# DATING THE ALMAGEST BY ERROR/PROPER MOTION CORRELATION:

Independent evidence corroborating Fomenko and Nosovsky's New Chronology

Carlos Baiget Orts
asinfreedom@gmail.com

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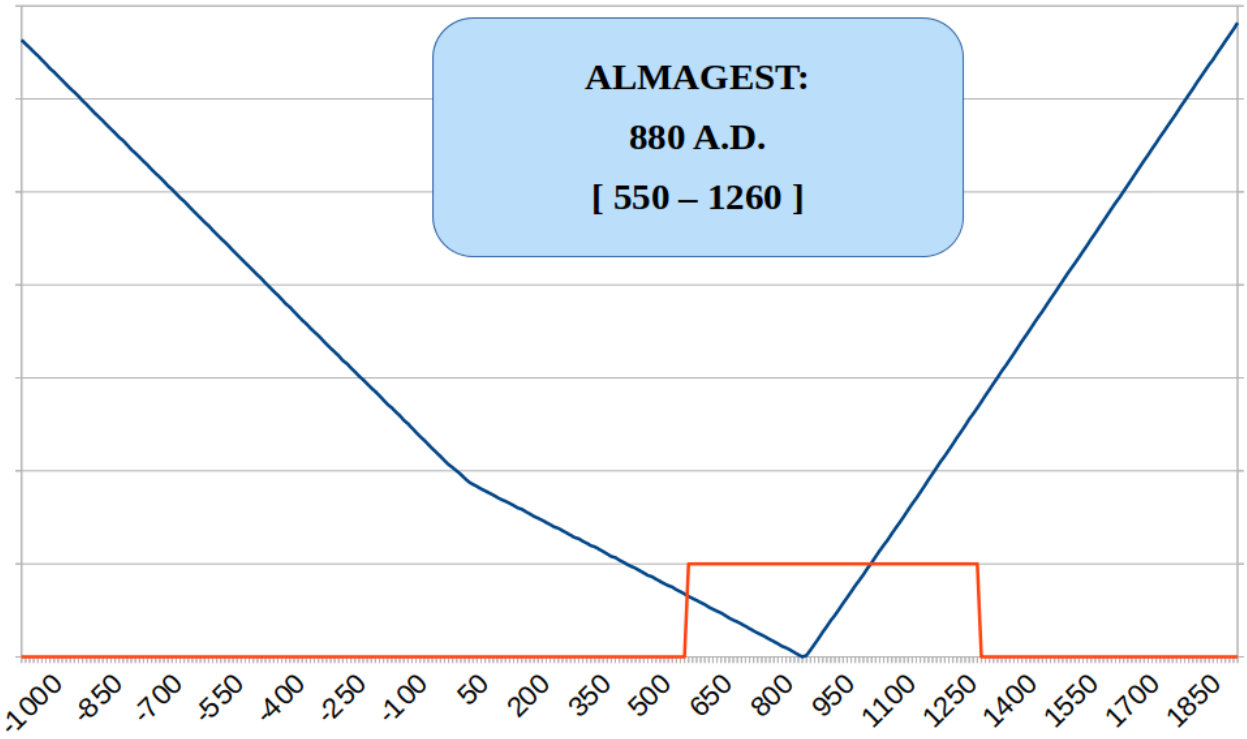


**Abstract:** A previously unexplored criterion for dating old stellar catalogs compiled in ecliptic coordinates, the error/proper motion correlation of the stars contained therein, not only proves to be enormously effective for this purpose, but also provides a direct and exact confirmation of the dates obtained by other more exhaustive systems based on statistical and geometric analyses.
The astronomical dating of stellar catalogs has given rise to various approaches tailored to each object of study, based on different considerations and based on arguments of complicated development.
While the debates on the results obtained at the end of the 20th century, particularly those centered on Claudius Ptolemy's Almagest, remain unrefereed, the interest of the academy in their oblivion is palpable, systematically avoiding the simple mention of their main actors, their arguments and their conclusions. The proposed method is an objective and impartial system with a simple and common criterion to process any stellar catalog compiled in ecliptic coordinates, which is easily tested both with catalogs of known date and synthetic and artificially adulterated ones, and which is totally consistent in its results.
The application of this method to the controversial Almagest renews and corroborates in a spectacularly accurate way the dating determined more than three decades in advance by the scientific New Chronology project of Fomenko and Nosovsky.

