SYNTHETIC SPECTRA OF LONG-PERIOD VARIABLES: A FIRST COMPARISON WITH ISO OBSERVATIONS

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Abstract. [1]
Exploratory synthetic spectra were computed for carbon-rich long-period variables. We used dynamic model atmospheres of Höfner & Dorfi (1997) and calculated partial pressures, absorption- and scattering coefficients as input for the spectral synthesis code of Jørgensen et al. (1992). First ISO SWS-observations of the carbon-Mira T Dra are compared with our synthetic spectra.

1. Models and Atmospheric Structure

We used one dynamic model and three MARCS models (cf. Jørgensen et al. 1992):

K7U4: $T_{\rm eff} = 2880\,$K, $\log(g) = -0.61$, $[C]/[O] = 1.40$
period $= 390\,$d, piston velocity $= 4\,$km/s
M2880: $T_{\rm eff} = 2880\,$K, $\log(g) = -0.61$, $[C]/[O] = 1.40$
M2550: $T_{\rm eff} = 2550\,$K, $\log(g) = -0.69$, $[C]/[O] = 1.40$
M3000: $T_{\rm eff} = 3000\,$K, $\log(g) = -0.00$, $[C]/[O] = 1.40$

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The dynamic model is similar to the models of Höfner & Dorfi (1997) except for the mean gas opacity which has been adjusted by comparison with standard model atmospheres to obtain more realistic gas densities.
Plotting gas pressure against the temperature for the MARCS model M2880, the hydrostatic initial model and dynamic structures at different pulsational phases shows that there is an overall agreement between the different models in the range where the spectra are formed, i.e. between approximately 2000 and 4000 K. However, the shock fronts produce local differences which strongly influence the emergent spectra. In the dynamic models the pressure is not a unique function of temperature anymore because of the shockwaves.

2. Synthetic Colours

We computed synthetic near-infrared colours (J−H) and (H−K) and studied the influences of selected molecules. The influence of omitting a single molecule for M2550 is given in the table below. The size of the effects depends on the effective temperature, but the trend of the changes is the same for all temperatures studied.

TABLE 1. Colour change due to omission of single molecules

molecule	(J−H)	(H−K)	molecule	(J−H)	(H−K)
CH	0.00	0.00	C_2H_2	0.08	0.45
CO	0.02	0.03	HCN	0.02	−0.02
C_2	−0.01	−0.23	C_3	0.33	0.10
CN	−0.21	−0.05			

3. ISO-SWS Spectra

We have obtained SWS01 (speed 2) spectra of various long-period variables at several phases of the light cycle. We focus on two spectra of the carbon-Mira T Dra taken at visual phases 0.64 and 0.97. Information on the reduction process can be found in the contribution by Hron et al. (this volume). The individual parts of the spectra were combined in such a way as to give L′-band fluxes consistent with our own, quasi-simultaneous photometry. The spectra were rebinned to a resolution of 100 to make them comparable with our synthetic spectra.
Due to the lack of real continuum points (see Fig. 2) and the significant

variations in the pseudo-continuum, it is difficult to approximate the continuum. One possibility is shown in Fig. 1 where we plot the spectra together with continua computed from the sum of two blackbodies, one for the dust envelope and one for the photosphere (Kerschbaum & Hron, 1996). The blackbodies were fitted through the fluxes at the wavelengths 0.55μm (V), 1.22μm (J), 1.65μm (H), 9.7μm (SWS), 13.0μm (SWS), 14.8μm (SWS) and 60μm (IRAS). The V magnitudes at the dates of the ISO observations were kindly provided by the AAVSO, the J and H data are interpolated from our own near IR photometry taken at the TCS, Tenerife.

4. Comparison with Synthetic Spectra

We have computed opacity sampling spectra including the molecules CO, CH, C_2, CN, HCN, C_2H_2 and C_3. In Fig. 2 (lower panel) dynamic models for approximately the same phases as the ISO spectra are plotted. The upper panel shows two MARCS models with different effective temperatures (M2550 and M3000). The different symbols identify various molecular features, broad features are indicated by several equal symbols (e.g. triangles denote C_3). The spectrum of model M2550 looks similar to the one of model K7U4 at phase 0.97, but especially the 3.1 μm and 6–7 μm features are deeper and broader in the spectrum of K7U4. The spectrum of model M3000 is comparable to the one of model K7U4 at phase 0.64. However, all the features are stronger in model K7U4 than in M3000.
There is rough agreement between the models and the observations in the sense that most features get stronger towards the luminosity minimum.

