What is Astronomy?

- Story of our understanding of the Universe
- By the end of the course, we will have traveled through the solar system, the Galaxy, clusters of galaxies to the beginning of the Universe.
What is Astronomy?

- Story of our understanding of the Universe
- By the end of the course, we will have traveled through the solar system, the Galaxy, clusters of galaxies to the beginning of the Universe.

Objectives

- Organization of the Universe
- Principal components that create this organization
- Scientific method: how we try overcome human perceptual limitations to figure this out
Overview

Earth in context
Scale of the Universe
Human Biases
Back in time
The Light-Year
The Course
Requirements
A100 structure
Policies
Grades
MasteringAstronomy
Scientific Notation
Light-year in km
Metric Prefixes
Measuring distance
Energy Output
Local motions
Galactic motions
Dark Matter
Expanding Universe
Motions summary
Origin of the elements
Time scales
Overview

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Earth in the Universe

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10^{10} \text{ km}

10^{4} \text{ km}
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Earth in the Universe

10^{18} \text{ km}

10^{10} \text{ km}

10^{4} \text{ km}
Earth in the Universe

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- $3 \times 10^{19}$ km
- $10^{18}$ km
- $10^{10}$ km
- $10^4$ km
Earth in the Universe

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- $10^{21}$ km
- $3 \times 10^{19}$ km
- $10^{18}$ km
- $10^{10}$ km
- $10^4$ km
Scale of the Universe

- **Sun** = basketball
- **Earth** = marble at a few hundred feet
- **Nearest star** = about 10,000 miles away (Tokyo)
- **Center of the Milky Way** = 10,000 times the nearest star or 100,000,000 miles away
- **Nearest Galaxy** = 1000 times distance to center of Milky Way 100,000,000,000 miles away
Human biases

- **Cosmic length scales**—very large compared to human size

- **Cosmic time scales**—very long compared to human lifetime

- **Cosmic events at many wavelengths**—humans have limited sensitivity to the electromagnetic spectrum
What was the Universe like in the past?

<table>
<thead>
<tr>
<th>Destination</th>
<th>Light travel time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>1 second</td>
</tr>
<tr>
<td>Sun</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Sirius</td>
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<td>2.5 million years</td>
</tr>
</tbody>
</table>

Observing at large distances is looking back in time!!
What was the Universe like in the past?

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<td>8 years</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 million years</td>
</tr>
</tbody>
</table>

This is known as the “Space-time continuum”
The distance light can travel in one year

About 10 trillion km (6 trillion miles)
The distance light can travel in one year

About 10 trillion km (6 trillion miles)

At great distances we see objects as they were when the Universe was much younger
The distance light can travel in one year

About 10 trillion km (6 trillion miles)

At great distances we see objects as they were when the Universe was much younger.
The **distance** light can travel in one year

- **About 10 trillion km (6 trillion miles)**

- **At great distances we see objects as they were when the Universe was much younger**

Question: can we see the entire Universe?
Three encompassing topics

- Motions, Light and Gravity
- Stars
- Galaxies & Cosmology
Three encompassing topics

- Motions, Light and Gravity
- Stars
- Galaxies & Cosmology

The Course

Three encompassing topics

- Motions, Light and Gravity
- Stars
- Galaxies & Cosmology


Attendance is optional, but you are responsible for topics covered in class whether you attend or not.
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My role is to help you understand. Please *ask questions*!!
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Three encompassing topics

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Web site:

http://www.astro.umass.edu/~weinberg/a100
**Requirements**

- **Reading:** Assignments in the text for each class will be given in preceding class and are required. The relevant chapters are also listed in the Syllabus by subject.
  - You should expect to spend about 3 hours out of class for every one hour of class time.
  - **Effort = Final Grade**


Exams: Three in-class one-hour exams and a final exam. Of the four, I will drop your lowest score. The exams will be multiple choice.

The exam dates are in the syllabus. They will only change if the University is closed (e.g. snow day). In that case, the exam will be held at the next class meeting.

