CHAPTER ONE

Stars and storytellers

EVERY NIGHT a pageant of Greek mythology circles overhead. Perseus flies to the rescue of Andromeda, Orion faces the charge of the snorting bull, Boötes herds the bears around the pole, and the ship of the Argonauts sails in search of the golden fleece. These legends, along with many others, are depicted in the star patterns that astronomers term constellations.

Constellations are the invention of human imagination, not of nature. They are an expression of the human desire to impress its own order upon the apparent chaos of the night sky. For navigators beyond sight of land or for travellers in the trackless desert who wanted signposts, for farmers who wanted a calendar and for shepherds who wanted a nightly clock, the division of the sky into recognizable star groupings had practical purposes. But perhaps the earliest motivation was to humanize the forbidding blackness of night.

Newcomers to astronomy are soon disappointed to find that the great majority of constellations bear little, if any, resemblance to the figures whose names they carry; but to expect such a resemblance is to misunderstand their true meaning. The constellation figures are not intended to be taken literally. Rather, they are symbolic, a celestial allegory. The night sky was a screen on which human imagination could project the deeds and personifications of deities, sacred animals, and moral tales. It was a picture book in the days before writing.

Each evening the stars emerge like magic spirits as the Sun descends to its nocturnal lair. Modern science has told us that those twinkling points scattered across the sky are actually glowing balls of gas similar to our own Sun, immensely far away. A star's brightness in the night sky is a combination of its own power output and its distance from us. So far apart are the stars that light from even the nearest of them takes many years to reach us. The human eye, detecting the faint spark from star fires, is seeing across unimaginable gulfs of both space and time.

Such facts were unknown to the ancient Greeks and their predecessors, to whom we owe the constellation patterns that we recognize today. They were not aware that, with a few exceptions, the stars of a constellation have no connection with each other, but lie at widely differing distances. Chance alone has given

Figure 1: The 48 constellations of the Greek astronomer Ptolemy, illustrated on a pair of woodcuts made by the German artist Albrecht Dürer in 1515, one showing the northern sky (left) and the other the southern sky (right). The figures are depicted from the rear, as

us such familiar shapes as the ‘W’ of Cassiopeia, the square of Pegasus, the sickle of Leo, or the Southern Cross.

The constellation system that we use today has grown from a list of 48 constellations published around AD 150 by the Greek scientist Ptolemy in an influential book called the *Almagest* (see Table 1, page 15). Since then various astronomers have added another 40 constellations, filling the gaps between Ptolemy’s figures and populating the region around the south celestial pole that was below the horizon of the Greeks. The result is a total of 88 contiguous constellations that all astronomers accept by international agreement. The tales of these constellations are told in this book – along with two dozen others that fell by the wayside.

on a celestial globe. Note the large blank area of the southern sky that was below the horizon to the people who invented the constellations. The size of this blank zone is a clue to the latitude at which the constellation inventors lived. (Sotheby's)

Ptolemy did not invent the constellations that he listed. They are much older than his era, although exactly when and where they were invented is lost in the mists of time. The early Greek writers Homer and Hesiod (*c.*700 BC) mentioned only a few star groups, such as the Great Bear, Orion, and the Pleiades star cluster (the Pleiades was then regarded as a separate constellation rather than being incorporated in Taurus as it is today).

The major developments evidently took place farther east, around the Tigris and Euphrates rivers in what is now Iraq. There lived the Babylonians, who at the time of Homer and Hesiod had a well-established system of constellations of the zodiac, the strip of sky traversed by the Sun, Moon, and planets. We know this from a star list written in cuneiform on a clay tablet dated to 687 BC.

Scholars call this list the MUL.APIN series, from the first name recorded on the tablet. The Babylonian constellations had many similarities with those we know today, but they are not all identical. From other texts, historians have established that the constellations known to the Babylonians actually originated much earlier, with their ancestors the Sumerians before 2000 BC.

1.1. *Eudoxus, Aratus, and the Phaenomena*

If the Greeks of Homer and Hesiod's day knew of the Babylonian zodiac they did not write about it. The first clear evidence we have for an extensive set of Greek constellations comes from the astronomer Eudoxus (*c*.390–*c*.340 BC). Eudoxus reputedly learned the constellations from priests in Egypt and introduced them to Greece, which makes his contribution to astronomy highly significant. He published descriptions of the constellations in two works called *Enoptron* (Mirror) and *Phaenomena* (Appearances). Both these works are lost, but the *Phaenomena* lives on in a poem of the same name by another Greek, Aratus (*c*.315–*c*.245 BC). Aratus's *Phaenomena* gives us a complete guide to the constellations known to the ancient Greeks; hence he is a major figure in our study of constellation lore.

Aratus was born at Soli in Cilicia, on the southern coast of what is now Turkey. He studied in Athens before going to the court of King Antigonus of Macedonia in northern Greece. There, at the king's request, he produced his poetic version of the *Phaenomena* of Eudoxus around 275 BC. In the *Phaenomena* Aratus identified 48 constellations, although they are not the exact same as Ptolemy's 48. Aratus included the Water (now regarded as part of Aquarius) and the Pleiades, while Corona Australis was only alluded to as an anonymous ring of stars beneath the feet of Sagittarius; evidently it had not yet become a separate constellation. Neither does he mention Equuleus, which first appeared in the *Almagest* four centuries later.

