Visual Photometry & Spectroscopy of R Sct in 2013

John Toone
David Boyd

BAA VSS, York, June 2014

R Sct – Properties

- Type RVa
- Range 4.5 – 8.5
- Period 141 days
- Spectrum G0-M3

R Sct Monograph 1795 - 1927

A KONKOLY-ALAPITVÁNYÚ BUDAPEST-SVÁBHEGYI M. KIR.
ASZTROFIZIKAI OBSZERVATÓRIUM CSILLAGÁSZATI ÉRTEKEZÉSEI

I. kötet. 3. füzet.

FELELŐS KIADÓ: DR. TASS ANTAL IGAZGATÓ.

R SCUTI FÉNYVÁLTOZÁSA

MÓRA KÁROLY

BUDAPEST, 1934.

DUNÁNTÚL PÉCSI EGYETEMI KÖNYVKIADÓ ÉS NYOMDA R.-T. PÉCSETT.

Tabelle III.

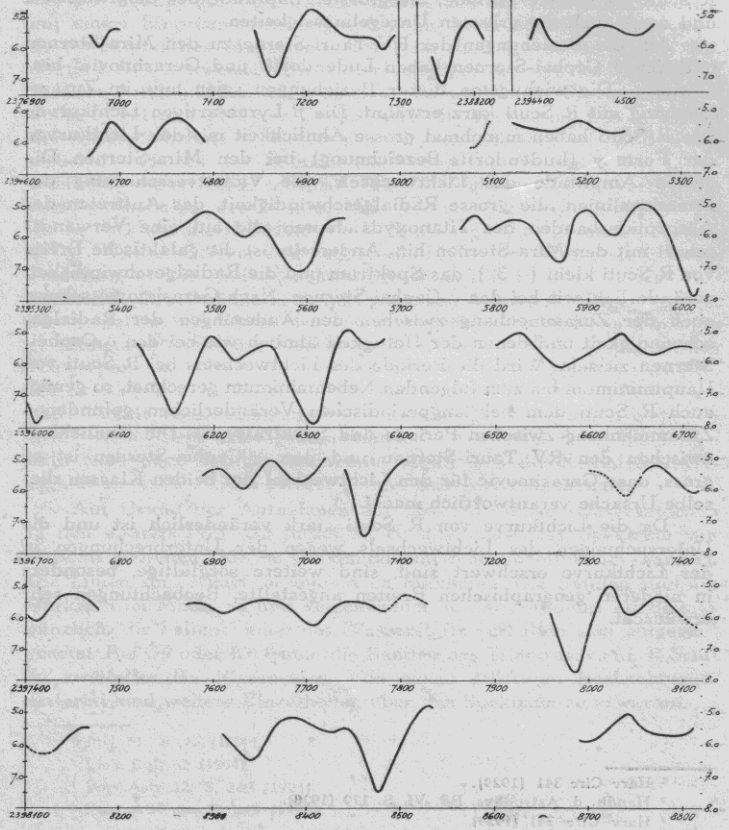
J. T.	Grösse	Beobachter	Bemerkung	J. T.	Grösse	Beobachter	Bemerkung	J. T.	Grösse	Beobachter	Bemerkung	J. T.	Grösse	Beobachter	Bemerkung
2376				**2377**				**2384**				**2385**			
938	4·8	P		197	5·0	P		921	<6	W		231	5·2	W	
944	4·8	„		201	4·8	„		922	6	„		232	5·6	„	
945	4·8	„		202	4·8	„		923	6	„		233	5·0	„	
946	4·8	„		207	4·8	„		930	<6	„		238	5·4	„	
947	4·8	„		211	4·8	„		934	6	„		239	5·8	„	
948	4·8	„		212	4·9	„		935	6	„		240	6·0	„	
949	4·8	„		216	5·0	„		948	6	„		242	5·6	„	
950	4·8	„		224	5·1	„		949	6	„		243	5·7	„	
951	4·8	„		225	5·1	„		950	6	„		244	5·5	„	
969	5·5	„		233	5·4	„	m	951	6	„		246	5·7	„	
973	5·9	„		236	5·7	„	m	953	6	„		248	5·7	„	
980	5·9	„		243	5·5	„		954	>6	„		249	6·0	„	
981	5·9	„		244	5·5	„		955	>6	„		250	5·7	„	
988	5·5	„		252	5·7	„		956	5·6	„		253	5·7	„	
2377				255	5·7	„		957	5·4	„		259	5·8	„	
001	5·4	„		260	5·7	„	m	958	5·4	„		261	5·8	„	
018	5·1	„		263	5·7	„	m	959	5·1	„		262	5·8	„	
078	6·1	„		267	5·7	„		984	5·6	„		271	5·8	„	
079	6·1	„		269	5·7	„		986	5·7	„		272	5·6	„	
099	6·9	„		270	5·7	„		987	5·2	„		273	5·4	„	
107	6·1	„		275	5·7	„		988	5·0	„		274	5·2	„	
133	5·4	„		277	5·9	„		991	5·0	„		287	6·2	„	
143	5·4	„		283	6·1	„		**2385**				288	5·6	„	
145	5·4	„		284	6·1	„		012	4·3	„		289	5·6	„	
156	6·5	„		286	6·1	„		013	4·6	„		290	5·2	„	
160	7·0	„		287	5·7	„		014	5·0	„		291	5·6	„	
166	7·0	„		295	5·4	„		015	5·1	„		294	5·2	„	
168	7·0	„		334	5·8	H		018	5·6	„		295	5·7	„	
169	7·0	„		343	5·6	„		035	5·1	„		299	5·8	„	
172	6·8	„		**2384**				043	4·9	„		300	5·8	„	
175	6·0	„		873	6—7	W		044	4·9	„		301	5·8	„	
180	5·8	„		875	>6	„		222	5·0	„		302	5·9	„	
187	5·5	„		876	>6	„		224	5·4	„		303	5·6	„	
191	5·3	„		880	<7	„		225	5·8	„		305	5·3	„	
196	5·0	„		918	6—7	„		229	5·8	„		306	5·7	„	

R Sct – Early Light Curves

ANHANG.

