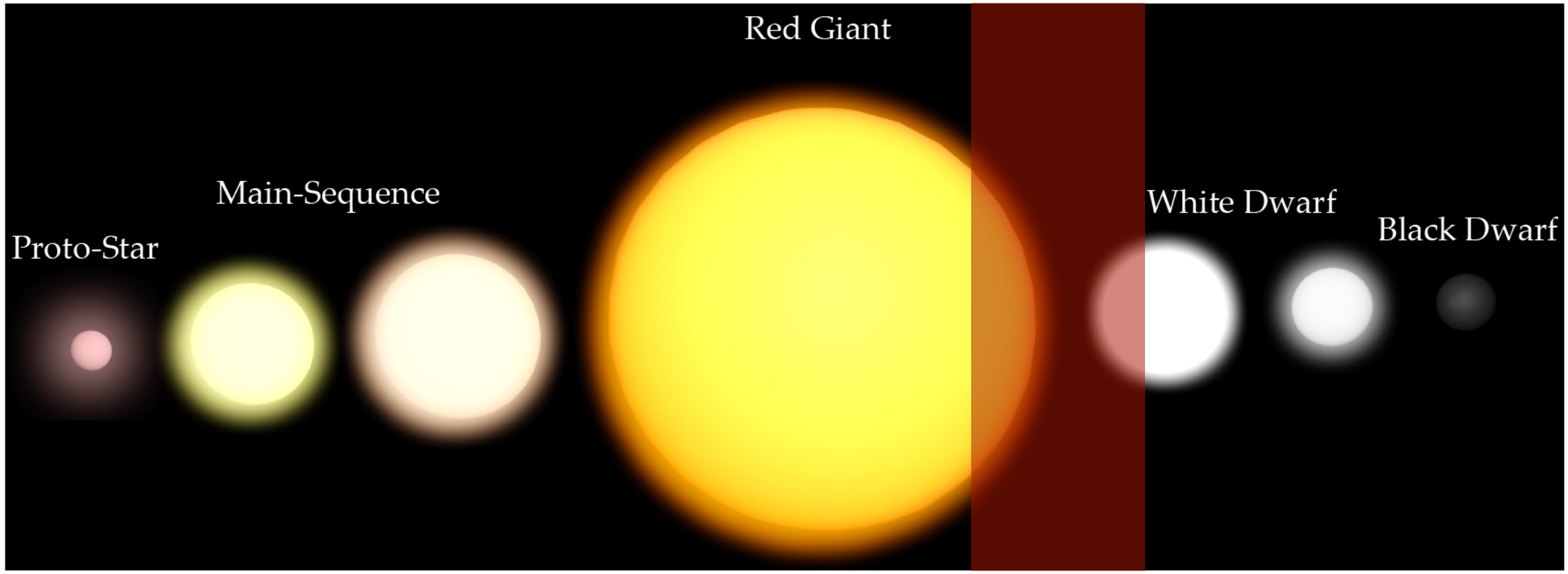


Image credit: WillGt

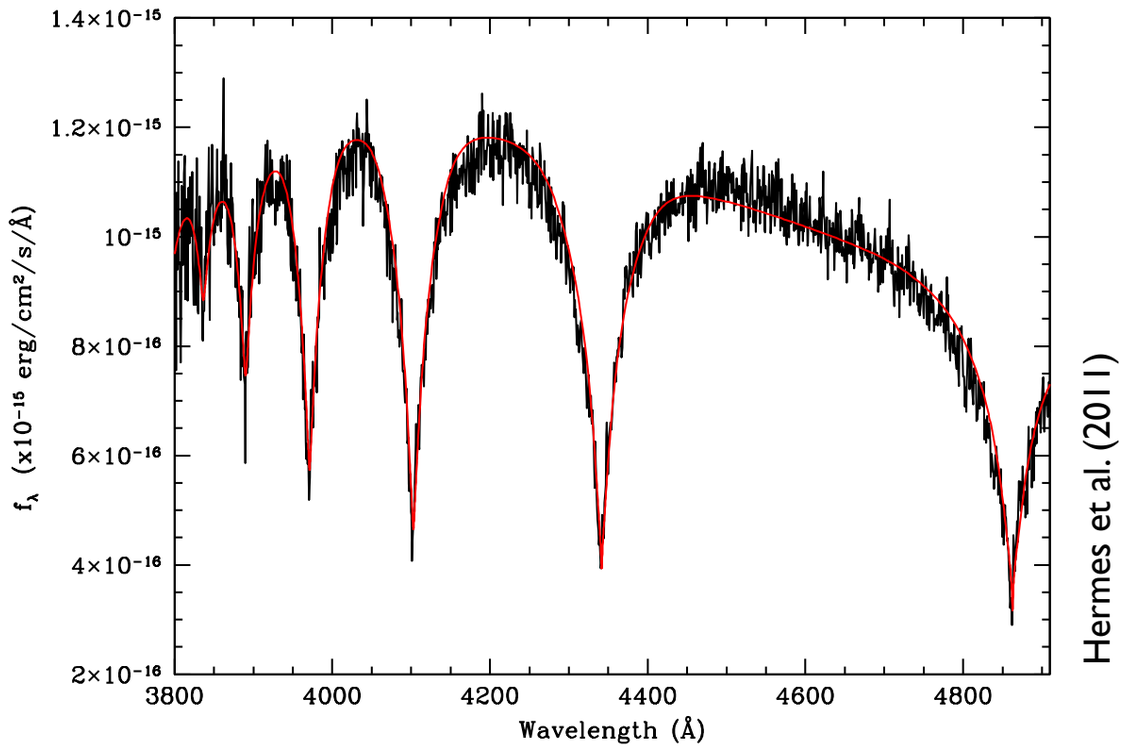
1 Myr (~0.01% of total lifetime)
crucial component: 200 yrs

poorly observed, understood, and constrained

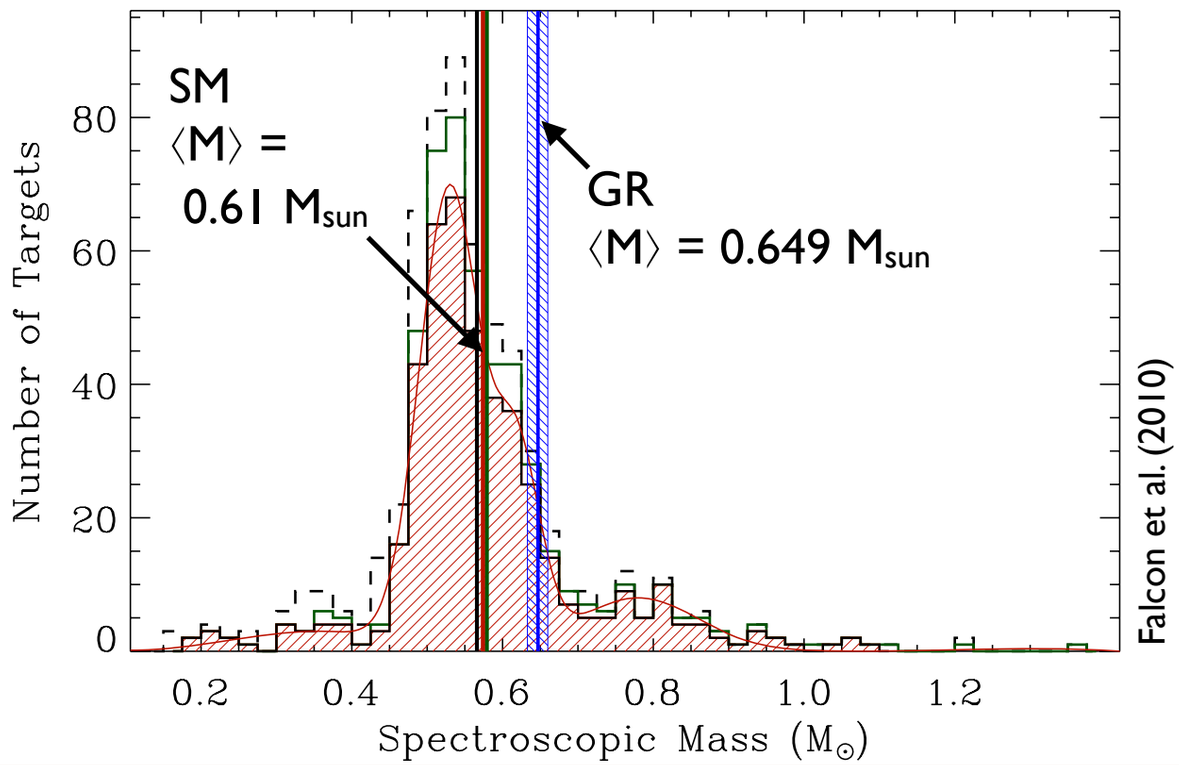
Initial experiments

- Disagreement in derived hydrogen-dominated (DA) white dwarf masses using two independent methods:
  - spectroscopic (fitting synthetic to observed spectra)
  - gravitational redshift:

