High resolution near-IR spectroscopic observations of B[e]sg from the Magellanic Clouds

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Introduction

The post-main sequence evolution of massive stars passes through several phases with strong, often eruptive mass-loss events, including the enigmatic B[e] supergiants. Stars in this group are surrounded by disks, which are cool and dense, and give rise to a complex chemistry, producing molecules and dust. Near infrared emission in CO bands has proven to be a major indicator for disk dynamics, as it originates typically from the inner edge of the molecular disk or ring. To better understand the mass-loss history in those objects, which is an essential ingredient for accurate predictions (e.g. of final stages) from stellar evolution calculations, a detailed study of their circumstellar material is crucial. In this work we present high resolution near-IR spectra of two B[e] supergiants from the Magellanic Clouds. We analyze the spectral features and model the molecular emission to derive kinematics and physical properties of the circumstellar disks.

Molecular emission

LHA115-S18: CO band emission and Pfund lines in emission are observed. In addition, the K-band spectrum of LHA115-S18 displays many small emission features shortward of and within the CO bands, which we identified as lines from water vapor. Our best-fitting model for LHA115-S18 is shown in Figure 1.

LHA120-S35: the K-band spectrum displays CO molecular emission and Pfund emission lines. The preliminary fit to the CO emission of LHA120-S35 in Figure 2.

We utilize the codes developed by Kraus et al. (2000, A&A, 362, 158) for the computation of Pfund line emission from a wind and ^{12}CO band emission from a circumstellar disk, and modified by Kraus (2009, A&A, 494, 253) to add the emission of the isotopic molecule ^{13}CO. The model considers that the CO gas is in LTE, which is a suitable approximation for circumstellar environments. The double-peaked line profiles indicate rotation of the CO gas.
For H_2O, synthetic spectra were computed for a similar model as for CO, i.e., considering a ring of gas with constant temperature and column density, and using the line list, energy levels, and Einstein transition coefficients from Polyansky et al. (2018, MNRAS, 480, 2597). No indication for rotation is detected for the lines of water vapor.

Targets and observations

High resolution (R $\approx$ 45000) near-IR observations were obtained using IGRINS echelle spectrograph (Park et al. 2014, Proceedings of the SPIE, Volume 9147, id. 91471D 12 pp), a visitor instrument at Gemini South Observatory. This instrument allows to observe H and K bands simultaneously, covering the spectral ranges: 1.45-1.75 μm and 2.05-2.45 μm. We selected 2 B[e] supergiant stars from the Magellanic Clouds which had already been reported to show CO emission in low resolution spectra, to model in detail their molecular emission.

Target name	Galaxy	V mag	K mag	Program ID	Obs. date	Classification
LHA115-S18	SMC	13.8	11.1	GS-2021B-Q-241	02/10/2021	B[e]sg/binary?
LHA120-S35	LMC	13.1	10.8	GS-2024A-Q-224	02/06/2024	B[e]sg