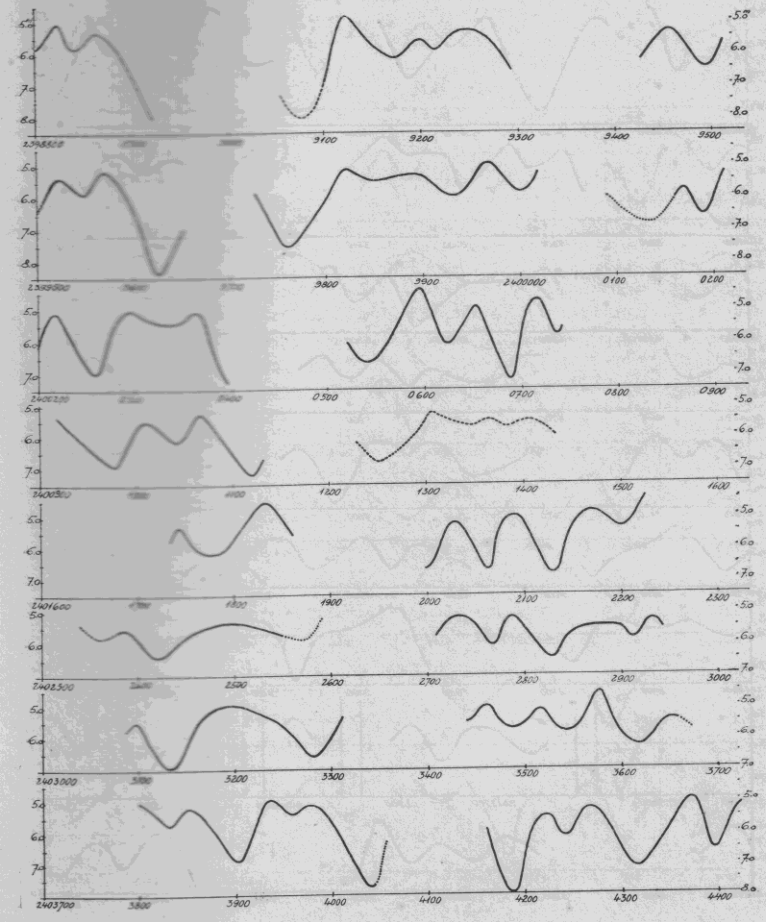
Lichtkurve von R Scuti (1795—1855).

. . . . . Unsichere oder zu wenig Beobachtungen.



Lichtkurve von R Scuti (1855—1870).

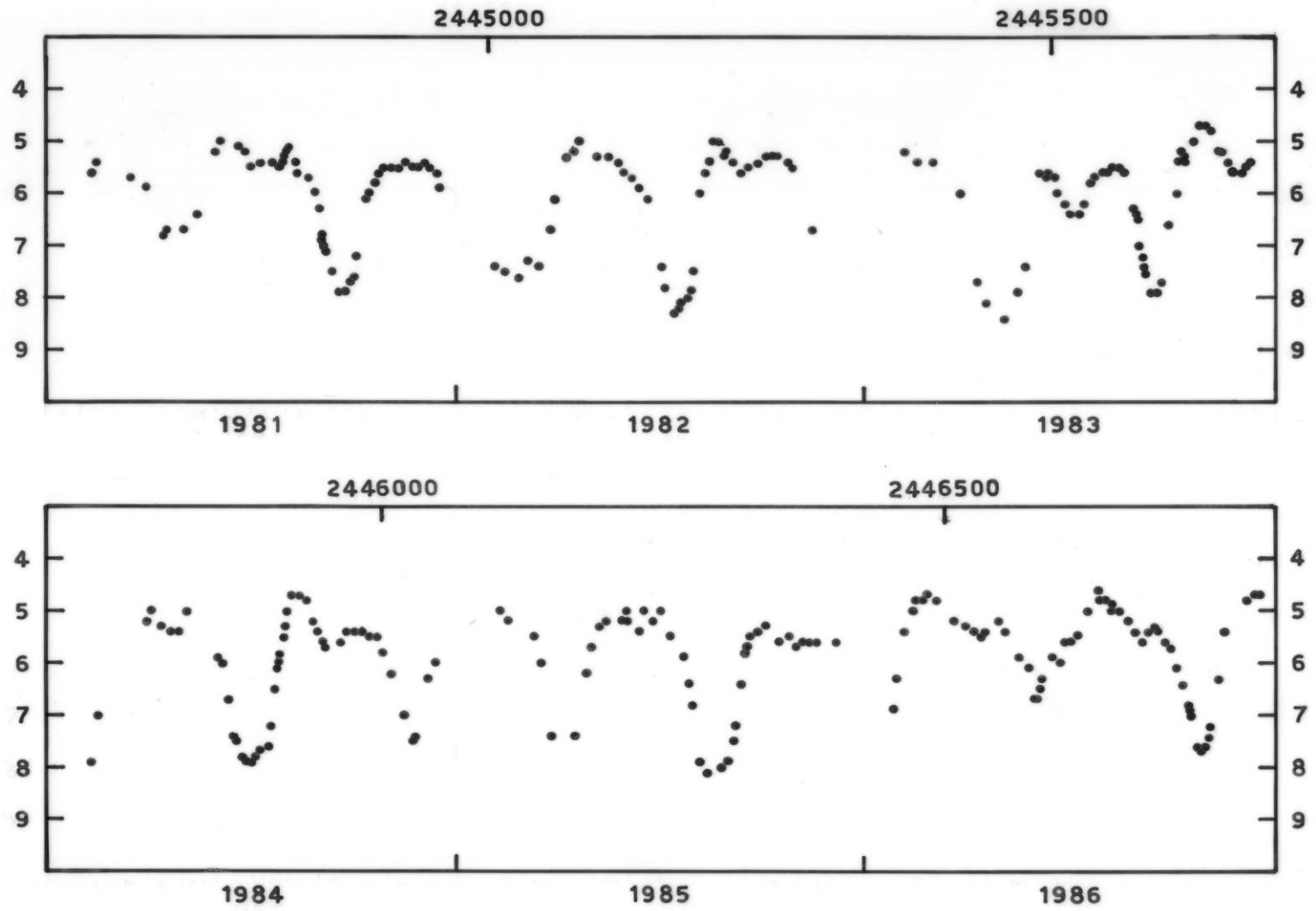
. . . . . Unsichere oder zu wenig Beobachtungen.



