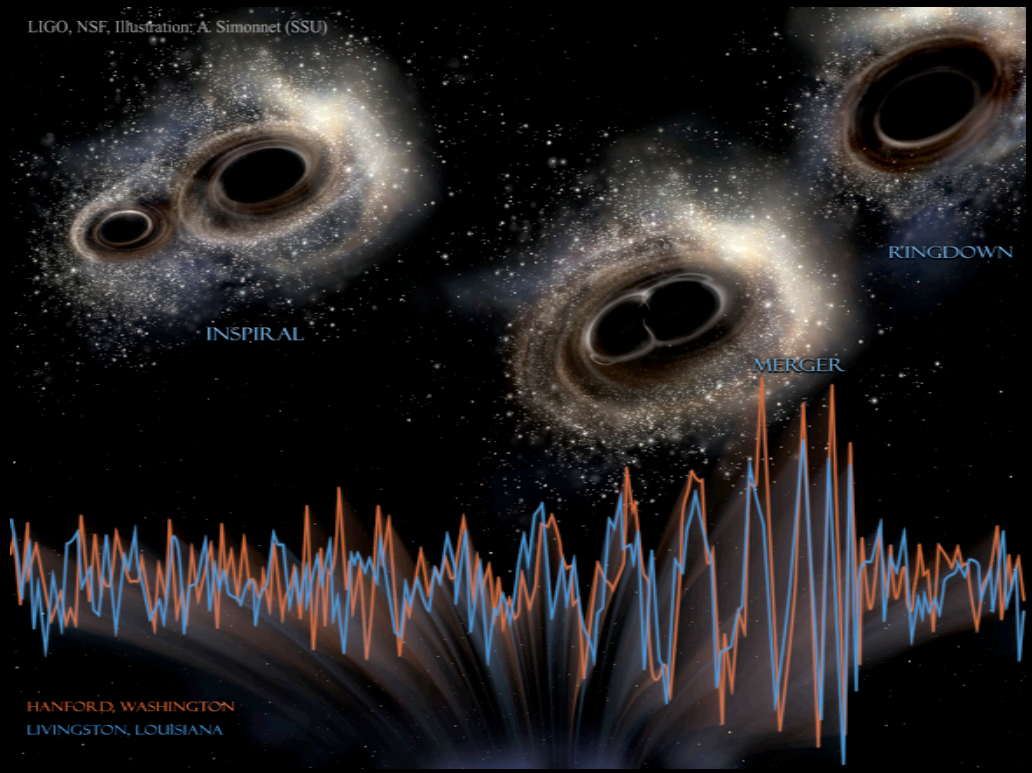
# AST 301: Introduction to Astronomy



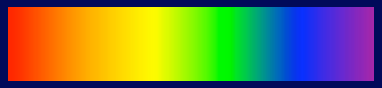

Sections 47791
Tu Th at 3:30 to 5:00 PM in Welch 1.308

John Kormendy
Department of Astronomy, University of Texas at Austin

**It is astonishing how much we can learn about the Universe.**

# AST 301: Introduction to Astronomy

## Introduction for non-science students to:

- Science: What is it? How does it work? Why?
- Machinery: How we measure distances, sizes, masses, etc.
- How things work: atoms, light, spectra 
- **The Astronomical Universe:**
  - Our Solar System, other solar systems, life in the Universe
  - Stars — their birth, life cycles, and death
  - Galaxies and the Universe

## Aims:

To help you to understand the wonderful, crazy Universe that we live in.

To give you perspective on our place in the Universe:
The Universe is beautiful and fascinating.
The Earth is a miracle.

To let you enjoy astronomy.

**The most important aim of this course:**

**Empowerment !**

# Instructor Information

**Prof. John Kormendy**

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☎ 512-471-8191
kormendy@astro.as.utexas.edu

office hours: Wednesday 2 — 4 PM
in RLM 15.326
or after class
or by appointment

**Note the class web site:**

**http://chandra.as.utexas.edu/~kormendy/a301-2017-spring.html**

# TA Information

- TA: **JinGyu Ock**
  RLM 13.126
  Office hours: TBA
  ☎ TBA
  ✉ oxjgu8@utexas.edu

# Textbook

- **Textbook: Horizons, Exploring the Universe (11th, 12th, 13th, or 14th Edition) by Michael A. Seeds Brooks/Cole**

**It is OK (although not ideal) to get the oldest editions.**

**Caution: Page and section numbers for reading assignments will be for the 13th Edition and may be different in the other editions.**

**The text will contain much (but not all) of the material of the course. Reading assignments will be included in the lecture slides that are posted before the start of each lecture. When a subject is not in the book, then the lecture slides will be more detailed.**

**Buying the book is optional … although most people find it helpful.**

## Lectures will be posted.

Each lecture's slides will be posted on the class web site well before the lecture is given. So you always have access to all the slides while you study.

Sometimes, some slides are study guides and will not be discussed in lectures. Example: today's slides on scientific notation, units, and unit conversion. These are easy subjects that you can study on your own.

Important: You are responsible for material that is in the posted slides but that I do not cover in class.

# Important Dates

- Jan. 17 First class
- Jan. 20 4th class day: Last day of official add/drop period
- Feb. 1 12th class day: Last day to add or to drop for a possible refund
- Apr. 3 Last day to withdraw from UT or to Q-drop or to change to or from credit/no credit
- May 4 Last class

## Exams

- **Feb. 7 Exam 1 = Part 1**
- **Mar. 2 Exam 2 = Part 2**
- **Mar. 7 Exam 3 = Parts 1 + 2 (cumulative)**
- **Mar. 9 Exam 4 = Parts 1 + 2 (cumulative)**
- **Apr. 6 Exam 5 = Part 3**
- **May 2 Exam 6 = Part 4**

**There will be no final exam. There will be no makeup exams.**

# Course Credit

- 20 % each for any 5 of the the following: 6 exams; average of 2 homeworks.

There will be 6 in-class exams on sections 1, 2, 1+2, 1+2, 3, and 4, respectively. All questions are multiple-choice. All exams are closed-book and have equal weight. **There will be no final exam.** However, your 2 lowest scores will be dropped, so you can miss even two midterm exams without penalty. **Therefore there will be no makeup exams.**

**This year, homework is optional and there are only 2 assignments.**
**Your homework average will be treated exactly like one exam score.**

**IMPORTANT: If you decide not to do the homework, then you depend completely on the exams. If you miss 2 exams, there will be NO makeup.**

**If you have to miss one homework, I WILL give you a makeup assignment.**

# Letter Grades

**Numerical grades will be converted to letter grades as follows:**

- **A 87 – 100 %**
- **A- 84 – 86 %**
- **B+ 81 – 83 %**
- **B 78 – 80 %**
- **B- 75 – 77 %**
- **C+ 70 – 74 %**
- **C 65 – 69 %**
- **C- 60 – 64 %**
- **D+ 55 – 59 %**
- **D 50 – 54 %**
- **D- 45 – 49 %**
- **F 0 – 44 %**

**I will not change the above; in particular, I will not make the scale more difficult.**

**If you are taking this course on a pass/fail basis, University rules say that a passing grade is equivalent to a D- or higher.**

**There will be 2 homework assignments, one for Part 1 and one for Part 2. Note that all homework assignments happen before Spring Break.**

**The due date will always be 2 weeks after homework is assigned.**
**There will be no credit for late homework.**

**All homework assignments will consist at least partly of multiple-choice questions.**

**These questions will be exactly like the ones on the exams.**

**So exams should be no mystery – you will know exactly what sorts of questions to expect and how easy or hard they will be.**

**Also, I will post examples of typical exam questions and answers.**

**There will be 2 homework assignments, one for Part 1 and one for Part 2.**

**Important:**

**The purpose of the homework**

**is not**

**to prepare you for exams.**

**The purpose of homework is**

**(1) to help you to learn to think about unfamiliar problems and**

**(2) to teach you certain concepts better and more concretely than you learn them from lectures.**

# Staying Caught Up

I recommend that you stay caught up by spending a little time each week studying the current lectures. Make sure that you understand the important concepts. Consider listing them as a study aid for exams.

If something puzzles you, please ask me or the TA about it. Please do not let confusion build up so that you can't understand later lectures, either.

It is easy to get swamped! It helps to stay caught up — to feel confident that everything is under control.

In this course, you get credit as you go, via the exams and homework.
You feel pressured at final exam time. I don't want this course to be the reason.

# What do I expect from you?

Everybody is different. No single piece of advice works for all. But:

1 — It helps to read the reading assignment + posted lecture before each class.

2 — **Come to class, listen, and take notes. Nothing else helps as much!**

3 — Study the lecture soon after class, before you forget. Try to understand. Professors often recommend 2 hours of study per hour of class time.

4 — Come to a TA or to me for help if you have trouble.

5 — Do all the homework, if you decide to do homework. Often students do well on exams but get a lower grade because they didn't do the homework.

6 — Study again before the exam. I encourage you to come to the help sessions; they often include hints on what to expect.

7 — No cheating on exams! Please be careful to answer the questions I ask.

# What do I expect from you?
# Class Attendance

**I strongly recommend that you come to classes.**

Astronomy is not difficult, but it is probably unfamiliar to you, and it is harder to understand the material if you only read about it.

Also, I will omit some subjects that are in the book, and I will lecture on some subjects that are not in the book. The best way to know what I cover and what I emphasize is to come to class. You are responsible only for the content of the lectures. The lectures will be posted as jpegs of the powerpoint slides. But:

These are meant to help you to remember what I said.

**They are not a substitute for coming to class.**

# What do I expect from you?

## Important Class Rules

**Please do not use cellphones in class.**

**Texting is not allowed.**

**It is OK to follow the class on your laptops. But I recommend that you print the slides before class and take notes on the printouts.**

# Math Anxiety

- Some of you had trouble with mathematics in the past.
- **I keep math to a minimum.  Most of it is in Parts 1 and 2.**
- You never need to memorize an equation.
- A few equations are important enough that I want you to understand what they mean and how to use them to answer simple questions.
- Mostly I want you to understand concepts — how things work — not do calculations.

