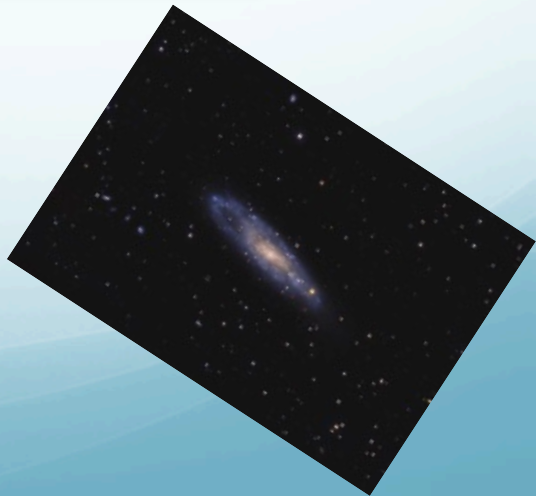
The nuclear star clusters survey

Kinematics and stellar populations from X-Shooter integrated light spectroscopy

Nikolay Kacharov – MPIA Heidelberg

with N. Neumayer, A. Picotti, J. C. Walcher, A. Seth



Motivation

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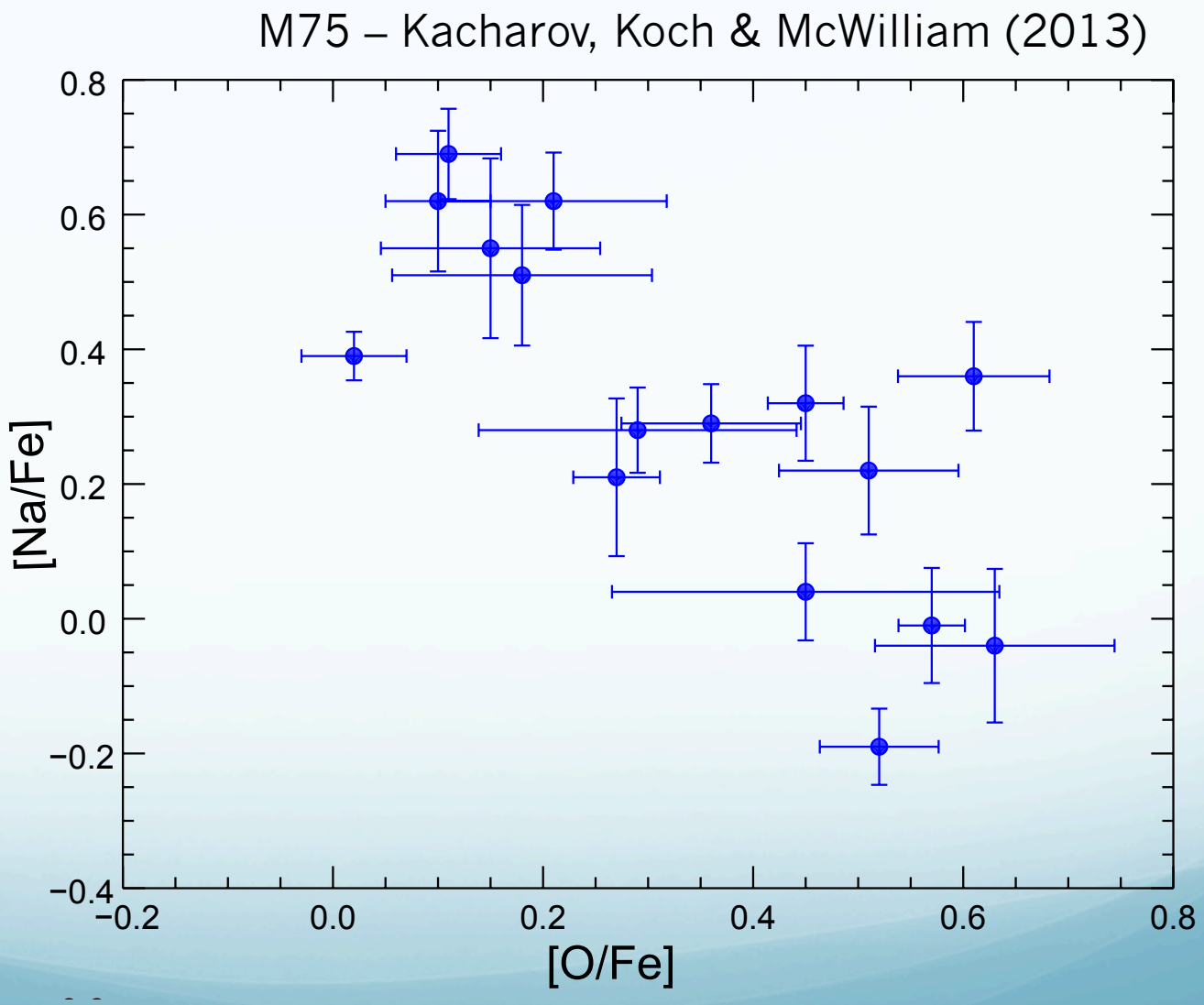
- ✓ light element variations.
- ✓ no Fe spread.
- ✓ simple CMD.



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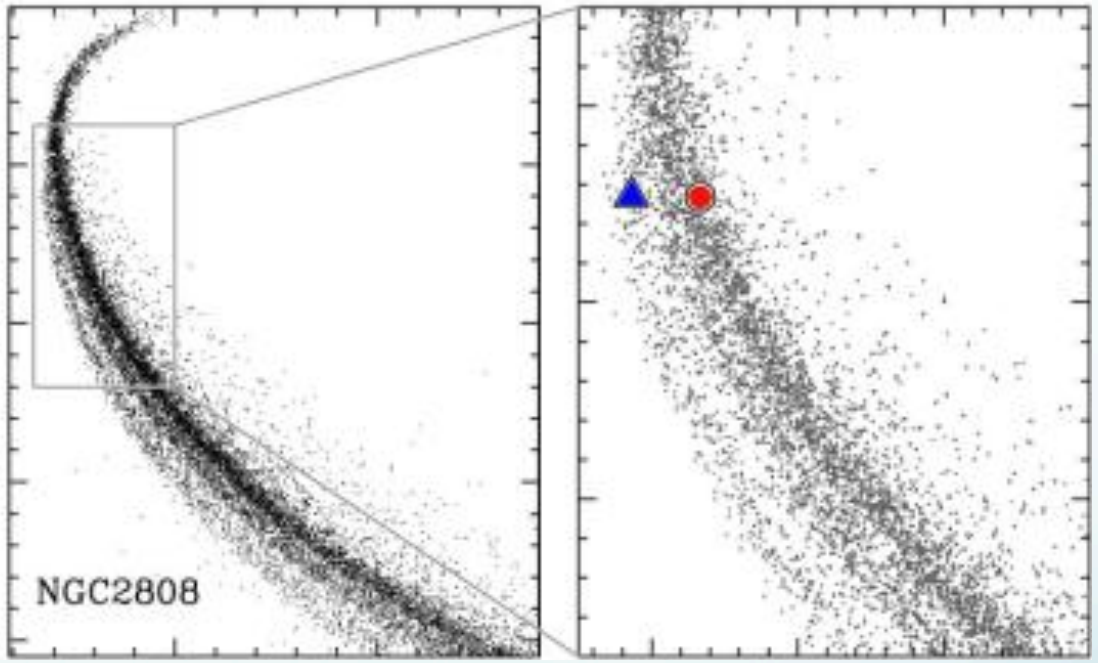
NGC 2808 - Piotto et al. (2007)



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- ✓ significant Fe spread.
- ✓ complex CMD consistent with extended SFH.

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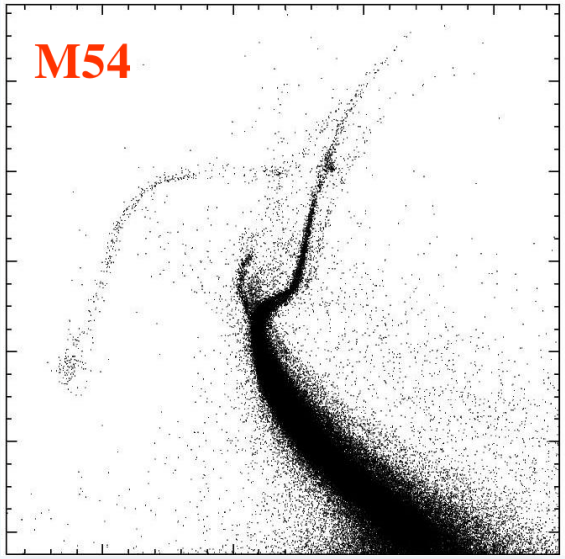
Siegel et al. (2007)



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Motivation

High mass GCs and UCDs
– tidally stripped nuclei.

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formation sites uncertain.

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Increasing mass – increasing complexity

NSC main questions

- **Formation mechanism** – dry vs. wet mergers, or a combination of both?
- **Formation epoch** – when was the nucleus assembled, is there still ongoing star formation?
- **Chemical enrichment history** – metallicities and build-up of individual elements.
- **Dynamics –** interplay between the nucleus with the surrounding galaxy and massive black hole (if existent).

Our NSC survey

- **X-Shooter** long-slit (350 – 2500 nm) observations of 8 bulge-less galaxies up to 6.5 Mpc in the southern hemisphere.
- **MMTO** long-slit (300 – 900 nm) observations of 7 additional galaxies in the northern hemisphere.
- More data coming aiming for completeness out to 10 Mpc.

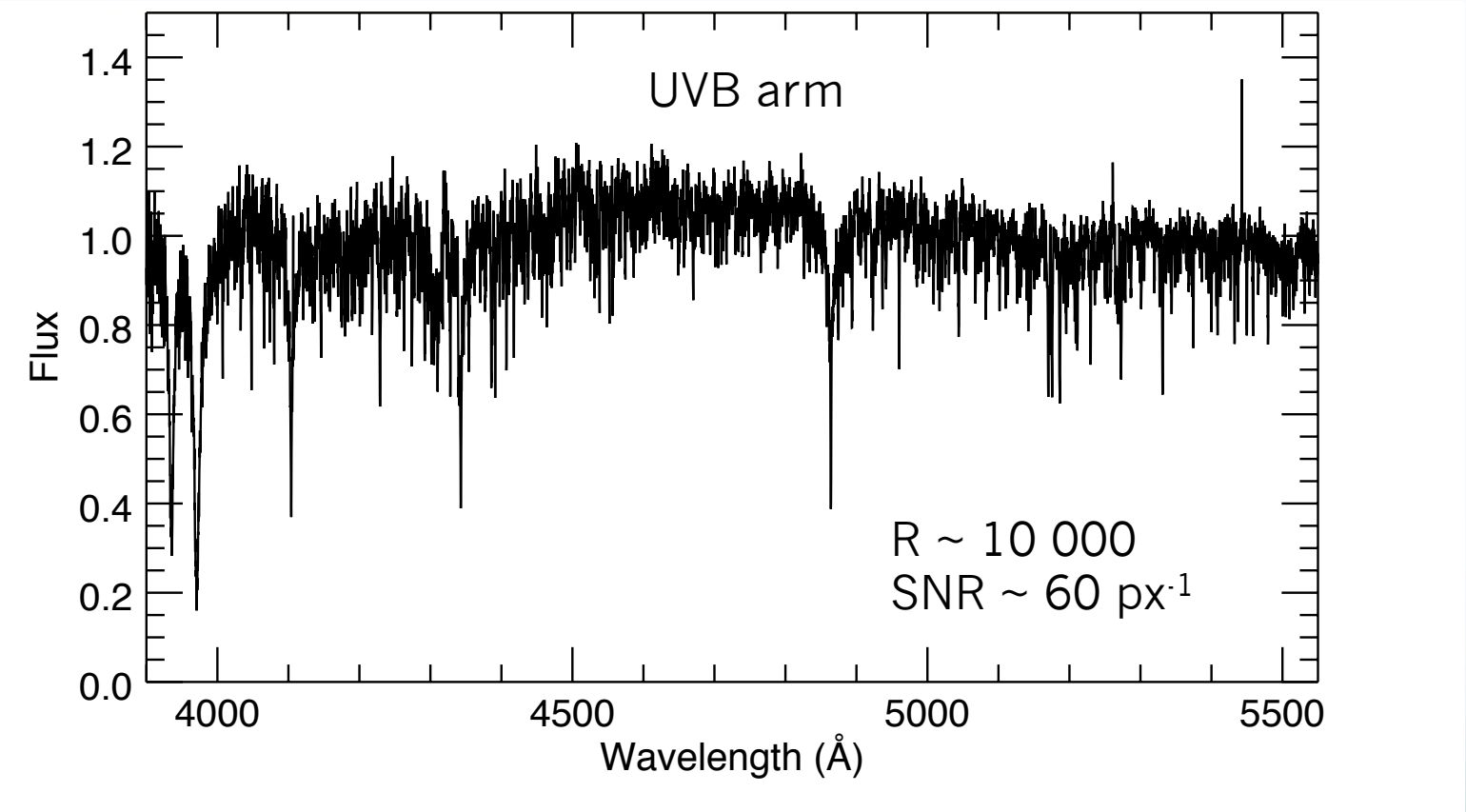
NGC247
3.6 Mpc

NGC300
2.2 Mpc

NGC5206
3.6 Mpc

NGC7793
3.3 Mpc

Unresolved stellar populations analysis technique



- **Full spectrum fitting** – use all the information by fitting all pixels, independently of the shape of the continuum and extinction.

