Chapter 4

Candragrahaṇa – Eclipse of the Moon

1. The structure of the material world
    a. Text 1; diameters of the Sun and Moon's disks
    b. Texts 6 – 9; situations leading to eclipses

8. Science
    c. Texts 1 - 3; apparent diameters of the Sun and Moon's disks, and method for calculating observed variations to this throughout their orbits, as well as the diameter of the Sun on the Moon's orbit, and the angular distance covered by the Sun and Moon as seen from Earth.
    a. Texts 4 – 5; finding the diameter of the Earth's shadow on the orbit of the Moon
    b. Texts 10 – 17; calculating the amount of the body eclipsed, the duration of the eclipse, and the times of contact and separation, as well as immersion and emergence.
    c. Texts 18 - 23; calculating the amount of obscuration at any given time during an eclipse, and conversely, the time at which a given amount of obscuration will be present.
    d. Texts 24 – 26; calculating the angle of the ecliptic to an east-west circle passing through the eclipsed body, and converting latitudes from minutes to digits for the purpose of constructing a projection.

Text & Translation

4.01a sārdhāni ṣaṭsahasrāṇi yojanāni vivasvataḥ/
4.01b viṣkambho maṇḍalasyendoḥ sahāśītyā catuśśatam//

The diameter of the Sun's disk is six thousand five hundred yojanas; of the Moon's, four hundred and eighty.

4.02a sphuṭasvabhuktyā guṇitau madhyabhuktyoddhṛtau sphuṭau/
4.02b raveḥ svabhagaṇābhyastaḥ śaśāṅkabhagaṇoddhṛtaḥ//

4.03a śaśāṅkakakṣāguṇito bhājito vā +arkakakṣayā/
4.03b viṣkambhaś candrakakṣāyāṁ tithyāptā mānaliptikā//

These diameters, each multiplied by the true motion, and divided by the mean motion, of its own planet, give the corrected (sphuta) diameters. If that of the Sun be multiplied by the number of the Sun's revolutions in an Age, and divided by that of the Moon's, or if it be multiplied by the Moon's orbit (kaksha), and divided by the Sun's orbit, the result will be its diameter upon the Moon's orbit: all these, divided by fifteen, give the measures of the diameters in minutes.

4.04a sphuṭendubhuktir bhūvyāsaguṇitā madhyayoddhṛtā/
4.04b labdhaṁ sūcī mahīvyāsasphuṭārkaśravaṇāntaram//

4.05a madhyenduvyāsaguṇitaṁ madhyārkavyāsabhājitam/
4.05b viśodhya labdhaṁ sūcyāṁ tu tamo liptās tu pūrvavat//

Multiply the Earth's diameter by the true daily motion of the Moon, and divide by her mean motion: the result is the Earth's corrected diameter (suci). The difference between the Earth's diameter and the corrected diameter of the Sun is to be multiplied by the Moon's mean diameter, and divided by the Sun's mean diameter (suci), and the remainder is the diameter of the shadow; which is reduced to minutes as before.

4.06a bhānor bhārdhe mahīcchāyā tattulye +arkasame +api/
4.06b śaśāṅkapāte grahaṇaṁ kiyadbhāgādhikonake//

The Earth's shadow is distant half the signs from the Sun: when the longitude of the Moon's node is the same with that of the shadow, or with that of the Sun, or when it is a few degrees greater or less, there will [may] be an eclipse.

4.07a tulyau rāśyādibhiḥ syātām amāvāsyāntakālikau/
4.07b sūryendū paurṇamāsyante bhārdhe bhāgādikau samau//

4.08a gataiṣyaparvanāḍīnāṁ svaphalenonasaṁyutau/
4.08b samaliptau bhavetāṁ tau pātas tātkāliko +anyathā//

The longitudes of the Sun and Moon, at the moment of the end of the day of new moon (amavasya), are equal, in signs, etc.; at the end of the day of full moon (paurnamasi) they are equal in degrees, etc., at a distance of half the signs. When dimished or increased by the proper equation of motion for the time, past or to come, of opposition or conjunction, they are made to agree, to minutes: the place of the node at the same time is treated in the contrary manner.

4.09a chādako bhāskarasyendur adhaḥstho ghanavad bhavet/
4.09b bhūcchāyāṁ prāṅmukhaś candro viśaty asya bhaved asau//

The Moon is the eclipser of the Sun, coming to stand underneath it, like a cloud: the Moon, moving eastward, enters the Earth's shadow, and the latter becomes its eclipser.

4.10a tātkālikenduvikṣepaṁ chādyacchādakamānayoḥ/
4.10b yogārdhāt projjhya yaccheṣaṁ tāvac channaṁ tad ucyate//

4.11a yad grāhyam adhike tasmin sakalaṁ nyūnam anyathā/
4.11b yogārdhād adhike na syād vikṣepe grāsasambhavaḥ//

Subtract the Moon's latitude at the time of opposition or conjunction from half the sum of the measures of the eclipsed and eclipsing bodies; whatever the remainder is, that is said to be the amount obscured. When that remainder is greater than the eclipsed body, the eclipse is total; when the contrary, it is partial; when the latitude is greater than the half sum, there takes place no obscuration (grasa).

