Bull. Astr. Soc. India (2002) 30, 671–674

High Resolution Spectroscopy of QY Sge

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Abstract. High resolution spectral analysis of QY Sge, a post AGB star is presented here. The spectrum of QY Sge is characterized by three major components: absorption lines representative of a G supergiant, sharp emission lines from resonance and low excitation transitions of abundant neutral atoms, and broad emission lines of Na D and K lines at 7665 Å and 7699 Å. The star is a velocity variable. The radial velocities of the star as measured from a set of unblended absorption lines are estimated as ~ -21 kms^{-1} for 1999 and ~ -23 kms^{-1} for 2000 spectrum. An abundance analysis shows that the star is of approximately solar composition but with the highly condensable elements (e.g, Sc and Ti), depleted by factors of 5 to 10.

Keywords : star: individual: QY Sge: variable

1. Observations and Data Reduction

QY Sge was observed, from about 3900 Å to 10000 Å (with gaps beyond about 5600 Å) with the McDonald Observatory's 2.7m Harlan J. Smith telescope and its '2dcoudé' cross-dispersed echelle spectrograph on two occasions: 1999 August 17 and 18, and 2000 June 14. Observations of a Th-Ar hollow cathode lamp provided a wavelength calibration. Data were reduced in the standard fashion using the IRAF software package.

Radial Velocity: The radial velocity was measured from a set of unblended absorption lines. The radial velocities are ~ -21 kms^{-1} for 1999, and ~ -23 kms^{-1} for 2000 spectrum. Low excitation Fe I lines show a more positive velocity by about 7 to 9 kms^{-1}. Lines of other species give very similar results. Intensive observations to determine the nature of the velocity variations would be valuable.

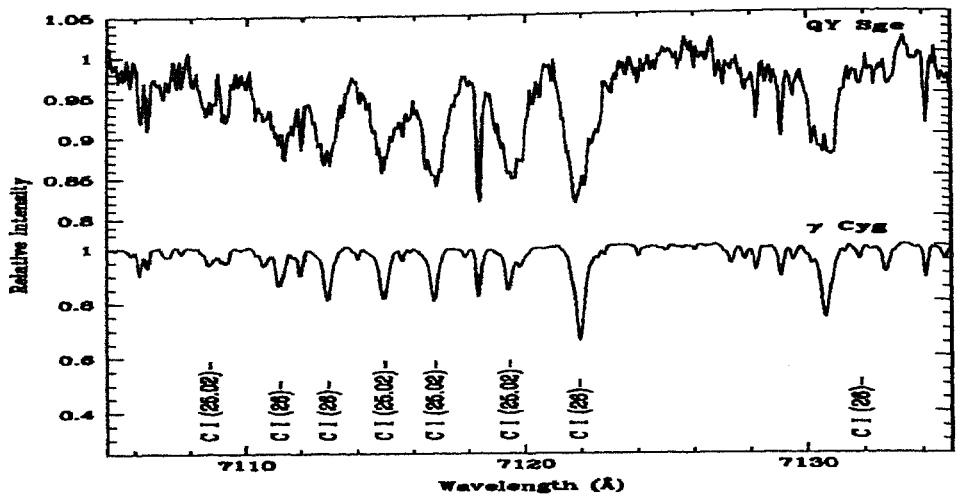

Figure 1. A comparison of the spectra of QY Sge and γ Cyg from 7105 Å to 7135 Å. Equivalent widths of the neutral carbon lines in this interval are considerably larger in QY Sge than in γ Cyg.

2. Spectral Features of QY Sge

Inspection of QY Sge's spectra shows three obvious components: absorption lines representative of a late-F to early-G supergiant, sharp emission lines from resonance and low excitation transitions of abundant neutral atoms and a few broad emission lines (e.g., Na D and K I 7665 Å and 7699 Å lines).

The spectrum broadly resembles that of γ Cyg. One striking difference is that QY Sge's lines are much broader. The broadening is attributed to the receipt of photons indirectly after scattering off moving dust grains in the stellar wind. Lines of singly-ionized atoms such as Sc II, Ti II, Y II and Nd II are greatly weaker in QY Sge. C I lines near 7110Å are stronger in QY Sge than in γ Cyg. Low excitation lines of neutral metals are also stronger in QY Sge. The equivalent widths of the lines are quite similar from one spectrum to the next and closely match the values of the same lines in γ Cyg's spectrum.

The most prominent of the sharp emission lines are the Na D and K I resonance lines. The radial velocities of the emission peak for the strongest examples are -21 kms^{-1} from the Na D lines, -24 kms^{-1} from the K I lines, and -24 kms^{-1} from the Ca II lines. Broad emission in addition to sharp emission is seen in QY Sge and R CrB. For R CrB the broad emission of the red wing of D2 overlaps the blue wing of D1, but D1 and D2 are well resolved for QY Sge. Broad emission is weakly present in the Ca II H line. Emission