Full spectrum fitting with UlySS
(Koleva et al. 2008)

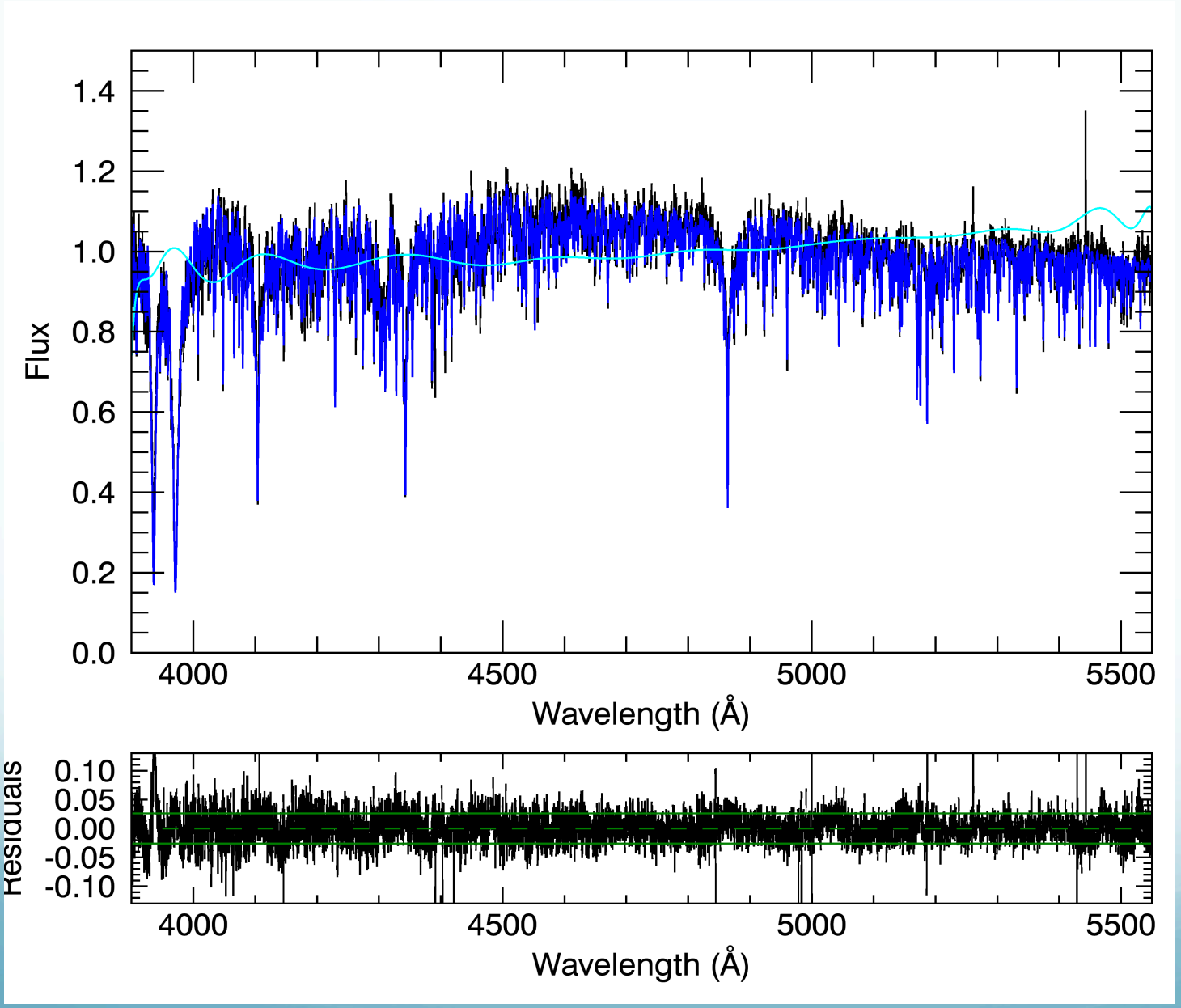
- Empirical stellar population models:
  - Pegase HR models computed with the Elodie 3.1 library.
  - Salpeter IMF (0.1 – 120 M_{Sun})
  - Wavelength range: 390 – 680 nm
  - R = 10 000

- Simultaneous estimation of the radial velocity and the internal velocity dispersion of the system.

- Use of a multiplicative polynomial to fit the continuum and remove effects from extinction or uncertain flux calibration.

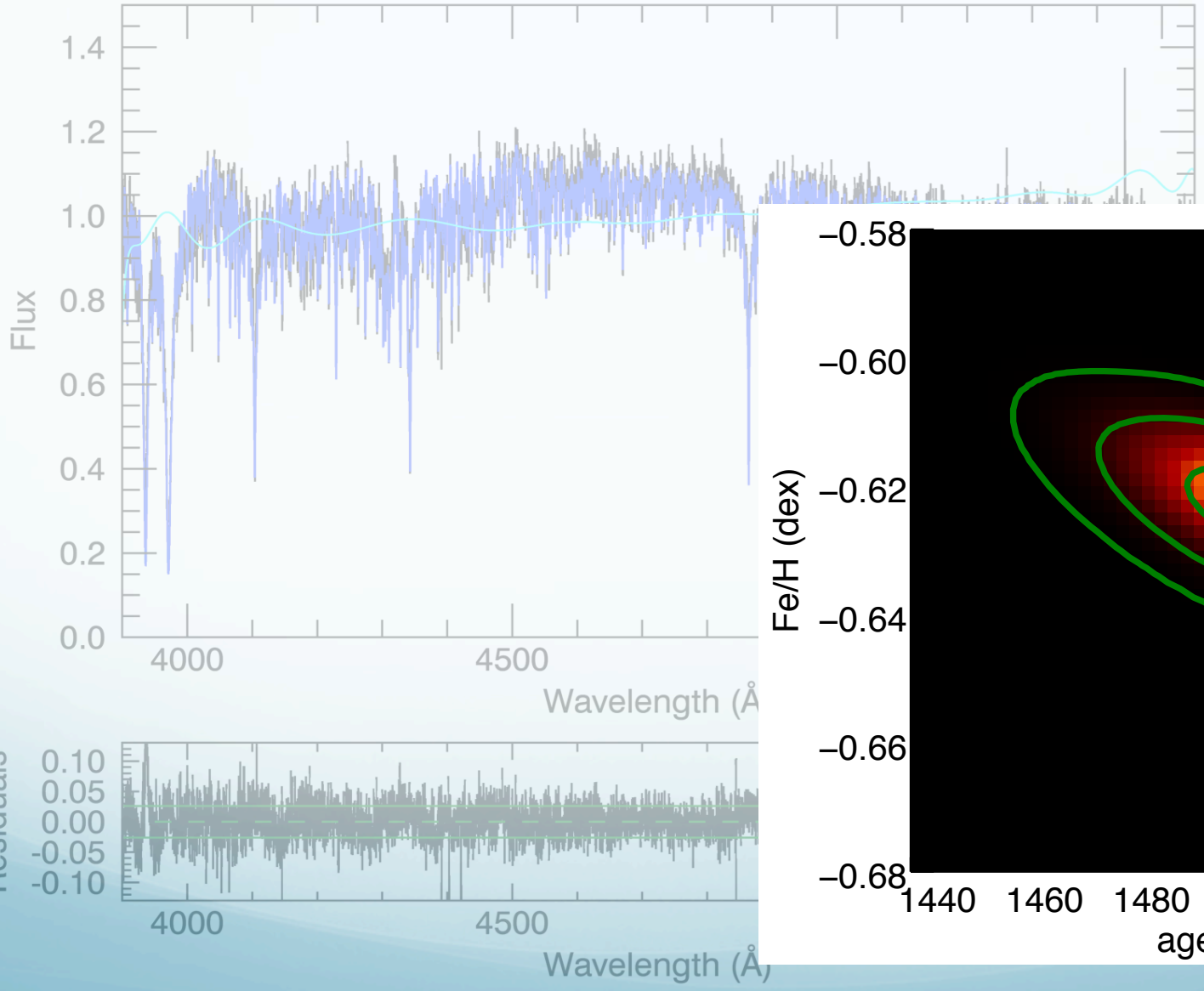
- Use velocity calibration stars to infer the line spread function.

NGC 300 UVB – best fit SSP



Age = 1500 Myr
[Fe/H] = -0.62

NGC 300 UVB – best fit SSP



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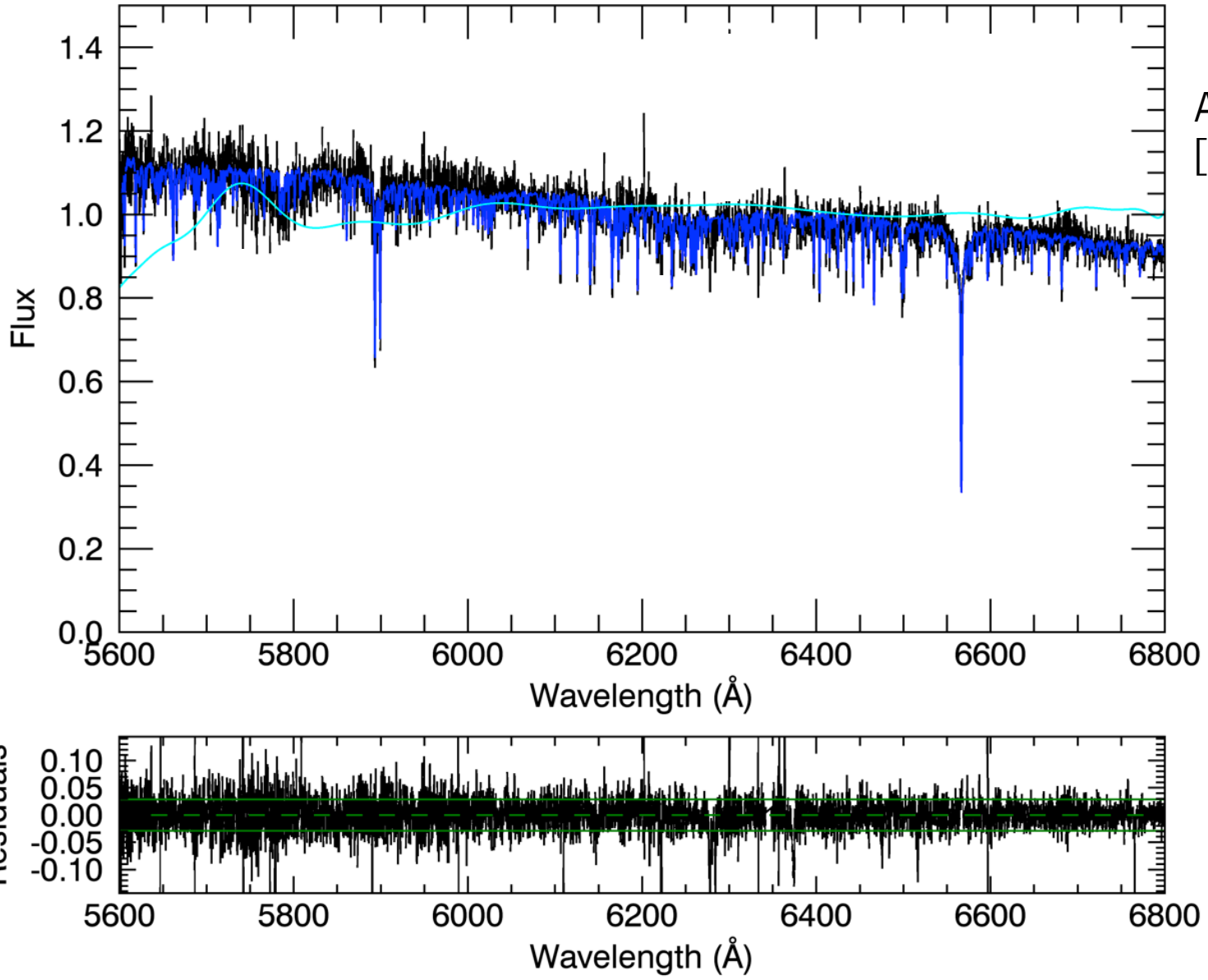
NGC 300 VIS – best fit SSP