4.12a grāhyagrāhakasaṁyogaviyogau dalitau pṛthak/
4.12b vikṣepavargahīnābhyāṁ tadvargābhyām ubhe pade//

4.13a ṣaṣṭhyā saṁguṇya sūryendvor bhuktyantaravibhājite/
4.13b syātāṁ sthitivimardārdhe nāḍikādiphale tayoḥ//

Divide by two the sum and differences respectively of the eclipsed and eclipsing bodies: from the square of each of the resulting quantities subtract the square of the latitude, and take the square roots of the two remainders. These, multiplied by sixty and divided by the difference of the daily

motions of the Sun and Moon, give, in nadis, etc., half the duration (sthiti) of the eclipse, and half the time of total obscuration.

4.14a sthityardhanāḍikābhyastā gatayaḥ ṣaṣṭhibhājitāḥ/
4.14b liptādi pragrahe śodhyaṁ mokṣe deyaṁ punaḥ punaḥ//

4.15a tadvikṣepaiḥ sthitidalaṁ vimardārdhe tathā +asakṛt/
4.15b saṁsādhyam anyathā pāte talliptādiphalaṁ svakam//

Multiply the daily motions by half the duration, in nadis, and divide by sixty: the result, in minutes, subtract for the time of contact (pragraha), and add for that of separation (moksha), respectively; by the latitudes thus derived, the half-duration, and likewise the half-time of total obscuration, are to be calculated anew, and the process repeated. In the case of the node, the proper correction, in minutes, etc., is to be applied in the contrary manner.

4.16a sphuṭatithyavasāne tu madhyagrahaṇam ādiśet/
4.16b sthityardhanāḍikāhīne grāso mokṣas tu saṁyute//

4.17a tadvad eva vimardārdhanāḍikāhīnasaṁyute/
4.17b nimīlanonmīlanākhye bhavetāṁ sakalagrahe//

The middle of the eclipse is to be regarded as occurring at the true close of the lunar day: if from that time the time of half-duration be subtracted, the moment of contact (grasa) is found; if the same be added, the moment of separation. In like manner also, if from and to it there be subtracted and added, in the case of a total eclipse, the half-time of total obscuration, the results will be the moments called those of the immersion and emergence.

4.18a iṣṭanāḍīvihīnena sthityardhenārkacandrayoḥ/
4.18b bhuktyantaraṁ samāhanyāt ṣaṣṭyāptāḥ koṭiliptikāḥ//

4.19a bhānor grahe koṭiliptā madhyasthityardhasaṁguṇāḥ/
4.19b sphuṭasthityardhasaṁbhaktāḥ sphuṭāḥ koṭikalāḥ smṛtā//

4.20a kṣepo bhujas tayor vargayuter mūlaṁ śravas tu tat/
4.20b mānayogārdhataḥ projjhya grāsas tātkāliko bhavet//

4.21a madhyagrahaṇataś cordhvam iṣṭanāḍīr viśodhayet/
4.21b sthityardhān maukṣikāc cheṣaṁ prāgvac ccheṣaṁ tu maukṣike//

If from the half duration of the eclipse any given interval be subtracted, and the remainder multiplied by the difference of the daily motions of the Sun and Moon, and divided by sixty, the result will be the perpendicular (koti) in minutes. In the case of an eclipse (graha) of the Sun, the perpendicular in minutes is to be multiplied by the mean half-duration, and divided by the true (sphuta) half-duration, to give the true perpendicular in minutes. The latitude is the base (bhuja): the square root of the sum of their squares is the hypotenuse (srava): subtract this from half the sum of the measures, and the remainder is the amount of obscuration (grasa) at the given time. If that time be after the middle of the eclipse, subtract the interval from the half-duration on the side of separation, and treat the remainder as before: the result is the amount remaining obscured on the side of separation.

4.22a grāhyagrāhakayogārdhāc chodhyāḥ svacchannaliptikāḥ/
4.22b tādvargāt projjhya tatkālavikṣepasya kṛtiṁ padam//

4.23a koṭiliptā raveḥ spaṣṭasthityardhenāhatā hṛtāḥ/
4.23b madhyena liptās tannāḍyaḥ sthitivad grāsanāḍikāḥ//

From half the sum of the eclipsed and eclipsing bodies subtract any given amount of obscuration, in minutes: from the square of the remainder subtract the square of the latitude at the time, and take the square root of their difference. The result is the perpendicular (koti) in minutes – which, in an eclipse of the Sun, is to be multiplied by the true, and divided by the mean, half-duration – and this, converted into time by the same manner as when finding the duration of the eclipse, gives the time of the given amount of obscuration (grasa).

4.24a natajyā +akṣajyayābhyastā trijyāptā tasya kārmukam/
4.24b valanāṁśā saumyayāmyāḥ pūrvāparakapālayoḥ//

4.25a rāśitrayayutād grāhyāt krāntyaṁśair diksamair yutāḥ/
4.25b bhede +antarāj jyā valanā saptatyaṅgulabhājitā//

Multiply the sine of the hour-angle (nata) by the sine of the latitude (aksha), and divide by the radius: the arc corresponding to the result is the degrees of deflection (valanamsas), which are north and south in the eastern and western hemispheres (kapala) respectively. From the position of the eclipsed body increased by three signs calculate the degrees of declination: add them to the degrees of deflection, if of like direction; take their difference, if of different direction: the corresponding sine is the deflection (valana) – in digits, when divided by seventy.

4.26a sonnataṁ dinamadhyārdhaṁ dinārdhāptaṁ phalena tu/
4.26b chindyād vikṣepamānāni tāny eṣām aṅgulāni tu//

To the altitude in time (unnata) add a day and a half, and divide by a half-day; by the quotient divide the latitudes and the disks; the results are the measures of those quantities in digits (angula).