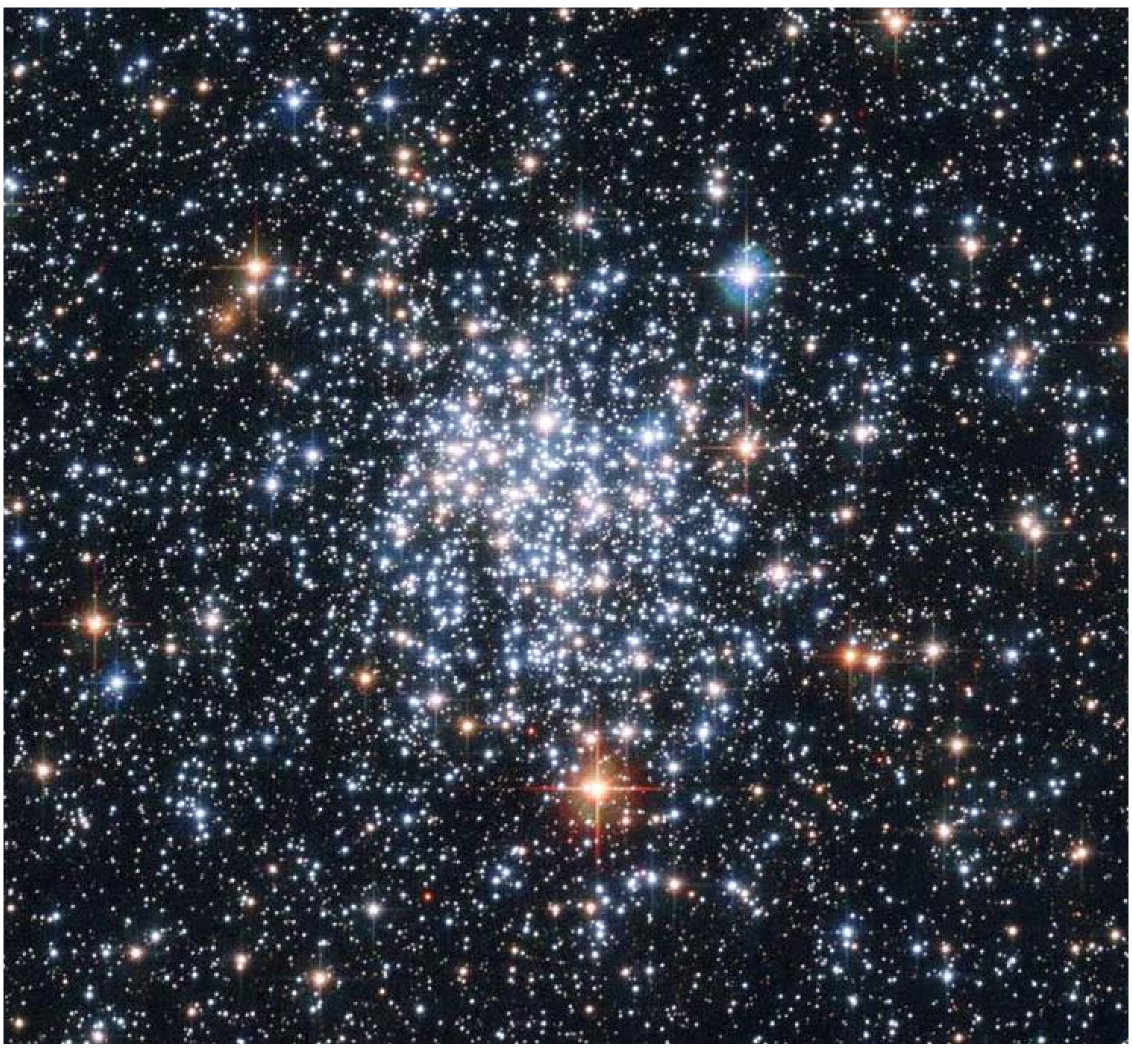
National Aeronautics and Space Administration

Exploring Stars in the Milky Way

Exploring Stars in the Milky Way



Math textbooks routinely provide 'real world' examples for students using familiar examples drawn from every-day situations, but there are many other areas where proportional relationships and working with large numbers aid in understanding our physical world.

This collection of activities is intended for students looking for additional challenges in the math and physical science curriculum in grades 3 through 6, but where the topics are drawn from astronomy and space science. This book 'Exploring the Stars in the Milky Way' introduces students to some of the most unusual places in our galaxy that are outside our solar system.

A common question that students might ask is 'How many stars are in the sky?' Answering this question introduces students to basic counting, tallying and grouping techniques, and to work with simple proportions. For example, a student will be shown an area of the sky and asked to systematically tally the number of stars, N, in this area. The student will then be told that this area represents a specific fraction of the full sky, 1/M, and will have to estimate the total stars in the sky by performing the multiplication MxN, where M is the number of groups and N is the number of members per group.

For more weekly classroom activities about astronomy and space visit the NASA website,

http://spacemath.gsfc.nasa.gov

Add your email address to our mailing list by contacting Dr. Sten Odenwald
Sten.F.Odenwald@nasa.gov

Front and back cover credits: Front) The NGC 3603 (Hubble Space Telescope) Back) NGC-6397 (Hubble). Inside: HST image of star cluster NGC 265; Pg 20 Ursa Major Courtesy Jerry Lodrigus (jerry5@astropix.com); pg 22 Enceladus Star Field PIA10526 (Cassini); Pg 24 Courtesy © T. Credner & S. Kohle, AlltheSky. Pg 26. Pluto field courtesy Bill Ferris (BillFerris@aol.com); Pg 28, Courtesy Richard Berry. BL Cam star field from AAVSO chart.

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Alignment with Standards

AAAS: Project:2061 Benchmarks

(3-5) - Quantities and shapes can be used to describe objects and events in the world around us. 2C/E1 **---** Mathematics is the study of quantity and shape and is useful for describing events and solving practical problems. 2A/E1 **(6-8)** Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone. The "things" from which they abstract can be ideas themselves; for example, a proposition about "all equal-sided triangles" or "all odd numbers". 2C/M1

NCTM: Principles and Standards for School Mathematics

Grades 3-5 :

- develop understanding of fractions as parts of unit wholes, as parts of a collection, as locations on number lines, and as divisions of whole numbers
- use models, benchmarks, and equivalent forms to judge the size of fractions

Grade 6-8 :

- understand and use ratios and proportions to represent quantitative relationships
- work flexibly with fractions, decimals, and percents to solve problems

Common Core Standards

Develop an understanding of fractions as numbers
3.NF.1. Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size 1/b.

Extend understanding of fraction equivalence and ordering
4.NF.1. Explain why a fraction a/b is equivalent to a fraction (n × a)/(n × b) by using visual fraction models, with attention to how the number and size of the parts differ even though the two fractions themselves are the same size. Use this principle to recognize and generate equivalent fractions

Build fractions from unit fractions by applying and extending previous understandings of operations on whole numbers.
4.NF.4. Apply and extend previous understandings of multiplication to multiply a fraction by a whole number.

Apply and extend previous understandings of multiplication and division to multiply and divide fractions.
5.NF.6. Solve real world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fraction models or equations to represent the problem.

Understand ratio concepts and use ratio reasoning to solve problems
6.RP.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities
6.RP.2. Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship

Have you ever looked at the night sky and seen thousands upon thousands of stars sprinkled across the heavens? You have probably tried to count them all, but gave up after a few minutes!

You probably also noticed that stars come in different brightnesses: some are very bright while many more are so faint you can almost not even see them at all.

Our sun is a star, and so we know that up close, stars can be incredibly bright. They can also come with different temperatures too. Our sun is a pretty yellow star with a temperature of 6,000 Celsius, but other stars can be much colder (2000 Celsius) or unimaginably hotter (50,000 Celsius!).

In this booklet, you will explore how astronomers measure the brightness of stars, how they classify them according to their temperature, and how they estimate how many stars there are in our Milky Way galaxy. You will also learn some very clever shortcuts for counting huge numbers of objects just by grouping them!

Why do astronomers count stars? It sounds like such a boring and uninteresting thing to do! Actually, this is one of the only ways that we have of finding out how big the Milky Way galaxy actually is, and where different kinds of stars are located. It also tells us exactly how many stars resemble our own sun.

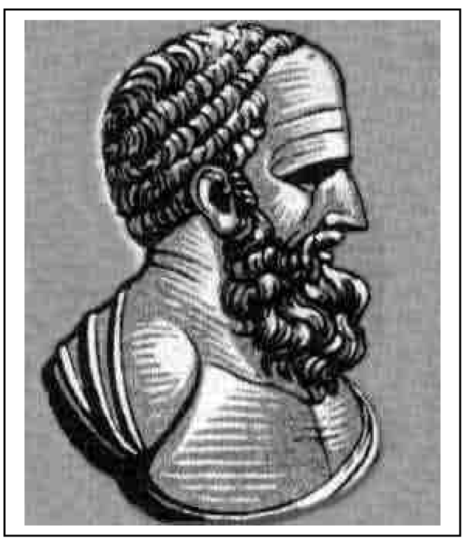
If you are searching for signs of life beyond Earth, its good to start with stars like our own sun, and to know where they are!

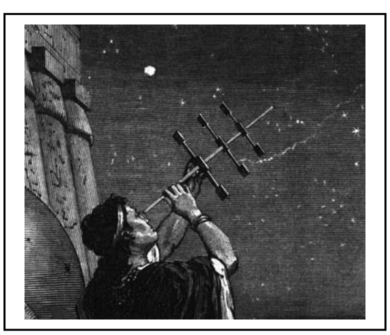
A small part of the star cluster NGC-6397
photographed by the
Hubble Space Telescope

When you look at the sky at night, the first thing you notice is the vast number of stars in the sky. The second thing you notice is that they are not all the same brightness. There are very bright ones like Vega and Rigel, and there are even more faint ones; many have no names at all!

When you look carefully at the stars, you can tell that even the faint stars are not all the same brightness. There are 'bright faint stars' that you have no trouble seeing, but then there are 'faint faint stars' that you can tell are there, but you really have to work hard at seeing them. These faint, faint stars cannot be seen in the glare of city lights, but if you go out into the country at night, you have a much easier time seeing them.