Age = 1400 Myr
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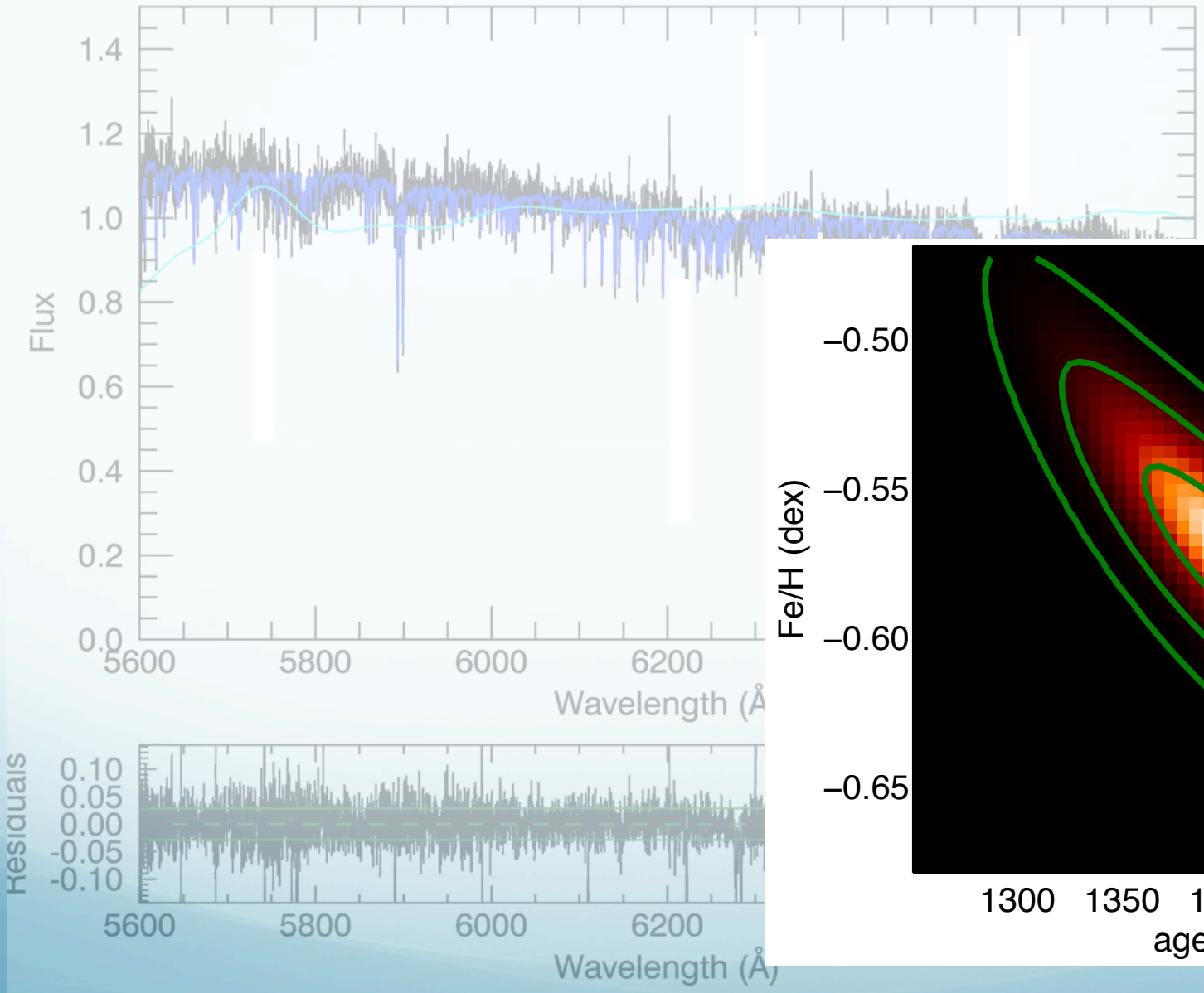
NGC 300 VIS – best fit SSP



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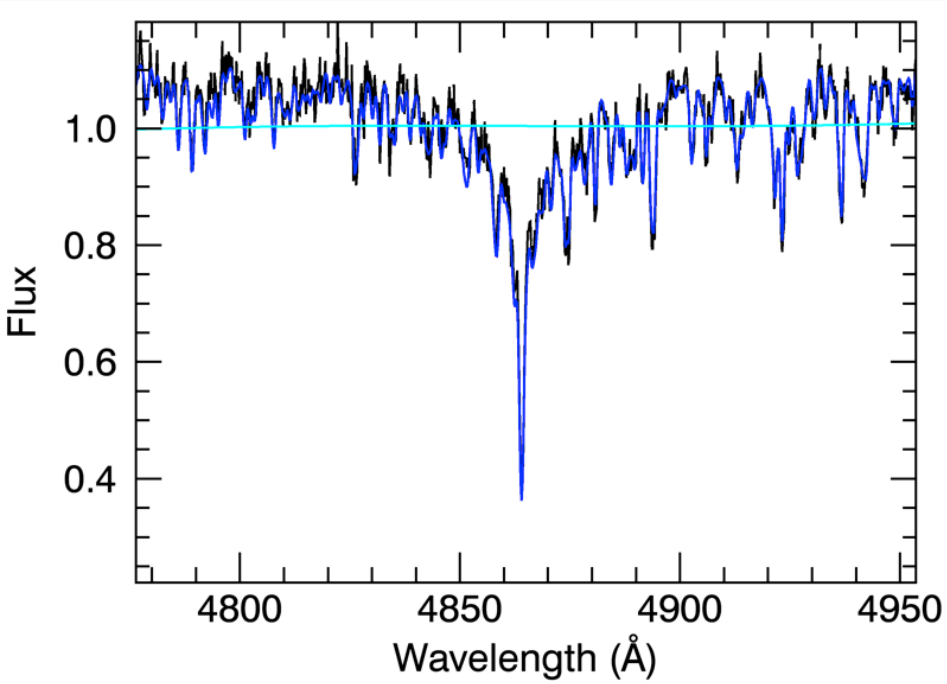
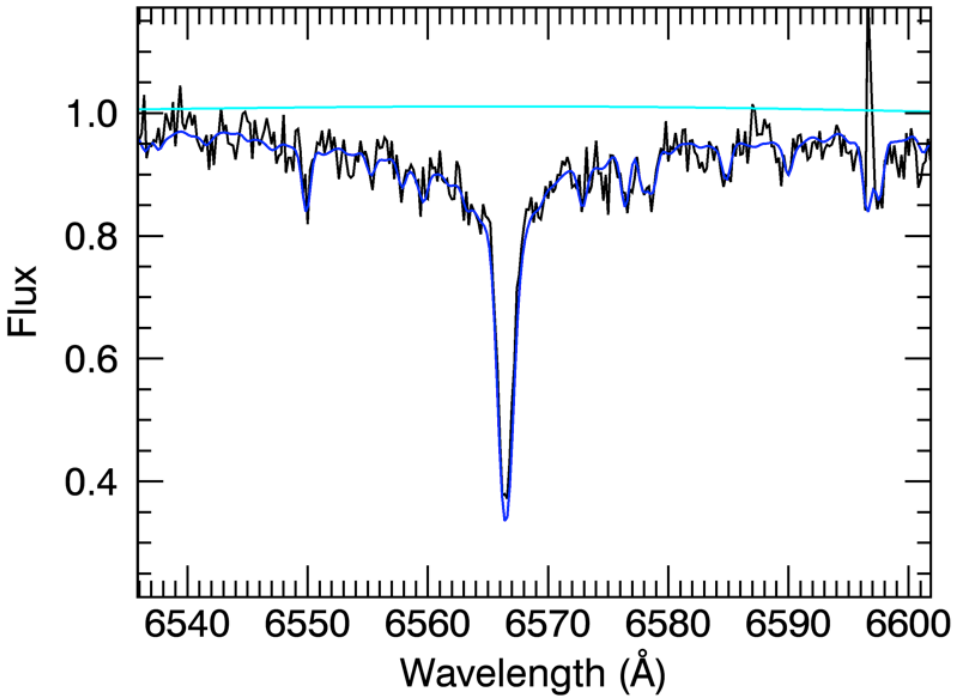
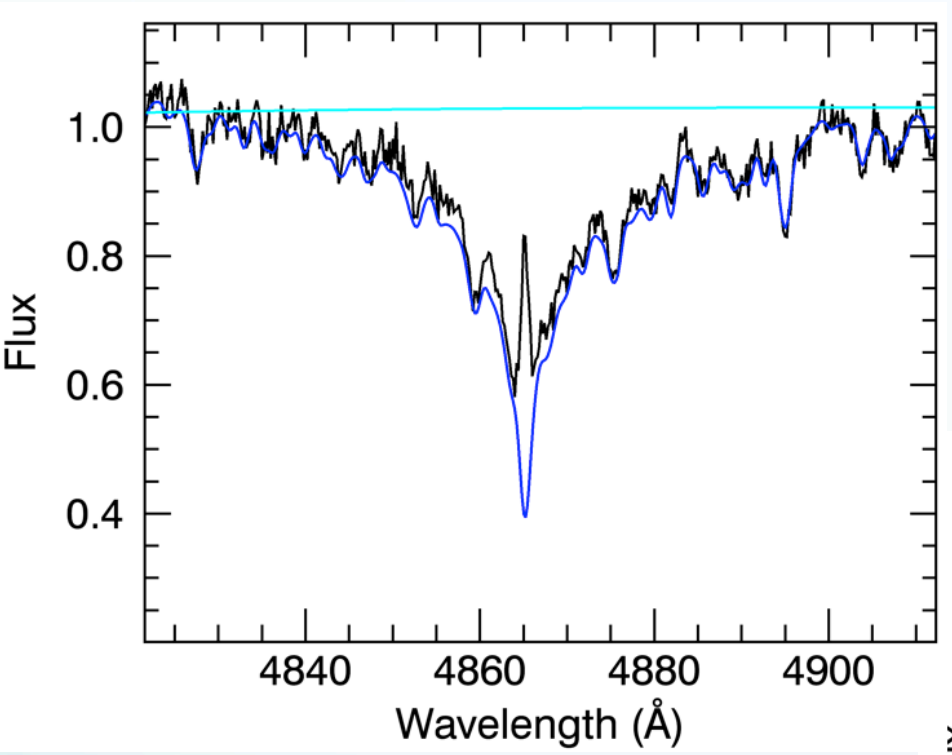
NGC 300: Hβ and Hα lines



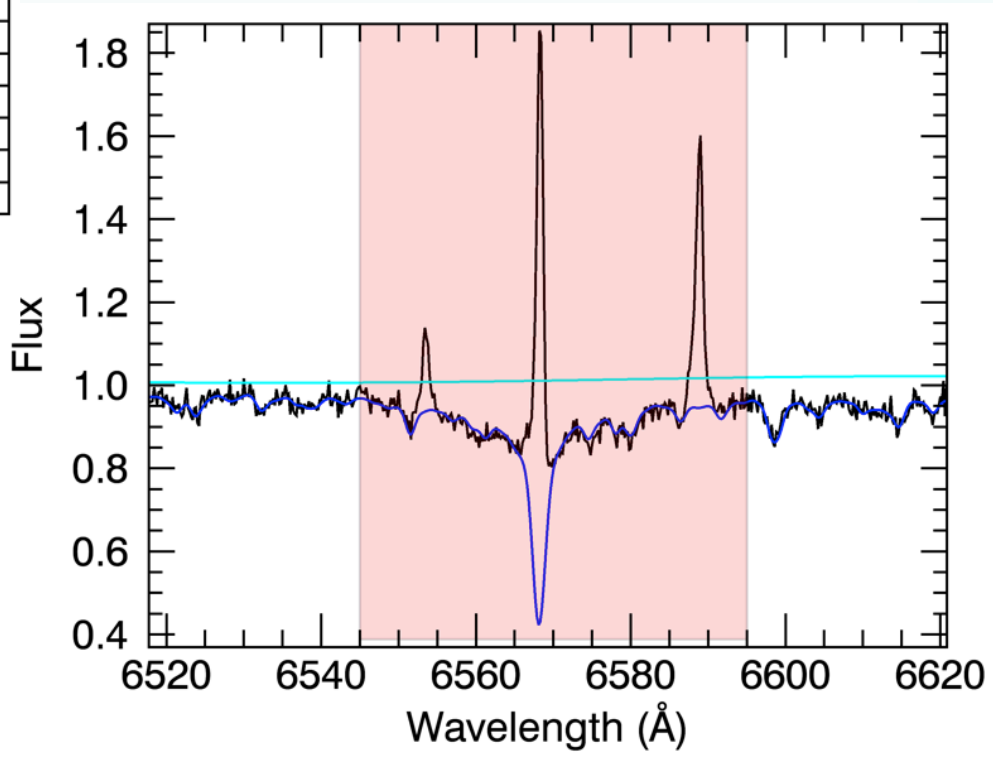
NGC300 and NGC5206 – no emission lines in the spectra.

