stars these lines are much stronger than the Th II and Nd II lines. The Eu II line shows hyperfine structure and the Ba II line is blended with a Ce II line, however, and one might therefore question these Eu/Ba ratios.

The new results do not resolve the many questions about the Th-Nd chronometer because the inclusion of the Co I contamination increases the scatter in the Th/Nd ratio. Furthermore, there are large differences between prediction of recent models of the galactic chemical evolution. Our results do show that the Co I contamination must be included in analysing the Th data, however, and that it affects the plot of Th/Nd ratio against age, providing a better constraint for models of the chemical evolution of the Galaxy. □

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MWC560—a unique astrophysical object

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DESPITE its interesting behaviour[1,2], the object MWC560 has been little studied since its discovery 50 years ago during the Mount Wilson Observatory Hα emission-line surveys[3]. To rectify this situation we have made systematic spectral and photometric observations of this star. Spectra of the hydrogen absorption Balmer lines show remarkable variability: they indicate that some components have radial velocities as large as $-6{,}000\ \mathrm{km\ s^{-1}}$, and the profiles are complex, showing pronounced variability on timescales of a few days. Photometric observations show that the V-band brightness of the star has risen by about three magnitudes over the past 20 years; during our own observations, this brightness was seen to change by a few tenths of a magnitude. We speculate that MWC560 may be a binary system containing a red giant and a compact companion—possibly a white dwarf—and exhibiting jet-like ejections along the line of sight[4].

In 1973 Sanduleak and Stephenson[1] observed strong blue-shifted absorption and variable emission lines, and TiO bands in the visible and infrared regions of objective-prism spectra of MWC560, and assigned it a spectral type of M4ep. Later, Bond and co-workers[3] noted the presence of broad ($\sim 3{,}000\ \mathrm{km\ s^{-1}}$) H I absorption in the blue-violet region whereas the M spectrum dominates in the Hα region. Both strong ultraviolet continuum and low-excitation absorption lines have been observed. They also observed flickering of up to 0.2 mag on a timescale of a few minutes and suggested that MWC560 is a symbiotic-like binary containing an M giant and a compact companion. The system loses matter by a highly variable high-speed wind from the compact star.

Previous observations have shown that the star's brightness is variable—in 1973 it was ~12.5 mag (ref. 2), and in 1984, ~11 mag (ref. 3).

We carried out our observations with the Coudé spectrograph of the 2-m telescope at the Bulgarian National Observatory Rozhen. The dispersion of the spectrograms, obtained on 103a0 emulsion is $18\ \mathrm{Å\ mm^{-1}}$ and the region covered was 3,600–4,900 Å. The spectra were digitized using a Joyce Loebl MDM6 microdensitometer and processing was performed on a PC-XT computer using the software ReWiA[5]. The UBV (ultraviolet-blue-visual) observations are performed with single-channel photometers attached to the 60-cm telescopes at the Rozhen and Belogradchik observatories.

Table 1 summarizes our estimates of the brightness of MWC560 in V band and for the colours B-V and U-B. The observations are reduced to a standard UBV system, but are not corrected for atmospheric extinction because of small angular distance between MWC560 and the standard star HD59380. The night-to-night changes in the V band are ~0.2 mag and the maximum difference over the set of observations is ~0.4 mag. Our monitoring of the ultraviolet with an integration time of 10 s confirms the presence of rapid variations with a wide range of timescales (~10 min to ~1 h) and a maximum amplitude ~0.3 mag. The standard deviation of the random noise is ±0.02 mag. The time-series analysis do not show any periodicity. Figure 1 shows an example of the flickering of MWC560.

TABLE 1 UBV observations of MWC560

Date	Julian date (HJD2447...)	V band (mag)	B–V colour (mag)	U–B colour (mag)	Observatory*
February 1990					
24	947.482	9.65	0.28	−0.48	R
25	948.383	9.83	0.31	−0.41	B
26	949.368	9.93	0.29	−0.51	B
26	949.384	9.83	0.27	−0.53	R
28	951.357	9.80	0.26	−0.56	B
March 1990					
3	954.268	9.66	0.34	−0.54	B
4	955.387	9.54	0.31	−0.50	B
5	956.349	9.62	0.30	−0.46	B
5	956.354	9.65	0.28	−0.51	R
14	965.276	9.82	0.33	−0.44	R
14	965.353	9.84	0.35	−0.46	R

Average standard deviation is ±0.02 mag. HJD is the heliocentric Julian date.
* R, National Astronomical Observatory Rozhen; B, Belogradchik Observatory.

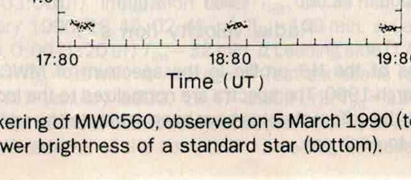

FIG. 1 The flickering of MWC560, observed on 5 March 1990 (top), compared to constant lower brightness of a standard star (bottom).