- **But: If the math gives you trouble, please ask questions.**

# Syllabus - 2017

Lecture date, number — Subjects

Tu Jan 17: 1 Introduction, syllabus & class rules; units and scales, Earth rotation, time zones, constellations, 'Grand Tour'
Th Jan 19: 2 Seasons, phases, eclipses
Tu Jan 24: 3 History 1: The Greeks, Copernicus, Tycho, Kepler
Th Jan 26: 4 History 2: Galileo, Newton
Tu Jan 31: 5 How science works
Th Feb 2: 6 The nature of light, telescopes
Tu Feb 7: Exam 1: Lectures 1 — 6

Th Feb 9: 7 How astronomers use spectra to learn about stars
Tu Feb 14: 8 Stars: distance, luminosity, mass,…, star formation
Th Feb 16: 9 Stars: our Sun
Tu Feb 21: 10 Stars: energy generation, main sequence life
Th Feb 23: 11 Stars: life from main sequence to white dwarf
Tu Feb 28: 12 Stars: death — supernovae, neutron stars, black holes
Th Mar 2: Exam 2: Lectures 7 — 12
Tu Mar 7: Exam 3: Lectures 1 — 12
Th Mar 9: Exam 4: Lectures 1 — 12

**Mar 13 — 17: Spring Break**

Tu Mar 21: 13 Our Galaxy — the Milky Way
Th Mar 23: 14 Galaxies: properties, clusters of galaxies, dark matter
Tu Mar 28: 15 Galaxies: evolution, distances, expansion of Universe
Th Mar 30: 16 Galaxies: active galaxies, supermassive black holes
Tu Apr 4: 17 Cosmology: Big Bang — evolution of the Universe
Th Apr 6: Exam 5: Lectures 13 — 17

Tu Apr 11: 18 Solar System: introduction, formation
Th Apr 13: 19 Solar System: other solar systems, Jupiter—Neptune
Tu Apr 18: 20 Solar System: outer parts: Pluto, Kuiper belt, comets
Th Apr 20: 21 Solar System: satellites, asteroids, Moon, Mercury
Tu Apr 25: 22 Solar System: Mars and Venus
Th Apr 27: 23 Solar System: Earth
Th May 2: Exam 6: Lectures 18 — 24
Tu May 4: 24 History of life on Earth, life in the Universe

**There will be no final exam.**

**There will be no makeup exams.**

**There will be a help session from 4 – 6 PM on the night before every exam.**

## Part 1: The Sky; History of Astronomy; How Science Works

- Tuesday, January 17 Reading: Chapters 1 & 2.1, Appendix A
  - Introduction, syllabus, class rules; units, scales,
  - rotation of the Earth, time zones, constellations; tour – where we go in the course
- Thursday, January 19 Reading: Chapters 2, 3 HW 1 assigned
  - The sky: Rotation of Earth, seasons, phases, eclipses
- Tuesday, January 24 Reading: Chapter 4-1, 4-2, 4-3
  - History of Astronomy: Greeks, Copernicus, Tycho, Kepler
- Thursday, January 26 Reading: Chapter 4-4, 4-5
  - History of Astronomy: Galileo, Newton
- Tuesday, January 31 Reading: "Windows on science" sections or
  - How science works "How do we know?" sections in Chapters 1, 2, 3, 4
- Thursday, February 2 Reading: Chapter 5 HW 1 due
  - The nature of light, telescopes, spectra
- Monday, February 6 Help session from 4 — 6 PM in RLM 4.102
- Tuesday, February 7 Exam 1

# Coping with Very Large and Very Small Numbers

## Two Tricks

- Use a very large or a very small unit:

  For example: 1 light year

  = distance light travels in 1 year at 299,800 m/s

  = 9,461,000,000,000,000 m

  Then you can say (for example):

  "The distance to the nearest star beyond the Sun is about 4.2 light years."

- Use scientific notation for numbers:

  For example: If the number is a power of 10, count the number of times you have to multiply 10 by itself to get that number:

  For example: 10,000 is 10 x 10 x 10 x 10.

  Scientific short-hand notation for 10,000 is $10^4$.

  The number in the superscript is called the exponent.

# Scientific Notation

- Some more examples:

  – 100,000,000 is 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 and can be written $10^{8}$.

  – When a number is not a power of 10, we divide it into two parts. For example:
  3,459 is the same as 3.459 × 1000. In scientific notation 1000 is $10^{3}$ ,
  so 3459 is the same as $3.459 \times 10^{3}$.

  – Numbers between 0 and 1 are expressed with negative exponents:
  0.01 is the same as 1/100 or $1/10^{2}$ or $10^{-2}$.

  0.00632 is the same as $6.32 \times 1/1000$ or $6.32 \times 10^{-3}$.

  0.00632 is also the same as $0.632 \times 1/100$ or $0.632 \times 10^{-2}$.

# Scientific Notation

- Scientific notation for numbers is important.
  Prefixes are not important except for a few special cases.

| | | | | |
|---|---|---|---|---|
| exa | E | $10^{18}$ | 1,000,000,000,000,000,000 | |
| peta | P | $10^{15}$ | 1,000,000,000,000,000 | |
| tera | T | $10^{12}$ | 1,000,000,000,000 | Trillion |
| giga | G | $10^{9}$ | 1,000,000,000 | Billion |
| mega | M | $10^{6}$ | 1,000,000 | Million |
| kilo | k | $10^{3}$ | 1,000 | Thousand |
| hecto | h | $10^{2}$ | 100 | Hundred |
| deca | da | $10^{1}$ | 10 | Ten |
| ------ | --- | $10^{0}$ | 1 | One |
| deci | d | $10^{-1}$ | 0.1 | Tenth |
| centi | c | $10^{-2}$ | 0.01 | Hundredth |
| milli | m | $10^{-3}$ | 0.001 | Thousandth |
| micro | μ | $10^{-6}$ | 0.000001 | Millionth |
| nano | n | $10^{-9}$ | 0.000000001 | Billionth |
| pico | p | $10^{-12}$ | 0.000000000001 | Trillionth |
| femto | f | $10^{-15}$ | 0.000000000000001 | |

Examples: 1000 meters = 1 kilometer = 1 km
$10^{6}$ hertz = 1 megahertz = 1 MHz
$10^{-3}$ seconds = 1 millisecond = 1 ms

# Scientific Notation: Application

Why is this useful? Consider the following examples…

Ex. 0: $17 = 1.7 \times 10^{1}$. *Big deal. By itself, this is no help, it is just obscure.*

Ex. 1: The number of cm in a light year = 946300000000000000 cm *argh!*

= $9.463 \times 10^{17}$ cm *better!*

Ex. 2: The mass of a hydrogen atom = 0.000000000000000000000000166 g

= $1.66 \times 10^{-24}$ g *better!*

Scientific Notation is most useful for discussing the very large and the very small.

Astronomy is very much a study of the very large (the Universe) and the very small (atoms and light waves).

# How To Do Arithmetic Using Scientific Notation

- Multiplication:
  - Example: $102 \times 40 = 4080$

$$= (1.02 \times 10^{2}) \times (4.0 \times 10^{1})$$

$$= 1.02 \times 4.0 \times 10^{2} \times 10^{1}$$

$$= 4.08 \times 10^{(2+1)}$$

$$= 4.08 \times 10^{3} = 4080$$

  - To multiply two numbers:
    - Multiply the two numbers in front and
    - Add the exponents

# Units

- We will use **metric units** throughout this course (*see Appendix A*).
- Here are some useful conversions between basic metric units and
  - ones you are more familiar with
    - 1 m = 1.0936 yd
    - 1 km = 0.6214 mi ≃ 5/8 mi
    - 1 kg = 2.2046 lb

    1 yd = 0.9144 m
    1 mi = 1.6093 km
    1 lb = 0.4536 kg

  - astronomical units. These are designed to deal with very large numbers:
    - Within the Solar System, it is convenient to measure distances in Astronomical Units, i. e., the average distance between the Earth and the Sun.

      $1\ \text{AU} = 1.50 \times 10^{11}\ \text{m} = 150\ \text{million km}$

    - To measure distances between stars, we use light years:

      $1\ \text{ly} = 9.46 \times 10^{15}\ \text{m} = 6.324 \times 10^{4}\ \text{AU}$

    - To measure masses, a convenient unit is the mass of the Sun:

      $1\ M_{\odot} = 1.99 \times 10^{30}\ \text{kg}$

# More Units

– Angles are measured in degrees (°):
  - 360° make a full circle
  - 1° = 60' (arcminutes) The smallest angle that a human eye can "resolve" is 1'.
  - 1' = 60" (arcseconds) The smallest angle that a telescope on the ground can resolve is about 1/3 arcsec (absent special equipment).

– We will also need the speed of light:
  - c = 299792458 m/s exactly = $2.99792458 \times 10^8$ m/s

Note 1: You do not need to memorize these. For homework problems, you can look them up in Appendix A of your text. If you need them on exams, we will provide them.

Note 2: Temperature scales are also discussed in Appendix A.
We will usually use the Kelvin scale.

# Converting Units

- Example: Convert miles/hour into kilometers/hour:
  - Recall:
    - 1 km = 0.6214 mi
    - 1 mi = 1.6093 km

    So: 100 mi/hr

    = 100 (1.6093 km) / hr

    = (100) (1.6093) km/hr

    = 160.9 km/hr

- Example: Convert miles/hour into feet per second:

