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NOTES FOR THE OBSERVER

by T. P. Prabhu

1. Variable stars

Stellar pulsations

All stars are elastic spheres and can pulsate radially. However, the physical conditions that trigger pulsations and sustain them against various damping mechanisms prevail only in some stars. These pulsating stars exhibit periodic variations in their luminosity, colour and radial velocity. The light and colour vary because of a change in the surface temperature; the surface temperature drops as the star expands and increases again as it contracts. The change in the surface temperature also affects the detailed spectrum of the star; the star moves towards later spectral types as it expands and moves back to earlier spectral types as it contracts. The variations in the radial velocity obtained from the absorption lines in the spectra reflect the movement of the outer layers, since the absorption lines are formed in these layers.

The stars known to be pulsating include various types of variables comprising the *great sequence* variables; the best known among these are the classical Cepheids. Other members of the Cepheid group are W Virginis types, RR Lyrae types and dwarf Cepheids. Besides these, the great sequence encompasses the RV Tauri type, semiregular and long-period variables. β Cephei (or β Canis Majoris) types are hotter pulsating variables. Pulsation is important in magnetic variables too.

The first Cepheid variable discovered was the prototype δ Cephei (1784) by John Goodricke. Belopolsky (1894) discovered its radial velocity variations which has the same period as the light curve. Karl Schwarzschild (1899) discovered the variations in colour and attributed the light variations to a temperature effect. Though August Ritter had already suggested in 1879 that some variables could be radially pulsating, a binary model of δ Cephei prevailed for several decades. The light, velocity and colour curves could not be explained by eclipses and hence complicated binary models with tidal effects were contrived. Shapley (1914) showed that the sizes of Cepheid variables are over ten times larger than the sizes of computed orbits and suggested for the first time that the pulsation hypothesis is a definite substitute.

Ritter had already developed the first elements of the pulsation theory and obtained an expression for the period P of the adiabatic radial pulsations of a homogeneous star :

$$P^2 = \frac{3\pi}{3\gamma - 4} \frac{1}{G\rho}, \qquad \ldots(1)$$

where γ is the ratio of specific heats, G the constant of gravitation and ρ the mean density. Shapley obtained the mean densities of Cepheids from equation (1) which agreed with the spectroscopic knowledge that Cepheids are giants. The pulsation hypothesis was placed on a firm footing by the subsequent theoretical analysis of the pulsation problem by Eddington (1918).

The pulsations are sustained in pulsating variables by a layer at a critical depth in the stellar atmosphere in which an abundant element is ionized. The layer responsible for pulsation is the He II zone just below the hydrogen ionization zone in the members of Cepheid family. Primary helium ionization, hydrogen ionization and hydrogen molecular dissociation are important in RV Tauri and the red (semiregular and long-period) variables. The pulsation mechanism in these cooler variables is complicated by the existence of deep convection in their envelopes.

Equation (1) can be rewritten as

$$P(\rho/\rho_{\odot})^{1/2} = Q \qquad \ldots(2)$$

where $\rho_{\odot}$ is the mean density of the sun and Q is defined as the pulsation constant. While equation (1) was derived for a star in which the matter is uniformly distributed, equation (2) holds good even for realistic stars (density increasing towards the centre) but with a different value of the pulsation constant Q. The observed values of Q for various types of stars are listed in Table 1 along with a few other gross properties. The regions occupied by these stars in the Hertzsprung-Russell diagram are shown in Figure 1.

Table 1. Different classes of pulsating variables

Class	Typical period d	Q d	Spectral type	Absolute magnitude	Comments
Dwarf Cepheids	0.1	0.045	A2–F5	+2 – +3	regular; multiple periods
β Cephei (β CMa)	0.2	0.027	B1–B2	−3.5 – −4.5	regular; multiple periods; secular changes
RR Lyrae	0.5	0.075	A2–F6	0.0 – +0.5	regular; multiple periods
Magnetic	7	1–2	A0–F0	+1 – +2	regular
Classical Cepheids	5–10	0.036	F6–K2	−0.5 – −6	regular
W Virginis	12–20	0.160	F2–G6	0 – −3	regular; slow changes in period
RV Tauri	75	0.25	G–K	−3	some irregularity
Semiregular	100	0.086	M, R	−1 – −3	some irregularity
Long-period	270	0.096	Me–Se	−3.5 – −4.5	some irregularity