# 1. Introduction

Astronomical dating of a stellar catalog is the process by which a chronological implication is found to the purely astronomical information contained in it. It is the equivalent of horoscope dating, but working with star positions instead of planets.

This process can also provide proof that a particular old catalog has been adulterated or falsified to appear to be from a different period than the one it actually belongs to, by providing its true date. This application, however, is only possible for catalogs produced before the 18th century, because if they were falsified, the falsification did not include the effect of the proper motion of the stars, a phenomenon discovered only later, and whose value for each star was only determined with sufficient precision later on.

It is thanks to the guarantee of not incorporating this effect in a hypothetical falsification of the stellar catalog data that we can aspire to date it astronomically in an objective way, since the projection into the past or into the future of a given list of observations, if this period is long enough, causes the appearance of excessive errors in it, ruling out any possibility that it could be the result of real observations in such epochs.

The ease with which a catalog can be adulterated to appear to be from another era by simply modifying the longitudes of each star to make them compatible with the precession is well known and, as has been shown, used for several centuries [1], so that in no case can the criterion of contrasting longitudes be used to determine the astronomical dating of a series of stars.

On the other hand, due to the fact that each star has its own motion vector whose direction and magnitude is unique, which gives rise to the name of the phenomenon, not all stars can be useful when using this feature to estimate the date on which the position recorded in the catalog for it coincided to some extent with its actual position in the firmament.

This is because every catalog has a maximum resolution, which is insufficient to discriminate the displacement that some of its stars have experienced over a period of a millennium or more. Therefore these samples are usually considered uninformative and discarded.

# 2. Motivation and method of forgery of stellar catalogs in antiquity

The first, more or less accurate understandings of the firmament and the solar system already indicate in an obvious way how to falsify a catalog. In the same way as a horoscope, which indicates in absolute terms a date, a stellar catalog can implicitly have the same function.

While, as the name suggests, the main function of a horoscope is to record a date in absolute terms using an astronomical phenomenon (the apparent position of the planets from the Earth), the main function of a catalog is to record the state of a part of the firmament in order to study its behavior. However, a consequence of this recording is that once the behavior of the firmament has been determined, the catalog itself also implies a date. This possibility was exploited in the past for the redesign of history for political purposes.

The motivation for falsifying a catalog was therefore mainly chronological. Without explicitly referring to a date, the catalog was dedicated to or referred to kings or important events close to the time when, according to the astronomer, his observations had taken place. These references were therefore datings relative to the date of the catalog itself, which thus became a mere allegedly scientific justification of a particular chronological conception of history.

Of the various possible reference frames for recording star positions, two were predominant in antiquity: equatorial coordinates and ecliptic coordinates. Both had different advantages and disadvantages according to different criteria, such as the ease with which star positions could be faithfully recorded, or the validity of the catalog over longer periods of time.

In the past, the use of ecliptic coordinates was considered to result in the ability of the catalog to be timeless in terms of the latitudes of the stars, which were considered fixed, while the passage of time would only affect the longitude of all stars in the same way, due to the effect of precession.

Statistical studies at the beginning of the 20th century demonstrated the existence of errors in the longitudes of the Almagest stars that did not affect the latitudes [2]. Some authors consider this fact as a confirmation of the adulteration of the longitudes suggested by other types of analysis (Robert Newton [3], Fomenko, Kalashnikov, Nosovsky, [4]).

