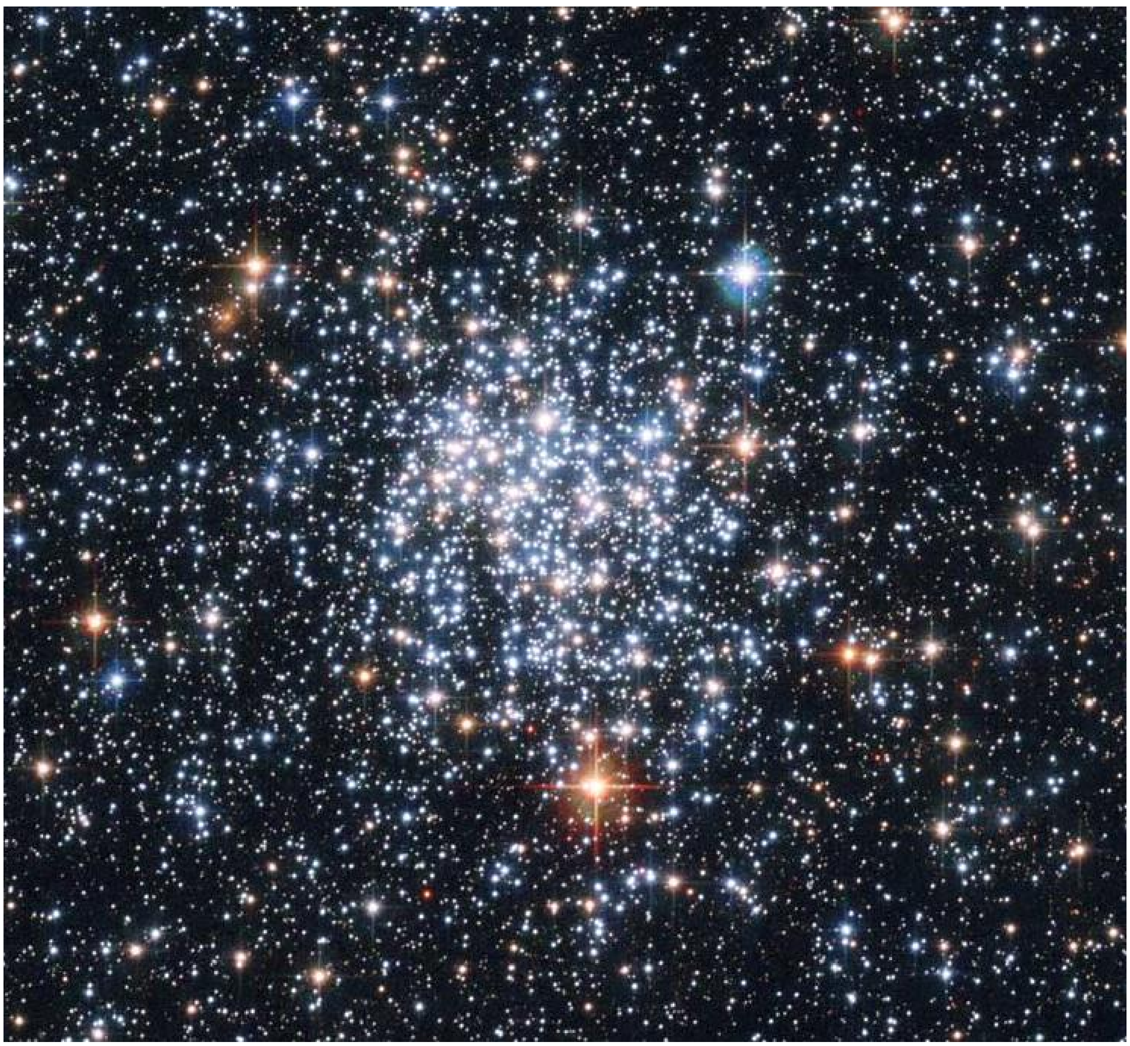
National Aeronautics and Space Administration

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 grade 6-8, 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

This booklet was created through an education grant NNH06ZDA001N-EPO from NASA's Science Mission Directorate.

Table of Contents

	Page
Cover Page	i
Acknowledgments	ii
Table of Contents	iii
Alignment with Standards	iv
An Introduction to the Stars	v
Introducing the magnitude scale for stars	1
Lesson 1 - Working with the stellar magnitude scale	7
Lesson 2 – Star magnitudes and multiplying decimals	9
How to count stars!	11
Lesson 3 – How many stars are brighter than +5?	15
Lesson 4 – How many stars are brighter than +8?	17
Lesson 5 – How many stars are brighter than +12?	19
Lesson 6 – How many stars are brighter than +16?	21
Lesson 7 – Classifying stars by temperature	23
Lesson 8 – Classifying stars in a star field using a catalog	25
Lesson 9 – Working with big numbers in astronomy	27
Lesson 10 – Shortcuts in counting – Grouping numbers	29
Lesson 11 – Counting stars in a big galaxy	31
Lesson 12 – Counting to a trillion in less than a minute!	33
Lesson 13 – So…How many stars are in the sky?	35
Answer Keys to Lessons	36

Alignment with Standards

NCTM: Principles and Standards for School Mathematics

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

CCSS.Math.Content.4.NF.B.4c Solve word problems involving multiplication of a fraction by a whole number, e.g., by using visual fraction models and equations to represent the problem. *For example, if each person at a party will eat 3/8 of a pound of roast beef, and there will be 5 people at the party, how many pounds of roast beef will be needed? Between what two whole numbers does your answer lie?*

CCSS.Math.Content.4.NBT.B.6 Find whole-number quotients and remainders with up to four-digit dividends and one-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.

