CRIRES Science Verification Proposal

A new absorption-free totally-spectroscopic distance method?

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Abstract:

We propose to develop a new absorption-free spectroscopic-only snapshot distance method based on the surface properties of stars. To achieve this goal, we propose to investigate the possible correlation between the classical "C" shape of the line bisector and the intirinsic luminosity. A single, high-resolution, near-IR flux-calibrated spectrum could provide in a single-shot all the necessary ingredient for such method: the absolute magnitude, a possible estimation of the absorption, and the absolute magnitude inferred from the bisector.

Scientific Case:

It is a well known phenomenon: the bisector (i.e. the line joining the midpoints of a spectroscopic line for a number of depth levels inside the line) shows a classical "C" shape, for star cooler than the convective zone limit. Recently, Gray (1995, PASP, 177, 711) has shown that the bluemost point of single-line bisectors is directly related to the luminosity (i.e. the absolute magnitude) of the object, potentially revealing a direct distance method. However, such bisectors require high resolution spectra, and very high S/N ratios (absolute minimum of 300). Fortunately, it has been shown recently by one of us (Dall et al., 2006 A&A, 454, 341) that the bisector of the cross-correlation function (CCF) can be used as much the same way as single-line bisectors! This open wide the window of distance estimate for many faint and embedded stars (Foellmi 2006, astro-ph/0609608).

The physical explanation on why the bisector shape is related to the luminosity is unclear yet, but interesting physical explanations emerge slowly, thanks to realistic time-dependent, 3D, hydrodynamical model of the solar atmosphere (see e.g. Asplund et al., A&A, 417, 751 and the other papers of this serie). The assymetry of spectral lines is the result of the superimposition of many profiles of that line, produced at different depths inside the star's photosphere. The *thickness* of the photosphere is, for instance the Sun, very small: 300 to 400 km. The whole star spectrum is produced in this photosphere, shaped by the underlying surface of the convective zone (N. Grevesse, January 2007, private communication). This convective zone depends mostly on the mass of the star (and also its abundances). The possible correlation between the line bisector and the luminosity probes how the total luminosity of a star influence the convective zone properties, in other words, the surface properties of the star, and how it reflects into the spectrum, through the spectrum creation in the photosphere. Therefore, it is possible that the correlation between the bisector shape and the intrinsic luminosity is a kind of mass-luminosity relationship, or at least a photosphere-thickness-luminosity relationship.

This question is a complex and interesting physical issue, but what remains is: *the intrinsic luminosity could possibly be measured through the surface properties of the star!*

We propose here to explore and validate this relationship, already observed in the optical with HARPS by Dall et al. (2006 A&A, 454, 341), and develop it into a fully consistent absorption-free distance method. We thus propose to obtain excellent spectra at two different sky-free wavelengths of 3 closeby single and bright stars, with known Hipparcos distances, already observed by Dall et al. (2006), and to measure their (CCF) bisectors. We are in contact with France Alard in Lyon's University (France) to obtain synthetic very-high-resolution spectra in the NIR (see Figure 1.). We will cross-correlate the CRIRES spectra, testing for different wavelength ranges, and compute the CCF. The bisector of this CCF will then be compared against the relationship of Dall et al. (2006, see their Fig. 4.). Using the flux-calibrated synthetic spectra of France Allard, we will also extrapolate the apparent magnitude of the star. By making a comparison of the bisector parameters with those already obtained with the HARPS data, we will explore the region of formation of different lines in the star's photospheres (the NIR lines are supposed to be produced slightly further away from the convectove zone surface).

We think that these observations are excellent for SDT time: (1) it could provide a simple scientific output with a great impact, opening the window for a determination of the distance of many other faint and embedded objects (2) it explores the physics of the spectrum and the surface properties of the stars, complementing the work done through asteroseismology (3) it is easy (hence fast) to reduce and analyse the data.

Current Status of Data from Previous SVT Run:

We have already obtained CRIRES data from the previous SVT Run. The idea was extremely similar, but we wanted to already applied it to a microquasar to determine its distance. Pipeline-reduced data looked very promising but it appears that the S/N ratio of the microquasar spectrum was actually 10 times smaller than expected (∼5! instead of 50). We have no real explanation for this, except maybe a mistake in our ETC computations. New tests with CRIRES ETC (v.3.1.3) showed that obtaining a S/N ratio of 50 with a K=14.5 star is totally unreallistic. We focused then on the standard star we requested (HD209100). We had troubles identifying the lines, and the match with the synthetic spectrum was very poor, even after careful treatement of the radial-velocity zero-point. We finally decided to reduce ourselves the data by hand with IRAF. We had no problems until being completely blocked in the Thorium-Argon lines identification, since many lines are not identified at all. We were then forced to come back to the pipeline-reduced data. After some struggling, we checked what we usually never really check: coordinates. The microquasar-comparison star was not the one requested. According to the coordinates, it is HD49517 is a K3III, instead of the K4V requested and for which we had a syntehtic spectrum! Our analysis is now waiting on the new synthetic spectrum of a K3III, expected very soon. We decided to give up for the moment the microquasar test, and focus on validating the distance method. We will of course use the data of this standard star to increase our sample, since this star fortunately has a known Hipparcos distance.

