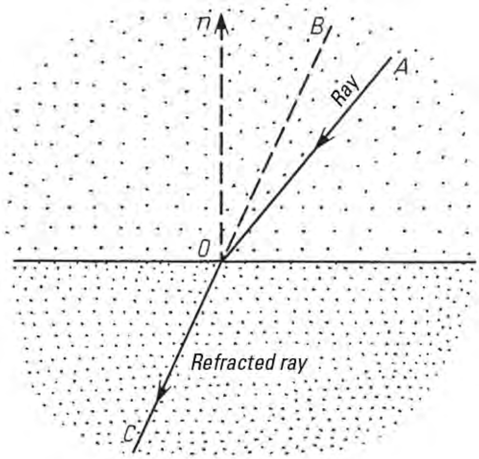

Fig. 2.19. Refraction of a ray of light at the boundary between two different environments.

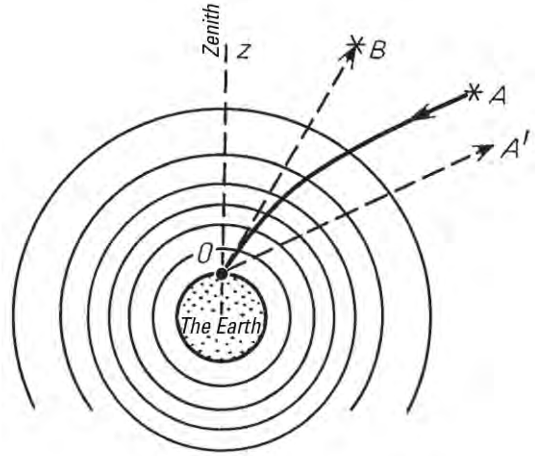

Fig. 2.20. Atmospheric refraction can distort the visible position of a star on the celestial sphere.

The closer a star happens to be to the horizon, the longer it will take a ray of light to get through the atmosphere of the Earth and the greater the "elevation" of the star. However, if the star is situated high enough, the distortion of its position shall be negligibly small. The theory of refraction has an approximated expression that characterises the refraction of zenith distances – namely, stellar zenith distance ζ, or the angle between the direction of zenith at the point of observation and the star direction, minus the value approximately expressed in the following formula (for $\varsigma < 70°$):

$$\rho = 60'' \frac{B}{760} \cdot \frac{273°}{273° + t°} \tan\zeta.$$

ζ stands for the zenith distance, *B* is the height of the barometer's mercury column at the moment of observation rendered to 0° centigrade, and *t*° is the air temperature in degrees (centigrade) at the observation location. The above formula demonstrates that the main variable component that affects refraction is tanζ. If the zenith distance is small (and the star is high enough above the horizon), the value of tanζ is small also, and the refraction is insignificant.

As the stars get closer to the horizon, the value of component tanζ grows, and refraction distorts stellar coordinates to a greater extent. This must be the reason why southern stars, which hang low above the horizon, were measured rather badly in the Almagest and the ancient catalogues in general.

We have already been confronted by this fact in section 3, having witnessed the fact that the percentage of poorly identifiable stars in regions *C* and *D*, which correspond to the southern part of the celestial sphere, happens to be much higher than in regions *A* and *B*.

It would be apropos to remark that the phenomenon of refraction was unknown to the ancient astronomers, and even upon its discovery the precise compensation of refraction remained a formidable problem – one that was only successfully solved in the epoch of Tycho Brahe. However, as it is mentioned in [65] (page 129), Tycho Brahe's compensation calculations were "rather far from perfection".

5. THE ANALYSIS OF THE INFORMATA DISTRIBUTION ACROSS THE ALMAGEST CATALOGUE

Table 2.2 contains the information about the distribution of the *informata* across the Almagest constellations. The table demonstrates that many constellations possessed no *informata* at all – namely, only 22 Almagest constellations out of 48 possess *in-*

formata. What is reflected in the presence or absence of *informata* stars in a given constellation? There may be many opinions on this issue. The one we consider to be the most plausible is as follows (it can be formulated in brief as the following hypothesis):

The *informata* were only indicated for the constellations that Ptolemy believed to be the most important.

In other words, the very presence of *informata* in a constellation signifies that the astronomer was particularly interested in said constellation.

It is possible that certain constellations were of particular importance and therefore marked as such on the celestial sphere. We do not ponder the reasons why there was an emphasis on these constellations – these reasons are of no importance to us and may have been of an astrological nature, for example. The stars of such constellations would therefore be measured several times for greater observation precision. Also, it might be that the observer, upon listing the stars that form the actual constellation figure, or the stars of the "pure" constellation in our terminology, added some of the "background stars" thereto – that is to say, the stars that do not constitute the constellation's skeleton, but rather happen to be located in its immediate vicinity. This is how the *informata* may have come into existence.

As we already know, these stars (most probably regarded as "secondary") could be measured worse on the whole than the stars of the main constellation.

It would be interesting to observe the distribution of the *informata* across the star chart of the Almagest.

In order to provide a quantitative characteristic of this distribution, let us do the following. We shall calculate she share of the *informata* stars for each of the Almagest constellations – otherwise, the value of $c = (a / b) \times 100\%$, where a stands for the number of *informata* stars and b for the full number of stars in a constellation with the *informata* added thereto.

Thus, if there are no *informata* stars in a constellation, $c = 0$. Next let us calculate the full share of *informata* in all constellations, which constitute a separate group. We are referring to constellation groups *A, B, M* etc.

Therefore, for each of the seven regions of the star chart discovered above we shall calculate a certain quantitative characteristic – the average share of *informata* stars in a given group. The higher the share, the more stars ended up as *informata*.

The result is represented graphically in fig. 2.21. We are following the same principle here as in fig. 2.17, namely, placing the numbers of Almagest constellations grouped by region (seven regions all in all, qv in fig. 2.17) on the horizontal axis. The average share of stars in the *informata* is indicated on the vertical axis. As a result, there is a horizontal segment that corresponds to each area.

The information in fig. 2.21 has the following important implication.

Corollary 1. The distribution of "*informata* density" in the Almagest star catalogue is in perfect concurrence with the distribution of dubiously identified stars in the "pure" constellations of the Almagest.

The same corollary can be reformulated as follows. The more attention was paid to one of the constellation groups by the compiler of the catalogue, the more trustworthy the identity of the stars in this group.

Indeed, as we can see in fig. 2.21, the highest density of the *informata* can be observed in region *Zod A*. Next we have region *A*. Furthermore, region *A* was

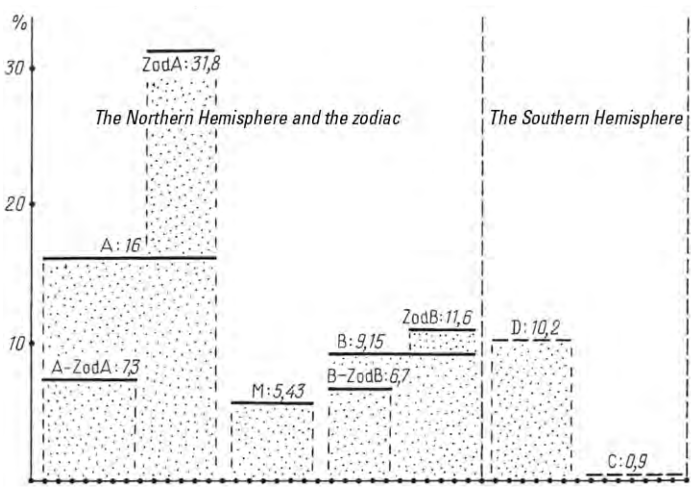

Fig. 2.21. The distribution of "*informata* density" in the Almagest star catalogue. We can see that this density is in perfect concurrence with the distribution of dubiously identified stars in the "pure" constellations of the Almagest.

clearly studied more attentively than region *B*. Region *M* was the least accurately measured part of the Northern Hemisphere. Regions *A* and *B* were observed with greater diligence than region *M*.

The least attention was paid to region *C* in the Southern Hemisphere. Although region *D*, also located in the Southern Hemisphere, enjoyed more attention from the part of the Almagest's compiler (poorly identifiable stars amounting to 10.2% here), this wasn't the case with region *C* (see fig. 2.17). Little wonder – regions *C* and *D* comprise the southern part of the Almagest star atlas, which is characterised by lower observation precision on the whole than the stars of the Northern Hemisphere and the Zodiacal constellations, as we have already mentioned repeatedly. Therefore, southern regions *C* and *D* must henceforth be considered separately and cannot be used in any conjectures due to low observation precision.

Thus, figs. 2.17 and 2.21 lead us to an important conclusion.

Corollary 2. The above analysis confirms the previously discovered division of the Almagest star atlas into seven regions of "varying precision". Observation precision for each of them is proportional to the amount of attention paid to this region. We are primarily referring to the Northern Hemisphere and the Zodiac. The higher the density of the *informata*, the better the measurements of the stars and the higher the percentage of reliably identifiable stars. The lower the density of the *informata*, the smaller the value corresponding to the percentage of reliably identified and "recognizable" stars. Detailed numeric data concerning individual Almagest constellations is cited in table 2.4 of Section 6, and this is the source that the reader may refer to. The share of *informata* is indicated for each and every constellation.