The changes in the surface temperature of a pulsating star affect the shape of the energy distribution as well as the surface brightness of the star. When the star expands and the outer layers cool, the star becomes redder and fainter; when the surface becomes hotter by contraction, the star becomes bluer and brighter. Because of the changes in the shape of the energy distribution, the variations of light in certain bands may exceed the variations in the total energy output (bolometric magnitude). Thus the light curves of Cepheids have a larger amplitude in the ultraviolet and blue than in red and infrared. Long period variables exhibit much

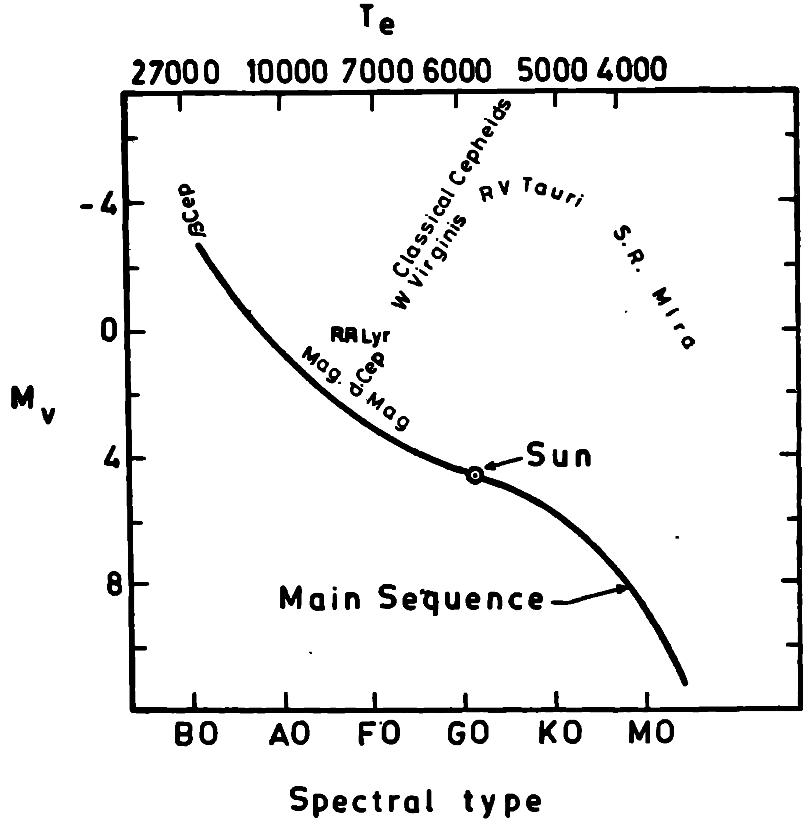

Figure 1. The positions of different types of pulsating variables in Hertzsprung-Russell diagram.

more variation in the visible region though their integrated luminosities vary very little. This is because more molecules are formed in their atmospheres when the star becomes cooler. These molecules absorb energy and increase the strength of the absorption bands in their spectra. Thus their light curves have deeper minima in the visible region as compared to the ultraviolet or infrared.

Three important observational data on pulsating variables are the light curves, colour curves and the radial velocity curves. The light variations reflect both the change in surface temperature and the change in the diameter of the star. The colour curve, on the other hand, can yield the variation in the effective temperature directly. The radial velocity curve gives us a measure of the velocity of the outer layers of the star. An integration of the velocity with respect to time yields the actual change in the radius of the star. The apparent magnitude and colour curves, together with an assumption of blackbody spectrum, yield the actual angular diameter of the star as a function of time. A comparison of the angular diameter curve with the actual change in diameter yields the true diameter of the star as a function of time. This procedure was first proposed by Baade in 1926 as a test of pulsation hypothesis; it has been developed by Wesselink (1946) and later astronomers into a powerful tool for measuring the diameters of pulsating variables.