So, when you tell some one that you counted 1000 stars, its important to say whether this count included only bright stars easily seen, the faint stars that fill-out the patterns of the constellations, or the faint, faint stars that you can only see far from a city.





Way back in the year 135 BC, the astronomer Hipparchos (190 – 120 BC) decided to catalog all the stars he could see from his location in Greece. He, also, thought about the star brightnesses and came up with a way to rank them, just the way your teacher might line you up in order of increasing height from shortest to tallest.

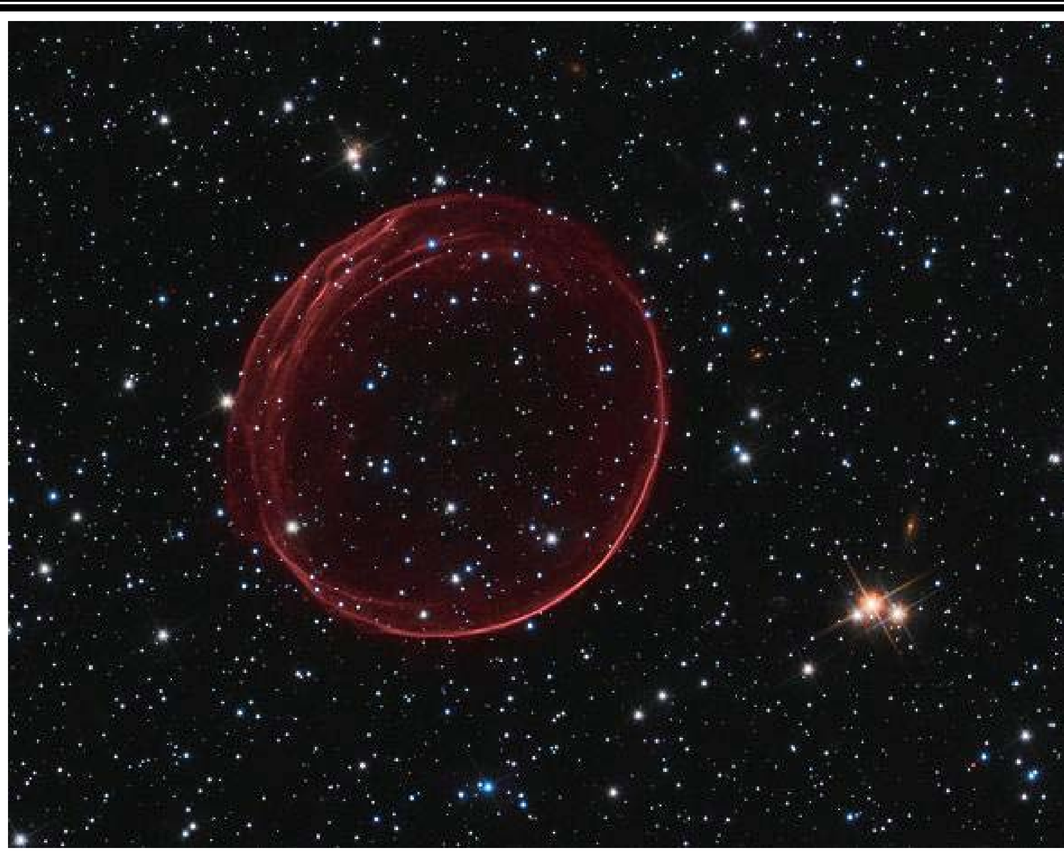
Hipparchos used only his normal eyesight and came up with a 6-step scale so that the brightest stars were Rank-1, the very faintest stars were Rank-6, and all the other 'naked eye' stars fell in one of the other ranks in-between.

Today, astronomers use this same ‘magnitude’ scale when they talk about the brightness of stars in the sky. A star with a magnitude of +6.0 is the faintest the human eye can see under the best conditions. The planets Venus, Mars, Jupiter and Saturn, along with several stars like Vega, can be very bright at times, and can be magnitude +1.0 objects.

Like a number-line, astronomers have also extended this scale so that it runs from the brightness of our sun at -26.0 to the faintest star visible by the Hubble Space Telescope with a magnitude of +35.0!

So now, when you tell someone that you counted 1,450 stars, you also can say that you counted these stars ‘down to’ a magnitude of +5.0, or +6.0. That tells everyone just how many of these faint stars you included in your count!

The NASA/Hubble photo below has stars as faint as +18.0



Another interesting thing about this magnitude scale is that for each change in magnitude by exactly 1.0, the brightness decreases by a factor of exactly 2.512 times!

For example, the star Vega in the constellation Lyra the Harp has a magnitude of +1.0, and the star Polaris has a magnitude of +2.0. The difference in their magnitudes is exactly 1.0, so that Polaris is 2.512 times fainter than Vega.

Here's another example: The star Betelgeuse in the constellation Orion has a magnitude of -0.5, and the star Markab in the constellation Perseus has a magnitude of +2.5. They differ by exactly 2.0 magnitudes. That means that Markab is 2.512 x 2.512 = 6.31 times fainter than Betelgeuse.

Question: Suppose we had two stars; a bright star A and a very faint star B, that differed by exactly 5.0 magnitudes. Using a calculator, how much fainter is Star B than Star A?

Answer: Each magnitude decreases is a brightness decrease by a factor of 2.512, so 5,0 magnitudes represents a brightness

$$(2.512) \times (2.512) \times (2.512) \times (2.512) \times (2.512)$$

This is just the same as $(2.512)^5$ which is 100 times!

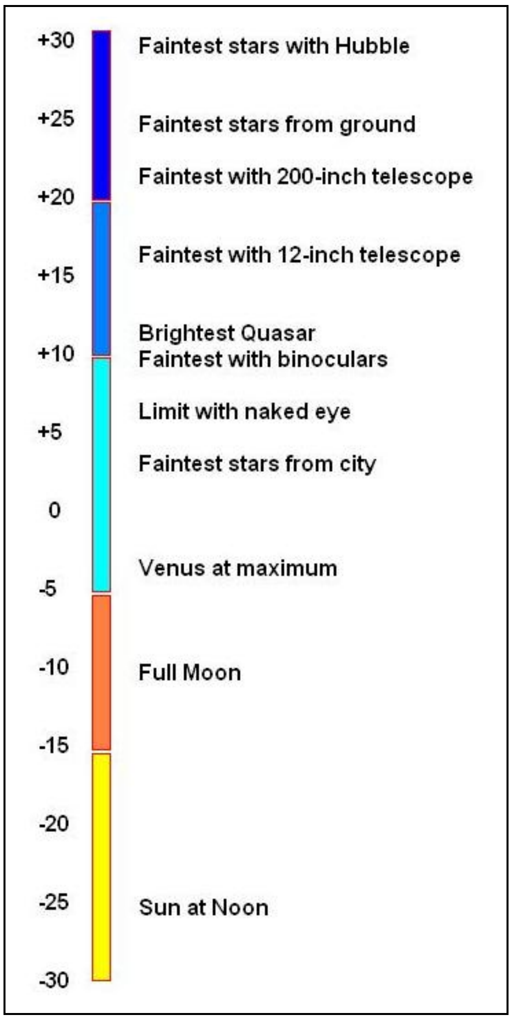
We can extend this pattern and figure out the brightness of even fainter stars that can only be seen with a telescope. Suppose the magnitude difference between two stars is 10 magnitudes, then 10 = 5+5 and according to the magnitude factors we have a brightness difference of

$$(100) \times (100) = 10{,}000.$$

Thousands of faint stars in the
Beehive Star Cluster

Working With the Stellar Magnitude Scale

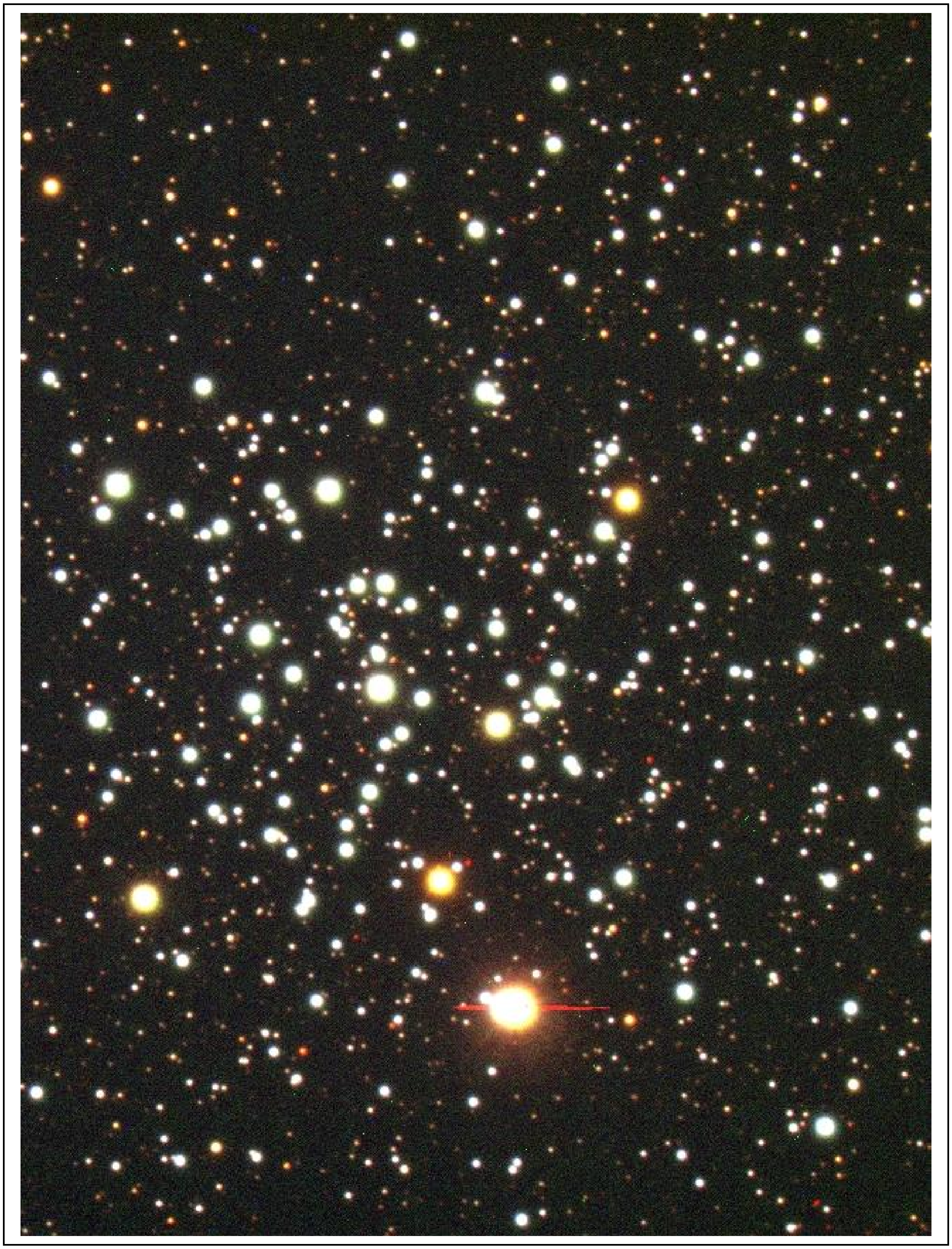
Astronomers measure the brightness of a star in the sky using a magnitude scale. The brightest objects have the SMALLEST number and the faintest objects have the LARGEST numbers.