  100 mile/hr

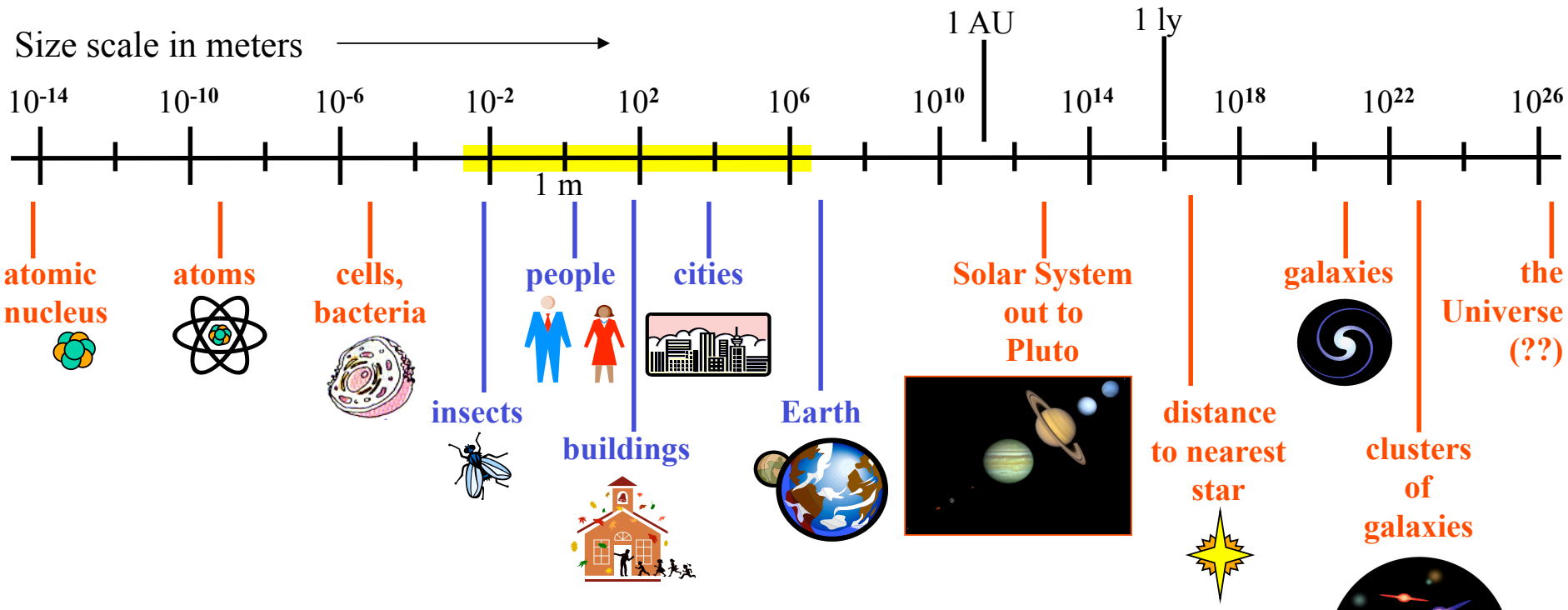
  = 100 mile/hr (5280 feet/mile) / (3600 sec / hr)

  = 146.7 feet/sec

  A baseball thrown at 100 mi/hr gets to home plate (flies 60 feet) in 0.41 sec.

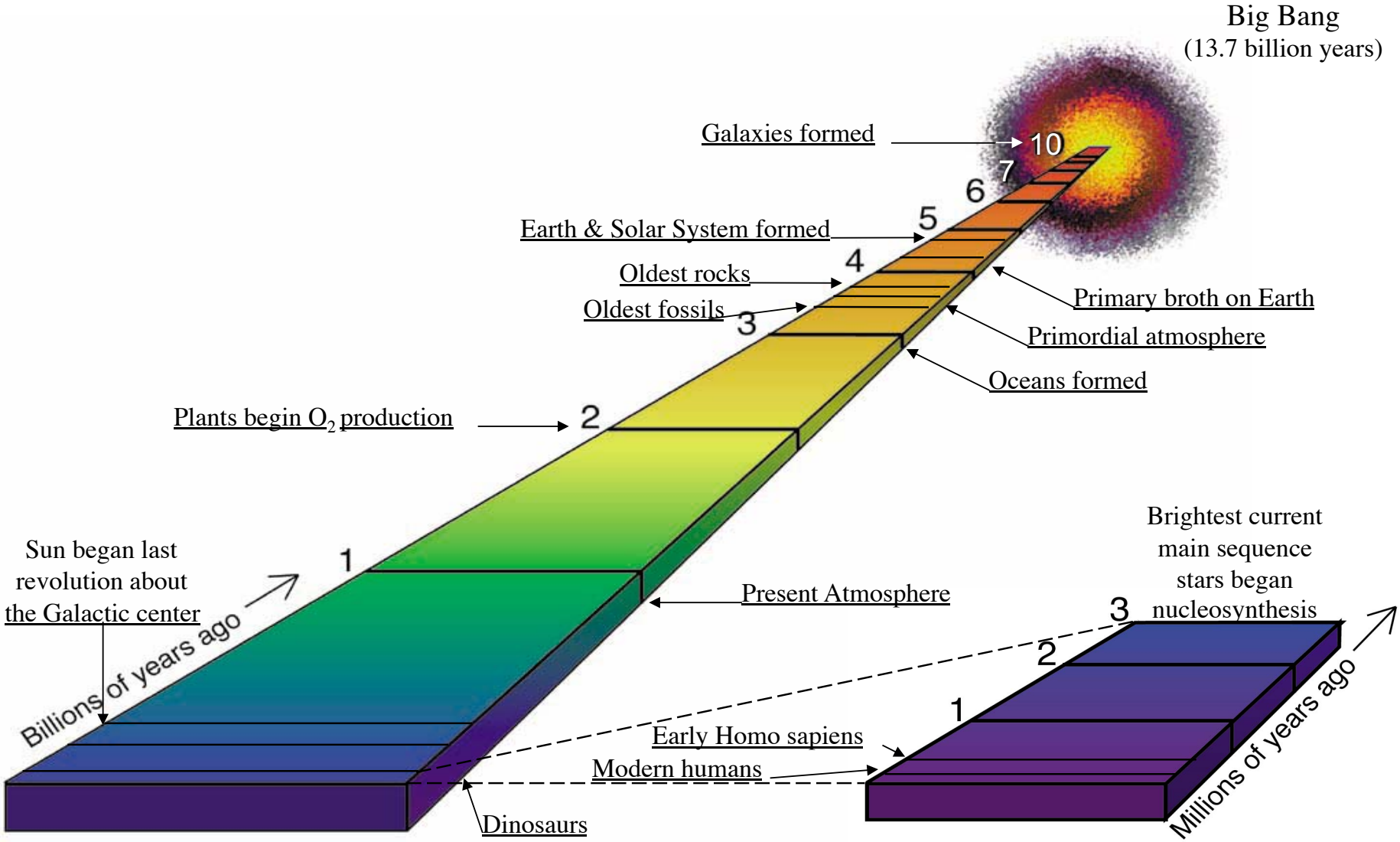
# Size Scales

Our personal experience covers a tiny fraction of the sizes of things in the Universe.

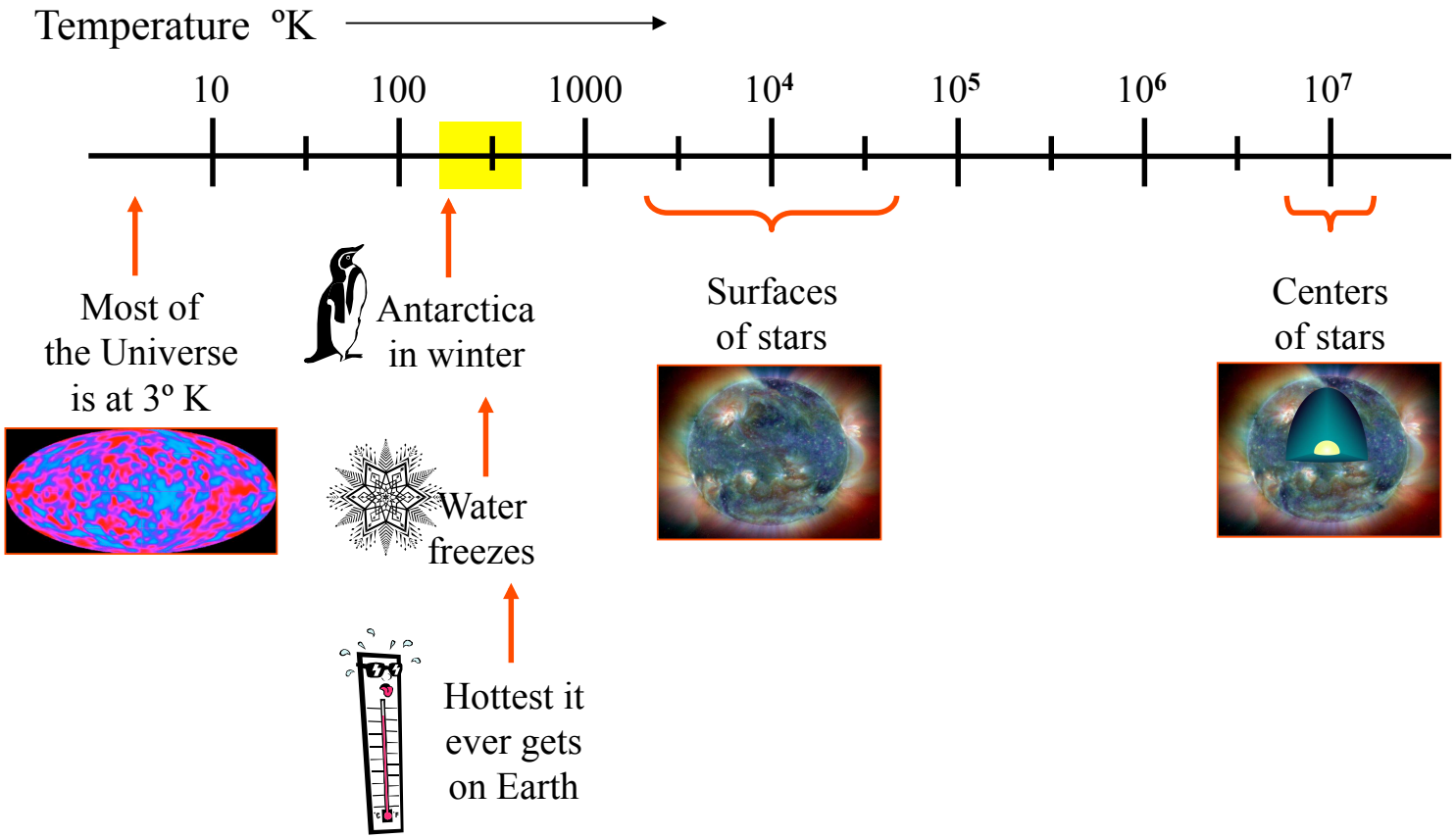



**This course is a voyage of discovery from the scale of the Earth upward and backward in time.**

# Time Scales


Big Bang
(13.7 billion years)
Galaxies formed
10
7
6
5
Earth & Solar System formed
4
Oldest rocks
Oldest fossils
3
Primary broth on Earth
Primordial atmosphere
Oceans formed
Plants begin $O_2$ production
2
Sun began last revolution about the Galactic center
1
Billions of years ago
Present Atmosphere
Brightest current main sequence stars began nucleosynthesis
3
2
1
Early Homo sapiens
Modern humans
Dinosaurs
Millions of years ago