There are several interesting semiregular and long-period variables near north celestial pole. The star Polaris itself is a Cepheid variable pulsating between 1.94 and 2.05 magnitudes with a period of 3.97 days. It is also a spectroscopic binary with a period of 29.6 yr. This system has a ninth magnitude companion 18 arcsec away, a thirteenth magnitude one 43 arcsec away and a twelfth magnitude one

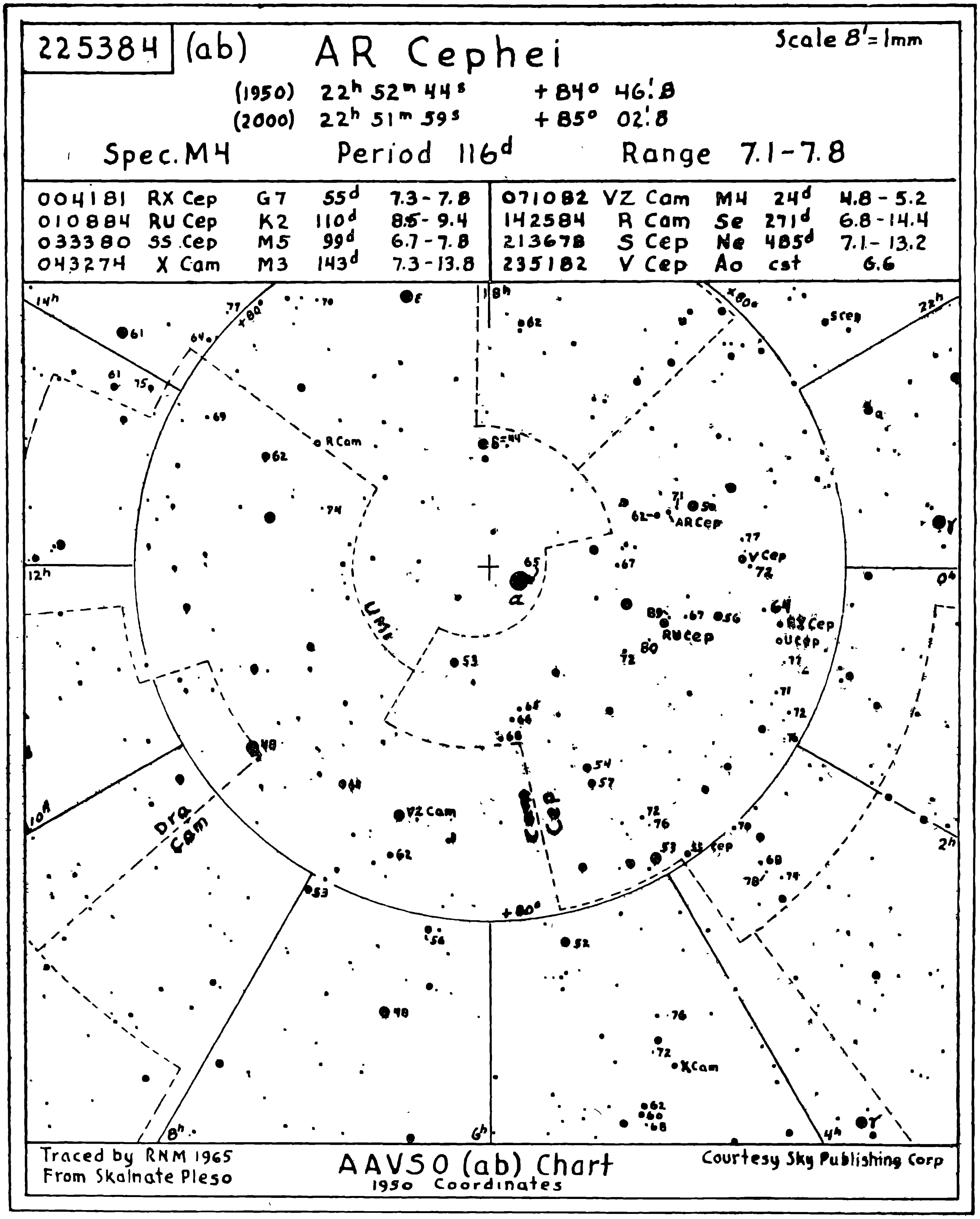

Figure 2. Standard chart for red variables near the north celestial pole (Courtesy AAVSO).

