Bull. Astr. Soc. India (1984) 12, 258-262

The occultation of Hyd −20°51695 by Uranus on 1982 May 1

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Received 1984 January 9; accepted 1984 May 18

Abstract. The observed emersion event of the occultation of the star Hyd −20°51695 by Uranus on 1982 May 1 has been used to evaluate the temperature of the Uranian upper atmosphere. Assuming an isothermal atmosphere the scale height comes out to be 48 $\pm$ 7 km which corresponds to an isothermal temperature of 105 $\pm$ 16 K for the Uranian upper atmosphere containing 90% hydrogen and 10% helium by number. From the inverted temperature profile, the mean temperature of the Uranian upper atmosphere comes out to be 100 $\pm$ 25 K for the altitude range 20 km above to 100 km below the half-light level. A comparison of all available independent determinations of mean atmospheric temperature since 1977 March suggests that the mean temperature of the Uranian upper atmosphere is changing with time. There is an increasing trend during the period 1977 to 1980 and a decreasing trend during the period 1980 to 1982.

Key words : occultation—Uranus—planetary atmosphere

1. Introduction

The observations of occultation of stars by planets provide an important method for determining temperature, pressure and number-density profiles of the planetary upper atmospheres (Elliot 1979). From the mean temperature as determined by the inversion method and isothermal fits to the light curves obtained from the observations of four separate occultations of the stars by Uranus between 1977 March and 1981 April, French *et al.* (1983) have suggested that the mean temperature of the Uranian upper atmosphere has changed significantly, with a typical variation of 15 K yr^{-1}.

In this paper, we describe the results of our observations of the occultation of the star Hyd −20°51695 by Uranus on 1982 May 1. We also discuss the variation of the mean temperature of the Uranian upper atmosphere on the basis of the mean temperature as determined by various authors from the observations of five separate occultations of the stars by Uranus between 1977 March and 1982 May.

2. Observations

The predicted occultation on 1982 May 1 of Hyd—20°51695, (star no. 15; Klemola *et al.* 1981) by Uranus was observed with the 104-cm reflector of the observatory, using a filter combination (Corning 2-58 and 7-62) and EMI 9658 photomultiplier tube, thermoelectrically cooled to −20 C. The peak response of the system was at 7500 Å. The photomultiplier output was recorded on a strip chart recorder. The response time of the system was ≃ 0.6s for a full scale change in the deflections. The images of Uranus and the star were kept near the centre of a 45 arcsec aperture. The star contributed about 4.5% of the total signal. Immersion event occurred at about $16^h52^m12^s$ UT, 3^m12^s after the predicted time, and the emersion event occurred at $17^h13^m15^s$ UT, 5^m45^s ahead of predicted time (Klemola *et al.* 1981). The immersion event could not be used for the analysis because of poor signal-to-noise ratio caused by large zenith distance.

3. Temperature of Uranian atmosphere

The observed emersion light curve is shown in figure 1 for 1s-time resolution. Each point of the light curve represents the running mean of observations for 3s. The data have been scaled such that the brightness of Uranus and the star equals one and of Uranus alone equals zero. Scintillation in the earth's atmosphere is primarily responsible for the scatter in the light curve.

In figure 1 solid line represents theoretical light curve obtained from the relation

$$\left(\frac{\phi_0}{\phi} - 2\right) + \ln\left(\frac{\phi_0}{\phi} - 1\right) = \frac{v\,(t - t_0)}{H},$$

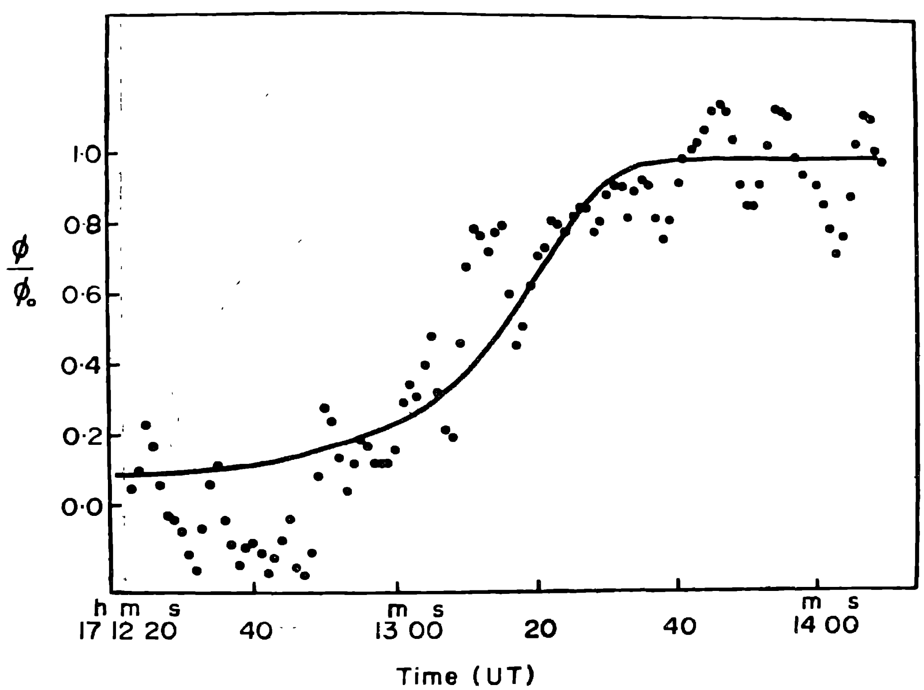

Figure 1. Emersion light curve. The solid line represents the theoretical light curve for H = 48 km.