# Temperature Scales



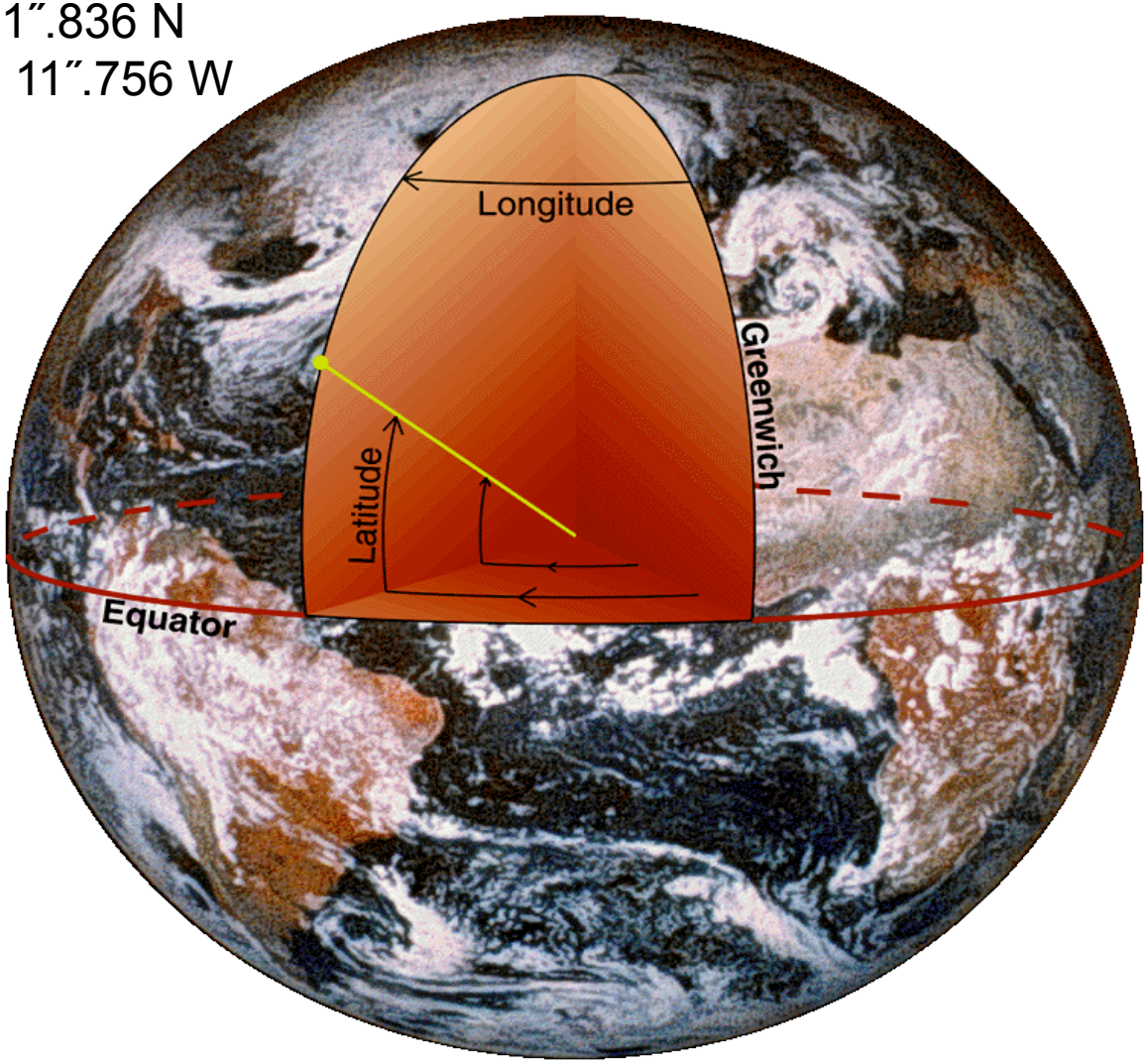
# THE MOST IMPORTANT DISCOVERY

**The most important discovery about the Universe is that it can be understood.**

**The physical laws are the same throughout the Universe.**

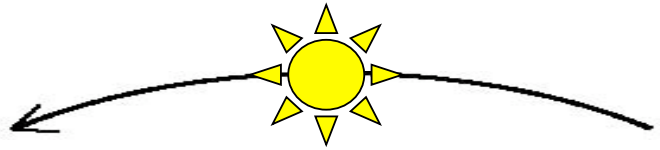
# Your Place on Earth

RLM is located at:
Latitude 30˚ 17´ 21˝.836 N
Longitude 97˚ 44´ 11˝.756 W



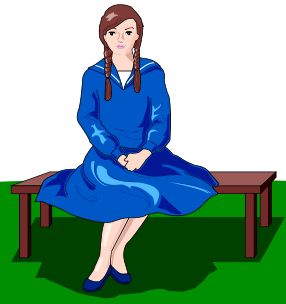
# Time Zones

The directions of different time zones are easy to remember:



Sun sets in the West

Sun rises in the East



West

East

At noon: The Sun has already passed places that are east of you

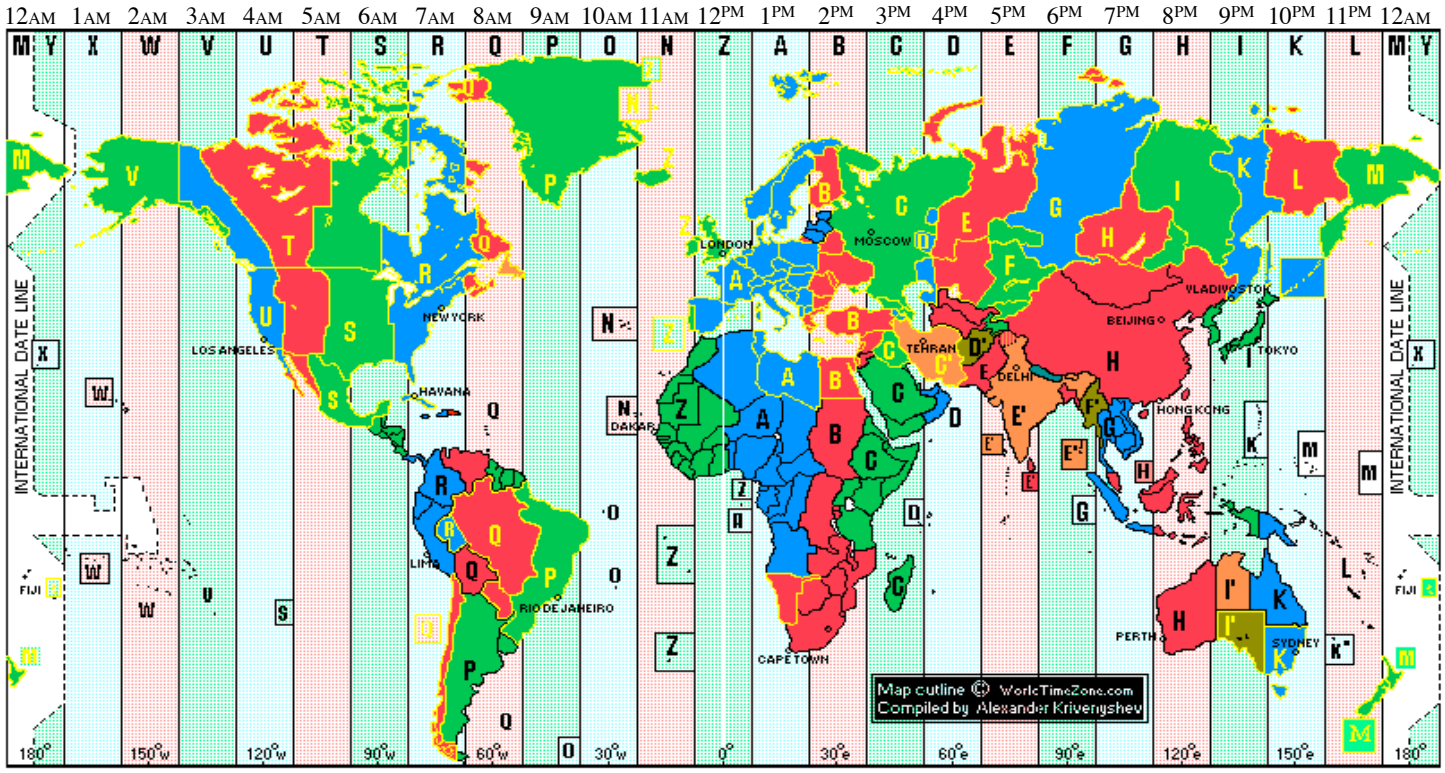
⇒ The Sun is past zenith in those places

⇒ It is later than noon there

⇒ The time of day is later eastward of you (e. g., New England)