CCSS.Math.Content.6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. *For example, "The ratio of wings to beaks in the bird house at the zoo was 2:1, because for every 2 wings there was 1 beak." "For every vote candidate A received, candidate C received nearly three votes."*

CCSS.Math.Content.6.NS.B.3 Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.

CCSS.Math.Content.6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.

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 levels of brightness: 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!

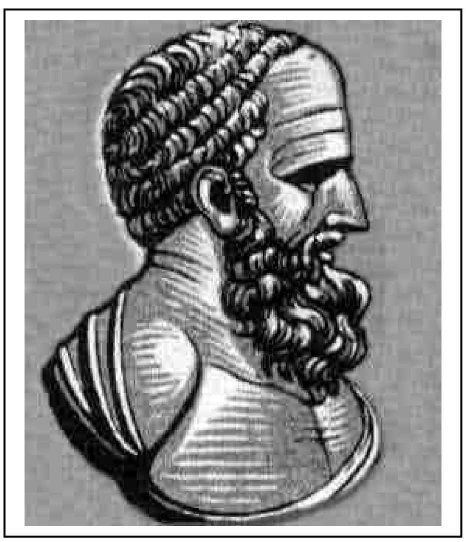
A small part of the star cluster NGC-6397
photographed by the
Hubble Space Telescope

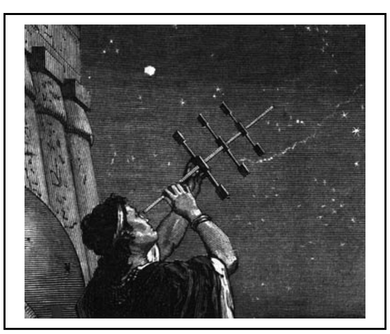
This photograph, taken by Jerry Lodriguss of the constellation Orion, shows the many stars that are too faint to be seen with the naked eye in this part of the sky.

When you look at the sky at night, the first thing you notice is the enormous 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 with your 'naked eye', (no binoculars or telescopes used!) 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, it's 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.

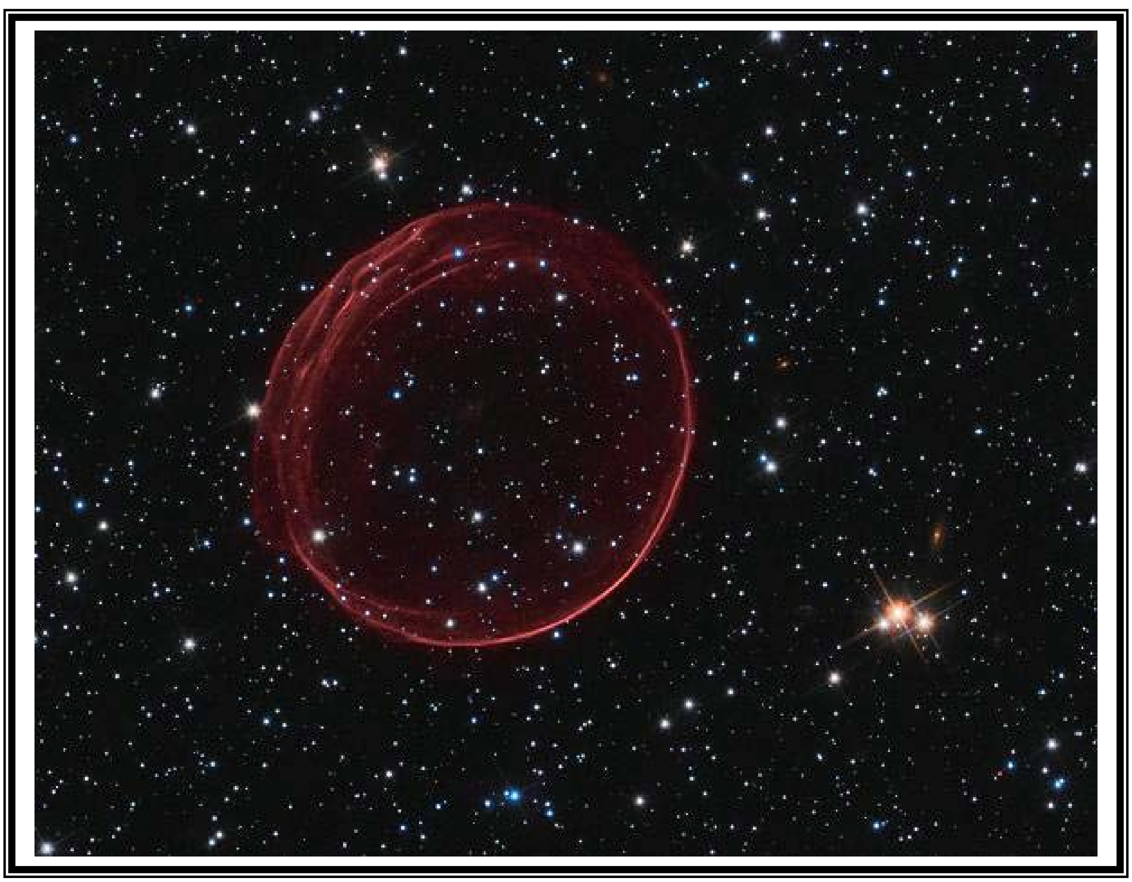
Hipparchos used only his normal eyesight and came up with a 6-step scale so that the brightest stars were Rank-1, the very faintest stars were Rank-6, and all the other naked-eye stars fell in one of the other ranks in-between.

Today, astronomers use this same 'magnitude' scale when they talk about the brightness of stars in the sky. A star with a magnitude of +7.0 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 of the supernova remnant SNR 0509-67.5 shows numerous stars as faint as +18.0



Another interesting thing about this magnitude scale is that for each increase 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 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 Pegasus has a magnitude of +2.5. They differ by exactly 3.0 magnitudes. That means that Markab is 2.512 x 2.512 x 2.512 = 15.85 times fainter than Betelgeuse. Negative magnitudes means the the object is very bright. For example, our sun has a magnitude of -26.0 and the Moon is fainter with a magnitude of -18.5.