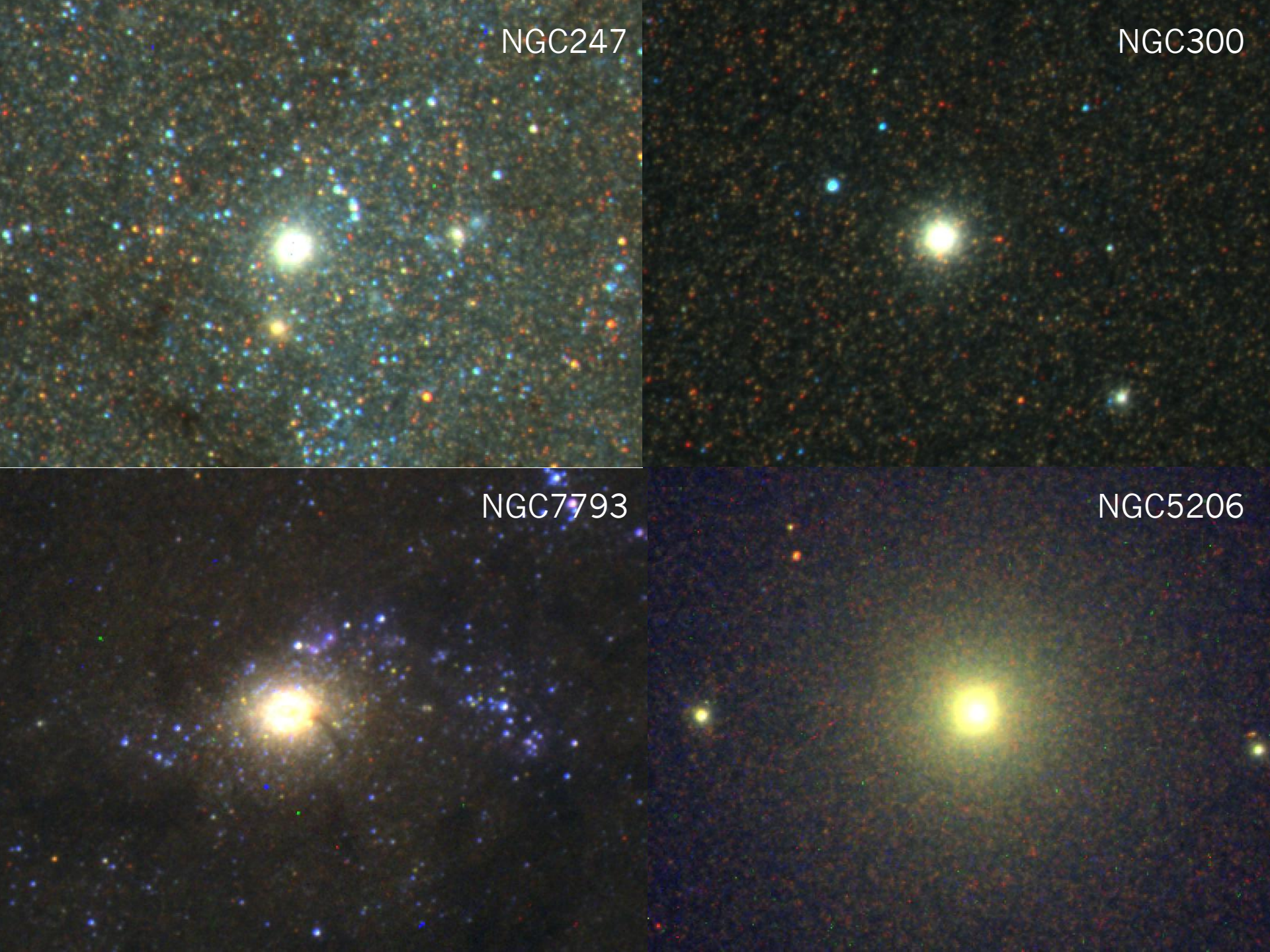


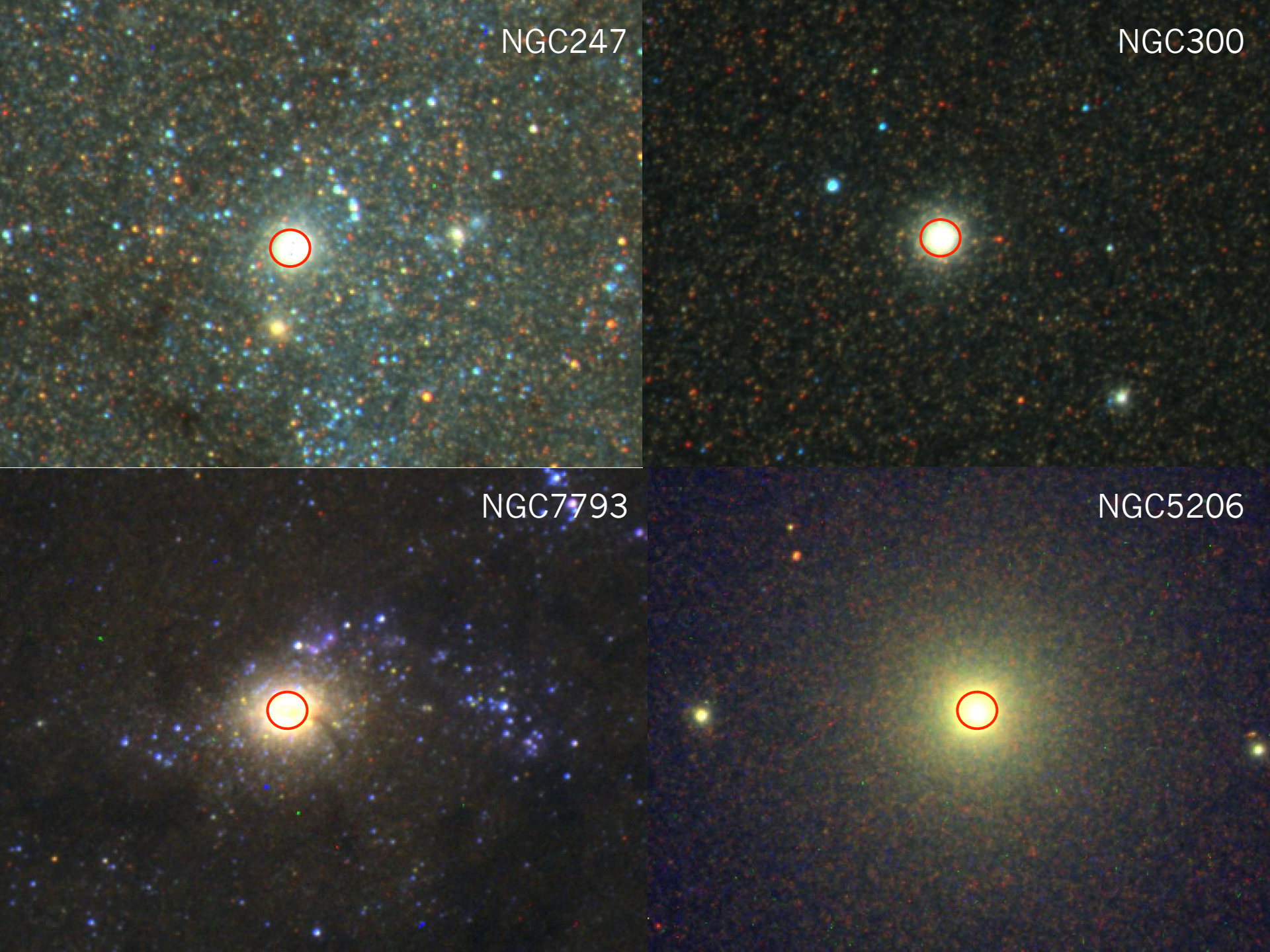
NGC 7793: Hα, Hβ emission



NGC247 and NGC7793 – strong emission lines in the spectra.




NGC247
NGC300
NGC7793
NGC5206


NGC247
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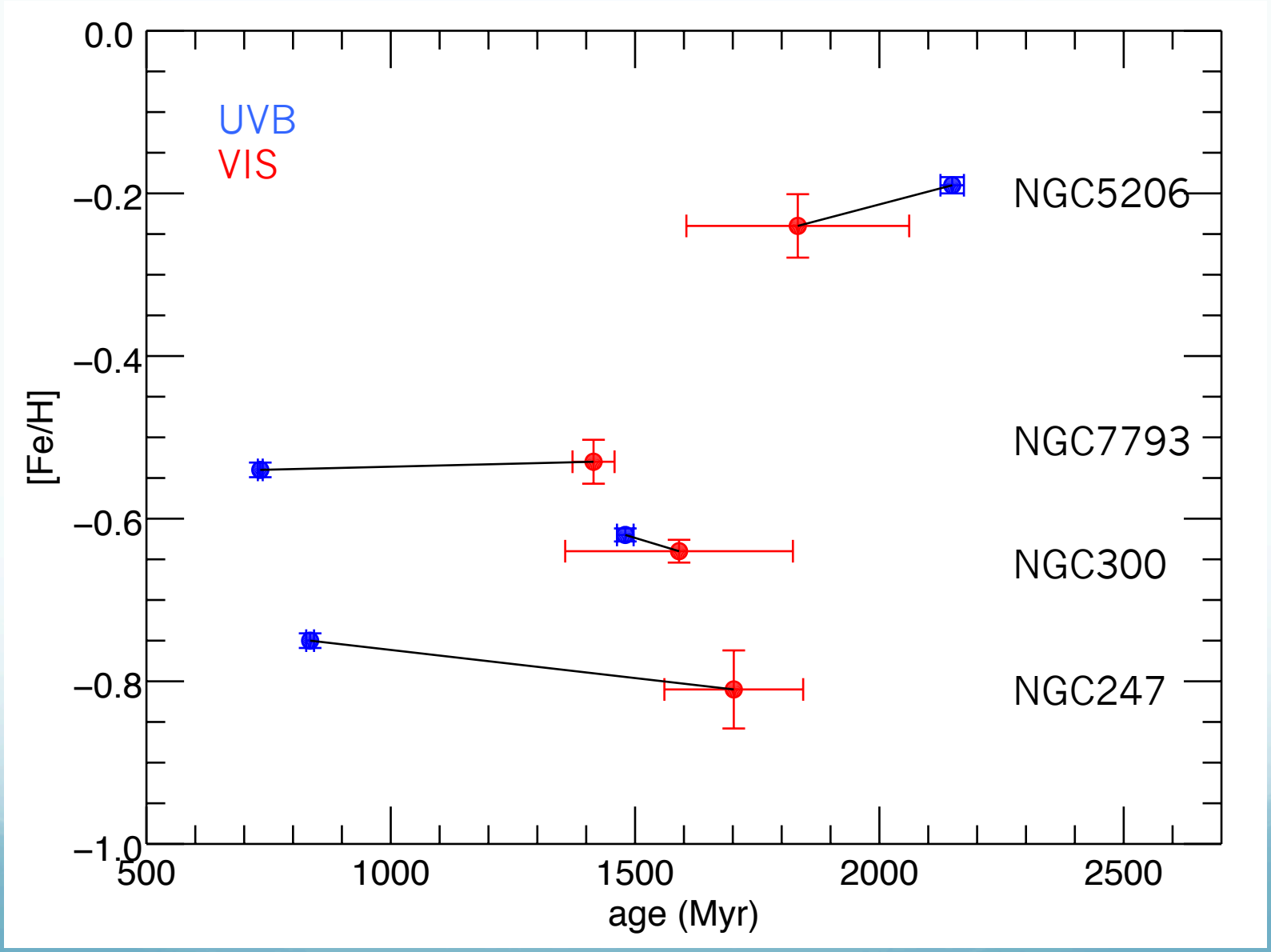
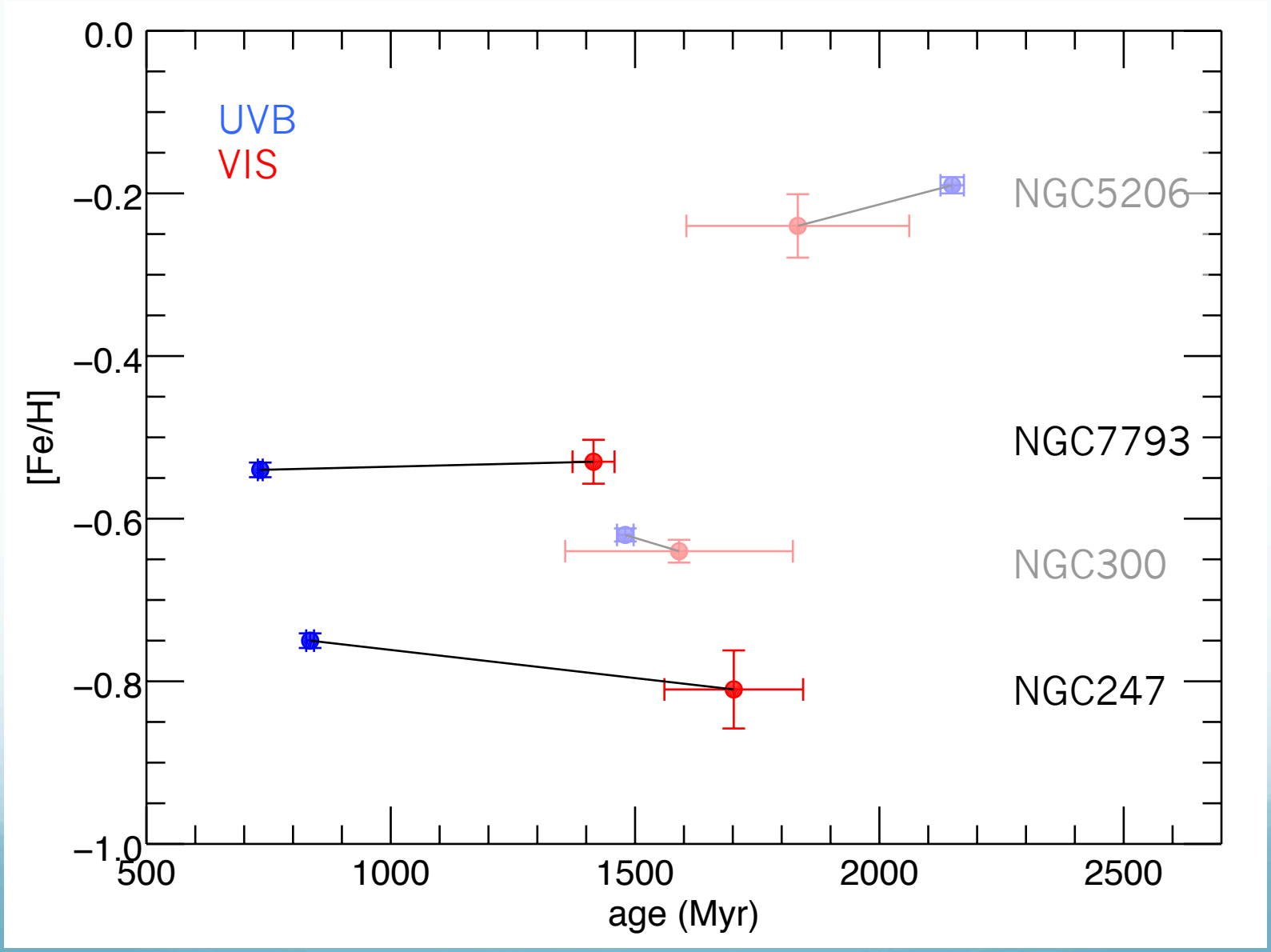
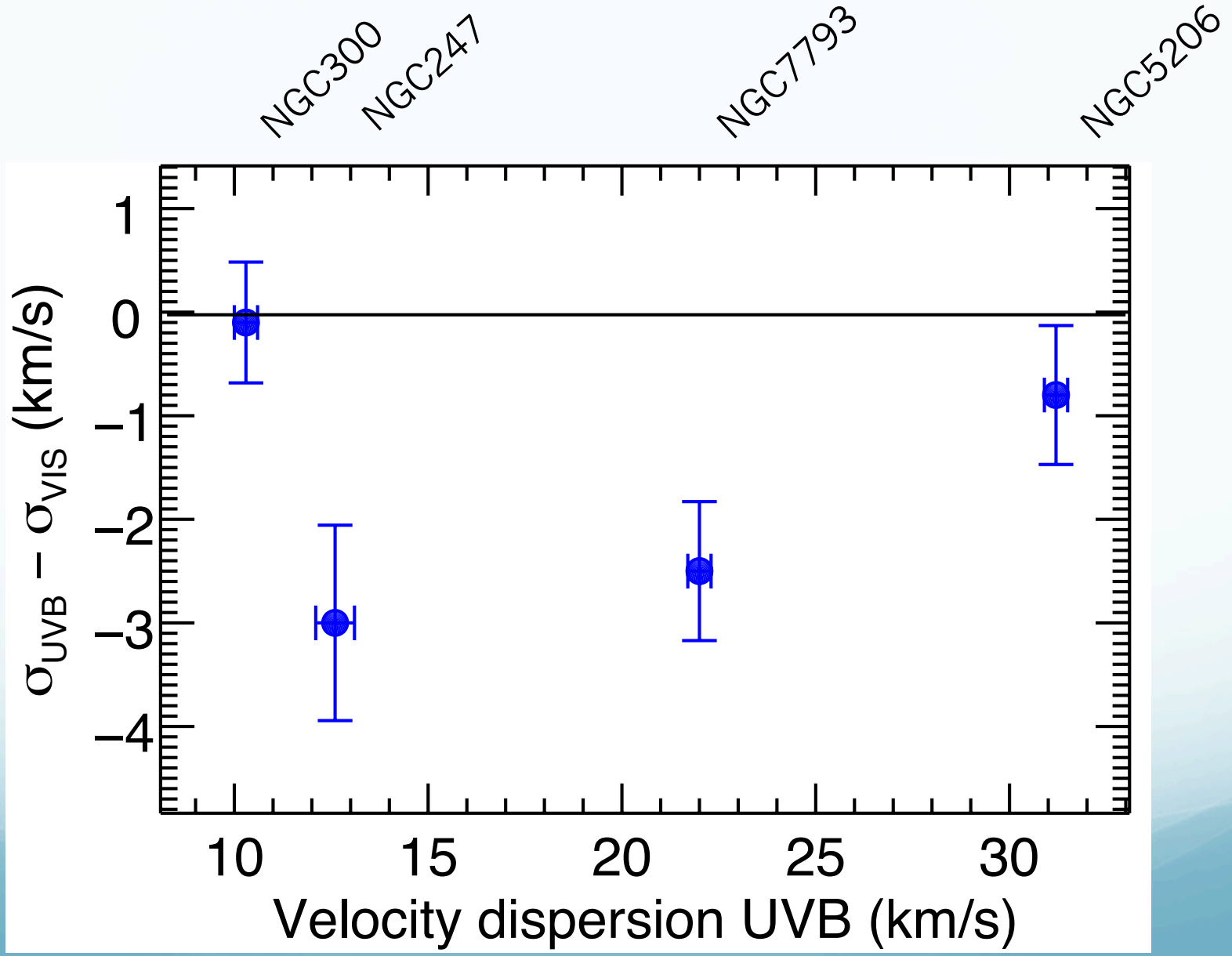
Age and metallicity estimates