Required observing time

We request only 3 stars, but already observed with HARPS, and chosen at the extreme points of the correlation shown in Fig. 4. of Dall et al. (2006), and visible in February/March, to ensure the best validation of the method. The stars have moreover very different surface gravities.

Target	RA	DEC	Wavelength Band	Magnitude	DIT	NDIT
α Hor	04 14 00.11	-42 17 39.7	1180-1210nm (47/0/n)	V=3.86 (K1III)	5	30
α Hor	04 14 00.11	-42 17 39.7	2170-2220nm (26/1/n)	V=3.86 (K1III)	5	30
EK Eri	04 20 38.64	-06 14 45.6	1180-1210nm (47/0/n)	V=6.1 (G8IV:)	5	30
EK Eri	04 20 38.64	-06 14 45.6	2170-2220nm (26/1/n)	V=6.1 (G8IV:)	5	30
α Men	06 10 14.47	-74 45 11.0	1180-1210nm (47/0/n)	V=5.09 (G6V)	5	30
α Men	06 10 14.47	-74 45 11.0	2170-2220nm (26/1/n)	V=5.09 (G6V)	5	30

Accounting for 40% of overheads, each star requires about 3 minutes observing for each wavelength, not counting for pointing. All observations need to be done with a slit of 0.2" to reach the required resolution, with AO. Following ETC 3.1.3, we expect a S/N ratio of about 100-150, which will allow us to reach 250-400 in the CCF.

