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1949

RSO XXIV 92-94

ASTRONOMICAL FRAGMENTS IN GALEN'S
TREATISE ON SEVEN-MONTH CHILDREN

R. Walzer published in vol. XV of this journal¹ an interesting article *Galens Schrift "Ueber die Siebenmonatskinder"* in which he made available, together with a German translation, the complete Arabic text of a short treatise of Galen which was until then only known in a fragmentary Greek version. This treatise contains several astronomical references, among which two concern the work of Hipparchus. Because a collection of fragments of the astronomical writings of Hipparchus is a much needed desideratum for the historian of ancient science it seems to me desirable to clarify as much as possible the details in these references.

From p. 347, and from p. 350, 214 ff. we know that according to Hipparchus half a year contains 182 days 15 hours "and a little fraction of about one 24th of an hour". This would correspond to a year of $365 \frac{1}{4} + \frac{1}{288}$ days. The *Almagest*, on the other hand, has preserved for us a direct quotation from Hipparchus's book on the length of the year where it was stated that a tropical year contains $365 \frac{1}{4}$ days minus "about $\frac{1}{300}$ " of a day (*Almagest* III, 1, 207, 24 f., Heiberg). If Galen, as is plausible, was really quoting from Hipparchus, one must assume that he erroneously added instead of subtracting. On the other hand the assumption of a year of more than $365 \frac{1}{4}$ is not isolated in the Greek tradition. For instance Vettius Valens IX, 11 (353, 10 ff. Kroll = CCAG 5,2, p. 127, 17 ff.) quotes several values exceeding $365 \frac{1}{4}$. Especially the Βαβυλώνιοι are mentioned with a year of $365 \frac{1}{4} + \frac{1}{144}$. This is twice the excess mentioned by Galen and agrees exactly with the value for the sidereal year deducible from Hipparchus's constant of precession.

We now can turn to the question of the length of the synodic month. Both the Greek and the Arabic texts are corrupt where they state the excess of a (mean) synodic month over $29 \frac{1}{2}$ days. The Greek text has (p. 354, 19 f.).

$$\frac{1}{30} + \frac{1}{20} + \frac{1}{27.000} + \text{a small part}$$

¹ *Rivista degli Studi Orientali*, XV (1935), 323-357.

whereas the Arabic version gives (p. 342 lines 195 ff.)

$$\frac{1}{372} + \frac{1}{27.000} + \text{a very small part.}$$

- Both texts agree that this accurate value is due to Hipparchus and that the small remainder is not worth mentioning.

Walzer followed Schoene in emending the τριακοστόν ($\frac{1}{30}$) of the Greek text to τριακοσιστόν ($\frac{1}{300}$). He furthermore assumes a missing seven and thus restores

$$\frac{1}{327} + \frac{1}{27.000}$$

The same restoration he obtains for the Arabic text by assuming a permutation of 27 into 72. He thus obtains for the mean synodic month the value $29^d 12^h 44.037^{\text{min}} 3 \frac{1}{5}^{\text{sec}}$, which he finds in sufficiently good agreement "mit dem von Rehm ... mitgeteilten Wert von $29^d 12^h 44^{\text{min}} 31 \frac{1}{3}^{\text{sec}}$ ". Unfortunately Walzer committed an error in determining the decimal point when he transformed $\frac{1}{327}$ day into minutes. The result is not 44.037^{min} but 4.4037^{min} .