UVB age inconsistencies



Velocity dispersions



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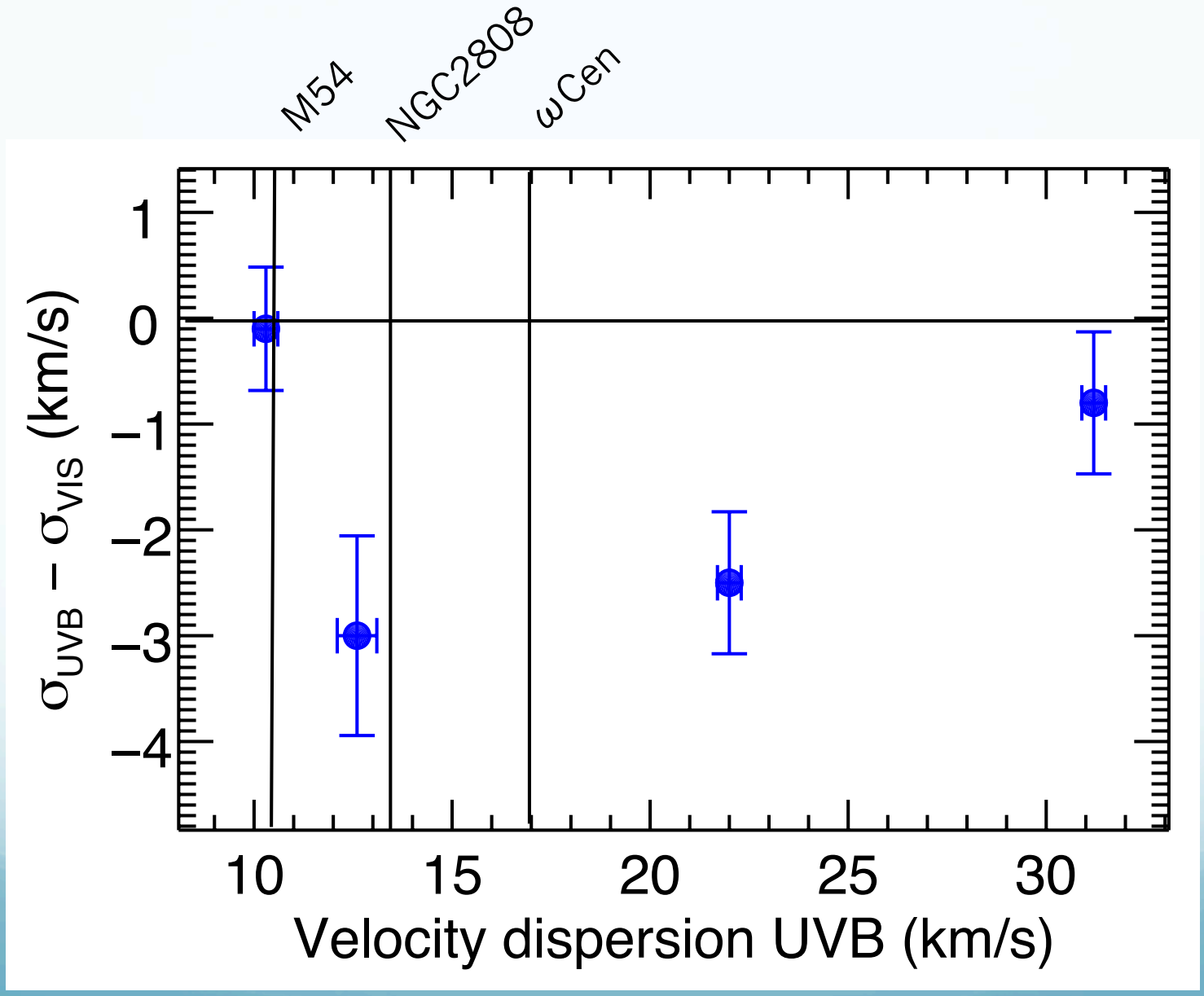
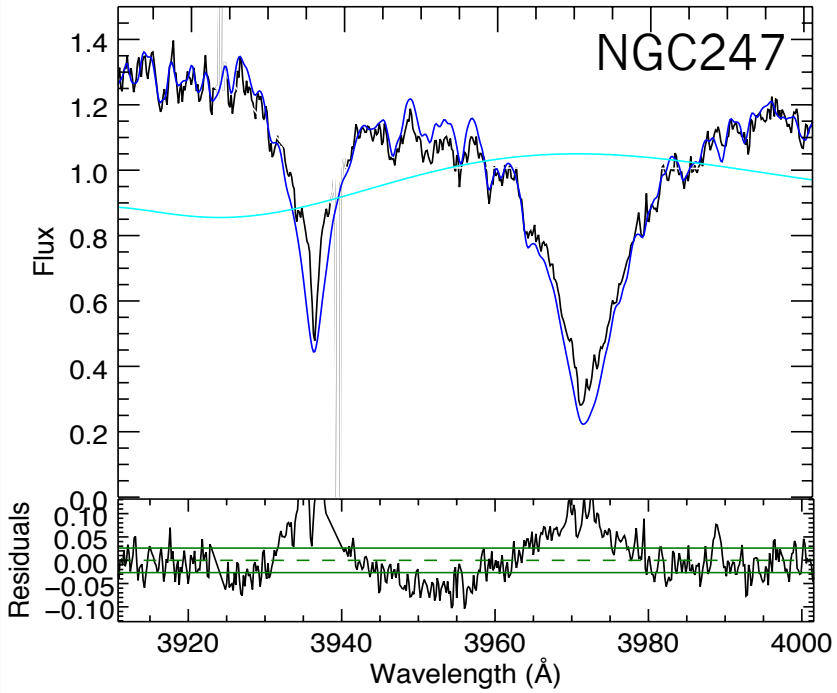
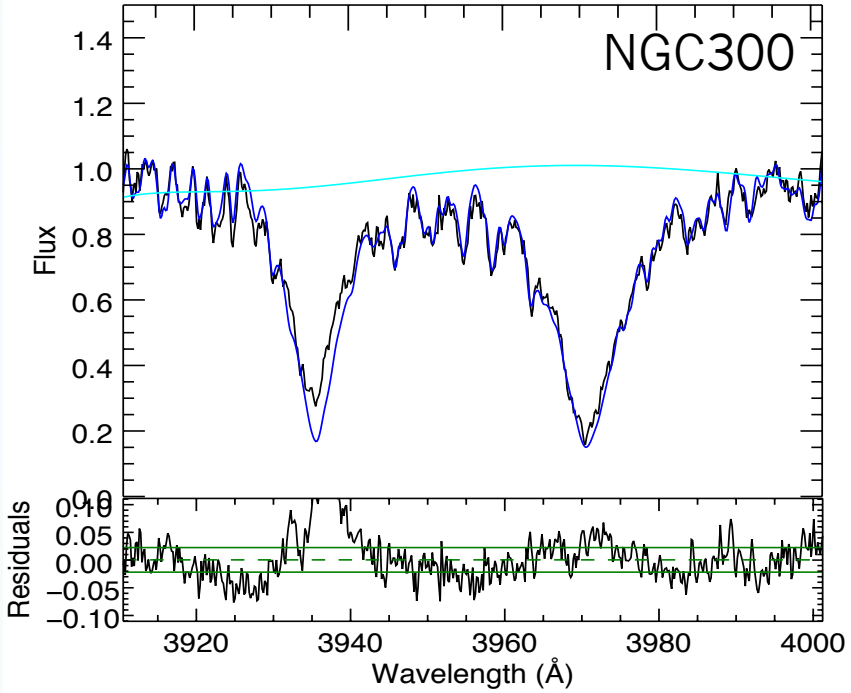
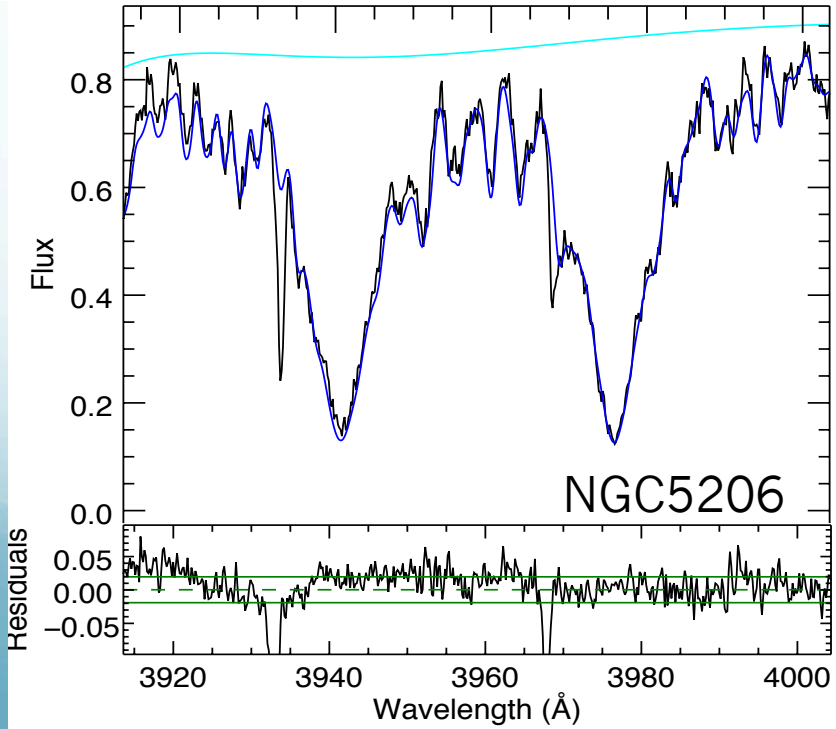
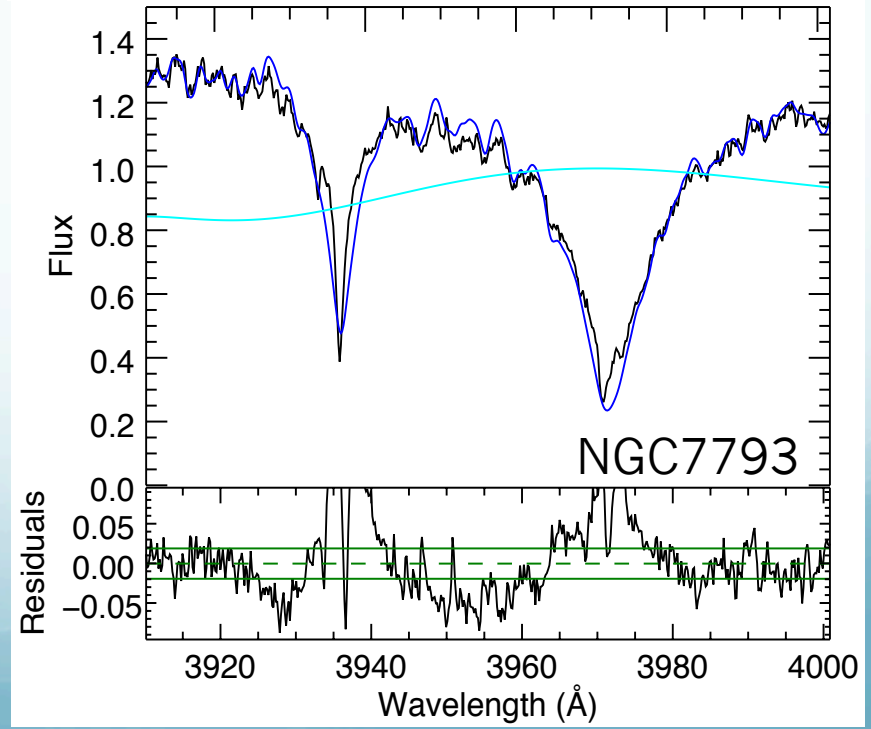
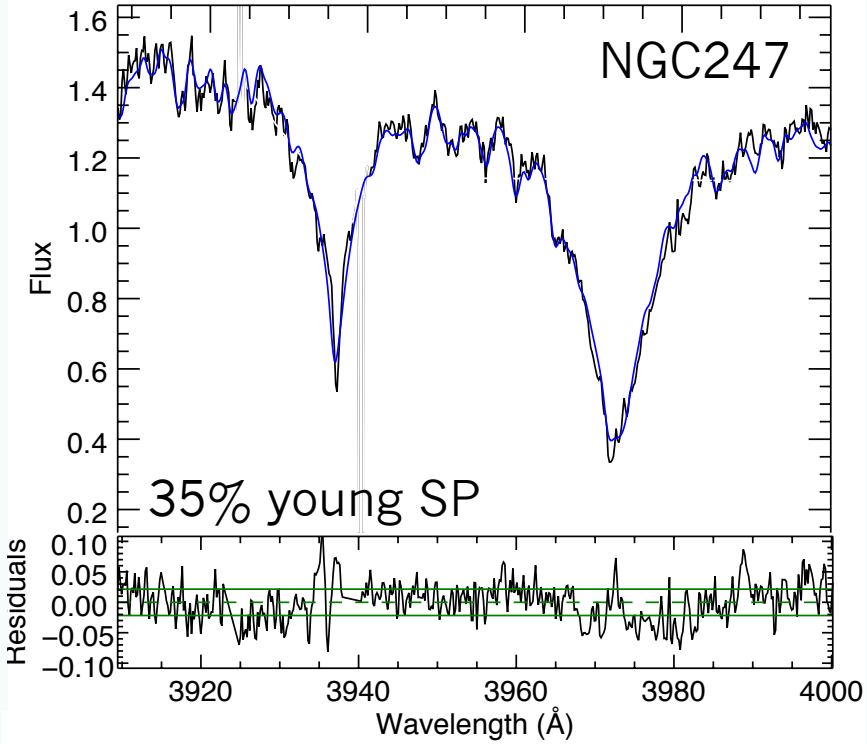


