IGRINS-2 SV Observation Evaluation Form 1 form per science case

Title: Exploring the oldest stars in the near-infrared

Program ID: GN-2024B-SV-109

Authors: Federico Sestito

Description of the primary goals and the main findings

Describe the science case and the main results. Please include some figures.

Abstract. The most metal-poor stars are extremely useful probes in Galactic Archaeology as they serve as invaluable tools for studying the early Universe. Their chemistry provide unique ways to gather information about the very First Stars and how they chemically enriched the interstellar medium of the earliest galaxies. Three bright Galactic metal-poor stars are selected. Their chemical properties are very well known in the optical wavelength range. One of them (HD 122563) has also been observed with IGRINS at McDonald telescope (Afsar+2016). The scope of this proposal is to explore the infrared spectra of these targets to 1) measure the chemical abundances of some atomic/molecular species not accessible in the optical, which are also linked to the earliest stages of nucleosynthesis, 2) estimate any offset between optical and infrared abundances and hence test the quality of laboratory atomic data in the infrared, 3) provide metal-poor standard stars to the Galactic archaeology community, which will be needed to calibrate future chemical abundance measurement in the infrared.

Results

1. After reducing the spectra, I have noticed that lines that are present in the overlapping region of two consecutive orders are slightly shifted between each other (see Figure 1). If these region are combined, the abundance from those lines would be affected.

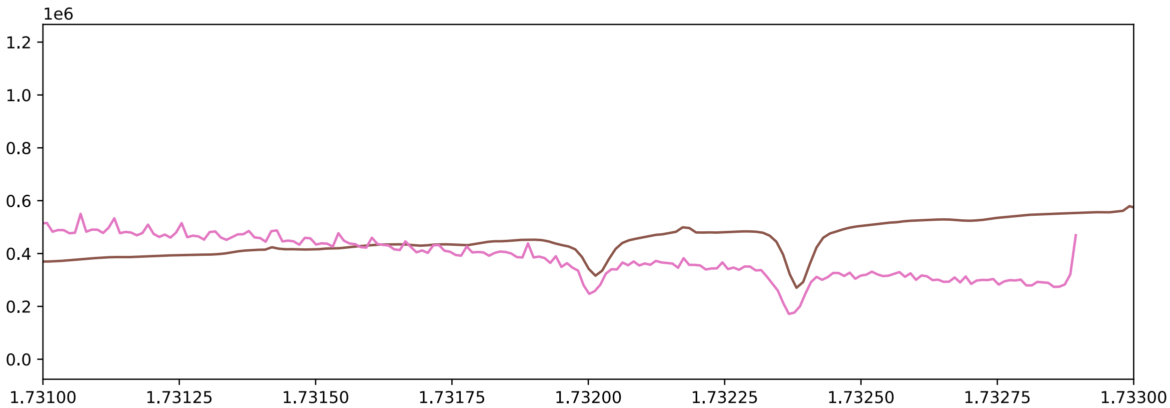

Figure 1. Example of two consecutive orders. The lines are slightly shifted between the overlapping regions of these two consecutive orders.