Please bring a #2 pencil to each exam!
A100 structure: lecture + lab

- **A100:** *four* credits with a lab
  - The lecture counts for 75% of your total grade
  - The lab counts for 25% of your total grade

**Your lecture grade:**

\[
\text{score} = \frac{\text{Your points}}{\text{Total points}} \times 100
\]

**Your course grade:**

\[
\text{score} = \text{Lecture grade} \times 0.75 + \text{Lab grade} \times 0.25
\]

Read: Chap 1
Tom Burbine runs the labs, not me …

The first lab meeting for the Wednesday lab will be this Wed. (5th) from 4:40PM - 5:30PM in Hasbrouck 20

The first lab meeting for the Monday lab will be next Mon. (10th) from 4:40PM - 5:30PM in Hasbrouck 20

After the orientation meeting, labs will be scheduled every other week

Most of the assignments will be submitted on the Lab’s Spark page

Here is the website for the lab:
http://blogs.umass.edu/astron100-tburbine/
**Policies**

- **Makeup exam policy:** Following the University guidelines, makeup exams will be given *only* for documented medical or family emergencies or by prior arrangement.

- **Homework:** There will be (roughly) weekly homework assignments worth 25% of the total lecture score. We will use [www.masteringastronomy.com](http://www.masteringastronomy.com), an online assignment system.
Extra credit: At the end of each class, you may pass in a sheet of paper with your name, UMass ID and

1. Brief description of an idea or topic from the day that you found particular interesting

2. Your top question from the day’s class

1/2 credit for each. Over the entire semester, this is worth up to 5% to your final score.

Some of the homework assignments will have additional questions that count for extra credit.

There are no other forms of extra credit.
Grades will be assigned on a modified straight scale. Scores will be adjusted upward if the exam is too hard.

92.5%  A
90%    A-
87.5%  B+
82.5%  B
80%    B-
77.5%  C+
72.5%  C
70%    C
67.5%  D+
60%    D

3 exams  37.5%
Online homework  18.75%
In-class feedback  3.75%
Lab score  25%

Academic Honesty is expected of all scientists, and also of all students of science.
Interactive, online homework and study system (see your handout)

You must register using the access packet that comes with your textbook
Go to www.masteringastronomy.com

Click Students
Step 1: Do you have an access code?

An access code is a 6-part code. Here is an example of what an access code looks like:
QUAYS-THUMB-PIPES-TRAWL-NOMAD-KNEAD

NOTE: Your text/package may have included a MasteringAstronomy access code, or you may have purchased a code separately at your bookstore. If not, you can purchase access online at www.masteringastronomy.com.
SKIP THIS SLIDE if you already have an access code.

If you **DO NOT** have an access code, click **No**, then select the book you are using.
SKIP THIS SLIDE if you already have an access code.

Select Yes or No and click Continue.

eText Options:
Access codes packaged with a new text include eText access. You can purchase access to the eText at this time or you can upgrade to the eText later.

Price will be shown before purchase.
By registering to use a Pearson Education online learning system, I certify that I have read and agree to the Pearson License Agreement and the Pearson Privacy Policy.

I understand that my personal information may be stored in and/or accessed from jurisdictions outside of my resident country. I consent to this storage and/or access.

The personal information that I use with a Pearson Education online learning system can include my name and contact information, my answers to questions that are part of the course, my marks on tests or other course requirements, and any comments about me made by my instructor.

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Read the Privacy Policy and License Agreement

Click I Accept
Create a **Login Name** and **Password**. Confirm Password.

Click **Next**

Do you have a Pearson Education account?
Select:
- **No** if this is your first Pearson product.
- **Yes** if you have another Pearson Account
- **Not Sure**

Enter your 6-part **Access Code** HERE

Create a **Login Name** and **Password**. Choose something that is easy to remember.

Your password cannot be the same as your login name.

*Access Information*

*Do you have a Pearson Education account?*

- [ ] Yes
- [ ] No

**Create a Login Name**

[chrispearson](#)

Create a login name and password. Choose something that is easy to remember.

**Create a Password**

[************](#)

Create a password. It must be at least 8 characters with at least one letter and one number. [See acceptable characters](#).