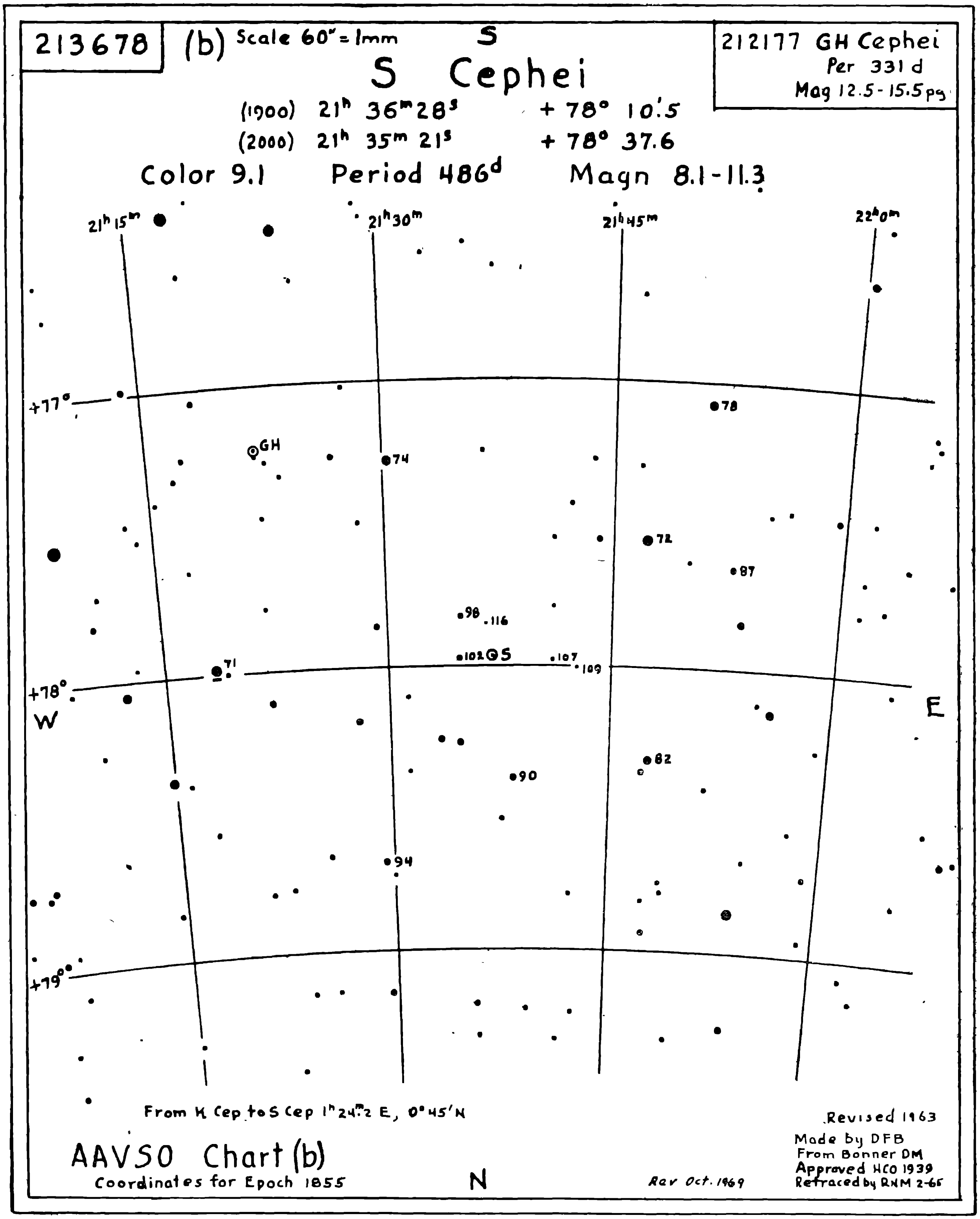

Figure 3. Standard chart for S Cephei (Courtesy AAVSO).

83 arcsec away. Figure 2 is an AAVSO identification chart for some variables around Polaris. The stars R Camelopardalis, X Camelopardalis and S Cephei are long period variables like Mira Ceti. All the three are within the range of small telescopes at their maximum brightness. X Camelopardalis will be near minimum in 1982 January but will rise to maximum in the beginning of March and again in the end of September. S Cephei will also be near minimum in 1982 January. This star has a very long period of 16 months and will rise to its next maximum only in 1982 September. A more detailed comparison chart is shown in Figure 3. R Camelopardalis will rise to maximum in March and is favourably placed such that a full cycle can be followed till 1982 December. It is only 5 degrees from the pole star, and crosses Meridian in the evenings of July when it is at minimum.

There are also a few bright semiregular variables around Polaris. The brightest is VZ Camelopardalis which varies with a short period of about 24 days. Three other semiregular variables in the field are SS Cephei, AR Cephei and RU Cephei all of which have longer periods of about 3 to 4 months. The quoted periods of these variables are average ones; the observed periods vary from one cycle to another.