2. Telluric lines are not properly removed when dividing by the A0V star. Spikes appear in the spectrum (Figure 2).

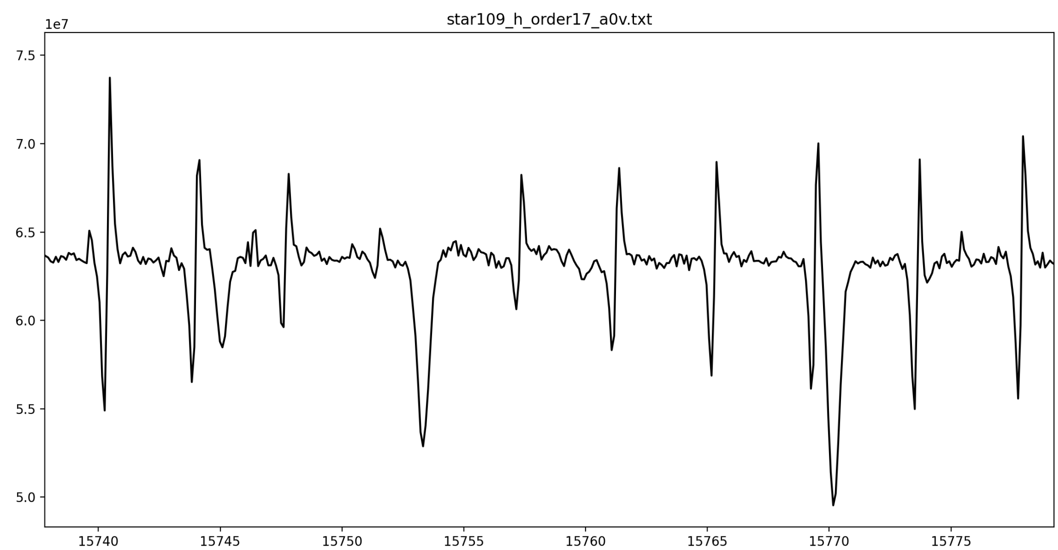

Figure 2. Example of spectrum divided by the A0V. Telluric lines have spikes.

3. There is wavelength calibration problem. Figure 3 shows the case for one star in the Magnesium triplet region around 15750 Angstrom. The star (HD 122563) has a precise radial velocity from optical studies of -26 km/s. Heliocentric corrections are -27 km/s for the day of observations. After correcting for those shifts in the Mg region, the stellar lines are not at rest, rather they are redshifted by 135 km/s or 7.1 Angstrom. If the heliocentric correction is wrong, it would beanyway shifted by a large amount. Repeating the same exercise for the other targets, I find a shift of 83 km/s (4.4 Angstrom) and 90 km/s (4.7 Angstrom).

I have repeated the exercise for the Si line at 15960 Angstrom. For HD 122563 I find a shift of 135 km/s, similar to the case for its Mg region. For the other two stars, I find a shift of 84 and 90 km/s, respectively. Which is exacly the same shift as for the Mg region in those stars.

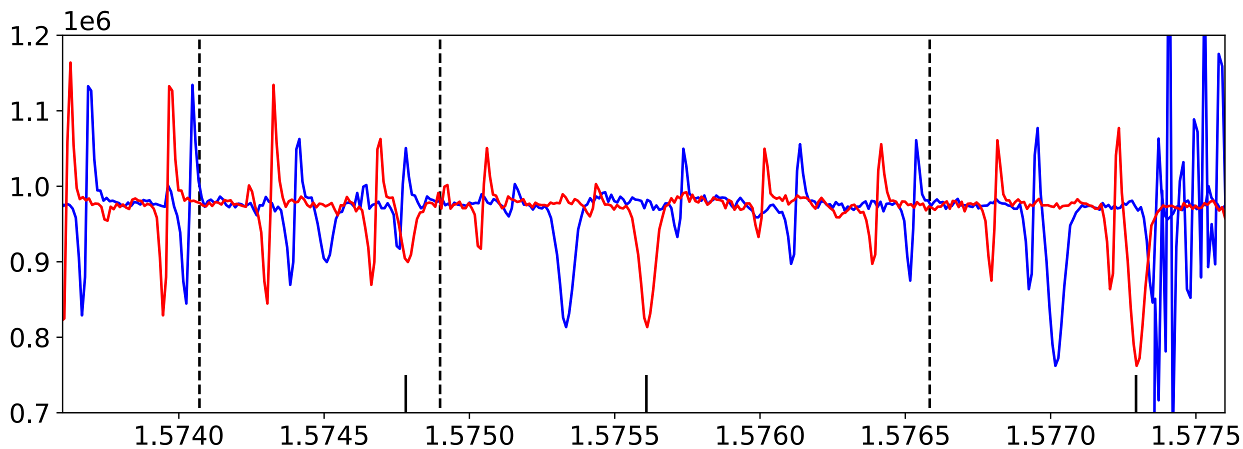

Figure 3. Mg Triplet region. Blue spectrum is the one observed. Red is the one corrected by motion of the star and by heliocentric corrections. Vertical dashed lines mark the position of the Mg Triplet lines at rest. Vertical ticks are the position of the Mg Triplet lines after correcting for the motion of the star and of the Sun. However, they are not at rest but shifted by 7.1 Angstrom on the red side, indicating wavelength calibration problems.

