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Anatomical Descriptions in Star Catalogues: Ptolemy, Brahe, Halley, and Hevelius

Abstract: This chapter focuses on the textual descriptions of stellar objects used in the influential star catalogues of Ptolemy, Brahe, Halley, and Hevelius. The primary purpose of this work is to provide a quantitative survey of these descriptions, and especially anatomical descriptions, i.e., ones that describe their objects by spatially relating them to body-parts of constellation figures. After identifying the functional components of descriptions, some basic statistical results are presented concerning the absolute and relative occurrences of these components and of the terms that comprise them. These results highlight both the differences and the similarities between the use of descriptions in the studied catalogues, and they allow us to form hypotheses about the individual preferences of the authors, the changes resulted by historical and cultural distance, and the general function of constellation lore within astronomy. Identifying stars as structural or anatomical elements of constellations served a cognitive purpose: it provided the means to memorize and recognize stellar objects, hence providing them with identity.

1 Introduction

The astronomical tradition from antiquity to the early modern era recorded visible stars in catalogues. For each star, these catalogues provide both a textual description and numerical data. The data – coordinates of celestial position and degree of brightness – have been studied with great care by scientists and historians of science.[1] However, only a minor interest has been devoted to the descriptions employed to identify stellar objects.

This chapter focuses on these descriptions. It is an extension of my earlier analysis of the language of descriptions in Ptolemy's catalogue (Kutrovátz 2022),[2]

1 For a concise history and evaluation of such approaches in case of Ptolemy's catalogue, cf. Graßhoff (1990). For analyses of two of the Latin catalogues, cf., e.g., Verbunt and van Gent (2010a, 2010b).

2 Therefore, this chapter contains some passages that are common with that paper, where the results and conclusions are the same, but tries to keep them to a minimum.

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here compared to three important catalogues published in the seventeenth century. The primary purpose of this work is to provide a quantitative survey of these descriptions, and especially anatomical descriptions, i.e., ones that describe their objects by spatially relating them to body-parts of constellation figures. After identifying the functional components of descriptions, I present, in a table format, some basic statistical results concerning the absolute and relative occurrences of these components, and of the terms that comprise them. These results highlight both the differences and the similarities between the use of descriptions in the studied catalogues, and allow us to form hypotheses about the individual preferences of the authors, the changes resulted by historical and cultural distance, and the general function of constellation lore within astronomy.

2 The catalogues

The oldest extant star catalogue[3] is found in Books VII and VIII of Ptolemy's groundbreaking astronomical work, the *Syntaxis mathematica* or *Almagestum.*[4] Ptolemy lists 1,028 entries representing 1,022 individual stars,[5] grouped into 48 constellations. The constellations are not definite areas of the sky, like in contemporary astronomy, but rather imaginary figures representing and conceptualizing star patterns. The identity of individual stars is usually defined by their position within these constellation figures, i.e., on (or near) which part of their figure they are found. This information is given by the textual descriptions, two to 16 words of length and around six on average, that accompany the numerical data of coordinates and 'magnitude' (degree of brightness). For example, the first entry defines its object as "[t]he star on the end of the tail" of Ursa Minor, the Little Bear (Toomer 1984, 341).

Most constellation figures are associated with Greek mythology. There are human figures (even if often deities) like Andromeda, Perseus, Orion, or Virgo, then there are animal figures like the Bull, the Lion, or the Crab, and there are some more irregular "monsters" like the Pegasus, the Centaur, or the Archer (also a centaur). In addition to these animate (live) figures, there are nine further figures representing inanimate objects, like a Crown, a river (Eridanus), or a Lyre.

3 For a detailed summary of the history of catalogues and constellation lore, cf. Ridpath (2018). Kanas (2007) is useful for relating this lore to its manifestation in historical star maps.

4 The analysis below is based on the standard edition of Heiberg (1903), 38–169.

5 Three stars are listed twice as belonging to two constellations simultaneously, and three items are treated as nebulous objects rather than stars.

All of these constellations are among the ones that are in official use today, except for the ship Argo that was divided into three smaller constellations in the eighteenth century.

While almost all star catalogues of the medieval and renaissance periods were close copies of Ptolemy's list, perhaps slightly updating or modifying details, the seventeenth century saw the publication of novel star lists. The first one we study is that of Tycho Brahe, mostly comprised in the last decades of the sixteenth century, but eventually published entirely, and with amendments, by Kepler (1627). This had approximately the same quantity of stars as Ptolemy's list, but the set of listed stars is not the same: Tycho observed more stars in the northern constellations and less in the southern ones. Also, he omitted some southern constellations he could not see,[6] but added two more to the northern list.

Halley's catalogue (1679) was specifically devoted to constellations in the southern hemisphere, observed from the island of Saint Helena. It was meant to be a supplement to Tycho's catalogue. While it partly overlapped with the regions surveyed by the previous two, its primary focus was the part of the sky surrounding the southern celestial pole, invisible from the geographical latitudes hosting the classical astronomical tradition. It contained 14 novel constellations, mostly introduced at the beginning of the century, but altogether far less stars than its predecessors.

Hevelius (1690) re-surveyed the northern and equatorial regions of the sky (as seen from Gdansk in Northern Europe), listing half as many more stars as Ptolemy or Tycho, and introducing eleven new constellations. Its main point of reference was Tycho's catalogue, but it often deviated from it. It was supplemented with a star atlas, published posthumously together with the catalogue.

The survey presented in this chapter is not based on the original editions, but on Baily (1843),[7] which publishes them in one volume. While I found this publication to be faithful to the originals in terms of textual descriptions, it also includes a lot of useful editorial notes concerning individual stars, as well as the so-called Baily numbering, which is handy for references to individual items.

6 Partly due to the difference in geographical latitude (Ptolemy lived in Alexandria, while Tycho in Denmark), and partly due to position shifts caused by the precession of the Equinoxes.