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 increase is a brightness decrease by a factor of 2.512, so 5,0 magnitudes represents a brightness

(2.512) x (2.512) x (2.512) x (2.512) x (2.512)

which is exactly 100 times!

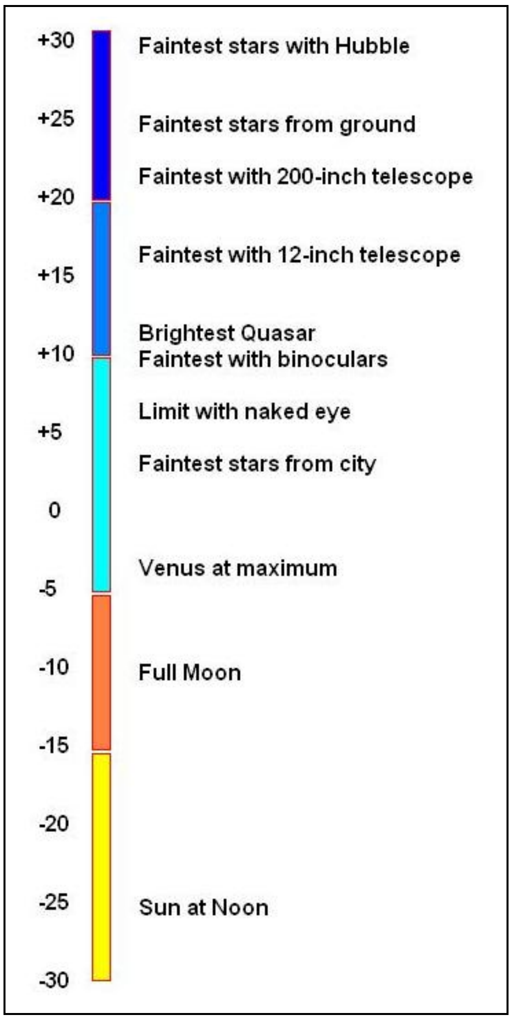
We can extend this pattern and figure out the brightness of even fainter stars that can only be seen with a telescope. Suppose the magnitude difference between two stars is 10 magnitudes, then 10 = 5+5 and according to the magnitude factors we calculated above we have a brightness difference of

(100) x (100) = 10,000.

Thousands of faint stars in the Beehive Star Cluster
in Cancer to a magnitude of about +18.0

Courtesy Stuart Heggie
(http://www.astrofoto.ca/stuartheggie/index.html)

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 +7.0. In terms of magnitude, 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. In magnitudes, how much fainter are these stars than the Sun?

Star cluster NGC-6649 in the constellation Scutum with stars as faint as magnitude +20.0

Courtesy Bill Keel (Kitt Peak National Observatory)

http://www.astr.ua.edu/gifimages/ngc6649.html

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 2.512 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 2.512 x 2.512 = 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?

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.

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

The Messier 29 star cluster image above was obtained by the 2MASS observatory and shows stars as faint as magnitude +20.

How to Count Stars!

The sky is a very big place!!

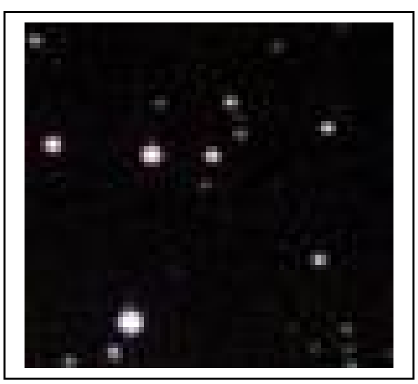
If you want to count how many stars you can see, you have a choice to make: Do you want a perfectly accurate number, or will your best estimate be good enough? If you are a scientist, you probably want to count each star and put it in a 'star catalog' with one line for each star like a phone book.

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!

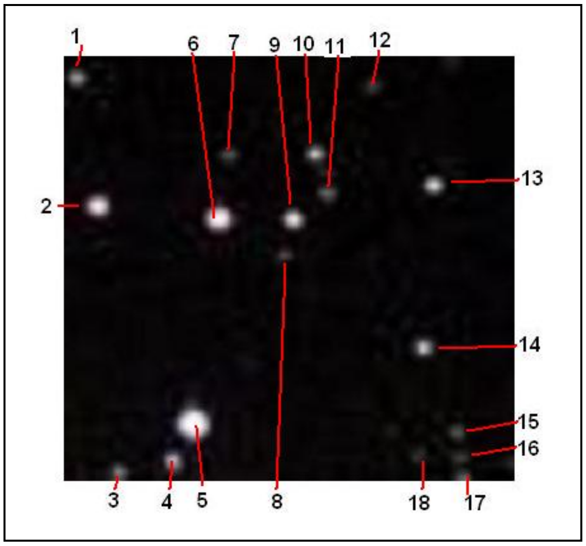
Here's how you do it!



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.

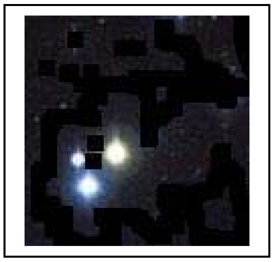
Compared to the size of the smaller picture, the larger picture can be covered by 11 x 11 = 121 of these smaller patches.

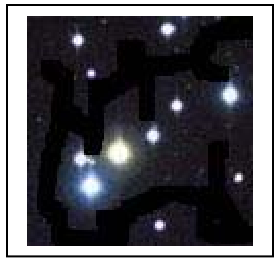
Instead of counting the stars in the bigger picture, one by one, you can estimate that the total number of stars in the bigger picture is about 121 x 18 = 2178 stars.

