Bull. Astr. Soc. India (1981) **11**, 152–158

The occultation of BD $-19°4222$ by Uranus on 1981 April 26

H. S. Mahra, A. K. Pandey, U. C. Joshi* and V. Mohan
Uttar Pradesh State Observatory, Manora Peak, Naini Tal 263 129

Received 1983 March 31; accepted 1983 April 30

Abstract. From the observations of the occultation of BD $-19°4222$ by Uranus on 1981 April 26 the temperature profiles of the Uranian upper atmosphere have been obtained. The mean temperature of the upper atmosphere of Uranus in the pressure interval 0.4 to 14 dynes cm^{-2} is found to be 80 ± 15 K.

The radius of the ϵ ring for preimmersion and postemersion events has also been obtained.

Key words : occultation—Uranus : atmosphere

I. Introduction

The temperature profile of the upper atmosphere of Uranus, obtained from the observations of the occultation of SAO 158687 by Uranus on 1977 March 10, indicates the presence of wavelike structure (Elliot & Dunham 1979a; Churms *et al.* 1979; Dunham *et al.* 1980). Similar type of thermal waves have also been observed in the atmosphere of Neptune, Jupiter and Mars. However, a generally accepted explanation for their origin has not yet been given (Elliot 1979; Dunham *et al.* 1980).

In this paper we present the temperature profiles of Uranian upper atmosphere and radius of ϵ ring derived from our photoelectric observations of the occultation of BD $-19°4222$ by Uranus on 1981 April 26.

2. Observations

Observations of the occultation were made with the 104-cm reflector of the Uttar Pradesh State Observatory, using a filter combination (Corning 2-50 and 7-62) and EMI 9658 photomultiplier tube thermoelectrically cooled to -20°C. The peak response of the system was at 7500 Å. The photometer output was recorded on a

*Present address : Physical Research Laboratory, Navrangpura, Ahmedabad 380 009.

strip chart recorder. The response time of the system was 1 s for a full scale change in the deflections. The image of Uranus and the star were kept near the centre of a 45″ aperture.

The preimmersion ϵ ring event occurred at $19^h\ 18^m\ 42^s$ UT, $2^m\ 21^s$ ahead of predicted time (Klemola *et al.* 1981). Ingress and egress occurred at $19^h\ 44^m\ 40^s$ and $20^h\ 04^m\ 02^s$ UT respectively. The postemersion ϵ ring event occurred at $20^h\ 28^m\ 16^s$ UT, $5^m\ 44^s$ ahead of predicted time (Klemola *et al.* 1981). Occulation events due to other known rings could not be identified in the tracing presumably due to faintness of the occulted star.

3. Atmosphere of Uranus

The immersion and emersion light curves for 1 s time resolution are shown in figures 1 and 2 respectively. The data have been scaled such that the brightness of Uranus and the star equals 1 and brightness of Uranus alone equals 0. Terrestrial scintillation is primarily responsible for the scatter in the light curves. The occultation light curve can be represented by the relation

$$(\phi_0/\phi - 2) + \ln (\phi_0/\phi - 1) = v\,(t - t_0)/H,$$

given by Baum & Code (1953), assuming an isothermal atmosphere of homogeneous composition. In the above relation v is the velocity normal to the limb of Uranus, H is the scale height, t_0 is the time at half light level (i.e. $\phi/\phi_0 = 0.5$) and ϕ/ϕ_0 is