7 Except for Ptolemy, as noted above.

3 Anatomical descriptions and references

Taking Ptolemy's text as the paradigm, descriptions fall into three kinds according to their relations to other descriptions. Independent descriptions define their objects in a self-sufficient way (see [P44] below),[8] while linked descriptions define groups of objects via interconnected textual entries. Members of linked descriptions are either premier descriptions (see [P15]) or subsequent descriptions (see [P16]). The examples below are pure cases, i.e., without any further complication:

[P44] "ὁ ἐπὶ τῆς γλώσσης" ["The star on the tongue"][9]

[P15] "τῶν ἐν τῷ τραχήλῳ β ὁ προηγούμενος" ["The more advanced of the two stars in the neck"]

[P16] "ὁ ἑπόμενος αὐτῶν" ["The one to the rear"]

As discussed in section 4.6, boundaries between these kinds would become less clear in the Latin catalogues of the early modern era.

These examples testify that textual descriptions tend to define their objects by relating them to body-parts of the constellation figures. In this chapter these are called anatomical descriptions. Not all descriptions are anatomical, however. On the one hand, we have inanimate descriptions where stars are identified with objects rather than body-parts. This is the case not only with stars in inanimate constellations without anatomical parts (e.g. [He1014], "In aplustri" ["On the stern" (of the ship Argo)]), but also with stars in animate constellations that represent artefacts held or worn by the figures (such as weapons, e.g. [T870], "Quæ in manubrio ensis" ["Which <is> on the sword's hilt" (in Orion)]). Also, star positions are occasionally defined with respect to previously identified stellar objects, rather than via direct correspondence to parts of the figures; these are relational descriptions (e.g. [T347], "Illa quæ supra hanc" ["That which <is> above this"], referring to the previous entry). Finally, stars are sometimes described as constituting abstract geometrical figures instead of fictional entities; these are geometrical descriptions (e.g. [He640], "Apex rhombi occidentalis" ["The western apex of the rhombus"]). Moreover, these methods of identification are not mutually exclusive: a star may by defined in multiple ways simultaneously, e.g., by providing both an anatomical and a relational reference (see below).

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8 Throughout the chapter, when referring to individual descriptions, the numbers in square brackets provide the Baily-ID's of the objects, which is simply the ordinal number of the entry in the catalogue as introduced in Baily (1843), prefixed here by 'P' for Ptolemy, 'T' for Tycho, 'Ha' for Halley, and 'He' for Hevelius.

9 English translations given here (and only here) are cited from Toomer (1984), 342–344. All other translations are mine.

The general structure of anatomical descriptions, based on the analysis of Ptolemy's text in Kutrovátz (2022), is as follows: {Description} = {Subject} + {Reference} + {Additional}, where {Subject} is the subject phrase denoting the stellar object, {Reference} is the referential phrase providing an external identification, and {Additional} consists of additional components. This formula expresses a structure at the level of semantical functions, rather than the level of syntax, even if many components and relations below tend to correlate with syntactical units and structures.

For us, the most important part is the referential phrase. In general, it can have four components: {Reference} = {Preposition} + {Term} + {Specification} + {Qualification}, where {Preposition} and {Term} are the core components, while {Specification} and {Qualification} are optional. For a full example, observe [He253], "In extremitate dextri pedis" ["On the end of the right leg"]. Here, {Preposition} is 'in', expressing the spatial relation between the star and the associated body-part. {Term} is 'pes', naming the body-part. The latter is always present, since by definition, an anatomical description is one that has an anatomical term in its referential phrase, while {Preposition} tends to become less ubiquitous in the Latin catalogues, as seen below. {Specification} specifies which one of the entities denoted by the referential term is referred to, if more than one exists (e.g., hands, legs); here it is 'dexter' ["right"]. {Qualification} qualifies which part of the entity denoted by the referential term is referred to, if it is given (quite rarely, as we shall see), in this case it is 'extremitas' ["end"].

Descriptions with only one {Term} contain single references, while those with two (or more) instances of {Term} contain double (or multiple) references. While the majority of descriptions provide a single reference, there are various reasons for using double references. For example, the description may define its object with respect to two separate body-parts simultaneously, e.g. [He256], "Sub sinistro brachio, in latere" ["Below the left arm, on the side"]. Or else it may provide both a larger body-part and a more specific area, e.g. [T878], "Quæ in surâ sinistri pedis" ["Which <is> on the calf of the left leg"].[10]

Next we need to make a distinction between explicit and implicit references. The latter are used in subsequent descriptions. For example, in the case of [P15]

10 While an anatomical term is taken to be expressed by a single word, and this results in intuitively clear instances most of the time, there are genitive structures that complicate matters. For example, 'ancon alae' (e.g., [T200], [Ha254]) is an expression where 'ancon' is meant to be the bend of the wing, while when used separately it means elbow (e.g., [T336]) – and the same ambiguity applies to Ptolemy's 'ἀγκών' (e.g., [P164] vs. [P186]). While this composite expression refers to one specific body region, it contains two terms with anatomical meaning, and therefore is treated in this study as a double anatomical reference.

and [P16] cited above, it is clear that the referential phrase of [P15] also applies to the object of [P16], so that the latter is also on the neck, even if it is not explicitly stated in the corresponding description, but rather implied by the context. Since the purpose of linked descriptions is to avoid repetition in cases where multiple stars are associated with the same part of the figure, it should be assumed that all components of the premier referential phrase have an implicit occurrence in the subsequent description, including the {Term}, the {Preposition}, and – if they are given – the {Specification} and the {Qualification} as well.

On top of the information contained in the referential phrase, further details are occasionally provided in the additional parts of the description: {Additional} = {Property} + {Name} + {Relational} + {Objectual} + {Geometrical}. The relevant parts are italicized in the following examples. {Property} is a distinguished property of the denoted star, such as in [Ha252], "In capite *lucida*" ["The *bright* <star> on the head"], with "*lucida*" constituting {Property}. {Name} is the name of the star, e.g. [Ha86], "In ore. *Fomalhaut*" ["In the mouth. *Fomalhaut*"]. The remaining three components are additional references (in addition to the anatomical one) of non-anatomical kinds: relational (e.g. [He1360], "In sinistro genu *sub Palilicio"* ["Below the left knee, *under Palilicium*" (i.e., Aldebaran)]), objectual (e.g. [He483], "In sinistro brachio, *ad sceptrum*" ["In the left arm, *by the sceptre*"]), and geometrical (e.g. [He511], "In *quadtrato* pectoris præcedens borealis" ["The leading [= western] <and> northern on the *rectangle* of the chest"]).