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 +15.0. The right picture shows stars as faint as magnitude +18.0.

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
CETUS
PEGASUS
ANDROMEDA
AQUARIUS
Alpheratz
Algenib
Markab
Scheat
Mesarthim
Mira
Deneb Kaitos Schemali

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.

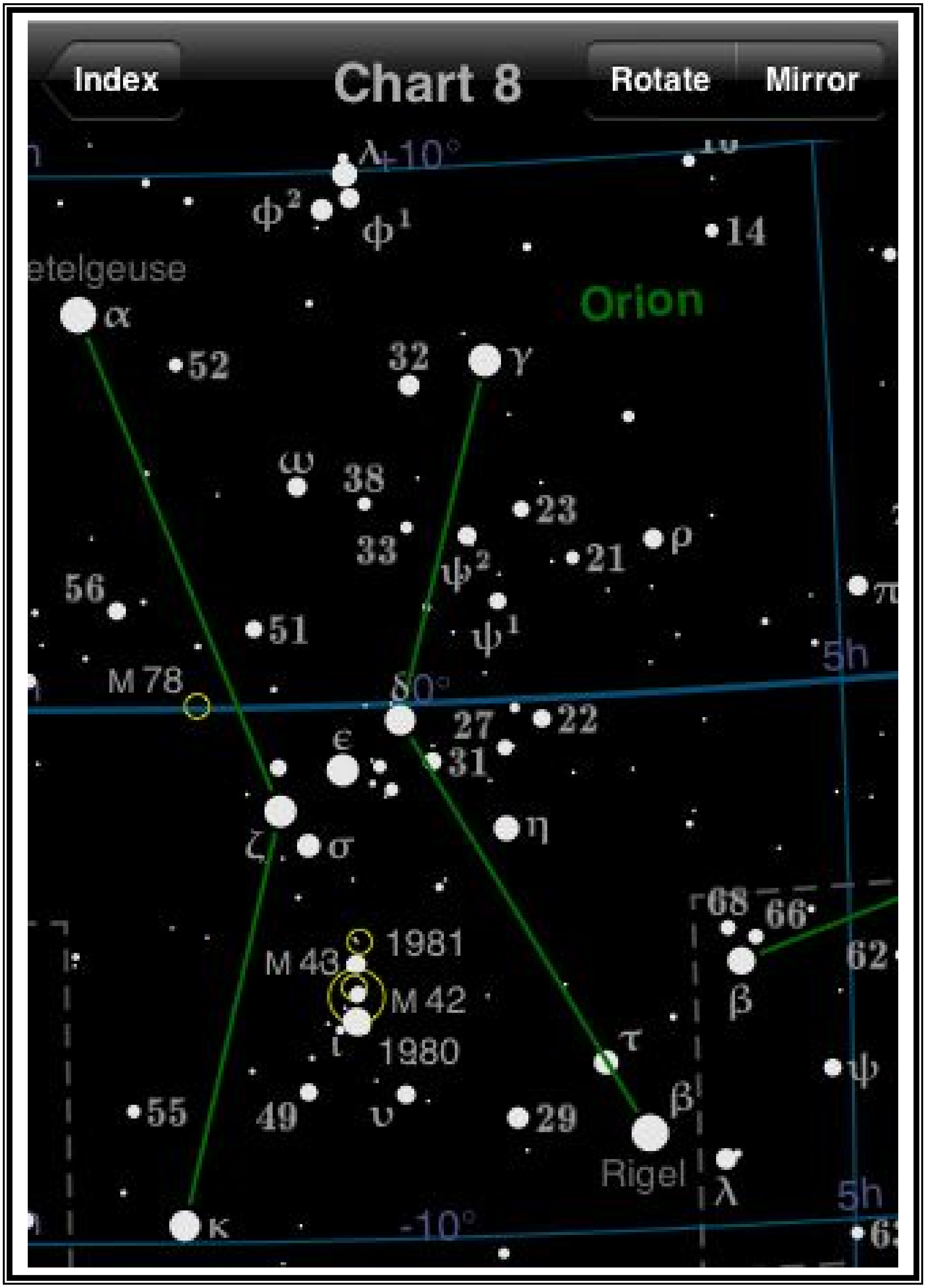
Before telescopes and photography were invented, astronomers measured very carefully the positions of each star they could see in the sky. They used these measurements to draw a map of the sky showing the locations of the stars. They also sketched what the constellation looked like to make a combination 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?

Photo of the Big Dipper by Astronaut Donald Pettit from the ISS


Index
Chart 8
Rotate
Mirror
Orion
etelgeuse
M 78
M 43
M 42
1981
1980
Rigel
52
32
38
33
23
21
14
56
51
27
22
31
55
49
29
68
66
62

How many stars are brighter than +8 ?

4

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?

This is a Cassini spacecraft image of Saturn's moon Enceladus, which also shows many background stars. Most solar system objects are so bright that to see details on them, cameras have to take short exposures, which means that faint stars rarely show up in planetary photographs from space even though they are there. This has led some people to think that NASA doctors all of its space photos to eliminate stars!

How many stars are brighter than +12 ?

5

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.