## 3. Existing stellar catalog dating methods

Since the mid-1980s, several analyses of the dating of the Almagest have appeared based on purely astronomical considerations, with a predominance of those based on the proper motion of the stars, because of their apparent potential for immediate application to the problem. Most of these studies, however, are attempts to indirectly refute the dating obtained by A.T. Fomenko, G.V. Nosovsky and V.V. Kalashnikov (hereafter FNK) which points to a date necessarily later than the 7th century, and most probably closer to the 10th century for this catalog [4]. These works of replication were in turn commented on and questioned by later developments of new authors [1], which makes the task of establishing the scope of both arguments and counter-arguments put forward by the various researchers who have dealt with the subject very difficult.

## 4. SCC-md: Cross-Correlation of Signals and Mutual Distances

A new method of dating stellar catalogs compiled in ecliptic coordinates is proposed, with universal applicability objectives and not based on considerations derived from a previous filtering of the stellar catalog according to the precision of each of the samples, or their potential application to the resolution of the problem by their proper motion.

This method applies Signal Cross Correlation (SCC), a resource widely used in other fields of science and with many applications in the field of science and technology[5]. Signal Cross Correlation is a measure of similarity of two data sequences.

The applicability of this metric to the dating of stellar catalogs is justified by the following argument. A stellar catalog is the result of the observation of the position of a series of identifiable stars, which are subsequently recorded in some universal coordinate system. The final compilation of these data is affected by the influence of a series of errors, some of a systemic nature due to the characteristics of the measuring tools used by the astronomer, as well as his or her particular way of using them, habits, circumstances, etc. These errors affect all stars equally.

In each sample, in addition, the position is also altered by a certain random error, which affected the final measurement recorded for each star. This type of error also affects all samples, but in a unique way in each case.

However, it is trivially demonstrated that in the sum of errors that can affect the records of a stellar catalog, the magnitude of the proper motion of each star, i.e. its velocity, can in no case be a factor to be considered.

On the other hand, when comparing the stellar positions of a given catalog with those observed, or calculated by modern astronomy for a given epoch, it is inevitable that with the passage of time the faster ones will show a higher error than the slower ones. It follows, therefore, that the existence of some statistical correlation between the error of each sample and the velocity of its proper motion is a necessary consequence of an incorrect dating of the catalog in question.

In other words, the calculation of the cross-correlation between the error/velocity signals of a catalog for a given time interval will converge to a minimum at a point in time within the time interval, from which it will again show an upward trend.

The final implication of this signal analysis, useful in the dating of stellar catalogs, is that the epoch of a stellar catalog is necessarily the epoch of the minimum correlation between the series describing the velocities of each sample, and the series describing the errors with which they were recorded.

How the signals are generated and compared is described below. Signal A, consisting of the list of velocities of the stars that are part of the catalog, is determined. (Figure 1).

A set of Signals B (Figure 2) is then generated, one for each possible dating within the interval to be considered. For each Signal B, a measure of its cross-correlation with Signal A is calculated. The Signal A,B pair whose correlation is minimal implies the dating of the cataloged to the epoch that generated the associated Signal B.