The subject phrase is plain for independent descriptions. In Ptolemy's catalogue, this kind of {Subject} is simply the masculine definite article in the singular nominative case: 'ὁ'. The article belongs to the term 'ἀστήρ' ["star"] which is, however, absent from the text, making the syntax elliptical, see, e.g., [P44] above.[11] Latin catalogues are more flexible since several forms coexist, with the common characteristic that the term for 'star' remains absent as well. Some examples from Tycho's catalogue, with the subject phrase italicized: [T78] "In ore" ["In the mouth"] – here the subject phrase actually disappears; [T80] "*Quæ* ad genam" ["*Which* <is> by the face"] – note that since Latin does not have articles, here the gender (feminine) of the relative pronoun indicates that it corresponds to 'stella'; [T77] "*Quæ est* in lingua" ["*Which is* on the tongue"] – here the copula is present (a rare case); [T117] "*Illa quæ* in humeris" ["*That which* <is> on the shoulders"] – here a demonstrative pronoun occurs. Similar solutions are used by Halley and Hevelius too – with a tendency to omit {Subject} altogether –, implying that language use in their descriptions was less formal or technical than in Ptolemy's text.

11 Such elliptical formulae were not only characteristic of common vernacular, but also of technical, e.g., mathematical, texts. For the latter, cf. Netz (1999), 127–167.

For premier descriptions, {Subject} contains the part {Quantity} referring to the quantity of the group members, plus at least one selective term, {Selective}, telling which one of the members is referred to, usually by stating its position within the group. E.g. [P15], "*τῶν ἐν τῷ τραχήλῳ β ὁ προηγούμενος*" ["*Of the two* <stars> on the neck, *the leading*" (i.e., western)], with elements of the subject phrase italicied: "τῶν [. . .] β" ["of the two (. . .)"] is {Quantity}, and "ὁ προηγούμενος" ["the leading"] is {Selective}. In the corresponding subsequent description, [P16], "ὁ ἑπόμενος αὐτῶν" ["The following [= eastern] of them"], "αὐτῶν" ["of them"] refers back to the {Quantity} of the premier description (and it always does so in this form), while {Selective} ("ὁ ἑπόμενος" ["the following"]) is a counterpart of the {Selective} in the premier description. In the Latin catalogues, similarly to individual descriptions, instances of {Subject} are often less formal and procedural than in Ptolemy's Greek, as seen below.

4 Quantitative analysis

4.1 General features

Equipped with all the definitions and distinctions introduced in the previous section, we are now ready to perform a quantitative analysis on the catalogues. Before we begin, it is essential to note that descriptions of the same stars in different catalogues often depend on each other. For many stars in the Latin catalogues, identification is determined by the tradition stemming from Ptolemy's list.[12] But that does not mean that individual variances are excluded. Even among very prominent stars, the star Antares is the heart of the Scorpion for Tycho ([T695)], Halley ([Ha9]), and Hevelius ([He1235]), but it is the middle of the body for Ptolemy ([P553]). The star Regulus is the heart of the Lion for Ptolemy ([P469]) and Tycho ([T598]), but for Hevelius it is only named without any anatomical or other kind of descriptive iden-

12 That is not to say that Ptolemy was the one to actually found this tradition. On the one hand he had Hipparchus' catalogue at his disposal, but since the latter is not extant, we, together with early modern astronomers, have no direct way to consult it. On the other hand, anatomical identification of stars was a central feature of the descriptive tradition represented by Aratus, Eratosthenes, and Hyginus, cf. Condos (1997) and Hard (2015). However, these texts do not identify stars individually as Ptolemy does, but rather list the number of stars representing specific body-parts for each constellation, and thus it is not possible to find 'descriptions' the way we do in this chapter, so we cannot provide a straightforward comparison between these texts and the catalogues we study. A number of anatomical references to individual stars can be found in Babylonian texts (Watson and Horowitz 2011, 187–205), but that period falls outside the scope of this study.

tification ([He852]), and it is missing from Halley's catalogue of the southern constellations.

We expect variations for the following reasons:

1. As we saw, each of these catalogues introduces some constellations unknown to the previous ones, while other constellations are omitted.
2. The number of stars in any specific constellation varies, meaning that the set of stars they work with differs.
3. Even when they discuss the same star, individual choices in the descriptions can occur, as seen above.
4. Anatomical identifications depend on the way the authors envisioned constellation figures, which in turn depends on which star charts they consulted.

However, it would be a daunting task to try and identify all individual entries across the catalogues, owing to the inaccuracy of coordinates (especially for the fainter stars that comprise the majority), and this chapter does not incorporate such considerations.[13] It is sufficient for our purposes to assume that, while there is an obvious convergence between the catalogues imposed by the tradition, this tradition is alive and it allows for considerable variations and differences that leave plenty of room for a comparative quantitative analysis.

Some general features of the catalogues are summarized in Table 1. Since this chapter focuses on anatomical descriptions (AD), i.e., descriptions with at least one anatomical term in their referential phrase, it is useful to note not only the size of the overall stellar population,[14] but also the number of entries belonging to animate constellation figures ('AC entry'), since those are the ones where ADs are primarily expected.[15] As we see, the proportion of AD to the overall stellar

13 Of course, modern editions usually attempt to identify the entries by assigning designations of standard catalogues in use today. However, the number of remaining uncertainties is always far from negligible, cf., e.g., the numerous notes in Baily (1843). For a heroic attempt to identify stars across many historical catalogues, cf. the useful book by Helmut Werner and Felix Schmeidler (1986).