Aratus also named six individual stars: Arcturus (Ἀρκτοῦρος); Capella, which he called Aix (Αἴξ); Sirius (Σείριος); Procyon (Προκύων), which formed a constellation on its own; Spica, which he called Stachys (Στάχυς); and Vindemiatrix, which he called Protrygeter (Προτρυγητήρ). This last star is a surprise, since it is so much fainter than the others, but the Greeks used it as a calendar star because its rising at dawn in August marked the start of the grape harvest.

Neither the Greeks nor the Egyptians actually invented the constellations that are described in the *Phaenomena*. The evidence for that statement lies not just in written records, but in the sky itself.

1.2. *Identifying the constellation inventors*

It is not too difficult to work out roughly where the constellations known to Eudoxus and Aratus were invented. The clue is that Aratus described no constellations around the south celestial pole, for the reason that this area of sky was permanently below the horizon of the constellation makers. From the extent of the constellation-free zone we can conclude that the constellation makers must have lived at a latitude of around 35°–36° north – that is, south of Greece but north of Egypt.

A second clue comes from the fact that the constellation-free zone is centred not on the south celestial pole at the time of Aratus but on its position many centuries earlier. The position of the celestial pole changes slowly with time because of a wobble of the Earth on its axis, an effect known as precession, and in principle this effect can be used to deduce the date of any set of star positions.

Because of the uncertainties involved, however, attempts to date the constellations as described by Aratus have produced a wide range of results. Derived values extend back to nearly 3000 BC, with a majority preference for somewhere around 2000 BC. A more comprehensive analysis by Bradley Schaefer of Louisiana State University published in 2004 concluded that Aratus's descriptions correspond to the sky as it appeared close to 1130 BC.

At present, the best we can say is that the constellations known to Eudoxus and Aratus were probably invented in the second millennium BC by people who lived just south of latitude 36° north. This date is too early for the Greeks and the latitude is too far south; Egyptian civilization is sufficiently old, but the required latitude is well north of them. The time and the place, though, ideally match the Babylonians and their Sumerian ancestors who lived in the area we know as Mesopotamia and who, as we have already seen, had a well-developed knowledge of astronomy by 2000 BC. Hence two independent lines of evidence point to the Babylonians and Sumerians as the originators of our constellation system.

But why had the constellation system introduced by Eudoxus not been updated by its makers to take account of the changing position of the celestial pole? As we have seen, the constellations introduced by Eudoxus and described by Aratus in the *Phaenomena* refer to the position of the celestial pole around a thousand years earlier. By the time of Aratus, the shift in position of the celestial pole meant that certain stars mentioned in the *Phaenomena* were now permanently below the horizon from latitude 36° north, while others not mentioned by Aratus had by then come into view. Oddly, Eudoxus himself seems not to have been bothered by these anomalies, if he even noticed them; but the great Greek astronomer Hipparchus (*fl.*146–127 BC) recognized the differences and was understandably critical.

Archie Roy of Glasgow University has argued that the Babylonian constellations reached Egypt (and hence Eudoxus) via some other civilization; he proposes that they were the Minoans who lived on Crete and the surrounding islands off the coast of Greece, including Thera (also known as Santorini). Crete lies between 35° and 36° north, which is the right latitude, and the Minoan empire was expanding between 3000 and 2000 BC, which is the right date. What's more, the Minoans were in contact with the Babylonians through Syria from an early stage. Hence they must have been familiar with the old Babylonian constellations, and they could well have adapted the Babylonian star groups into a practical system for navigation.

But the Minoan civilization was wiped out around 1700 BC by the explosive eruption of a volcano on the island of Thera about 120 km north of Crete. It was one of the greatest natural catastrophes in the history of civilization, the probable origin of the legend of Atlantis. Professor Roy supposes that Minoan refugees brought their knowledge of the stars to Egypt after the eruption, where it was eventually encountered by Eudoxus in unchanged form over a thousand years later.

The thesis is an attractive one, for it is easy to imagine the Minoans utilizing the Babylonian constellations in this way. In addition, many star myths are centred on Crete. However, it must be admitted that there is no direct evidence, such as wall paintings or star lists like those of the Babylonians, to demonstrate any Minoan interest in astronomy. So, for now, the theory that the Minoans were middlemen to our constellation system remains nothing more than an appealing speculation.

1.3. *The mythographers*

The *Phaenomena* of Aratus was immensely popular and became an essential part of the culture not just during the Greek era but for many centuries afterwards. It was translated several times into Latin, often with extensive commentaries by its translators and editors, and medieval versions were highly illustrated. For our purposes the most useful version is a Latin adaptation of Aratus attributed to Germanicus Caesar (15 BC–AD 19), which has more information about the identification of certain constellations than Aratus's original. According to the classicist David B. Gain this Latin version of the *Phaenomena* could have been written either by Germanicus himself or by his uncle (and adoptive father) Tiberius Caesar, but in this book I refer to the author simply as Germanicus.