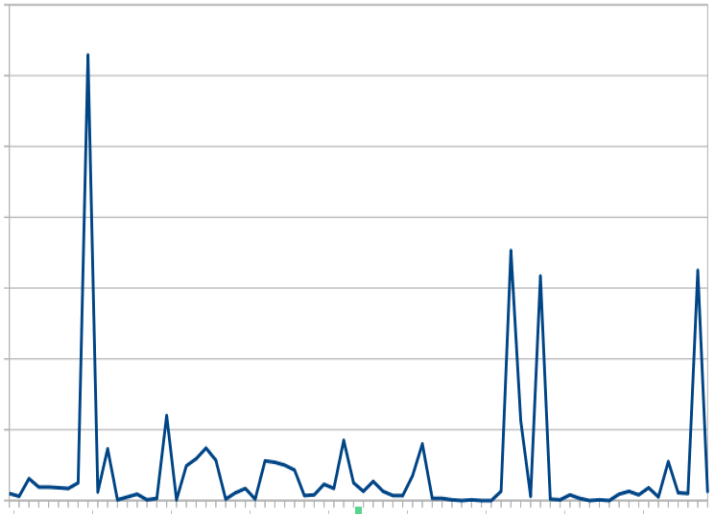

*Figure 1: Example of Signal A: List of star velocities from a catalog.*

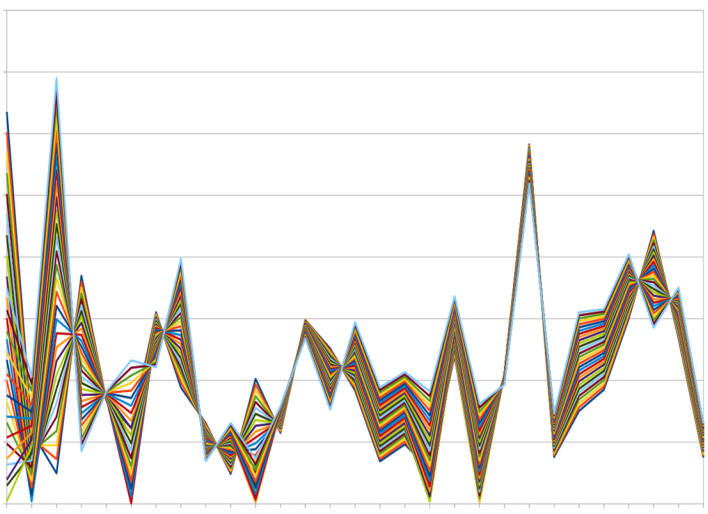

Figure 2: Example of the set of B Signals: Lists of positional errors for each star at each epoch. Each color is a different signal, corresponding to a specific dating. One of these lists constitutes a minimum in the correlation with Signal A, implying a matching dating of the catalog

One of the main problems affecting all attempts to date the Almagest by the proper motion of the stars is that of star identification. Since only 12 of them are mentioned by name, the rest are identified on the basis of their approximate description, position and magnitude (brightness).

This is a complicated problem, as not only have different researchers proposed different identifications, but different versions of the Almagest also contain different coordinates for a large number of stars. Table IX of [2] lists the discrepancies about the coordinates of the stars in the different existing versions of the Almagest. It is a very extensive table, which clearly demonstrates the difficulty in identifying the stars mentioned by Claudius Ptolemy. The same work details the ambiguity in the identification of some stars.

Since some stars dominate a certain region of the firmament because of their greater brightness, and a subjective assessment of that magnitude is recorded in the Almagest, their identification is straightforward and unambiguous. However, the fainter the star, the more ambiguous is its identification with respect to its fainter neighbors, and sometimes the identification has been made on the basis of the preconceived chronology of the catalog.

A paradigmatic example is the Keid star, usually associated with 779 in the Almagest. This star is so fast that the association originates from the assumption that the catalog is necessarily from the 2nd century. For this reason, no purely astronomical dating can be based on this star.

A detailed study on this problem has been previously carried out in[4]. Interestingly, however, the results of the present study, without relying on them, confirm the same result.

The criterion followed in this study has been to consider only the brightest stars in the catalog, not only because they are the best identified, but also because it is also thanks to this feature that their measurement must have been less erroneous in the past. The reason is that the brightest stars were used as a reference to measure the fainter surrounding stars. That is why more attention was paid to them. Moreover, they were the first to be measured. Secondary stars were also more likely to accumulate twice the systemic error in the final result.

For the SCC-md dating of the Almagest, we have considered the stars recorded in this catalog with a magnitude lower than 4 (the lower the magnitude, the brighter the star). Although nowadays we have objective measurements of the brightness of the stars, we have preferred to use the data recorded in the Almagest, as it is a better indicator of the subjective consideration they had for the astronomer who recorded them. The resulting set is that of the 350 brightest and best-identified stars in the catalog, which is about 1/3 of the total. They were presumably also the first stars to be measured when the catalog was compiled.

