GAPS: F6 mask for the HARPS-N pipeline

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Change Record

Issue	Rev.	Paragr.	Page	Date	Observations
0	1	All			First release

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1. GENERAL ASPECTS

1.1 Scope of the document

This document will present the new mask created to be used with the HARPS-N reduction pipeline.

Four new masks were created for the F6V star Tau Bootis, two of them derived from the G2 mask, following the work done by R. Gratton for HIP11952, and other two created using theoretical line lists. They were subsequently tested in YABI, and the best one was selected and permanently add to the YABI workflow, thanks to A. Bignamini.

1.2 Applicable Documents

no.	document name	document number, Iss./Rev.
AD1		
AD2		
AD3		

1.3 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	New template mask for F-type stars	GAPS-SCI-REP-002, Issue 0.2, 22 Mar 2013
RD2	Improved radial velocities for HIP11952 with a dedicated template mask	GAPS-SCI-REP-001, Issue 0.1, 18 Mar 2013
RD3		

1.4 Acronyms

AD	Applicable Document
GTO	Guarantee Time Observing
HARPS-N	High Accuracy Radial velocity Planetary Search - North
INAF	Istituto Nazionale di Astrofisica
NA	Not Applicable
PB	Project Board
PI	Principal Investigator
PM	Project Manager
PS	Project Scientist
RD	Reference Document
TBC	To Be Confirmed
TBD	To Be Defined
TNG	Telescopio Nazionale Galileo

2. CREATION OF THE MASKS

The best mask for Tau Bootis was selected from four masks created following two different methods. Two of them were created modifying the G2 mask of the HARPS-N pipeline, following the work done by R. Gratton for HIP11952, while the other two were created from theoretical line lista.

The new masks were subsequently tested in YABI, along with the G2 mask and the G2V mask for comparison reasons. The best one, tau-bootis.mas, was selected and add to the YABI workflow as TAU-BOOTIS, thanks to A. Bignamini.

2.1 Working from the G2 mask

Using the G2 mask as a starting point, we measured the depths of several unblended lines in a well-exposed, high signal-to-noise ratio Tau Bootis spectrum. From these measurements, we found the following empirical correlation between the line depths of the G2 mask and those of the Tau Bootis spectrum:

$$ld_{(TB)} = 0.0409321*\exp(2.80654*ld_{(G2)})$$

Using this equation, we corrected the values of the line depths in the G2 mask and created the file tau-bootis.mas.
Then we took into account the blending of the lines due to the rotation of the star, and created a new mask, tau-bootis-sel.mas, from tau-bootis.mas by eliminating the lines near enough to each other to become blended due to the rotational broadening of Tau Bootis. This work reduced the line list from 3625 to 2209 lines.

2.2 Working from theoretical line lists

In order to better compare the results from the different masks, we built two additional ones from a library of theoretical line masks. From literature, Tau Bootis has T_{eff} = 6387 +/- 44, log(g) = 4.256 +/- 0.06 and [Fe/H] = 0.234 +/- 0.03. The nearest masks to these values have T_{eff} = 6250, log(g) = 4, [Fe/H] = 0 and T_{eff} = 6500, log(g) = 4, [Fe/H] = 0: we converted them to the right format for the HARPS-N pipeline and eliminated the weaker lines in order to reach a total line numbers similar to the G2 mask.
The masks created this way are mask.6250.40.p00.mas (3852 lines) and mask.6500.40.p00.mas (3606 lines).

3. TESTING THE MASKS

Once the masks have been created, we tested them using the YABI workflow and re-reducing all of the Tau Bootis spectra. Just to have a complete survey, we used also the G2V.mas mask created by R. Gratton for HIP11952.

The resulting radial velocities were shifted up to more than 400 m/s, as it is shown in Fig. 1.