After Aratus, the next landmark in our study of Greek constellation lore is Eratosthenes (*c.*276–*c.*194 BC), to whom an essay called the *Catasterisms* is attributed. Eratosthenes was a Greek scientist and writer who worked in Alexandria at the mouth of the Nile. The *Catasterisms* gives the mythology of 42 separate constellations (the Pleiades cluster is treated individually), with a listing of the main stars in each figure. The version of the *Catasterisms* that survives is only a summary of the original, made at some unknown date, and it is not even certain that the original was written by the real Eratosthenes; hence the author of the *Catasterisms* is usually referred to as pseudo-Eratosthenes. The antiquity of his sources is certain, though, because he quotes in places from a long-lost work on astronomy by Hesiod (*c.*700 BC).

Another influential source of constellation mythology is a book called *Poetic Astronomy* by a Roman author named Hyginus, apparently written in the second century AD. We do not know who Hyginus was, not even his full name – he was evidently not C. Julius Hyginus, a Roman writer of the first century BC. *Poetic Astronomy* is based on the constellations listed by Eratosthenes (Hyginus differs only by including the Pleiades under Taurus), but it contains many additional stories. Hyginus also wrote a compendium of general mythology called the *Fabulae*. In medieval and Renaissance times many illustrated versions of Hyginus's writings on astronomy were produced, the most famous of which was published by the German printer Erhard Ratdolt in Venice in 1482.

Marcus Manilius, a Roman author of whom virtually nothing is known, wrote a book called *Astronomica* around AD 15, clearly influenced by the *Phaenomena* of Aratus. Manilius's book deals mostly with astrology rather than astronomy

PTOLEMY'S ALMAGEST
The source of our modern constellations

In the *Almagest* Ptolemy listed 1,028 objects forming the classical 48 constellations. Three stars were deliberately entered twice, since Ptolemy regarded them as being shared between constellations: these were the stars we know as Alpha Piscis Austrini (Fomalhaut), Beta Tauri (Elnath), and Nu Boötis. Another three entries in Ptolemy's catalogue are actually not stars at all but star clusters: the Double Cluster in Perseus; M44 (Praesepe) in Cancer; and the globular cluster Omega Centauri. Hence it is usually said that the *Almagest* contains 1,022 stars. However, the stars 18 and 20 in Cetus are now thought to be duplicates of Cetus 17 and 19, so the total number of separate stars in the *Almagest* is actually 1,020. The number of stars Ptolemy catalogued in each constellation ranged from a mere two in Canis Minor to 45 in Argo Navis.

At the end of some constellations Ptolemy listed what he called ἀμόρφωτοι, i.e. *amorphotoi* – 'unformed' stars (*informatae* in Latin) that lay outside the recognized constellation pattern. Most of these unformed stars have since been absorbed into the relevant constellation or a neighbour, although in some cases later astronomers incorporated the orphan stars into new constellations.

Ptolemy's catalogue was not fully superseded until the end of the 16th century when the Danish astronomer Tycho Brahe produced a thousand-star catalogue that was ten times more accurate, heralding a new era of star surveying (see page 18).

Table 1

The 48 constellations listed by the Greek astronomer Ptolemy in the *Almagest*, second century AD (modern Latin names)

Andromeda	Cetus	Lyra
Aquarius	Corona Australis	Ophiuchus
Aquila	Corona Borealis	Orion
Ara	Corvus	Pegasus
Argo Navis (*now subdivided into Carina, Puppis, and Vela*)	Crater	Perseus
	Cygnus	Pisces
	Delphinus	Piscis Austrinus
Aries	Draco	Sagitta
Auriga	Equuleus	Sagittarius
Boötes	Eridanus	Scorpius
Cancer	Gemini	Serpens
Canis Major	Hercules	Taurus
Canis Minor	Hydra	Triangulum
Capricornus	Leo	Ursa Major
Cassiopeia	Lepus	Ursa Minor
Centaurus	Libra	Virgo
Cepheus	Lupus	

but it contains numerous insights into constellation lore and I have quoted him a number of times throughout this book.

The names of three other mythologists appear frequently on the following pages, and although they are not astronomers they must be introduced before we return to the history of the constellations. Foremost among them is the Roman poet Ovid (43 BC–AD 17), who recounts many famous myths in his books the *Metamorphoses*, which deals with transformations of all kinds, and the *Fasti*, a treatise on the Roman calendar. Apollodorus was a Greek who compiled an almost encyclopedic summary of myths known as the *Library* some time in the late first century BC or the first century AD. Finally there is the Greek writer Apollonius Rhodius (Apollonius of Rhodes) whose *Argonautica*, an epic poem on the voyage of Jason and the Argonauts composed in the third century BC, includes much mythological information. These are the main sources for the stories in this book.

1.4. *Ptolemy's 48 constellations*

Greek astronomy reached its pinnacle with Ptolemy (*c.* 100–*c.* 178) who worked in Alexandria, Egypt. Around AD 150, Ptolemy produced a summary of Greek astronomical knowledge usually known by its later Arabic title of the *Almagest* meaning 'the greatest'. At its heart was a catalogue of over a thousand stars arranged into 48 constellations (see Table 1, previous page), with estimates of their brightness, based largely on the observations of the Greek astronomer Hipparchus three centuries earlier.