14 The number of relevant entries in Hevelius is open to interpretation: there are 23 entries where he borrows the descriptions from Tycho's catalogue, but is unable to find the corresponding star. While these are "empty" catalogue entries not representing objects with assigned numerical data, nevertheless they contain descriptions – even if only repetitions of Tycho's descriptions – and, therefore, are included in this survey.

15 However, some descriptions are refined by giving the stellar position with respect to a nearby part of an adjacent constellation figure as well, although the number of these cases is relatively small (17 in Ptolemy, 26 in Tycho, 9 in Halley, 35 in Hevelius, all within the corpus of anatomical descriptions). For this reason, inanimate constellations can occasionally contain stars with anatomical descriptions.

population varies between 55% (Halley) and 76% (Hevelius), indicating differences between the authors in terms of favour for anatomical identifications. However, the possibilities for AD depend on the set of constellation figures, and if we narrow down our scope to animate constellation figures then we find more coherence, with the proportion of AD to this reduced population ranging between 73% (Tycho) and 85% (Halley). This means that all these astronomers had a similar tendency to apply ADs as the default means of identification, but without persistence to apply the method as a rigid rule.

Table 1: General features of the catalogues. Entry: № of objects listed. Constellation: № of constellations. Anim. const's (AC): № of live/animate constellation figures. AC entry: № of stellar objects contained by all AC. Anat. desc. (AD): № of anatomical descriptions. AD to entries: proportion of AD to all descriptions or entries. AD to AC entries: proportion of AD to AC entries. Anat. ref. (AR): № of anatomical references. Multiple AR: № of multiple anatomical references. Multiple AR to AD: proportion of multiple AR to AD.

GENERAL	Ptolemy	Tycho	Halley	Hevelius
Entry	1028	1005	341	1564
Constellations	48	46	23	56
Anim. const's (AC)	39	37	17	44
AC entry	895	904	222	1417
Anat. desc. (AD)	721	658	189	1182
AD to entries	70.14%	65.47%	55.43%	75.58%
AD to AC entries	80.56%	72.79%	85.14%	83.42%
Anat. ref. (AR)	785	702	202	1336
Multiple AR	64	41	13	147
Multiple AR to AD	8.88%	6.23%	6.87%	12.44%

We also indicate the number of anatomical references (AR).[16] The quantity of multiple ARs seems to indicate an attitude toward descriptive precision: multiple references make descriptions both more cumbersome and more informative. While the proportion of multiple AR to AD is slightly lower in Tycho and Halley than in Ptolemy, suggesting a decreasing preference for descriptive identifications, the difference is too small to be significant. However, Hevelius is definitely more meticulous than the others, not only because the proportion of double ARs is notably higher, but also because he is the only one to employ triple ARs (albeit

16 In some descriptions, Hevelius contrasts his anatomical identification with Tycho's different anatomical identification of the same star. Since Tycho's cited anatomical references are not accepted by Hevelius, the latter references are ignored in this survey.

only in 5 cases altogether). While this may be attributed to the fact that he has the highest number of entries and, therefore, he needs to deal with numerous faint stars[17] that are difficult to describe (as opposed to Halley with his relatively small population), the overall impression based on several further results below is that Hevelius' pedantry in descriptions is a personal preference. His descriptive precision is also shown by the many cases where he separates references within the same description with the terms 'sive,' 'seu' and 'vel' ['or'], suggesting that he offers alternative references for better identification.

4.2 Terms

When identifying anatomical terms, a number of methodological decisions had to be made. For example, on top of terms signifying actual body-parts, I chose to include a few terms referring to pieces of garment where the general positions are obvious enough to be seen as anatomical specifications, e.g. 'tiara' (*tiara*) instead of 'head' or 'forehead,' or 'belt' (*cingulum*) instead of waist. On the other hand, terms denoting non-regular parts of a body (such as the cut-offs of half-figures like Taurus or Pegasus) were ignored, similarly to 'curves' (*flexura*), like in Draco or Serpens, without stable anatomical identity, in contrast to 'segments' (*spondylus*) of Scorpio. Moreover, reference instances are considered only when terms are applied in their anatomical sense: for example, 'side' (*latus*) counts when referring to parts of organic bodies but does not count when referring to geometrical objects.

Table 2 summarizes the results. While the number of different anatomical terms (i.e., ignoring in how many instances they are used) is basically the same for Ptolemy, Tycho, and Hevelius (despite the latter dealing with substantially more entries), Halley employs less than half as many terms. The reason is primarily not the significantly smaller size of his sample,[18] but mainly two factors: first, that the new constellations he surveys are mostly animals (such as birds), instead of human figures with plenty of anatomical details, and second, that these new

17 While this paper does not discuss the numerical data contained in the catalogues, let us note that Hevelius is the first to attribute a brightness of 7 magnitudes to some stars (11 cases, plus 9 cases of 6.5 magnitudes), while previous catalogues had 6 as the value for the faintest objects.

18 For a graph displaying the aggregated sum of already introduced terms against the number of descriptions in Ptolemy's catalogue, cf. Kutrovátz (2022), 99, Figure 2. This shows that the number of different terms is far from being directly proportional to the number of descriptions. By the point where Ptolemy's catalogue reaches the number of descriptions equal to Halley's overall population, he already introduced 49 different terms, in contrast with Halley's 34.

Table 2: Anatomical terms in the catalogues. Instances: № of overall occurrences of anatomical terms (equal to the № or AR in Table 1). Explicit: № of overall occurrences of explicitly stated anatomical terms. Explicit prop.: proportion of explicit occurrences to all instances. Kinds: № of different anatomical terms used. Instance/Term: № of times one term is used on average. 10 most frequent: the most frequently used anatomical terms, with the № of occurrences in parentheses.