As a supporting metric to establish a possible interval around the date obtained by the SCC method, this method uses the list of mutual distances (MD) between the stars that form the studied stellar configuration. This list consists of the distances that all the stars in the configuration have between them, two by two. The size of this list is determined by the possible combinations, which grow exponentially as the size of the sample set increases.

The list of mutual distances is useful to characterize a given star configuration. A fundamental analysis of the latitudinal values of the catalog can immediately provide its maximum resolution, based on the minimum fraction it can record for the position of a star. Only those dates will then be considered as possible where the list of mutual distances for the optimal date does not disagree with a close one beyond this limit imposed by the catalog data itself. This is an approximate measure that can be established more precisely by more complex analyses, which may extend or reduce this interval.

In this work the stellar positions for different epochs have been calculated using the high-precision astronomical library Skyfield [6]. For the calculation of the cross-correlation we have made use of the implementation provided by the numerical analysis library Numpy [7]. The associations and positions of the Almagest stars are those detailed in the reference work for this type of study, Toomer's annotated translation [8].

# 5 .Application of SCC-md to some catalogs of known date

The method described above has been tested by comparing the results obtained from the analysis of catalogs compiled at known dates. On the other hand, the number of modern catalogs compiled in ecliptic coordinates is scarce.

In all cases the catalog has been filtered on the basis of a single criterion, consisting of considering only stars with a magnitude lower than 3. Special attention was devoted to these stars, as they usually served as a reference in each region, in order to subsequently measure the surrounding stars with respect to them.

This is a documented fact until relatively recent times, an example being the origin of the error in Halley's stellar catalog, which is attributed to the fact that he used Tycho Brahe's positions for these stars [9].

This is furthermore clearly demonstrated by the application of the SCC-md method on this particular catalog, as shown below.

## 5.1 Tycho Brahe's catalog

Tycho Brahe's catalog is the result of his observations at Uraniborg, which had a very short existence between 1576 and 1597. The midpoint of this interval is 1586, applying the SCC-md method we obtain a date close to 1570, with a difference of about 20 years (Figure 3).

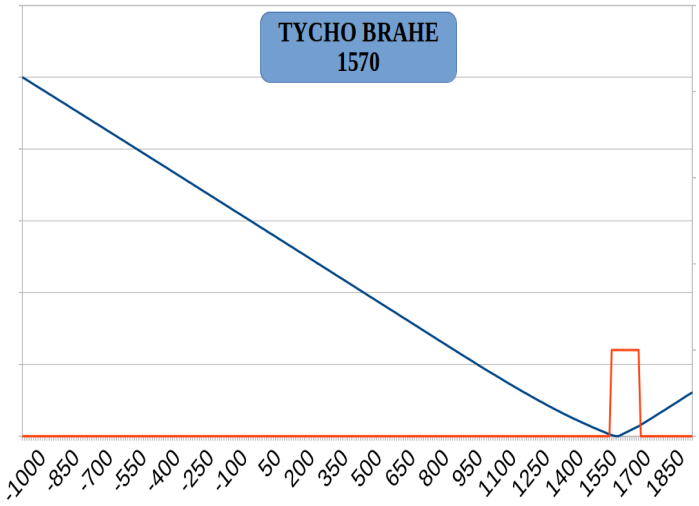


Figure 3: The SCC-md dating of Tycho Brahe's catalog from his observations at Uraniborg (1576-1597)

## 5.2 Flamsteed's catalog

John Flamsteed (1646 - 1719) was an English astronomer and the first Astronomer Royal, the post of director of the newly built Royal Observatory at Greenwich (1676), created by King Charles II.

He devoted 40 years of his life to observing the firmament, documenting his findings in the work "Historia Coelestis Britannica" in 1725. The dating of his catalogue by SCC-md with a resolution of a decade places it in the year 1700, which is very close to the peak of his scientific activity (Figure 4).