Historical Deep Minima of R Sct

Date	Magnitude	Duration <7	Duration <8
7 Nov 1857	8.4	53	17
9 Oct 1927	8.3	27	12
7 Feb 1956	8.4	>34	23
3 Jul 1956	8.3	38	15
17 Jun 1970	8.5	42	18
15 Jul 1982	8.4	34	16
3 Dec 1982	8.3	32	16
1 May 1983	8.4	52	27
20 Aug 1985	8.3	38	20

R Sct 1981 - 1986



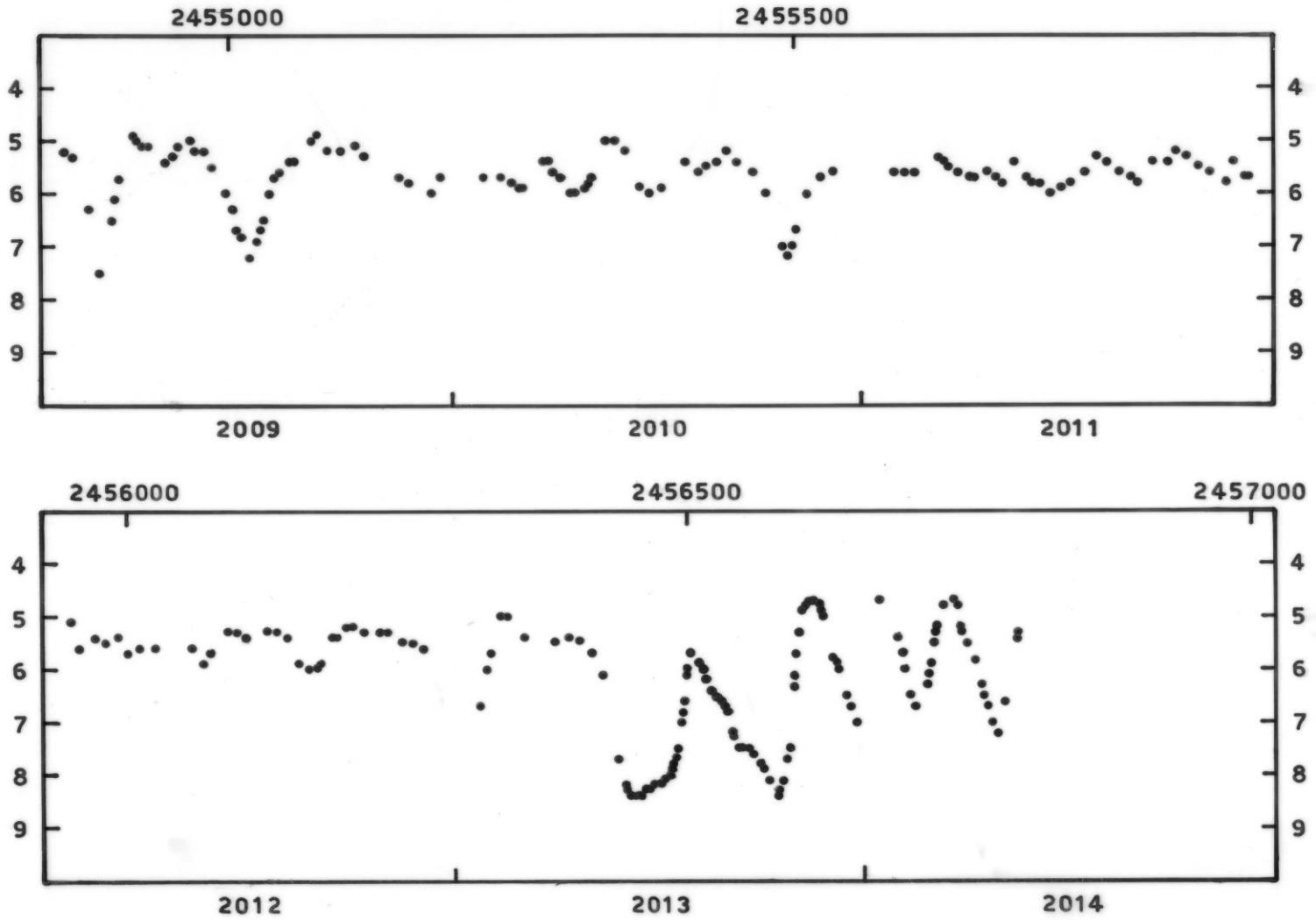
R Sct –August 1985

- Previous deep minima to those seen in 2013
- Was fainter than mag 8 for 20 days