TERM	Ptolemy	Tycho	Halley	Hevelius
Instances	785	702	202	1336
Explicit	553	557	147	1313
Explicit prop.	70.45%	79.34%	72.78%	98.28%
Kinds	73	73	34	76
Instance/Term	10.75	9.62	5.94	17.58
10 most frequent	κεφαλή (53)	pes (69)	cauda (46)	pes (156)
	πούς (48)	caput (67)	ala (24)	cauda (128)
	οὐρά (47)	genu (43)	caput (17)	caput (69)
	γόνυ (42)	cauda (41)	collum (14)	collum (63)
	ὦμος (41)	manus (38)	pes (12)	ala (58)
	τράχηλος (28)	humerus (32)	femur (8)	manus (49)
	κέρας (23)	collum (31)	cor (7)	humerus (48)
	μηρός (23)	ala (30)	spondylus (7)	genu (47)
	πτέρυξ (21)	dorsum (27)	dorsum (6)	femur (44)
	χηλή (21)	brachium (26)	frons (6)	venter (41)

constellations lack the mythological context that would highlight specific body-parts. The former reason is also evidenced by the overwhelming dominance of tails over other body-parts.

Also note that there are significant differences in the proportion of explicit instances to the overall cases (i.e., to the number of AR in general). While Ptolemy, Tycho, and Halley display a tendency to be explicit (in 70–80% of the cases) but apply implicit references quite regularly, Hevelius keeps implicit references to a minimum. Implicit references are tied to subsequent descriptions, and this result may seem to indicate that Hevelius avoids this kind of description, but as we shall see in section 4.6, this is not the case. Also, this difference can partly be explained by the following consideration: Previous catalogues arrange their stars according to proximity, following the outline of the constellation figure along an arbitrary path (often from head to foot/tail) and therefore juxtaposing entries that represent the same body-parts. Hevelius, on the other hand, mixes this figural ordering with the governing practice of listing stars of an asterism in descending order of brightness. As a result, nearby stars often become separated in the list, making it impossible for the elements of the referential phrase to remain implicit and implied by the directly previous entries. However, even when members of linked descriptions are next to each other in the catalogue, Hevelius

prefers to explicitly repeat every detail, which is another sign of his descriptive pedantry.

Figure 1 illustrates the proportion of references to body regions in the four catalogues, combined from all animate constellation figures, presented on a human figure with some animal parts. Note that

1. several localizations are questionable, both because attributing animals' anatomical terms to human body-parts are sometimes problematic, and because of the ambiguity regarding the precise meanings of terms (especially in the Greek).[19]
2. Multiple different terms can refer to the same region (e.g. synonyms).
3. Some terms were ignored as not fitting any of the depicted regions.

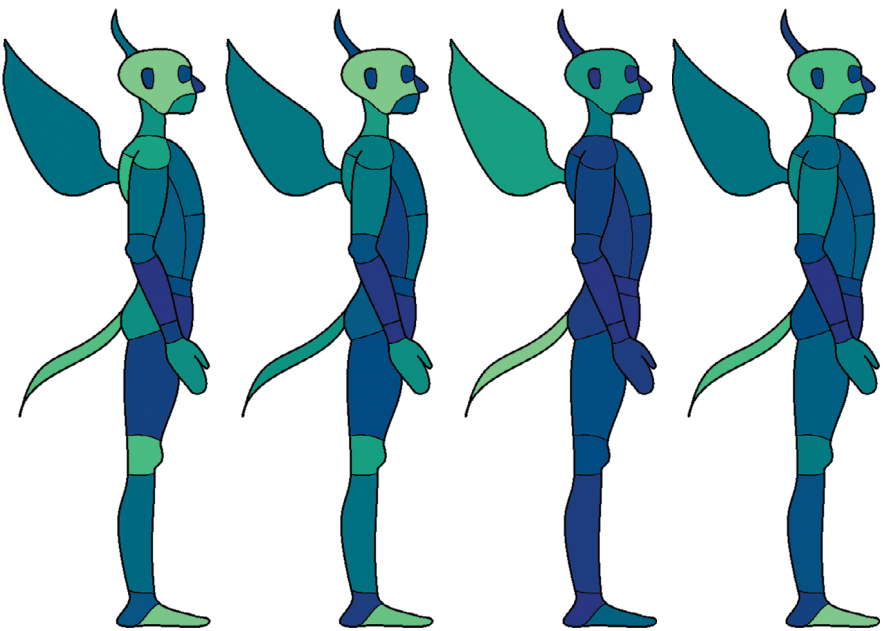

Figure 1: The proportion of references to body regions in the catalogues. From left to right: Ptolemy, Tycho, Halley, Hevelius. The colour scale ranges between pure blue (0 references) and pure green (maximum number of references). Note that the scale is slightly more sensitive toward the lower end of the spectrum.

19 Ancient Greek anatomical vocabulary, found to be largely flexible and variable, is surveyed by Lloyd (1983), 149–167. His conclusions are recited and summarized by Netz (1999), 121–122.

4.3 Prepositions

While Ptolemy almost always attaches a preposition to an anatomical term, the Latin catalogues are more flexible. One way to avoid a preposition is to simply name the body-part (in the nominative case) as the identity of the star, e.g. [T420], "Caput" ["Head"]. Another way is to use a genitive structure, e.g. [T424], "Lucida colli" ["The bright <star> of the neck"]; or [Ha38], "Sequens capitis" ["The following [= eastern] <star> of the head"]. We can see in Table 3 that these irregular solutions become rather frequent, reducing the quantity of actual prepositions relative to anatomical references. Also, quite unsurprisingly, we can observe that the proportion of explicit prepositions is very similar to (but slightly lower than) the proportion of explicit terms, as terms and prepositions usually stick together.