6. THE ANALYSIS OF THE COORDINATE VERSIONS AS SPECIFIED IN DIFFERENT MANUSCRIPTS OF THE ALMAGEST CATALOGUE. Comparison of the 26 primary manuscripts to the canonical version of the catalogue

The work of Peters and Knobel ([1339]) contains Table IX, where we see data that are at odds with the commonly used canonical version of the catalogue. These variances were discovered in the 26 primary "ancient" manuscripts of the Almagest. Table IX in [1339] contains all such versions. The following manuscripts were used in its compilation (see Chapter 11 for an exhaustive list of sources):

Greek manuscripts:
1) Paris 2389,
2) Paris 2390,
3) Paris 2391,
4) Paris 2394,
5) Venice 302,
6) Venice 303,
7) Venice 310,
8) Venice 311,
9) Venice 312,
10) Venice 313,
11) Vatican 1594,
12) Vatican 1038,
13) Vat. Reg. 90,
14) Laurentian 1,
15) Laurentian 47,
16) Laurentian 48,
17) Bodleian 3374,
18) Vienna 14.

Latin manuscripts:
19) Laurentian 6,
20) Laurentian 45,
21) Vienna 24,
22) British Museum Sloane 2795.

Arabic manuscripts:
23) British Museum 7475,
24) British Museum Reg. 16,
25) Bodleian 369,
26) Laurentian 156.

Table IX in [1339] contains 26 vertical columns corresponding to the above manuscripts of the Almagest. Each row of the table corresponds to some star from the catalogue whose coordinates differed from the canonical version. The table makes a very chaotic impression, since the versions are distributed randomly.

We must point out an important detail. Numbers (or versions) found in a single line of the table may coincide with each other, which means that several manuscripts contain the same version (of the star's longitude, for instance) that differs from the canonical version.

Let us consider an example, assuming that the longitude of 16°10' is mentioned four times in a single table row, whereas the longitude of 16°20' is indicated in seven table cells. If we are to assume further that there are no other longitude versions in said table row, there will be exactly two longitude values that differ from the canonical in all 26 abovementioned manuscripts. We have simply considered the number of versions here, regardlessly of the number of repetitions – a more in-depth study would be very useful indeed. The total number of different stellar longitude versions (with repetitions) apparently equals 7 + 4 = 11.

Both numeric characteristics are important to us. The former is geometric and demonstrates the number of different dots, or stars, which have to be drawn on the celestial sphere in order to account for all the versions of this star's coordinates contained in the manuscripts. The second characteristic corresponds to manifestation frequency of a given version. It is obvious that the more manuscripts insist on a single version, the more reasons there are to try and find out why this particular version happens to be so popular.

Table IX is very voluminous as per [1339], and so there is hope of finding certain tendencies that will be useful to our research.

According to the Scaligerian viewpoint, the versions collected in Table IX ([1339]) result from scribes' errata that have accumulated over the centuries as the Almagest was copied many a time. The original of the Almagest is presumed to have been lost a long time ago, and has only reached us as several mediaeval copies. Each of the following copyists introduced new errata while copying the previous copy. As a result, we have several versions of the catalogue today. Of course, there could be errors made in the course of copying, since digits were transcribed as letters back then. Some letters can easily be confused for each other. This would lead to a certain distortion of the original numeric material. To sum up, we could say that Scaligerian history considers the differing manuscripts of the Almagest and its catalogue to be nothing but mechanical copies introduced by different scribes. Each of these copies is presumed to be the end product of a certain "copy tree" rooted in the lost original of the Almagest.

At the same time, it is possible that the catalogue wasn't merely copied, but rather complemented by new observations conducted in the epoch of the scribe. New coordinates could be introduced into the catalogue as a result – the ones that the mediaeval researcher believed to be more precise than the originals. It is therefore possible that the surviving versions of the catalogue have reflected both kinds of discrepancies – mechanical errata of the scribes as well as the results of independent star observations and repeated coordinate measurements. Which versions constitute the majority? Which of the two versions that we formulate below happens to be closer to the truth?

1) Contradictory versions we have at our disposal today are nothing but errata introduced by the scribes.

2) Discrepancies between versions are primarily a result of repeated independent measurements of star coordinates conducted by a single observer (or group of observers) during a single epoch. The estimation of the epoch is a separate task.

In other words, is it possible that the differing versions we have today aren't necessarily copies of the source catalogue – some are "drafts", which were used for the compilation of the catalogue's final canonical version. In order to find out which of the two postulations is closer to the truth, we have processed table IX in [1339] and collected the results in table 2.4. Let us comment on the principle of our table's construction. It contains seven columns and 48 rows.

The *first column* contains the constellation numbers according to the list in the Almagest.

The *second column* contains the name of the constellation (with the sum total of stars in the constellation indicated in parentheses).

In the *third column* we have the number of stars in the *informata* of the constellation in question (with 0 used for constellations without the *informata*). The percentage value of stars in a constellation comprised by the *informata* is indicated as well.

In the *fourth column* we see the full number of versions for longitudes and latitudes, as well as repetition frequency per single version (for the entire constellation with the *informata* included.

The *fifth column* corresponds to the full number of

Constellation numbers in the Almagest	*Name of constellations and the amount of stars in "pure" constellations (without informatae)*		*Amount of stars in an informata and its percentage in comparison with the constellation with its informata included*		*Number of options for latitudes and longitudes in a constellation with informata*			
					Full number		*Average number*	
					with miltiplicities	*w/o miltiplicities*	*with miltiplicities*	*w/o miltiplicities*
1	Ursa Minor	(7)	1	(12.5%)	73	29	9.1	3.63
2	Ursa Major	(27)	8	(22.8%)	227	103	6.49	2.94
3	Draco	(31)	0		150	89	4.84	2.87
4	Cepheus	(11)	2	(15.4%)	60	29	4.62	2.23
5	Bootes	(22)	1	(4.3%)	132	55	5.74	2.39
6	Corona Boreal.	(8)	0		25	17	3.13	2.13
7	Hercules	(29)	1	(3.3%)	202	79	6.73	2.63
8	Lyra	(10)	0		49	22	4.9	2.2
9	Cygnus	(17)	2	(10.5%)	95	45	5	2.37
10	Cassiopeia	(13)	0		60	28	4.62	2.15
11	Perseus	(26)	3	(10.3%)	87	49	3	1.69
12	Auriga	(14)	0		68	35	4.86	2.5
13	Ophiuchus	(24)	5	(17.2%)	213	85	7.34	2.93
14	Serpens	(18)	0		92	36	5.11	2
15	Sagitta	(5)	0		43	12	8.6	2.4
16	Aquila	(9)	6	(40.0%)	49	36	3.27	2.4
17	Delphinus	(10)	0		72	33	7.2	3.3
18	Equuleus	(4)	0		6	5	1.5	1.25
19	Pegasus	(20)	0		68	39	3.4	1.95
20	Andromeda	(23)	0		78	39	3.39	1.7
21	Triangulum	(4)	0		9	5	2.25	1.25
22	Aries	(13)	5	(27.7%)	83	41	4.61	2.28
23	Taurus	(33)	11	(25.0%)	259	110	5.89	2.5
24	Gemini	(18)	7	(28.0%)	192	60	7.67	2.39
25	Cancer	(9)	4	(30.7%)	107	44	8.23	3.38
26	Leo	(27)	8	(22.8%)	170	83	4.86	2.37
27	Virgo	(26)	6	(18.7%)	207	87	6.47	2.72
28	Libra	(8)	9	(52.9%)	85	39	5	2.3
29	Scorpius	(21)	3	(12.5%)	56	31	2.33	1.3
30	Sagittarius	(31)	0		179	67	5.77	2.16
31	Capricornus	(28)	0		217	85	7.75	3.04
32	Aquarius	(42)	3	(6.6%)	207	109	4.6	2.42
33	Pisces	(34)	4	(10.5%)	246	96	6.47	2.53
34	Cetus	(22)	0		130	54	5.91	2.45
35	Orion	(38)	0		212	96	5.58	2.53
36	Eridanus	(34)	0		210	81	6.18	2.38
37	Lepus	(12)	0		71	36	5.92	3
38	Canis Major	(18)	11	(37.9%)	88	38	3.03	1.31
39	Canis Minor	(2)	0		12	5	6	2.5
40	Argo Navis	(45)	0		250	100	5.56	2.22
41	Hydra	(25)	2	(7.4%)	209	73	7.74	2.7
42	Crater	(7)	0		33	18	4.71	2.57
43	Corvus	(7)	0		20	17	2.86	2.43
44	Centaurus	(37)	0		179	70	4.84	1.89
45	Lupus	(19)	0		133	57	7	3
46	Ara	(7)	0		70	24	10	3.43
47	Corona Austr.	(13)	0		85	31	6.54	2.38
48	Pisces Austr.	(12)	6	(33.3%)	72	36	4	2

Table 2.4. Number of options for stellar coordinates in different constellations of the Almagest.

versions for longitudes and latitudes without repetitions given for the entire constellation, *informata* included.

