CRIRES Science Verification Observations

Topic : CO emission from transitional protoplanetary disks

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Project

Abstract:

We propose to observe spatially and spectrally-resolved CO emission at 4.7 micron from two transitional disks around young stars: GQ Lup(d=200 pc) and T Cha (66 pc). These sources have recently beencharacterized on the basis of our Spitzer data as "transitional" or"cold" disk sources, i.e., disks with evidence for large 25-40 AUradius inner holes in the dust distribution, perhaps created by thepresence of a planet (Brown et al., ApJ Letters submitted). Keckspectra of GQ Lup and other cold disk sources in our sample showstrong and narrow (<20 km/s) CO vibration-rotation (12CO v=1-0 and2-1, 13CO 1-0) emission lines indicating that - surprisingly - thereis still hot gas close to the star, i.e., INSIDE the dusthole. However, the Keck data lack the spatial and spectral resolutionto resolve the lines. CRIRES, with its AO capabilities and stableastrometry and up to 4 times higher spectral resolution, can uniquelydetermine the location and kinematics of the gas, which is a crucialingredient for planet formation theories. Both thermal excitation andUV pumping are expected to play a role, so different spatialdistributions are expected for the 1-0 and 2-1 lines.

The proposed high S/N data on these bright objects will allow us to test the ability of CRIRES to perform accurate spectro-astrometry on line emission from protoplanetary disks. Relative spectro-astrometry means that we will measure the spatial centroid of an emission line in each velocity bin to construct position-velocity diagrams. Optical spectro-astrometry routinely achieves milli-arcsecond resolution on a 4-meter class telescope (e.g. Takami et al. 2001, MNRAS 323, 177). With CRIRES, it should be possible to determine the spatial centroid of a bright line to at least 1/10 of a pixel or ~1 AU at 100 pc. In essence, this means CRIRES should be able to {\it directly} image the CO ro-vibrational line emission on 1 AU scales in nearby T Tauri disks. Using three different slit rotation angles, we will be able to

1) Determine size, position and inclination angles of the gas disk, to be compared with those of the dust disk.

2) Estimate the importance of various excitation mechanisms as a function of disk radius (e.g. UV excitation versus thermalized excitation).

3) Determine the gas temperature and intrinsic turbulent width in the CO emitting layer as a function of disk radius, for comparison with dynamical and physical disk models.

4) Determine the mass of the central star (assuming Keplerian rotation).

5) Estimate departures from Keplerian rotation on <10 AU scales in the disk surface layers, enabling us to measure any radial motion in the gas.

As a backup source (in case sources in a different RA range are needed) TW Hya is proposed, another well known case from the literature (Rettig et al. 2004, ApJ 616, L163).

Target List and Table

name	alfa 2000 delta 2000	lambda range / wavelength ID	Fnue	exp. time / DIT, NDIT	Prior.
T Cha	11 57 13.5 -79 21 32	4697-4803nm	1000 mJy		
		12/1/n		30s, 20	1
		12/1/i		30s, 20	1
		4588-4702nm			
		12/-1/n		30s, 20	2
		12/-1/i		30s, 20	2
GQ Lup	15 49 12.1 -35 39 05	4697-4803nm	1000 mJy		
		12/1/n		30s, 20	1
		12/1/i		30s, 20	1
		4588-4702nm			
		12/-1/n		30s, 20	2

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          |                      | 12/-1/i      |           |  30s, 20 | 2
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Back-up:

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TW Hya    |11 01 51.9 -34 42 17  | 4697-4803nm  | 1700 mJy  |
          |                      | 12/1/n       |           |  30s, 20 | 1
          |                      | 12/1/i       |           |  30s, 20 | 1
          |                      | 4588-4702nm  |           |          |
          |                      | 12/-1/n      |           |  30s, 20 | 2
          |                      | 12/-1/i      |           |  30s, 20 | 2
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Fnue or Fline according to CRIRES-ETC;
consider width of spectral features relative to pixels
DIT, NDIT per wavelength ID !!!
DIT, NDIT from ETC
wavelength ID from CRIRES manual, appendix A

if appropriate give angular size, slit width and postion angle
(recommended slit is ~ 0.4 arcsec for the moment