R Sct Deep Minima in 2013

Date	Magnitude	Duration <7	Duration <8
10 Jun 2013	8.4	62 days	42 days
13 Oct 2013	8.4	53 days	16 days

R Sct 2009 - 2014



Intervals between groups of deep minima

- 1927 minimum
- 29 year interval
- 1956 minima
- 27 year interval
- 1983 minima
- 30 year interval
- 2013 minima

Deep Minimum Spectrum from 1981

Publications of the Astronomical Society of the Pacific
95:762–767, October 1983

THE REMARKABLE SPECTRUM OF THE RV TAURI STAR R SCUTI AT DEEP MINIMUM

STEVE B. HOWELL
Ritter Observatory, The University of Toledo, Toledo, Ohio 43606
and
Physics Department, General Motors Research Laboratories, Warren, Michigan 48090

BERNARD W. BOPP* AND PAUL V. NOAH
Ritter Observatory, The University of Toledo, Toledo, Ohio 43606

Received 1983 July 5

In September 1981 R Sct declined in brightness to $V \sim 8.5$, an exceptionally faint minimum. We obtained a 15 Å mm^{-1} spectrogram of the Hα region of R Sct two days past minimum brightness, when the visual magnitude was ~ 8.3. This is apparently the first spectral observation of R Sct close to such a deep minimum.

Contrary to spectroscopic observations during "ordinary" minima of $V \sim 6$–7, at this deep minimum the expected G–K *Ia* absorption spectrum is not seen. Instead, a fantastic array of dozens of strong, narrow emission features and strong TiO absorption bands are present. The emission lines are due to neutral metals, and closely resemble a reversed photospheric spectrum. The deep minimum spectrum is apparently purely chromospheric, and is not produced in a stellar wind or extended atmosphere.

The spectroscopic behavior of R Sct at deep minimum, as well as a number of other kinematic and photometric properties, is surprisingly similar to that of the R Coronae Borealis variables.

Key words: RV Tauri stars—variable stars—spectroscopy

I. Introduction

R Scuti is classified as an RVa-type variable in the *General Catalogue of Variable Stars* (Kukarkin et al. 1969). The photometric period is given as 140.2 days but an inspection of the visual light curve shows that pronounced irregularities can occur. Among these are sudden drops to "deep minima", when the star may dim by 2–3 magnitudes.

The first extensive spectroscopic study of R Sct was that of McLaughlin (1939). From his analysis of 134 relatively low-dispersion spectrograms, many of the present-day parameters for R Sct were derived. McLaughlin obtained virtually no spectrograms of R Sct near deep minima. He did find, however, that Hα was always present with both absorption and emission components, and at minimum light TiO bands appeared in the spectrum. This latter behavior only occurred after the visual magnitude was fainter than 5.8.

Preston (1962) studied R Sct with high spectral resolution. He noticed doubling of the absorption lines at maximum light and, as with previous studies, found the velocity cycle to be one-half the photometric period. During 1961, a relatively bright minimum ($V \sim 6$, $B \sim 7.6$) was observed by Preston. Spectrograms obtained during this interval showed that many metallic absorption lines had weak central emission components.

In September 1981 we began a program, in collaboration with R. Gehrz, to obtain routine Hα spectrograms of several RV Tauri stars. Our first observation was of R Sct on 1981 September 26 UT. Unknown to us at the time, R Sct on this night was within a day or two of an extremely deep minimum (Fig. 1). We report the results from this unique and serendipitous spectrogram in this paper.

II. Observations and Reduction

We observed R Sct (and several other RV Tauri stars) spectroscopically at Kitt Peak National Observatory (KPNO) in September 1981. These data were obtained with the coudé feed telescope using spectrograph camera five and a Carnegie image tube. The spectrum was recorded on a IIIa-J plate which was sensitized by baking in forming gas. The dispersion was 15 Å mm^{-1}, and the estimated signal-to-noise ratio was 30:1. Only one spectrogram, covering the wavelength interval λλ6300–6700, was obtained. (Considering the unusual appearance of the spectrum of R Sct at this time, additional wavelength coverage would have been of great interest. This being our first observation of any RV Tauri star, we unfortunately did not realize the significance of the spectrum until later.)

In April 1982 we obtained additional spectroscopic observations of R Sct near maximum to compare with our earlier data. These spectra were also obtained at the coudé feed but used a Fairchild CCD as the detector.

*Visiting Astronomer, Kitt Peak National Observatory, which is operated by AURA, Inc., under contract with the National Science Foundation.