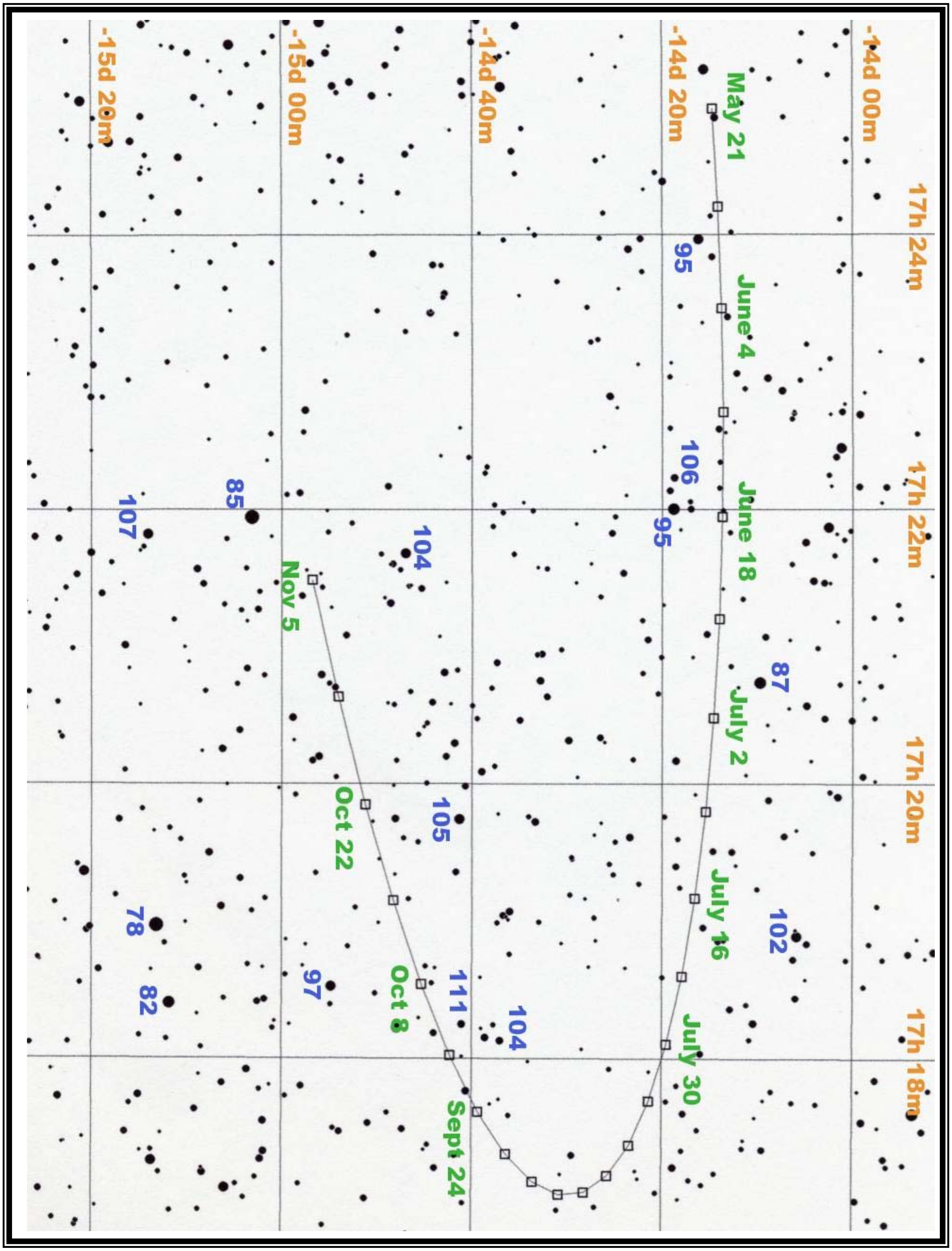
The faintest stars in this picture are magnitude +12, and the field only covers about 1/3400 of the full sky.

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 (+7)?

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 2.512 in brightness)



This chart shows the path of Pluto through the constellation Serpens from May 21 to November 5, 2004.

How many stars are brighter than +16 ?

6

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 near the path of the dwarf planet Pluto in 2004. 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. The coordinate grid gives the Right Ascension and Declination position of the objects, which are similar to longitude and latitude coordinates on Earth.

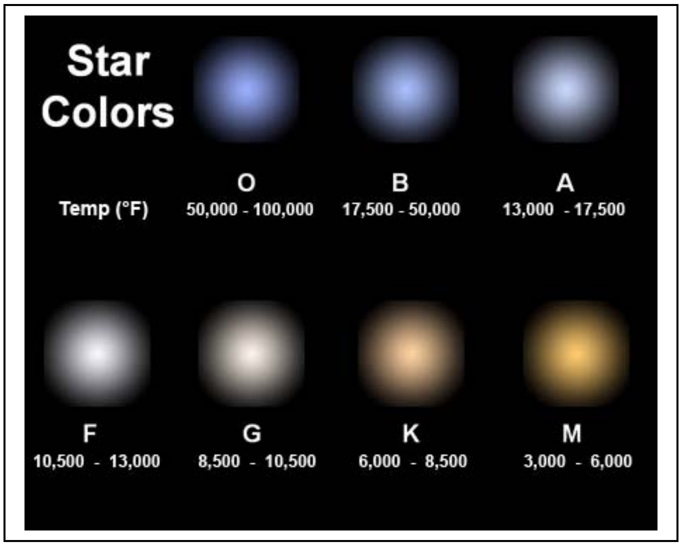
To avoid making a very confusing and crowded diagram, the field of this atlas is only 1/18000 the size of the full sky!

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

2 - How many stars are in the full sky?

Classifying Stars by Temperature

7



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, and 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

8

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 table also gives the sky position of the star in Right Ascension and Declination.