Prepositions indicate the spatial relation between the star and the mentioned body-part. In the majority of cases stars fall on the named body-part, as expressed by prepositions that serve as exact markers: "ἐν" ["in"] and "ἐπὶ" ["on"] in Greek, and "in" in Latin. However, some stars are only nearby the named anatomical region, as expressed by prepositions – e.g. 'above,' 'below,' 'between' etc. – that are called approximate markers here. The latter cases usually involve fainter stars, when body-parts are already defined by more prominent objects. Note that nominative or genitive references are also exact markers, identifying the star with the body-part. Table 3 presents the proportion of exact markers (i.e., the actual prepositions 'in' and 'on,' plus nominative and genitive markers) to the number of anatomical references. There is an interesting but understandable correlation between the size of the stellar population and the proportion of exact markers: the larger the population, the smaller this proportion, since the more stars we have, the more frequently they fall nearby (and not exactly on) the already defined figures.

The relatively wide range of preposition kinds (i.e., different prepositions) is somewhat unexpected. Not all of them are prepositions in the grammatical sense – e.g., Tycho uses expressions such as "præcedit" ["precedes"] ([T241]) or "contingit" ["touches"] ([T357]), which have the same descriptive function here as actual prepositions –, but most of them are. This suggests that the authors intended to provide accurate relations, especially Ptolemy and Tycho. Hevelius, however, seems less meticulous in this matter.

A possible objection to the above results could be that it is worth making a distinction between constellation stars and unformed stars (Greek: 'ἀμόρφωτοι', Latin: 'informata'). For many constellations, Ptolemy first lists those stars that actually constitute the constellation figure, and then separates those that are unformed in the sense that they are near, but not actually on, the figure. Out of the 48 constellations, 22 have unformed companions, totalling 108 in number (10.5% of all the objects). One could expect that exact markers are present in constella-

Table 3: Prepositions in the catalogues. Null – nominative: № of instances with a nominative case instead of a preposition. Null – genitive: № of instances with a genitive case instead of a preposition. Instances: № of actual prepositions. Explicit: № of explicitly stated prepositions. Explicit prop.: proportion of explicit prepositions to all actual prepositions. Exact markers: № of instances suggesting a spatial coincidence of body-parts and stars. Exact m. to AR: proportion of exact markers to all anatomical references. Kinds: № of different prepositions used. 6 most frequent: the most frequently used prepositions, with the № of occurrences in parentheses.

PREPOSITION	Ptolemy	Tycho	Halley	Hevelius
Null – nominative	3	22	12	99
Null – genitive	7	76	31	149
Instances	774	604	159	1078
Explicit	531	473	117	1052
Explicit prop.	68.60%	78.31%	73.58%	97.59%
Exact markers	619	564	172	964
Exact m. to AR	78.85%	80.77%	85.15%	72.16%
Kinds	25	24	12	14
6 most frequent	ἐν (327)	in (466)	in (129)	in (716)
	ἐπὶ (282)	ad (28)	ante (5)	ad (135)
	ὑπὸ (51)	inter (26)	sub (5)	sub (89)
	ὑπὲρ (23)	super (20)	ad (3)	super (60)
	μεταξύ (12)	sub (15)	inter (3)	inter (45)
	κατὰ (11)	infra (13)	super (3)	infra (14)

tion figure descriptions, while approximate markers in unformed star descriptions. However, we ignore this distinction for two reasons. First, Latin catalogues do not follow Ptolemy in this practice. They occasionally use the term “informis” in individual descriptions, but no systematic distinction is made, and the difference seems to lose its significance as the relative number of cases drops.[20] Second, even in Ptolemy, while he does use anatomical descriptions for unformed stars frequently,[21] discounting these cases from the corpus of descriptions yields 86.7% for the proportion of exact markers among the restricted population of constellation stars, which is not radically higher than the proportion of 78.9% among the overall list of anatomical references.

20 71 in Tycho, 10 in Halley, and 29 in Hevelius, all within a sample restricted to anatomical descriptions.

21 While the proportion of AD is altogether 70.1%, the proportion of AD in the limited corpus of unformed entries is still 63.0%.

4.4 Specifications and qualifications

Table 4 shows the results concerning specifications, i.e., which one of the possible multiple body-parts denoted by the anatomical term is specifically referred to. As we see, Ptolemy, Tycho, and Hevelius use specifications in around half of all anatomical references, while for Halley, this proportion is less than a third. This difference is probably not primarily due to individual variations in descriptive precision, but due to the set of constellation figures and named body-parts the authors deal with. Classical constellations are often human figures, viewed from the front, and bilateral organs such as arms, hands, legs, and feet, play a prominent role in these figures. It is not surprising that for all the catalogues, the specifications 'left' and 'right' are predominant. The southern constellations surveyed by Halley, on the other hand, are mostly animals viewed typically from the side, with less anatomical detail, leaving a narrower room for specification. Admittedly, limbs of quadrupedal animals require more specification so that the cases of double specifications often correspond to these cases (like 'right front leg'), but, e.g., tails (very frequent in Halley's case, and for animals in general) are unique, and the same goes for necks that are often long enough to host multiple stars.

Table 4: Specifications in the catalogues. Single spec.: № of anatomical descriptions with one specification. Double spec.: № of anatomical descriptions with two specifications. Sum total: overall № of specifications. Explicit: № of explicitly stated specifications. Explicit prop.: proportion of explicit to all specifications. Freq. per AR: proportion of the overall № of specifications to the № of anatomical references. Kinds: № of different specifications used. Most frequent: the most frequently used specifications, with the № of occurrences in parentheses.

SPECIFICATION	Ptolemy	Tycho	Halley	Hevelius
Single spec.	337	277	49	515
Double spec.	29	24	5	64
Sum total	395	325	59	643
Explicit	282	246	45	620
Explicit prop.	71.39%	75.69%	76.27%	96.42%
Freq. per AR	50.32%	46.30%	29.21%	48.13%
Kinds	17	16	14	18
Most frequent	ἀριστερὸς (139)	dextra (113)	dextra (26)	sinistra (237)
	δεξιὸς (139)	sinistra (110)	sinistra (12)	dextra (220)
	βόρειος (32)	superior (19)	laeva (5)	australis (44)
	νότιος (25)	borealis (16)	prior (4)	posterior (41)
	ὀπίσθιος (21)	praecedens (14)		borealis (38)
	ἐμπρόσθινος (15)	australis (13)		anterior (19)

For the same reasons, qualifications (i.e., which part of the named organ the star falls on) are significantly more frequent in Halley than the others, see Table 5. In case of larger body-parts with multiple references, one needs to qualify which portion represents the star in question. These cases are usually handled by using linked descriptions (see below), but qualifications can also serve this purpose. Also, even when there is only one star coinciding with the named large body-part, and linked descriptions are not feasible, it is informative to qualify whether the star is, e.g., on the tip or the root of the long tail. Moreover, these latter cases are more typical when relatively few stars are listed (like in the case of Halley) than when we have many small stars and, therefore, individual body-parts are more likely to be represented by several of them (e.g., Hevelius), prompting linked descriptions with selective terms instead of qualifications.