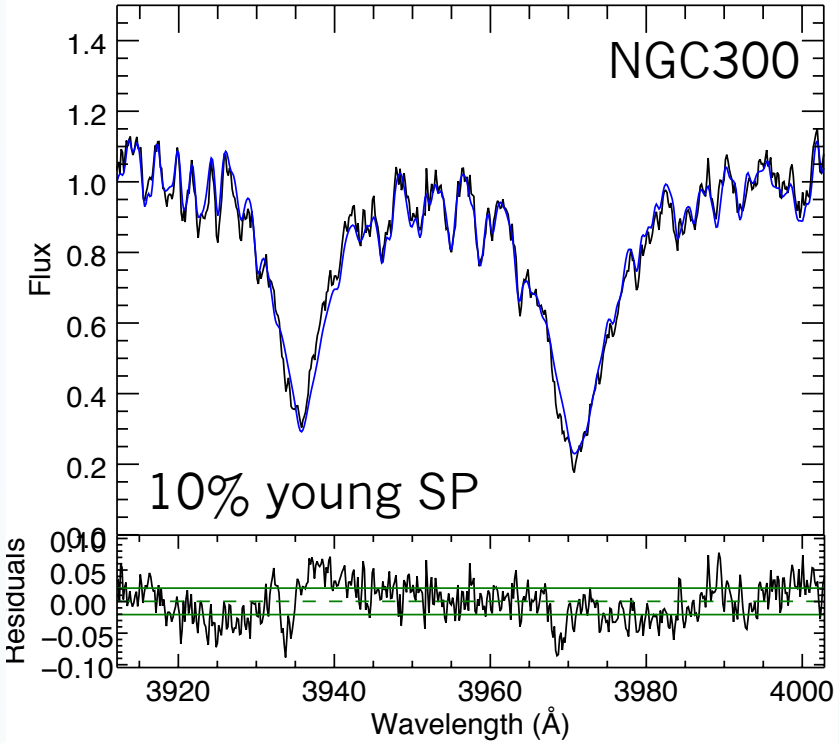

NGC247
Flux
Residuals
Wavelength (Å)

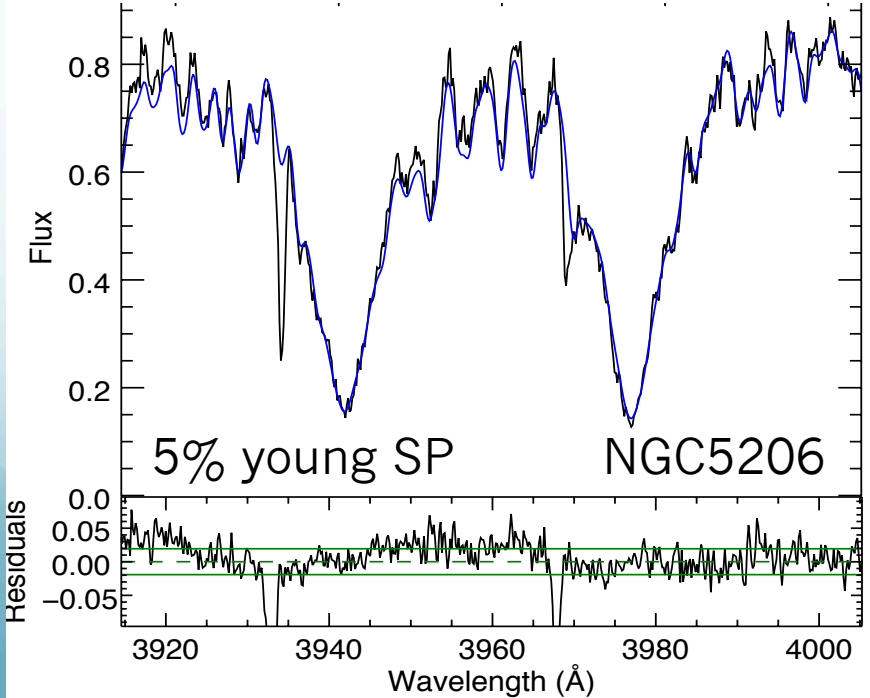

NGC300
Flux
Residuals
Wavelength (Å)

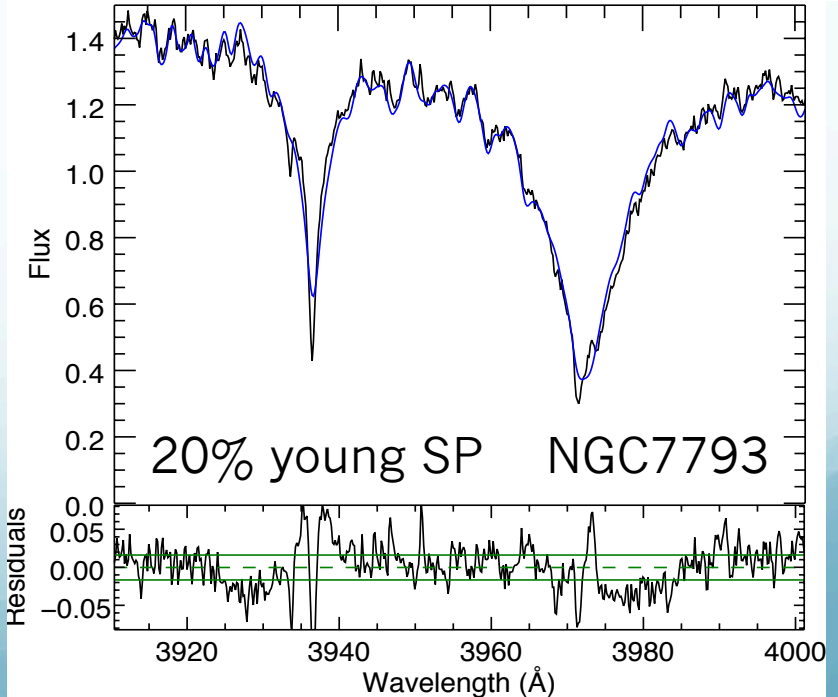

NGC5206
Flux
Residuals
Wavelength (Å)


NGC7793
Flux
Residuals
Wavelength (Å)


NGC247
35% young SP
Flux
Residuals
Wavelength (Å)


NGC300
10% young SP
Flux
Residuals
Wavelength (Å)


5% young SP
NGC5206
Flux
Residuals
Wavelength (Å)


20% young SP
NGC7793
Flux
Residuals
Wavelength (Å)

Abundances from integrated light spectroscopy

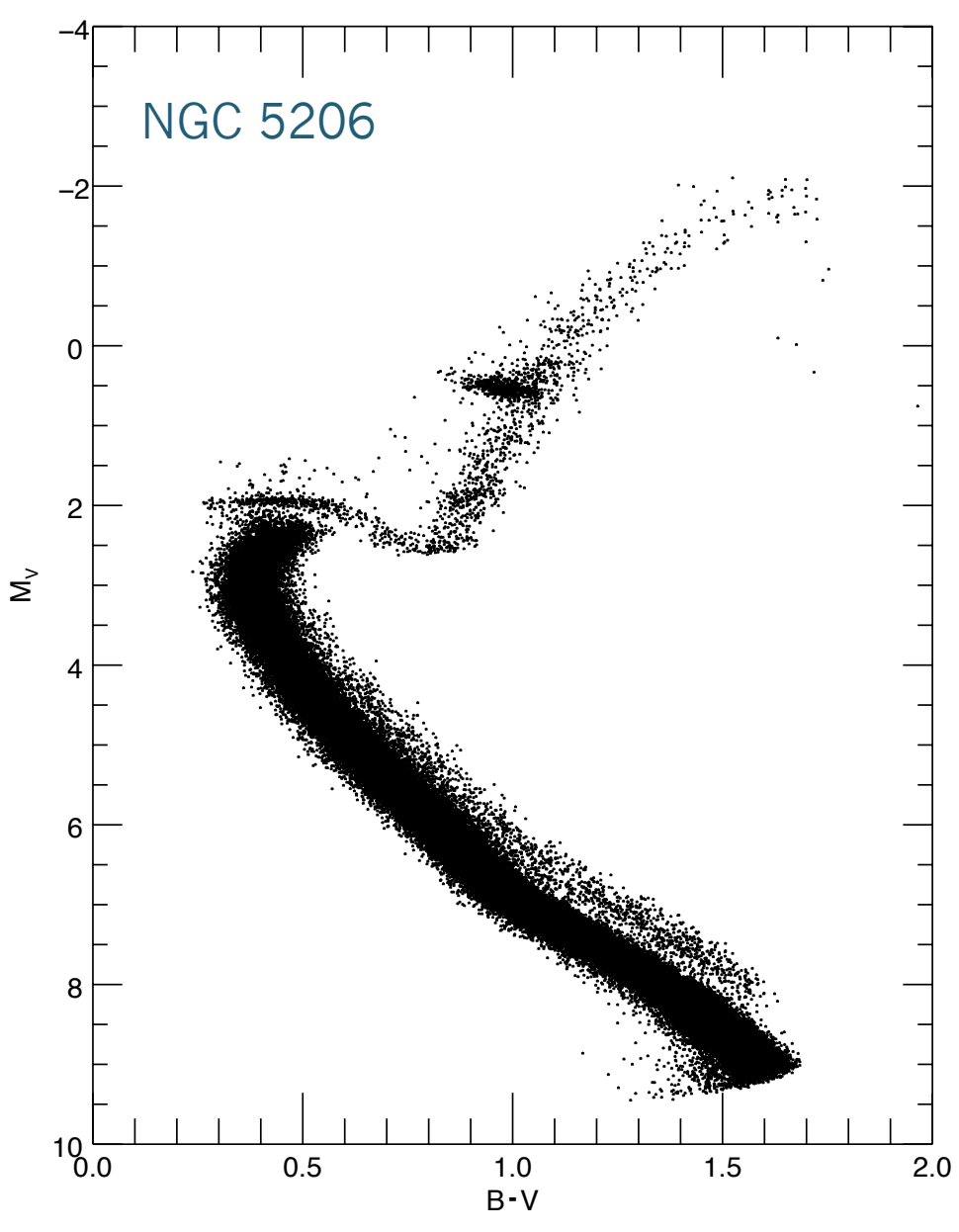
Following methodology from

Sakari et al. 2014, MNRAS, 443, 2285

Using Chris Sneden's MOOG (2014):

http://www.as.utexas.edu/~chris/moog.html

Creating synthetic CMD



- BaSTI web site – stellar populations synthesis tool.
- http://basti.oa-teramo.inaf.it
- Courtesy to Santi Cassisi et al.