Ptolemy did not identify the stars in his catalogue by means of Greek letters as astronomers do today, but described their position within each constellation figure. For instance, the star in Taurus which Ptolemy referred to as 'the reddish one on the southern eye' is known today as Aldebaran. At times, this system became cumbersome: 'The northernmost of the two stars close together over the little shield in the poop' is how Ptolemy struggled to identify a star (now called Xi Puppis) in the constellation of Argo Navis.

The tradition of describing stars by their positions within a constellation had already been established by Eratosthenes and Hipparchus. Clearly, the Greeks regarded the constellations not merely as assemblages of stars but as true pictures in the sky. Identification would have been easier if they had given the stars individual names, but Ptolemy added only four stars to those named by Aratus four centuries earlier: Altair which Ptolemy called Aetos (Ἀετός), meaning eagle; Antares (Ἀντάρης); Regulus which he called Basiliskos (Βασιλίσκος); and Vega which he called Lyra (Λύρα), the same name as its constellation.

It would be difficult to overemphasize the influence of Ptolemy on astronomy; the constellation system we use today is essentially Ptolemy's, modified and extended. Mapmakers in Europe and Arabia used his constellation figures for over 1,500 years, witness this passage from the preface to the *Atlas Coelestis* by the first Astronomer Royal of England, John Flamsteed, published in 1729:

> From Ptolemy's time to ours the names that he made use of have been continued by the ingenious and learned men of all nations; the Arabians always used his forms and names of the constellations; the old Latin

> catalogues of the fixed stars use the same; Copernicus's catalogue and Tycho Brahe's use the same; so do the catalogues published in the German, Italian, Spanish, Portuguese, French and English languages. All the observations of the ancients and moderns make use of Ptolemy's forms of the constellations and names of the stars so that there is a necessity of adhering to them, that we may not render the old observations unintelligible by altering or departing from them.

1.5. *Arabic influences*

After Ptolemy, Greek astronomy went into permanent eclipse. By the eighth century AD the centre of astronomy had moved east from Alexandria to Baghdad where Ptolemy's work was translated into Arabic and received the name *Almagest* by which we still know it. ʿAbd al-Raḥmān al-Ṣūfī (AD 903–986), one of the greatest Arabic astronomers (also known by the Latinized name of Azophi), produced his own version of Ptolemy's star catalogue called *Kitāb al-Kawākib al-Thābita* (*Book of the Fixed Stars*) in which he recorded many Arabic star names.

Bedouin Arabs had their own names for various bright stars, an example being Aldebaran which we have inherited from them. They also had a very different star lore from the Greeks, and commonly regarded single stars as representing animals or people. For example, the stars we know as Alpha and Beta Ophiuchi were regarded by the Arabs as a shepherd and his dog, while neighbouring stars made up the outlines of a field with sheep. Elsewhere could be found camels, gazelles, ostriches, and a family of hyenas.

Some of the Arabic names were already so many centuries old by the time of al-Ṣūfī that their meanings were lost even to him and his contemporaries, and they remain unknown today. Other star names used by al-Ṣūfī and his compatriots were direct translations of Ptolemy's descriptions. For example, the star name Fomalhaut comes from the Arabic meaning 'mouth of the southern fish', which is where Ptolemy had described it in the *Almagest*.

Another rich source of Arabic star names were astrolabes, star-finding devices like a flattened celestial sphere invented by the Greeks but developed to the height of sophistication by the Arabs. Each astrolabe had a rotating disk with decorative pointers that indicated the positions of various bright stars, the names of which were engraved on the pointer to assist identification.

From the tenth century onwards the translated works of Ptolemy were introduced into Europe by Islamic Arab incursions. There they were retranslated from Arabic into Latin, the scientific language of the day. The Spanish city of Toledo, in particular, is said to have become a veritable translation factory during the 12th century and scholars flocked there from all over western Europe to study the marvellous new works – not just on astronomy but mathematics and all other branches of science. It is through this roundabout route of old Greek writings being transmitted through Arabic hands and then translated back into Latin in Europe in the middle ages that we have ended up with a polyglot system of Greek constellations with Latin names containing stars with a mixture of Arabic and Greek titles.

1.6. *Extending Ptolemy's 48*

Although Arab astronomers increased the number of star names, the number of constellations remained unchanged. The first extension of Ptolemy's 48 was made in 1536 on a celestial globe by the German mathematician and cartographer Caspar Vopel (1511–61) who depicted Antinous and Coma Berenices as separate constellations; Ptolemy had mentioned these star groups in the *Almagest*, but only as subdivisions of Aquila and Leo respectively. Vopel's lead was followed in 1551 on a celestial globe by the great Dutch cartographer Gerardus Mercator (1512–94). The Danish astronomer Tycho Brahe (1546–1601) listed Antinous and Coma Berenices separately in his influential star catalogue of 1602 (see box), ensuring their widespread adoption. Coma Berenices is still a recognized constellation, but Antinous has since been remerged with Aquila.

By now the European age of exploration was well under way and navigator–astronomers turned their attentions to the hitherto uncharted regions of the sky in the southern hemisphere which had been below the horizon for the ancient Greeks. Three names stand out from this era. The first is Petrus Plancius (1552–1622), a Dutch theologian and cartographer; his name is the Latinized form of Pieter Platevoet – literally, Peter Flatfoot. The other two were the Dutch navigators Pieter Dirkszoon Keyser (*c.*1540–96), also known as Petrus Theodorus or Peter Theodore, and Frederick de Houtman (1571–1627). Surprisingly, all three are little-known today despite their lasting contributions.