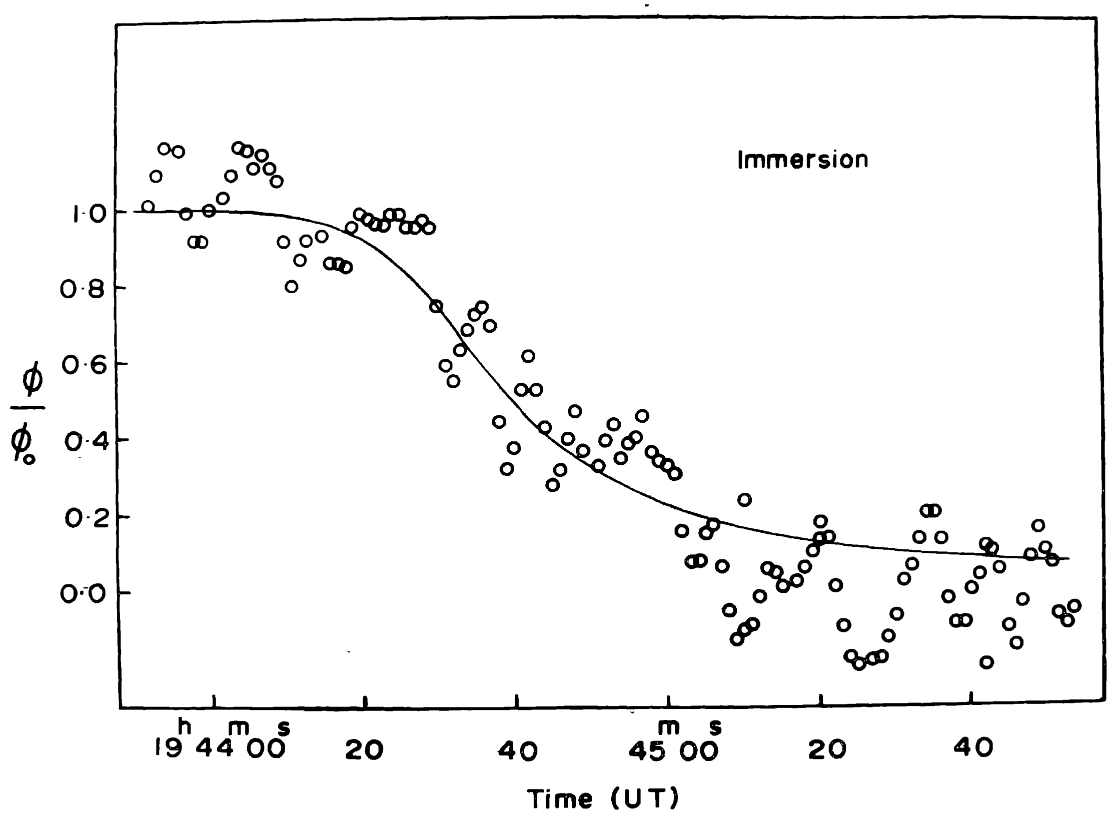

Figure 1. Immersion light curve where the solid line represents the theoretical light curve for $H = 56$ km.