Two other variables in the field shown in Figure 2 are RX Cephei and U Cephei, RX Cephei varies slowly over time scales of about two months. U Cephei is an eclipsing variables with a period of 2.49 days. It varies between 6.6 and 9.8 magnitudes. The variable star designation was given to V Cephei (Figure 2) by Chandler (1882) who felt that the star varies between sixth and seventh magnitude with a period of one year. Such a variability has not been observed during this century. The star is not a variable and Chandler's observations are probably erroneous. If the comparison stars are not close enough to the variable, such errors can easily creep into the estimates of magnitude.

2. Lunar occultations

Lunar occultations of stars ($\leqslant 7.5$ mag) observable from Kavalur during 1982 January–April are listed in Table 2. Lunar ephemeris and Greenwich Standard Times listed in Table 3 should be useful in calculating accurate predictions at other geographical locations.

δ Geminorum is continuing a series of occultations which started on 1981 November 15. It is being occulted on 1982 January 9 and April 1. The occultation of April 1 is at the dark limb of half moon, but occurs at a low altitude. The occultation on January 9 takes place during a lunar eclipse. The moon begins to enter the penumbra at $17^h 15^m$ UT and umbra at $18^h 14^m$ UT. The totality is between $19^h 17^m$ UT and $20^h 35^m$ UT. Moon will be fully outside umbra by $21^h 38^m$ UT and out of penumbra at $22^h 37^m$ UT. The star δ Geminorum is occulted just as the moon is moving into penumbra and the star reappears while moon is fully inside penumbra. A few stars of magnitude 9 or fainter are occulted in the umbral shadow. BD $+ 21°1596$ is occulted after totality while the moon is in penumbra.

Another interesting occultation of the forthcoming months is that of the Beehive Cluster (Praesepe = M 44) on March 6. The diameter of the cluster is 95 arcmin which is three times as large as moon. Thus the cluster is never completely hidden by moon. The prediction for M 44 listed in Table 2 is for the cluster's centre.

Table 2. Lunar occultations in 1982 January–April

Date 1982		Time (UT) h	m	s	Type	Star	Mag.	Sp. T	α 1982 h	m	s	δ °	′	″	Altitude	Percentage illumination
January	1	15	10	18	D	BD − 8°6141	7.4	K5	23	30	7.1	−7	46	48	33	33+
		15	35	21	D	HR 8951	5.8	K0	23	34	35.1	−7	34	1	27	33+
		16	40	21	R	HR 8951									12	33+
	4	12	41	36	D	BD + 6°324	6.9	F0	20	45	1.0	6	56	27	71	65+
	5	18	10	46	D	BD + 12°445	7.1	G5	3	8	1.4	12	47	24	42	77+
		19	27	49	D	BD + 12°452	6.4	G5	3	10	22.3	12	58	44	24	78+
	6	20	33	57	D	HR 1295	6.1	K0	4	11	29.4	17	13	51	22	87+
	7	14	58	20	D	HR 1642	6.4	A7	5	4	28.6	19	46	54	64	93+
		17	8	25	D	BD + 19°853	6.6	G5	5	7	46.9	19	50	11	81	94+
		21	46	33	D	CD Tau	6.9–7.5	F5	5	16	27.5	20	6	44	20	94+
		22	29	14	D	HR 1741	6.1	G8	5	18	11.0	20	6	56	10	94+
	8	15	59	40	D	TV Gem	7.0–7.8	M1	6	10	46.8	21	52	19	63	98+
		17	24	14	D	BD + 21°1163	6.7	K0	6	13	24 0	21	47	11	79	98+
		23	17	9	D	BD + 21°1232	6.6	G5	6	24	38.3	21	39	17	14	99+
	9	17	19	30	D	δ Gem	3.5	F0	7	19	3.4	22	0	54	67	100+
		18	47	56	R	δ Gem									81	100+
		21	37	34	D	HR 2835	6.4	F4	7	25	46.9	21	34	16	50	100+
	20	23	5	4	D	HR 6294	6.1	B8	16	55	58.6	−19	30	39	15	15−
	21	0	16	59	R	HR 6294									31	15−
	27	14	2	30	D	HR 8565	6.2	F1	22	29	1.9	−13	0	37	8	6+
	30	15	50	22	D	26 Cet	6.0	F0	1	2	52.2	1	16	4	20	29+
		16	50	22	R	26 Cet									5	29+
February	3	15	45	14	D	BD + 18°684	7.1	G5	4	41	48.5	18	41	11	71	73+
	4	18	26	58	D	BD + 21°1003	7.2	B9	5	48	8.4	21	7	48	48	83+
	5	14	54	15	D	BD + 22°1473	7.0	K0	6	46	8.7	22	12	51	65	91+
	6	17	23	40	D	BD + 21°1714	7.0	M0	7	53	10.4	21	9	6	81	97+
		19	11	41	D	BD + 21°1724	7.1	G5	7	56	3.1	21	0	52	65	97+
	10	18	35	2	D	ν Vir	4.0	M1	11	44	56.5	6	37	45	52	92−
		20	0	41	R	ν Vir									73	92−
	19	23	29	49	D	BD − 22°5021	6.9	A0	19	13	2.5	−22	5	30	15	14−
	20	0	16	23	R	BD − 22°5021									25	14−