Table 5: Qualifications in the catalogues. Instances.: № of anatomical references with qualification. Explicit: № of explicitly stated qualifications. Explicit prop.: proportion of explicit to all qualifications. Freq. per AR: proportion of the overall № of qualifications to the № of anatomical references. Kinds: № of different qualifications used. Most frequent: the most frequently used qualifications, with the № of occurrences in parentheses.

QUALIFICATION	Ptolemy	Tycho	Halley	Hevelius
Instances	92	49	36	111
Explicit	75	44	26	111
Explicit prop.	81.52%	89.80%	72.22%	100%
Freq. per AR	11.72%	6.98%	17.82%	8.31%
Kinds	11	16	6	16
Most frequent	ἄκρα (51)	medium (10)	medium (11)	eductio (29)
	ἔκφυσις (21)	extremitas (6)	eductio (10)	medium (25)
	μέσος (13)	extremus (6)	extremus (10)	extremitas (17)
		eductio (4)	summus (2)	cuspis (11)

For specifications, it would be tempting to address the question, in which instances they are meaningful at all, and restrict the above results to those body-parts where specifications are required. In Ptolemy's catalogue, out of the 73 anatomical term-kinds, only around 30 are such that can have multiple referents within the figure. But, on the one hand, not all instances are clear: e.g., for animals with a side view, it is not obvious whether distinguishing between 'left' and 'right' limbs is always feasible. On the other hand, specifications are often missing even for those body-parts that have multiple specimens. In Ptolemy, the percentage of specifications within the corpus of those references that have several possible referents is still only around 60%, showing that this tradition is somewhat negligent with regards to specifications. Surely, the discursive context often provides

clues: when following the outline of a constellation figure, if a 'right knee' is mentioned in one description, then it is sufficient to refer to the 'shin' in the next one without the specification, but my impression is that there remains a considerable body of instances where not even the context is informative.

All in all, we can conclude that specifications, when theoretically required, are more often used than not. Qualifications on the other hand are quite rare, indicating a tendency to identify stars with body-parts, as opposed to placing stars on specific locations of body-parts.

4.5 Additional components

Descriptive components outside the referential and subject phrases are altogether rare. Properties (i.e., of the star itself) are shown in Table 6. We need to add some notes here. First, only Ptolemy employs descriptions with two properties mentioned, in 5 cases, while the others are always content with naming one property, if at all. Second, variants of the same term can appear (e.g., "lucida," "lucidior," "lucidissima" ["bright," "brighter," "brightest," respectively]), and while these are counted separately in the number of term kinds, they are lumped together in the results showing frequencies (see the instances where only the roots are given). Third, the meaning of implicit instances requires some explanation. In the cases so far, implicit instances were made possible by assuming that the referential phrase of the premier description simultaneously applies to the object(s) of the subsequent description(s) as well. However, properties belong to individual stars, and are not part of the anatomical reference. Nevertheless, there are cases where properties are attributed to groups of objects via linked descriptions, e.g. [T133], "Præcedens trium obscurarum in pede sinistro" ["The leading of the three obscure <stars> in the left leg"], where 'obscure' obviously applies to the two subsequent descriptions as well.

While Tycho has both the highest number of instances and the widest range of expression (implying a personal preference), but all in all, the number of instances is always small (less than 10% of descriptions), and this is not surprising. One the one hand, while providing information about the brightness or faintness of the object is informative (see the relatively high frequency of the corresponding terms), it is nevertheless redundant since that information is already contained in the data section for each star (by giving its magnitude). On the other hand, stars appear as light points, and they rarely have any notable property, except for some scarce cases when they seem nebulous, double, or slightly reddish.

Table 6: Properties of stars in the catalogues. Instances.: № of descriptions stating properties. Explicit: № of explicitly stated properties. Freq. per AD: proportion of the № of AD with properties to the overall № of AD. Kinds: № of different terms for properties. Most frequent: the most frequently attributed properties, with the № of occurrences in parentheses.

PROPERTY	Ptolemy	Tycho	Halley	Hevelius
Instances	46	65	4	55
Explicit	37	55	4	52
Freq. per AD	6.38%	9.88%	2.12%	4.65%
Kinds	7	15	3	9
Most frequent (root)	λαμπρὸς (19)	lucid . . . (29)	nebula (2)	parv . . . (20)
	ὑπόκιῤῥος (6)	parv . . . (12)	clara (1)	lucida (12)
	νεφελοειδὴς (6)	obscur . . . (9)	lucida (1)	nebulosa (11)

For other additional components, see Table 7. Providing names for stars is scarce. Let us mention, first, that Tycho provides five descriptions offering two alternative names each, so the total number of names is 31 in his case.[22] Second, Hevelius tends to omit descriptions entirely when they can be substituted with star names, and that is why his anatomical descriptions contain significantly less names than the whole catalogue.

Table 7: Further additional components in descriptions. Name (AD): № of AD containing individual star names. Name (all): № of all descriptions containing individual star names. Relational: № of AD containing an additional relational reference. Geometrical: № of AD containing an additional geometrical reference. Objectual: № of AD containing an additional inanimate reference.