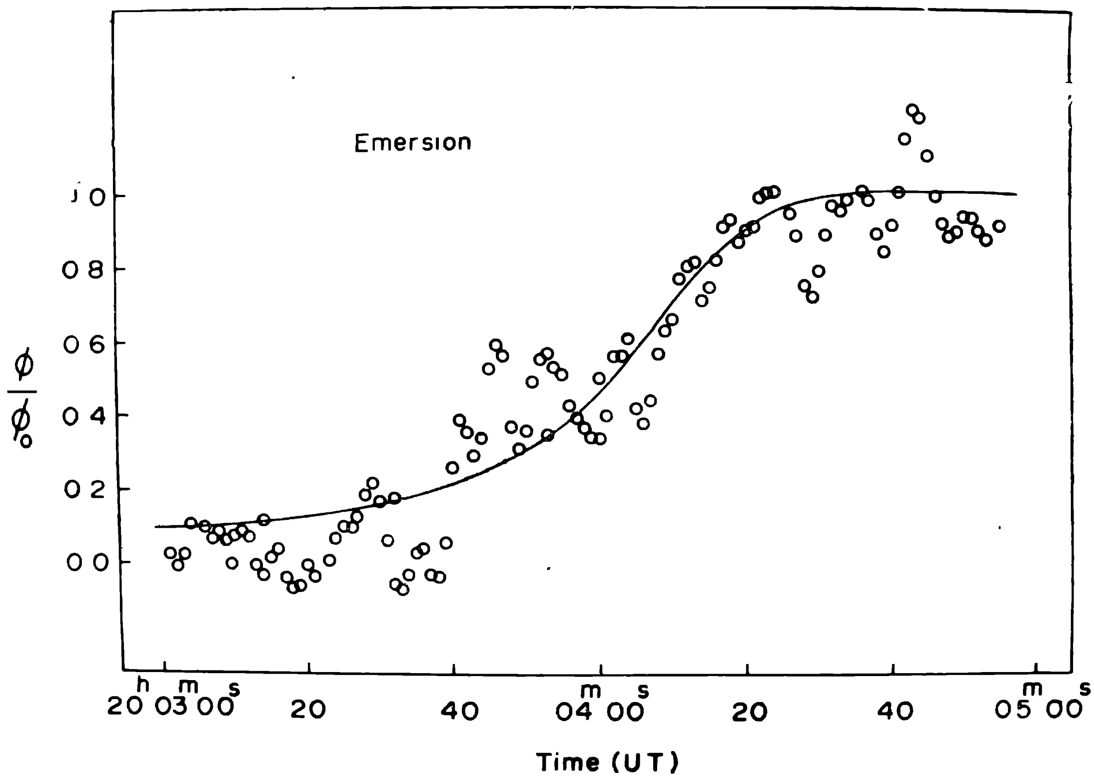

Figure 2. Emersion light curve where the solid line represents the theoretical light curve for $H = 56$ km.

the relative flux at time t. The above relation has been used to calculate the theoretical light curves for comparison with the observed occultation curves. On comparision of the theoretical light curves for different assumed values of H with the observed occultation curves, we find that $H = 56$ km seems to give the best fit. The various parameters obtained for immersion and emersion events are listed in table 1. Assuming mean molecular weight $\mu = 2.2$ gm mole^{-1} and $g = 830$ cm s^{-2}, the temperature for Uranus atmosphere comes out to be 122 ± 15 K.

Table 1. Occultation parameters

Sl. No.	Parameter	Immersion	Emersion
1.	Velocity normal to limb (kms^{-1})	9.44	9.44
2.	Position angle (degrees)	344.9	39.4
3.	Time at half intensity	$19^h\ 44^m\ 40^s \pm 1^s$	$20^h\ 04^m\ 02^s \pm 1^s$
4.	Scale height (km)	56 ± 7	56 ± 7
5.	Temperature (K)	122 ± 15	122 ± 15

The scale height determined by this method may not be significant because the Uranian atmoshere is nonisothermal (Dunham *et al.* 1980). However, by fitting the theoretical light curves to the observations we have obtained the midtimes of immersion and emersion events.

We have obtained the temperature profiles for Uranian atmosphere from occultation observations using the method of numerical inversion of the light curves given by Wasserman & Veverka (1973). The procedure given by French *et al.* (1978) has been adopted for numerical inversion of the observed light curves. We have assumed the gravitational acceleration $g = 830$ cm s^{-2}, the mean molecular weight of the gas in the occulting atmosphere $\mu = 2.20$ gm $mole^{-1}$ and the 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). The temperature profiles are shown in figures 3 and 4. The error in the temperature determination is the largest at the upper portion of the profile where the uncertainities are about 40%. Error decreases smoothly reaching about 14% for the lower portion of the profile.