1 – At its brightest, the planet Venus has a magnitude of -4.6. The faintest star you can see with your eye has a magnitude of +7.2. How much brighter is Venus than the faintest visible star?

2 – The full moon has a magnitude of -12.6 while the brightness of the Sun is about -26.7. How many magnitudes fainter is the moon than the Sun?

3 – The faintest stars seen by astronomers with the Hubble Space Telescope are about +30.0. How much fainter are these stars than the Sun?



Star cluster NGC-6649 in the
constellation Scutum

The brightness of a star is indicated by the magnitude scale, which leads to some interesting math!

Rule 1: The larger the number, the fainter the star. For example, Procyon has a magnitude of +0.4 while Wolf-359 has a magnitude of +13.5, so Wolf-359 is fainter than Procyon.

Rule 2: Each difference, by one whole magnitude, represents a brightness change of 2.51 times. For example, the star Tau Ceti has a magnitude of +3 while Fomalhaut has a magnitude of +1. The brightness difference between them is +3 - (+1) = 2 magnitudes or a factor of 2.51 x 2.51 = 6.3 times.

Use these two rules to answer the following problems:

Problem 1 - UV Ceti has a magnitude of +13.0 while Wolf-294 has a magnitude of +10.0. Which star is fainter, and by what factor?

Star	Apparent Magnitude
Ross-47	+11.6
Antares	+1.0
Alpha Centauri	-0.1
36 Ophichi	+5.1
Beta Hydra	+2.7
Rigel	+0.1
Eta Cassiopeia	+3.5
Sirius	-1.5
Wolf-359	+13.5
Kruger-60	+9.9

Problem 2 - Sirius has a magnitude of -1 and Mintaka has a magnitude of +2, which star is faintest. What is the magnitude difference, and by what factor do they differ?

Problem 3 - Sort the stars in the table so that the brightest star appears first, and the faintest star appears last.

Messier 29 star cluster image obtained
by the 2MASS observatory

How to Count Stars!

The sky is a very big place!!

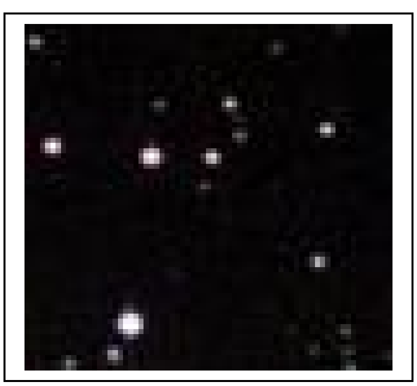
If you want to count how many stars you can see, you have a choice to make: Do you want a perfectly accurate number, or will your best estimate be good enough? If you are a scientist, you probably want to count each star and put it in a 'star catalog' with one line for each star like a phone book.

If you just want to get a 'good idea' of how many stars there are that you can see, you can pick your favorite spot and start counting 1…2..3… What could be simpler?

Big Problem: If you could count one star every second, it would take you two hours or more to finish, and it would not tell you how many were in the other hemisphere 'beneath your feet'.

If you use a little arithmetic and work with a simple proportion, you could do your counting in less than 5 minutes!

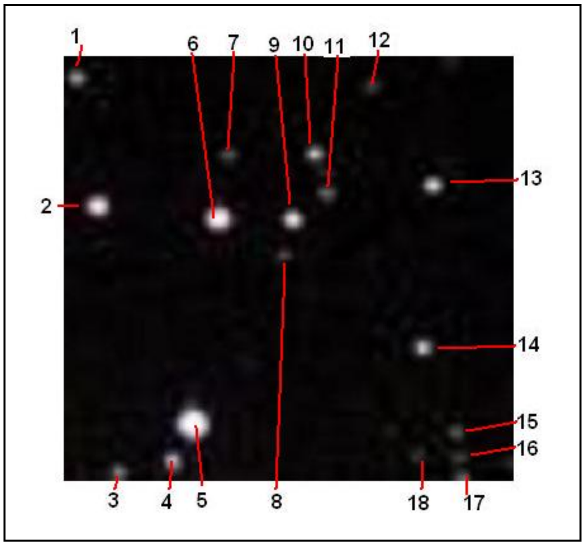
Here's how you do it!



The picture on the left shows a small piece of the sky. It's a perfectly ordinary spot: Not too many stars and not too few.

The photograph makes the star images look like small white or grey balls.

How many stars can you count?



If you counted carefully, you should have found **18 stars**, both bright and faint, covering this field. You could even tell that there are 10 bright stars and 8 faint stars!

The location of this patch in the original photograph is shown below.

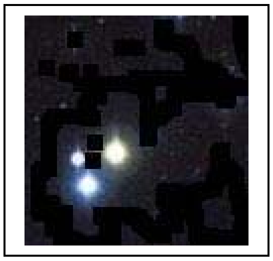
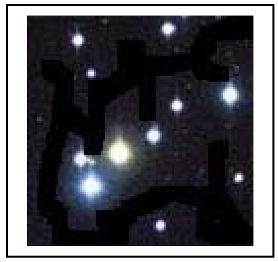
Compared to the size of the smaller picture, the larger picture can be covered by 11 x 11 = 121 of these smaller patches.

Instead of counting the stars in the bigger picture, one by one, you can estimate that the total number of stars in the bigger picture is about 121 x 18 = 2178 stars.

Because we used a photograph, all of the stars you just counted are too faint for the human eye to see! In fact, if you were to look for this patch of stars in the sky it would be called the 'Beehive Star Cluster' in the constellation Cancer the Crab. It is only about the diameter of the full moon! The full sky can be covered by 165,000 full moons, so if our little patch is typical, there are 18 x 121 x 165,000 = 359,370,000 stars in the sky! It would have taken us almost 12 years to count them one-by-one!

The answer you get for the number of stars in the sky depends on how faint you keep counting the stars.

Look at these three identical areas of the sky:


You can see there is a big difference between counting only the bright stars (left picture) to get only 3 stars; counting both the brightest and the not-so-bright stars (middle picture) to get 10 stars, or counting all of the stars including the faintest ones we can see (right picture) to get 48 stars!

Remember, astronomers use the magnitude scale to denote how bright a star appears to be. The left image shows stars as faint as magnitude +7.0. The middle picture shows stars as faint as +10.0. The right picture shows stars as faint as magnitude +13.0.

This is why, if you want to tell someone very accurately how many stars are in the sky, you have to also tell them to what magnitude level you counted stars!

The following examples let you test your counting and scaling abilities to explore how star counts change with magnitude


PISCES
PL.27.
ARIES
ANDROMEDA
PEGASUS
CETUS
AQUARIUS
Alpheratz
Scheat
Markab
Algenib
Mira
Mesarthim

How Many Stars are Brighter than +5 ?

3

On most clear nights, you can easily see the stars in the Big Dipper, which are brighter than magnitude +3, but if you look closely you can usually pick out several faint stars inside the bowel of the Big Dipper too. The brightest of these faint stars have a magnitude of about +5. The photo below shows a photo of this area taken by Astronaut Donald Pettit on the International Space Station.

Before telescopes and photography were invented, astronomers measured very carefully the positions of each star they could see in the sky. They used these measurements to draw a map of the sky showing the locations of the stars. They also sketched what the constellation looked like to make a combination of art and science. These Sky Atlas books are often works of art!

The figure to the left of the constellation Pisces the Fish was drawn by Sidney Hall for his book Urania's Mirror published in 1825 in London. It shows the locations of all the stars brighter than magnitude +5 . This area of the sky is 1/30 of the area of the full sky.

1 - How many stars (asterisks) can you count?

2 - How many stars are in the full sky?