given by Baum & Code (1953), for an homogeneous isothermal atmosphere. In the above relation v is the velocity normal to the limb of Uranus; H, the scale height; t_0, the time at half light-level (*i.e.* $\phi/\phi_0 = 0.5$); and ϕ/ϕ_0, the relative flux at time t. This equation has been used to determine the midtime of the emersion event and the mean scale height of the Uranian atmosphere. The mean scale height thus obtained comes out to be 48 $\pm$ 7 km. Further, assuming the gravitational acceleration, $g = 830$ cm s^{-2}, the mean molecular weight of the gas in the occulting atmosphere, $\mu = 2.2$ gram mole^{-1} and refractivity of the atmosphere at S.T.P., $\nu_{STP} = 1.28 \times 10^{-4}$ for the Uranian atmosphere containing 10% helium and 90% hydrogen by number (Dunham *et al.* 1980), we obtain for the Uranian atmosphere a temperature of 105 $\pm$ 16 K. The various parameters thus obtained for the emersion event are listed in table 1.

The temperatue profile for the Uranian atmosphere obtained by using inversion technique (French *et al.* 1978) is shown in figure 2. The mean temperature obtained

Table 1. Parameters of the occultation

Velocity normal to limb (km s^{-1})	10.9
Position angle (degrees)	40.9
Time at half light (UT)	$17^h13^m15^s$
Scale height (km)	48 $\pm$ 7
Temperature (K)	105 $\pm$ 16

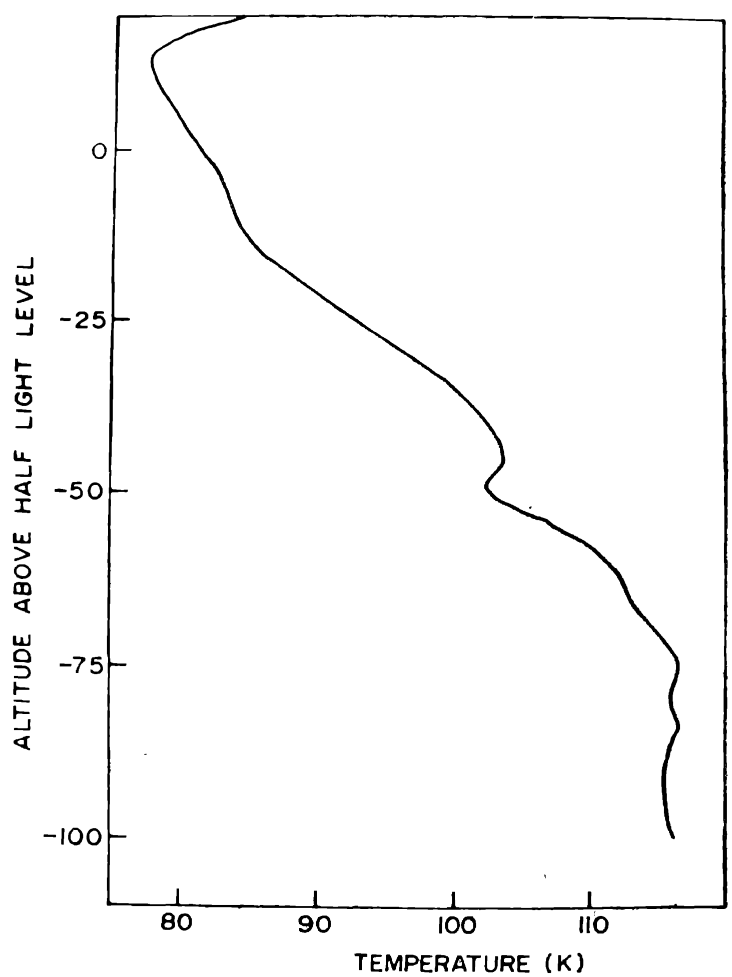

Figure 2. Variation of temperature with height for the upper atmosphere of Uranus.

from the temperature profile in the altitude range 20 km above to 100 km below the half-light level comes out to be 100 ± 25 K.

