TURBULENCE-DRIVEN ATMOSPHERIC INSTABILITY AND LARGE-SCALE MOTIONS IN SUPER- AND HYPERGIANTS

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Abstract: Spectral studies of super- and hypergiants show that the (outward directed) turbulent acceleration approaches the value of the gravitational acceleration for the most luminous stars, which makes their atmospheres unstable.

With the aim to study the influence of microturbulent motions on the atmospheric stability of super- and hypergiants, such stars are being studied by us. So far, results are available for the five objects, listed in the table (ζ_μ = microturbulent velocity; s = sound speed.)

star	spectrum	T_{eff} (K)	Δ log L	g_{grav} (cm s^{-2})	$\langle\zeta_\mu\rangle$/s	$\langle g_{turb}\rangle$ (cm s^{-2})
Alpha Per	F5 Ib	6500	- 2	- 63	0.75	+ 24
Alpha Sco	M1.5 Iab	3600	- 1.1	- 1	0.5	+ 0.2
Alpha Cyg	A2 Iae	9200	- 0.9	- 26	1.0	+ 7
HD 80077	B2 Ia^+	17000:	0	- 87	1.0:	
HR 8752	G0-5 Ia^+	4200	- 0.3	- 1	1.1	+ 2

From photometric data in the visual and infrared spectral regions and from literature, the values of the photospheric parameters T_{eff} and log g_{grav} were derived. Since the work by Blackwell and Shallis (1977) it is known that T_{eff} is thus found with high accuracy, particularly if use is made of photometric data in the near-infrared. The luminosities were always taken from literature.

The equivalent widths of some 30 well-observed Fraunhofer lines were then used - with the help of appropriate photospheric models -

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for the determination of chemical abundances and of the microturbulent velocity component ζ_μ. Since the average depth of line formation for different lines normally varies over a large range of optical depths we thus get the variation of microturbulence with height z. The (outward directed) turbulent acceleration g_t is then found with

$$g_t = \frac{\alpha}{\rho} \frac{dP_t}{dz} \qquad (1)$$

where ρ is the density, and α depends on the spectrum of turbulence. We usually took $\alpha = 0.5$. Although the sample is still small, the table shows that ζ_μ/s as well as $-g_t/g_{grav}$ tend to approach or surpass unity when $\Delta \log L$ approaches zero. Here, $\Delta \log L$ is the difference between the stellar luminosity and the upper limit of stellar existence (the Humphreys-Davidson limit). This result is a - preliminary - confirmation of the hypothesis (De Jager, 1984) that the instability of cool hypergiant atmospheres is due to dissipation of turbulent energy, leading to an effective acceleration near to zero:

$$g_{grav} + g_{rad} + g_{turb} \approx 0, \qquad (2)$$

where g_{rad} is negligible in cool supergiants.

A study of high-resolution UV spectra of Alpha Cyg (Boer et al., 1988) has shown that the large-scale (macroturbulent) velocity field peaks at plus and minus 14 km s^{-1}, indicating the presence of strong supersonic motions in the atmosphere. A comparison with average radial velocities of the whole star shows that at any time there must be about 30 such elements present on the disk; this yields an average element diameter of appr. 30 x 10^6 km. One should call such motions convection were it not that theory does not predict convective motions in a star as hot as α Cyg. Alternative suggestions are non-radial or stochastic pulsations. In any case, it seems obvious that the observed microturbulent motions in Alpha Cyg originate in such large-scale motion fields.

References:

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