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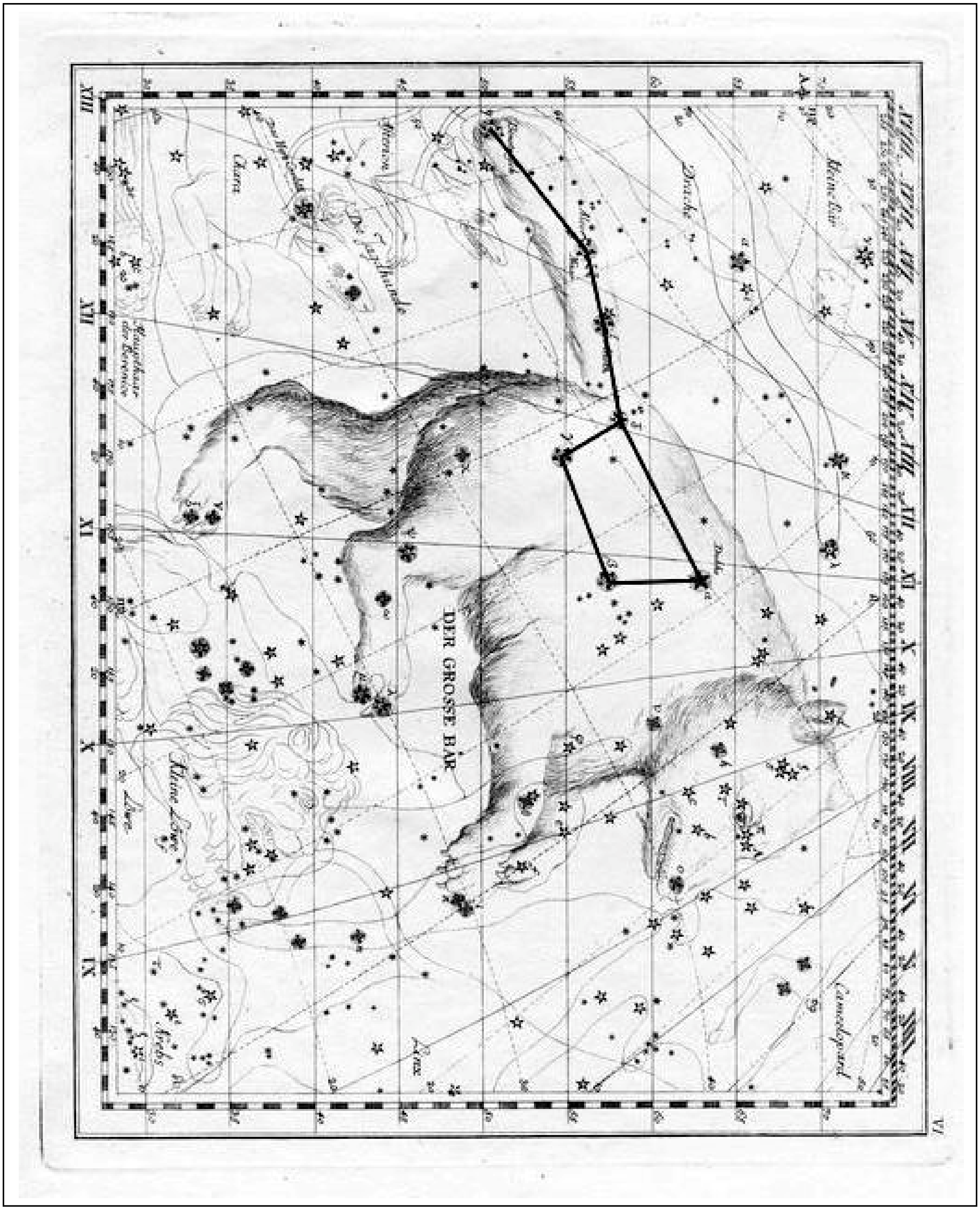

DER GROSE BAR

How many stars are brighter than +6 ?

4

More complicated star atlases tried to show, not just the bright stars you could easily see, but the faintest stars that could be seen by the human eye under the darkest sky conditions.

Today, we only find these conditions when we travel far from city lights into the country or the mountains.

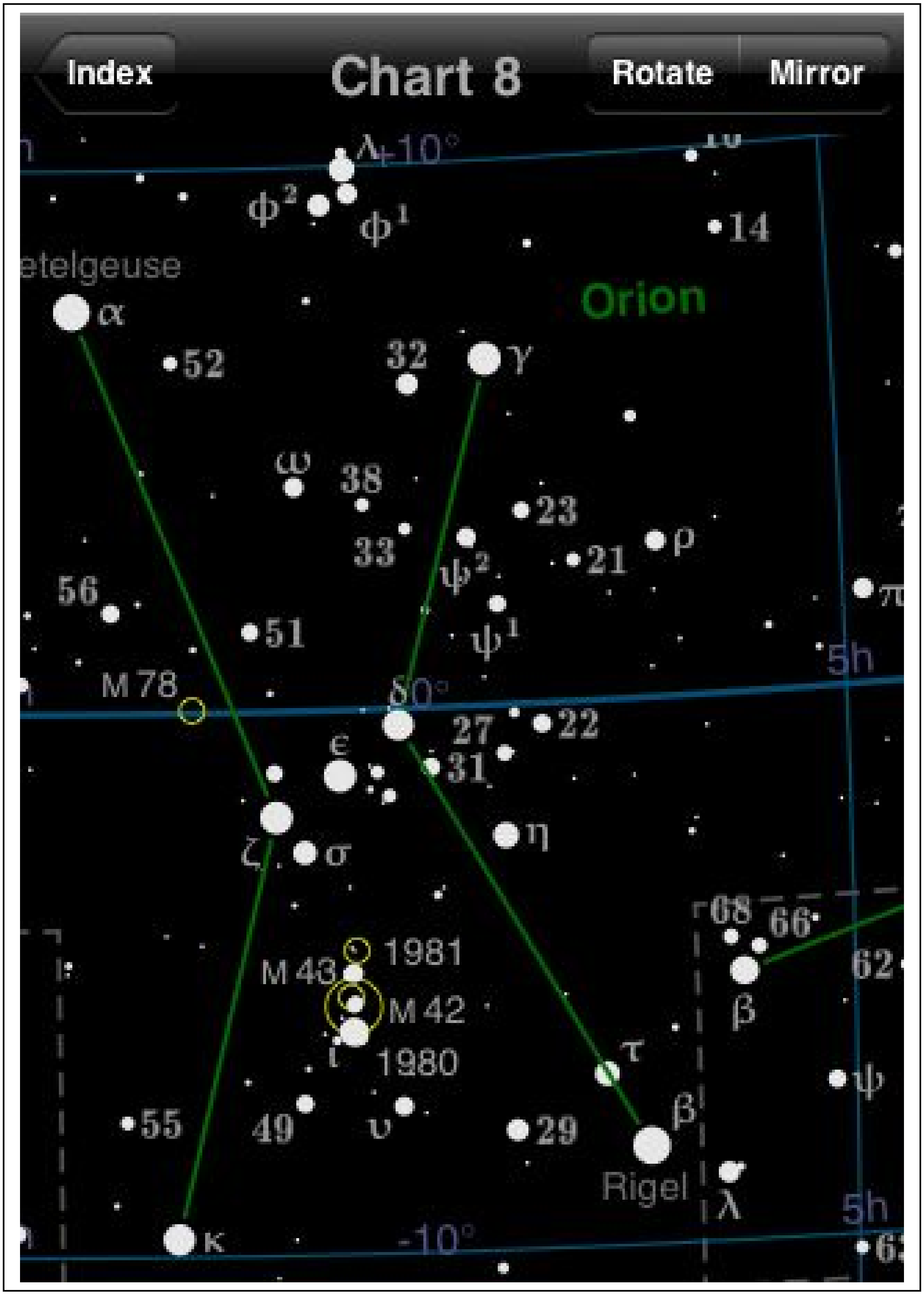
Before electric lights were invented, when candle light was common, you could step outside the door of your house in the city and see the stars in their dazzling multitudes. The faint light from the milky way would even cast shadows!

Here is an illustrations from the atlas by astronomer Johann Elert Bode published in 1782. It shows the constellation of the Great Bear, which astronomers call Ursa Major.

The atlas page gives the locations of all stars brighter than magnitude +6 , over an area of the sky that is 1/18 of the full sky area.

1 - How many stars (black dots and asterisks) can you count?

2 - How many stars are in the full sky?



Index
Chart 8
Rotate
Mirror
Orion
etelgeuse
M 78
M 43
M 42
1981
1980
Rigel

How many stars are brighter than +8 ?

5

Today you can buy an iPhone 'app' that displays portions of the sky in atlas form, like the image to the left for the constellation of Orion.

This app displays all catalogued stars brighter than a magnitude of +8 in their correct locations, and represents an area equal to 1/163 of the full sky area.

Although all of the stars have 'catalog numbers' that astronomers use to identify them, only the names for the brightest stars are shown, often with Greek letters or numbers.

1 - How many stars (white dots) can you count?

2 - How many stars are in the full sky?


© 2006 Jerry Lodriguss

How many stars are brighter than +8 ?

To study and count stars fainter than what the eye can see, you need to use a telescope to make the stars appear brighter to the eye when you look through the telescope's eyepiece.

You can also use photography to capture an image of the sky. The starry night sky is a popular subject for amateur and professional photographers.

The photograph to the left was taken by Jerry Lodrigus and shows the entire Big Dipper rising over a horizon of trees and mountains at night. The field of view of this photograph is 1/120 of the full sky.

The faintest stars in this picture are magnitude +8 , which means that they are more than 6 times fainter than what the human eye can see.

1 - How many stars (white dots) can you count?

2 - How many stars are in the full sky?

How many stars are brighter than +12 ?

Sometimes when astronomers are photographing one particular object, they also capture in the same photograph the background stars surrounding their object.

The photograph to the left was taken by the Cassini spacecraft as it was approaching Saturn's moon Enceladus. It was only 83,000 kilometers (52,000 miles) from this small moon, which is about 500 km (300 miles) across.