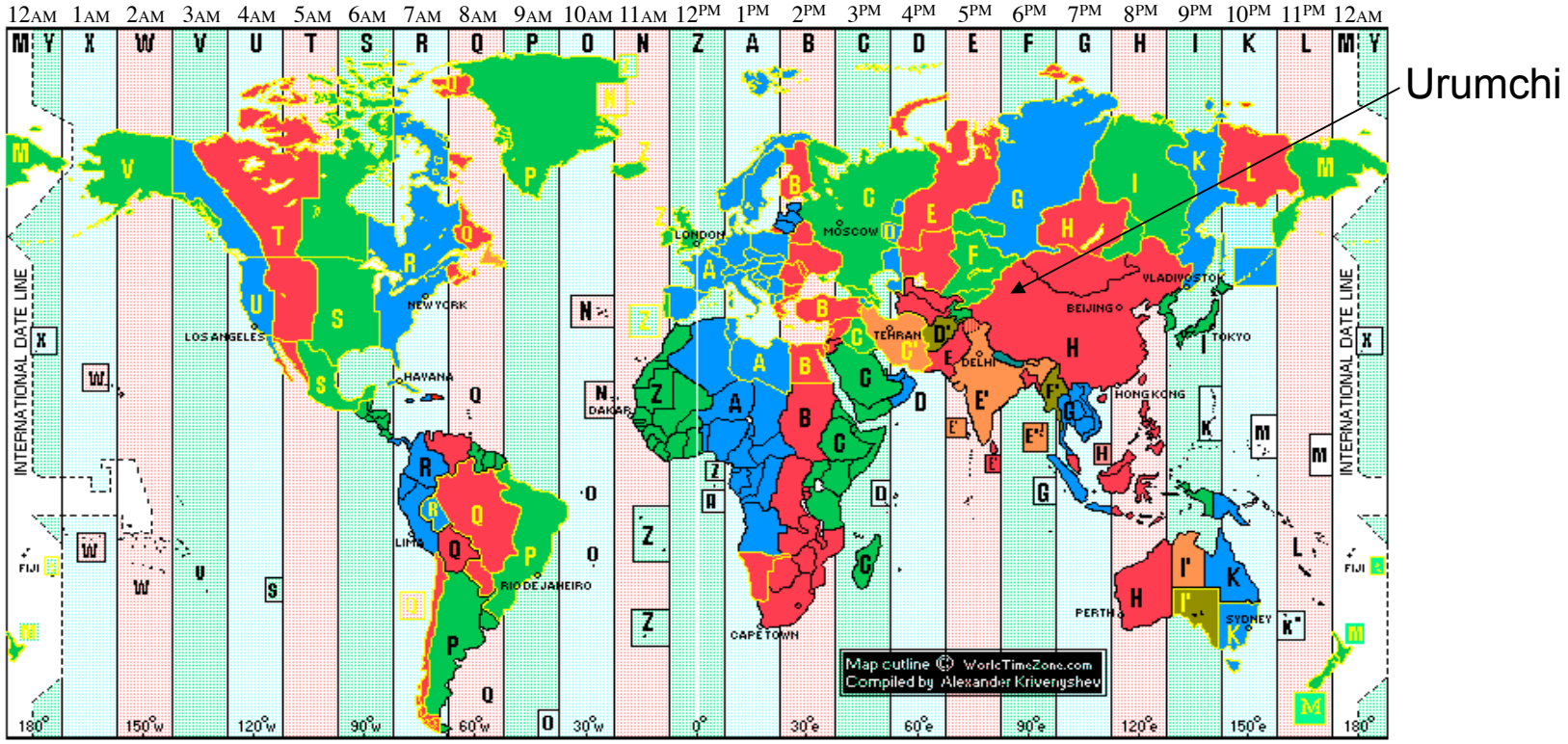
# Time Zones

- The colors code nationally adopted time zones.
- They are loosely tied to solar time, i. e., to longitude, but they get modified for reasons of political and social convenience.  Or inconvenience.



# Time Zones

- All of China is on the 120˚ = +8 hour time zone (Beijing).
  But China is 4 hours wide! So:
  At Urumchi, when it should be 5:30 PM, it is officially 8 PM.
- Nepal is at +5.75 h. If you stand on Everest's summit with one foot in Nepal and the other in China, the time difference between your two feet is $2^{1}/_{4}$ h!



# Time Differences to Various Places

The amount of time difference* to various places is not easy to remember or to figure out.

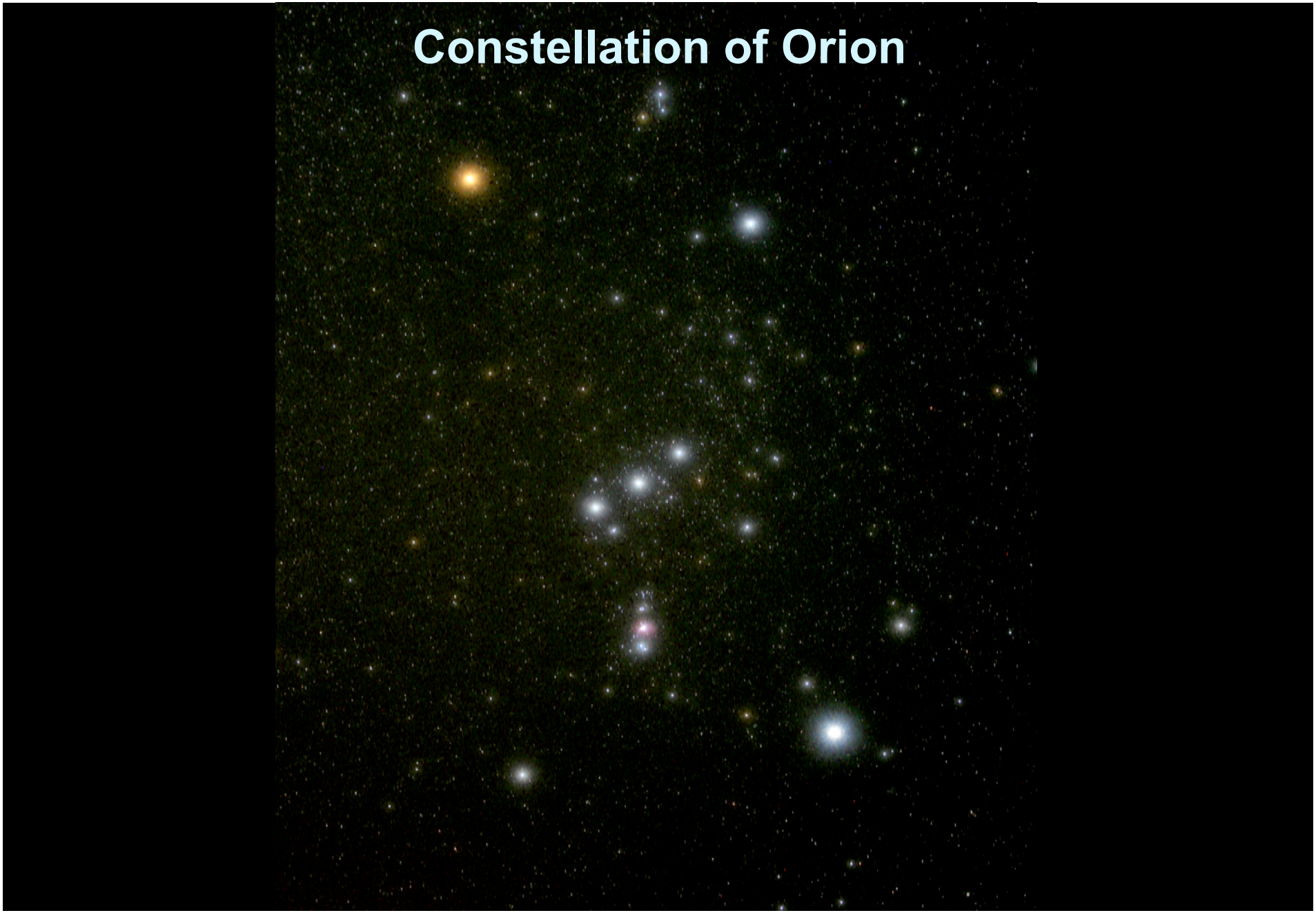
With respect to us in Texas,

| | | | | |
|---|---|---|---|---|
| | in | England (Greenwich) it is | $6^h$ | later |
| ↑ E | | New York (EST) | $1^h$ | later |
| W ↓ | | California (PST) | $2^h$ | earlier |
| | | Japan: $15^h$ later or | $9^h$ | earlier, but on the next day |

So noon = 12 PM here (Texas)
is 3 AM tomorrow there (Tokyo)

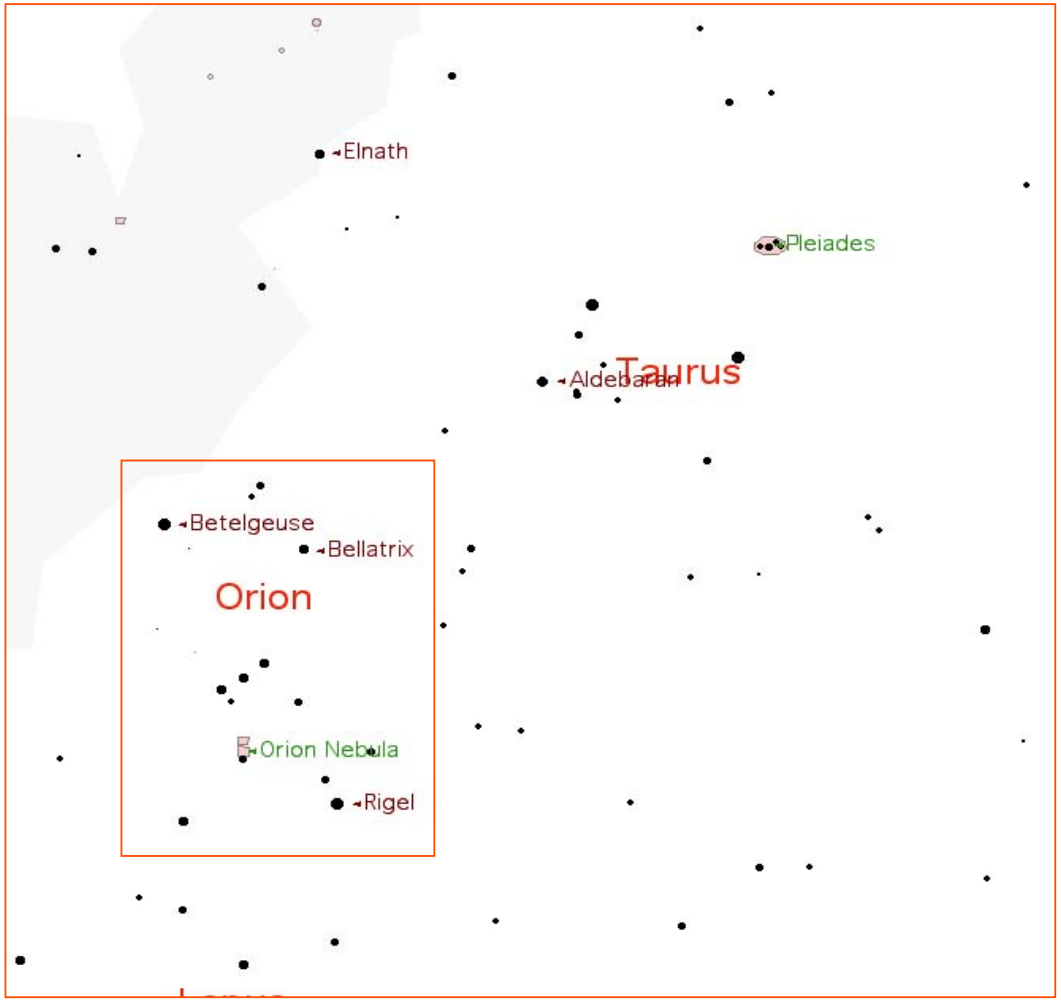
*Caution: In summer, we have Daylight Savings Time — we set our clocks 1 hour ahead so it stays light longer in the evening. Some places do not have Daylight Savings Time.