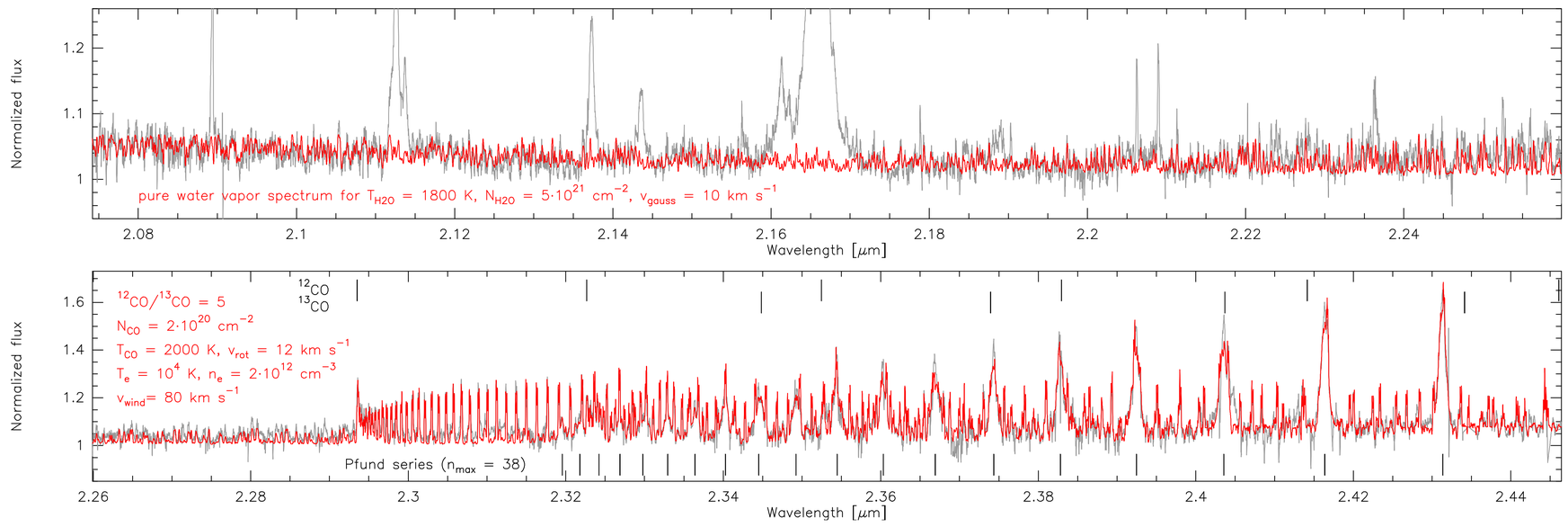

Figure 1. GEMINI/IGRINS portion of the K-band spectrum of LHA115-S18 (gray) containing the first-overtone CO bands and lines from the hydrogen Pfund series (bottom panel) and emission from water vapor spread over the entire spectrum. The best-fitting model is shown in red. We noticed a blue-shift of the Pfund lines by about 25 km s^{-1} with respect to the molecular lines, suggesting that LHA115-S18 could be binary.

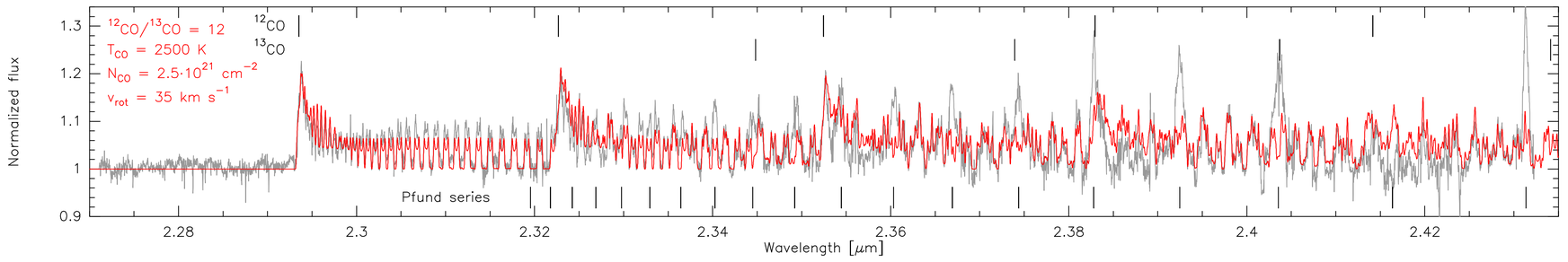

Figure 2. GEMINI/IGRINS portion of the K-band spectrum of LHA120-S35 (gray) showing the first overtone CO bands. Our preliminary fit is included (red).