From a comparison of Uranus occultation data for the period 1977 March to 1981 April, French *et al.* (1983) have suggested that the mean temperature of Uranian upper atmosphere is increasing with a typical rate of 15 K yr^{-1}. All the available, independent determinations of the mean atmospheric temperature of Uranus obtained by different authors from observations of five separate occultations of star by the planet during the period 1977 March to 1982 May 1 are listed in table 2. The mean temperatures for the events of 1981 April 26 (Mahra *et al.* 1983) and 1982 May 1 (present work) given in table 2 have been re-estimated for the altitude interval 25 km above to 150 km below the half light level so that the mean temperature, in each case, refers to the same altitude range.

A plot of mean temperature with time in figure 3 shows that the mean temperature of the upper atmosphere of Uranus is changing with time with an increasing trend during the period 1977 to 1980, and a decreasing trend is noticed for the period 1980 to 1982.

Sicardy *et al.* (1980) have shown that although the inversion method is the best usable procedure for deriving the temperature in the outer atmospheric layers, significant temperature information cannot be obtained above the half-light level because the results are significantly affected by different boundary conditions. The most accurate results, which do not change significantly with the boundary conditions, are obtained in the atmospheric range corresponding to a residual stellar flux of 0.3 to 0.1, which nearly corresponds to an altitude range of −80 to −150 km. Therefore, we have estimated the mean temperatures for the Uranian upper atmosphere in this altitude range from the available published temperature profiles for different events and tabulated them in column 5 of table 2. The mean temperatures thus estimated for individual events are in close agreement with the corresponding isothermal temperatures and also exhibit a similar variation with time.

Table 2. Mean atmosphere temperatures

Date	Station	Event	Mean Temperature (K) Isothermal	Inversion −80 to −150 km	Inversion +25 to −150 km	References
1977 Mar. 10	KAO Ch. 2	I	122	123	109	Elliot & Dunham (1979)
	KAO Ch. 2	E	110	110	96	
	Cape Town	I	104	109	87	Churms *et al.* (1979)
	Cape Town	E	108	107	90	
1979 Jun. 10	CLCO	I	116	—	122	French *et al.* (1983) (figure 8)
	CLCO	E	122	—	114	
1980 Aug. 15/16	CTIO	I	151	155	156	French *et al.* (1983)
	CTIO	E	156	—	—	
	ESO	I	143	147	152	Sicardy *et al.* (1982)
	CLCO	I	145	147	140	French *et al.* (1982)
1981 Apr. 26	ANU	I	121	—	119	French *et al.* (1983)
	AAT	I	129	129	138	
	AAT	E	131	126	129	
1981 Apr. 26	UPSO	I	122 ± 15	100	86 ± 20	Mahra *et al.* (1983)
	UPSO	E	122 ± 15	110	90 ± 20	
1982 May 1	UPSO	E	105 ± 16	115	105 ± 25	Present work

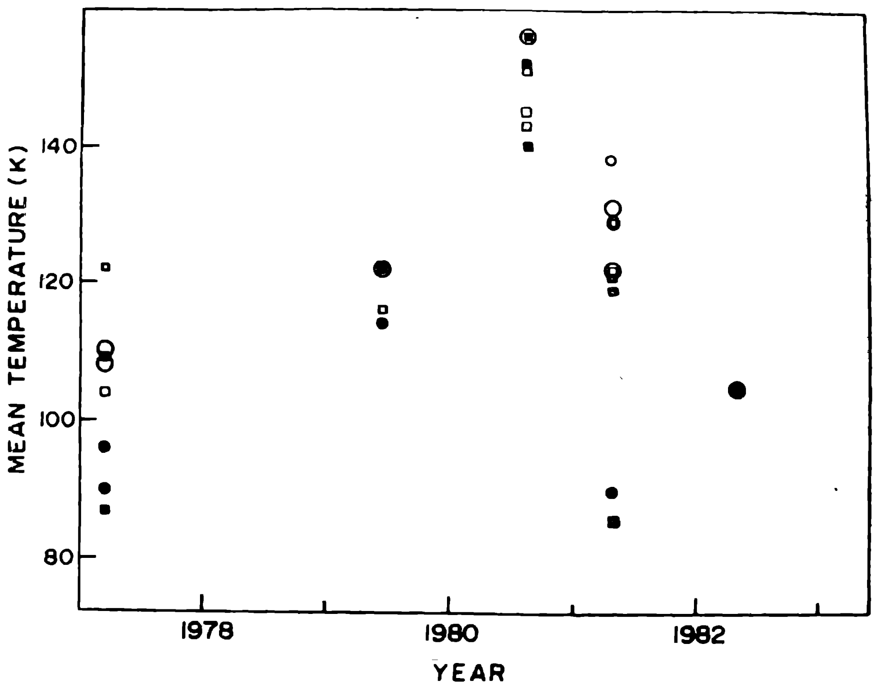

Figure 3. A plot of mean temperature of upper atmosphere of Uranus with time. The open and closed squares represent the mean temperatures obtained from isothermal fits and inversion technique respectively for immersion events. Similarly open and closed circles represent the mean temperatures for emersion events.

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