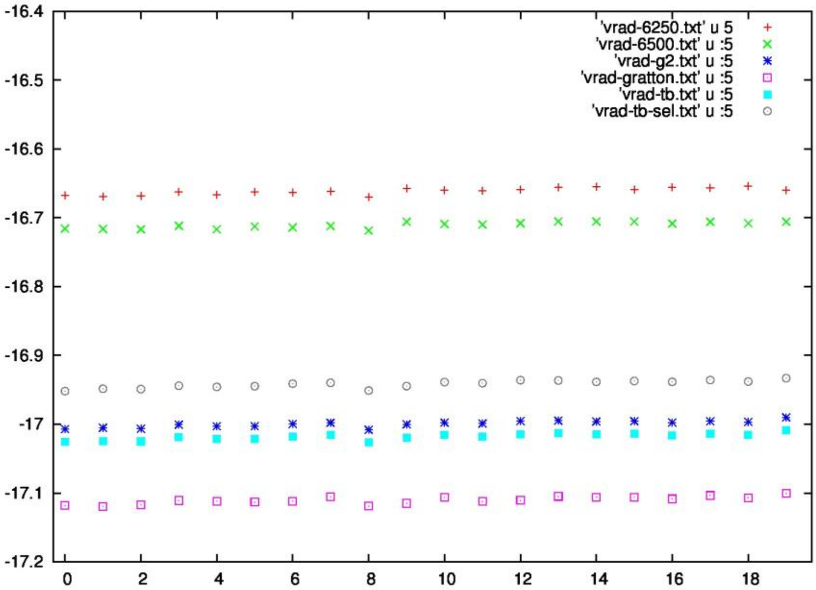

Figure 1 – Radial velocities of a sample of Tau Bootis spectra, reduced with different template masks

The changes in the radial velocity errors are shown in Fig. 2, where it is possible to see how the selection of the mask tau-bootis.mas (pale blue filled squares) improves the results.

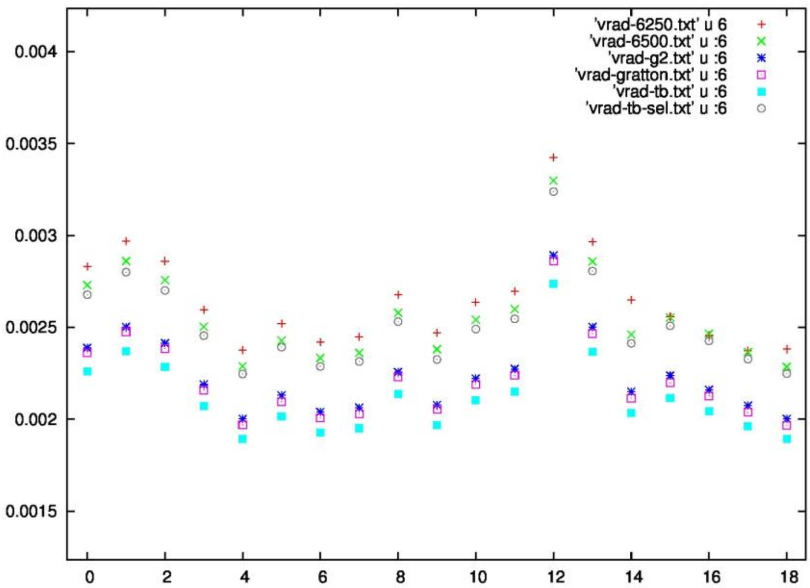

Figure 2 – Errors in the radial velocities of a sample of Tau Bootis spectra, reduced with different masks

The improvement is not very high, probably due to the effect of the high v*sin*i (~15 km/s) of Tau Bootis. In any case, using tau-bootis.mas we found a slight improvement in the internal scatter of the radial velocities resulting from the different orders of the echelle spectra, while there is no notable difference in the internal errors.

We selected tau-bootis.mas as the best mask for this object and removed the other three from the YABI workflow.

3.1 An additional issue: the ccf half-window definition

Testing the masks, we found out that there are not negligible (i.e., larger than the errors on the radial velocities) radial velocity shifts when using different values of the ccf half-window, as already hinted by Gratton (Science Report 002).
In Fig. 3 it is possible to see the differences found with the G2 template: the reference values are the ones computed with a ccf half-window of 30 km/s and no initial radial velocity guess value ('rv 30 non gv'). It is interesting to notice that using an initial guess value ('rv 30 gv') or increasing the ccf half-window ('rv 40 non gv') does not cause large differences in the radial velocities found, while decreasing the ccf half-window (to 15 and 25 km/s) results in changes in the radial velocities up to more than 10 m/s from one night to the other.

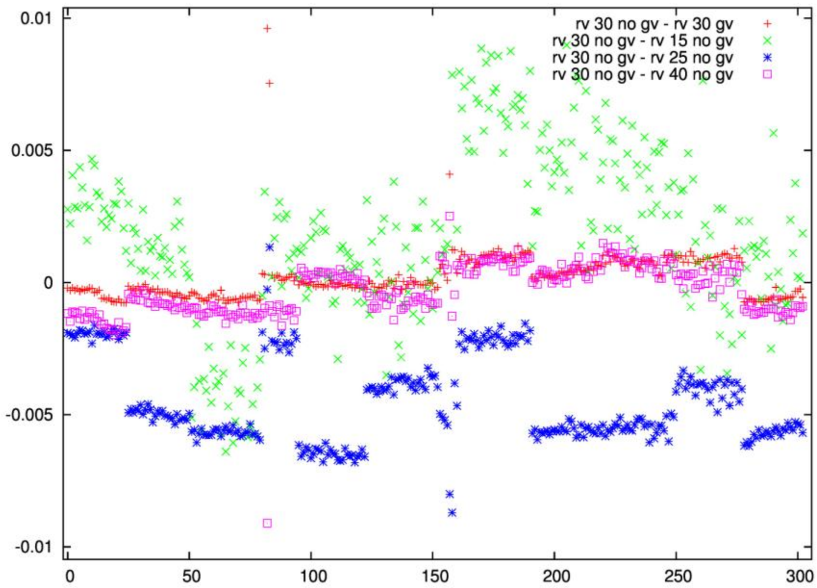

Figure 3 – Differences between the radial velocities found with the G2 template using different ccf windows