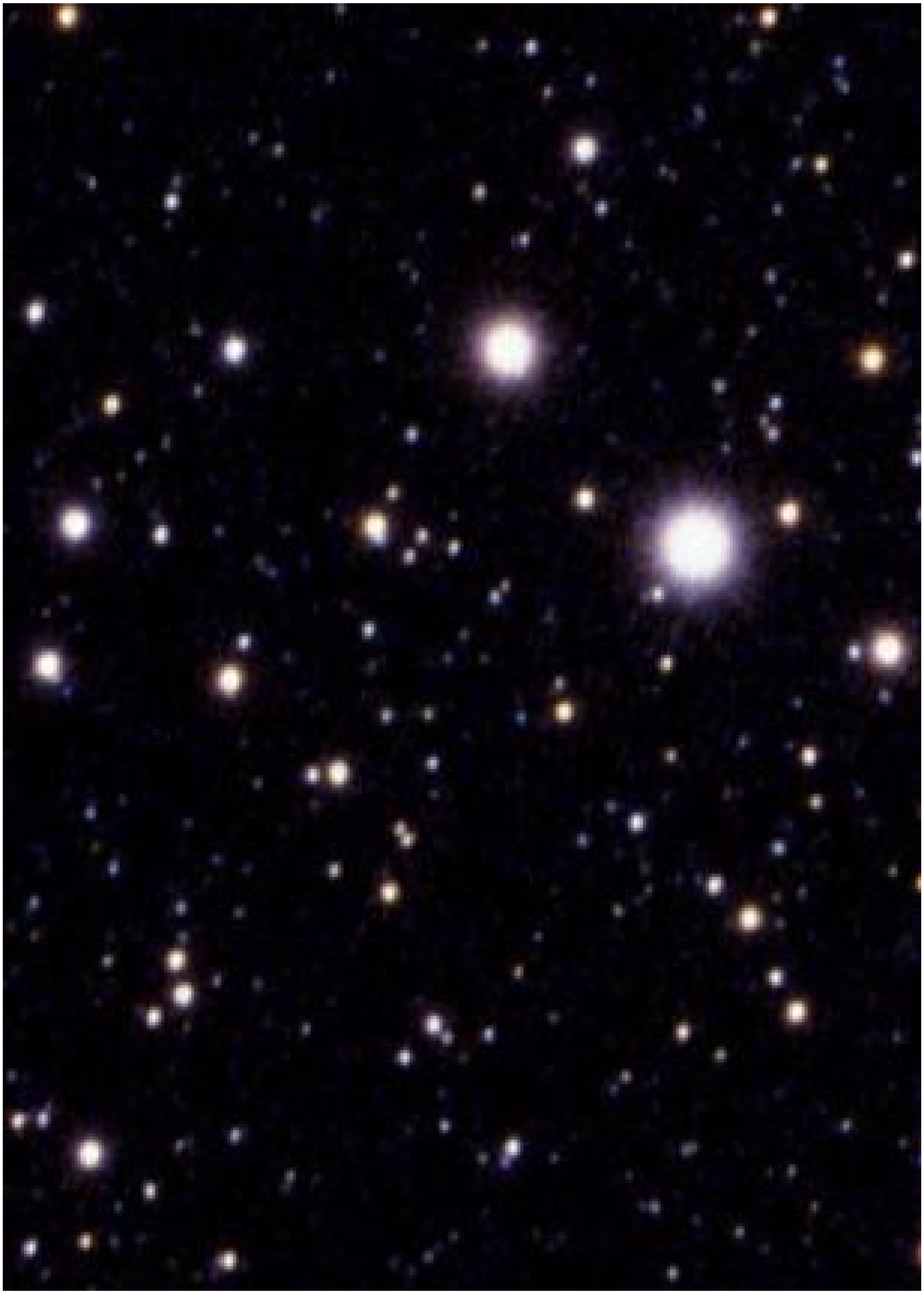
The faintest stars in this picture are magnitude +12, and the field only covers about 1/3400 of the full sky.

1 - How many stars (white dots) can you count?

2 - How many stars are in the full sky?

3 - How many magnitudes fainter are the stars in the Enceladus field compared to the faintest star you can see with your eye (+6)?

4 – By what factor are these stars fainter than what you can see with your eye? (Hint: A 1.0 magnitude difference is a factor of 2.5 in brightness)



How many stars are brighter than +13 ?

8

The constellation Crater the Cup is a faint constellation made from stars between magnitudes +4 and +5. It is located far from the teaming star clouds of the Milky Way, in a rather 'boring' part of the night sky.

Its location makes it a perfect target for studying faint stars in the sky, without the glaring brilliance of brighter stars to overshadow them.

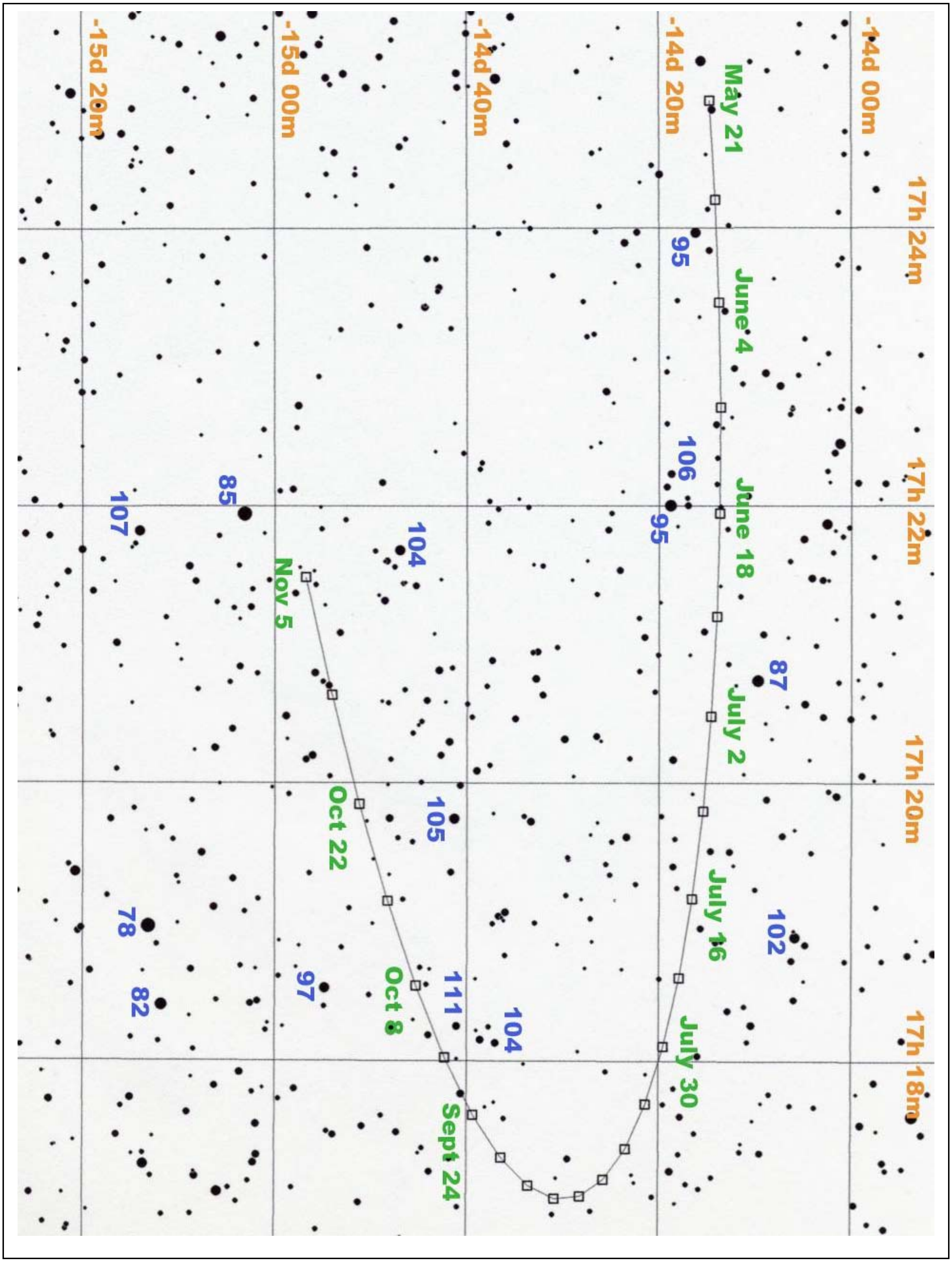
This photograph was taken by Till Credner and Sven Kohle from a dark sky location in Namibia using a Nikon camera. They had to use a telescope to guide the camera for this 30-minute exposure. Because Earth rotates on its axis, all exposures longer than 10 seconds have to be guided to keep up with the moving stars.

The two bright stars are called Algorab (lower) and Minkar (upper). Algorab is located 87 light years from Earth, while Minkar is 318 light years from Earth. Algorab is only about 260 million years old, and was not born until long after earth was formed.

The field of this photograph is about 1/3500 of the full sky. You could fit four full moons across the width of this picture!

1 - How many stars (white dots) can you count?

2 - How many stars are in the full sky?


-14d 00m
-14d 20m
-14d 40m
-15d 00m
-15d 20m
17h 24m
17h 22m
17h 20m
17h 18m
May 21
June 4
June 18
July 2
July 16
July 30
Sept 24
Oct 8
Oct 22
Nov 5
95
106
95
87
102
104
85
107
104
105
111
97
78
82

How many stars are brighter than +16 ?

Astronomers first started cataloging the stars in the sky over 2000 years ago. Since that time, photography and satellite-based telescopes have appeared.

This new technology has allowed astronomers to create computer-based star atlases that now include the accurate positions and magnitudes of extremely faint stars.

The diagram to the left is on such computer display, which shows the locations of all the stars brighter than magnitude +16. The blue numbers give the magnitudes of the brightest stars without decimal points that could be mistaken for stars. For example '106' means a magnitude of +10.6.

To avoid making a very confusing and crowded diagram, the field of this atlas is only 1/18000 the size of the full sky!

1 - How many stars (black dots) can you count?

2 - How many stars are in the full sky?


142
120
148
158
135
123

How many stars are brighter than +18 ?

When you use big telescopes to study the sky, you see more and more stars. At the same time, the size of the field that you are studying shrinks!

Your eye is a low-power magnifier. This lets you see almost the entire sky over your head. If you used a pair of 50-power binoculars, you would certainly see much fainter stars, but you would see them over a much smaller area of the sky.

The image to the left shows the stars in a direction of the sky close to the Milky Way, so you will see many more faint stars than you would towards the Big Dipper.

This field is only 1/one millionth of the area of the Milky Way, where most of the very faint stars in the sky are located. It would take 1 million of these little pictures placed side-by-side to fill up the entire surface of the Milky Way night sky!

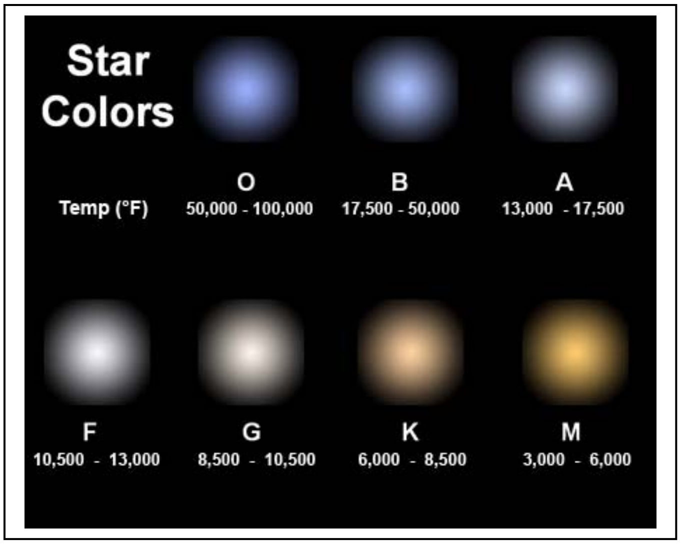
1 - How many stars (white dots) can you count?