TYCHO BRAHE'S STAR CATALOGUE

First true successor to the *Almagest*

During the last two decades of the 16th century the Danish astronomer Tycho Brahe (1546–1601), usually known simply as Tycho, exercised his exceptional ingenuity and energy to produce the first major star catalogue since the *Almagest* over 1,400 years earlier. Tycho's observatory, called Stjerneborg, was on the Danish island of Hven. His largest instrument, a wall-mounted quadrant, was in his adjacent castle called Uraniborg. Tycho's obsessive attention to detail resulted in a tenfold improvement in positional accuracy over his predecessors. Working solely with naked-eye instruments – the telescope had not yet been invented – he set new standards in celestial surveying and provided reliable data for constellation chartmakers.

Because he worked at latitude 55.9°, some 25° farther north than Ptolemy, Tycho was unable to observe the more southerly stars in the *Almagest*, but he observed additional stars in most of the other Ptolemaic constellations. An abridged version of Tycho's catalogue, containing 777 of the most accurately determined star positions divided into 45 constellations, was printed in 1602, the year after his death. This formed the basis of the first great celestial atlas, Johann Bayer's *Uranometria*, published in 1603 (see Section 2.4, page 32). Tycho's full catalogue of 1,004 entries was edited and published in 1627 by his former assistant, the German mathematician Johannes Kepler (1571–1630).

Table 2
Twelve southern constellations introduced 1596–1603 from the observations of Pieter Dirkszoon Keyser and Frederick de Houtman

Apus	Hydrus	Phoenix
Chamaeleon	Indus	Triangulum Australe
Dorado	Musca	Tucana
Grus	Pavo	Volans

1.7. *Scouting the southern sky*

Plancius instructed Keyser to make observations to fill in the constellation-free zone around the south celestial pole. Keyser was chief pilot on the *Hollandia* and later on the *Mauritius*, two of the fleet of four ships that left the Netherlands in 1595 on the first Dutch trading expedition to the East Indies. The outbound expedition spent several months anchored at Madagascar and it was there that Keyser made most of his observations. The Dutch historian and geographer Paul Merula (1558–1607) wrote in *Cosmographiae Generalis* (1605) that Keyser observed from the crow's nest using an instrument given to him by Plancius. This instrument was probably either a cross-staff or a universal astrolabe (sometimes known as an *astrolabium catholicum*), as this was still the pre-telescopic era.

Keyser died in September 1596 while the fleet was at Bantam (now Banten, near the modern Serang in western Java). His observations were delivered to Plancius when the fleet returned to Holland the following year. Regrettably, little else seems to be known about Keyser's life and accomplishments, but he left his mark indelibly on the sky.

Keyser's stars, divided into 12 newly invented constellations, first appeared on a globe by Plancius in 1598, and again two years later on a globe by the Dutch cartographer Jodocus Hondius (1563–1612). The acceptance of these new constellations was assured when Johann Bayer, a German astronomer, included them in his *Uranometria* of 1603, the leading star atlas of its day (see Section 2.4, page 32). Keyser's observations were eventually published in tabular form by Johannes Kepler in the *Rudolphine Tables* of 1627.

Unfortunately, Keyser's original manuscript is long lost and so we do not know whether he sorted his stars into the 12 new southern constellations himself or whether that was done later by someone else. If it was not Keyser, then a plausible candidate for the inventor of the dozen southern constellations is Frederick de Houtman (see box overleaf), younger brother of the commander of the Dutch fleet to the East Indies, Cornelis de Houtman (1565–99). Frederick was also a member of the crew and made celestial observations of his own, independently of Keyser.

After Keyser died, Frederick de Houtman would have had access to his records and might well have taken custody of them on the long voyage home. We can easily imagine him whiling away the time at sea by collating the joint observations, grouping them into constellations representing the wondrous things they had seen, and planning a more extensive observing campaign for his next voyage south, which was not long coming.

1.8. *A second voyage south*

The de Houtman brothers departed on a second voyage to the East Indies in 1598. During this voyage Cornelis was killed and Frederick was imprisoned for two years by the Sultan of Atjeh in northern Sumatra. Frederick made good use of his time as a captive by studying the local Malay language and making astronomical observations. In 1603, following his return to Holland, Frederick published his observations as an appendix to a Malay and Madagascan dictionary that he had compiled – one of the most unlikely pieces of astronomical publishing in history. In the Introduction he wrote: 'Also added [are] the declination of several fixed stars which during the first voyage I have observed around the south pole; and during the second [voyage], in the island of Sumatra, improved upon with greater diligence, and increased in number.'

De Houtman increased Keyser's measured star positions to 303, although 107 of these were stars already known to Ptolemy, according to a study of

FREDERICK DE HOUTMAN'S CATALOGUE

Explorer of the southern sky

The oldest surviving catalogue of the southern stars was made by the Dutch seafarer Frederick de Houtman (1571–1627) from Sumatra and published in Amsterdam in 1603. De Houtman made some observations of the southern stars on his first voyage to the East Indies in 1595–97 and revised and increased the number on his second voyage in 1598–1602.