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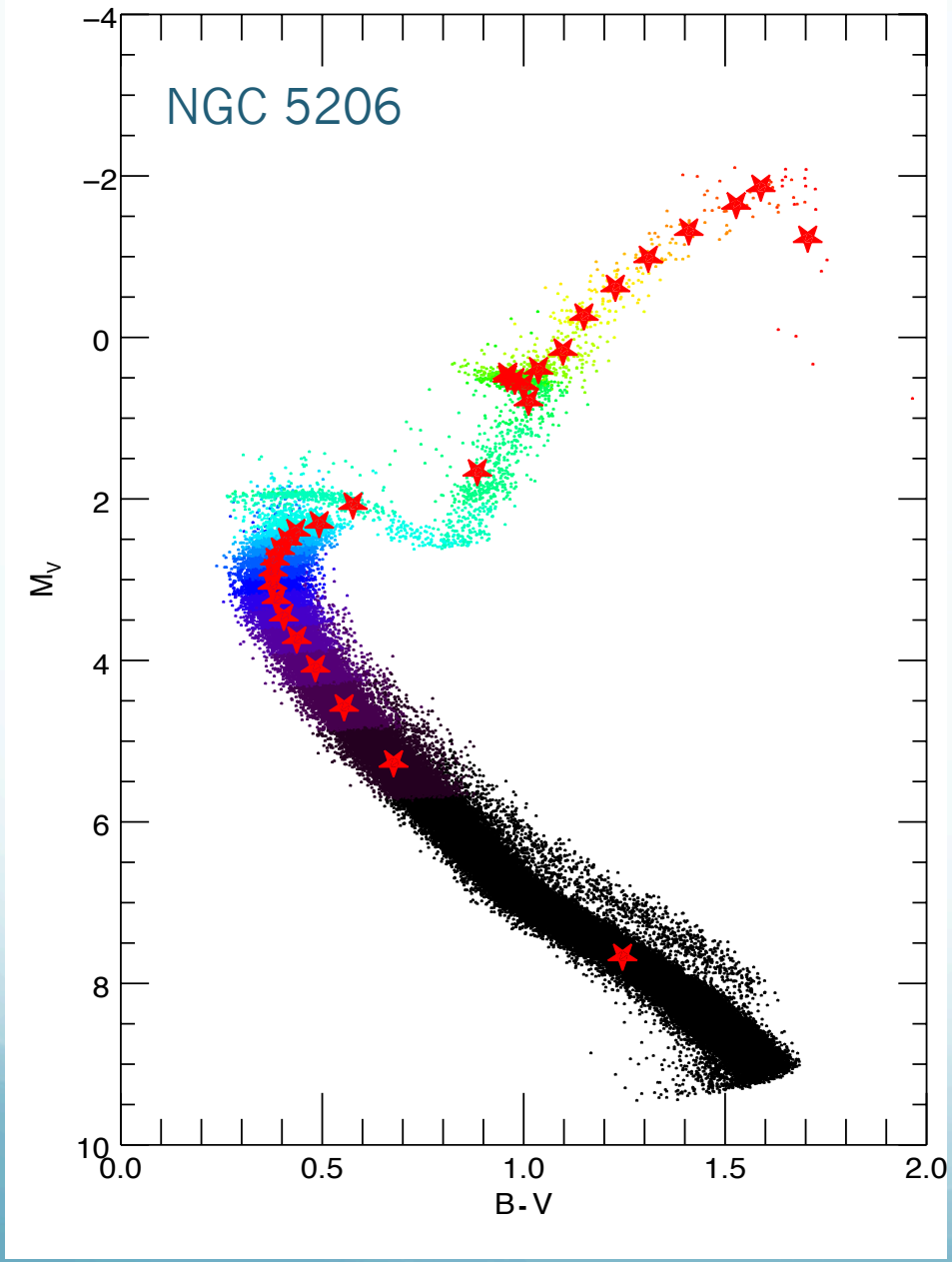

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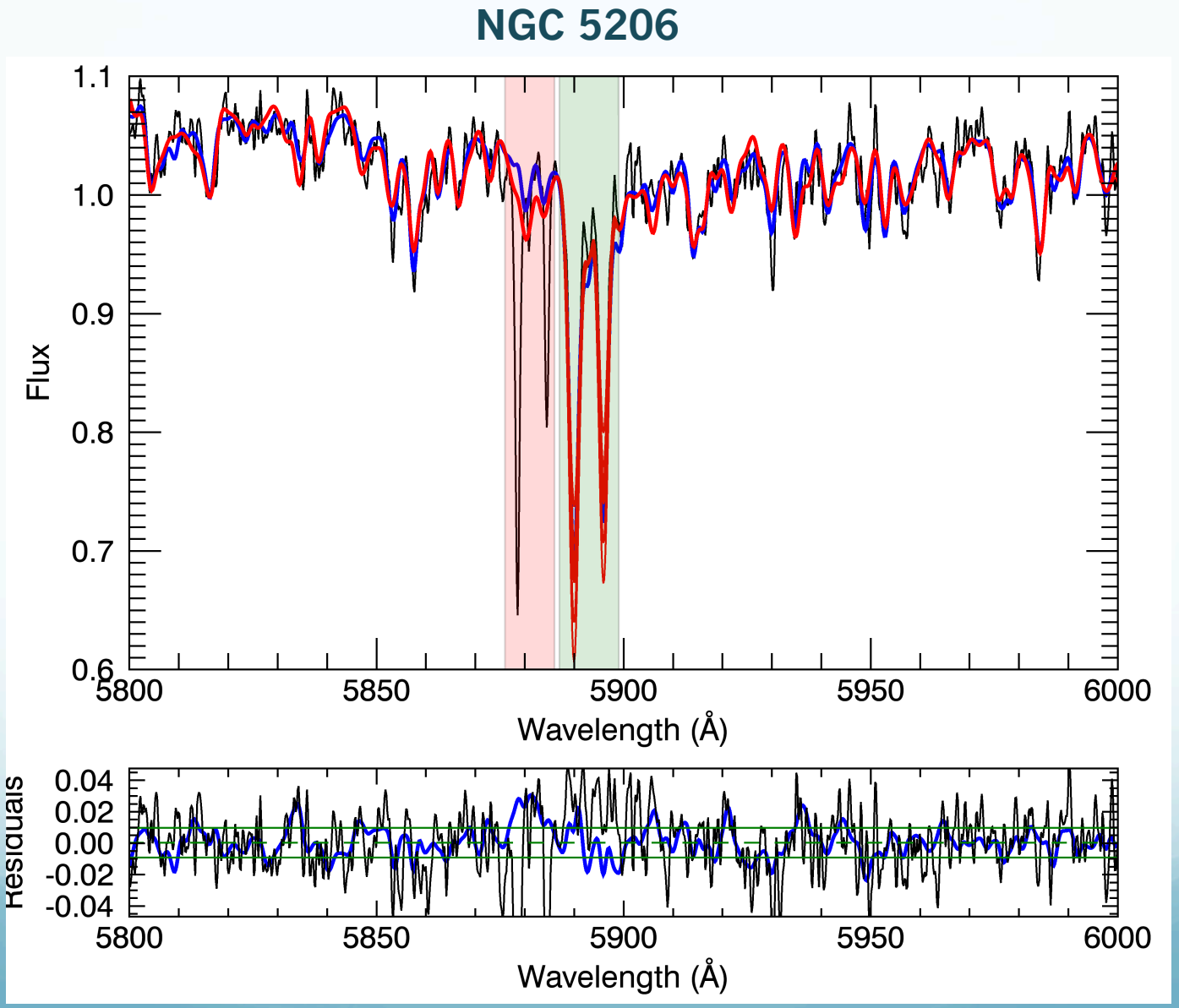
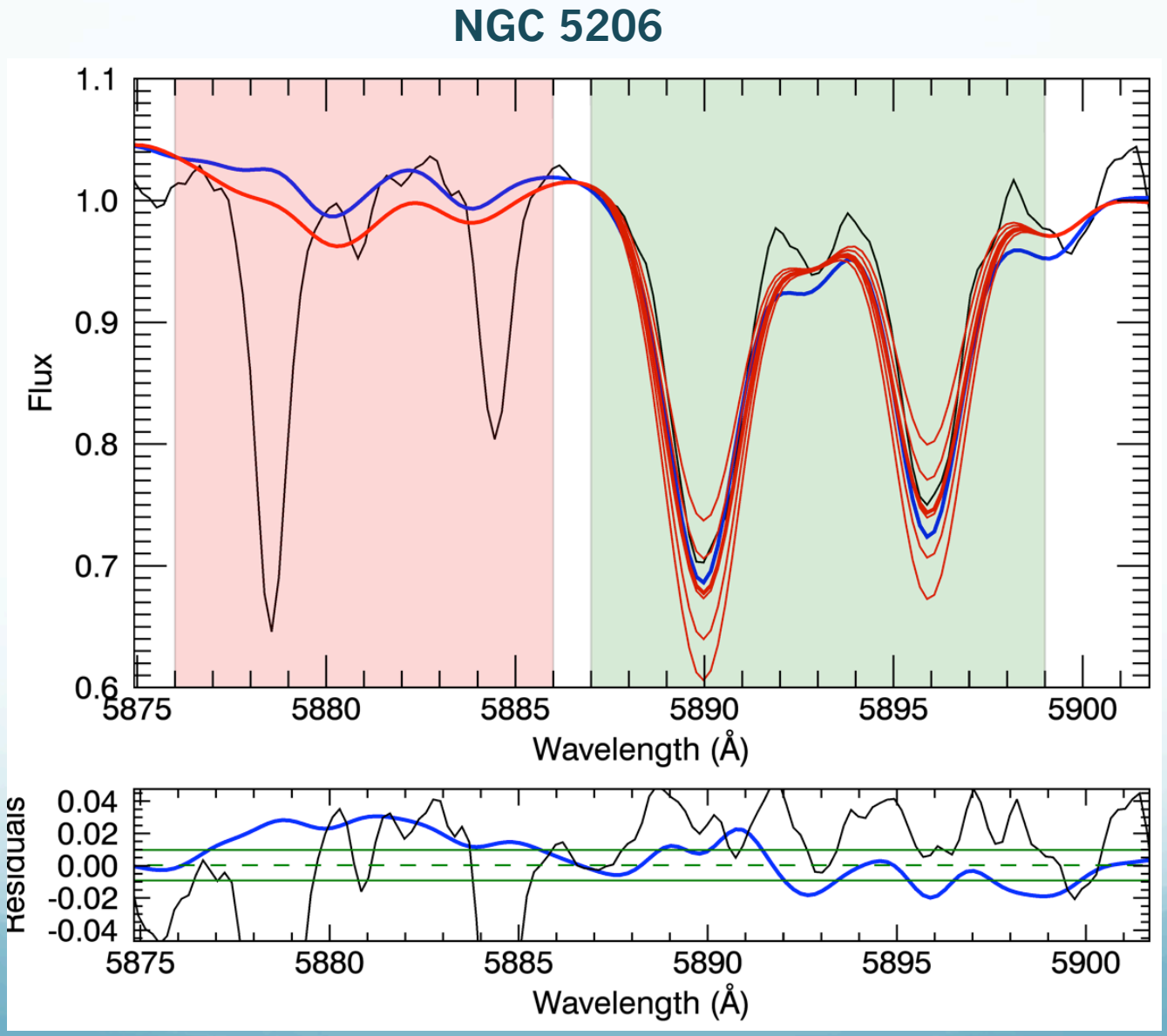
- ATLAS9 atmosphere models
- VALD3 atomic and molecular line lists
- MOOG radiative transfer