March	2	15	41	18	D	BD + 17°724	6.9	A0	4	26	1.7	18	9	59	44	47+
	3	14	52	49	D	BD + 20°948	6.8	B2	5	24	5.9	20	34	2	67	58+
	4	17	34	15	D	BD +21°1268	7.5	G5	6	29	52.9	21	49	1	44	70+
		17	51	49	D	BD + 22°1364	7.2	A0	6	30	54.5	22	11	55	40	70+
	5	13	52	10	D	BD + 22°1687	6.9	K5	7	26	36.5	22	10	40	67	79+
	6	16	30	34	D	η Cnc	5.3	K3	8	31	40.8	20	30	7	82	88+
		20	42	24	D	BD + 20°2149	6.7	F0	8	38	41.3	19	50	29	28	89+
		20	46	19	D	BD + 20°2150	6.7	K0	8	38	49.5	19	36	14	27	89+
		20	48	14	D	BD + 20°2152	6.9	A0	8	38	55.3	19	36	58	27	89+
		20	58	23	D	BD + 20°2163	7.4	A0	8	39	16.9	19	35	42	25	89+
		20	59	22	D	HR 3428	6.4	K0	8	39	20.8	19	43	59	25	89+
		21	0	3	D	M 44	3.9		8	39	20.9	19	45	7	24	89+
		21	1	53	D	ϵ Cnc	6.3	A2	8	39	25.8	19	36	29	24	89+
		21	12	34	D	BD + 19°2069	6.8	F0	8	39	19.0	19	24	43	21	89+
		21	14	16	D	BD + 20°2172	6.7	A5	8	39	42.0	19	46	57	21	89+
		21	24	59	D	BD + 20°2175	6.8	A3	8	39	55.1	19	38	38	21	89+
		21	47	57	R	M 44									21	89+
	7	14	52	14	D	BD + 18°2207	7.5	K0	9	28	33.7	17	43	37	56	94+
		20	37	32	D	8 Leo	5.7	K1	9	36	3.9	16	31	3	42	95+
	18	22	57	18	D	ν¹ Sgr	4.8	K2	18	53	4.2	−22	46	4	34	38−
		23	30	15	D	ν² Sgr	5.0	K3	18	54	1.1	−22	41	40	40	38−
	19	0	24	5	R	ν² Sgr									49	38−
	29	13	36	7	D	HR 1280	5.9	K5	4	6	56.4	17	17	27	44	21+
		14	44	7	R	HR 1280									28	21+
	30	13	26	58	D	106 Tau	5.2	A3	5	6	43.6	20	23	40	40	31+
		14	47	51	R	106 Tau									56	31+
	31	13	33	10	D	HR 2169	5.9	K4	6	8	26.8	22	11	36	70	43+
		14	57	33	R	HR 2169									51	43+
		15	18	16	D	TV Gem	7.0–7.8	M1	6	10	45.9	21	52	21	47	43+
		16	47	56	D	BD + 21°1163	6.7	K0	6	13	23.1	21	47	13	27	44+
		17	46	50	D	BD + 22°1257	7.2	G5	6	16	14.8	22	9	2	14	44+
April	1	16	29	4	D	BD + 22°1620	7.4	K5	7	14	29.0	21	59	54	44	55+
		18	26	24	D	δ Gem	3.5	F0	7	19	2.8	22	0	57	18	56+
		19	22	31	R	δ Gem									5	56+
	2	18	39	20	D	HR 3264	5.8	K1	8	19	18.3	20	48	17	28	67+
		20	38	32	D	BD + 20°2079	7.2	A5	8	23	46.9	20	12	41	2	68+