The *sixth column* is the average number of different longitudinal and latitudinal values with number of repetitions (per constellation, whole, *informata* included).

The *seventh column* is the average number of different versions (longitudes and latitudes) – taken without repetitions for the entire constellation, *informata* included.

Let us comment the resulting table. The third column serves as the basis of fig. 2.21, which we discuss at length in Section 5. Values from this column correspond to informata density distribution in the Almagest star atlas.

The principle behind the calculation of values from columns 4 and 5 is obvious enough. We counted the full number of variations for every star in a given constellation, with all the repetitions included. The results for all stars in this constellation were subsequently added up. Let us emphasise that our current objective is to study the distribution of coordinate variations across the entire catalogue. We see that the Almagest constellations are anything but uniform in this relation. Some constellations are poor in variance. It has to be said that we did not consider longitudes and latitudes separately in this research, but rather studied their sum characteristics for more confident statistical corollaries.

7. VERSION DENSITY AS THE DENSITY OF INDEPENDENT STAR OBSERVATIONS. Seven areas of the Almagest star atlas revisited with a new concurrence with the previous results

In order to make conclusions from table 2.4 we shall perform an additional simple operation – namely, calculating the average amount of stellar coordinate versions for all of the seven areas of "varying precision" on the Almagest star chart as listed above. For this purpose we shall divide the rows of the last two columns of table 2.4 into seven groups (*A, B, M* etc), and then average the values from a single group. The result is presented as table 2.5. The fourth row of the table provides the basis for fig. 2.21 and shows the *informata* percentage for every celestial region.

The last two lines of table 2.5 are the most important for table 2.5. The fifth line shows the version density with multiplicities taken into account, whereas the sixth provides the same information without multiplicities, or repetitions. Let us turn to fig. 2.22 for a more demonstrative representation of these data. The horizontal line contains numbers of the Almagest constellations grouped by the seven areas of the star chart, see fig. 2.17. In the vertical we see the average amount of versions for each of these areas.

Tables 2.5 and fig. 2.22 lead us to the following corollaries:

Parts of the Almagest's celestial sphere	*A*	*B*	*A w/o ZodA*	*B w/o ZodB*	*ZodA*	*ZodB*	*M*	*D*	*C*
Number of constellations in an area	14	12	8	6	6	6	7	7	8
Compounds of an area (constellation numbers according to the Almagest)	1-8, 24-29	16-23, 30-33	1-8	16-21	24-29	22, 23, 30-33	9-15	34-38, 47, 48	39-46
Informata percentage in an area	16	9.2	7.3	6.7	31.8	11.6	5.4	10.2	0.9
Average number of versions for latitudes and longitudes (with multiplicities)	5.72	4.68	5.69	3.5	5.76	5.85	5.5	5.31	6.09
Average number of versions for latitudes and longitudes (without multiplicities)	2.53	2.23	2.63	1.96	2.41	2.49	2.29	2.29	2.59
Northern constellations and the zodiac							Southern constellations		

Table 2.5. Average number of versions for latitudes and longitudes in the Almagest constellations.

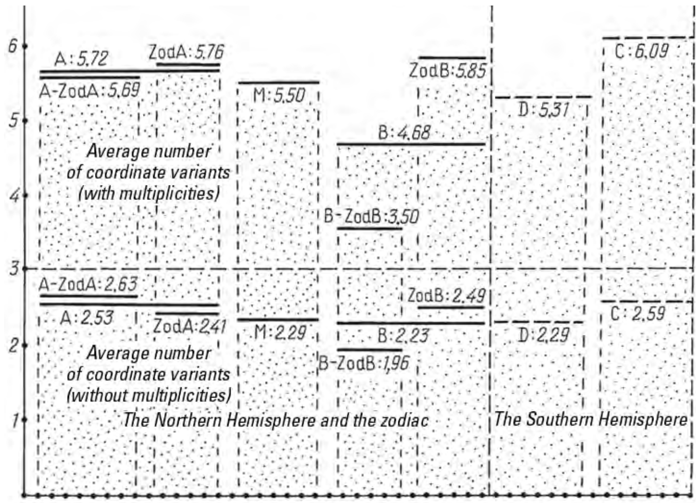

Fig. 2.22. Density distribution of stellar coordinate version numbers in the Almagest catalogue. Densities are given with and without multiplicities.

Corollary 1. The version density graph with multiplicities concurs well to the one without them.

This implies that the logical patterns listed below manifest in both graphs. Let us point out that the density graph without multiplicities has smaller amplitude fluctuations as compared to the density graph that accounts for multiplicities. This is quite natural, since when one includes them, the density fluctuations are observed more realistically; fig. 2.22 demonstrates precisely this.

Corollary 2. Star coordinate density on the Almagest star atlas concurs perfectly with the distribution of the reliably identified stars in pure Almagest constellations as well as the *informata* density distribution.

We present the information which concerns the distribution of said densities as four tables – 2.6, 2.7, 2.8 and 2.9. Table 2.6 demonstrates the distribution of safely identifiable stars in the pure constellations of the Almagest. The rows and the columns of the table correspond to the following regions that we discover on the Almagest chart: *A, B, A* minus *Zod A, B* minus *Zod B, Zod A, Zod B, M, D* and *C*. Three last columns and rows of the table refer to the areas of the Southern hemisphere.

The cells of the table contain + and – signs (or +=/–=, in some cases). Their meaning is as follows. Let us consider the first row of the table, for instance, which corresponds to area *A*. The respective percentage is larger for area *A* than for area *B*; therefore, we put a + on the crossing of the first row and the second column. Furthermore, the percentage is formally greater for area *A* than for *A* minus *Zod A*, but equal to the latter de facto; therefore, we put a += sign into the respective cell; should this percentage prove smaller, we use –; if smaller but equal de facto, –=.

	A	*B*	*A w/o ZodA*	*B w/o ZodB*	*ZodA*	*ZodB*	*M*	*D*	*C*
A	=	+	+=	+	–=	+	+	+	+
B	–	=	–	+	–	–	–	+	+
A w/o ZodA	–=	+	=	+	–=	+	+	+	+
B w/o ZodB	–	–	–	=	–	–	–	–=	+
ZodA	+=	+	+=	+	=	+	+	+	+
ZodB	–	+	–	+	–	=	–=	+	+
M	–	+	–	+	–	+=	=	+	+
D	–	–	–	+=	–	–	–	=	+
C	–	–	–	–	–	–	–	–	=

Table 2.6. A comparison of the percentage of reliably identifiable stars in the pure constellations of the Almagest (without informata) for different parts of the celestial sphere.

	A	B	A w/o ZodA	B w/o ZodB	ZodA	ZodB	M	D	C
A	=	+	+	+	–	+	+	+	+
B	–	=	+	+	–	–	+	–=	+
A w/o ZodA	–	–	=	+	–	–	+	–	+
B w/o ZodB	–	–	–	=	–	–	+=	–	+
ZodA	+	+	+	+	=	+	+	+	+
ZodB	–	+	+	+	–	=	+	+	+
M	–	–	–	–=	–	–	=	–	+
D	–	+=	+	+	–	–	+	=	+
C	–	–	–	–	–	–	–	–	=

Table 2.7. A comparison of informata density for various parts of the Almagest star atlas.

	A	B	A w/o ZodA	B w/o ZodB	ZodA	ZodB	M	D	C
A	=	+	+=	+	–=	–=	+	+	–
B	–	=	–	+	–	–	–	–	–
A w/o ZodA	–	+	=	+	–=	–=	+	+	–
B w/o ZodB	–	–	–	=	–	–	–	–	–
ZodA	+=	+	+=	+	=	–=	+	+	–
ZodB	+=	+	+=	+	+=	=	+	+	–
M	–	+	–	+	–	–	=	+	–
D	–	+	–	+	–	–	–	=	–
C	+	+	+	+	+	+	+	+	=

Table 2.8. A comparison of the relative stellar coordinate version numbers for various areas of the Almagest star atlas, with multiplicities accounted for.

	A	B	A w/o ZodA	B w/o ZodB	ZodA	ZodB	M	D	C
A	=	+	–=	+	+	+	+	+	–
B	–	=	–	+	–	–	–=	–	–
A w/o ZodA	+=	+	=	+	+=	+=	+	+	+
B w/o ZodB	–	–	–	=	–	–	–	–	–
ZodA	–	+	–=	+	=	–=	+	+	–
ZodB	–	+	–=	+	+=	=	+	+	–
M	–	+=	–	+	–	–	=	≈	–
D	–	+	–	+	–	–	≈	=	–
C	+	+	–=	+	+	+	+	+	=

Table 2.9. A comparison of the relative stellar coordinate version numbers for various areas of the Almagest star atlas, without multiplicities.