De Houtman listed 304 stars (one without coordinates), 111 of them lying in the 12 new southern constellations which had been invented during or just after his first voyage. The bulk of his catalogue, though, was devoted to filling out the existing Ptolemaic figures – in particular, he gave positions for 56 stars in Argo Navis and 48 in Centaurus, of which 52 were new. He listed Crux as a separate constellation ('De Cruzero') for the first time.

The 12 new southern constellations as listed by de Houtman in Dutch, with their present-day names in brackets, are:

Den voghel Fenicx (Phoenix); De Waterslang (Hydrus); Den Dorado (Dorado); De Vlieghe (Musca); De vlieghende Visch (Volans); Het Chameljoen (Chamaeleon); Den Zuyder Trianghel (Triangulum Australe); De Paradijs Voghel (Apus); De Pauww (Pavo); De Indiaen (Indus); Den Reygher – literally 'the heron' (Grus); Den Indiaenschen Exster, op Indies Lang ghenaemt – literally 'the Indian magpie, named Lang in the Indies' (Tucana). In addition, he listed stars in the pre-existing constellations of Ara, Argo Navis, Centaurus, Corona Australis, Crux, Lupus, Columba (which he called De Duyve met den Olijftak – literally 'The dove with olive branch'), the tail of Scorpius, and southern Eridanus, which he termed 'den Nyli', the Nile.

THE CONSTELLATIONS OF PETRUS PLANCIUS
Adding to Ptolemy's 48

Petrus Plancius (1552–1622), Dutch cartographer and constellation inventor, left no written records so what we know of his role in the development of our system of constellations is based on examination of his surviving maps and globes. His first foray into celestial mapping came on a terrestrial map of 1592 which contained small insets showing the northern and southern sky. Among the constellations were two inventions of his own: Columba, the dove, and Polophylax, a pole-watcher, intended as the southern equivalent of Boötes (which the Greeks termed Arctophylax, i.e. bear-watcher). Columba, formed from stars listed in Ptolemy's *Almagest* south of Canis Major, became established. Polophylax, based on sketchy information about the southern stars and positioned between Piscis Austrinus and the southern pole in an area now occupied by Grus and Tucana, did not.

In 1598 Plancius produced a globe in conjunction with fellow Dutchman Jodocus Hondius (1563–1612) that was a landmark in constellation history. For the first time 12 new southern constellations were shown (see Table 2), based on the observations of Pieter Dirkszoon Keyser which had been brought back from the East Indies in 1597 after Keyser's death.

A later Plancius globe of 1612 introduced Camelopardalis and Monoceros, along with others in both hemispheres that never gained acceptance: Jordan, Tigris, Apes, Gallus, Cancer Minor, and Sagitta Australe. All but the last two first appeared in print (as distinct from on a globe) on the charts in Jacob Bartsch's book *Usus Astronomicus Planisphaerii Stellati* (Astronomical Use of the Stellar Planisphere) published in 1624, which led some to wrongly attribute their formation to Bartsch himself.

the catalogue by the English astronomer Edward Ball Knobel. Nowhere did de Houtman give Keyser credit for his priority – in fact, relations between the two men seem to have broken down during their voyage together, despite their common interest in the sky.

De Houtman's catalogue of southern stars, divided into the same 12 constellations as shown on the globes of Plancius and Hondius, was used by the Dutch cartographer Willem Janszoon Blaeu (1571–1638) for his celestial globes from 1603 onwards. Keyser and de Houtman are now credited jointly with the invention of these 12 southern constellations, which are still recognized today (see Table 2, page 19).

The Dutch historian Elly Dekker has argued that the true credit for dividing the newly observed stars into 12 constellations is actually due to Petrus Plancius, after he received Keyser's observations in 1597. Whatever the case, Plancius invented some other constellations that are indubitably his own, among them Columba, the dove, which he formed from nine stars that Ptolemy had listed as surrounding Canis Major. He also invented the unlikely sounding Monoceros,

THE STAR CATALOGUE AND ATLAS OF JOHANNES HEVELIUS

Johannes Hevelius (1611–87), compiler of the last major star catalogue to be made with naked-eye instruments, was a wealthy brewer from Danzig, now Gdańsk, Poland. In the 1640s he set out to enlarge and improve upon the star catalogue of Tycho Brahe. Hevelius observed from a platform over the roof of his house with naked-eye instruments such as a quadrant and sextant, assisted from 1663 by his second wife, Elizabeth (*c*.1646/7–*c*.1693). In 1679 a fire destroyed much of the building but his precious catalogue was saved. This, along with his star atlas, was in the process of being printed when Hevelius died in 1687. Elizabeth supervised its final publication in 1690.

Hevelius's master work came in three parts: an introduction called *Prodromus Astronomiae*, which included descriptions of the ten new constellations he had invented; the catalogue of 1,564 stars, called *Catalogus Stellarum Fixarum*; and the star atlas, *Firmamentum Sobiescianum*. Seven of the constellations introduced by Hevelius are still accepted and are listed in Table 3. Of these seven, Scutum had already been published in 1684 to honour the King of Poland who had helped Hevelius with rebuilding his observatory after the destructive fire. The remainder had been invented by 1687, the date on the printed catalogue, although they were not published until 1690. Three other Hevelius constellations shown on his charts – Cerberus, Mons Maenalus, and Triangulum Minus – were later dropped by other astronomers.