$$v_g = \frac{c\Delta\lambda}{\lambda} = \frac{GM}{Rc}$$

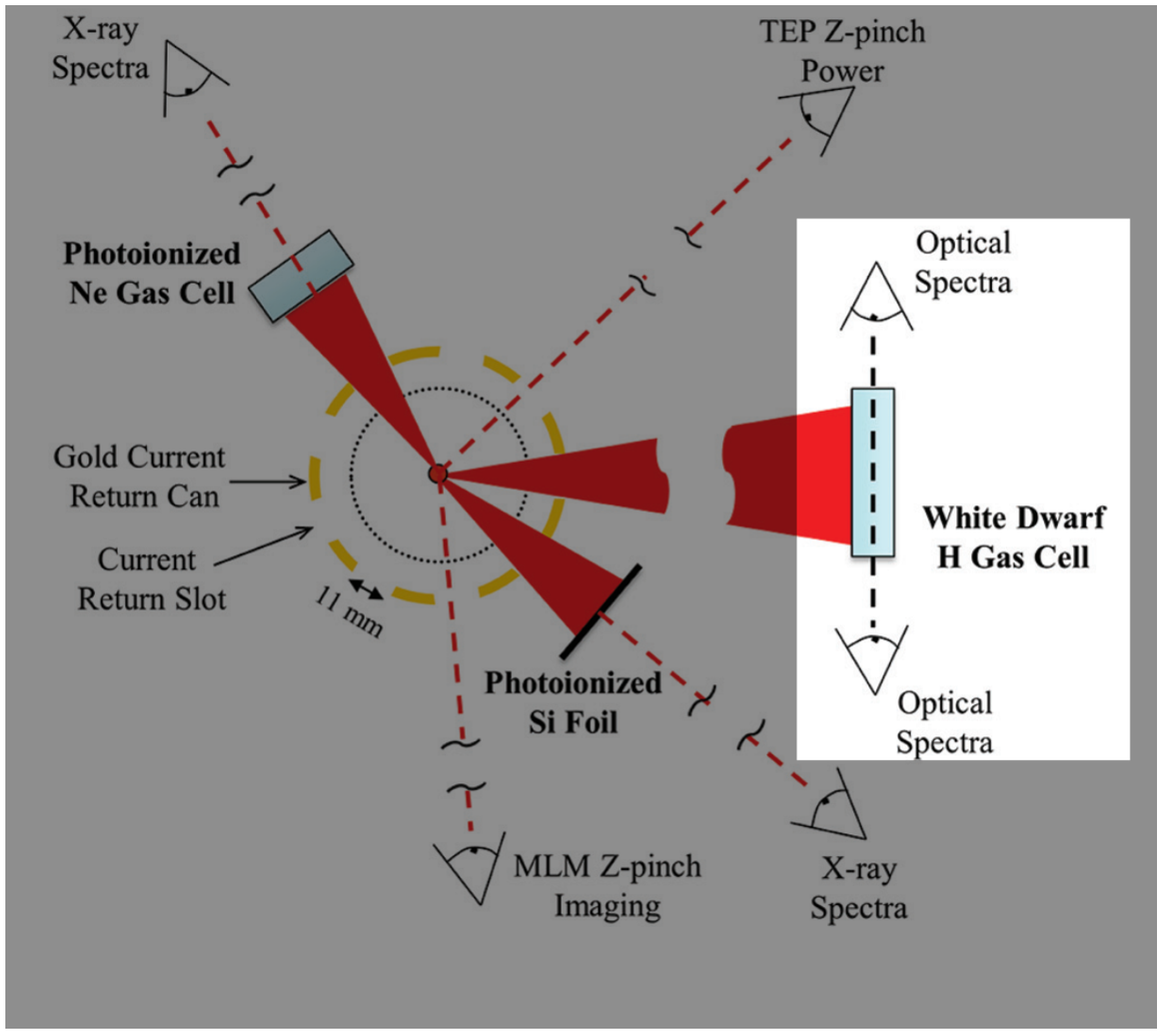


Hermes et al. (2011)



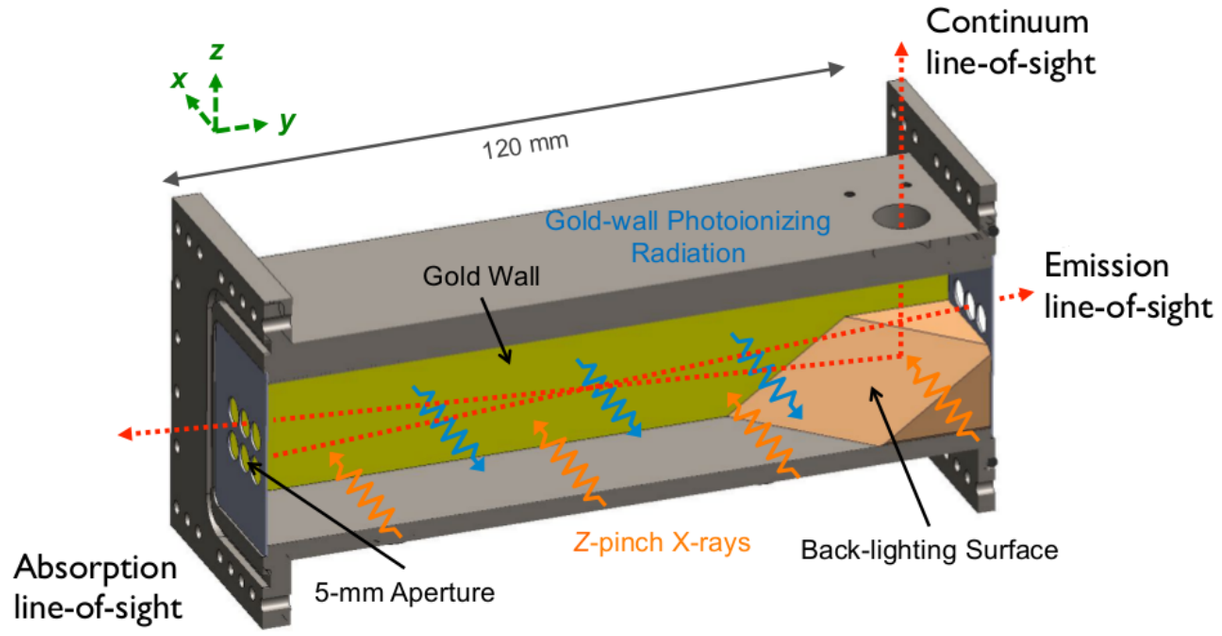
Falcon et al. (2010)

Initial experiments



Rocha et al. (2014)

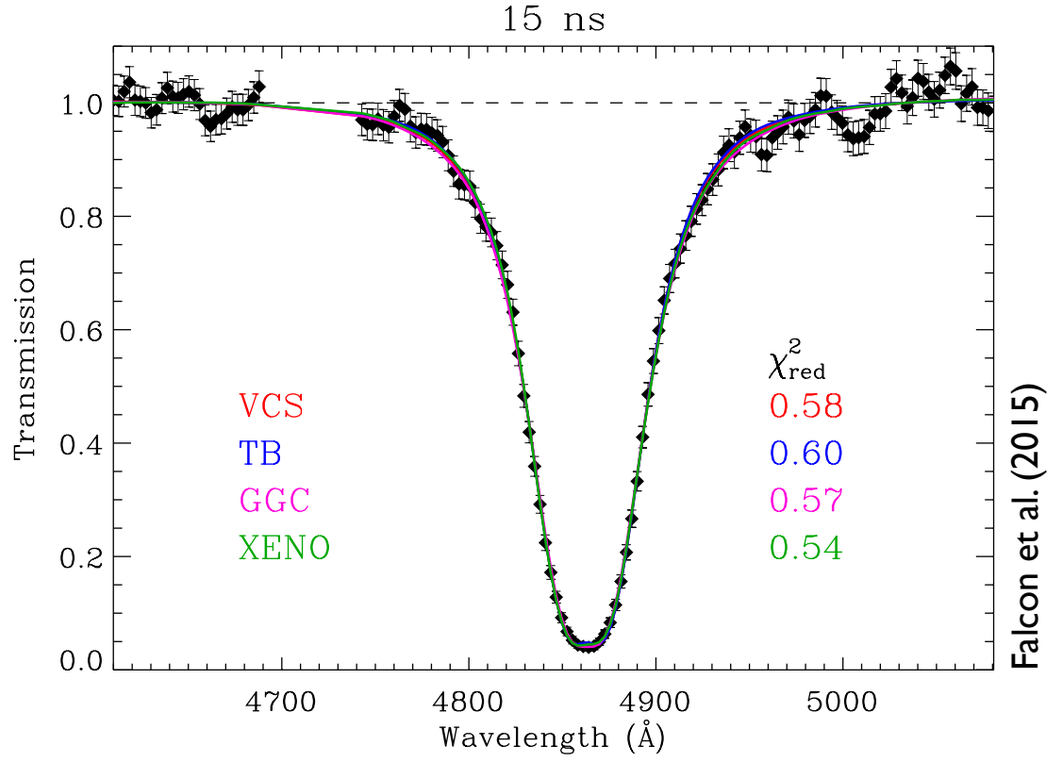
Gas cell design:

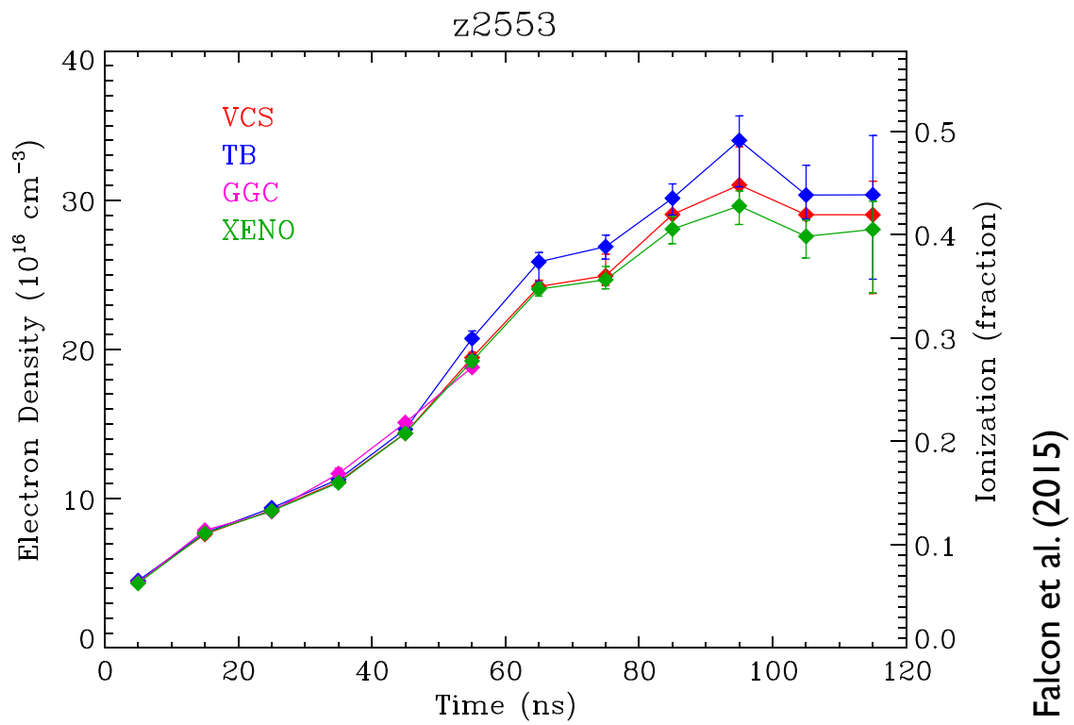


Falcon al. (2015)