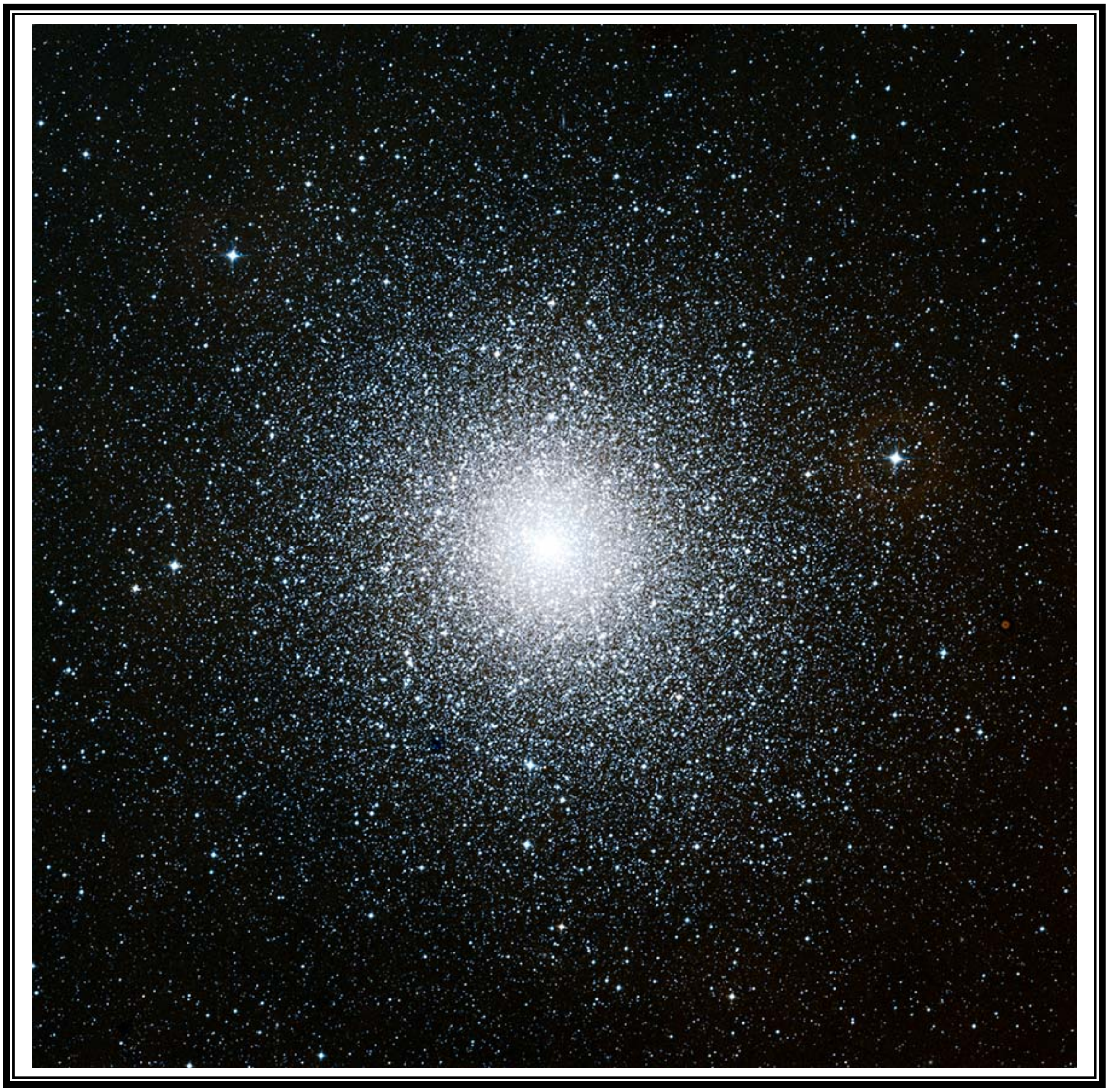
The stars cover an area of the sky that is only 1/6580 of the full area of the sky. There are many things that you can learn from this star catalog!

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?



The globular star cluster 47 Tucanae photographed by the Sloan Digital Sky Survey.

Working with Big Numbers in Astronomy

9

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.

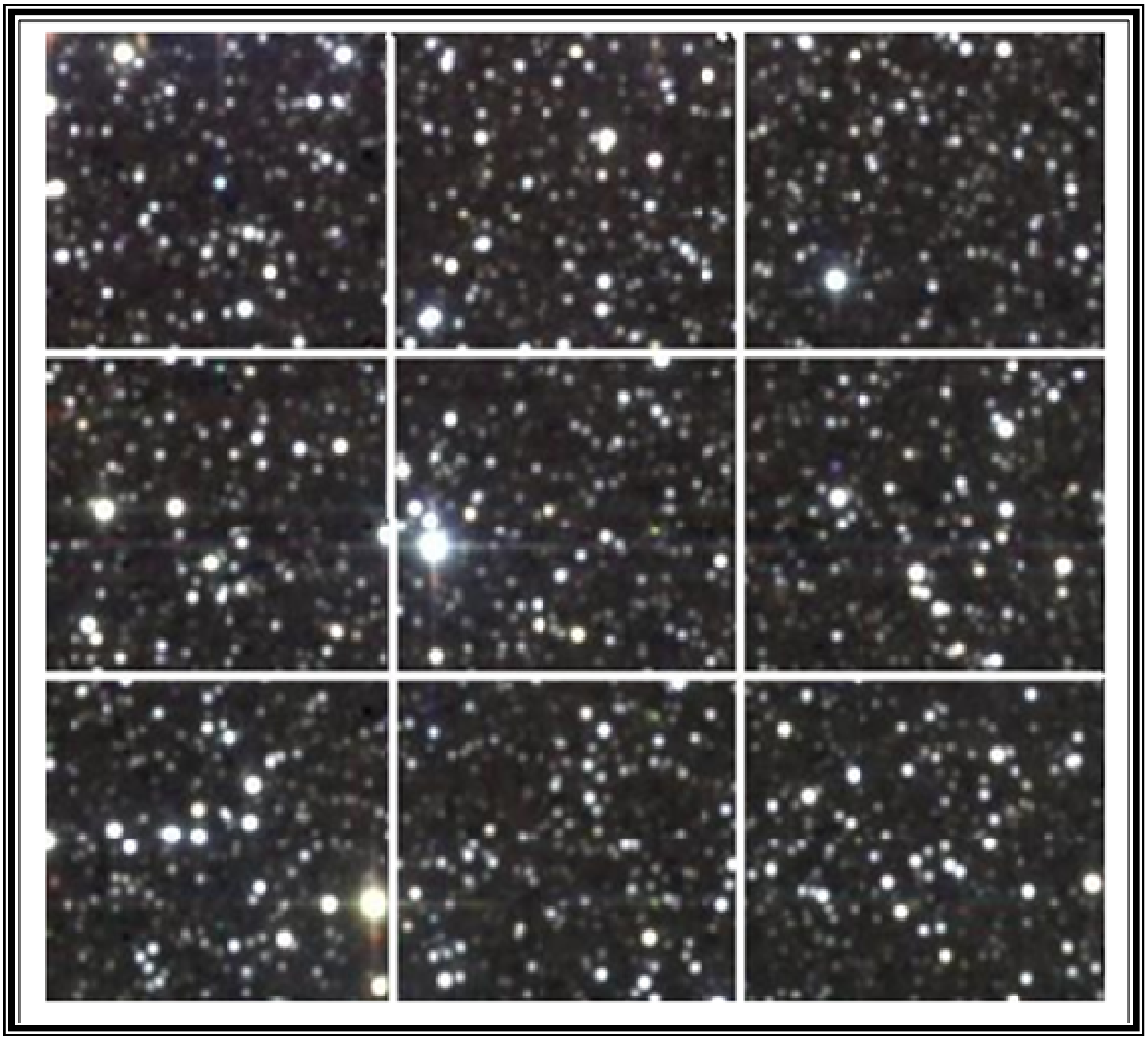
Problem 1 – The number of seconds in one year can be written as 30,000,000. Write this number in words.