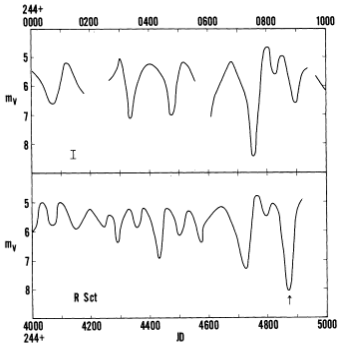


FIG. 1—AAVSO light curve of R Sct. Our spectroscopic observation on 1981 September 26 (arrow) took place very close to the faintest minimum of R Sct since 1970 (top curve). The scatter in the individual brightness estimates is indicated by the error bar in the top portion of the figure.

With the same camera setup as above, these data provided a spectral coverage of ~ 160 Å, centered near λ6500. The resolution of the CCD data was ~ 0.4 Å. About 6000 counts per pixel were obtained in the continuum, but noise problems in the chip limited the signal-to-noise ratio to about 30:1.

In July 1982 R Sct *again* declined to faint minimum, reaching $V \sim 8.7$ on July 20–21 (Mattei 1982). We were not able to obtain spectroscopic data until July 29 UT, when three spectrograms, covering the wavelength interval λλ5800–8700 were obtained with our Ritter Observatory 1-meter reflector and image-tube spectrograph. The dispersion of these data was 40 Å mm^{-1}, the resolution about 1.5 Å.

The photographic data were traced on a PDS microphotometer and converted to intensity at the Midwestern Astronomical Data Reduction and Analysis Facility (MADRAF) in Madison. The CCD data were reduced using KPNO routines; wavelength calibration was provided by an iron-argon hollow cathode lamp. Spectral line identification was done by using previously published data on R Sct and using the solar wavelengths given by Moore, Minnaert, and Houtgast (1966).

A log of the observations of R Sct is given in Table I. Line identification and radial-velocity data for the September 1981 observation are given in Table II.

Table I

Spectroscopic Observations of R Sct

Date (UT)	$JD_\odot$ 2440000+	Mag.	Wavelength (Å)
26 September 1981	4873.606	8.3	6300–6700
4 April 1982	5063.974	5.5	6420–6580
10 April 1982	5069.960	5.5	6420–6580
29 July 1982	5179.604	~8	5800–8700

Table II

Emission Line Identifications and Radial Velocities

26 September 1981

Rest λ (Å)	Species	Radial Velocity (km s^{-1})
6358.69	Fe I	44.5
6366.36	Ti I	42.1
6393.61	Fe I	37.3
6395.15	Co I/Ca I	55.8
6400.32	Fe I	48.4
6411.66	Fe I	24.2
6430.86	Fe I	47.9
6494.99	Fe I	39.0
6496.90	Ba II	48.9
6498.95	Fe I	44.0
6508.15	Ti I	41.7
6546.25	Fe I/Ti I	46.8
6554.24	Ti I	41.9
6562.82	Hα	53.5
6574.25	Fe I	43.6
6592.93	Fe I/Ti I	43.4
6625.04	Fe I	47.0
6678.00	Fe I	45.6
6710.32	Fe I	34.3
6743.13	Ti I	61.7