H- and K- band atomic features

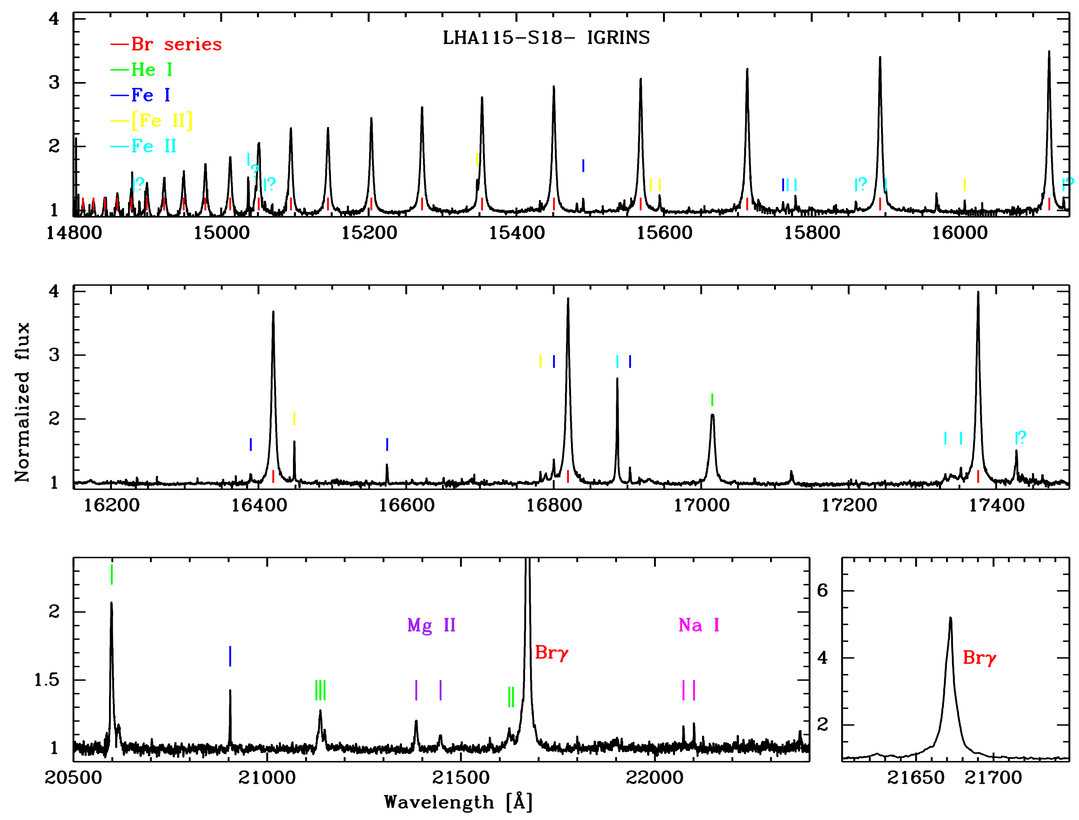

Figure 3. GEMINI/IGRINS H-band (top and middle) and portion of the K-band (bottom) spectrum of the star LHA115-S18. Brackett series lines appear in emission with one-peaked profiles. Also noticeable are strong He I emission lines at 1.7, 2.112, 2.113, 2.161 and 2.05 μm, and several Fe I, Fe II and [Fe II] emission lines.The K-band spectrum shows emission lines from Mg II at 2.137 and 2.144 μm and Na I at 2.206 and 2.209 μm.

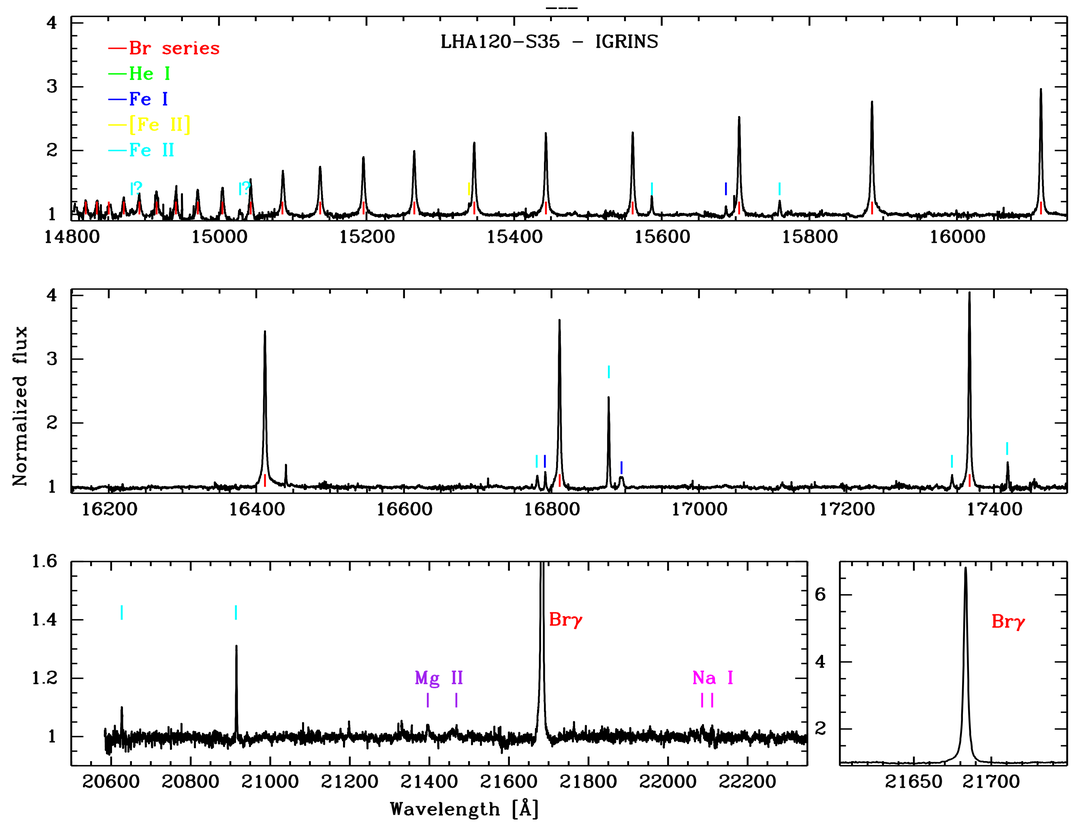

Figure 4. GEMINI/IGRINS H-band (top and middle) and portion of the K-band (bottom) spectrum of the star LHA120-S35. Brackett series lines appear in emission with one-peaked profiles. We identified several emission lines of Fe I, Fe II and [Fe II] and weak emission lines of Mg II and Na I. No He I line is detected.

Conclusions

The high-quality near-IR spectra of the two B[e] supergiants reveal rotationally broadened emission from CO, suggesting a Keplerian rotating ring of molecular gas as is typical for this class of stars. Both objects also have intense wind emission traced by the various hydrogen series in both the H- and K-band and numerous emission lines from metals. The discovery of water vapor emission in LHA115-S18 is so far unique in B[e] supergiants. But LHA115-S18 is a special representative of its class because it also displays occasionally emission of Raman-scattered lines in tandem with intense emission from He II in the optical spectrum discovered by Torres et al. (2012, MNRAS, 427, L80). These authors speculated whether LHA115-S18 could be a symbiotic object. The shift in radial velocity between the molecular and the Pfund line emission seen in our spectrum supports a binary nature of that object. In that case, the molecular gas might be circumbinary.

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