

Search for DIBs in Emission: MWC 922 - The Red Square Nebula

N. Wehres^{1,2,†}, B. Ochsendorf³, J. Bally², T. Snow^{1,4}, V. Bierbaum^{1,2},
N. L. J. Cox⁵, L. Kaper⁶ and A. G. G. M. Tielens³

¹Center for Astrophysics and Space Astronomy, 389 UCB, University of Colorado,
Boulder, CO 80309-0389, USA
email: Nadine1.Weheres@emory.edu

²Department of Chemistry and Biochemistry, 215 UCB, University of Colorado,
Boulder, CO 80309-0215, USA

³Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands

⁴Department of Astrophysical and Planetary Sciences, 391 UCB, University of Colorado,
Boulder, CO 80309-0391, USA

⁵Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium

⁶Astronomical Institute Anton Pannekoek, University of Amsterdam,
Science Park 904, 1098 XH Amsterdam, The Netherlands

Abstract. This work focusses on MWC 922, the central object in the Red Square Nebula. We obtained low and medium resolution spectra of both, the central object and the surrounding nebula, using the DIS and TSPEC spectrograph. The spectra show the whole spectral range between ~ 3500 Å up to ~ 25000 Å. The central object shows a plethora of emission lines, including many Fe II and forbidden Fe [II] lines. Here, we present the inventory of the emission lines of the central object, MWC 922. Future work will comprise the identification of the nebula emission lines by using newly obtained X-Shooter spectra. That way we want to gain further insight into the physical and chemical conditions in this environment. A comparison of the Red Square to the Red Rectangle Nebula is anticipated and will guide our search for DIBs in emission.

Keywords. Red Square Nebula, MWC 922, DIBs in emission

1. Introduction

The Red Square Nebula is surrounding the B[e] emission line object MWC 922. The evolutionary stage of MWC 922 is still unclear, and both pre and post-main sequence evolutionary status have been suggested (Tuthill & Lloyd 2007). The central object is mainly known for its infrared properties (Allen & Swings 1976). Allen & Swings (1976) give also a brief description of the optical properties of MWC 922 in their paper on B[e] stars with infrared excess. Whereas Fe II lines are mentioned absent in that paper, Rudy *et al.* (1992) published the IR spectrum of MWC 922 and noted unusually strong Fe II and [Fe II] lines. In turn, Rudy *et al.* (1992) mentioned the absence of the Paschen series as well as any other absorption features. Here, we present our spectra with higher spectral resolution and larger spectral coverage. Most of the stellar emission lines could be identified and are shown in Fig. 2 and listed in table 1.

† Present address: Department of Chemistry, Emory University, 1515 Dickey Drive, Atlanta, GA 30322, USA

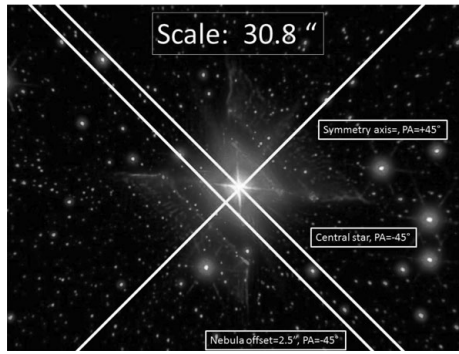


Figure 1. Slit positions used for obtaining the DIS and TSpec spectra. Image credit: Peter Tuthill and James Lloyd

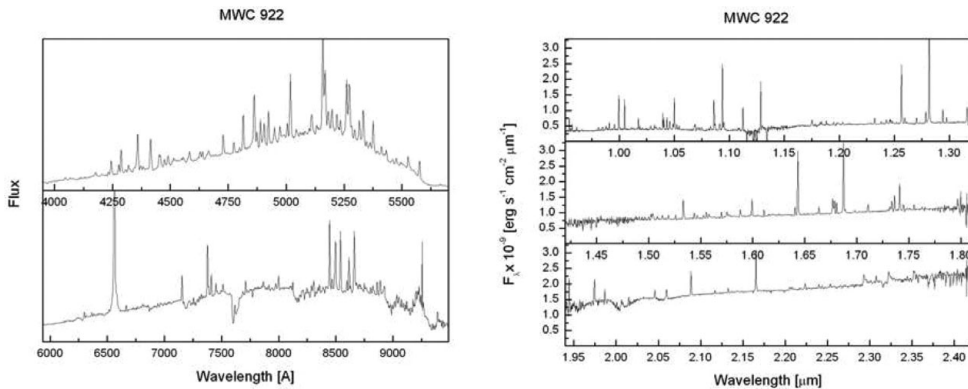


Figure 2. DIS (left panel) and TSpec (right panel) spectra of emission line object MWC 922.