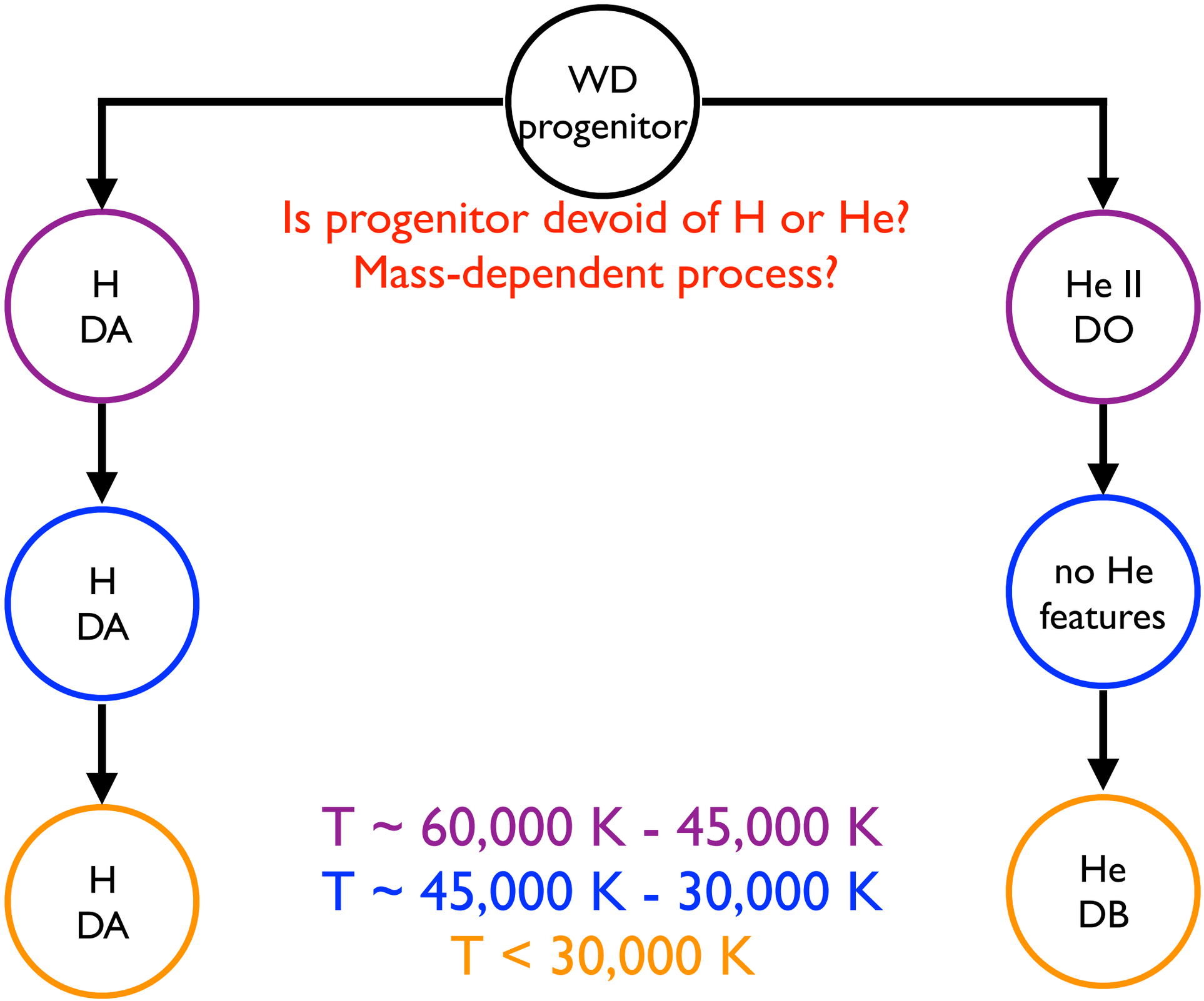
Initial experiments

- Experiment was designed to measure transmission spectra of Balmer series at white dwarf photosphere conditions.
- We can use the Hβ line to infer electron density (n_e), level populations, and temperature.

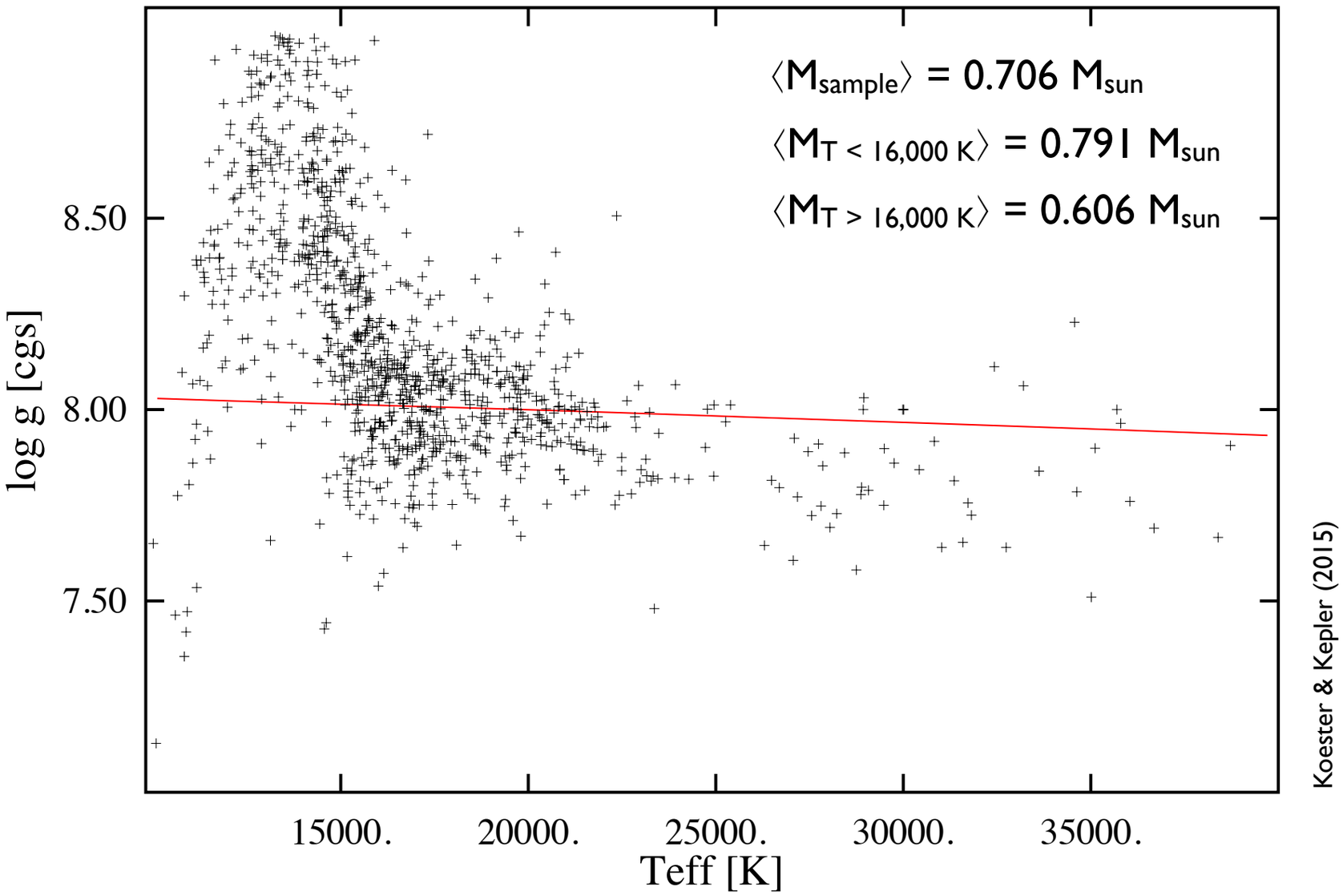




Helium-dominated (DB) WD evolution



Current work



Gravitational redshift:

$\langle M_{DB} \rangle = 0.710\ M_{sun}$

$\langle M_{DA} \rangle = 0.647\ M_{sun}$

Plot of surface gravity (log g) vs. surface temperature
for a sample of ~1,000 helium-dominated (DB) white dwarfs

Current work

The impact approximation

$$\mathrm{w} + i\mathrm{d} \;=\; \mathrm{N}_e \int_0^\infty c f(v) dv \int^{\rho_{\max}} 2\pi\rho d\rho \left\{ 1 - \langle i|S|i\rangle \langle f|S^{-1}|f\rangle \right\}_{\mathrm{av}}$$