# Constellation of Orion

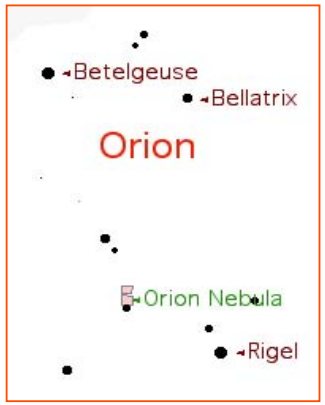


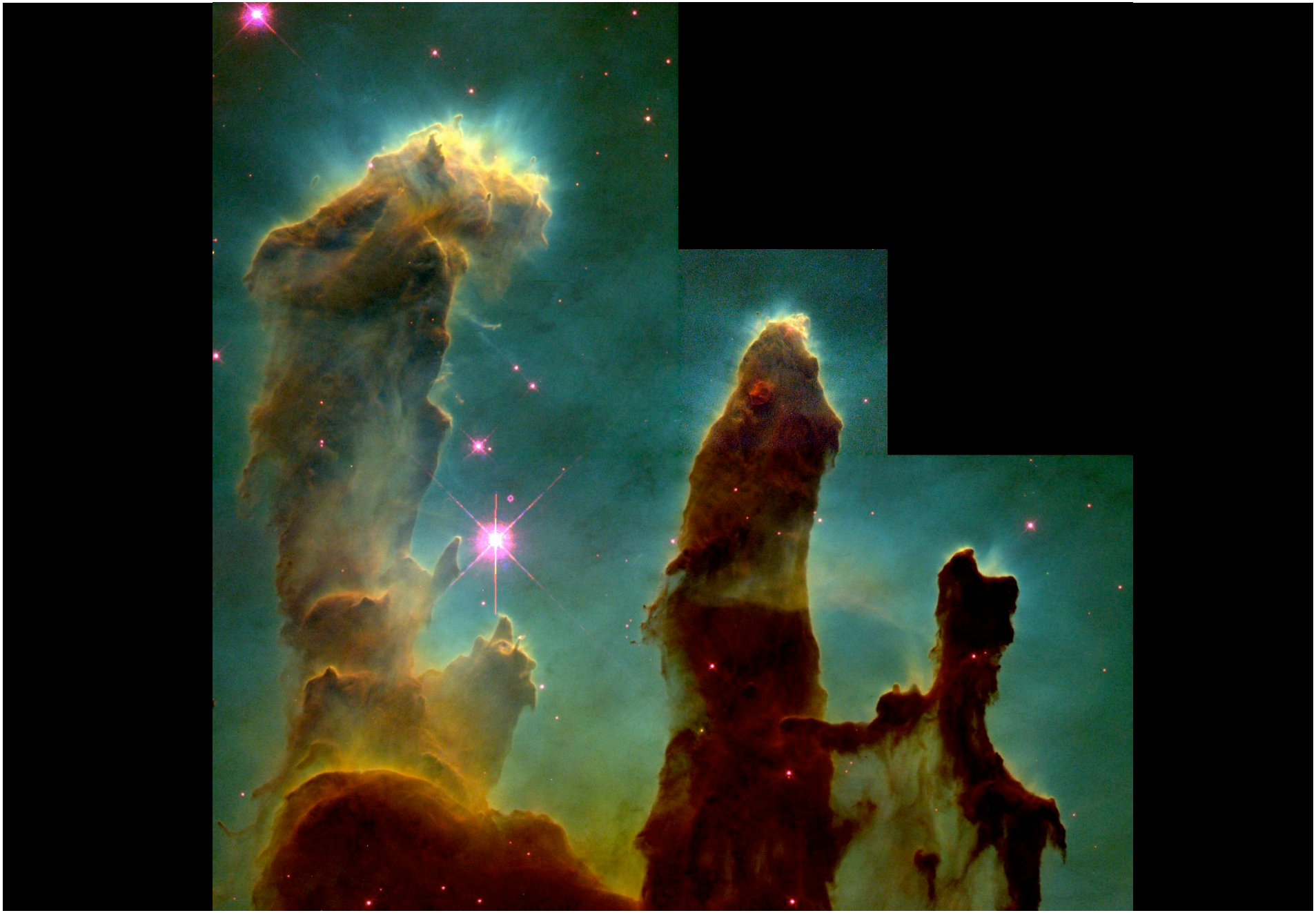
# Constellations of Orion and Taurus

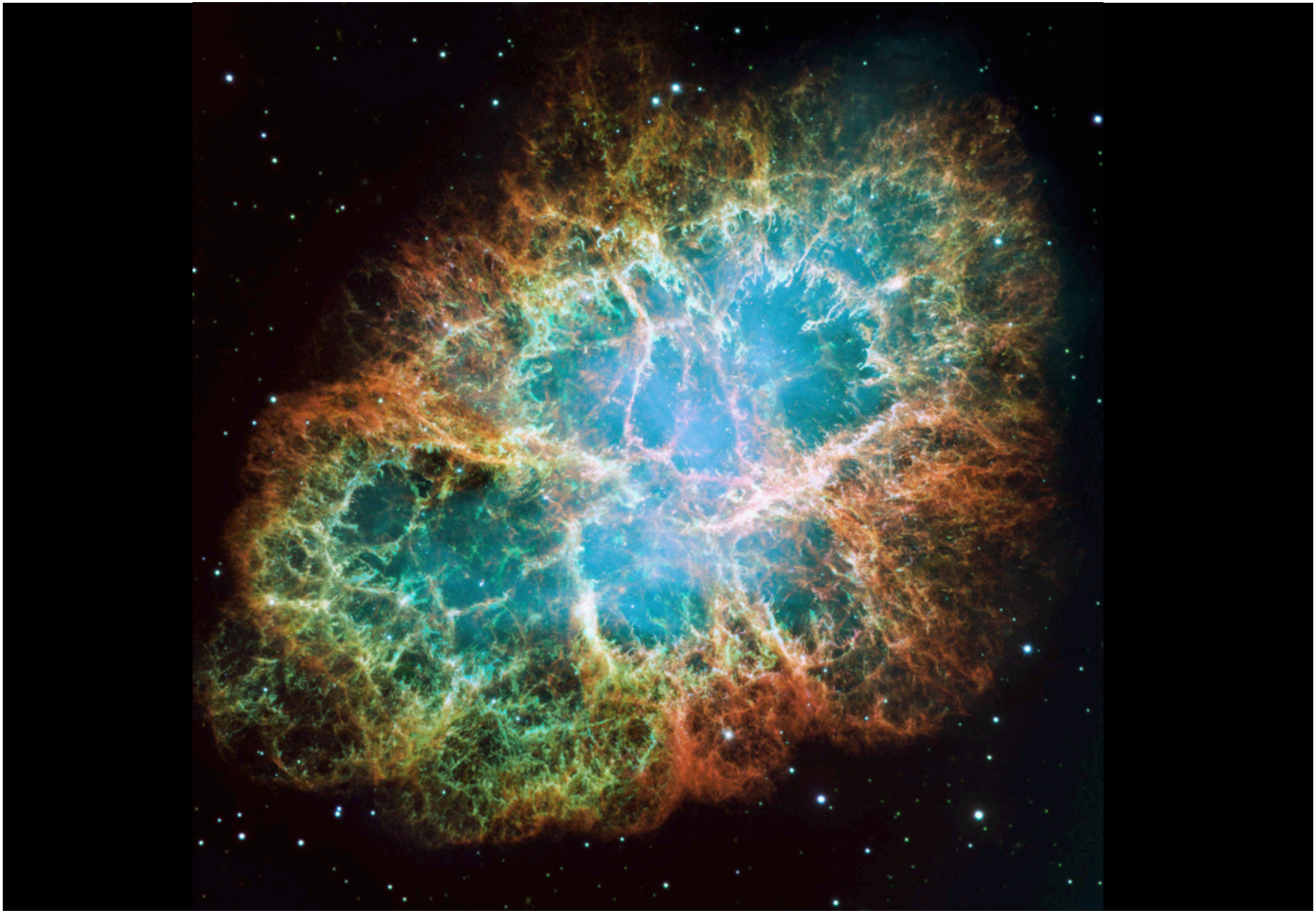
# Diagram of Orion

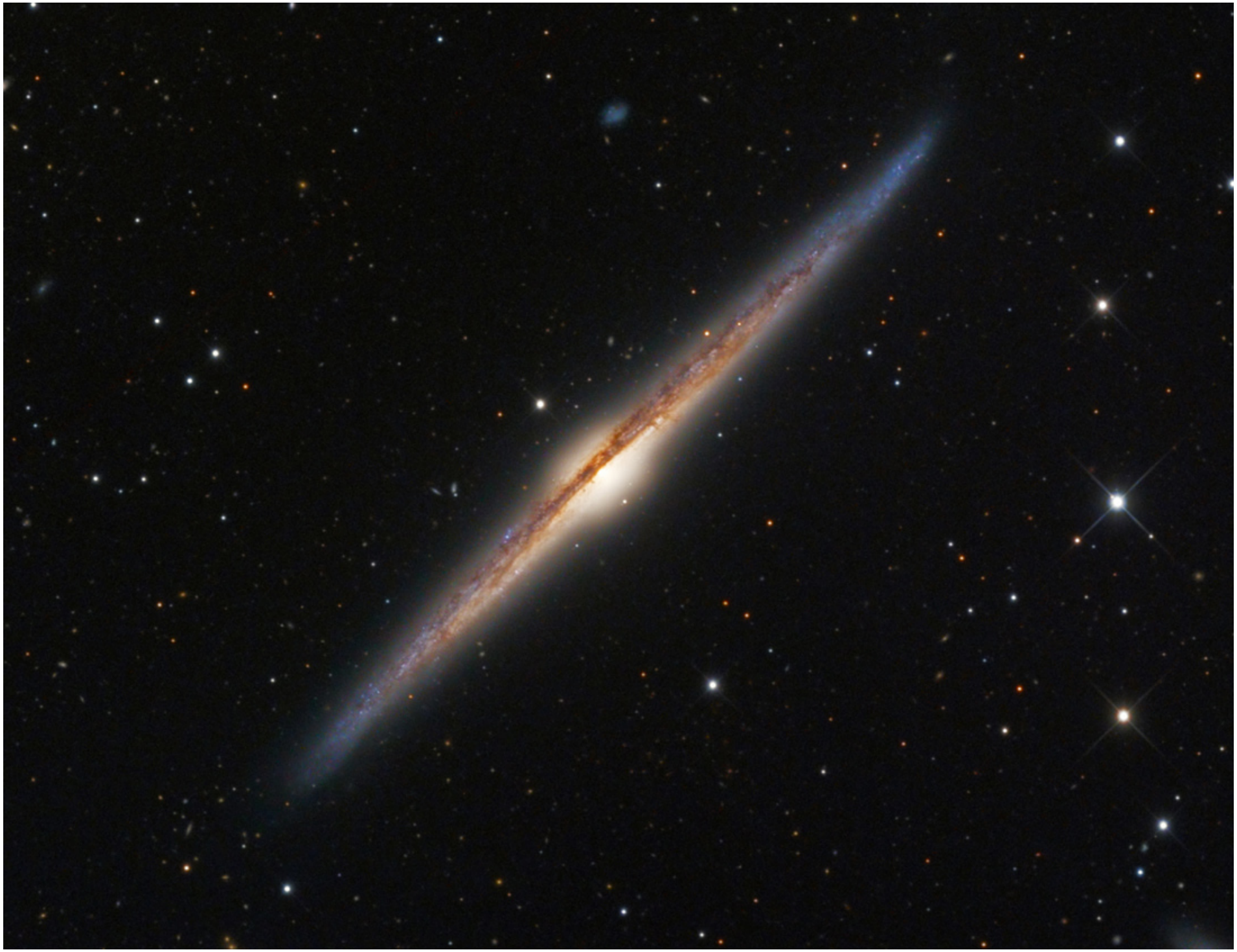


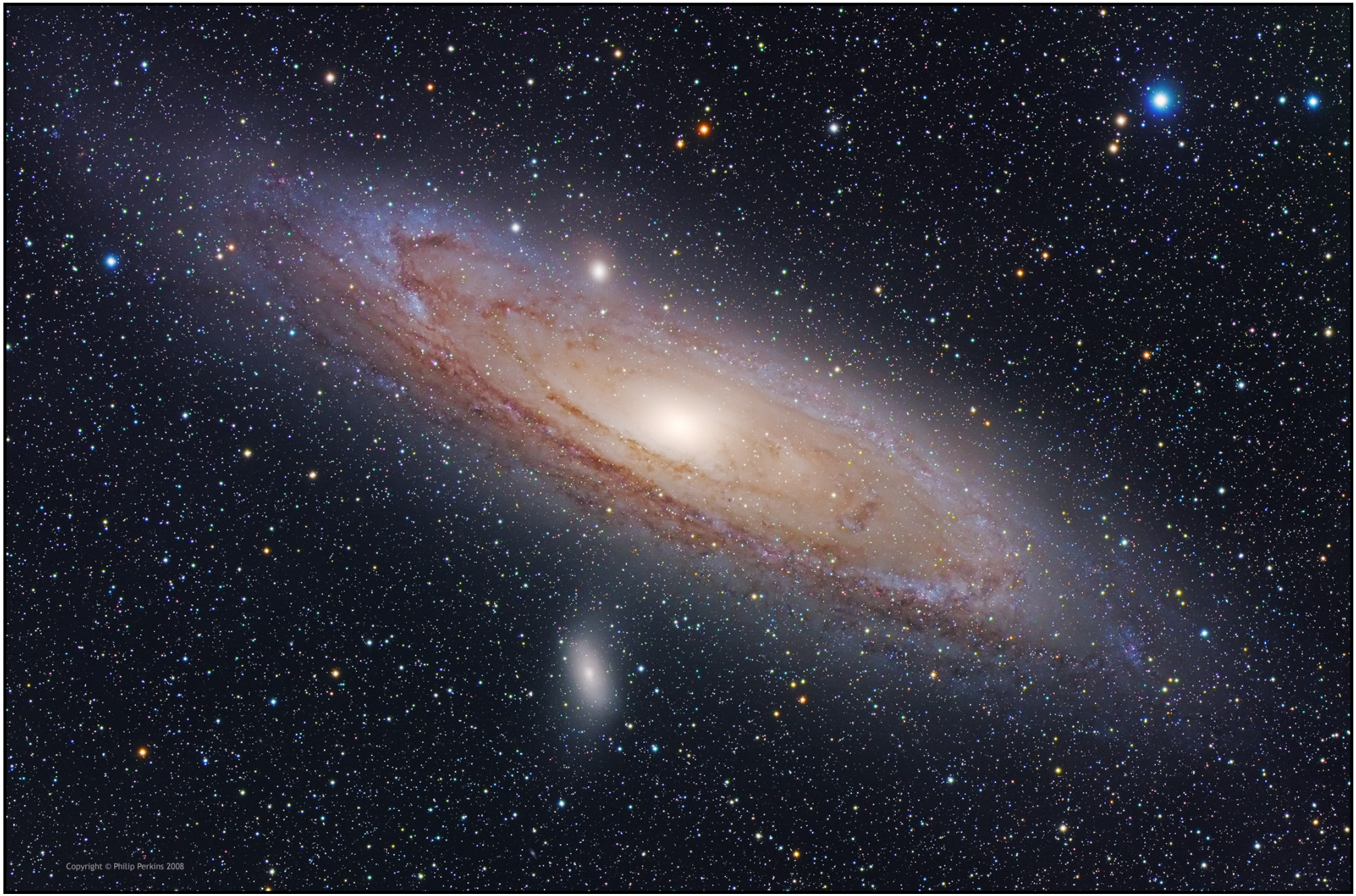