2 - How many stars are in the Milky Way down to this magnitude level ?

3 – How many magnitudes fainter than the human limit are the faintest stars in this field?

4 – By what factor are these stars fainter than what you can see with your eye? (Hint: A 1.0 magnitude difference is a factor of 2.5 in brightness)

Classifying Stars by Temperature



Since the early-1900s astronomers have carefully studied the light from thousands of stars and discovered that stars do not all have the same temperature.

Very cool stars like Betelgeuse and Antares appear red is they have temperatures near 3,000 Celsius. Stars appear yellow like our sun if they have temperatures near 5,000 Celsius. They can also appear blue-white like Vega or Sirius if they have temperatures near 10,000 Celsius.

Type	Temperature	Color	Example
O	40,000	Blue	Alnitak
B	20,000	Blue-White	Rigel
A	10,000	White	Vega
F	7,000	Yellow-white	Canopus
G	5,000	Yellow	Sun
K	4,000	Orange	Arcturus
M	3,000	Red	Betelgeuse

Suppose an astronomer studies 1000 stars and finds that 1 is a B-type star, 30 of them are stars with temperatures near 7000 Celsius, 76 are like our sun, and 765 are M-type stars.

Problem 1 – What percentage of the stars are sun-like?

Problem 2 – If the astronomer surveyed the entire sky to a magnitude limit of +13 and counted 945,000 stars, about how many sun-like stars might there be?

Name	Right Ascension	Declination	Magnitude	Type
2	00:00.2	+01:05:19.83	9	F
74	00:27.8	+00:12:17.90	9	F
94	00:34.5	+01:03:58.40	9	K
100	00:39.1	+00:13:21.78	8	K
218	01:27.6	+00:18:03.45	9	K
285	01:58.1	+00:07:43.51	9	G
308	02:06.5	+00:24:54.28	9	F
518	03:38.9	+01:35:08.98	9	K
644	04:45.3	+00:03:21.46	9	F
645	04:46.4	+01:32:12.26	8	A
691	05:03.5	+01:02:15.35	9	G
820	06:08.1	+00:07:16.50	8	G
909	06:52.3	+01:51:39.80	9	F
951	07:07.9	+01:02:47.77	9	G
954	07:08.7	+00:20:25.08	9	K
980	07:19.5	+01:39:53.96	9	G
1023	07:38.5	+00:10:44.37	9	K
1024	07:40.0	+01:05:38.86	8	A
1052	07:50.2	+00:07:47.39	9	F
1061	07:55.8	+00:47:26.56	9	A
1179	08:52.3	+00:41:32.60	8	K
1232	09:12.5	+00:04:29.57	9	K
1256	09:24.6	+00:04:18.96	9	F
1261	09:28.1	+01:14:37.92	8	G
1762	13:15.0	+01:07:59.23	9	K
1795	13:32.4	+00:50:49.76	9	K
1834	13:47.6	+01:23:00.55	7	K
1857	14:01.2	+00:52:06.86	9	G
1933	14:36.5	+01:17:48.25	7	F
2100	15:43.8	+00:07:05.57	9	K
2171	16:18.4	+00:02:37.80	9	F
2220	16:39.4	+01:51:02.56	7	M
2243	16:48.7	+01:50:05.01	9	K
2310	17:19.8	+00:35:22.91	9	G
2321	17:28.8	+00:19:17.76	8	F
2348	17:41.5	+01:19:25.64	9	F
2363	17:47.7	+01:41:18.84	6	G
2379	17:54.7	+00:22:39.33	9	G
2399	18:03.5	+00:37:01.82	7	G
2948	22:40.7	+01:49:23.44	9	A

Classifying Stars in a Star Field

12

For many decades, astronomers have carefully created catalogs of stars. These are large tables or books that organize the stars in the sky by their name, position, brightness and type.

The table on the facing page shows a small portion of such a catalog. It is taken from the Smithsonian Astronomical Observatory's 1966 star catalog, which lists all of the stars in the sky that are brighter than magnitude +9.

The stars cover an area of the sky that is only 1/6580 of the full area of the sky. There are many things that you can learn from this star catalog!

Problem 1 – How many stars are listed in this small patch of the sky?

Problem 2 – About how many stars cover the entire sky to a faintness of magnitude +9 if this is a typical patch of the sky?

Problem 3 – What fraction of the stars have the same classification as our sun, which is Type-G?

Problem 4 - The table shows that there are 4 times as many 9^{th} magnitude stars as 8^{th} magnitude. How many 10^{th} magnitude stars would you predict, and how many stars brighter than 10^{th} magnitude would there be across the entire sky?

Working with Big Numbers in Astronomy

In astronomy, we almost always work with very big numbers because all of the things that we study are either very big, very far away, or very old.

This picture shows the 47 Tucanae globular star cluster located in the constellation Tucana. It contains about 1 million stars!

To learn more about this star cluster, such as its size (120 light years) and distance from the sun (13,400 light years), we have to work with very big numbers if we want to use units like kilometers or meters. But if we use a unit like the light year, the numbers can be made much smaller, and easier to work with.

Calculating a Light Year – the distance light travels in 1 year.

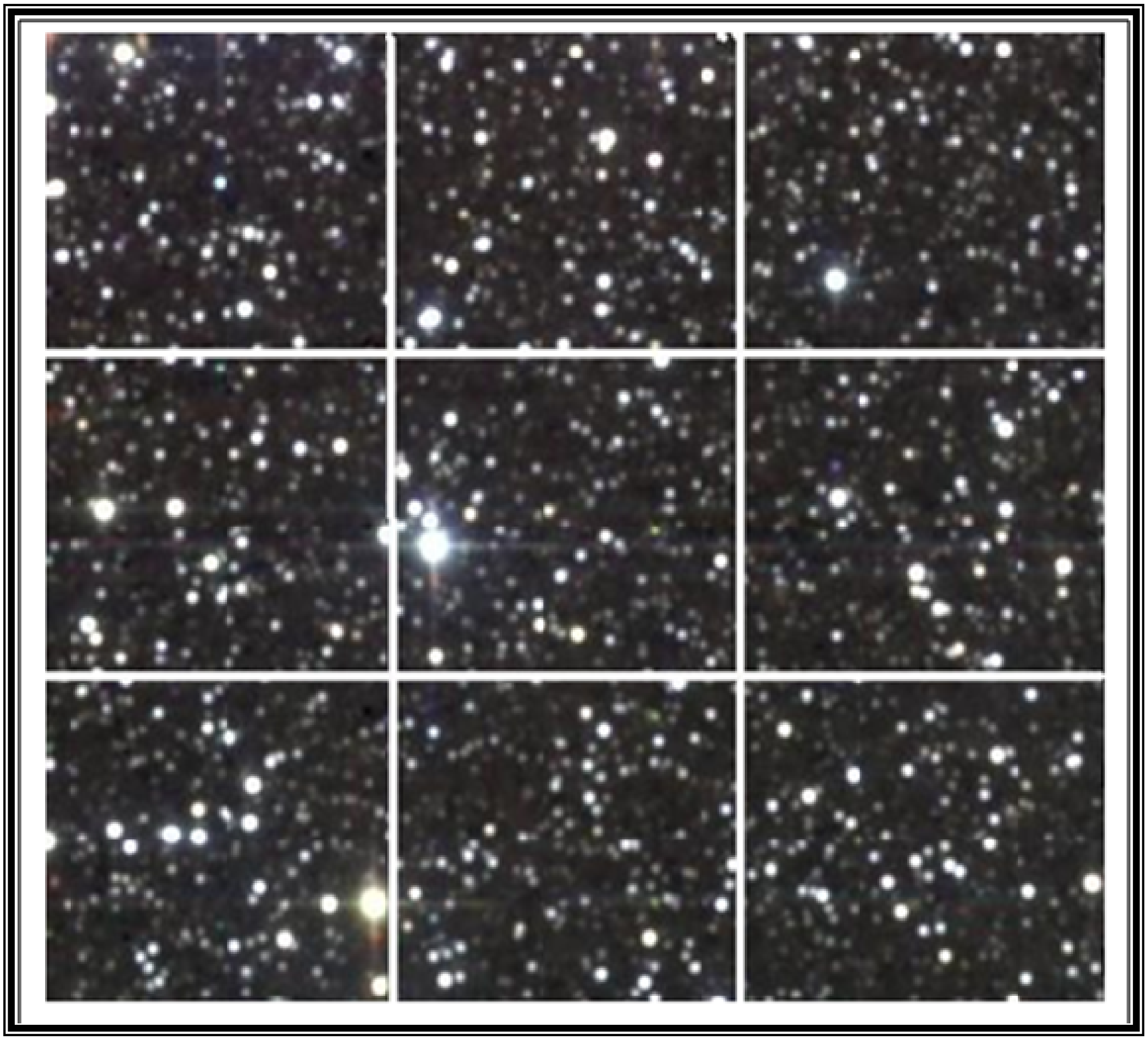
Problem 1 – The number of seconds in one year can be written as 30,000,000. Write this number in words.

Problem 2 – The distance that light travels in one second is 300,000 kilometers. Write this number in words.

Problem 3 – Using words only, multiply these two numbers together to get the distance traveled in one year.

Problem 4 – Do the calculation using numbers and then write the answer as words.

Problem 5 – Is it easier to calculate with words or numbers?



Shortcuts in counting – Grouping numbers

It is impossible to count the large things in space the same way we do apples in a fruit stand!