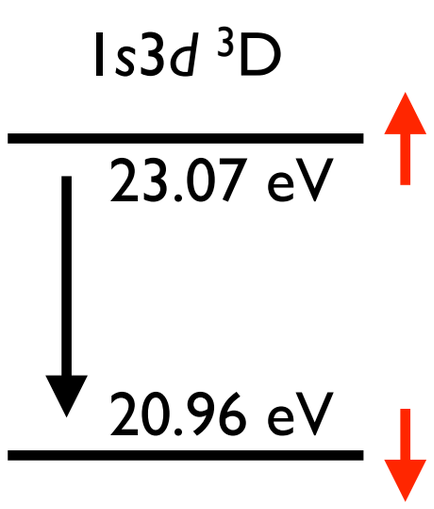
thermal average

angular average of impacts

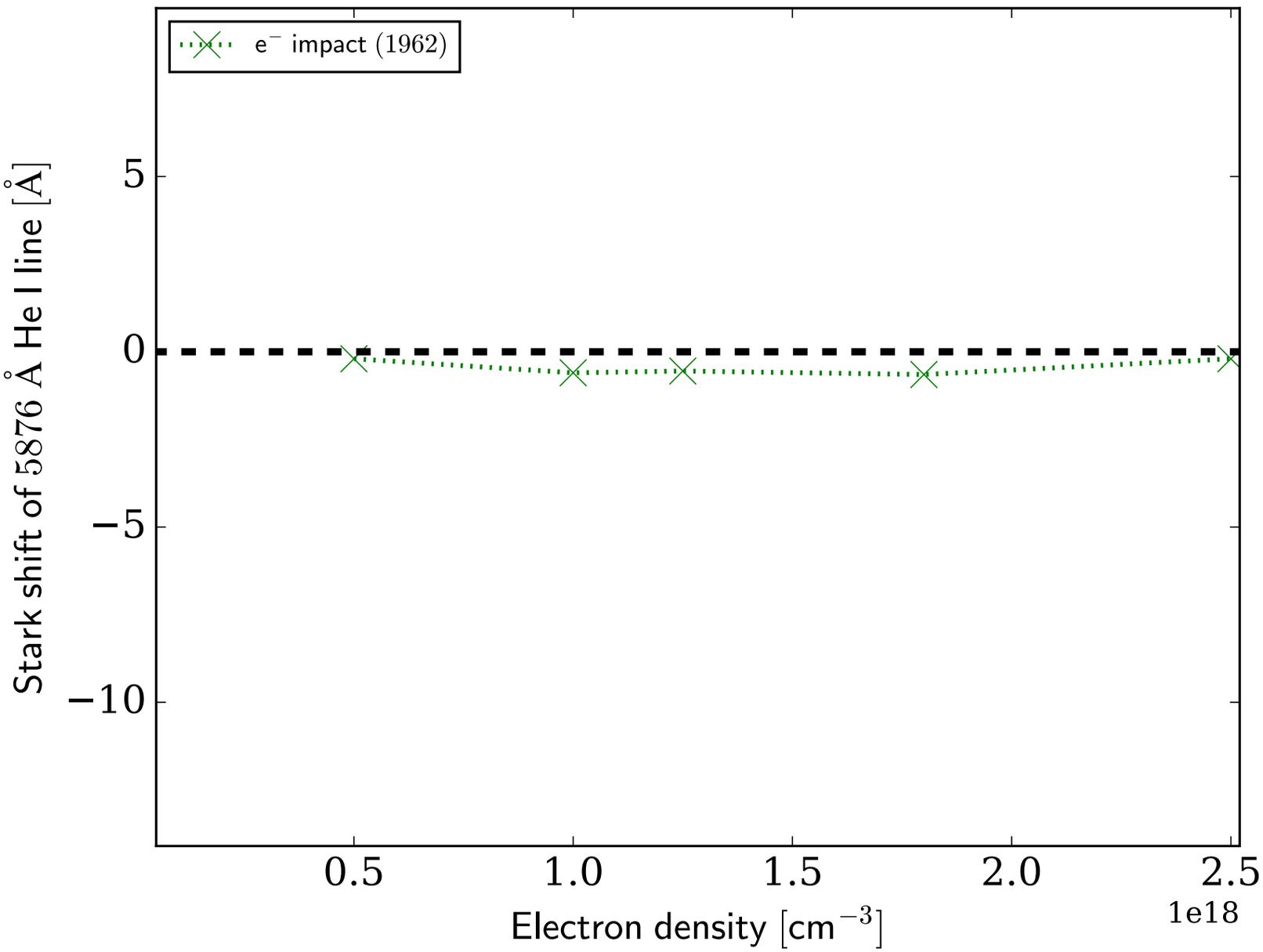
w: width of line
d: shift of line

Current work

e⁻ impact

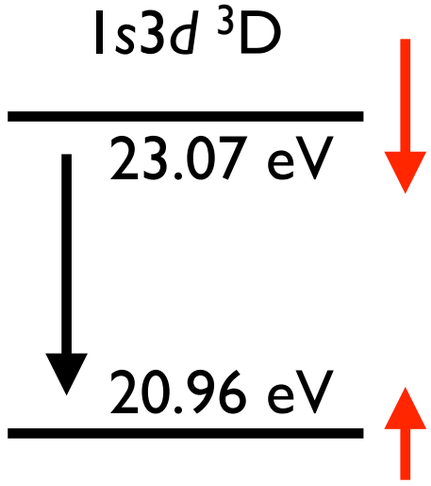


Levels of
5876 Å He I

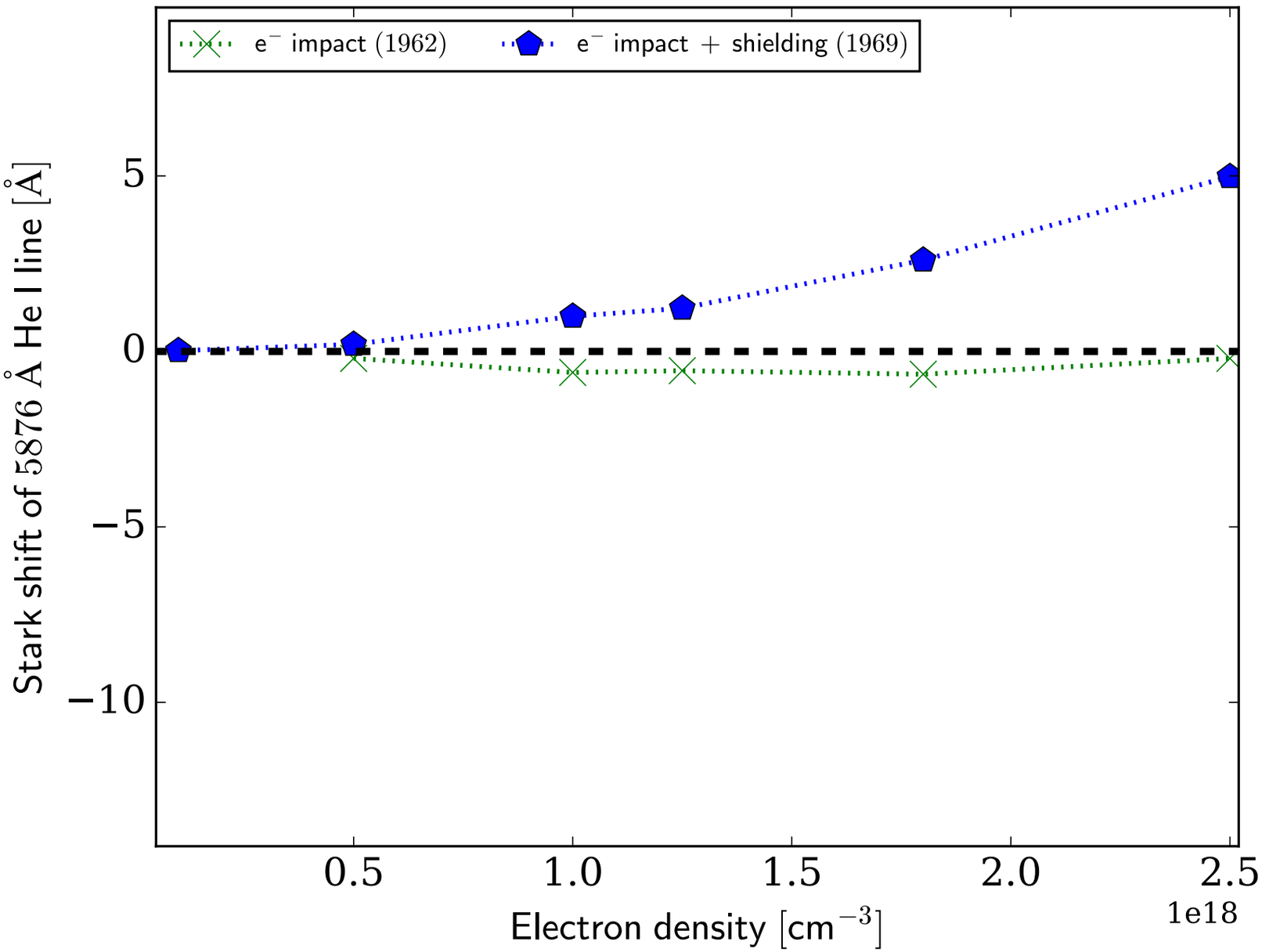