TABLE 2 Heliocentric radial velocities

Date Julian date (HJD24479...)	12 January 04.420	17 January* 09.468	3 February 26.380	6 March 57.307	12 March 63.270	14 March 65.313
Emission lines						
Metallic	+45 ± 1 (98)	+40 ± 1 (82)	+41 ± 1 (57)	+39 ± 1 (68)	+42 ± 1 (47)	
Hydrogen	+67 ± 3 (5)	+59 ± 4 (3)	+51 ± 4 (3)	+54 ± 1 (4)	+62 ± 4 (4)	
Absorption components of H I lines						
Fastest	−3,040 ± 50 (12)	−4,150 ± 60 (5)	−4,260 ± 70 (13)	−4,440 ± 30 (6)	−3,400 ± 25 (6)	−5,630 ± 10 (7)
Slowest		−290 ± 40 (3)	−210 ± 70 (3)	−270 ± 20 (4)	−270 ± 25 (4)	−240 ± 80 (5)
Sharp absorption Ca II K line				+51 −44	+50 −38	+49 −50

The numbers in parentheses indicate the number of measured lines. The radial velocities are in units of km s^{-1}.
* Slightly defocused spectrum.

There are also significant changes in the continuum of MWC560. Recent observations[6,7] show a large increase in the ultraviolet continuum, compared with 1984. The continuum in our spectra looks like that from a hot late B or early A star. We do not see any of the spectral features associated with an M4 giant. Other observations[8,9,10] show that TiO bands are present in the red and infrared regions, but they are partially veiled[8,9].

The hydrogen lines of Balmer series dominate the line spectrum. Both emission and absorption components are observed but the former are measurable only for Hβ, Hγ and Hδ. They correspond to an almost constant radial velocity (Table 2) and moderate variations of the intensity. There are also many emission lines from, mainly, Fe I, Fe II, Cr II and Ti II. The corresponding radial velocity is also constant, but slightly lower than the velocity calculated from the hydrogen emissions. This is due to the influence of the low-velocity absorption components on the emissions in the profiles of Balmer lines.

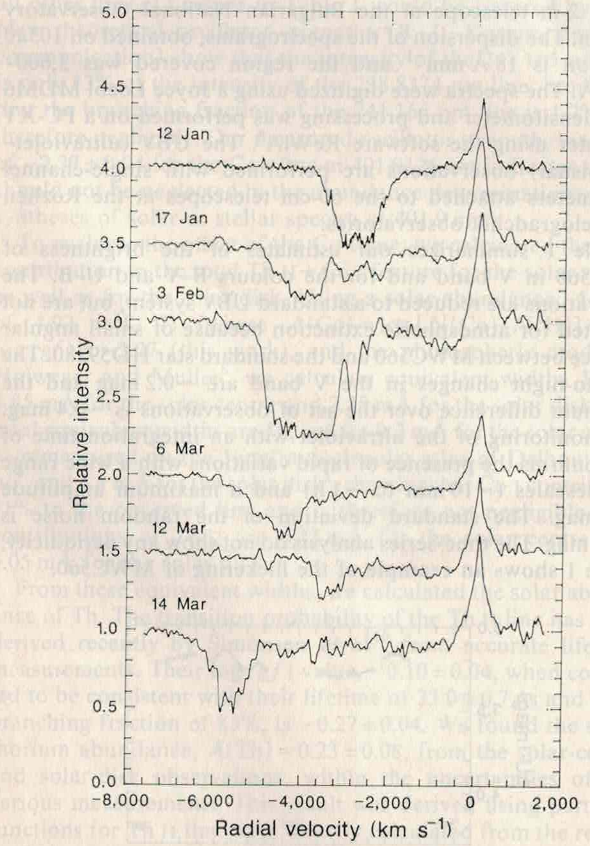

FIG. 2 Changes of the Hβ profile in the spectrum of MWC560 between January and March 1990. The spectra are normalized to the local continuum. The spectra for the different dates have been separated by adding a different constant shift to each one.

The system of absorption lines consists mainly of hydrogen lines and often shows multi-component structure (Fig. 2). The profiles of the components are very different from the usual stellar profile and represent the velocity distribution rather than the temperature and the pressure effects in the absorbing gas. When the lines have a simple shape they are visible up to $H_{20} \div H_{23}$. The equivalent width of the strongest Hβ component reaches 25 Å. Sometimes it is possible to measure the absorptions of the Ca II K line and He I 4,025 Å and 4,471 Å lines . They have the same radial velocity as the strongest hydrogen absorptions and an equivalent width of ~0.6 Å. Except for the hydrogen lines, only the sharp Ca II K line is present in absorption. It shows two components possibly of circumstellar and/or interstellar origin.

There is insufficient data to propose any detailed model of this object. Our data support the idea that MWC560 is a binary system comprising an M giant and a compact companion[3] and having high rate of mass transfer. But our observations rule out the suggestion of the high-velocity stellar wind, due to absence of the specific wind-profiles. We propose that the matter transferred from the giant forms an accretion disk around the compact companion and that the emission lines originate in the outer parts of the disk. The lack of significant variation in the radial velocities calculated from the emission lines indicates that the disk is viewed face on. The strong changes in the Balmer absorption lines may be due to jet-like ejections along the line of sight. The absence of emission components with high radial velocities is evidence that these ejections are strongly collimated. The evolution of the hydrogen absorption lines may be due to dissipation on a timescale of a few days.

If the high-velocity Balmer absorption lines originate in the ejections we can compare MWC560 to another well-known jet-ejecting object, SS433. Both systems contain a main star and a compact companion. In the case of SS433 they are a massive OB star and a neutron star or black hole. In MWC560 the main star is a red giant. The observed velocities of these two objects differ by about a factor of 10 owing to the difference in ejection processes. We therefore speculate that the companion star in MWC560 is a less massive object—probably a white dwarf. Systems comprising an M giant and a white dwarf are quite common (as is well known from the evolutionary theory). The lack of any estimate of the distance to MWC560 and of data for the system geometry and the physical parameters of its components make it difficult to discuss this interesting object in more detail. □

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