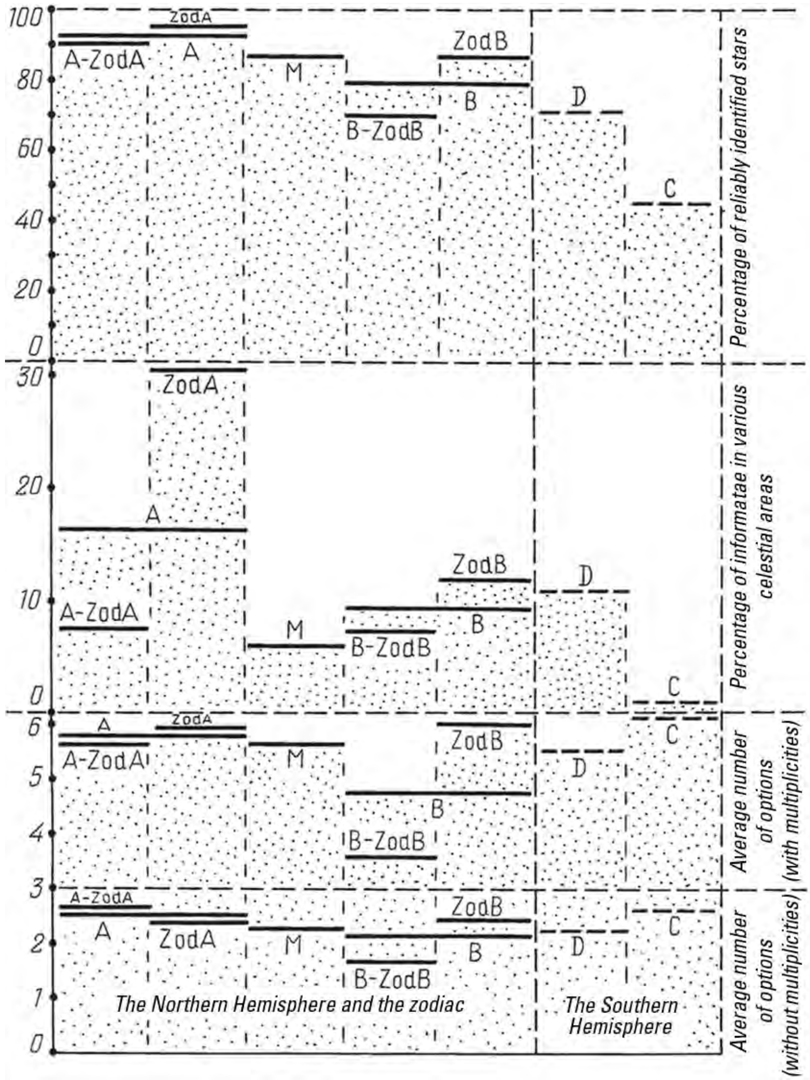

Fig. 2.23. A graph where we simultaneously see the following: 1) the distribution of whatever percentage the reliably identified stars of the Almagest catalogue comprise; 2) the percentage of informatae in various areas of the Almagest's celestial sphere, 3) average number of stellar coordinate options in various manuscripts of the Almagest, with multiplicities, 4) average number of coordinate options, without multiplicities. One can see that all four density graphs for the Northern Hemisphere correlate with each other well.

The implication is that when we look at table 2.6, we can safely tell the comparative percentage of reliably identifiable stars for every area pair. Table 2.6 is a compact representation of density distribution in all of the star chart areas described above.

The next three tables are based on the same principle. Table 2.7 demonstrates the *informata* density distribution for the Almagest star atlas, and table 2.8 gives us an opportunity to compare the version density of the Almagest stellar coordinates for different celestial areas. The versions that constitute this table were calculated with multiplicities, which means that if the same version was encountered several times, the entire amount was accounted for accordingly. If we are to leave multiplicities out, or just count each version once, the result will be a comparative presentation of the relative coordinate version quantity for varying areas of the Almagest star atlas, qv in table 2.9.

Tables 2.6-2.9 make it obvious that the distribution of pluses and minuses is virtually equal, which implies a good correlation between the following four values:

1) the percentage of reliably identifiable stars in a given area of the Almagest star chart;

2) *informata* density in the Almagest star chart area in question;

3) stellar coordinate version density with multiplicities;

4) stellar coordinate version density without multiplicities.

In particular, the higher the *informata* density and the coordinate version density in a given area, the more reliable the identification of the stars located therein.

The implication is that we cannot interpret the coordinate versions presented in the 26 manuscripts of the Almagest exclusively as scribe errors. Had this been the case, this would lead us to the a priori false statement that the error rate growth for a given area results in better star identification. We must therefore reject the hypothesis about this abundance of versions being attributable to the inaccuracy of the scribes. In this case, the only reasonable explanation of the effect discovered can be rendered as follows.

The multitude of different stellar coordinate versions in the Almagest manuscripts results from independent star observations performed several times by an observer, or a group of observers. Due to the imprecision of the instruments used for these observations, the results would often differ from each other. The more measurements of a given star's coordinates were performed, the more versions would get into manuscripts. Therefore, the areas of the star chart with high coordinate version density are the ones whose stars were observed several times with their coordinates measured anew; in other words, these areas enjoyed more of the researchers' attention than the others. It is natural that the more attention a given celestial region got, the more dependable the identifications of the stars it contains. As we shall demonstrate in the subsequent chapters of our book, the coordinates of those stars were indeed measured a great deal better on the average in Ptolemy's epoch.

Thus, if we are to simplify the situation somewhat, one has reasons to presume that the 26 primary manuscripts of the Almagest are for the most part its "drafts" rather than mechanical copies. They were subsequently used for the creation of the final canonical text. The Scaligerian version of these manuscripts' origins does not concur with our conclusion. Indeed, why would mediaeval scribes copy the "drafts" together with the "final version" for centuries of end? It would make a great deal more sense if we are to assume that both date to approximately the same epoch, and the number of copies was far from great. Let us reiterate that observations of this manner shall not be used in our research; they are but a number of naturally arising questions which are to demonstrate several possible explanations of the effect that we discovered, nothing more.

Finally, let us cite fig. 2.23 where we combine all of the above density distribution graphs into one. The dependency between various graphs is obvious.

8. IN RE THE RELIABILITY OF LATITUDINAL AND LONGITUDINAL MEASUREMENTS CONTAINED IN THE ALMAGEST

8.1. According to Robert Newton, the longitudes in the Almagest were re-calculated by somebody; however, this suspicion does not arise insofar as their latitudes are concerned

Let us begin with the commentary in re the Almagest measurement precision made by R. Newton, the astronomer. In general, we are of the opinion that these observations of his are applicable to a wider spectrum of issues. R. Newton actually gives us a very forthright account of a rather meandrous scenario around the readings and interpretations of a great number of "ancient" astronomical documents. He is referring to "the so-called principle of 'error immortalization', which can be formulated as follows. Let us assume that the error of author *A* became published, and a later author *B* is referring to it in some manner deeming the erroneous statement veracious. Thus the error becomes immortalized in scientific literature; erasing it from scientific literature becomes an impossibility. One can hardly be serious about there being no exceptions for this rule; however, there is a great number of examples that do follow this principle – readers are likely to have quite a few such examples of their own" ([614], page 165).

Something similar appears to be happening with the Scaligerian interpretation of the Almagest – its dating in particular. The analysis of the Scaligerian version, which dates it to the beginning of the new era requires a new study of its content. This is a complex scientific problem that requires a great deal of labour. We accomplish a significant part of this task in our research, and the reader has the opportunity to evaluate the complexity of this task. The main difficulty is that one has to get to the very roots of this or the other scientific statement or opinion. It appears that their overwhelming majority was initially made with the a priori or taciturn presupposition that the Almagest dates to an early A.D. century. Our "excavations" required the analysis of source material, which requires a great deal of work by itself.

Let us now get back to the issue of the complexity of latitudinal and longitudinal measurements. In Chapter 1 we already explain that the very nature of the ecliptic and equatorial coordinates allows to measure the latitudes more securely than the longitudes.

Also, the use of an *armilla,* for instance, can generate errors if the astronomer makes an incorrect ecliptic inclination choice. The matter is that the observer has to determine the angle between the ecliptic and the equator and then fix it in order to use the instrument for the measurement of stellar coordinates, for instance, having adjusted it in accordance with the previously found ecliptic inclination. In general, the *armilla* can be adjusted by any object whose latitude and longitude are known. Ptolemy often used the Moon for this purpose. This makes it possible to calculate the coordinates of any other object that might interest us. However, in this case, as R. Newton is perfectly correct to remark, the imprecisions in the determination of the known object's coordinates automatically lead to incorrect calculation of the second object's coordinates ([614], page 151).

It also has to be borne in mind constantly that in case of the Almagest we are dealing with copies where numbers were transcribed as letters. This would frequently cause confusion. For instance, according to the astronomers R. Newton ([614], page 215), Peters and Knobel ([1339]), one could easily confuse the "ancient" Greek digits for 1 and 4 due to the fact that the figure of 1 was transcribed as α, and one of its widely-used old forms was very similar to the letter δ, which stood for 4 – hence the confusion.