4. HD 122563 is well analysed in the optical. Figure 4 shows the observed IGRINS-2 spectrum of HD 122563 in the Mg Triplet region. Overplotted a synthetic spectrum. Assuming the stellar parameters from the optical, the best synthetic spectrum that reproduce the Mg region has a [Mg/Fe] = +0.3, in line with optical measurement assuming non-local thermodynamical equilibrium. (divided by the A0V, corrected for the motion of the star and the Sun, and for the wavelength shift problem)

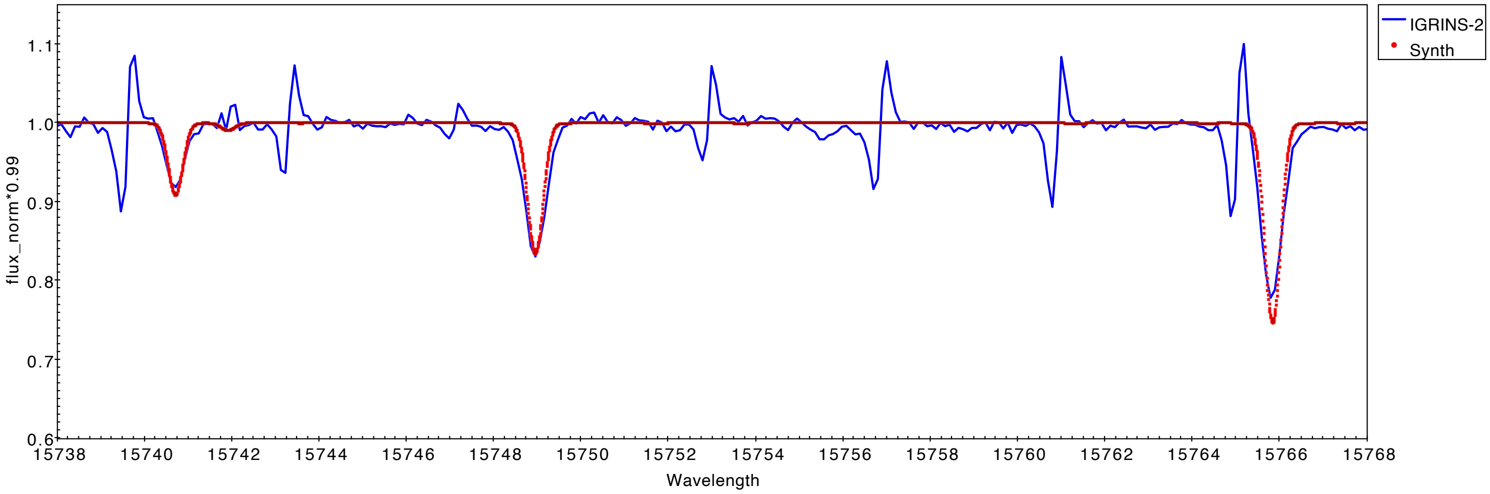

Figure 4. Mg Triplet region. Blue line is the observed spectrum of HD 122563, corrected by the motion of the star, the Sun and by the wavelength issue. Red dots denote the synthetic spectrum with [Mg/Fe] = +0.3.

Additional comments on IGRINS-2 performance:

Results of any other IGRINS-2 capability tested and comparison with other instruments

Suggestions for improvements:

Any comments on ITC, PIT, OT, data reduction pipeline, website, archive, etc…

PIT, OT, ITC is very similar to other Gemini instruments, therefore very user-friendly. Data reduction pipeline runs very smoothly.
Comment for the OT:

- I had to manually search for a A0V star (telluric standard). Not a big problem at the end. However, would it be possible to have an automatic search in the tool given the coordinates of the targets?

I have some comments for the data reduction pipeline:

- Add heliocentric and barycentric corrections. It will be easier to then measure the radial velocity and combine spectra taken in different days.

- Improve the wavelength calibration in the interorder regions between two consecutive orders. Lines that appears in such regions have slightly different velocity (see Figure 1). If the orders are combined together, the equivalent width of the lines (their strength) will be affected and so the chemical abundances from those lines.
- Improve the overall wavelength calibration. Some lines are shifted by 100 km/s or more (see Figure 3). This implies that it would be hard to detect weak lines as in case of metal-poor stars and to measure radial velocity.
- Telluric lines are not removed, rather spikes appear in the spectrum (Figure 2). For my science case is not a big problem. I can remove lines from my list that are blended with tellurics.
- I would like to see the 1D spectrum with the orders stitched together.

Any additional comments about IGRINS-2 SV

Thanks for these observations!