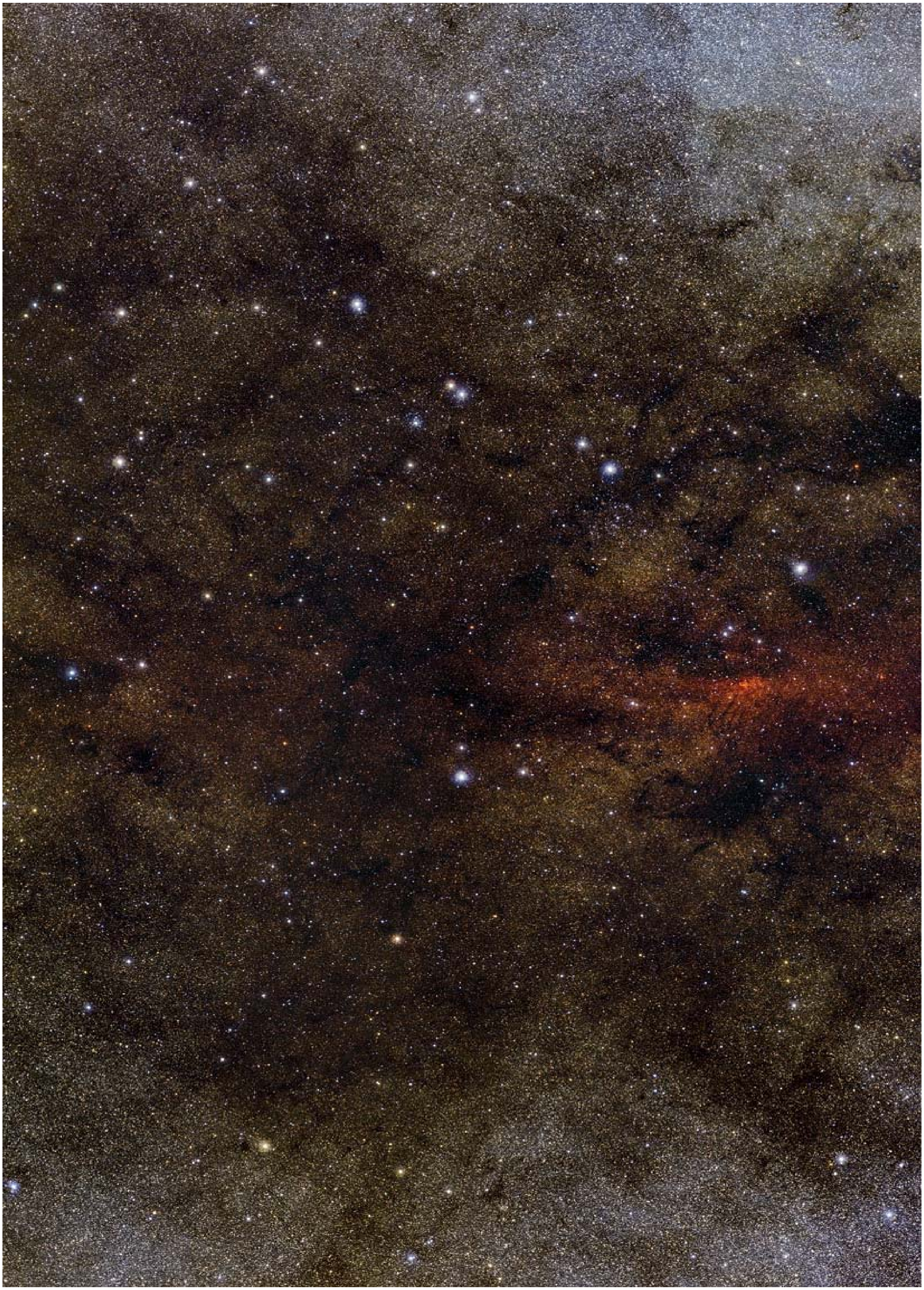
On June 18, 2007 Jeremy Harper began counting to one million. It took him until September 14, 2007 to finish counting out-loud. He is now in the Guinness Book of World records!

When it comes to counting large things in space, astronomers use many different short-cuts. The most important one is to group things (like stars) into equal-numbered groups, then multiply the number in each group by the total number of groups. This is very important in star counting, as the previous exercises showed!

Problem 1 – An astronomer took a photograph of an area of the sky with his telescope shown on the left. He divided this photograph into 9 equal areas, and counted 160 stars in each box. A) How many stars are in the photograph? B) If the counting of the 160 stars took 2 minutes, how long would it have taken him to count all of the stars individually in the photograph?

Problem 2 – If the astronomer divided the entire sky into 183,000 squares, each square would be the same size as the photograph. How many stars would there be in the entire sky?

Problem 3 – If you had counted each star one-by-one, how many days would it take for you to complete your counting?



Counting to 8 billion in less than a minute!

This amazing photograph was taken by the European Space Agency's (ESA) VISTA telescope and shows an area of the Milky Way towards the constellation Sagittarius.

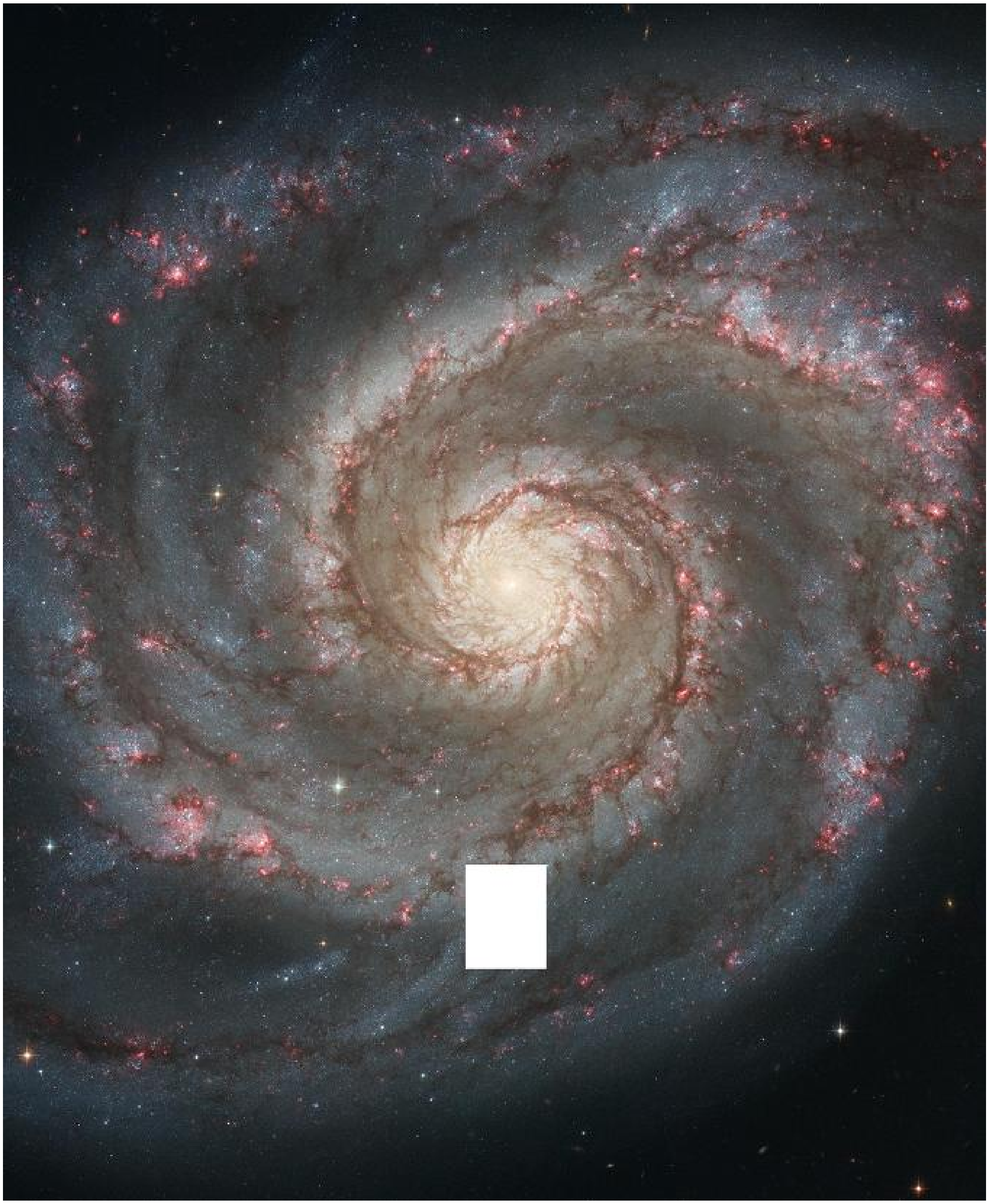
The brightest stars in the field can be seen with the naked eye and trace out part of the constellation Sagittarius. All of the other stars cannot be seen with the eye. You only see their combined glow, which outlines the Milky Way when you see it on a clear night.

The photograph was assembled from over 50 smaller photographs that were patched together like a quilt to make this image. The entire Milky Way in the sky could be created from 8000 of these large images.

Using a computer that can recognize stars and count very, very fast, about 20,000 stars were seen in each of the 50 images.

Problem 1 – How many stars would you estimate are in the full picture shown on the left?

Problem 2 – If this region is similar to other regions of the Milky Way in the sky, about how many stars would there be in the part of the Milky Way we can see from Earth?



This is the Whirlpool Galaxy in the constellation Canes Venatici. It is located 31 million light years from the Milky Way.

From edge to edge, this galaxy is about 100,000 light years making it about the same size as our own Milky Way galaxy!

Counting the Stars in a Big Galaxy

16

This is a small patch of the Whirlpool Galaxy photographed by the Hubble Space Telescope. Its location is shown by the white rectangle in the image on the left.

A huge star cluster appears in the upper right, and dark interstellar clouds of dust and gas are shown in the upper right corner. The small cluster of red stars in the lower left are young stars formed from dust clouds.

Although this patch measures only about 9,000 light years wide, astronomers can estimate that it contains over 3 billion stars!

Problem 1 – The Whirlpool Galaxy is in the shape of a circle. In the photograph, it has an area of about 135 square centimeters. The white patch, which corresponds to the image above, has an area of 1.5 square centimeters. How many times bigger is the entire galaxy than the patch?

Problem 2 - What would you estimate as the total number of stars that might be in the Whirlpool Galaxy?

Counting to one trillion in less than a minute!

All of the stars you see in the night sky are part of a huge collection of stars we call the Milky Way galaxy.

No single photograph taken from Earth can capture images of all of the stars that exist in our galaxy, but we can photograph other galaxies that are similar to our own.