3	19	14	46	D	BD + 18°2165	6.6	F5	9	17	59.1	17	46	53	32	77+
4	14	2	55	D	BD + 15°2167	7.2	F8	10	6	41.6	15	14	42	61	85+
	20	50	7	D	37 Leo	5.5	M1	10	15	43.5	13	49	2	22	86+
6	18	36	52	D	BD + 6°2529	7.5	K0	11	55	53.9	5	26	37	75	97+
9	16	2	48	D	BD − 8°3737	6.6	K0	14	15	52.3	−8	48	10	29	98−
	16	12	1	R	BD − 8°3737									32	98−
11	16	22	32	D	θ Lib	4.1	K0	15	52	48.8	−16	40	40	21	89−
	17	4	47	R	θ Lib									41	89−
25	14	32	51	D	BD + 16°514	7.5	F5	3	47	53.6	16	24	13	1	4+
28	17	29	40	D	BD + 22°1558	7.3	G5	7	1	11.1	22	7	21	3	30+
29	17	59	30	D	BD + 21°1753	7.3	A2	8	3	24.5	21	3	34	9	41+

Table 3. Lunar ephemeris and the sidereal time

Date 1982		UT	p_1	$\Delta p_1/\Delta t$	α_1			$\Delta\alpha_1/\Delta t$	δ_1			$\Delta\delta_1/\Delta t$	GST		
Month	Day	h	arcsec	arcsec h⁻¹	h	m	s	s h⁻¹	°	′	″	arcsec h⁻¹	h	m	s
January	1	16	3421	+1.7	23	37	46.6	123.5	−7	22	17	+697	22	43	54.9
	4	13	3549	+1.8	2	3	21.3	132.6	6	57	55	+752	19	55	15.0
	5	19	3600	+1.6	3	11	53.4	142.4	12	56	34	+669	2	0	10.0
	6	21	3633	+1.1	4	15	21.9	151.0	17	18	8	+534	4	4	27.0
	7	16	3651	+0.5	5	4	9.7	156.9	19	43	11	+383	23	7	34.2
		22	3654	+0.5	5	19	55.9	158.4	20	18	58	+332	5	8	33.3
	8	17	3656	−0.2	6	10	40.3	161.6	21	36	22	+154	0	11	40.7
		23	3654	−0.2	6	26	50.9	161.9	21	48	50	+95	6	12	39.8
	9	20	3632	−0.9	7	23	24.2	160.6	21	45	50	+112	3	16	6.8
	20	23	3245	+0.1	9	26	41.7	145.6	−17	30	12	−498	6	59	58.4
	27	14	3381	+1.2	22	32	19.6	125.9	−13	1	37	+596	22	26	5.7
	30	16	3473	+1.3	1	5	52.1	125.4	1	21	2	+757	0	38	15.0
February	3	16	3584	+0.8	4	42	47.1	149.0	18	47	48	+433	0	54	1.2
	4	18	3599	+0.4	5	48	49.1	155.3	21	11	33	+224	2	58	17.5
	5	15	3604	−0.1	6	43	38.4	157.5	21	56	28	+31	0	1	44.5
	6	18	3602	−0.6	7	54	15.7	155.5	21	13	48	−218	3	5	10.6
	10	19	3410	−2.0	11	42	42.7	126.0	6	51	11	−719	4	22	6.7
	19	23	3284	+0.8	19	7	35.8	130.5	−21	57	10	−40	8	58	15.1
March	2	16	3551	+0.3	4	28	37.6	145.1	18	14	27	+464	2	40	28.2
	3	15	3556	+0.1	5	25	13.0	149.9	20	40	37	+293	1	44	14.9
	4	18	3556	−0.1	6	33	29.5	152.9	22	1	18	+62	4	48	41.1