Current work

e⁻ impact + shielding

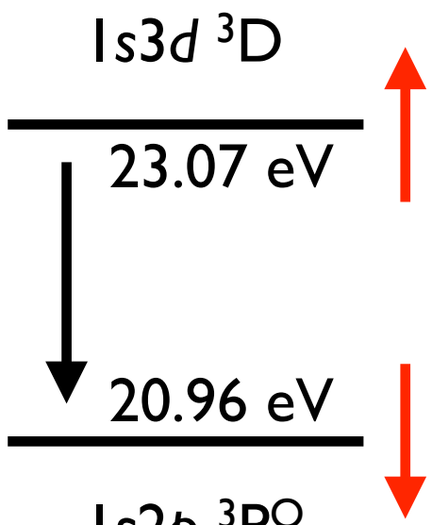


Levels of
5876 Å He I

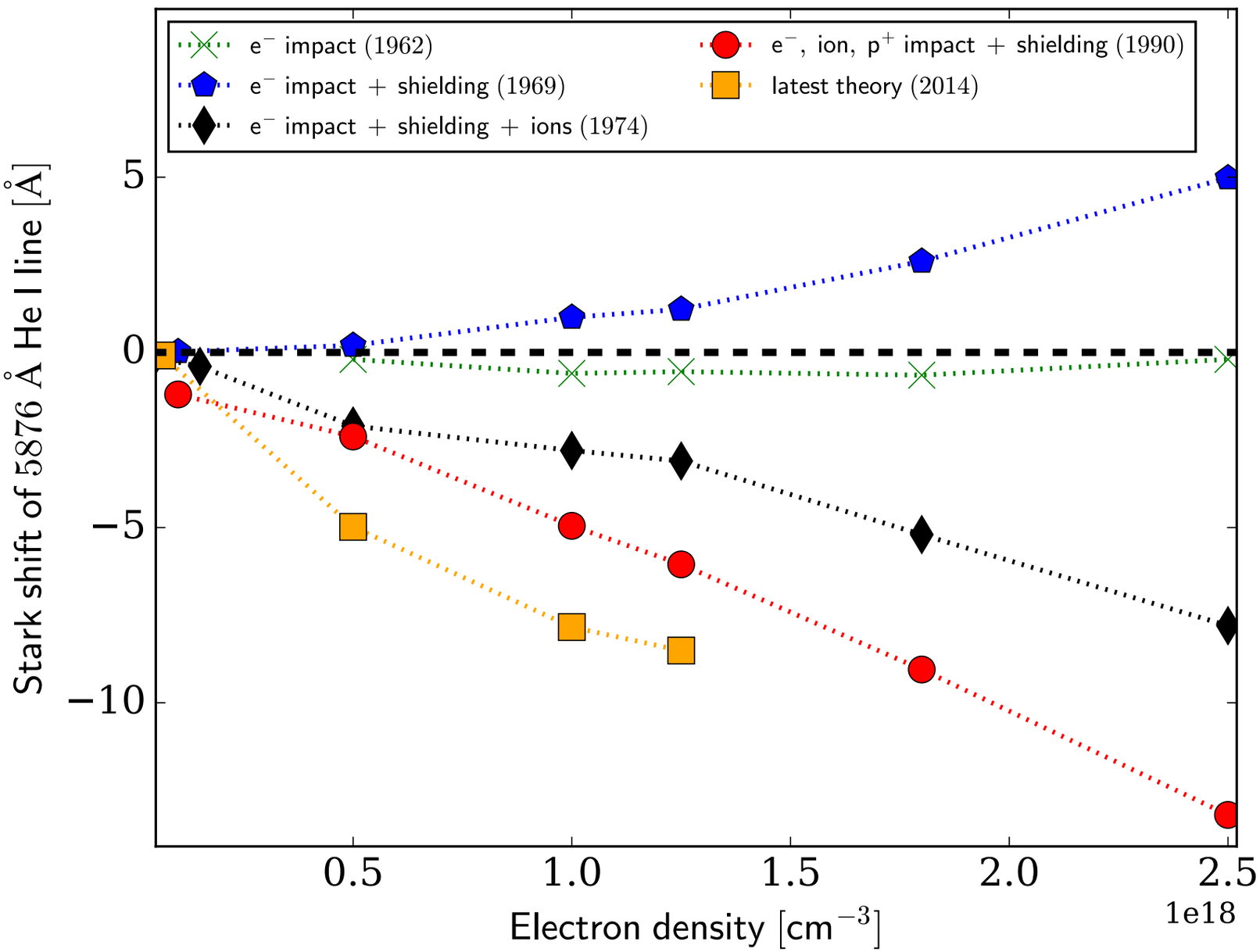


Current work

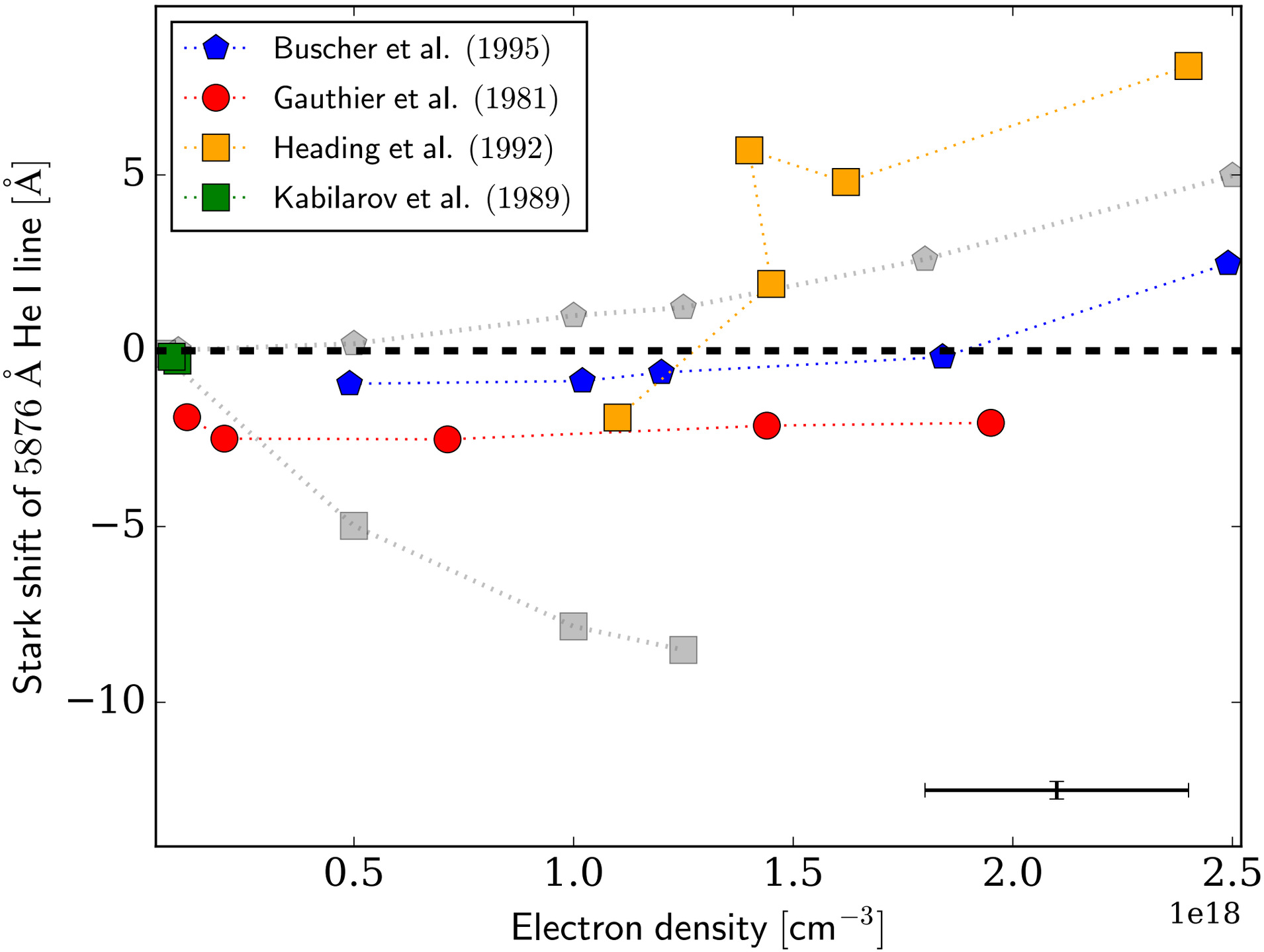
e-, ion impact + shielding
e-, ion, p^+ impact + shielding
latest atomic data



