CRIRES Science Verification Proposal

Which black-hole is the closest to the Sun?

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Abstract:

We propose to determine which stellar black-hole, among the two galactic microquasars GRO J1655-40 and 1A 0620-00, is the closest to the Sun. Microquasars are stellar binaries with a compact object, either a neutron star or a black-hole, showing emission in X-rays, radio, and collimated relativistic jets, sometimes superluminal. They are simply the closest relativistic objects to us, and are therefore of prime importance for the future studies of General Relativity in the strong field limit. Moreover, the distance is one of the basic ingredient of all models of such sources. Two microquasars are competing for the shortest distance to the Sun: GRO J1655-40 (for which we have just revised the distance to less than 1.7 kpc – Foellmi, Depagne, Dall, Mirabel, A&A in press, astro-ph/0606269) and 1A 0620-00 at a very uncertain 1.0 kpc. To answer the question, we propose to validate the very promising distance method based on cross-correlation bisector. If it proves to work, CRIRES becomes de-facto the dedicated instrument for distance determination for many faint and embedded stars.

Scientific Case:

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 as single-line bisectors! This open wide the window of distance estimate for many faint and embedded stars.

This is the case for microquasars, since these objects have often a very faint magnitude in the optical while being much brighter in the NIR. CCF bissectors condense all the information of the spectrum in one function, allowing for reasonable S/N ratio in a reasonable amount of time. For example, for the microquasar GRO J1655-40 (V=18+), we computed that we would need more than 2 weeks (days and nights!) of continuous UVES time to make a good bisector... With CRIRES however, this should take a about 2 hours (K=12).

The point is that current estimations of absolute magnitude in microquasars is made within 2 magnitudes, at least! Any improvement of that below one magnitude accuracy is enormous. The relation provided by Dall et al. has not a very good accuracy, but it is by far better to anything we have today, as it is a completly direct estimation. In Foellmi et al. 2006 (astro-ph/0606269) we have shown that the numerous distance methods used for GRO J1655-40 are very weak, and lead to very large uncertainties. Moreover, we have developed only a maximum-distance method, and astronomical considerations only (namely proper motion vector) led us to think that GRO J1655-40 is related to the open cluster NGC 6242, which is at 1.0 kpc. But a direct measurement of the absolute magnitude would be definitive, and confirming the very interesting link with the open cluster. This latter provides thus information such as age, metallicity, progenitor mass, type and so son, and allow a detailed analysis of the formation of the black-hole in GRO J1655-40.

The only remaining method to determine the distance of the closest black-hole to the Sun, as far as we can tell, would be to wait for GAIA.

As for 1A 0620-00, a careful check of the litterature shows that the estimation of the absolute magnitude is based on a tricky computation from NIR magnitude and an estimation of the extinction based on a 30-years old UV spectrum that has only 5 points(!), using the method of nulling the UV line at 2200A. Unfortunately a HST/STIS spectrum has been published elsewhere and reveal the total absence of such feature in this object, showing the total unreliability of the old UV data... According to a preliminary work with our maximum distance method, 1A 0620-00 could well be the closest BH to the Sun, and actually much closer than expected (200 pc, instead of 1.0 kpc), and would become a target for the VLTI.

We think that these observations are excellent for SDT time: (1) it could provide a simple scientific output with a great impact, (2) it validates a new and efficient distance method that CRIRES could make available in the NIR opening the window for a determination of the distance of many other faint objects, (3) it is easy (hence fast) to reduce and analyse the data, and (4) finally it opens the door for additional observations (is the closest BH to the Sun a good VLTI target?)

We will reduce the data with IRAF. We will check for possible emission lines coming from the accretion disk around the black-hole, but both objects should be in quiescence according to the latest Astronomy Telegrams. Then we will compute the cross-correlation function, with the std star and with a template. We will measure the bissectors the same was as in Dall et al. 2006, A&A, 454, 341. We will then use the relation between bissectors and absolute magnitude given by Dall et al. We will cross-check for consistency with the known spectral type of the companion stars in the two microquasars.

Required observing time

Target	RA	DEC	Wavelength Band	Magnitude	DIT	NDIT
GRO J1655-40	16 55 00.1	-39 50 44.9	2170-2220nm (26/1/n)	K=12.5	30	163
HD 156098	17 17 03.6	-32 39 46.2	2170-2220nm (26/1/n)	V=5.5	5	1
1A 0620-00	05 47 17.1	-51 03 59	2170-2220nm (26/1/n)	K=14.5	30	250
HD 209100	22 03 21.65	-56 47 09.5	2170-2220nm (26/1/n)	V=5.5	5	1

Exposure times have been computed to account for 40% of overheads, and brings total exposure times of ∼2 hours for GRO J1655-40 and ∼3 hours for 1A 0620-00 (and 0.0021 hours for HD 156098 and HD 209100...).

The idea is to obtain one single good spectrum (S/N about 50) per target, in a region where there are the maximum of spectral lines, with a spectral resolution similar or above that of UVES. With about 40 lines, a S/N of 50 in the spectrum will translates to about S/N of 300 in the cross-correlation function (CCF).

To cross-check our method, we want to also make a snapshot spectrum of a reference star that has the same spectral type and luminosity class. This is of primordial importance to have such star to validate the method. Both reference stars have an known Hipparcos distance. For GRO J1655-40, the reference star is HD 156098. For 1A 0620-00, the reference star is HD 209100.

All observations need to be done with a slit of 0.4" to reach the required resolution. AO must be used for the microquasars, since we need a maximum of flux, with a slit of 0.4".

Minimum dataset: One spectrum of either microquasar, with one spectrum of its associated reference star. A microquasar spectrum without the reference star spectrum is useless.