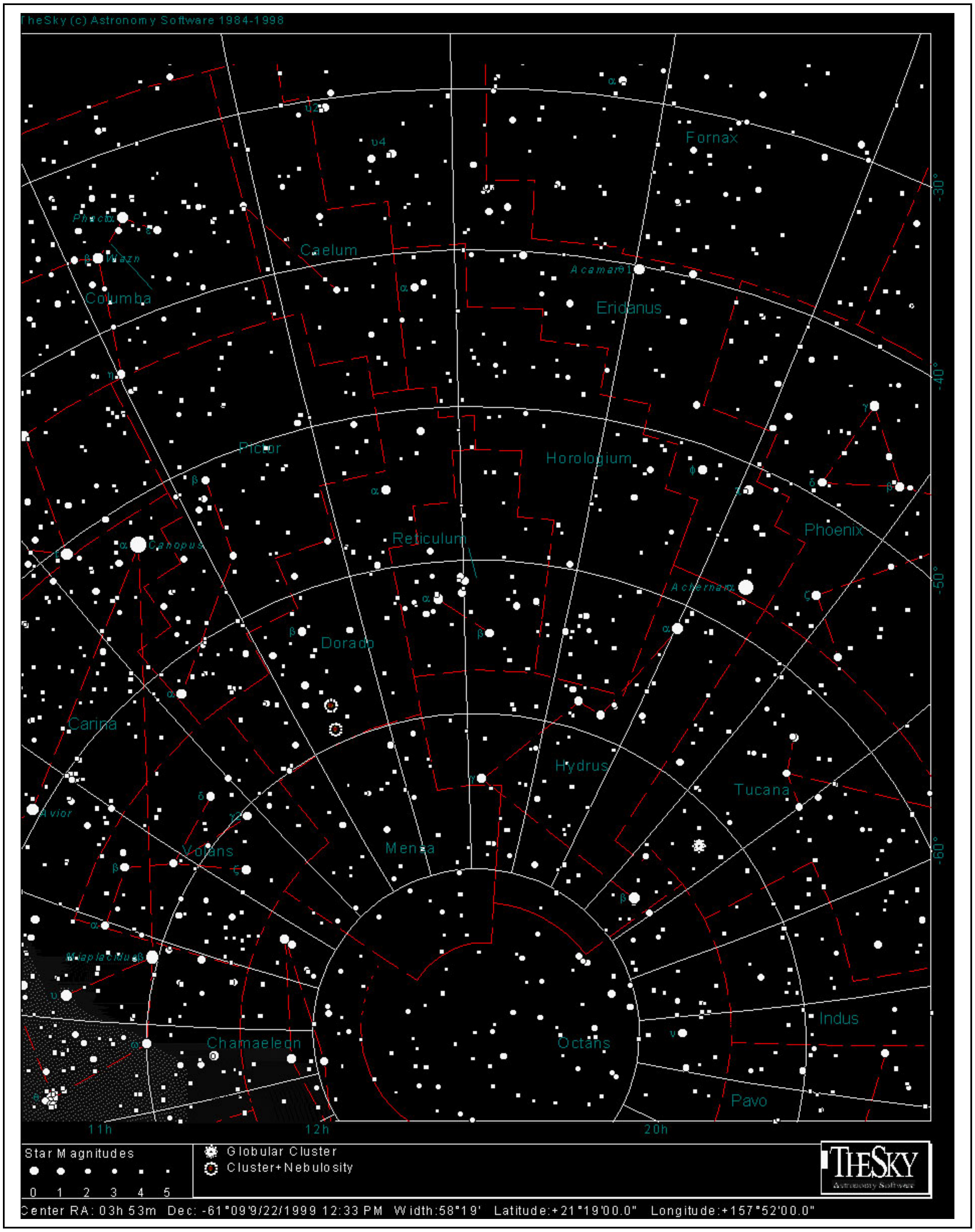
This photograph, taken by the Hubble Space Telescope is the Pinwheel Galaxy (Messier 101) in the constellation Ursa Major. It is located 25 million light years from our Milky Way.

If this were our Milky Way, the bright bulge of stars at the hub would be in the direction of the constellation Sagittarius, and we would be located in one of the spiral arms about 2/3 of the way from the center to the outer edge.

In Lesson 15, you estimated that the total number of stars that VISTA could photograph along the entire Milky Way in the sky was about 8 billion stars.

Problem 1 – If the volume of space surveyed by VISTA were only 1/125 the volume of the entire Milky Way galaxy, about what is the total number of stars in the Milky Way galaxy?

Problem 2 - Another survey over a much smaller area of the sky, and with a more sensitive telescope, detected about 500 million stars in a volume of space that was 1/2000 the volume of the Milky Way galaxy. What is the total number of stars in the Milky Way using this new data?


TheSky (c) Astronomy Software 1984-1998
Fornax
Caelum
Columba
Eridanus
Pictor
Horologium
Reticulum
Phoenix
Canopus
Achernar
Dorado
Carina
Hydrus
Tucana
Avior
Volans
Mensa
Chamaeleon
Octans
Indus
Pavo
11h
12h
20h
-30°
-40°
-50°
-60°
Star Magnitudes
0 1 2 3 4 5
Globular Cluster
Cluster+Nebulosity
THESKY
Center RA: 03h 53m Dec: -61°09'9/22/1999 12:33 PM Width:58°19' Latitude:+21°19'00.0" Longitude:+157°52'00.0"

So…How many stars are in the sky?

You now know the answer to this question! The answer is that 'It Depends!'

It depends on how many faint stars you decide to count. The fainter you make your counting limit, the more stars you will find across the whole sky.

The table on the left shows how the various star counts depend on the magnitudes of the faintest stars you include.

Magnitude of faintest star	Stars found in sampled area	Size of sky compared to sampled area	Total stars in the sky
+5	52	30	1560
+6	230	18	4140
+8	142	163	23,146
+8	270	120	32,400
+12	220	3400	748,000
+13	270	3500	945,000
+16	658	18,000	11,844,000
+18	300	1 million	300 million

Problem 1 – What is the average number of stars found across the sky that are brighter than magnitude +8?

Problem 2 – The faintest star the human eye can see on a perfect night is +6. Why is it that no human can ever count a million stars in the sky using only normal eyesight?

Problem 3 – Suppose you counted 200 stars brighter than +6 in an area of the sky 1/20 the size of the sky. About how many of these stars would you expect to find in an area 1/80 the size of the full sky?

Answer Key

Lesson 1
1 : +7.2 – (-4.6) = +7.2 + 4.6 = +11.8 magnitudes brighter
2 : -12.6 – (-26.7) = -12.6 + 26.7 = +14.1 magnitudes fainter.
3 : +30.0 – (-26.7) = +30.0 + 26.7 = +56.7 magnitudes fainter.

Lesson 2
1 : UV Ceti has the larger apparent magnitude so it is the fainter star. They differ by +13 - +10 = +3 magnitudes, which is a factor of 2.51 x 2.51 x 2.51 = 15.8 times.
2 : Mintaka has the larger apparent magnitude so it is the fainter star. They differ by +2 - (-1) = +3 magnitudes, which is a factor of 2.51 x 2.51 x 2.51 = 15.8 times.
3 : The order from brightest to faintest is: Sirius, Alpha Centauri, Rigel, Antares, Beta Hydra, Eta Cassiopeia, 36 Ophichi, Kruger-60, Ross-47 and Wolf-359.

Lesson 3 – There are 52 stars, and a total of 30 x 52 = 1560 stars.

Lesson 4 – There are about 230 stars for a total of 230x18= 4140 stars over the full sky.

Lesson 5 - Stars in this chart = 142 Total in full sky = 142 x163 = 23,146 stars.

Lesson 6 – Stars in field = about 270. Total in full sky = 270 x 120 = 32,400 stars.

Lesson 7 – Students should be able to carefully count about 220 stars. The total number across the sky is 220 x 3400 = 748,000 stars. The faintest stars are +12.0 – (+6.0) = +6.0 magnitudes fainter than human vision limits. The factor is 2.1 x 2.5 x 2.5 x 2.5 x 2.5 x 2.5 = 244 times fainter than the human eye limit!

Lesson 8 - Students should count about 270 stars. The total number is 270x3500 = 945,000 stars.

Lesson 9 - Students should be able to count about 658 stars .The total number across the full sky is 658 x 18,000 = 11,844,000 stars. Answers near 10 million are acceptable.

Lesson 10 – Students should counts about 300 stars. Total stars in the Milky Way on the sky = 300 x 1 million = 300 million stars. The faintest stars are 18-6 = 12 magnitudes fainter than what the human eye can see. This is a factor of $(2.5)^{12}$ = 59,604 times fainter than the faintest star a human can see.

Lesson 11 – 1) 76/1000 = 0.76 %. 2) 945,000 x (76/1000) = 71,820 G-type stars.

Lesson 12 – 1) 40 stars. 2) 40 x 6580 = 263,200 stars, 3) Out of 40, there are 11. So 11/40. There are about 72,380 that are G-type. 4) There are 28, 9th magnitude stars in the table, so there are 4x28= 112, 10th magnitude stars. Adding these to the 40 in the patch we get 152 stars and a total of 6580x152 = 1,000,160 over the entire sky.

Lesson 13 – 1) thirty million seconds. 2) three hundred thousand kilometers. 3)) thirty million times three hundred thousand equals nine thousand thousand million or 9 million million or 9 trillion kilometers. 4) 30,000,000 x 300,000 = 9,000,000,000,000 kilometers. 5) With numbers!

Lesson 14 – 1) A) 160 x 9 = 1440 stars. B) 2 minutes x 9 = 18 minutes. 2) 1,440 x 183,000 = 263,520,000 stars. 3) 18 minutes x 183,000 = 3,294,000 minutes or 2,287 ½ days.

Lesson 15 – 1) 50 fields x 20,000 stars per field = 1 million stars! 2) 1 million stars x 8000 fields = 8 billion stars!

Lesson 16 - 1) 135/1.5 = 90 times bigger. 2) 90 x 3 billion = 270 billion stars in the Whirlpool Galaxy.

Lesson 17 – 1) 125 x 8 billion = 1 trillion stars. 2) 2000 x 500 million = 1 trillion stars.

Lesson 18 – 1) Students will average the two numbers 23,146 and 32,400 to get 55546/2 = 27,773 stars. 2) There are only about 4,140 stars that can be seen in the full sky with normal eyesight. To see 1 million stars you have to be able to see stars as faint as magnitude +13, which is impossible with the human eye and no telescopic assistance. 3) The new sky area is 1/80 which is 4 times <u>smaller</u> than the original sample area, so you will see about ¼ the number of stars or 50 stars in the smaller field.

National Aeronautics and Space Administration

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