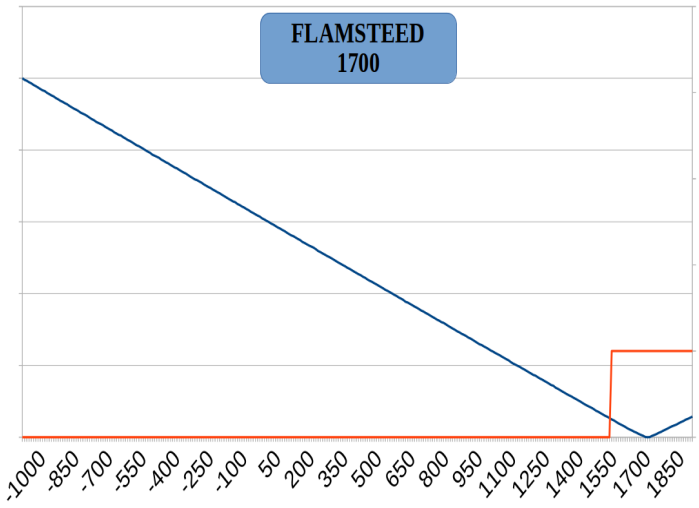


Figure 4: SCC-md dating of the Flamsteed catalog, published in 1725.

### 5.3 Halley's catalog

Halley's catalog was published in 1676. The SCC-md dating of this catalog gives a date almost two centuries earlier. Verbunt et al. studied in 2011 the positional errors affecting Halley's catalog [9], the origin of which is the use of Tycho Brahe's positions as a reference. The dating obtained by SCC-md is consistent with this fact (Figure 5).

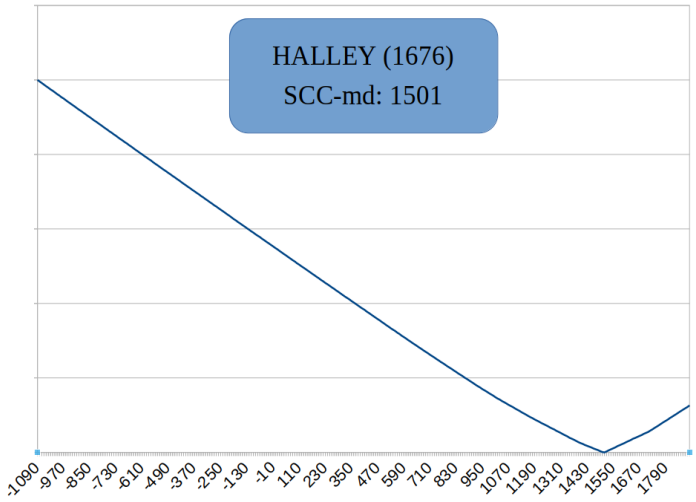


Figure 5: SCC-md dating of the Halley catalog, whose errors are mainly due to the use of Tycho Brahe positions for the reference stars.

## 5.4 Dating of the Almagest by SSC-md

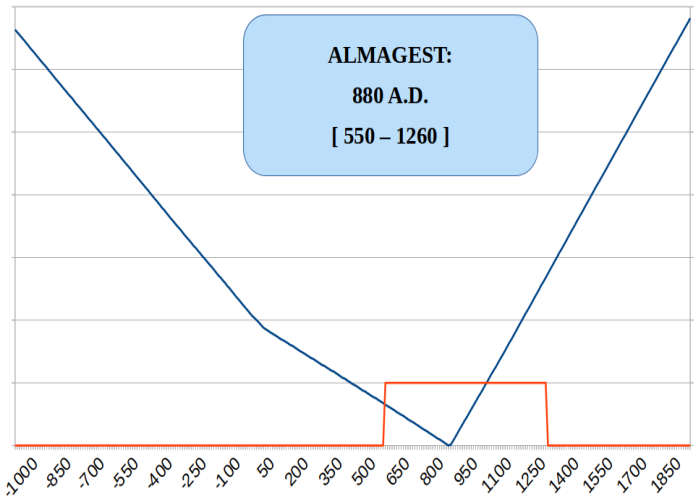


Figure 6: SCC-md dating of the Almagest: 880 AD, a result that perfectly corroborates what was previously determined by the New Chronology scientific project.