Levels of
5876 Å He I

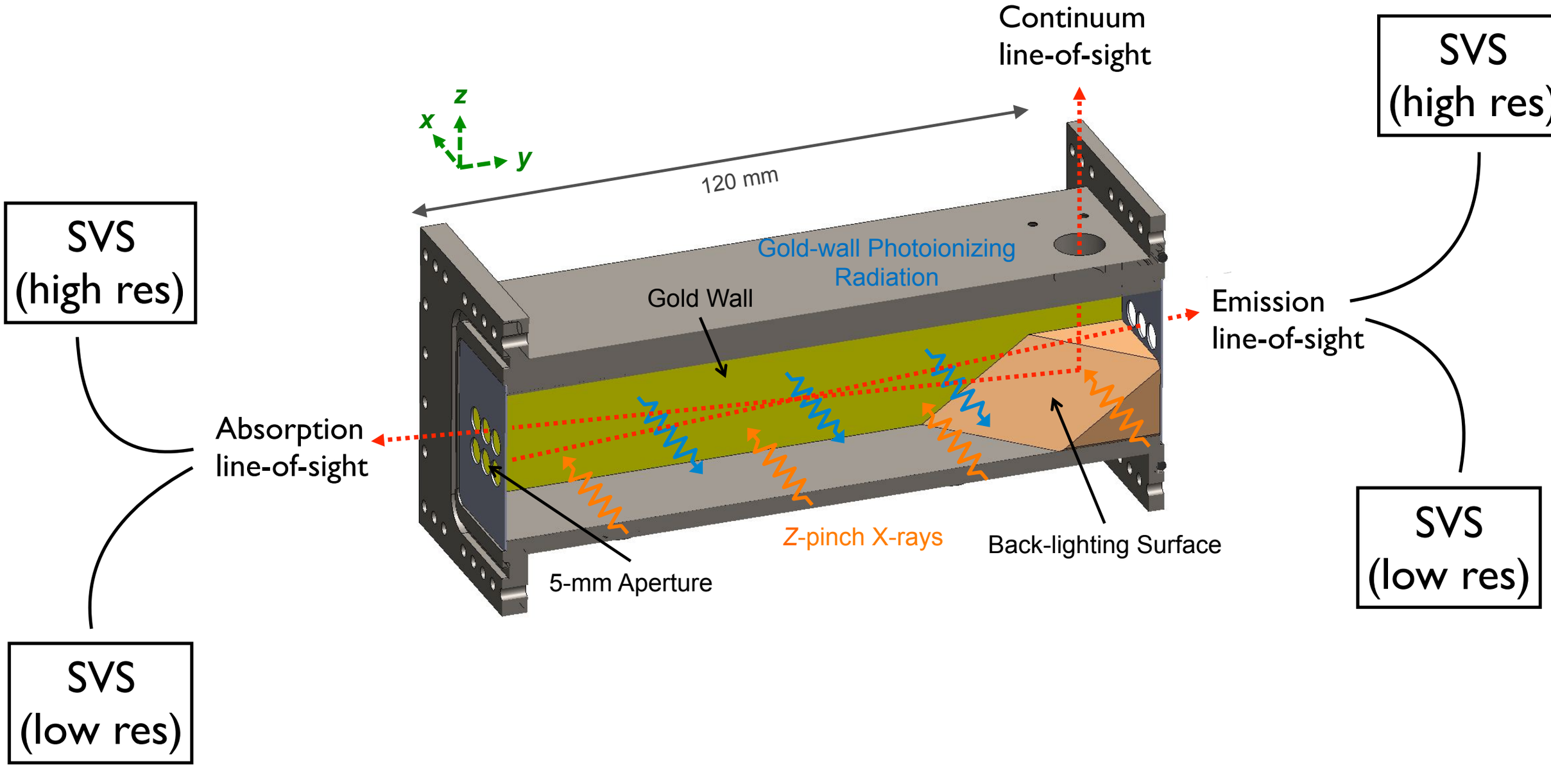


Current work



Comparison of theoretical and experimental shifts of 5876 Å He I line

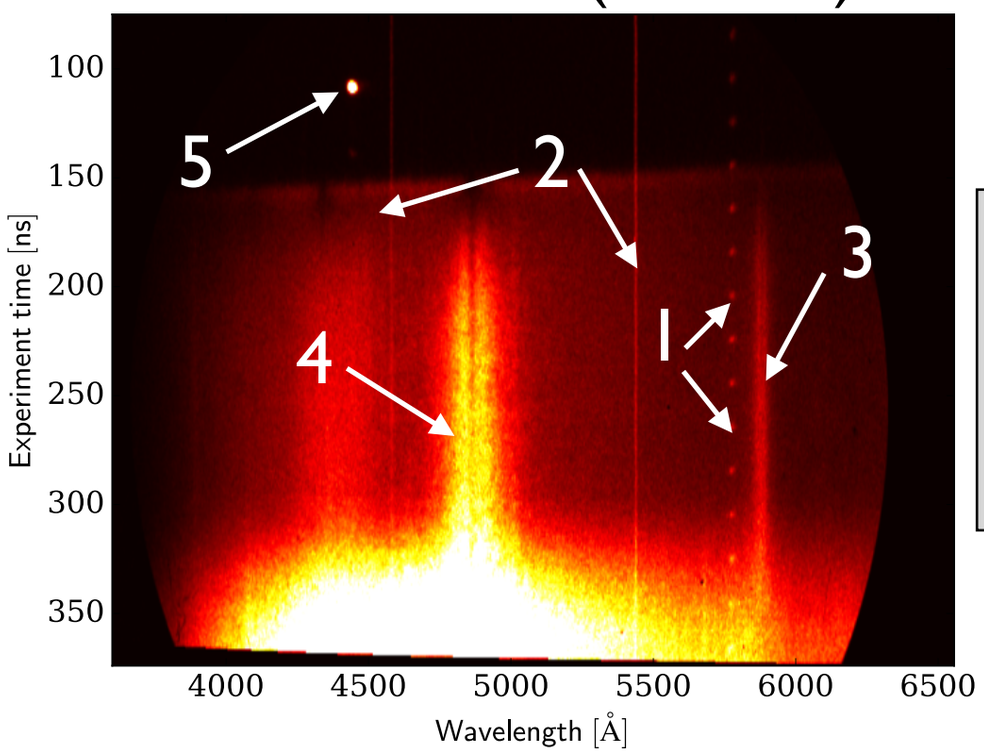
Updates to experimental platform



SVS: Streaked visible spectrometer

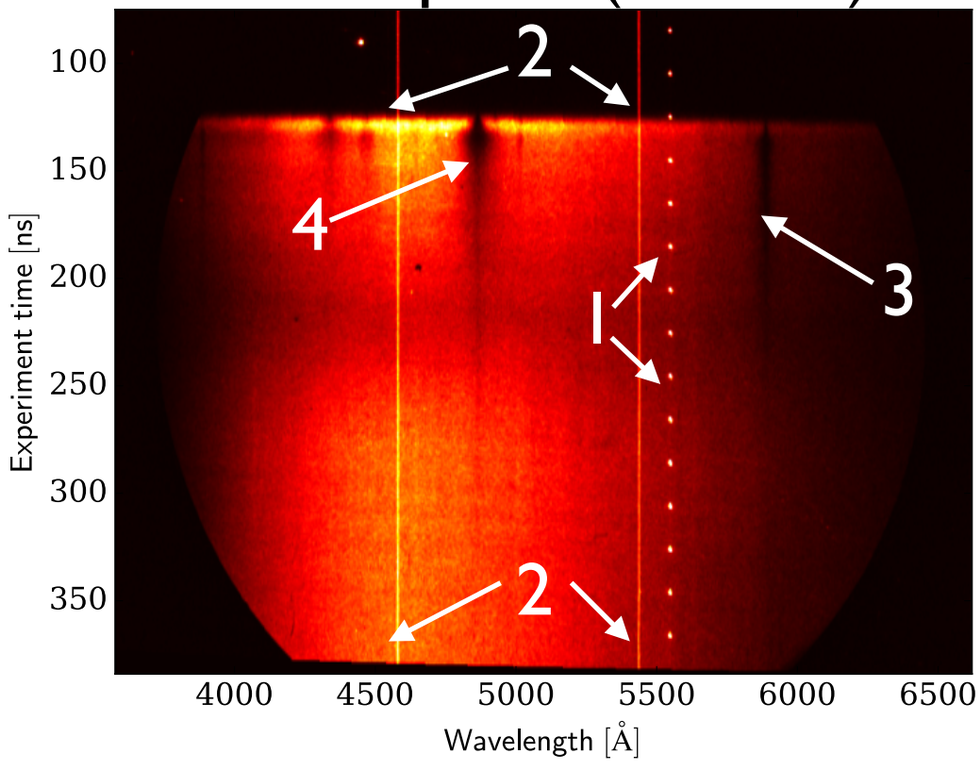
Preliminary He data

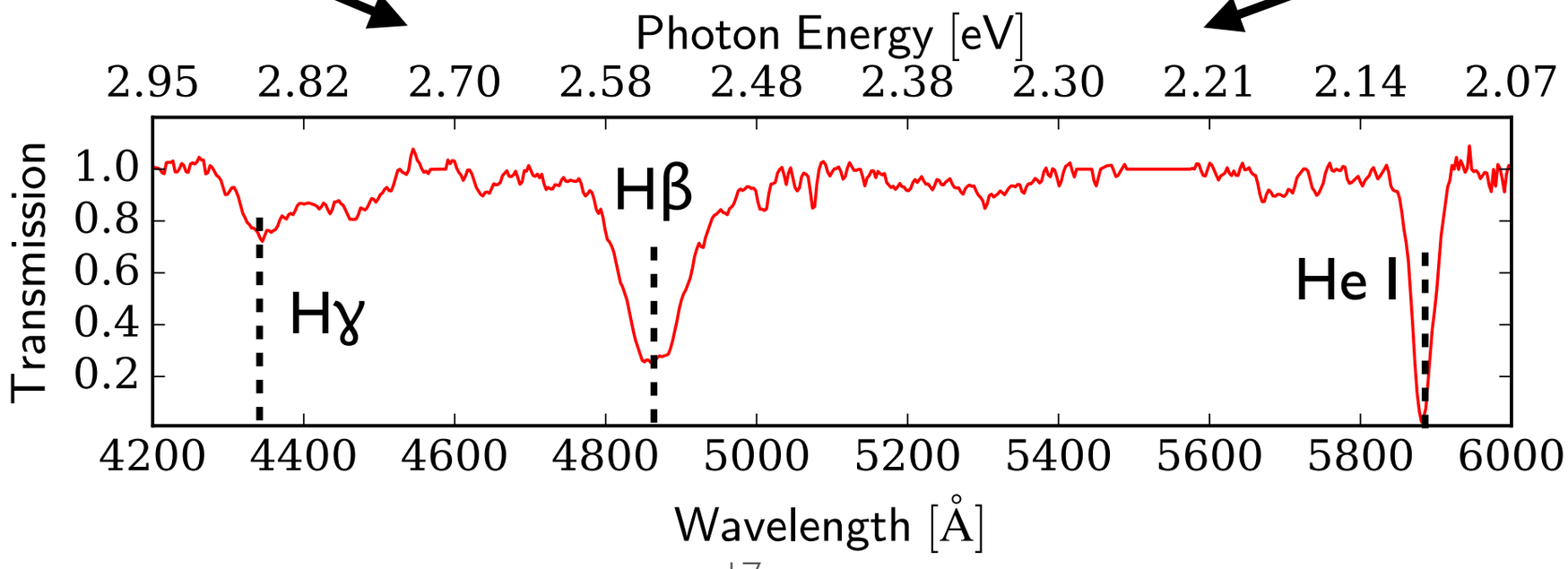
Emission (low res)