We have obtained the mean temperature of the Uranian atmosphere by taking mean of the inverted profiles. The mean temperature comes out to be 80 K both

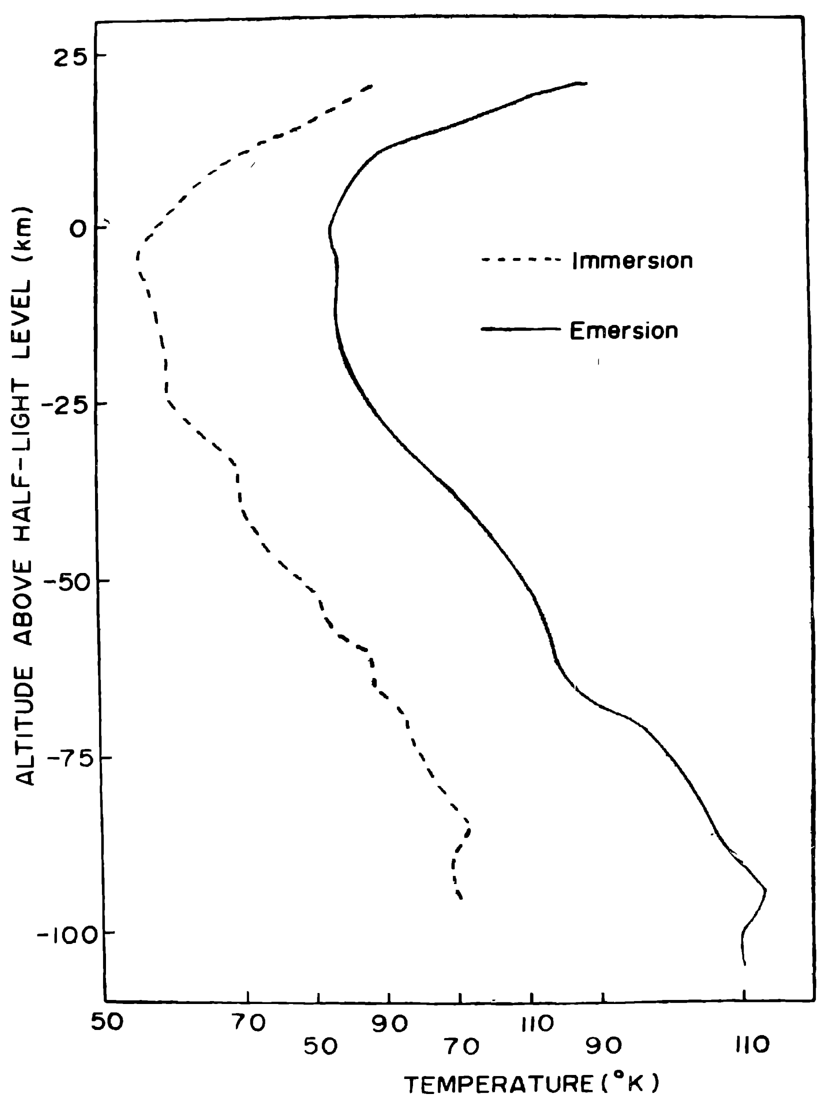

Figure 3. Variation of temperature with height for the upper atmosphere of Uranus.

