CRIRES Science Verification Proposal

Disk winds and envelopes associated with BN–type objects

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Abstract:

We propose to observe two well–known massive YSOs belonging to the class of BN–type objects. Benefitting from the high spectral resolution of CRIRES we want to investigate the line shapes and kinematics of the ionised and molecular gas in the immediate vicinity of the central sources by means of Brackett γ and CO line series measurements. Our interest is mainly triggered by the fact that we have gathered a series of MIDI interferometric visibilities (tracing the warm dust) for these two objects, and the CRIRES data can help us to better understand the geometry of the ionised and molecular gas of these peculiar sources and hence to restrict the related parameters for a subsequent modelling. The proposal is – in parts – a resubmission of a previous CRIRES SV proposal since the related observations failed last August due to technical difficulties.

Scientific Case:

Massive stars predominantly form in very opaque and highly clustered environments much farther away from the Sun, on average, than typical low–mass star–forming regions. This has severely hampered most observational attempts to make progress in this field of research. Furthermore, in the case of massive star formation, *all* phases prior to the main sequence are usually deeply embedded. However, there is a class of massive young stellar objects (YSOs) that appear intriguingly bright already in the near infrared: the so–called BN-type objects (e.g., Henning et al. 1990), named after the prototypical Becklin–Neugebauer object in Orion. These objects are not associated with well–developed ultracompact HII regions, and seem to be quite young. Most of the BN–type sources are associated with strong outflow activity (cf. Mitchell et al. 1992), and several of these objects are suspected to possess circumstellar disks (e.g., recently Jiang et al. 2005 for Orion BN itself). Nevertheless, whether IR excess emission due to a circumstellar disk in combination with a favourable outflow geometry can sufficiently explain the phenomenology of these objects is still not clarified (e.g., Menten & van der Tak 2004).
Our group is actively working on a sample of these objects, mainly in the framework of the MIDI GTO program. For the CRIRES SV observations we propose to observe **the well–known objects M8E–IR and AFGL 4176**, for which we gained the most progress during recent months. Neither a pure *disk model* nor a pure *spherical shell model* can alone explain the obtained MIDI visibilities.
From high spectral resolution observations in the K band one can derive further restrictions for a compound model. Hydrogen recombination lines which are a prominent feature of the IR spectra of massive YSOs (e.g. Simon et al. 1981, Persson et al. 1984) may provide a clue to disk question. The observed line strengths and widths point to an origin in stellar winds (e.g., Bunn et al. 1995). Interestingly, there are indications that the geometry of the optically thick flow deviates significantly from spherical symmetry (e.g. Simon et al. 1983; Bunn & Drew 1992). Based on their hydrodynamical simulations, Drew et al. (1998) proposed that the intense radiation field produced by a massive YSO may drive mass loss off the surface of the inner parts of its disk. Recently, line radiative transfer modelling by Sim, Drew & Long (2005), based on this approach, strongly supports the idea that the HI lines arise (at least partly) from a disk wind. Therefore, **we propose CRIRES observations in the Brγ line for both objects**. In principle, the high spectral resolution of CRIRES can reveal doubly peaked features with separations of $\sim 100 - 500$ km/s (depending on inclination), as predicted by the Sim et al. models. This has not been possible with the old spectral line observations from the 1980s ($R < 10000$).

Furthermore, pure shell models would predict the CO roto-vibrational band series (around 2.3 μm) in absorption which was confirmed for a few BN–type objects in the 1980s by means of medium spectral resolution data. **We propose to observe both objects around 2.3 μm in the CO settings** to estimate a shell contribution (CO in absorption) and to distinguish this from a potential contribution from a disk (CO in emission) by means of high spectral resolution observations. An emission contribution could be kinematically shifted wrt the absorption component. In any case, the data will be used to study the thermal *and* dynamical state of the molecular gas near the YSOs. (There are no published CO 2.3 μm observations for AFGL 4176 yet.)

Required observing time

Target	**RA**	**DEC**	**Wavelength Band**	**Magnitude**	**DIT**	**NDIT**
M8E-IR	18 04 53.17	-24 26 41.4	2.116-2.168 (26/-1/n)	K=4.4	90	2
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M8E-IR	18 04 53.17	-24 26 41.4	2.254-2.305 (25/1/n)	K=4.4	90	3
M8E-IR	18 04 53.17	-24 26 41.4	2.261-2.311 (25/1/i)	K=4.4	90	3
M8E-IR	18 04 53.17	-24 26 41.4	2.292-2.349 (24/-1/n)	K=4.4	90	3
M8E-IR	18 04 53.17	-24 26 41.4	2.299-2.356 (24/-1/i)	K=4.4	90	3
AFGL 4176	13 43 01.73	-62 08 51.2	2.116-2.168 (26/-1/n)	K=6.4	60	4
AFGL 4176	13 43 01.73	-62 08 51.2	2.254-2.305 (25/1/n)	K=6.4	60	6
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We plan to always deploy the 0.4$''$ slit. Note that in the case of M8E–IR no bright optical guide stars are within 30 arcsecs of the source. The target itself is weak in the optical (R=16.8 mag), so these are non-AO observations. However, we want to test whether here the the spectroastrometry technique can be applied. As already insinuated for the first Science Verification run (see below) we propose to observe M8E–IR at four different slit orientations in Brγ: -40, +50, +140, and +230 degrees since we have to investigate if asymmetries in the slit shape exist, which is done here by cross-checking the results derived from anti–parallel slit position. (-40 degrees is the known orientation of the large scale bipolar CO outflow in the mm regime.) All other observations shall be performed with one slit orientation only. For AFGL 4176, an AO guide star is available, however only at a considerable distance (24$''$). We used the CRIRES ETC v3.1.3 to estimate the exposure times which result in the above table. We used the K band magnitudes as reference, only for M8E–IR the Brγ flux is known (1.2×10^{-15} W m^{-2}, Bunn et al. 1995). We arrive at SNRs of 65 – 95. Such elevated numbers are vital to reach our science goals. Although very bright in the K broad band, the line strengths for both objects are relatively weak, a result of the strongly rising continuum towards longer wavelengths and hence a dominating line veiling. In order to reach a reasonable SNR in the weak lines, we opt for relatively long exposure times. Still, the pure exposure time for all proposed observations is 3480 s, hence less than one hour. Including moderate overheads and additional observations of telluric standard stars, **the project might take 2 – 3 hours**.

Notice about previous CRIRES observations:

A proposal had been accepted to observe one of our objects, M8E–IR, at several K-band settings during the first CRIRES Science Verification run in August 2006. The observations have been conducted as one part of the Bik/Linz programme 60.A-9063(A). However, it turned out that problems during the observations led to a misalignment of the grating: "Both the grating and the intermediate slit were in (software) simulation. That the grating was in software simulation means that the template will not set the right wavelength: the grating angle was left at the last value before it was set into simulation." (message by A. Smette). We cannot really recover which wavelength bin of the K-band has actually been observed. The Brγ line was obviously not in the spectral bandpass. Therefore, we resubmit the proposal and give a slightly more elaborate reasoning for the science case. M8E–IR was a good target for the August observations in terms of accessibility. For SV 3, it can only be observed during the last part of the night. However, we enlarge our target sample and also propose observations of AFGL 4176 which is conveniently observable during most parts of the night.