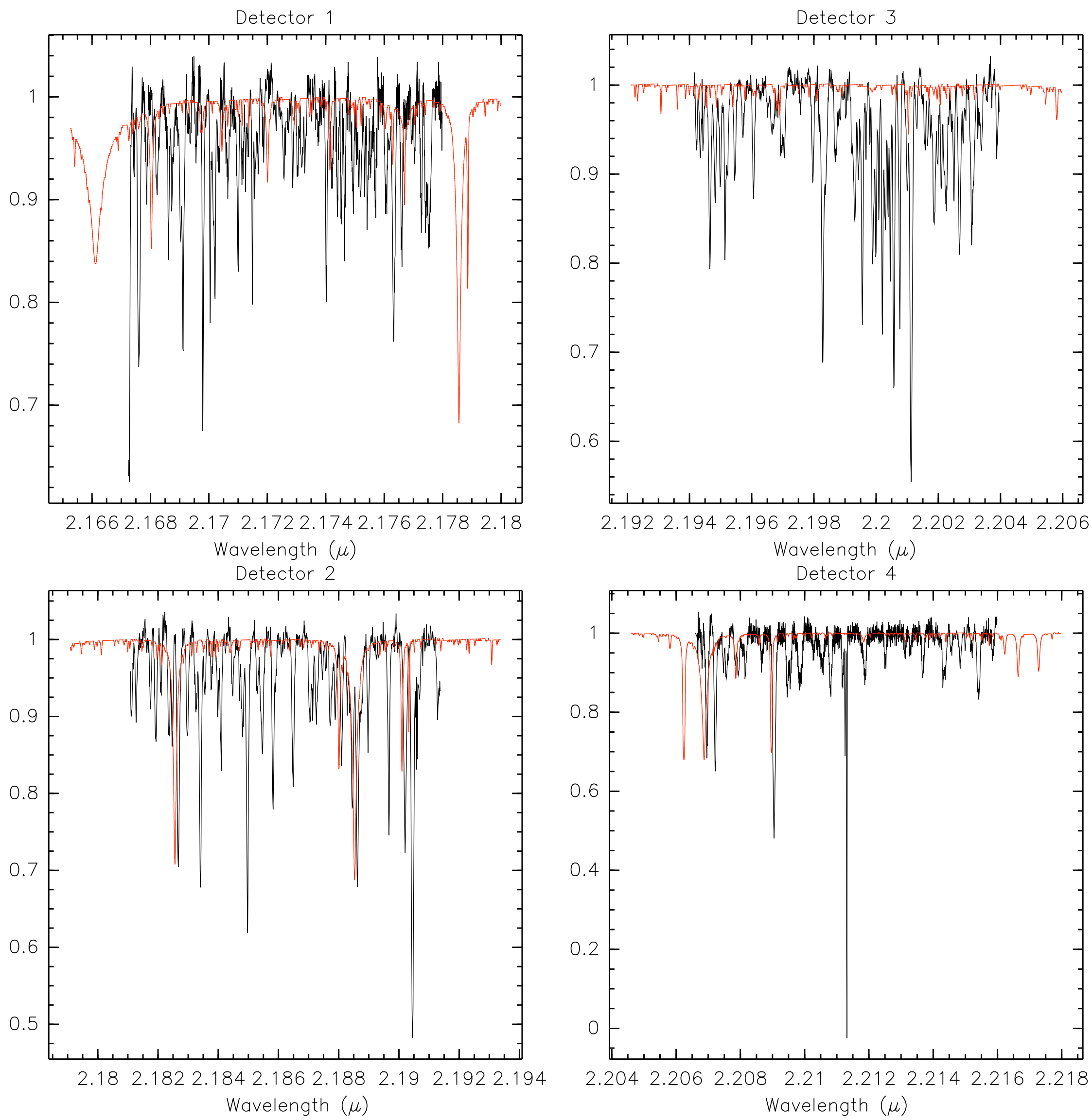

Figure 1: Comparison between the K3III standard star spectrum HD49517 (black line) and the synthetic K4V spectrum from Lyon (red). The expected agreement is irrelevant since the standard star effectively observed has not the right spectral type. Once we have a corresponding synthetic spectrum, we will redo the cross-correlation.

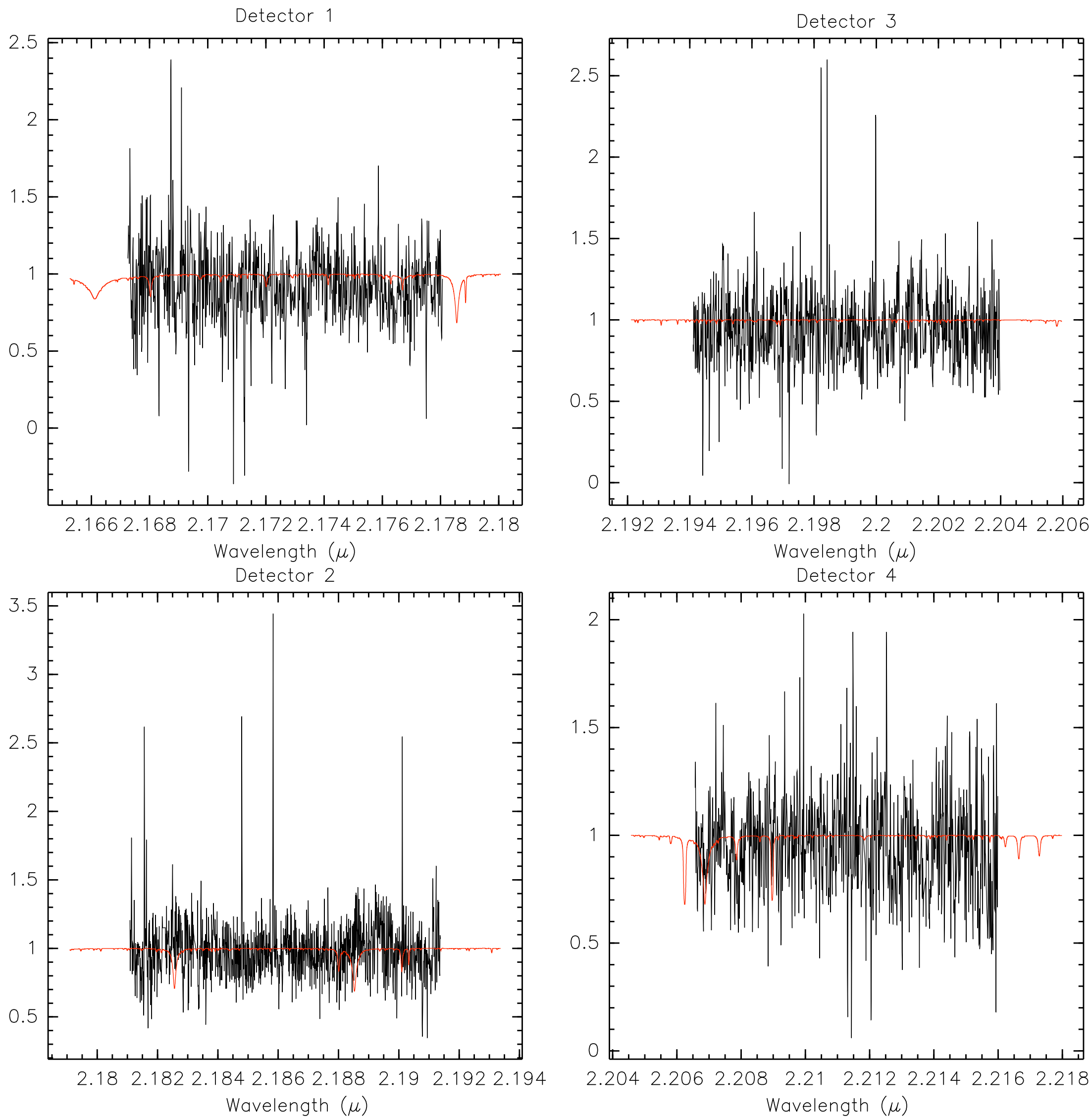

Figure 2: Comparison between the 1A 0620-00 microquasar spectrum (black line) and the synthetic spectrum from Lyon (red). The comparison is pointless here, because of the S/N ratio ($\sim$5) of the microquasar spectrum.