1: timing comb
2: fiducial laser
3: 5876 Å He I
4: Hβ
5: impulse

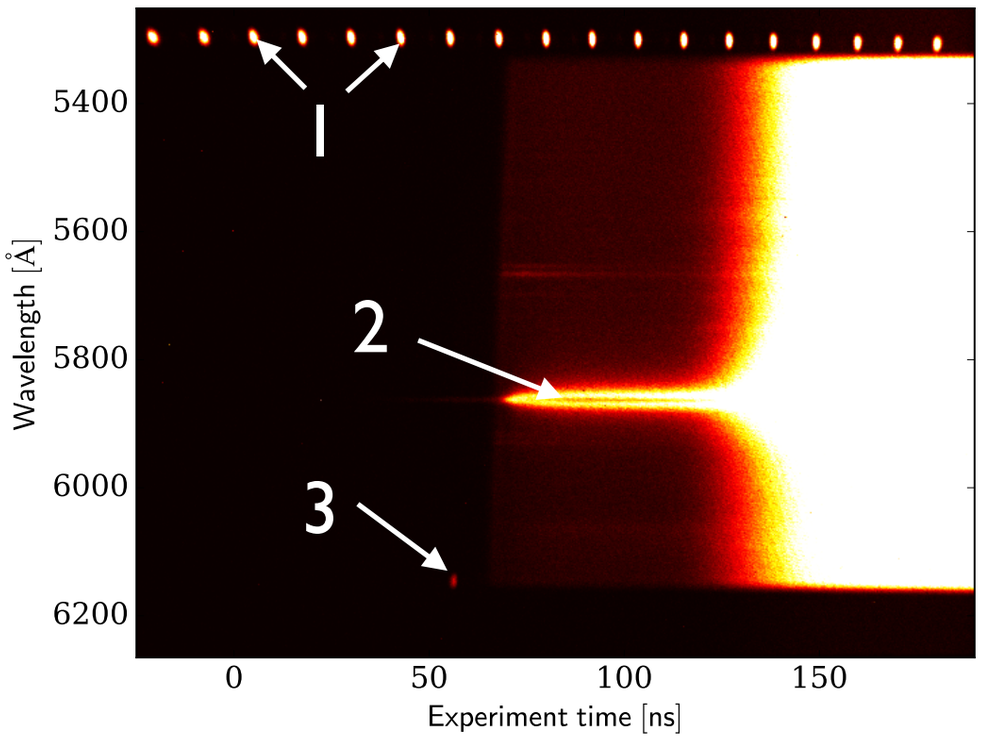
Absorption (low res)





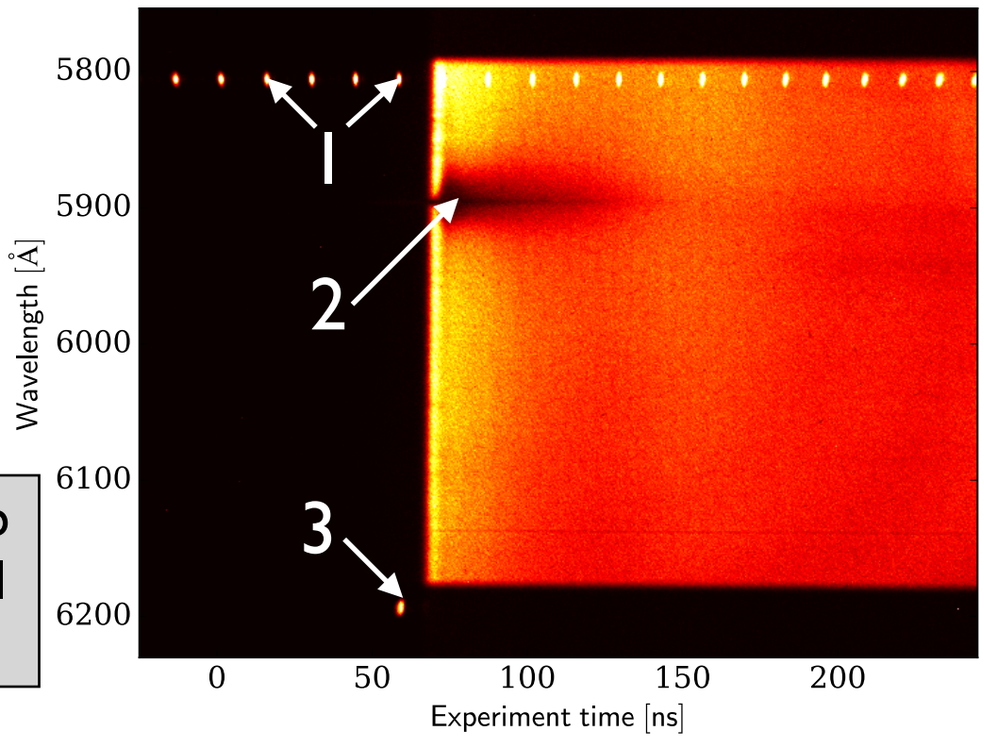
Preliminary He data

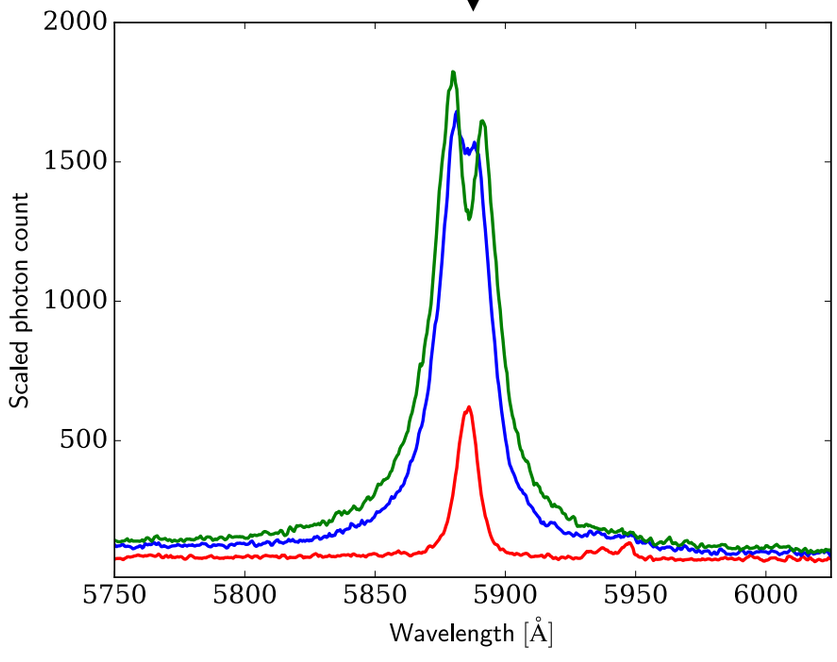
Emission (high res)

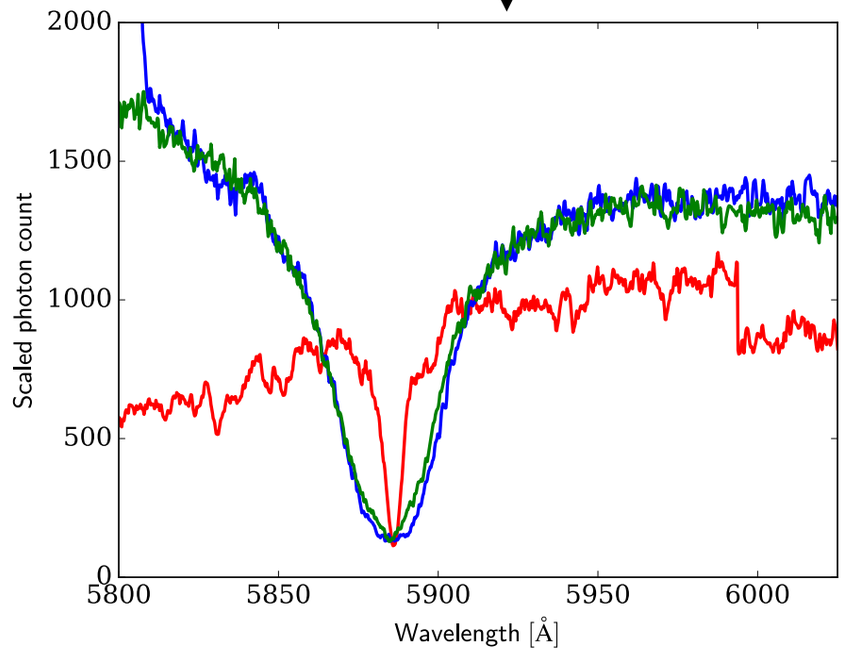


1: timing comb
2: 5876 Å He I
3: impulse

Absorption (high res)