One has to make an important observation in this respect. Our research is based on the canonical version of the Almagest star catalogue translated in the work of Peters and Knobel ([1339]). As R. Newton points out, "a careful comparison of various manuscript often reveals the errors made in the process of multiple copying and gives the researcher an opportunity to correct them. Peters and Knobel studied the "Syntaxis" [Almagest – Auth.] with the utmost attention; it is possible that their version of this catalogue is the most precise of all" ([614], page 216).

We shall also be using the detailed analysis performed by the astronomer Robert Newton in the large special chapter IX of his book ([614]) in order to evaluate the reliability of the longitudes and latitudes as given in the Almagest. We shall omit the details pertaining to the statistical analysis conducted by R. Newton and merely cite his results.

R. Newton wrote that "the latitudes in the star catalogue were most probably measured by a single observer employing a single instrument for the purpose" ([614], page 253). Further also: "the latitudes educed from the observations were put down in the catalogue without alterations (it is however possible that there were errors in the transcription)" ([614], page 249). According to R. Newton, the latitudes of the Almagest star catalogue are a reliable enough body of material obtained as a result of actual observations performed by either Ptolemy or one of his predecessors (Hypparchus, for instance). This concurs perfectly well with the information cited above that shows latitudinal measurements to be a lot simpler as a procedure than the longitudinal, therefore, stellar latitude is a more reliably measurable coordinate.

The picture with the longitudes is drastically different. R. Newton claims that "the longitudes weren't deduced from any observations whatsoever … the longitudinal values are fabricated" ([614], page 249). Further also: "the multitude of longitudes contained in the star catalogue is highly unlikely to have been determined from observations" ([614], page 250). We have already explained to the reader that the measurements of ecliptic longitudes prove to be a lot more sophisticated and complex procedure than longitudinal measurements. Furthermore, it is presumed that the longitudes in the Almagest catalogue were rendered to 137 A.D. Such a rendition to an a priori chosen date is quite simple; all it takes is adding some common constant to the ecliptic longitudes of all the stars. This constant is proportional to precession and depends on how much older the compiler of the catalogue really wanted the longitudes to look. R. Newton is of the opinion that the original longitudes obtained by the ancient observer experimentally were subsequently re-calculated anew by someone else. This is his fundamental solution based on the analysis of how frequently degree fractions appear in the catalogue: "Longitudes were altered. Observation results were made greater by several degrees and 40 minutes" ([614], page 249). This operation (an addition of a whole number of degrees whose value could be either positive of negative, with a couple of fractions) could make the catalogue either gain or lose a considerable amount of age at the will of its compiler or forger. Bear in mind that such an operation would be either altogether impossible with latitudes, or a great deal more complicated at the very least. However, we cannot determine how many grades exactly were either added to the initial longitudes or subtracted therefrom if we are to base our research upon nothing but the longitude analysis in the existing copies of the Almagest. R. Newton points out the very same thing: "The actual distribution of grade fractions tells us nothing of just how many grades were added to the initial longitude by Ptolemy" ([614], page 251).

Apart from the simple operation of shifting all the longitudes by an unknown number of grades mentioned above, R. Newton discovered traces of finer longitudinal recalculations ([614], pages 246-247). Thus, someone had conducted an extensive body of work in the field of recalculating the initially observed longitudes. Therefore, the modern list of longitudes that we find in the Almagest does not represent the actual observational material, but rather the likely result of its having been processed in a certain rather complex way which was meant to help meeting a certain end. According to N. A. Morozov, for instance, this end could be formulated as giving the catalogue an arbitrary amount of extra age – in other words, we have a case of falsification. However, we shall refrain from taking any sides a priori and analyze longitudes and latitudes both together and separately.

Let us conclude with another summary made by R. Newton: "We get an altogether different picture from the longitudes [as compared to the latitudes – Auth.]. No colourable explanation can possibly be given to the fraction distribution in longitude, regardless of whether or not the observations were in fact performed by a single person who had used a single instrument for this purpose" ([614], pages 146-247).

8.2. Examples proving that the dating of the star catalogue by longitudinal precession often leads to great errors. Mediaeval catalogues are subject to becoming erroneously dated to an antediluvian epoch

The Scaligerian version of astronomy often uses the following apparently simple method for catalogue dating. The ecliptic longitudes of the old catalogue's stars are compared to the modern longitudes. The resulting difference, which is roughly the same for all the stars, is then divided by the precession value, which equals roughly 50 seconds per year or one degree in 70 years. This is how the historians determine the residual between the dates of the modern catalogue and those contained in the old one. In particular, this method allows to "deduce" the ecliptic coordinates from the 1538 edition of the Almagest as equalling those which roughly correspond to some early A.D. epoch.

However, the "method" described above makes the taciturn implication that the compiler of the old catalogue would count ecliptic longitudes from the vernal equinox point of his era, or the epoch when the star observations were conducted. Had this indeed always been the case, the resulting residual accumulated by today could really be considered a result of precession. Assuming this to be true, the method described above would indeed give us the approximate date of the old catalogue's creation. However, it is important to emphasise that it wasn't in fact a charac-

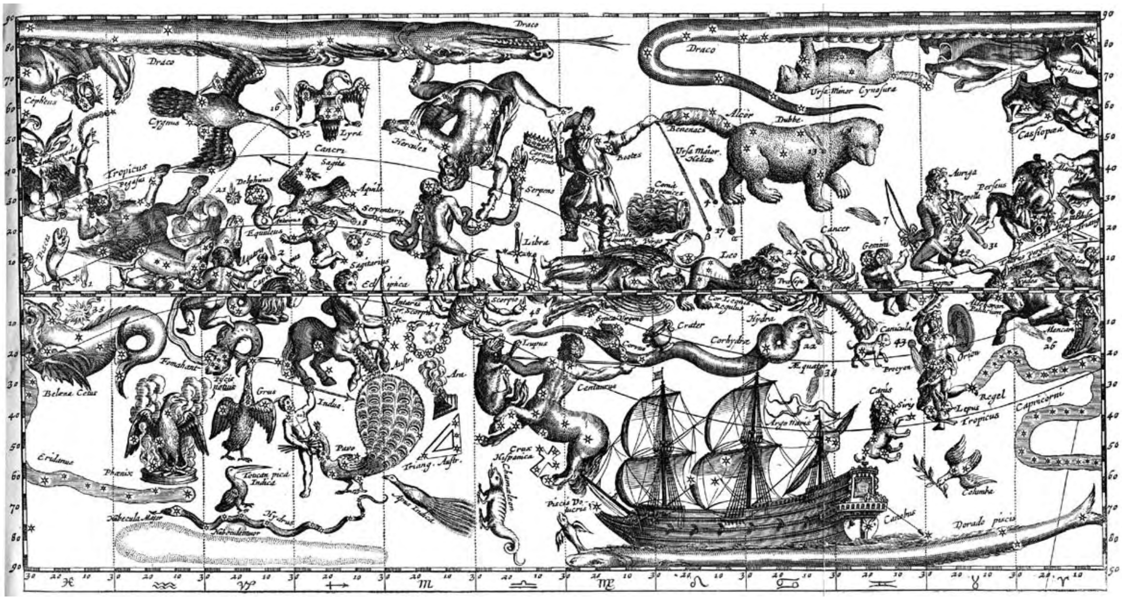

Fig. 2.24. Star chart from a XVII century book by Stanislaw Lubienietski. One sees that the Gamma of Aries was chosen as the initial longitudinal reference point. This is where the equinoctial crosses the ecliptic. Taken from [543], inset between the pages 26 and 27.

teristic of all the ancient authors to use the vernal equinox point of their own epoch for the initial reference point.

Let us linger on the above for a while. One shouldn't get the impression that the astronomers of as recent an epoch as the XVI-XVII century necessarily count the longitudes in the exact same manner as the modern astronomers. We shall refer the reader to the well-known ***Cometography*** by the mediaeval author Stanislaw Lubienietski published in 1681: S. de Lubienietski, ***Historia universalis omnium Cometarum*** ([1257]). This book is a priori known to have been written in the XVII century. It lists many comets observed up until the year 1680. S. Lubienietski, its author, belonged to the XVII century school of astronomers, preceding our time by a mere 300 years. Let's take a closer look at how Lubienietski counts the longitudes on his star charts. We discover that he uses the meridian crossing the γ star from the Aries constellation as the initial celestial meridian, qv in fig. 2.24. The "sine curve" that stands for the equinoctial, or the celestial equator in this projection, is directly referred to as "Aequator" here, which is the legend that we see over the masts of the Argonaut ship from the constellation of Argo Navis, closer to the right end of the map, and once again near the constellation of Ophiuchus near the left end of the map – see fig. 2.24. The ecliptic is represented by a thick horizontal line with degree grades. One can see perfectly well that the ecliptic and the equator cross right where the map boundary is located – at the γ star of the Aries constellation. There can be no doubt about this (see figs. 2.25 and 2.26).