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	5	14	3551	−0.4	7	24	26.0	152.3	21	52	20	−115	0	51	58.2
	6	17	3538	−0.7	8	32	9.9	148.1	20	8	59	−339	3	56	24.4
		21	3531	−0.7	8	42	0.4	147.1	19	45	22	−369	7	57	3.8
	7	15	3520	−0.9	9	25	27.5	142.4	17	35	40	−495	2	0	1.1
		21	3516	−0.9	9	39	36.9	140.7	16	44	42	−527	7	1	0.3
	18	23	3271	+0.7	18	49	35.8	129.1	−22	11	45	−3	10	44	42.1
	29	14	3577	−0.1	4	9	45.8	145.9	17	24	9	+528	2	26	35.5
	30	14	3570	−0.5	5	9	4.5	150.3	20	20	43	+349	2	30	32.1
	31	15	3557	−0.7	6	12	17.5	152.5	22	2	8	+135	3	34	38.5
April	1	18	3537	+0.8	7	20	45.3	151.0	22	8	42	−104	6	39	4.6
	2	19	3552	+0.3	8	22	48.2	146.3	20	41	45	−308	7	43	11.1
	3	19	3556	+0.1	9	20	6.0	140.0	18	4	13	−473	7	47	7.6
	4	14	3556	0.0	10	3	33.7	134.5	15	17	32	−575	2	50	14.9
		21	3556	0.0	10	19	8.7	132.6	14	8	31	−607	9	51	23.9
	6	19	3537	−0.7	11	56	30.5	122.2	5	28	4	−727	7	58	57.3
	9	16	3463	−1.5	14	13	7.4	117.6	−8	17	23	−666	5	10	17.3
	11	17	3389	−1.8	15	50	14.8	120.9	−16	15	33	−489	6	18	20.3
	25	14	3513	+1.4	3	49	58.9	148.5	16	18	5	+605	4	14	2.5
	28	17	3576	+0.2	7	3	16.2	155.3	22	32	24	+43	7	25	21.8
	29	18	3576	0.0	8	6	57.3	149.8	21	27	46	−262	8	29	28.1

Table 4. Meteor streams active during 1982 January–June

Stream	Epoch	Limits	Maximum hourly rate	Radiant α h	Radiant α m	Radiant δ deg	Age of moon	Local time of transit h
Quadrantids	Jan. 3	Jan. 1–Jan. 6	80	15	28	+50	8	8.6
Arids	Mar. 16	Mar. 13–Mar. 18	5	16	20	−50	21	4.8
April Lyrids	Apr. 22	Apr. 19–Apr. 25	12	18	8	+32	27	4.2
π Puppids	Apr. 24	Apr. 21–Apr. 26	40	7	18	−44	1	17.1
η Aquarids	May 5	Apr. 24–May 20	55	22	20	−1	11	7.6
α Scorpids	Apr. 28	Apr. 20–May 19	20	16	32	−24	4	2.0
	May 13			16	4	−24	20	0.6
Ophiuchids	June 10	May 19–July 1		17	56	−23	17	
	June 20			17	20	−20	27	23.5
Minor showers								
δ Leonids	Feb. 26	Feb. 5–Mar. 19						
σ Leonids	Apr. 17	Mar. 21–May 13						
τ Herculids	June 3	May 19–June 14						

The disappearance of different members of the cluster takes place for 228 min and the reappearance for 209 min about the tabulated value. Most of the occultations listed against March 6 in Table 2 refer to the brighter members of the cluster including ϵ Cancri.

The list in Table 2 contains two variable stars too. The star CD Tauri being occulted on January 7 is an eclipsing variable with a period of 3.43 days. The semiregular variable TV Geminorum (Period : 182 days) is occulted twice : on January 8 and on March 31. BD + 17°724 (March 2) has a $9^m.5$ companion 19 arcsec to the north-east which is occulted 38 s later in Kavalur. BD + 22°1687 (March 5) has a $9^m.5$ companion 39 arcsec to the northwest which is occulted 87 s earlier.

3. Meteor streams

The period between January–June is a lean season for sporadic meteors as well as meteor streams. However, there are a few interesting meteor streams (Table 4) like Quadrantids in January with their blue meteors shooting from a diffuse radiant. Also η Aquarids of May have produced very high rates in the recent years. This stream also stays near maximum for a long time, displaying activity above one-fourth of maximum for about 3 days compared to just one day of Quadrantids and 2 days of April Lyrids. The April Lyrids have bright meteors and this year's recurrence is favourable since it is close to the new moon. This stream has had spectacular displays in the past, the best noted being the one in 1830. A spectacular display of meteors in 687BC is also ascribed to this stream. The parent of π Puppids is the periodic comet Grigg-Skjellerup which is due at perihelion in May. We may expect higher activity this year. π Puppids are characterized by bright yellow meteors. Moon is also favourable this year. The α Scorpids are part of a large complex in Scorpio-Sagittarius and have several radiants from April through July.