Note: from the manual and the ETC you select the relevant numbers;
you must check, how your spectral features are mapped on the
detector array

adaptive optics notes:
reference star alpha, delta; V/R-magnitude,
relative location: distance in arcsec, position angle

*****Our notes on these issues**

- Integration times etc: All three sources are bright at M band, at least 1 Jy. The integration times are chosen such that a S/N>100 is reached on the continuum using ETC. Note that the overall program time hardly changes whether NDIT=5 or 20 is chosen since the integration times are short and the overall program time is dominated by overheads for acquisition and calibration; for these first exploratory observations we prefer to have a redundancy in NDIT. From Keck data on GQ Tau and TW Hya, the feature/continuum ratio is expected to be at least 20%.

- Velocity shifts: We checked that the source lines for GQ Tau are shifted from telluric lines by nearly 30 km/s in late February. For T Cha and TW Hya, the shifts are about 10 km/s.

- Slit width, position angle: Emission will be compact and lines will be narrow. Thus, the 0.2" slit is strongly preferred for best spectral and spatial resolution. Because the sources are bright, slit losses are not a problem. We request two different slit position angles, one north-south and one east-west. Note: if the 0.2" slit option is not available, we can still do useful science with the 0.4" slit.

- AO notes: AO can be performed on the sources themselves: T Cha has V=10.1 (B-R=1.9) and GQ Lup V=11.7 (B-R=1.8). TW Hya has V=11.1.

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Finding chart attached (if appropriate)

- Finding charts are enclosed as files:
TCha_chart.eps
GQLup_chart.eps

Comments:

- For each source, we propose two wavelength ranges to cover the largest possible range in J-values of the CO lines. If cuts are needed to reduce the program time, we strongly prefer to drop the 4588-4702 nm setting (labeled as priority 2 in the table, i.e., just do a single wavelength range for each source), rather than dropping one source and/or one slit orientation entirely.

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Detailed description of Suggested observations:
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General notes:
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- It is of critical importance to observe a nearby standard star at same airmass (preferably within 0.05 airmass) as the source. Our previous ISAAC M-band data show that this is the single most important factor for proper removal of the telluric lines and reaching high S/N on the spectrum.

- Standard stars (from ISAAC experience these are good at M-band):

T Cha: HR 4679: 12 18 26.3 -64 00 11.1, V=4.0, B2.5V
GQ Lup: BS 5812: 15 38 39.4 -29 46 39.9, V=3.6

Observation sequence:
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- Acquire star at K band
- Turn on AO at optical; all three stars have V=10-11 mag
- Select slit in N-S orientation; 0.2" slit strongly preferred
- Select wavelength range(s) according to above table
- Perform integrations on source with nodding cycles (ABBA); select non-zero jitter box for astrometry
- Rotate slit by 90 degrees to E-W
- Perform integrations on source
- Perform same observations on standard star within 0.05 airmass (BEFORE science target) with exactly the same spectral set-up and integration times such that S/N>100 is obtained (e.g., DIT=10 s, NDIT=30). No need to rotate slit on standard star; any orientation is fine.

NOTE: our team would be happy to prepare the phase 2 OBs

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SCIENCE GOALS:
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A longer science justification can be provided if needed.

Our team has extensive experience with high-resolution mid-infrared spectroscopy at both VLT (ISAAC,VISIR), Keck, ISO and Spitzer. We have developed data reduction tools ourselves within IDL for ISAAC, VISIR, and NIRSPEC both for "quick-look" and more extensive data reduction. We expect that these can be readily extended to CRIRES, should the pipeline not yet be fully operational. This will allow us to obtain a rapid assessment of the quality of the data and provide feedback to the ESO CRIRES team. We have done so already with the preliminary data received in December; for example, we could confirm our astrometry goals.

Our team also has the proper tools to analyse the data, ranging from simple 1-D excitation models to sophisticated disk models which include the line radiative transfer (Blake & Boogert 2004, ApJ Letters, Pontoppidan, Dullemond et al., in prep.). Thus, we expect that the data can readily lead to a publication.