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?



A portion of the sky photographed by the 2 Micron Sky Survey revealing stars as faint as magnitude +20.

Shortcuts in counting – Grouping numbers

10

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

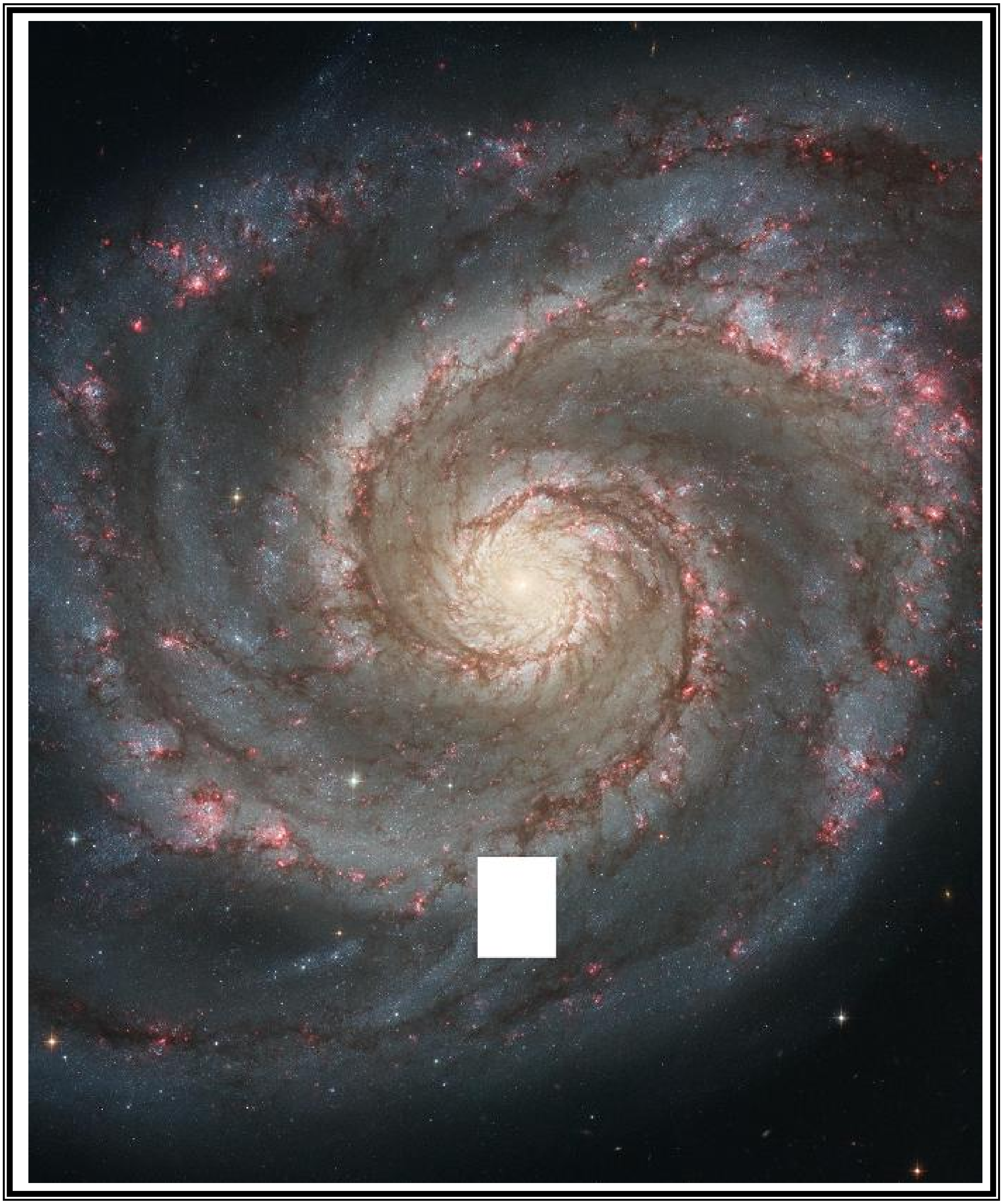
On June 18, 2007 Jeremy Harper began counting to one million. It took him until September 14, 2007 to finish counting out-loud. He is now in the Guinness Book of World records!