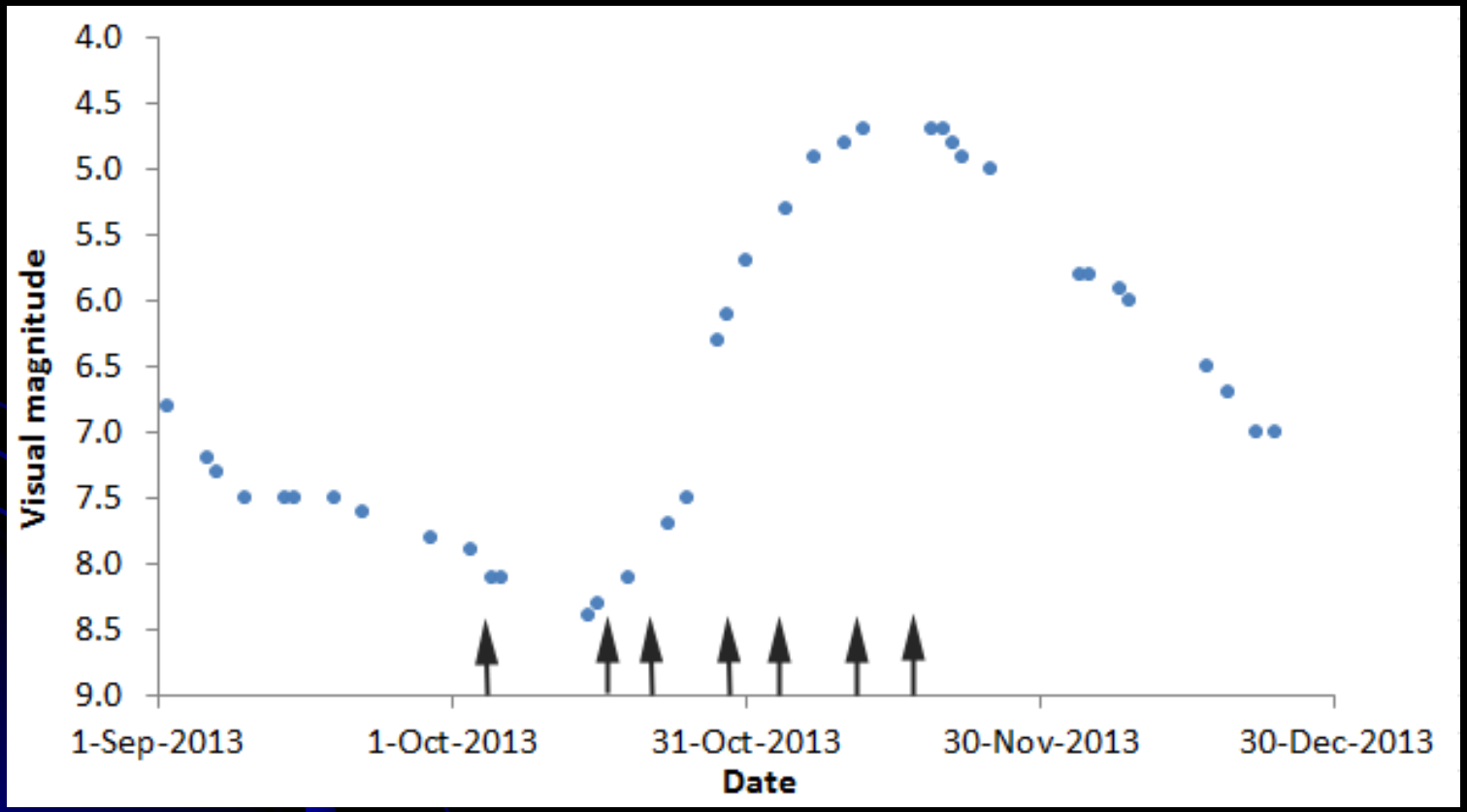
III. Discussion

The "deep minimum" spectrogram of R Sct is unique in that it is apparently the first high-dispersion spectrum of this star recorded when it was this faint. It is shown in Figure 2, along with an illustration of an ordinary RV Tauri star (U Monocerotis) near maximum brightness, also obtained in September 1981. Instead of the expected G–K *Ia* absorption spectrum that is described by McLaughlin and Preston, what is seen at deep minimum is a bewildering array of dozens of narrow emission features, as well as extremely strong TiO bands (typical of spectral type M2–M4). We see from an examination of the original spectrogram, and confirmed on the microphotometer tracing (Fig. 3), that virtually *no* absorption features remain in the spectrum (except for TiO). At the limits of the resolution and signal-to-noise ratio of the plate we see a kind of "picket fence" pattern that suggests the presence of dozens of weak emission lines just near the detection threshold.

The mean radial velocity from the September 1981 spectrogram does not appear unusual, despite its emission character. The observed value of +44.6 ± 1.8 km

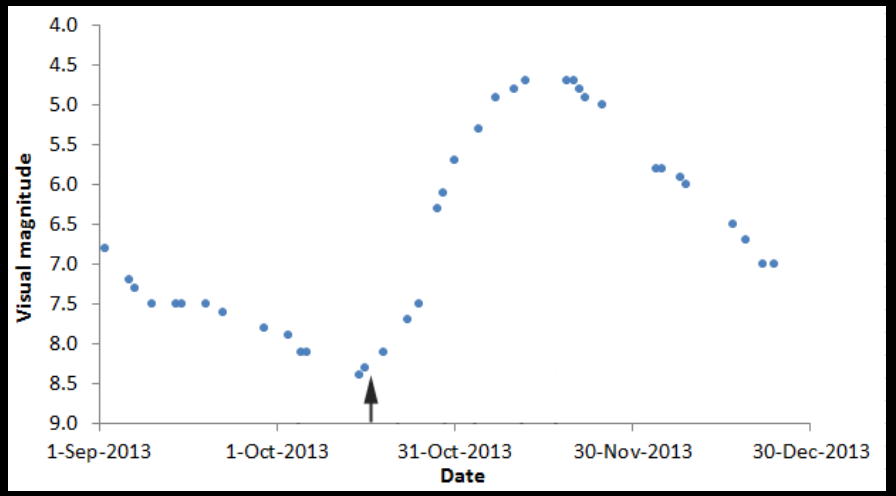
Spectroscopy of R Sct

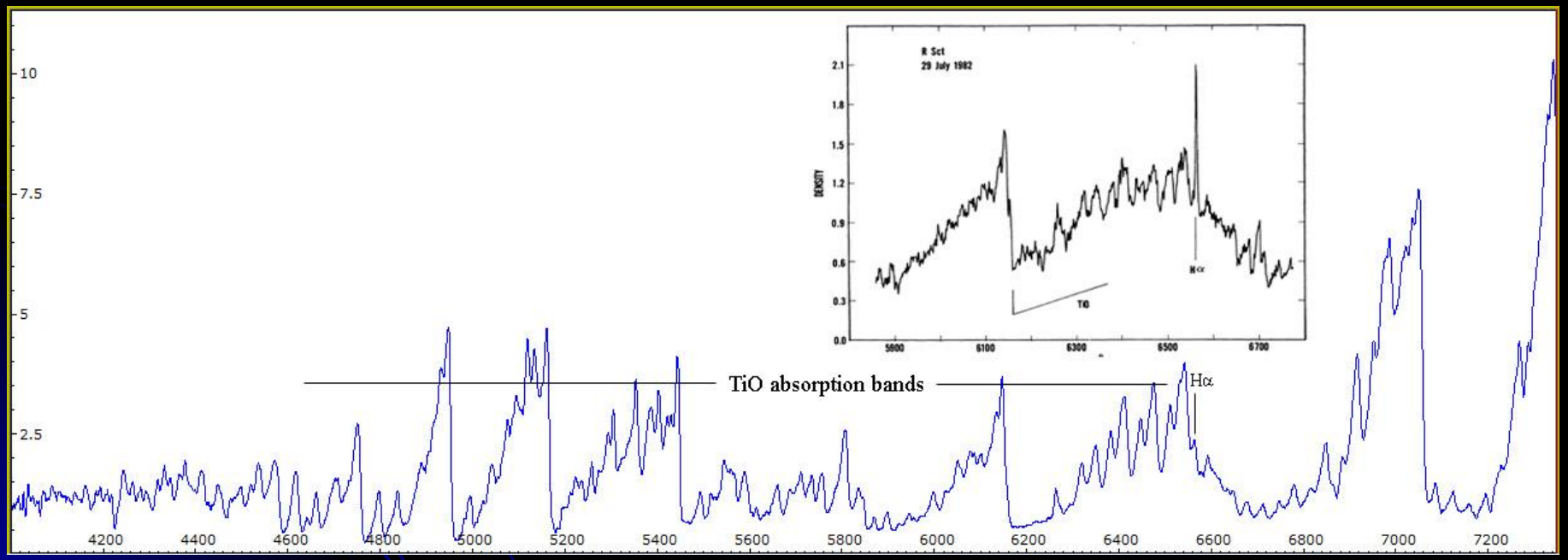
Seven spectra of R Sct were taken with a C11 SCT and LISA spectrograph (R~1000) as it rose from minimum during October and November 2013