**The stars of Orion are (mostly) unrelated:**
**They are at different distances.**
**Constellations are not important.**
**We will not talk about them.**







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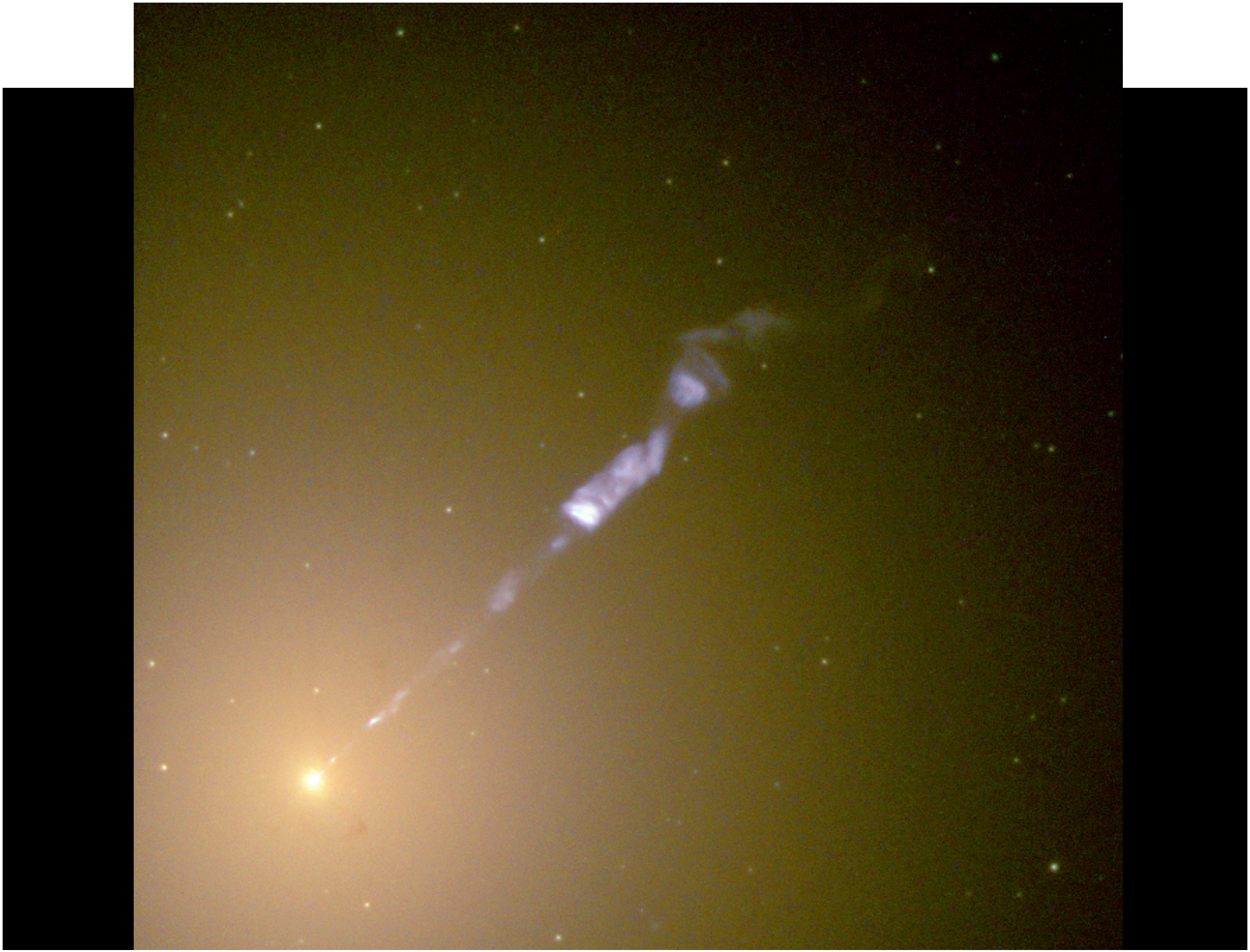