Repeating the same analysis with our mask TAU-BOOTIS shifts a bit the results, but does not improve the situation, as can be seen in Fig. 4.

The choice of the ccf half-window is quite important when observing objects like Tau Bootis with v*sin*i large enough that the default window (20 km/s) is not able to cover the whole ccf function, as shown in Fig. 5.

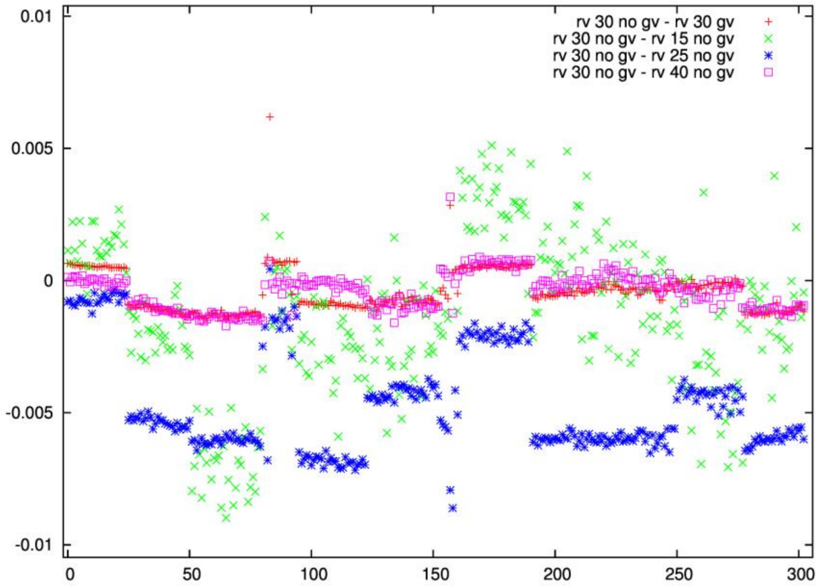

Figure 4 – Differences between the radial velocities found with the TAU-BOOTIS template using different ccf windows

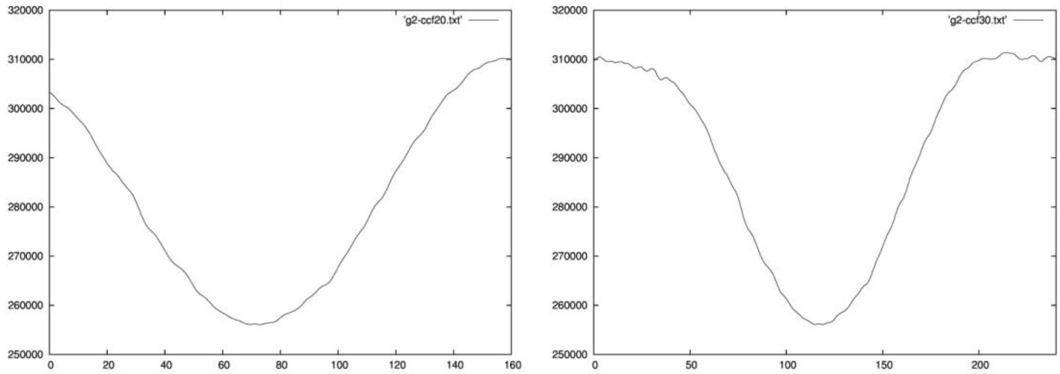

Figure 5 – Tau Bootis ccf functions with a 20 km/s (left) and 30 km/s (right) half windows

4. CONCLUSION

We tested four new masks on the Tau Bootis spectra in order to select the best one to use when reducing F-type stars. This resulted in the TAU-BOOTIS mask being added to the YABI workflow, where it can be selected for the reduction of data.

In addition to that, we stress the importance of setting a ccf half-window value large enough to cover the whole ccf function, otherwise the pipeline will introduce some not negligible radial velocity shifts, that vary from night to night. In the case of Tau Bootis, the best option was to use a ccf half-window value which was roughly the double of the v*sin*i value.