Na Doublet at 5890 Å



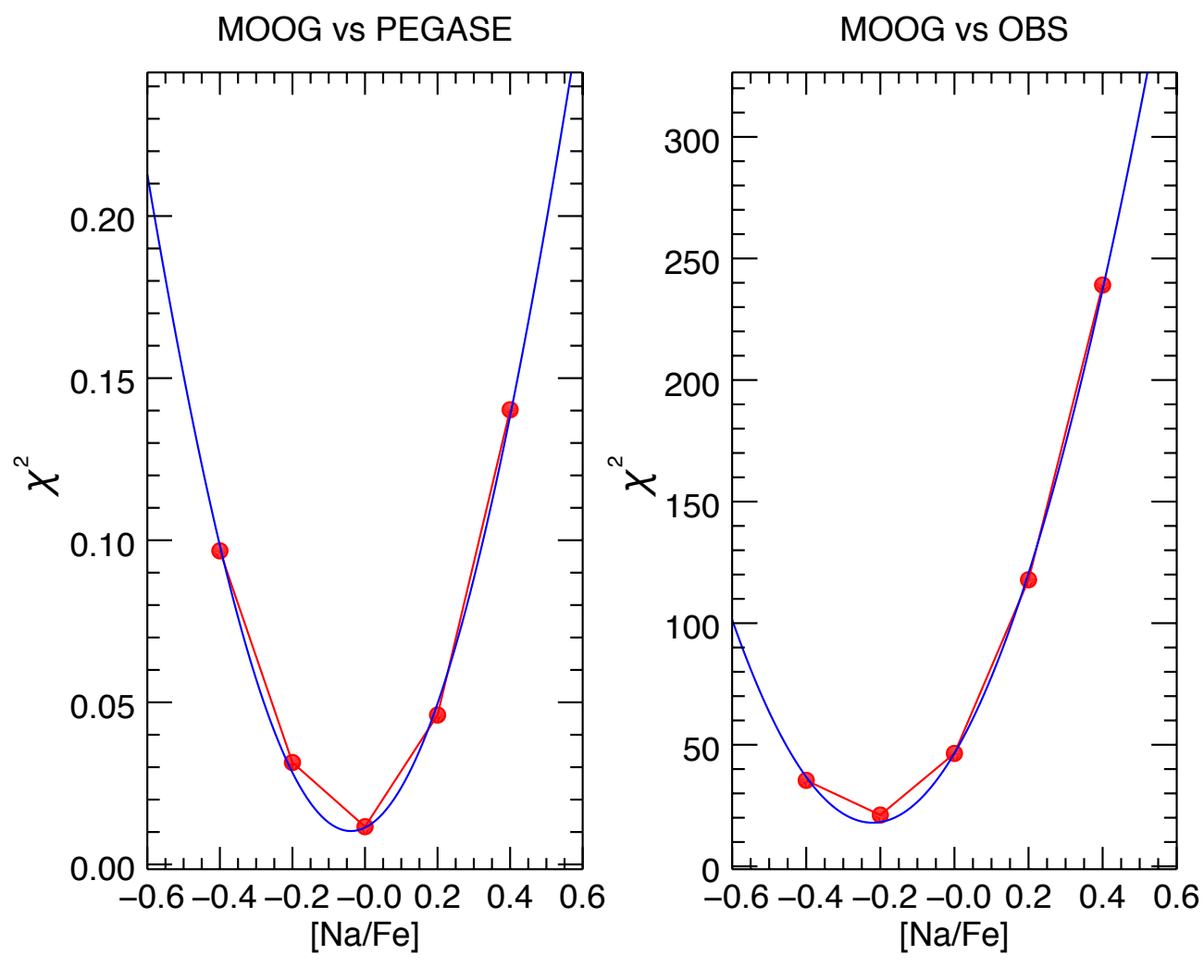
Observed
PEGASE-HR
MOOG

Na Doublet at 5890 Å

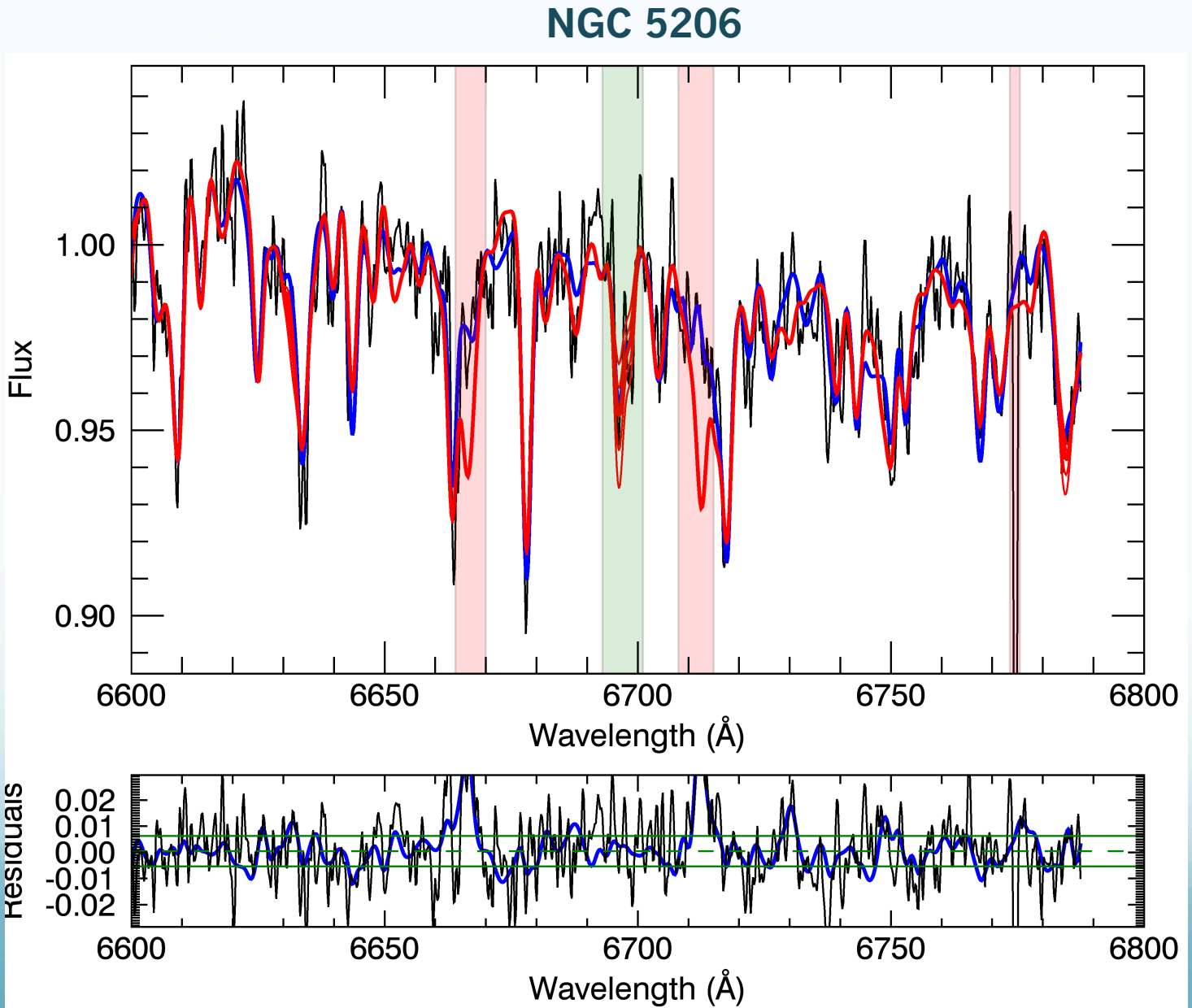


Na Doublet at 5890 Å

NGC 5206



Al Doublet at 6700 Å



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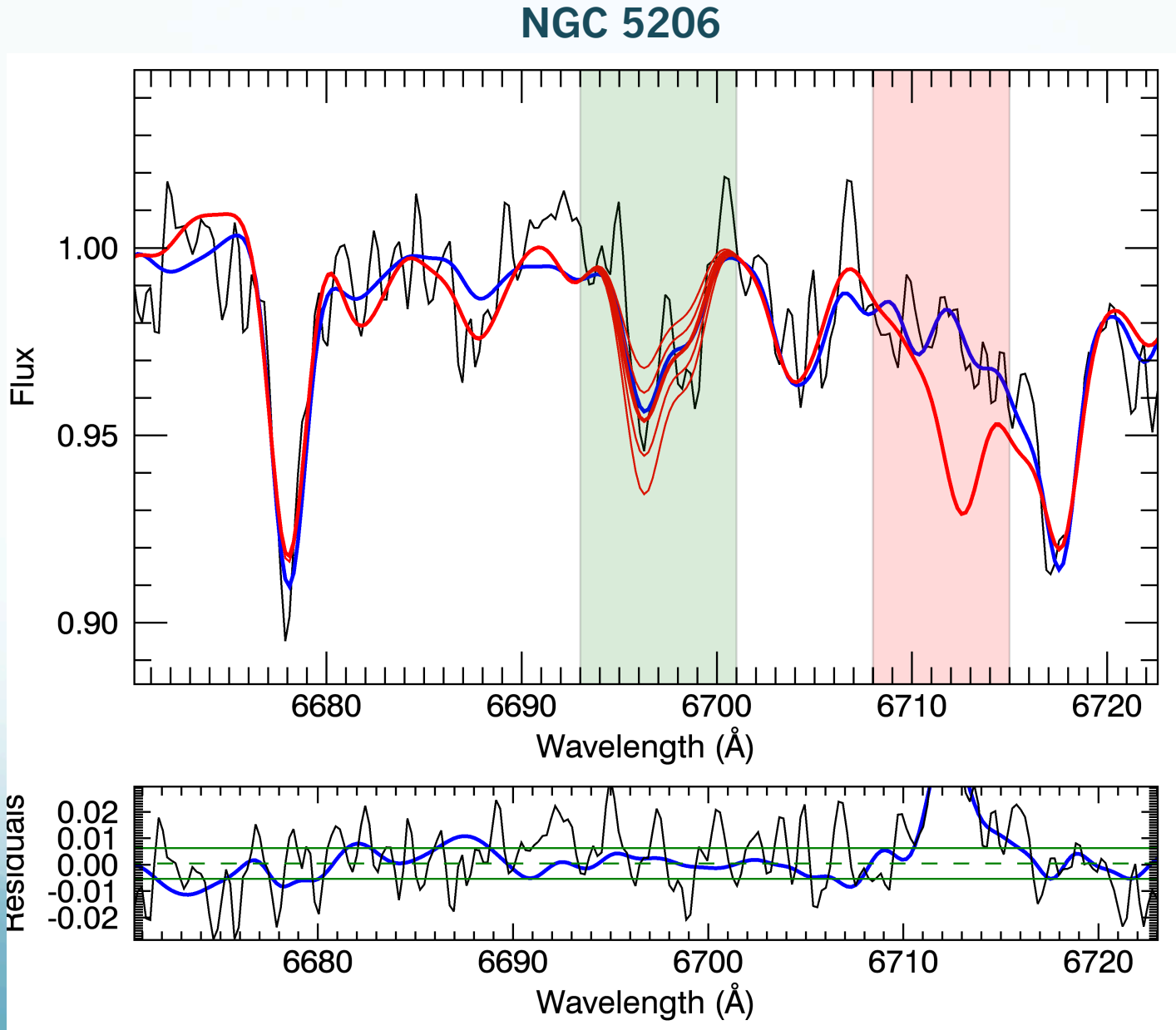
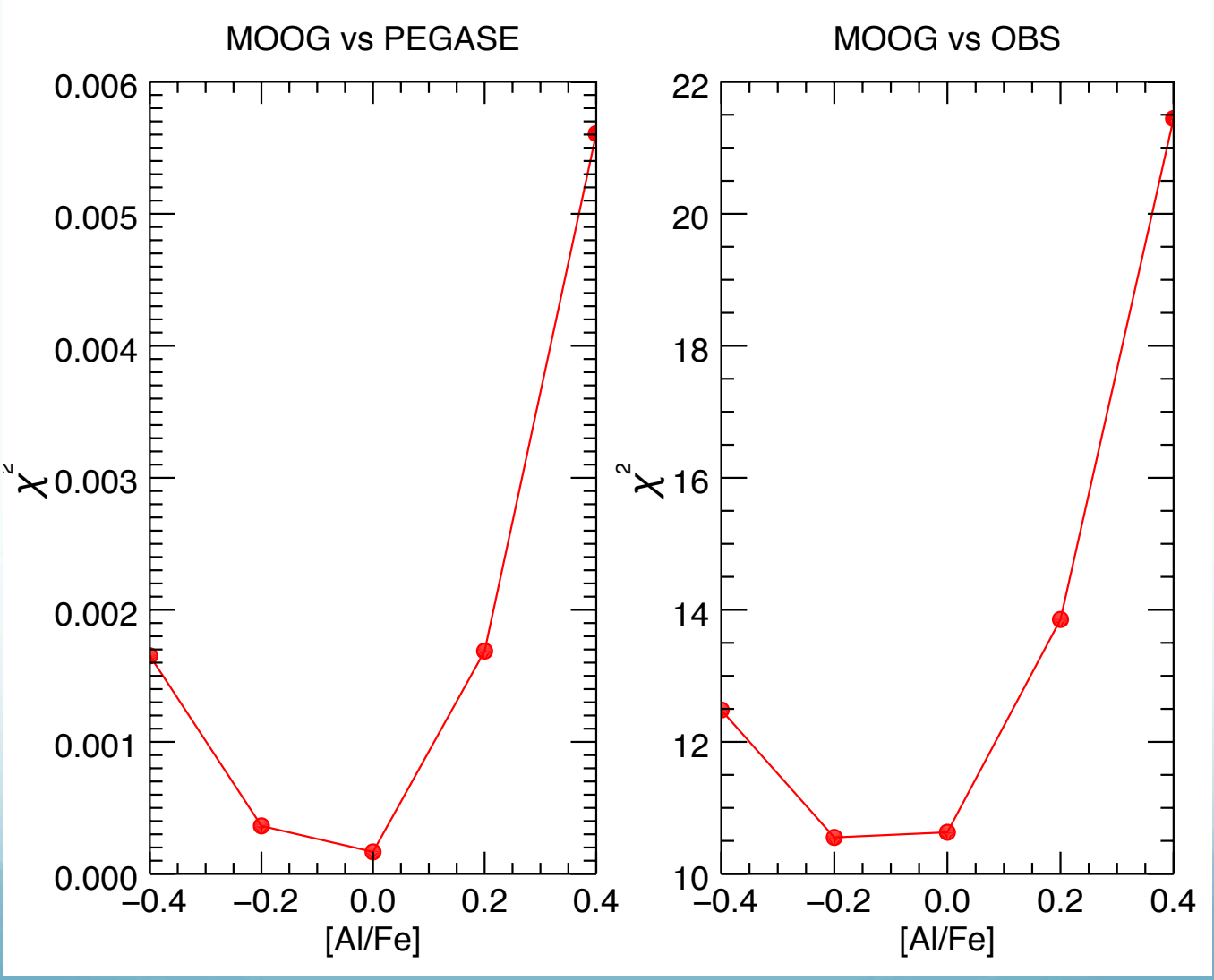


Observed
PEGASE-HR
MOOG

[Al/Fe]
-0.4
-0.2
0.0
0.2
0.4

Al Doublet at 6700 Å

NGC 5206



Outlook

- Test new models that cover the full wavelength range of X-Shooter.
- Better constrain the effects of an extended star formation history.
- Measure the abundances of individual elements.
- Measure the stellar population properties of the surrounding galaxy.