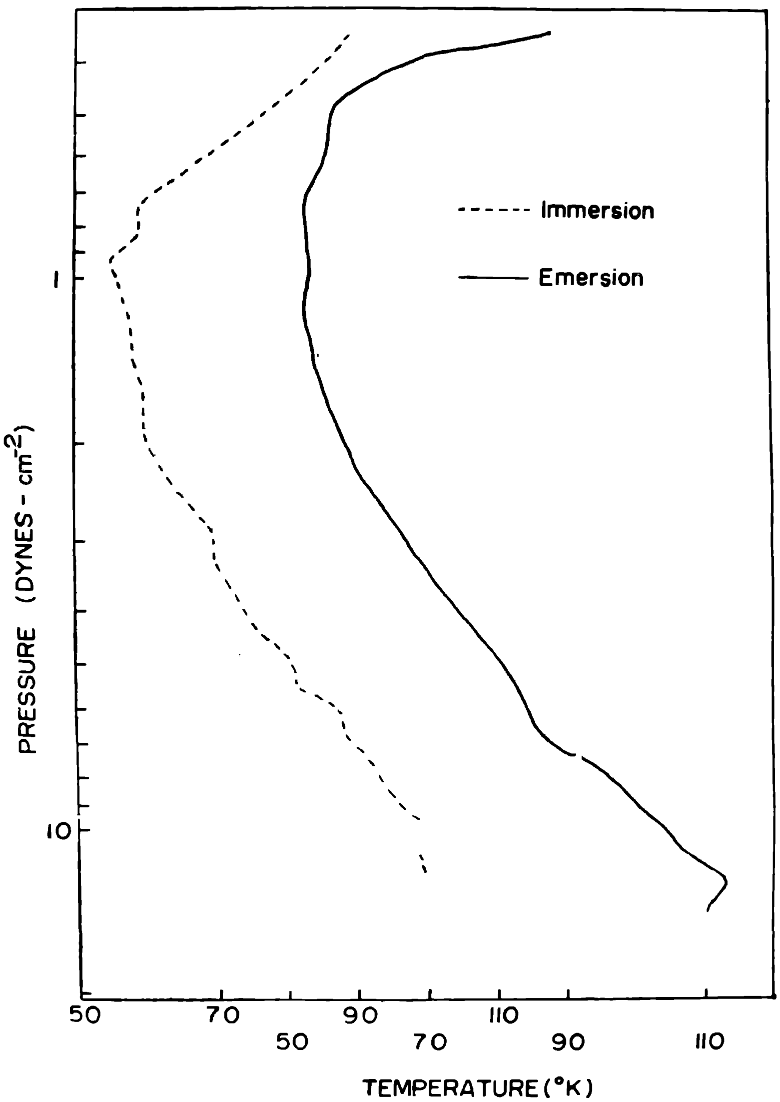

Figure 4. Temperature-pressure relationship for the upper atmosphere of Uranus.

for immersion and emersion events. The estimated error in mean temperature determination is about $\pm$ 15 K. The mean temperature of the Uranian atmosphere obtained by Dunham *et al.* (1980), in the pressure range 0.3 to 30 dynes cm^{-2} is 95 $\pm$ 10 K from the occultation observations of SAO 158687 by Uranus on 1977 March 10.

4. The ϵ ring

The positions of the occulting segments of the ϵ ring, projected on the sky plane were calculated from the observed timings of occultation in the manner described by Elliot *et al.* (1978). The apparent geocentric position of the Uranus, table 2, obtained by interpolation of data supplied by Liller (personal communication) and the stellar coordinates for the epoch 1950 are taken from Klemola *et al.* (1981). For the present observations, the inclination of the ring plane to the sky plane was found to be 70°.08 and the position angle of the north pole of the ring plane projected on the sky was 259°.85.

Table 2. Geocentric ephemeris of Uranus

Time (U.T.)	Right ascension	Declination	Distance (a.u.)
$14^h.00^m$	$15^h47^m23^s.13537$	−19°43′ 7″.15548	17.87734309
16.00	15 47 22.36242	−19 43 4.74909	17.87679796
18.00	15 47 21.58878	−19 43 2.34048	17.87625074
20.00	15 47 20.81446	−19 42 59.92963	17.87570544
22.00	15 47 20.03946	−19 42 57.51657	17 87516205

Assuming that Uranus is spherical in shape having a radius of 26200 km (Elliot *et al.* 1978), we have obtained a constant offset in the coordinates of the centre of the Uranus from its ephemeris. For the present occultation the relative errors are 4842 km in R.A. and 1819 km in Dec., after applying a correction ($\approx$ 25 km for a ray passing near the limb of Uranus) for the gravitational bending of star light (Elliot *et al.* 1978).

From the present observations the radius of the ϵ ring comes out to be 51340 $\pm$ 20 km and 50895 $\pm$ 20 km for preimmersion and postemersion events respectively. From our observations, the durations (FWHM) of ϵ ring events are 3 s and 1.3 s for preimmersion and postemersion respectively. These correspond to apparent radial widths of 64 km and 28 km for preimmersion and postemersion events respectively.