2. Observations

The optical spectra were obtained using DIS (Dual Imaging Spectrograph), and the near-IR spectra were obtained using TSpec. Both spectrographs are mounted on the 3.5 m telescope at the APO. DIS was operated in his standard settings using a $1.2'' \times 6'$ slit and the B400/R300 gratings. This gives about $1.83 \text{ \AA pix}^{-1}$ and $2.31 \text{ \AA pix}^{-1}$ spectral resolution, and a coverage between 3 500 and 7 500 \AA . The near-IR spectra were obtained using a slit dimension of $1.1'' \times 43''$, giving a spectral resolution of $\frac{\lambda}{\Delta\lambda} \sim 3\,500$. The spectra cover the region between 9 500 \AA and 25 000 \AA . The slit positions for both spectrographs are displayed in Fig. 1. We positioned the slit along the symmetry axis of the nebula as well as perpendicular to the symmetry axis. The PA of the Red Square Nebula is 46° . Not discussed here is the offset position at $2.5''$ distance from the central star.

3. Results and Discussion

Fig. 2 gives an overview of the stellar spectra in the optical (left panel) and near-IR (right panel), respectively. All identified emission lines are presented in table 1. The first column gives the wavelength position of the peak maximum in the optical (DIS) spectrum. The second column gives the species name. The third column gives the central band position of the peak maximum of the near-IR emission line (TSpec), the identification is given in column four. For the near-IR spectra we obtained an absolute flux calibration and the flux of the peak maximum is given for a first indication of relative peak strengths

Table 1. Overview of the stellar emission lines in the DIS and TSpec spectrum of MWC 922.

λ optical nm	species name	λ IR μm	species name	Flux at Peak Maximum [10^{-9} erg s $^{-1}$ cm $^{-2}$ μm^{-1}]
4243.43	[Fe II]	1.000	Fe II	1.5
4286.98	[Fe II]	1.005	H I Pa (7-3)	1.4
4357.74	[Fe II]	1.017	Fe II	0.757
4413.99	[Fe II]	1.051	Fe II	1.403
4452.09	[Fe II]	1.086	Fe II	1.344
4490.19	Fe I	1.094	H I Pa (6-3)	2.482
4582.73	Fe II	1.112	Fe II	1.095
4628.09	[Fe II]	1.129	O I	1.923
4815.00	[Fe II]	1.252	[Fe II]	0.622
4862.15	H I H β Ba (4-2)	1.257	[Fe II]	2.477
4905.69	[Fe II]	1.270	[Fe II]	0.755
4923.84	Fe II	1.282	H I Pa (5-3)	5.801
5018.19	Fe II	1.294	[Fe II]	1.037
5157.90	[Fe II]	1.316	O I	1.094
5168.78	Fe II	1.513	H I Br (21-4)	0.918
5197.81	Fe II	1.519	H I Br (20-4)	0.925
5234.10	[Fe II]	1.526	H I Br (19-4)	0.929
5261.31	[Fe II]	1.533	H I Br (18-4) and [Fe II]	1.419
5295.79	O I	1.544	H I Br (17-4)	0.989
5315.75	Fe II	1.556	H I Br (16-4)	1.024
5333.90	[Fe II]	1.570	H I Br (15-4)	1.026
5362.93	Fe II	1.588	H I Br (14-4)	1.091
5411.92	[Fe II]	1.599	[Fe II]	1.44
5431.87	Fe I	1.611	H I Br (13-4)	1.093
5495.38	Fe I	1.641	H I Br (12-4)	1.190
5526.22	[Fe II]	1.643	[Fe II]	2.988
5575.21	[O I]	1.664	Fe II	1.185
6298.65	O I	1.677	[Fe II]	1.451
6362.83	O I	1.679	H I Br (11-4)	1.386
6562.22	H I H α Ba (3-2)	1.736	H I Br (10-4)	1.557
6665.35	[Ni II]	2.165	H I Br (7-4)	3.092
7153.52	[Fe II]	2.224	H ₂	2.023
7375.83	[Ni II]			
7410.21	[Ni II]			
7451.46	[Fe II]			
7513.35	Fe II			
7710.45	Fe II			
8306.33	Fe II			
8446.14	O I			
8466.76	H I Pa (17-3)			
8496.56	Ca II			
8540.10	Ca II / H I Pa (15-3)			
8597.40	H I Pa (14-3)			
8615.73	[Fe II]			
8661.57	Ca II / H I Pa (13-3)			
8748.66	H I Pa (12-3)			
8863.26	H I Pa (11-3)			
8890.76	[Fe II]			

in the last column. Our data shows a plethora of emission lines, including neutrals and cations and also one molecular species: H₂. We clearly identify Fe II lines in addition to [Fe II]. Paschen lines, Balmer and Brackett lines are also observed in emission. A first rough comparison to HD 44179, the central object in the Red Rectangle Nebula, shows overlap in Fe II, [Fe II] and some Ca II lines (Hobbs *et al.* 2004). A thorough analysis of the emission bands of the Red Square Nebula obtained with X-Shooter is underway.

References

- Allen, D. A. & Swings, J. P. 1976, *ApJ*, 47, 293
Hobbs, L. M., Thorburn, J. A., Oka, T., *et al.* 2004, *ApJ*, 615, 947
Rudy, R. J., Erwin, P., Rossano, G. S., & Puetter, R. C. 1992, *ApJ*, 398, 278
Tuthill, P. G. & Lloyd, J. P. 2007, *Science*, 316, 247