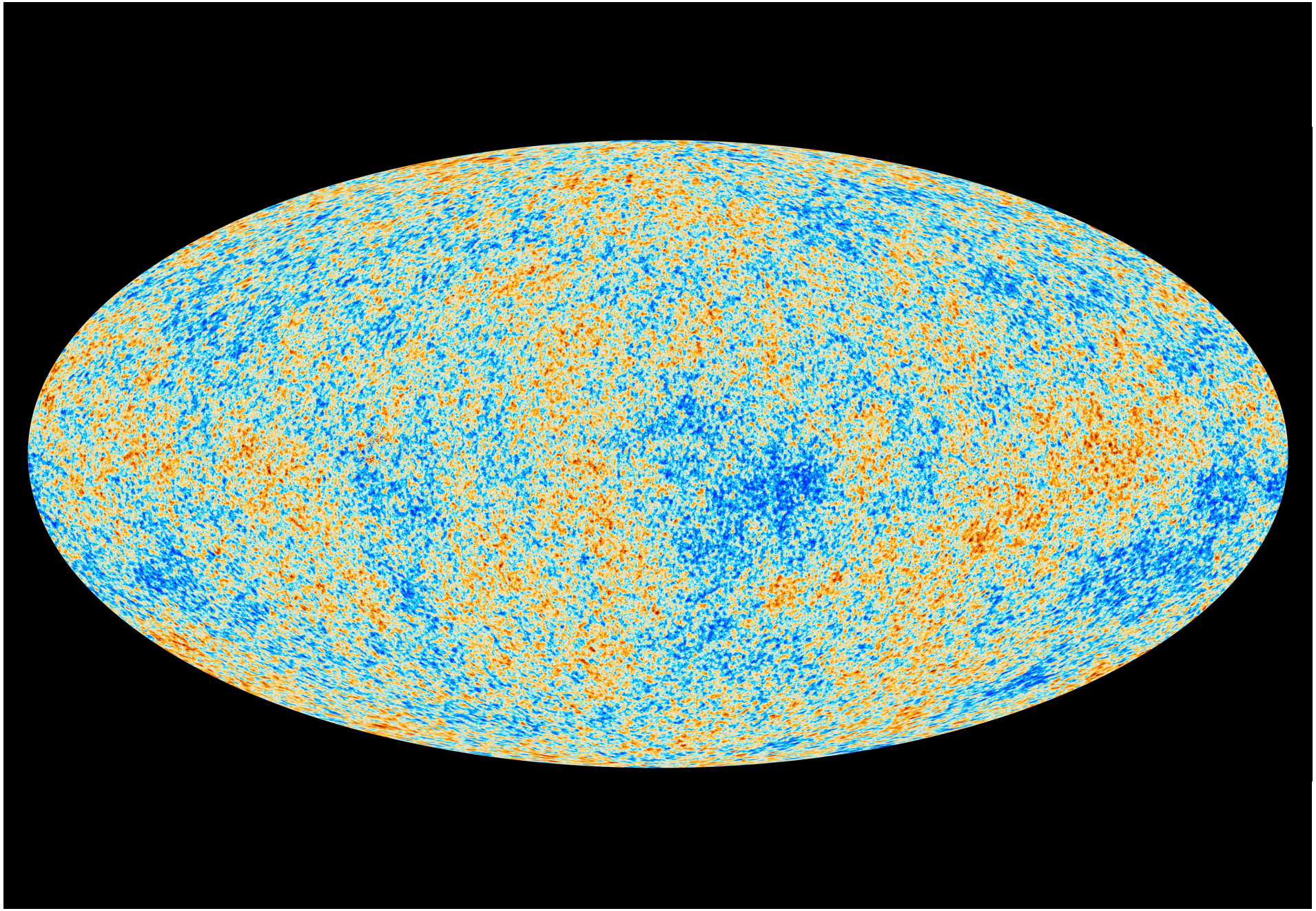

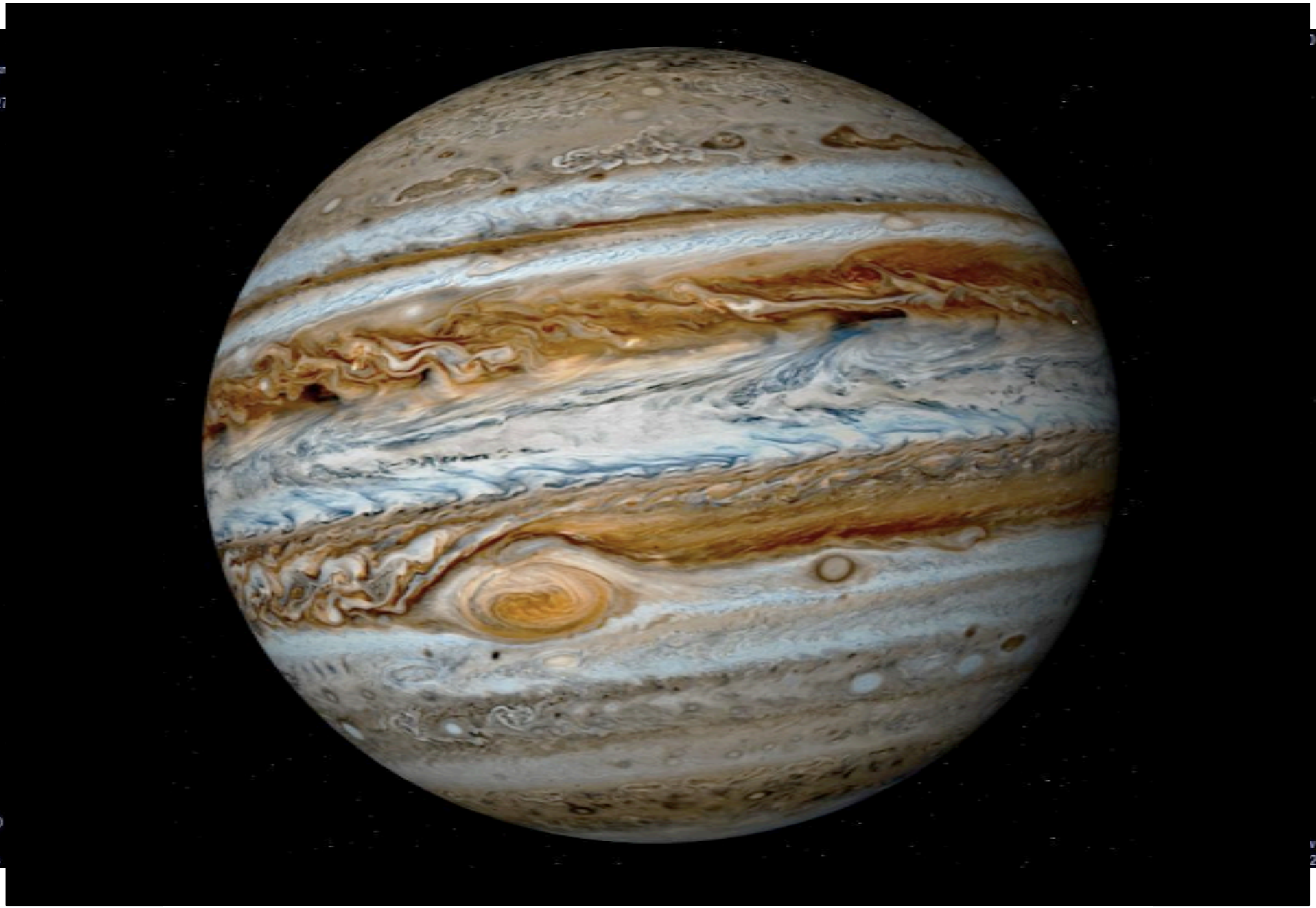

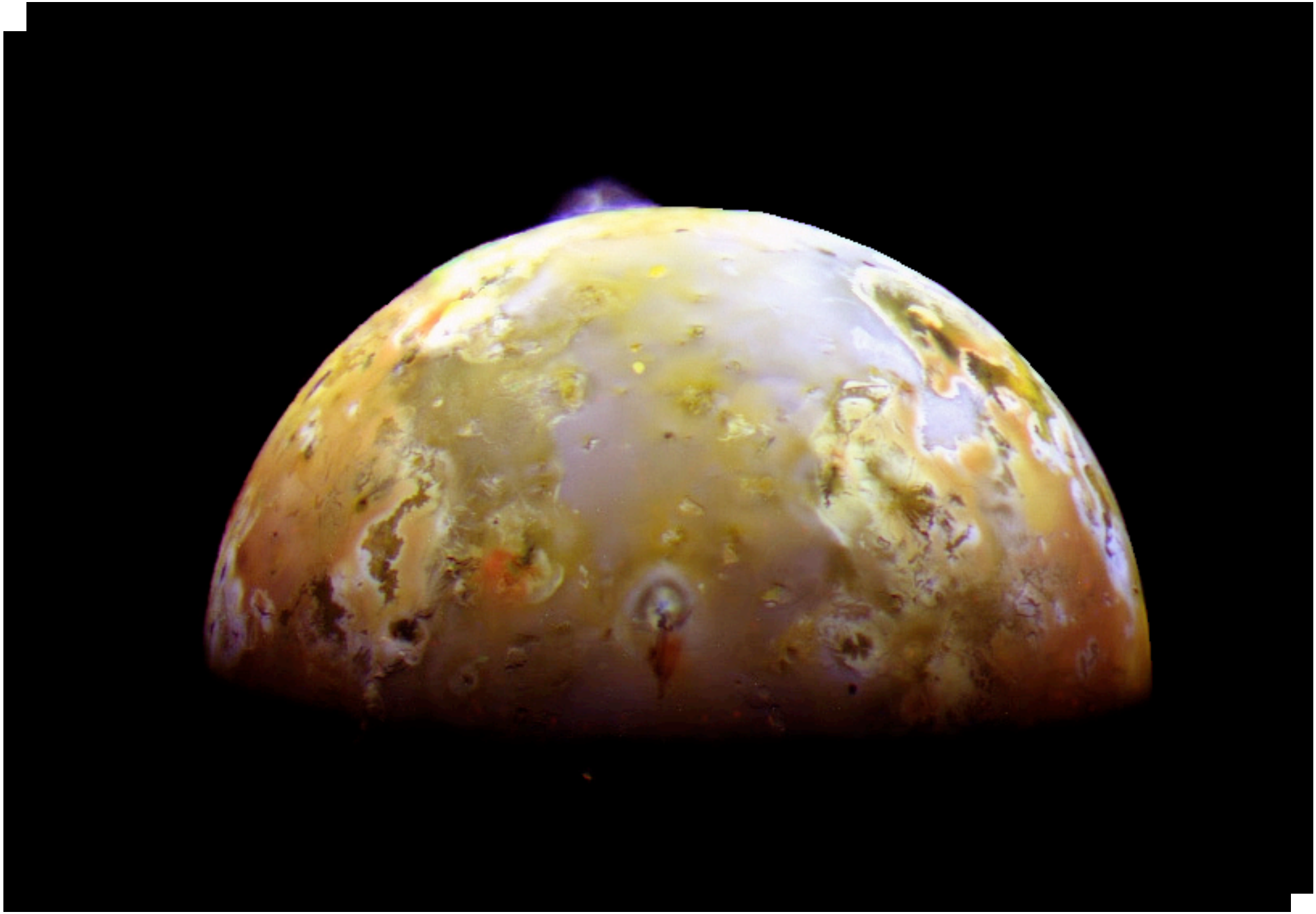

Art by
Christian Lassen


JAMES CAMERON'S
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