Thus, all the stellar longitudes indicated by S. Lubienietski were smaller than the ones we find in the Greek longitudes from the 1538 Almagest by roughly 7 degrees (see the respective comparative tables as well as the actual charts in [544], Volume 4, pages 233-234, and also [543], inset between pages 26 and 27).

Let us retort to the strange "logic" of the Scaligerite historians which they advocate with such persistence and even obstinacy in their dating of the Almagest by the longitudes of the Greek edition, thereby implying Lubienietski to have counted the coordinates beginning with the vernal equinox point of his epoch. In that case his book will have to be dated to the V century B.C., since this is when "the vernal equinox point was really located near the first stars of the Aries constellation, qv in Lubienietski's case", according to the most apropos comment made by N. A. Morozov [544], Volume 4, page 33. However, Lubienietski's book was written in the XVI century!

The ensuing absurd corollary is yet another proof of how careful one has to be in one's dealings with the "dating method" described above – which, as we feel obliged to reiterate, has always been used by the Scaligerian historians in case of the Greek edition of the Almagest.

All of the above implies lucidly that the astronomers of the XV-XVII century A.D. hadn't yet come to any unified agreement concerning the initial reference point for the longitude count. The unification epoch would come after quite a while. Each astronomer would select his own point of reference guided by considerations of his very own. Lubienietski, for one, used the first stars of the Aries constellation for this purpose. As for the Greek edition of the Almagest, the star coordinates were counted from the meridian that crosses the ecliptic at the point whose longitudinal distance to the γ of Aries equals 6°40'.

Lubienietski's case is by no means unique. The star catalogue compiled by Copernicus provides for a more impressive example. Copernicus also counts the longitudes beginning with the γ of Aries, just like Lubienietski (or, rather, the latter follows the tradition of Copernicus). The only difference is that the γ of Aries occupies the longitude of zero in the catalogue of Copernicus ([1076]). The latter gives its coordinates as equalling 0 degrees 0 minutes of longitude, and 7 degrees 20 minutes of latitude (see [544], Volume 4, pages 224 and 227). Thus, if we decided to "date" the catalogue of Copernicus using the "Scaligerian method" described above, we would also date it to times immemorial, which would be perfectly erroneous since it is presumed that Copernicus had lived in the XV-XVI century (1473-1543).

Thus, the precession of the stellar ecliptic longitudes cannot serve for any secure dating of the catalogue whatsoever.

The varying initial reference points used for longitude count in the works of the XVI-XVII century authors as indicated above shouldn't surprise us at all. There were many different astronomical schools at the dawn of this discipline, which would often compete with each other and adhere to different catalogue compilation rules etc. It is well possible that each school remained loyal to a tradition of its own which specified the rules for choosing the basis points, reference points and so on. The considerations for such a choice may have been astronomical, religious, or of an altogether different nature.

It was only when astronomy developed into a grown science when the necessity of a unified system

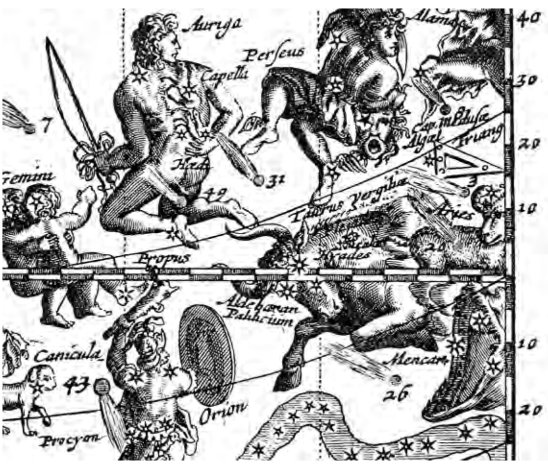

Fig. 2.25. A fragment. Right side of Lubienietski's chart, where the equinoctial crosses the ecliptic near the Gamma of Aries ([1257]). Taken from [543], inset between the pages 26 and 27.

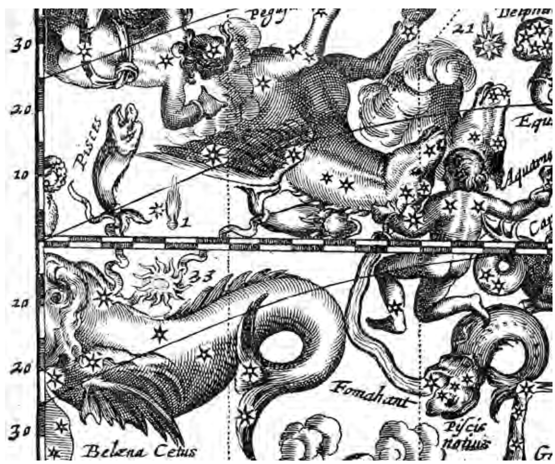

Fig. 2.26. A fragment. Left side of Lubienietski's chart, where the equinoctial crosses the ecliptic near the Gamma of Aries. Taken from [543], inset between the pages 26 and 27.

of indications and concepts was realized that the astronomical language became more uniform. In particular, the vernal equinox point was agreed upon as the initial reference point (an invisible one, as a matter of fact; furthermore, its celestial position changes with the passage of time). This point cannot be affixed to some star located nearby. It is therefore hardly surprising that certain mediaeval astronomers would use an actual star for reference instead of the equinox point – the γ of Aries, for instance.

When we study the Almagest star catalogue in our book (the same is indeed true for other old star catalogues), we make sure our research is in no way dependent on any presumptions that concern the particular longitudinal reference point used by the catalogue compiler. There are no such indications in the actual star catalogues, after all. Our opponents might counter that a direct reference to the choice of the equinox point for the measurement of longitudes can be found elsewhere in the Almagest.

However, if we are to be guided by such notions, it shall imply the use of some "extraneous" or foreign information which, as we must emphasize, is not contained in the star catalogue itself. However, our goal is to date the catalogue by its own internal characteristics without citing any external sources. As for the issue of determining the dating of the remaining texts together with its genesis is a problem of its own, and one that possesses no reliable single solution (see [544] and [614]).

9. THE DUBIOUS NATURE OF THE TRADITIONAL OPINION THAT PTOLEMY'S TEXT IMPLIES ACTUAL "OBSERVATIONS" ON HIS PART, as well as his "personal participation" in the stellar measurements and observations described in the Almagest

Ptolemy's text can by no means imply the veracity of the consensual opinion, namely, that all the observations and measurements that the Almagest contains were performed by the author in person. Its actual text allows for several interpretations. However, what we are most likely to be seeing here represents the research result of a great many astronomers and not a single author's account of his own observations. Apart from that, the Almagest is basically a textbook, or a guidebook for young astronomers and scientists in general that contains descriptions of varying observation methods etc – a mediaeval astronomical encyclopaedia of sorts. Here are a few examples to confirm this. We shall be using Toomer's edition of the Almagest ([1358]).

In his description of the transit circle in Chapter 1, Ptolemy tells us the following: "We made a bronze ring of the fitting size [what size exactly? – Auth.] … in order to use it as a transit circle, wherefore it was graded into 360 parts [degrees]; each of those were divided into as many parts as the instrument's size would allow [How many? – Auth.] … We have further discovered an easier method for conducting such measurements, having forged a stone or wooden wall [?! – Auth.] to be used instead of the rings" ([1358], pages 61 and 62).

What we see here obviously differs from the description of an actual device used for measurements by either Ptolemy alone, or himself and his team. How else could one explains such ambiguity as "fitting size", "as many parts as the instrument's size would allow", or "stone or wooden wall"? Really, was it stone or wooden?

Everything shall fall into place if we are to suppress the inner Scaligerite and realize that what we have in front of us isn't a report made by an observer, but rather an encyclopaedic textbook that explains a potential student or scientist the construction of various instruments; different methods of conducting research etc.

Consider the following passage from the Almagest, for instance: "Before [the reign of] Antoninus, when we conducted the most observations of immobile stars' positions" ([1358], page 328). Scaligerian astronomy reads the implication of Ptolemy claiming personal responsibility for the observations performed at the beginning of the reign of Antoninus Pius into this phrase. The Scaligerian dating of this emperor is 138-161 A.D. However, Ptolemy's phrase is rather vague and allows for different interpretations. Firstly, who are the "we" who conducted the observations? Ptolemy himself or his predecessors from the same scientific school? Furthermore, what exactly do "the most observations" refer to? The use of "we" etc has to be considered a distinctive of the Almagest's author's literary style rather than an indication of his actual participation in the research; it is also possible that the hoaxer editors of the XVI-XVII century were intending to create an impression that what the work in question had been written to relate the research of a single person.

For example, let us take account of the words chosen by Ptolemy as the introduction to the Almagest star catalogue. It would be natural to expect the author/observer who had conducted the research in question himself to provide detailed descriptions of how his research was conducted, which stars were chosen for reference etc. Nothing of the kind. Ptolemy's text is very vague:

"Again, the very same instrument [the astrolabon – Auth.] permits to observe as many stars as humanly possible, including those of the sixth magnitude. We would always direct the first ring at the nearest bright star whose position in relation to the moon would already be calculated by then" ([1358], page 399).