5. Conclusions

- C_2, CN, C_2H_2 and C_3 strongly influence the near-infrared colours (J$-$H) and (H$-$K) while CO and HCN produce only a small effect.
- The synthetic spectra from the hydrostatic and dynamical models show some similarity although the dynamical models have stronger features, especially at 3.1 μm and 6–7 μm.
- The ISO-SWS data for T Dra and the models show stronger molecular absorption around the minimum than near maximum light, but there are also marked differences between the observations and the models, especially concerning the overall strength of the absorption.

References

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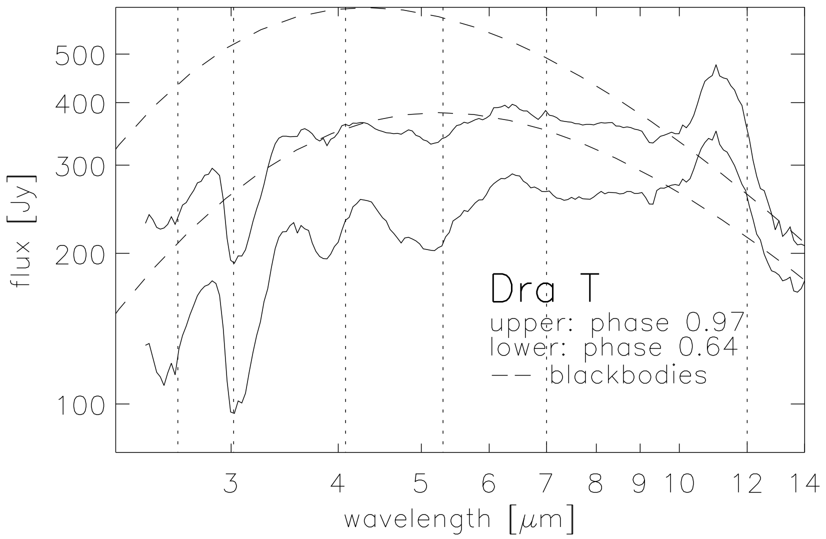

Figure 1. Observed SWS-spectra of T Dra for phases 0.97 and 0.64 and continua from blackbody fits. The dashed lines mark the borders of different SWS bands.

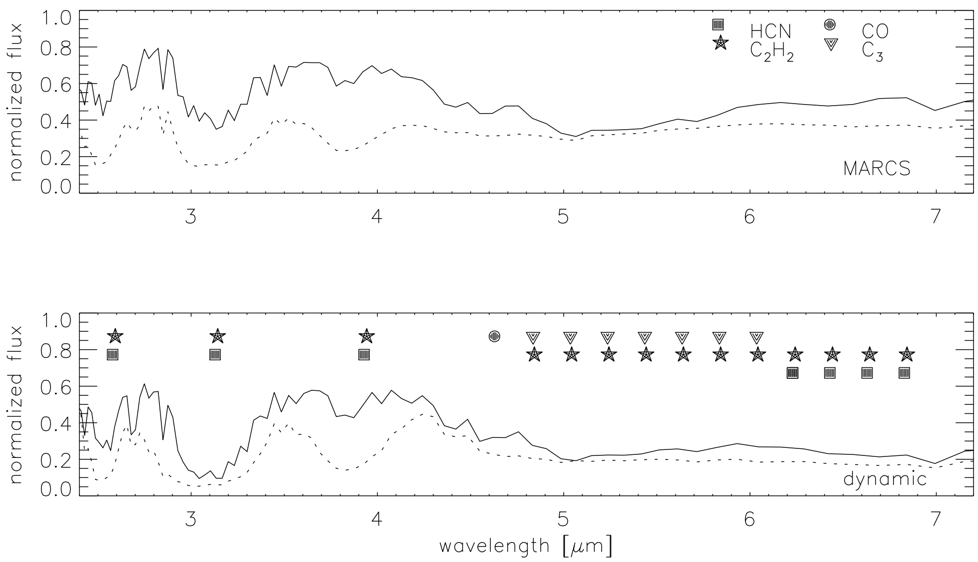

Figure 2. Dynamic models (lower panel) for approximately the same phases as the ISO spectra in Fig. 1 are plotted (maximum/minimum light denoted by full/dashed lines). The upper panel shows two MARCS models with effective temperatures of 3000 K (full) and 2550 K (dashed). The different symbols indicate different molecular features.