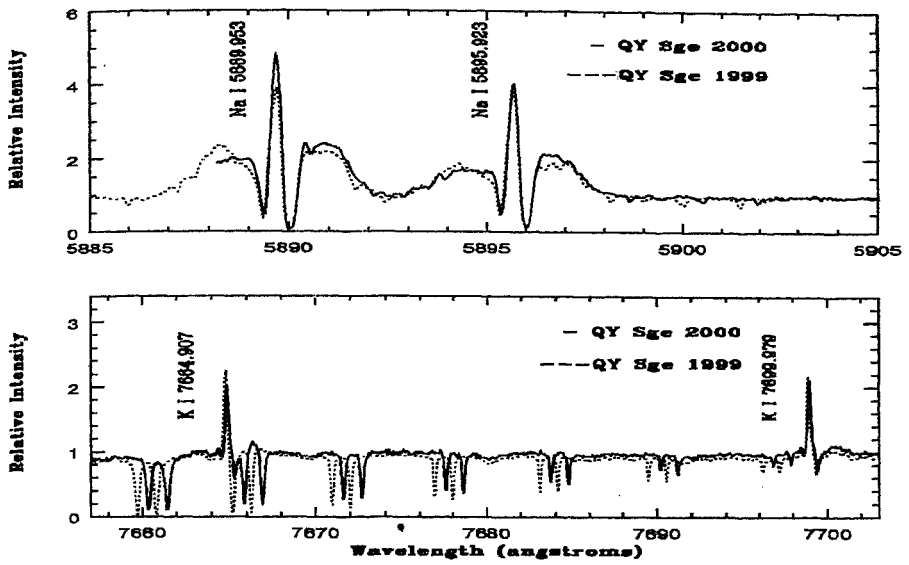

Figure 2. Spectra of QY Sge in 1999 August and 2000 June. The figure shows the presence of the sharp and broad components of the emission profiles of the Na D lines (upper panel) and the K I resonance lines (lower panel).

in the Ca II infrared triplet and the [Ca II] 7291, 7323 Å lines necessarily occurs following absorption of photons in the H and K lines. QY Sge's broad emissions are approximately centered on the systemaic velocity. Average velocity of the blue and red peaks is -24 kms^{-1} for the Ca II K lines and -27 kms^{-1} for D2 and -29 kms^{-1} for D1 from the 1999 August spectrum for which the systemic velocity was -21 kms^{-1}.

3. Abundance Analysis

A standard LTE model atmosphere based analysis was undertaken to determine the stellar parameters $T_{eff} = 5850\pm200$K, log g = 0.7 ± 0.25 in cgs units, $\zeta_t = 4.5\pm0.5$ kms^{-1}, and [Fe/H] = -0.4±0.1. The star is of approximately solar composition but with highly condensable elements (e.g. Sc and Ti) depleted by factor of 5 to 10. C, N and Na are overabundant. Heavy elements have unusual relative abundances. Y, Zr and Ce are underabundant by about 1 dex but Ba and Eu show approximately solar abundances. The initial metallicity of the star as indicated by sulphur and zinc is close to solar. Iron and other elements are only slightly depleted. Elements of highest T_{cond} are found to be underabundant relative to those of low T_{cond}. The severe depletions are restricted to Sc, Ti and three heavy elements. The derived chemical composition of QY Sge are presented in Table 1.

Table 1. Chemical composition of QY Sge

Element	Z		*No of lines*	*Meteorites*[a]		
		logϵ		logϵ	*[X/H]*	*[X/Fe]*
C I	6	8.80±0.19	6	8.56	+0.24	+0.61
N I	7	8.77±0.15	4	8.05	+0.72	+1.09
Na I	11	6.74±0.21	3	6.33	+0.41	+0.78
Mg I	12	7.12	1	7.58	-0.46	-0.09
Mg II	12	7.48	1	7.58	-0.10	+0.29
Al I	13	5.81	1	6.47	-0.66	-0.29
Si I	14	7.42±0.17	9	7.56	-0.14	+0.23
Si II	14	7.74	1	7.56	+0.18	+0.57
S I	16	7.55±0.22	4	7.21	-0.34	+0.03
Ca I	20	5.91±0.12	10	6.36	-0.45	-0.08
Ca II	20	6.17±0.12	2	6.36	-0.19	+0.20
Sc II	21	2.28±0.19	4	3.10	-0.82	-0.43
Ti II	22	3.84±0.04	3	4.99	-1.15	-0.76
Cr I	24	5.69±0.21	3	5.67	0.02	0.39
Cr II	24	5.69±0.14	6	5.67	0.02	0.41
Fe I	26	7.15±0.16	69	7.52	-0.37	
Fe II	26	7.13±0.07	11	7.52	-0.39	
Ni I	28	5.86±0.15	7	6.25	-0.39	-0.02
Zn I	30	4.13±0.29	2	4.60	-0.47	-0.10

[a] from Grevesse et al. 1996, ASP Conf. Ser. No. 99, 117

4. Results and Conclusions

High-resolution optical spectra of QY Sge are presented. Photospheric lines are unusually broad indicating scattering of photons from dust in the stellar wind. Presence of very broad Na D and other resonance lines in emission is confirmed. Sharp emission lines in low excitation lines of abundant neutral metal atoms are reported for the first time. There is no evidence that QY Sge is hydrogen deficient. H_α profile is similar to that of 89 Her; the central absorption strength is comparable to that of the photospheric line in γ Cyg. The pattern of abundance anomalies is reminiscent of those exhibited by the warmer RV Tauri variables whose photospheres are depleted in those elements which first condense into grains as gas is cooled from high temperatures. QY Sge shares T_{eff}, log g and abundance anomalies with the RV Tauri variables. Further photometric and spectroscopic observations are desirable to investigate whether QY Sge is a RV Tauri variable.