Spectrum on 2013 October 17.8 at mag 8.2 with strong TiO molecular absorption bands. Spectral type is ~mid-M. This is believed to be the faintest state of R Sct at which a spectrum has been obtained.

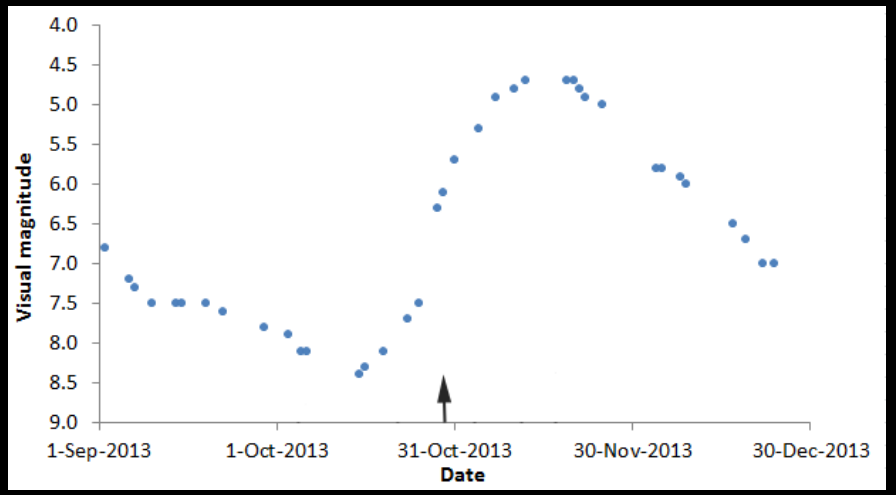
Shown inset is a spectrum from Howell et al. (1983) taken at KPNO on 1982 July 29 with R Sct 14 days past minimum.

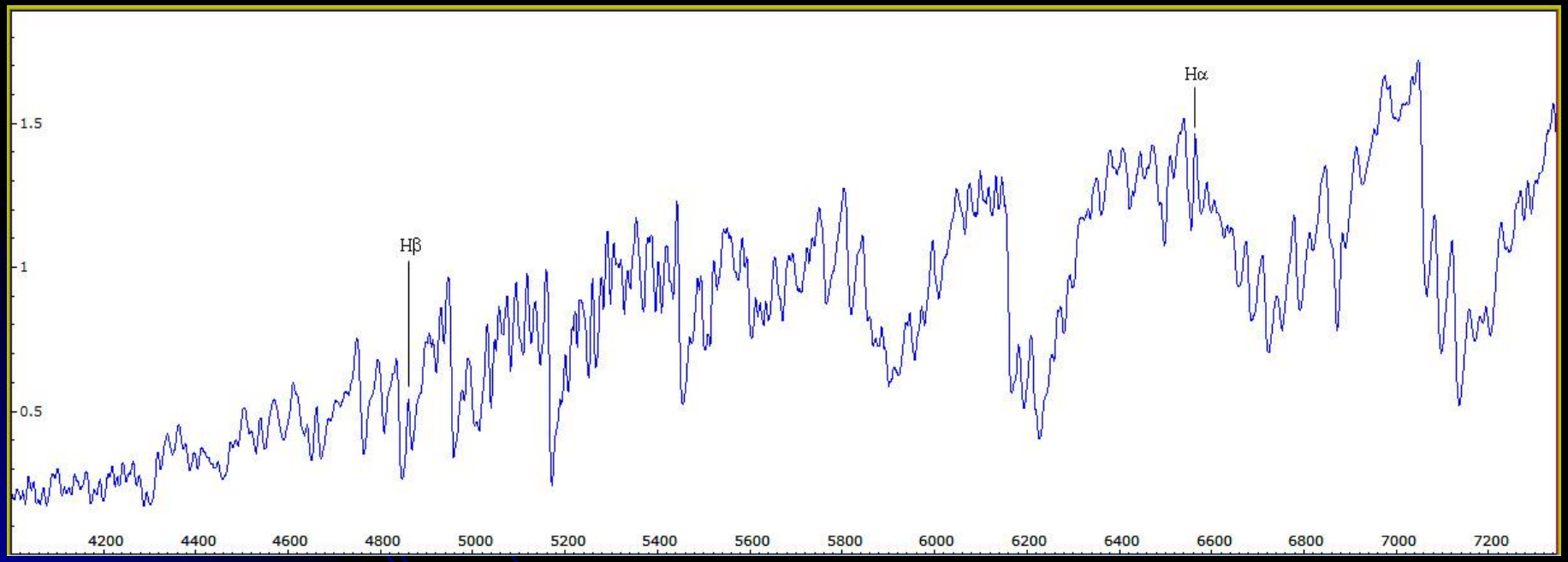




Spectrum on 2013 October 29.8 as the star increased in brightness, the TiO bands are becoming weaker and the H-alpha line is starting to increase.