Preliminary He data

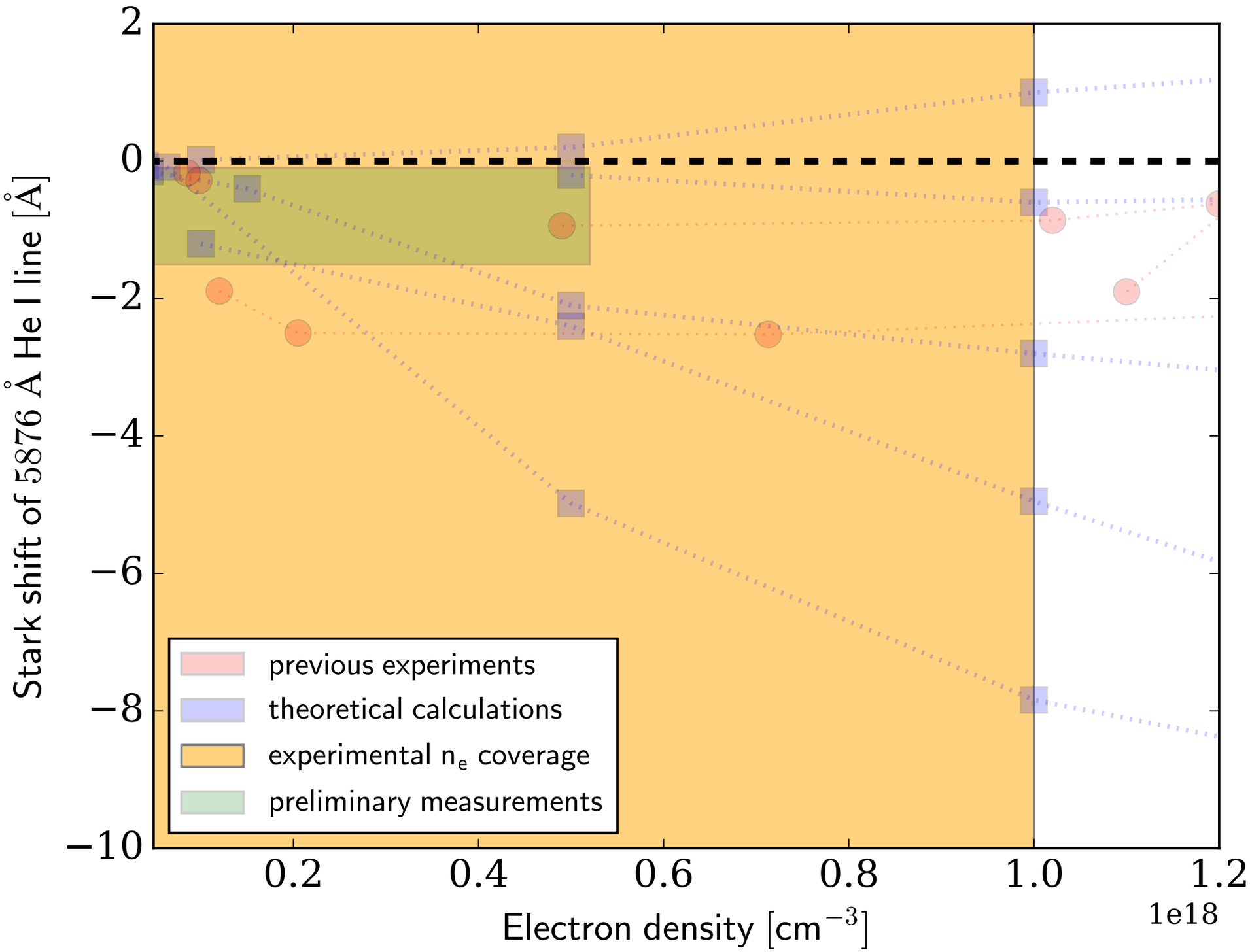
Previous experiments

- Weaknesses:
  - emission only
  - single datapoints
  - large n_e uncertainty
  - possible Doppler shift
- Strengths:
  - simpler optical setup

Our experiment

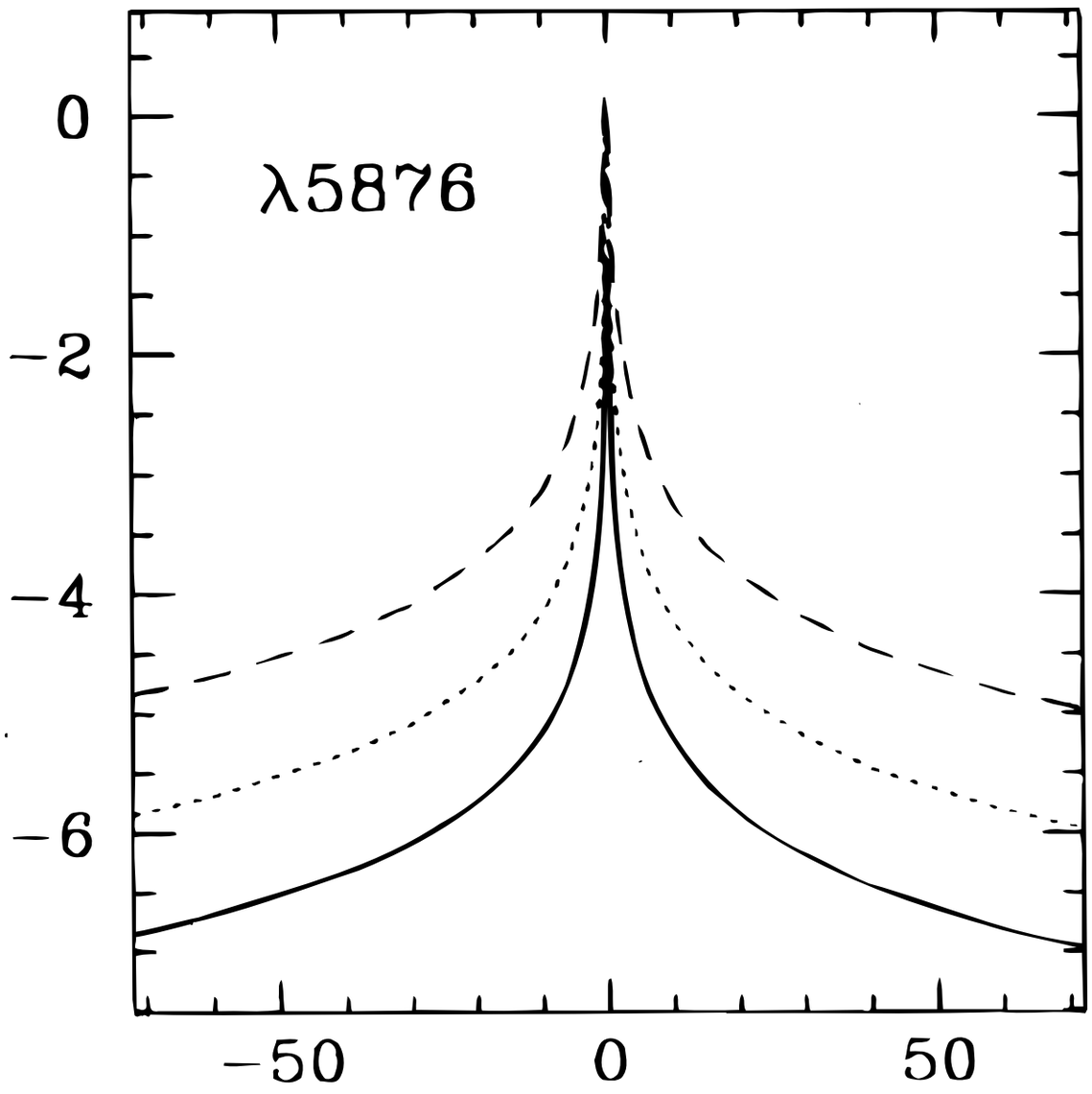
- Weaknesses:
  - complicated optical setup
- Strengths:
  - emission and absorption
  - range of n_e and T
  - smaller n_e uncertainty
  - no Doppler shift

Preliminary He data

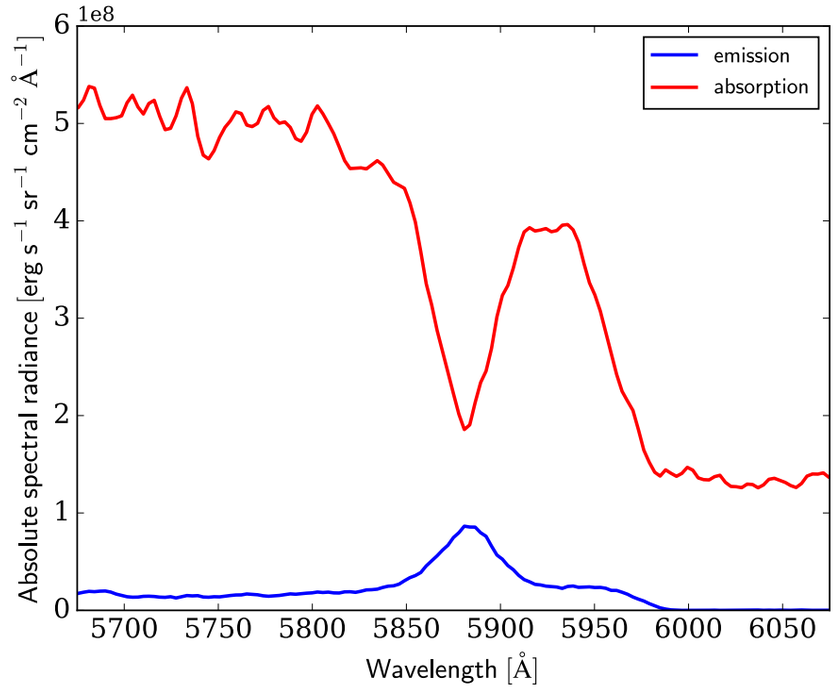


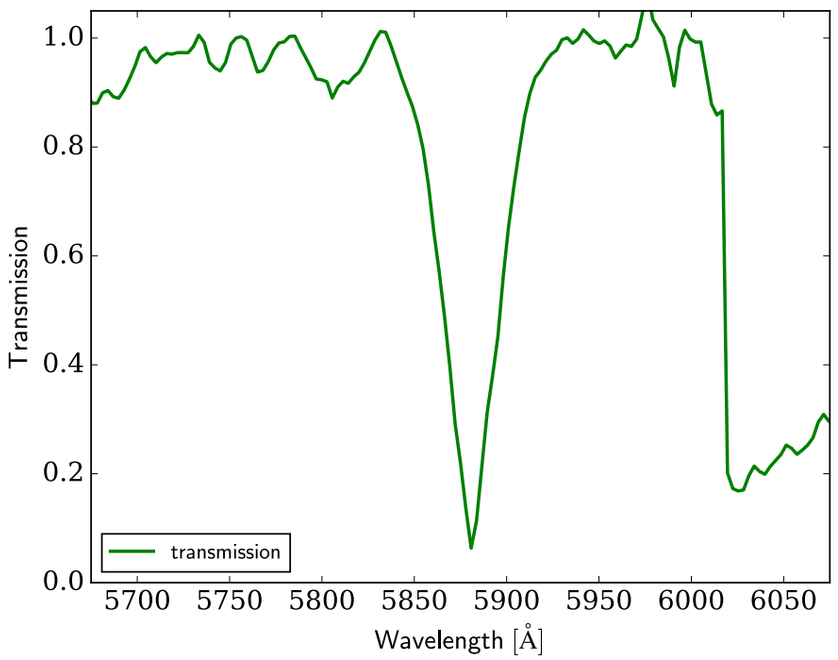
Preliminary He data

- We can validate Stark width calculations of Beauchamp et al. (1997)



Beauchamp et al. (1997)





Summary

- The WDPE platform to study hydrogen has been altered to study helium, and carbon at conditions found in white dwarf atmospheres.

- To investigate the origin of helium-dominated white dwarfs, preliminary pressure shifts and line profiles at appropriate conditions have been obtained. These measurements will also help in constraining theoretical models.

- Further work in characterizing wavelength and flux-level behavior of streak cameras is needed. These will allow us to extract true line profiles, widths and shifts.