This is followed by the description of the method used for stellar coordinate calculations when the longitude is measured by relatively bright stars, and the latitude in relevance to the astrolabon's ecliptic ring. This description is once again given in rather general terms, followed by the remarkable phrase:

"In order to represent the stars on a solid cosmosphere in accordance with the method described above, we have arranged the stars into a table with four columns" ([1358], page 340). Further on we find explanations of the indications used in the table. The "table" in question is the famous star catalogue. Therefore it turns out that Ptolemy's catalogue was created with the main purpose of using it for the creation of a cosmosphere.

Once again, this resembles a textbook – "in order to make a globe, one has to do this and that". A propos, Ptolemy makes another reference to Emperor Antoninus in his description of the "table", or catalogue: "In the second column one finds the longitudinal value deduced from the research [conducted by an anonymous scientist – Auth.] for the beginning of Antoninus' reign ([1358], page 340).

Once again, one needn't interpret these words of Ptolemy's as evidence of him having personally conducted observations in the epoch of Antoninus. This phrase can also be interpreted in the following manner: a late mediaeval observer rendered the catalogue to the values corresponding with the reign of Antoninus. By the way, the Almagest doesn't give us any datings for the reign of Antoninus. As we already know, the simplest action which can be undertaken in order to render a catalogue to any a priori known ancient epoch's ecliptic coordinates is the subtraction of a suitable constant value from the original longitudes. Furthermore, this explanation of ours is explicitly confirmed by the text of the Almagest! Ptolemy continues his thought right there: "The latitudinal values always remain immutable; as for the longitudinal values [contained in the Almagest catalogue – Auth.], they allow for easy longitudinal calculations for other moments of time as well, for which the distance between the current epoch and the necessary moment in time needs to be recalculated assuming the alteration speed equal to 1 degree every 100 years. The resulting value would then have to be subtracted from that of the current epoch in order to get a date in the past or added thereto for a future date" ([1358], page 340).

Thus, Ptolemy gives a perfectly clear explanation of how one is to shift the star catalogue in time subtracting the constant, which would make it "more ancient", or adding it for the opposite effect. Once again, this is very similar to a textbook that explains the technique of dating and re-dating star catalogues to students. This book may have also been a useful source of all the necessary guidelines in the XVI-XVII century A.D., especially considering as how the construction of a cosmosphere as related in the Almagest does not require absolute longitudinal values – namely, they are counted from an arbitrarily chosen immobile star. Ptolemy suggests to use Sirius for this purpose ([1358], page 405).

Apparently, the absolute values of ecliptic stellar latitudes simply have never been used in Scaligerian astronomy at all. Therefore, the longitudinal reference point could be chosen more or less arbitrarily. Copernicus, for instance, having copied the Almagest catalogue into Volume 6 of his own ***Revolutionibus Orbium Caelestium***, with some circumstantiation, counts latitudes off the γ star of the Aries constellation, which was located at the distance of 27° from the point of vernal equinox in the epoch of Copernicus.

One has to point out that the work of Copernicus, as history of astronomy is telling us, wasn't apparently "appreciated" until a century after his death, in Kepler's epoch, or the XVII century ([614], page 328). See Chapter 10 for more details. One can therefore ask the legitimate question of the exact date when the book attributed to Copernicus nowadays was written or edited. Could it have been the early XVII century and not the XVI – Kepler's epoch, in other words?

10. WHAT ECLIPTIC POINT DID PTOLEMY USE FOR LONGITUDINAL REFERENCE?

As we already know, the choice of the initial longitude count reference point influences the longitudinal precession dating of the catalogue to a substantial extent. Let us conduct a more in-depth study of the question which point of the ecliptic was used by Ptolemy for longitudinal calculations in his catalogue. It is traditionally assumed that he had used the vernal equinox point for this purpose, likewise many late mediaeval astronomers.

It turns out that the initial reference point issue as rendered by Ptolemy is far from simple, and cannot be resolved without controversy if we are to use nothing but the text of the Almagest for that end. Let us turn to the Almagest and provide the relevant quotations.

Ptolemy writes that "we shall be using the names of the Zodiac signs in order to refer to the correspondent twelve parts of the tilted circle which shall begin in the equinox and solstice points. The first twelfth part that begins at the vernal equinox point and whose direction is counter to that of the Universe shall be known as Aries, the next as Taurus …" (II:7 – [704], page 45). The signs in question are merely the arcs of the even Zodiac – not stellar longitudes. Furthermore, when Ptolemy tells us of the longitudes, he describes the second (longitudinal) column of his star catalogue as follows: "In the second column we find their [referring to the stars – Auth.] longitudinal positions educed from observations conducted in the beginning of Antoninus' reign. These positions are located inside the Zodiac signs; the beginning of each Zodiacal quadrant is determined by either a solstice or an equinox point, qv above" (VII:4, [1358], page 340).

Stellar longitudes in the Almagest are indeed indicated separately for every arc sign of the uniform zodiac and counted from the beginning of the respective arc sign. In other words, the stellar longitudes that we encounter in the Almagest should not be considered absolute and are counted off a single chosen point on the ecliptic. Instead of this, the relative longitudes contained by every respective arc sign of the uniform Zodiac are given, totalling to 12. It is also pointed out that one of the quadrants is oriented at the equinox point.

Therefore, the calculation of some absolute longitudinal value requires the addition of a certain integer number of degrees divisible by 30, or the size of a certain arc sign of the even Zodiac. The absolute ecliptic longitudes of the catalogue can only be deduced after this procedure, which is hardly all that complex in principle.

Let us illustrate by the following example. The North Star's longitude in the Almagest is given as Gem 0°10'. In order to calculate the absolute longitude value, we have to add an integer number of degrees to 0°10' that equals 60°, as contemporary tradition suggests. This is the number of degrees believed to correspond to the beginning of the Gem arc sign of the even Zodiac. We shall thus get the value of 60°10'. If we are to consider it to be the ecliptic longitude of the North Star as compared to the vernal equinox point, it shall correspond to the position the latter had occupied in the beginning of the new era.

One observes a perfectly similar situation with the remaining longitudes of the thousands of stars contained in the Almagest catalogue. The simplicity of the abovementioned calculations notwithstanding, one has to point out that this is our first opportunity to misinterpret the source data offered by the Almagest, namely, the fact that the integer degree values corresponding to zodiacal signs depend on the choice of the first arc sign of the even Zodiac, whose beginning coincides with the initial reference point – vernal equinox, or, possibly, some other point on the ecliptic. The alteration of the first Zodiac sign shall apparently alter the absolute degree values added. The vagueness of Ptolemy's phrase leaves plenty of space for interpretation.

As we shall find out, Ptolemy's description of the cosmosphere does not use the vernal equinox point for initial reference. He writes that "as it makes no sense to mark the solstice and equinox points on the globe's Zodiac (since stars maintain no constant distance to these points), we should select a number of fixed immutable reference points among the immobile stars. The brightest of those is the star in the mouth of Canis Major [Sirius, that is! – Auth.] … then for each or the remaining immobile stars in the catalogue [apart from Sirius – Auth.] we must mark its location [longitude – Auth.] rotating the graduated ring around the ecliptic pole – the point that we must mark on this ring's ecliptic is to be at the exact same distance from the reference point that we discovered (Sirius) as lays between the star in question and Sirius in the catalogue" ([1358], page 405).

Thus, Ptolemy gives us a direct reference to Sirius as to a convenient absolute beginning for the ecliptic longitude count. This is completely at odds with the consensual version which tells us that Ptolemy would definitely use the vernal equinox point for reference.

Furthermore, since the Almagest is an astronomical encyclopaedia of sorts, it may have been compiled from the works of various astronomers from different schools in its present form. Therefore, different measurements principles may have been used for different parts of the Almagest – in particular, it is possible that the longitudinal reference point in the Almagest catalogue varies as taken for its different parts.

All of this indicates that the attempts to date Ptolemy's catalogue by longitudinal precession may lead to gravest errors, which is exactly what we see in some modern works on the history of astronomy, qv below.

Other contentious issues arise as well. The quotation mentioned above demonstrates that the creation of a cosmosphere requires circa 1000 astronomical operations – namely, the subtraction of the longitude of Sirius from the longitudes of a thousand other catalogue stars. However, the longitude of Sirius is expressed as a fraction in the Almagest catalogue, namely, 17°40' of Gemini. It is perfectly clear that the operation of subtracting this number from other longitudes a thousand times shall consume a great deal of labour. On the other hand, Ptolemy, who advocated using Sirius for reference, could well have chosen another very bright star – Arcturus. This is a star of great luminosity; most importantly, its longitude is expressed as an integer in the catalogue – namely, 27° of Virgo. Why would one perform a thousand operations with fractions when it would be a lot simpler and less time-consuming to perform the very same operations with degrees expressed as an integer?