Table 3

Seven constellations introduced by Johannes Hevelius in his star catalogue of 1687

Canes Venatici	Leo Minor	Scutum	Vulpecula
Lacerta	Lynx	Sextans	

the unicorn, and Camelopardalis, the giraffe, from faint stars uncharted by Ptolemy. These three Plancius constellations are still accepted by astronomers, but his other inventions fell by the wayside.

1.9. *Filling the remaining gaps*

As the accuracy of astronomical observations improved and fainter stars were charted, the opportunities grew for innovators to introduce new constellations even among the area of sky known to the ancient Greeks. Ten more constellations were introduced later in the 17th century by the Polish astronomer Johannes Hevelius (1611–87), filling the remaining gaps in the northern sky. These were listed in his star catalogue dated 1687 and depicted on his accompanying star atlas called *Firmamentum Sobiescianum*, both published posthumously in 1690. Oddly, Hevelius insisted on measuring star positions with the naked eye even though he possessed telescopes for observing the Moon and planets; many of his constellations were deliberately faint as though he was boasting of the power of his eyesight. Of Hevelius's inventions, seven are still accepted by astronomers (see Table 3). The rejected three were Cerberus, Mons Maenalus, and Triangulum Minus.

Although the northern constellations were now complete, there were still gaps in the southern sky. These were filled by the French astronomer Nicolas Louis de Lacaille (1713–62) who sailed to South Africa in 1750. There he set up a small observatory at the Cape of Good Hope (not yet known as Cape

NICOLAS LOUIS DE LACAILLE AT THE CAPE

Fourteen more southern constellations

From August 1751 to July 1752 the French astronomer Nicolas Louis de Lacaille (1713–62) observed the southern skies from the rear of a house near Table Bay at the Cape of Good Hope, using a telescope of a mere 13.5 mm (half an inch) aperture mounted on a 3-ft quadrant. With this basic equipment he diligently compiled accurate observations of some 9,800 stars between the Tropic of Capricorn and the south celestial pole. He marked 1,930 naked-eye stars on a planisphere which he presented to the French Academy of Sciences in 1754. Lacaille's planisphere included the 14 new constellations he invented to accommodate the otherwise unadopted stars he had catalogued.

The names of his constellations in French, with modern equivalents, were: l'Atelier du Sculpteur (Sculptor); la Boussole (Pyxis); les Burins (Caelum); le Chevalet et la Palette (Pictor); le Compas (Circinus); l'Equerre et la Regle (Norma); le Fourneau (Fornax); l'Horloge (Horologium); la Machine Pneumatique (Antlia); le Microscope (Microscopium); Montagne de la Table (Mensa); l'Octans de Reflexion (Octans); le Reticule Romboide (Reticulum); le Telescope (Telescopium).

Lacaille's final catalogue, *Coelum Australe Stelliferum*, containing 1,942 entries was published posthumously in 1763. It included the same planisphere as before but this time with the constellation names in Latin rather than French and the stars identified with Greek and Roman letters. In both his initial and final catalogues Lacaille divided the stars of Argo Navis into three parts – the keel, the stern, and the sails – but his charts still showed it as a single figure.

Table 4

Fourteen constellations introduced by Nicolas Louis de Lacaille in 1754

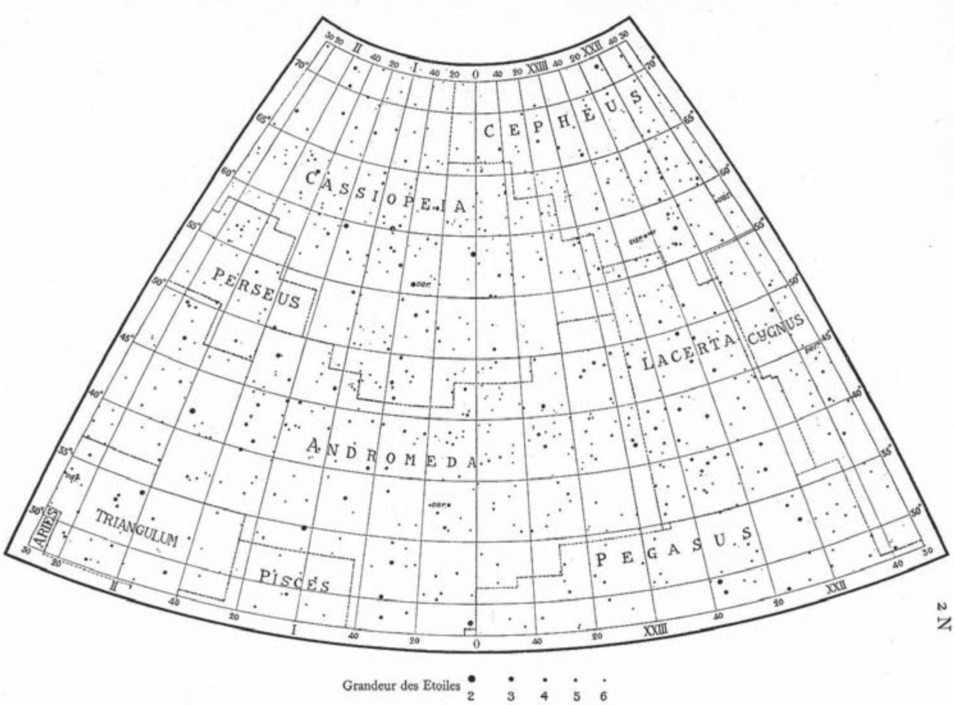
Antlia	Horologium	Octans	Sculptor
Caelum	Mensa	Pictor	Telescopium
Circinus	Microscopium	Pyxis	
Fornax	Norma	Reticulum	