ADDITIONAL	Ptolemy	Tycho	Halley	Hevelius
Name (AD)	11	22	2	7
Name (all)	15	26	4	24
Relational	85	46	6	34
Geometrical	56	28	0	15
Objectual	9	6	5	36

Cases where additional non-anatomical references are provided, on top of the anatomical ones within the same description, are also relatively rare (not more than a few per cent for each type). The authors are mostly content with offering

22 These include “Nova anni 1572” and “Nova anni 1600” as well, which are not strictly names but serve a similar purpose.

anatomical references, and complementing these with further clues for identification is rather uncommon.

4.6 Selective terms

Finally, we examine selective terms that are used to differentiate between the members of groups covered by linked descriptions. This is complicated by the fact that identifying these cases is more obvious in Ptolemy than the others. First, Ptolemy almost always uses the {Quantity} phrase (in premier descriptions) to indicate how many members the group has. Second, subsequent descriptions in his catalogue are always juxtaposed with the premier ones. Third, descriptive phrases in subsequent descriptions nearly always remain implicit, guiding the identification of groups. For the Latin authors however, indication of the quantity of group members is quite rare, implicit references are treated more casually, and group members are often separated by other objects in the list (especially for Hevelius). I found a significant number of instances where a description seems to have a form of a linked description, but other members of the group cannot be found (or have to be assumed based on vague circumstantial clues). As the structure of descriptions becomes less formulaic, the precise function of some terms is more flexible, and the boundary between instances of {Selective} on the one hand, and instances of {Property}, {Qualification}, and {Relational} on the other, becomes unclear (see Tycho's large number of selective term-kinds in Table 8).

Table 8: Selective terms in the catalogues. 1 selective term: № of AD containing one selective term. 2 selective terms: № of AD containing two selective terms. Instances SUM: overall № of selective terms in AD. Freq. per AD: Proportion of AD with selective term(s) to AD in general. Kinds: № of different selective terms. Most frequent: the most frequently used selective terms, with the № of occurrences in parentheses.

SELECTIVE	Ptolemy	Tycho	Halley	Hevelius
1 selective term	337	295	96	514
2 selective terms	11	54	0	142
Instances SUM	359	403	96	798
Freq. per AD	49.79%	55.89%	50.79%	67.51%
Kinds	11	42	20	29
5 most frequent (root)	ἑπόμενος (87)	praecedens (65)	borea . . . (20)	praecedens (156)
	προηγούμενος (80)	sequens (64)	austr . . . (19)	sequens (133)
	νοτιώτερος (74)	austr . . . (62)	praecedens (16)	borea . . . (78)
	βορειότερος (71)	borea . . . (56)	sequens (15)	austr . . . (72)
	μέσος (40)	media (31)	media (8)	superior (65)

Despite these uncertainties, the results shown in Table 8 illustrate variations in discursive preferences. Again, Hevelius is the most precise as he applies selective terms the most often (two thirds of descriptions, as opposed to half in case of the others). We may assume that it is because he deals with the highest number of stars, and therefore it is more frequent to have multiple stars falling on the same body-part. But the fact that Halley's proportion is so close to those of Ptolemy and Tycho, despite listing third as many stars, seems to contradict this explanation. The use of double selective terms also indicates intent on descriptive care, and here Hevelius is clearly superior to the others, especially Halley who never uses two selective terms in one description. However, a direct correspondence between the number of these instances and the overall number of stellar objects is made implausible by the huge difference between Ptolemy (eleven objects) and Tycho (54 objects).

Altogether, selective terms are used frequently, providing descriptive information about the objects, and especially about their relative locations.

5 Conclusions

While Ptolemy's language use is so formal and, to some degree, ritual that it can be considered technical jargon, the Latin catalogues are more flexible and narrative in the way descriptions are articulated. Ptolemy's descriptions conform to a generic formula that we took as our starting point, but this formula falls apart in the later catalogues, especially due to the variability (and even complete disappearance) of the subject phrase. I do not see any grounds for blaming this divergence on the difference between Greek and Latin, but rather, it seems to depend on the different eras and scientific cultures. However, this survey seems insufficient to support any detailed explanation for this contrast.

Apart from the formality of language use, there are further differences between individual catalogues in terms of the tools they prefer to employ to describe objects. The range of {Term} and the frequency of {Specification} are influenced by the set of constellation figures, while the percentage of exact markers and {Qualification} partly depend on the overall number of stars. But the correlations are never strict, and more often than not, variations seem to have more to do with individual preferences than with the properties of the surveyed stellar population.

Despite the differences, textual descriptions in general, and anatomical descriptions in particular, remained an integral part of star catalogues up to the eighteenth century. These descriptions indicate a genuine relation between body-

parts and corresponding stars, which is evidenced by a number of common discursive features. First, anatomical descriptions predominantly contain one anatomical reference each, i.e., they define their object by identifying it with one body-part only, without specifying its position by relating it to another body-part or providing a smaller part of the larger one mentioned. Then, the great majority of {Preposition} are exact markers, as opposed to approximate ones, showing that body-parts and star positions tend to coincide when possible. Furthermore, body-parts with structural significance (such as head, knee, foot, shoulder, or hand) are overrepresented as opposed to otherwise larger areas of the body (belly, back, chest). Also, details about the position within the named body-part, i.e., {Qualification}, are rarely given. Moreover, textual descriptions seldom provide further clues (i.e., other than anatomical, such as {Property} or {Name}) to single out their object, and additional identifications are also infrequent. On the other hand, the relative abundance of {Specification} indicates that the correspondence is meant to be unambiguous: when applicable, there is a tendency to specify which one of the multiple body-parts is referenced in the description. In sum, language use testifies to constellation figures as the conceptual framework to identify stars.

Modern readers are often inclined to view constellations as accidental cultural garnish, products of excessive imagination, or remnants of lingering superstition distinct from astronomy proper. But the results presented in this chapter indicate that constellations were functional within classical astronomy. Identifying stars as structural or anatomical elements of constellations served a cognitive purpose: it provided the means to memorize and recognize stellar objects, and that is how stars were endowed with identity.

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