Finally, the result of the application of the SSC-md method to date the Almagest of Claudius Ptolemy is shown. Based on historiographical considerations, this catalog should be the result of observations made in the 2nd century AD at the latest.

The dating of this catalog and its implications for the establishment of the historical chronology has been very controversial after the results obtained by FNK at the end of the 20th century within the framework of the scientific project of New Chronology, demonstrating through the application of statistical and geometric methods, that it cannot correspond to a period prior to the 7th century, and with a greater probability of being a work produced in the vicinity of the 10th century.

Numerous subsequent works have tried to refute their conclusions, which in turn have been the subject of study and criticism. After a few years of superficial debate, the scientific literature ceased to address this issue in the early 2010s. Subsequent works around the Almagest not only fail to mention the findings of New Chronology, but actively avoid the subject as well as the mere mention of its authors, in order not to reopen the controversy and give the appearance of avoiding a demonstrably sterile debate.

The SCC-md method presented in this work implies the need to reopen this debate from a purely astronomical point of view, as it perfectly corroborates the results achieved by New Chronology more than three decades ago, obtaining exactly the same dating by applying totally different considerations, and more importantly, not taking into account any particularity of this catalog.

Figure 6 shows the dating of the Almagest by SCC-md. Figure 7 shows the conclusions about it that are the result of the statistical and geometrical study carried out by New Chronology three decades ago, which are perfectly confirmed by the Cross-Correlation method.

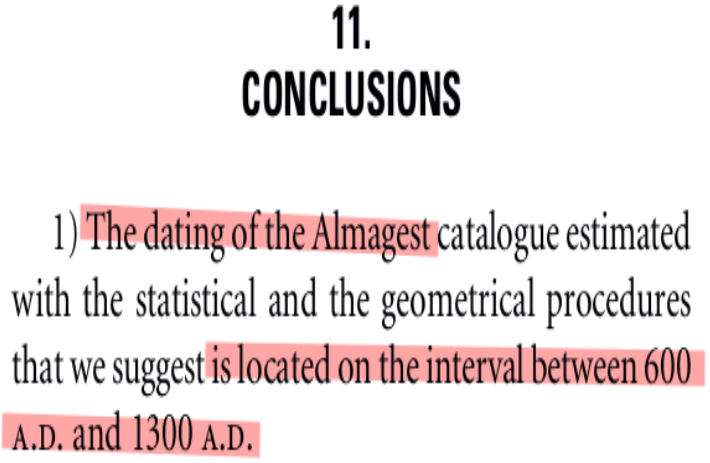


Figure 7: Dating of the Almagest determined by the New Chronology scientific project at the end of the 20th century. Excerpt from "History: Science or Fiction vol. 3. A.T. Fomenko, V.V. Kalashnikov, G.V. Nosovsky.

## 6. Conclusions

The application of the signal cross-correlation calculation to the dating of stellar catalogs provides dates in agreement with those corresponding to modern stellar catalogs whose publication date is well documented. For older catalogs such as the Almagest and Ulugh Beg, the convergence of the dates obtained with those determined some decades ago by the New Chronology scientific project through the application of statistical and geometrical methods is simply ideal.

The SCC-md method is presented as a simple, objective and very easily reproducible tool, the results of which should force the scientific community either to reconsider the dating of the Almagest and its significance for historical chronology, or to renew the whole battery of excuses and argumentative gibberish that have so far tried to justify not doing so, despite the evidence.

The study of the error/proper motion correlation implies a late 9th century dating for the Almagest. Considering even those stars with magnitude less than 4, this dating is confirmed by the subset of the 350 brightest, best measured and identifiable stars. These figures are more than sufficient to disprove any criticism of the dating achieved by Fomenko, Nosovsky, Kalashnikov as being based on an informative core of only 8 stars.

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