In order to restore the text correctly we must start from the correct value for the length of the mean synodic month as it was used by Hipparchus, his Babylonian predecessors, and by astronomers of the Middle Ages¹. This value, expressed in days and sexagesimal fractions² of a day, is

$$29; 31, 50, 8, 20.$$

The excess beyond $29; 30$ days is consequently $0; 1, 50, 8, 20$. Because $0; 0, 0, 8 = \frac{1}{27.000}$ and $0; 0, 50 = \frac{1}{72}$ we see immediately that we should expect

$$\frac{1}{60} + \frac{1}{72} + \frac{1}{27.000} + \text{a small fraction}$$

where the "small fraction" stands for $0; 0, 0, 20 = \frac{1}{648.000}$. Consequently the $\frac{1}{72}$ of the Arabic text and the $\frac{1}{27.000}$ of both versions are correct. The error of the Arabic text in writing 300 instead of 60 is explained simply enough by assuming that the original manuscript used

¹ KUGLER, *Babylonische Mondrechnung*, p. 24 and p. 111. GEMINUS, *El. astr.*, VIII, 43 (116,22 f. Manitius). PTOLEMY, *Almagest*, IV, 2 and IV, 3 (271,11 and 278,5 f. Heiberg). Al-BIRUNI, *Chronology*, VII (143,24 tr. Sachau). MAIMONIDES, *Mishnah Torah, Kiddush Hachodesh*, VI, 3. Cf. also FELDMAN, *Rabbinical mathematics and astronomy*, London 1931, p. 123; S. GANDZ, *Complementary fractions in Bible and Talmud* (Am. Ac. Jewish Research, 1945, p. 148). This list makes no claim of completeness.

² Notation: numbers preceeding the semicolon are integers, numbers following the semicolon are sixtieths and sixtieths of sixtieths etc. Thus $0; 1,50 = \frac{1}{60} + \frac{50}{3600}$.

number signs instead of spelled-out words. It would follow that we are dealing with the erroneous writing of $\frac{1}{3} = 300$ ش for $s = 60$ می. Hence the Arabic texts undoubtedly agreed with the classical value for the length of the synodic month.

It is clear that also the Greek text must have had an expression for $\frac{1}{60} + \frac{1}{72}$ which was distorted into $\frac{1}{30} + \frac{1}{20}$. That these values are incorrect is obvious for two reasons. First, their total is $0;2 + 0;3 = 0;5$ thus much larger than $0;1,50$. Secondly, the smaller fraction should follow, not precede, the bigger fraction. Also Schöne's emendation to $\frac{1}{320}$ leads to the totally wrong result $0;0,11,15$ which is not surprising in view of the fact that Schöne thought that he was dealing with the sidereal year (!) and not with the synodic month¹. The real explanation of the preserved numbers 30 and 20 seems to me to lie in the ordinary use of sexagesimal fractions. The original value in Hipparchus's text was, as we have seen, $29;31,50,8,20$. Galen, or a later copyist, wanted to translate this technical writing into popular language. The main part $29;30 = 29 \frac{1}{2}$ days was mentioned before. In the remainder $0;1,50,8,20$ he dropped the last $0;0,0,0,20$ as being "a very small fraction". Then he replaced $0;0,0,8$ correctly by $\frac{1}{27.000}$. Finally he expressed $0;1,50$ as "a sixtieth of a day and $\frac{5}{6}$ (of a sixtieth)". The ordinary writing for $\frac{5}{6}$ is either $\frac{1}{2} + \frac{1}{3}$ or, using sexagesimal fractions, $\kappa' \lambda'$ (corresponding to our notation $0;30 + 0;20$) which is exactly the arrangement in our text. Some editor misinterpreted $\kappa' \lambda'$ as $\frac{1}{30} \frac{1}{20}$ and wrote *τριακοστόν και εικοστόν*. Thus the only error in the archetype of the Greek version consists in the omission of a word or, more likely, of a symbol for a sixtieth. The only difference between Greek and Arabic version consists in replacing $\frac{5}{6}$ of $\frac{1}{60}$ by the equivalent $\frac{1}{72}$ but both represent the same well-known value for the length of the synodic month.

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¹ H. SCHÖNE, *Galens Schrift über Siebenmonatskinder. Quellen und Studien z. Gesch. d. Naturwiss. u. d. Medizin*, 3,4 (1933), p. 137 [345].