All the available independent measurements of radii of ϵ ring and apparent radial widths are given in table 3. We have plotted the width (FWHM) of ϵ ring versus the radii in figure 5. The radii of the segments of the ϵ ring and apparent radial

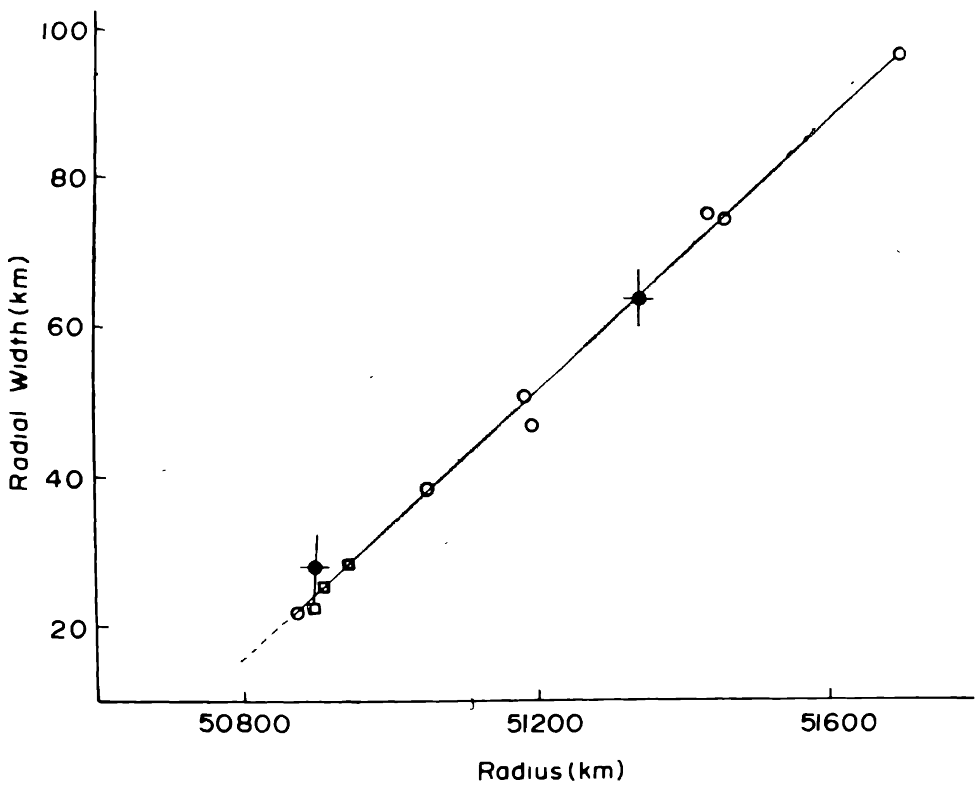

Figure 5. Relation between radial width (FWHM) and radius of ϵ ring—[open circles = Nicholson *et al.* (1981), squares = Elliot *et al.* (1981), closed circles with error bars = present work]

Table 3. Radii and widths of the ϵ ring

Date of Observation	Radius (km)	Radial width (km)	Reference
1977 March 10	51702.5	98	Nicholson *et al.* (1981)
1979 June 10	51457	75	,,
1978 April 10	51434	76	,,
1981 April 26	51340	64	Present work
1977 Dec. 23	51190	47	Nicholson *et al.* (1981)
1979 June 10	51180	51	,,
1977 March 10	51045.5	38.5	,,
1980 March 20	50940.7	28.4	Elliot *et al.* (1981)
1980 March 20	50906	25.4	,,
1980 March 20	50894.9	22.7	,,
1981 April 26	50895	28	Present work
1978 April 10	50874	22	Nicholson *et al.* (1981).

widths for preimmersion and postemersion events, obtained from our observations, are in agreement with the width-radius relation given by Nicholson *et al.* (1978).

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