One can make the natural presumption that a certain constant value was either added to, or subtracted from, the initial longitudes of the Almagest, which made the longitude of Sirius a fractional value instead of an integer. Therefore, this value had to comprise a certain amount of degrees and 40 minutes, since the longitude of Sirius in the modern version of the Almagest catalogue equals 17° 40'.

This is where we unexpectedly run into a good concurrence with the result of R. Newton ([614]). He proves that the longitudes contained in the catalogue were recalculated by someone, with an indefinite amount of degrees and 40 minutes added to the original longitudinal values, and bases his conclusion on altogether different considerations – those of a statistical nature. We deem such a good concurrence between two varying observations to be anything but random.

One has to make the following general observation, which bears no formal relation to astronomy, but might yet prove useful for our understanding of the role and the place of the Almagest. Modern literature on the history of astronomy gives one the impression that the Almagest chapters dealing with stars are a commentary of sorts, or an annex to the central document, which is the star catalogue. However, we are of a different opinion. The primary content of these chapters is Ptolemy's guidelines for the construction of the cosmosphere whereupon one was to point out the locations of the stars. The actual construction process, the paint one needs to use for the purpose etc are described with great detail; the catalogue itself is but a "reference table" for the construction of the cosmosphere.

It is quite possible that such cosmospheres were used for astrological or mystical purposes in the Middle Ages. The most curious fact is that the history of astronomy has many references to the construction of such cosmospheres – however, this "celestial globe construction epoch" isn't even close to the beginning of the new era, it pertains to the Middle Ages. In particular, the first news of such globes that we have date from the epoch of Tycho Brahe, who constructed a cosmosphere himself ([395], page 127); this was considered an important task. We are told that "the large brass-plated cosmosphere, 149 centimetres in diameter, deserves to be mentioned separately. Its surface bore the representations of the Zodiacal belt, the equinoctial, and the positions of 1000 stars whose coordinates had been determined over the years of Tycho's observations. Tycho proudly confessed: "I believe that no other cosmosphere of this size, built with such accuracy and precision, has ever been made anywhere in the world". He also claimed that multitudes would come to Denmark specifically in order to admire the cosmosphere. Alas, this true wonder of science and art perished during a blaze in the second half of the XVIII century" ([395], page 127).

Thus, the respective Almagest chapters fit into the epoch of the XVI-XVII century perfectly well.

Furthermore, experts in history of astronomy suggest that even if the longitudes of the Almagest were recalculated, it was for a more recent epoch and never backwards. We are being convinced that the recalculation of old stellar longitudes for the current epoch was a common enough practice amongst mediaeval astronomers. References are also made to the "early mediaeval" catalogues predating Brahe. Mediaeval astronomers are supposed to have been "too lazy" to conduct new research. They would rather grab an "ancient" catalogue dating from times immemorial, alter all of its values by the factor of a single constant and come up with "modern star coordinates" as a result, subsequently using this ancient but so conveniently "updatable" catalogue in their own research.

One has to admit that this hypothesis looks rather strange. It is unlikely that each new generation of astronomers would contend itself with a mere "fabrication" of the kind of catalogue they needed via a shift of longitudes contained in some old and rather obsolete, catalogue. Every new epoch creates new and more advanced astronomical instruments. Therefore, it is most likely that the astronomers of every subsequent epoch would measure stellar coordinates again, with greater precision. Not only the longitudes were made more realistic, but the latitudes as well – those corrections may have varied from star to star. As a result, the astronomers of every new generation would compile a maximally accurate new catalogue for themselves (inasmuch as their instruments would allow, of course). This very method was used for scientific applications, such as navigation, as opposed to obsolete near-forgotten catalogues which contained many errors due to the imprecision of the primitive early instruments.

If anyone in the XVI-XVII sought to fabricate and introduce a falsified "ancient" history, the approach may have been radically different. Some recently-compiled star catalogue would be taken, and his longitudes shifted into "the past", or "the necessary historical epoch" – the early A.D. period, for instance. The operation was simple and did not consume much of the hoaxers' time. After that they would loudly claim having discovered "an extremely ancient star catalogue". Let us reiterate that the simplest and fastest falsification method would employ a shift of all stellar longitudes by a single constant value. Apparently, this is how the "personal observations" of Ptolemy from the II century A.D. came into existence, as well as many other "observations" conducted by "early mediaeval astronomers". The hoaxers couldn't just open a modern catalogue, since they would be immediately caught, and preferred to use some catalogue dating to 100-200 years backwards, well-forgotten and out of print already.

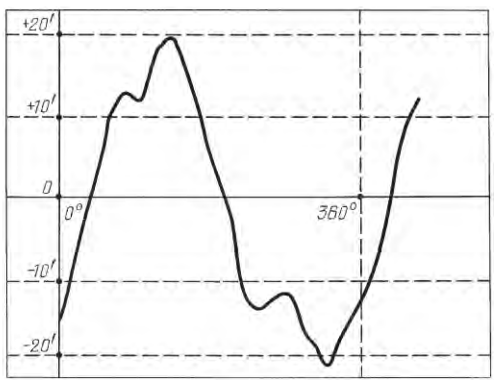

Fig. 2.27. The sinusoid of Peters in the latitudes of the Almagest star catalogue.

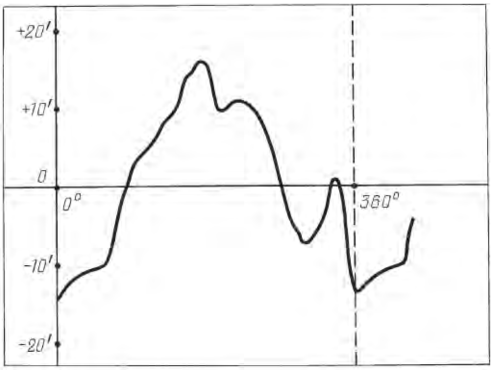

Fig. 2.28. The somewhat odd graph of average longitudinal discrepancy as a function of ecliptic longitude in the Almagest catalogue.

11. PETERS' SINUSOID IN ALMAGEST LATITUDES

Let us now consider the latitudes of the Almagest star catalogue. This is where we immediately discover a most peculiar effect that defies explanation in the paradigm of earlier Almagest studies. We shall be referring to this effect as to the "Peters' sine curve". The matter at hand is as follows: Peters analyses the average error distribution in the Almagest as a longitudinal function. For this purpose he calculates the positions of the modern sky's Zodiacal stars for 100 A.D., or the alleged epoch of the Almagest creation. Then Peters calculates the latitudinal discrepancy of $\Delta_i = B_i - b_i$. Thus, B_i is the latitudinal value of star *i* from the Almagest, and b_i – the meaning of its latitude for 100 A.D. as per Peters. Therefore, the Δ_i value demonstrates "Ptolemy's error" in the determination of star *i*'s latitude, made under the assumption that the Almagest was created around 100 A.D. Peters proceeds with the division of the ecliptic into 10 degree intervals and then calculates the average latitudinal discrepancy value for all the Almagest stars that wind up in this interval, which naturally varies from one interval to another.

A special graph has been built as a result, one that demonstrates how the average latitudinal discrepancy manifests along the ecliptic. Points of the ecliptic can be characterized by ecliptic longitude; the graph built as a result will represent latitudinal discrepancy as a longitudinal function. The sine curve of Peters can be seen in fig. 2.27. It is very much like a sine curve with the amplitude of circa 20'. One could choose a sinusoidal curve considered best in its class for the approximation of the curve in fig. 2.27. The resulting sine curve was named after Peters.

The appearance of Peters' sinusoid is very hard to explain within the framework of the modern ideas of the Almagest. At any rate, we have found no reasonable explanation of this distinctly periodical phenomenon in any kind of literature.

One has to point out that [1339] contains no details related to the calculation of this curve by Peters. In particular, we learn nothing of the actual Zodiacal stars he used for calculations. Therefore, in order to confirm the actual existence of the effect and study it we had to recalculate the curve in question for all the Zodiacal stars with the aid of a computer. Our results, as well as their implications and related commentary can be found in the chapters to follow. Let us however jump ahead for a moment and divulge to the reader that we find a perfect explanation for this strange sine.

NB. Apart from the latitudes, Peters also studied the longitudes of the Almagest catalogue ([1339]). He counted the average latitudinal discrepancy for 10-degree sectors and came up with the graph that we see in fig. 2.28. The curve represents the behaviour of the average longitudinal discrepancy as a function of ecliptic longitude. It is remarkable that the graph is drastically different from the one with the Almagest latitudes. The longitudinal graph is by no means sinusoidal; its amplitude is smaller; besides, and it has two rather distinct local maxima. It is possible that this oddly irregular nature of the "longitudinal" curve is a result of the mysterious ecliptic longitude recalculation as discovered by R. Newton in [614] (see section 8). As it has been pointed out, the longitudes of the Almagest catalogue are by no means a reliable source of information; therefore, we have no reasons to study the resulting graph more attentively. Such analysis would only make sense if the longitudinal recalculation mechanisms, which must have been used by later astronomers (possibly of the XVI-XVII century), could be reconstructed, which we believe to be a very difficult task at this point.