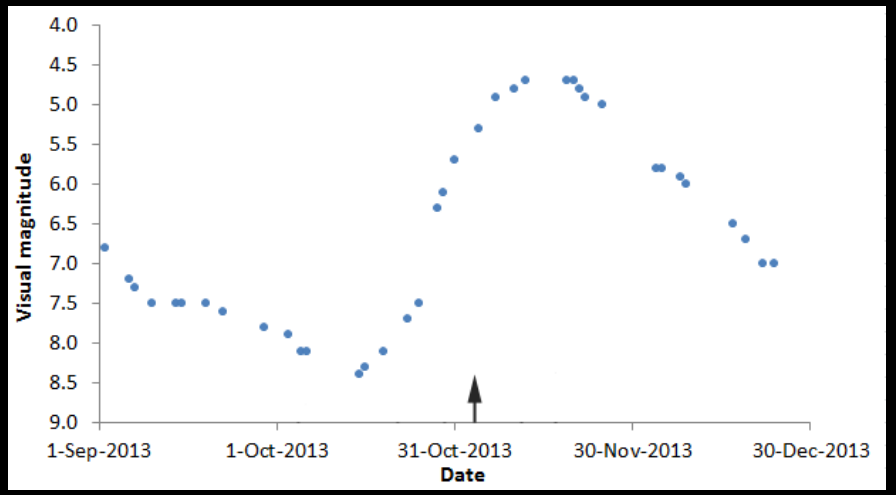
Spectral type is now similar to M3iii.

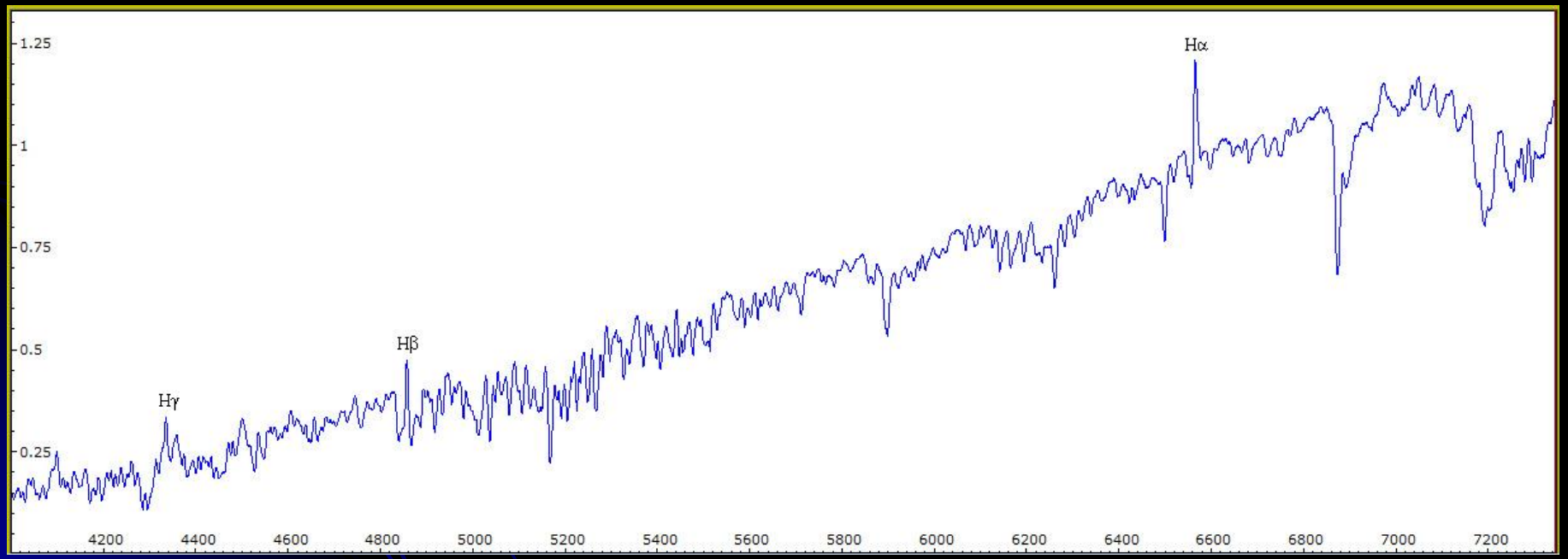




Spectrum on 2013 November 4.7 with the hydrogen Balmer lines now clearly visible in emission.

Spectrum is now a complex mixture of mid-K and early M with Balmer emission lines.





Spectrum on 2013 November 14.7 at maximum light. Spectral type is now a combination of mid/late-G and early K.

Also shown is a segment of a spectrum from Shenton et al. (1994) taken at SAAO when R Sct was in a similarly bright state. This is displaced vertically for clarity.