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?



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

11

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 left, 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!

12

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.

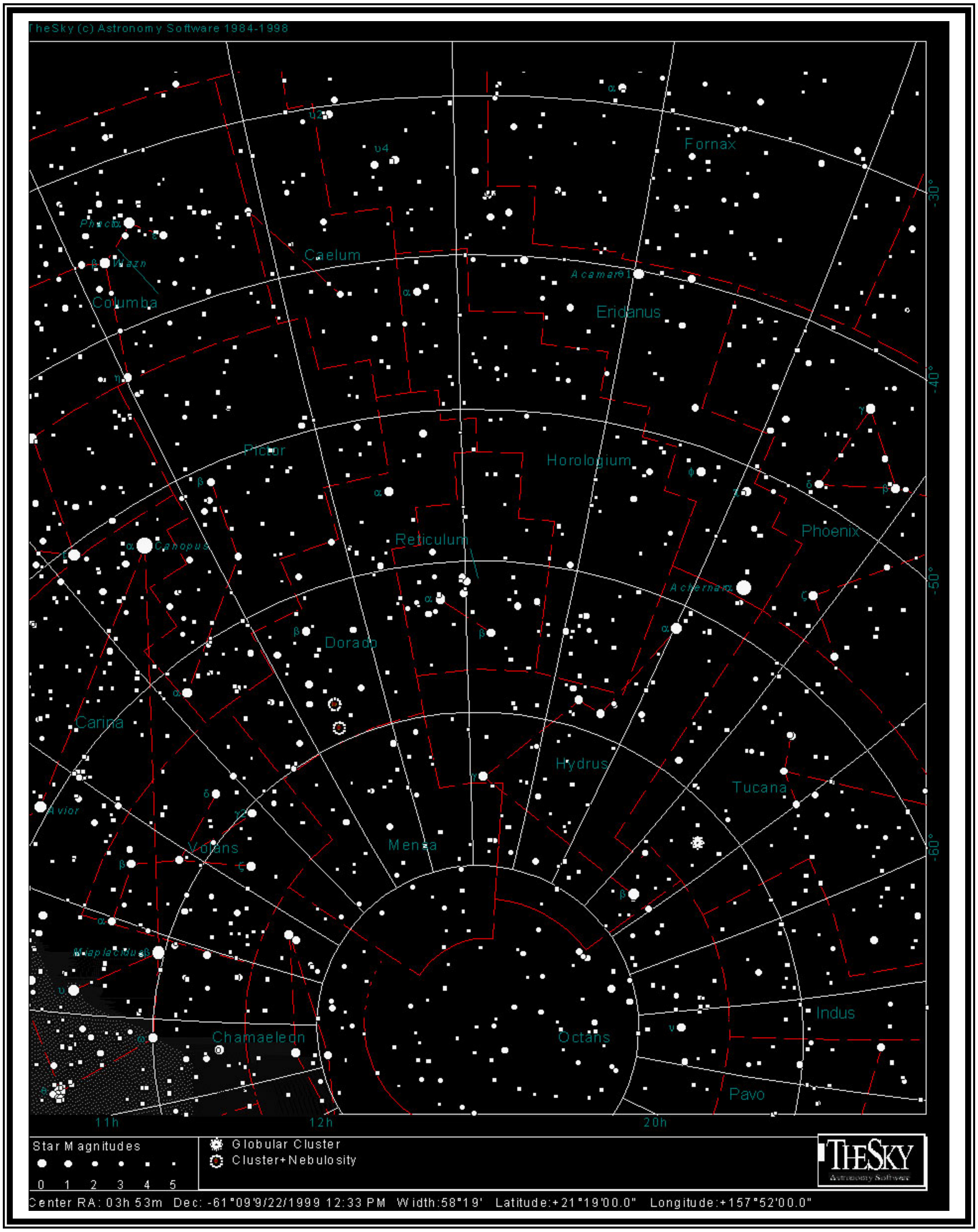
This photograph, taken by the Hubble Space Telescope is the Pinwheel Galaxy (Messier 101) in the constellation Ursa Major. It is located 25 million light years from our Milky Way.

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
Dorado
Carina
Hydrus
Tucana
Volans
Mensa
Chamaeleon
Octans
Indus
Pavo
Canopus
Achernar
Acamar
Avior
11h
12h
20h
-30°
-40°
-50°
-60°
Star Magnitudes
0 1 2 3 4 5
Globular Cluster
Cluster+Nebulosity
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"
TheSky
Astronomy Software

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 below 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 +7. 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 +7 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 : +7.0 – (-4.6) = +7.0 + 4.6 = +11.6 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 - Stars in this chart = 142 Total in full sky = 142 x163 = 23,146 stars.

Lesson 5 – 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 – (+7.0) = +5.0 magnitudes fainter than human vision limits. The factor is 2.512 x 2.512 x 2.512 x 2.512 x 2.512 = 100 times fainter than the human eye limit!

Lesson 6 - 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 7 – 1) 76/1000 = 0.76 %. 2) 945,000 x (76/1000) = 71,820 G-type stars.

Lesson 8 – 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 9 – 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 10 – 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 11 - 1) 135/1.5 = 90 times bigger. 2) 90 x 3 billion = 270 billion stars in the Whirlpool Galaxy.

Lesson 12 – 1) 125 x 8 billion = 1 trillion stars. 2) 2000 x 500 million = 1 trillion stars.

Lesson 13 – 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 smaller 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

Space Math @ NASA
Goddard Spaceflight Center
Greenbelt, Maryland 20771
spacemath.gsfc.nasa.gov

www.nasa.gov