Ancient Jewish Mathematical Astronomy

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1. Introduction

The new moon was proclaimed in Israel on the basis of observation until the mid-fourth century C.E.1 In his treatise Sanctification of the New Moon,2 (completed circa 1178), Rabbi Moshe ben Maimon (Maimonides) asserts (1:6,6:1,11:1)3 that each month, the court calculated astronomically whether the new crescent would be visible on the evening preceding the 30th day of the month; only when visibility was deemed possible, would the court be in session on the 30th day to accept witnesses. Now a lunar visibility theory is no trifling matter: Greek mathematical astronomy, which reached its culmination in the Almagest of Ptolemy, shows no trace of such a theory4. It is to be expected, then, that some scholars would find Maimonides' assertion startling5. Their skepticism is fueled, no doubt, by the apparent lack of evidence—in talmudic and midrashic literature—of the existence of a mathematical lunar theory. In this paper, I will show that it is very plausible, perhaps even probable, that the talmudic calendar council (sod ha'ibbur) possessed a lunar theory whose visibility component ultimately reached the hands of Maimonides.

To advance our thesis, I will present and analyze both the Maimonidean

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1 See note 66 below. “C.E.” stands for Common Era, of which the present year is 1987.
2 The best edition of the Code of Maimonides is Mishneh Torah, Vol. 2: Sefer zemanim, Shabse Frankel, Jerusalem 5735 (1975); it contains variant readings from manuscripts and early editions. The English translation by S. Gandz was published as The Code of Maimonides, Sanctification of the new moon, Yale Univ. Press, New Haven, 1956; it contains an introduction by J. Obermann and an astronomical commentary by O. Neugebauer. For the quotations in this paper I found it preferable to do my own translating from the Hebrew.
3 All references to Maimonides are to chapter and section of Sanctification.
5 Obermann2, p. xvii.
evidence, and the midrashic-talmudic evidence. First of all, it will be demonstrated that MAIMONIDES’ visibility theory itself (Ch. 17) points to a Jewish source dating back to the period when the new moon was determined by observation. But the main task of this article will be to uncover and analyze Hebrew mathematical astronomy from the talmudic period (1st through 5th centuries), most of which has been overlooked until now.

The most direct link is a midrashic visibility parameter which, as I will show in Section 2, is in complete accord with MAIMONIDES’ visibility criterion; but the main extant body of ancient Jewish mathematical astronomy is found in the first half of Baraitha diShmuel (BdS), which probably dates from the talmudic period, as we shall see in Section 3. Although first published in 1861, its importance for the history of Jewish astronomy has not been noticed until now. Its Babylonian-type arithmetical methods, which are couched in somewhat obscure verbal form, will be elucidated in Section 3; only since the publication, in the last few decades, of many texts in Babylonian and ancient Indian astronomy, could the astronomy of BdS be properly analyzed and appreciated. In Sections 4 and 5, I will discuss additional midrashic parameters, and evaluate the pertinent talmudic evidence. The picture that will emerge is that Hebrew mathematical astronomy was practiced in the talmudic period, and that significant traces of it have remained in spite of the inherent secrecy connected with the *sod ha’ibbur*.

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2. The visibility criterion

The lunar theory which MAIMONIDES presents in Chapters 11–16 and Chapter 19 is based on the exposition of Ptolemaic astronomy by Muslim astronomers, notably AL-BATTANI. This was demonstrated by NEUGEBAUER and is alluded to by MAIMONIDES himself in 17: 25. But the question of his sources for Chapter 17, which gives the actual procedure for determining visibility or invisibility, is a different matter, as we shall see below.

Of special interest in Chapter 17 is the visibility criterion, which can be summarized as follows: let $\lambda_1$ denote the true elongation for the evening in question, and let $b$ be the “arc of vision”$^{8a}$, i.e., the length of the equator arc which sets between sunset and moonset of that evening. Then the moon will surely be invisible if $\lambda_1 \leq 9^\circ$, and surely visible if $\lambda_1 > 15^\circ$, provided the moon is in the spring semicircle. For the autumn semicircle, the corresponding limits are given as $10^\circ$ and $24^\circ$ (17: 3, 4). When $\lambda_1$ is between the above limits, then we have

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6 As we shall see below, the basic direction has been pointed out by NEUGEBAUER.
7 *Baraitha diShmuel*, Saloniki 5621 (1861).
8a “Arc of vision” is GANDZ’S translation of MAIMONIDES’ qesheth rē'iyah. It should not be confused with the term arcus visionis.