Town) under the famous Table Mountain, which impressed him so much that he later named a constellation after it, Mensa. At the Cape from August 1751 to July 1752 Lacaille observed the positions of nearly 10,000 stars, an astounding total in the short time.

On his return to France in 1754, Lacaille presented a map of the southern skies to the French Royal Academy of Sciences which included 14 new constellations of his own invention (see Table 4). An engraved version of the map was published in the Academy's *Mémoires* in 1756 along with a preliminary catalogue and Lacaille's new constellations were rapidly accepted by other astronomers.

Whereas Keyser and de Houtman had mostly named their constellations after exotic animals, Lacaille commemorated instruments of science and the arts, with the exception of Mensa, named after the Table Mountain under which he had carried out his observations. His full catalogue, and a revised map with the names of his new constellations in Latin, was published posthumously

Figure 2: Official boundaries to the constellations were fixed in 1928 by a Belgian astronomer, Eugène Delporte, acting on behalf of the International Astronomical Union. Here is his chart for part of the northern sky, including Cassiopeia and Andromeda, from *Délimitation Scientifique des Constellations* (1930). The constellation boundaries follow circles of right ascension (the equivalent of longitude in the sky) and parallels of declination (the celestial equivalent of latitude). In this new and more scientific depiction of the sky, the old constellation figures have gone for good. (Author's collection)



in 1763 under the title *Coelum Australe Stelliferum*. In his catalogue, Lacaille divided up the unwieldy constellation Argo Navis, the ship, into the subsections Carina, Puppis, and Vela that astronomers still use as separate constellations. As well as creating 14 new constellations, Lacaille eliminated a pre-existing one – Robur Carolinum, Charles's Oak, introduced by the Englishman Edmond Halley in 1678 to honour his monarch King Charles II.

All those from Lacaille's time onwards who gerrymandered the constellations did so without lasting success, but there were plenty of astronomers who tried to leave their mark on the sky. Constellation mania had reached its height by 1801 when the German astronomer Johann Elert Bode (1747–1826) published his immense star atlas, *Uranographia*, containing over 100 different constellations; but by then astronomers realized that things had gone too far, and during the ensuing century this number was eroded by a process of natural wastage. The English astronomer Francis Baily (1774–1844) was influential in whittling down the number; his *British Association Catalogue* of 1845 included 87 constellations, the only omission from the modern total being Hevelius's Scutum. In 1899 the American historian Richard Hinckley Allen summed up the prevailing situation in his book *Star Names and Their Meaning*: 'From 80 to 90 constellations may be considered as now more or less acknowledged'.

1.10. *The final 88*

The matter was settled once and for all by astronomy's newly founded governing body, the International Astronomical Union (IAU). One of the tasks undertaken by the IAU at its first General Assembly in 1922 was to agree a definitive list of 88 constellations covering the entire sky, with standardized names and three-letter abbreviations. The IAU did not explain how the final choice came about, but the names are the same as those in the leading star catalogue of the day, the *Revised Harvard Photometry*, published by Harvard College Observatory in 1908, so it seems that the IAU simply adopted those.

One serious deficiency remained, though: the constellations still had no properly defined boundaries. Since Bode's time cartographers had drawn free-hand lines snaking vaguely between constellation figures, but these were arbitrary and varied from atlas to atlas. What's more, some stars were shared between constellations, a tradition that extended back to the catalogue in Ptolemy's *Almagest*. Some form of standardization was needed. The Belgian astronomer Eugène Joseph Delporte (1882–1955) of the Royal Observatory in Brussels presented proposals for a clearly defined system of constellation boundaries to the IAU's second General Assembly in 1925, and the IAU gratefully handed him the task of turning them into reality.

Delporte drew his boundaries along lines of right ascension and declination for the year 1875. This date was chosen for consistency with the earlier work of the American astronomer Benjamin Apthorp Gould (1824–96), who in 1877 had published boundaries for the southern constellations in his atlas called *Uranometria Argentina*. Delporte's boundaries zig-zagged to ensure that all named variable stars remained within the constellations to which they were already assigned, as requested by the IAU's Variable Stars committee. Delporte also modified some of Gould's boundaries, particularly in places where he had used diagonal lines rather than verticals and horizontals.

Delporte's work, approved by the IAU at its meeting in 1928 and published in 1930 in a book called *Délimitation Scientifique des Constellations*, amounts to an international treaty on the demarcation of the sky, to which astronomers throughout the world have conformed ever since. Constellations are now regarded not as star patterns but as precisely defined areas of sky, rather like countries on Earth. Unlike the map of the Earth, though, the map of the sky is unlikely to change.