**Re-type your Password**

[************](#)

**Access Code**

[**Access Code**](#)

**Example**

SIMPLE - FRILL - TONLE - WEIRS - CHOIR - FLEES

Switch to a single box for pasting your access code

**Enter your access code.**

- [ ] Cancel
- [ ] Next
Enter First Name, Last Name, and Email Address

Enter School Country, Zip Code, School Name
Select a **Security Question** and answer it.

![Security Question Form](image)

- **Security Question**: What town was I born in?
- **Your Answer**: Boston
- **May we contact you?**
  - Let me know about other Pearson Education products and services to help me succeed.
For online purchase, you will need a major credit card.

**SKIP THIS SLIDE if you are NOT purchasing access online.**

![Pearson Payment Information Form](image)
CONGRATULATIONS!
You have successfully registered for MasteringAstronomy.

Click Log In Now
If you received a Course ID from your instructor, click **Yes**, enter your Course ID and click **Continue**.

If you **DO NOT** have a Course ID, follow the instructions on the NEXT slide.
Select your textbook from the drop-down menu and click Continue.

Click **No** if you **DO NOT** have a Course ID from your instructor. (You can join your course later.)
Your instructor may provide specific instructions for completing this field. If so, enter the appropriate information and click Continue.

If you are not sure what to enter, contact your instructor or click Skip This Step.

(You can enter your Student ID later.)
You are now viewing your MasteringAstronomy homepage!

Click here to access the **Study Area**

Click here to access the **eText**

Click here to **View Assignments**

Tips to improve your grade!
If you **DID NOT** enter a Course ID during registration, your MasteringAstronomy welcome screen will look like this.

Click **Join a Course** and enter your Course ID to access your assignments, messages from your instructor, and more.
Click **Introduction to MasteringAstronomy** to learn how to use the program.
Click **Welcome!**

These items will explain how to navigate in the program, how to submit your answers, and how you can expect to be graded.
Read the question and answer all parts as instructed.

Type of help offered

- Mastering tells you immediately whether or not your answers are correct. Usually, you will have multiple chances to arrive at the correct answer. Your instructor will determine how many tries you have available.
- In many items, hints are available to help you if you get stuck. If you don’t need the hints to solve the problem, you can still use them for review later on.
- If you submit an incorrect answer, Mastering often responds with specific, helpful feedback.
- Mastering is forgiving of many types and formatting mistakes. If it can’t figure out what you entered, it will let you know and give you another chance.

These exercises were chosen specifically to lead you through the key features of Mastering and are not intended to test your knowledge of any specific subject material. Therefore, on this item you will not be penalized for using hints and submitting incorrect answers. In fact, you should submit incorrect answers and use the hints to see what happens!

Part A

How many squares are in this 2 x 2 grid? (Part A figure) Note that the figure link lets you know that a figure goes along with this part. This figure is available to the left.

Enter your answer as a number in the box below and then submit your answer by clicking Submit.

Number of squares =

submit my answers give up review part

Grading

See the help file available by clicking the Help tab in the top right corner, if you want to know more about how grading works. Here is an example of a numeric answer.

Additional Resources
The Study Area provides abundant self-study material. Select self-study resources from the menu on the left side of the page.
Return to www.masteringastronomy.com for future login.

Enter your Login Name and Password.
Click Log In
Interactive, online homework and study system (see your handout)

You must register using the access packet that comes with your textbook
The assignments untimed. You may stop in the middle, go back later, etc.

The system offers you hints, if you want them. Not using hints is worth 2% bonus credit.

If you give an incorrect response, in many cases, you will get some extra help from the system and you can try again. However, every time you answer incorrectly, you lose 20% of the available credit for that problem.

Assignments submitted before the due date, of course, get full credit. For every day an assignment is late, you lose 7%. So after one week, you will have lost 50%.

Assignments that are more than two weeks late receive no credit.
Scientific Notation

- Earth in context
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- Back in time
- The Light-Year
- The Course
- Requirements
- A100 structure
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- Grades
- Mastering Astronomy

**Scientific Notation**

- Light-year in km
- Metric Prefixes
- Measuring distance
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Read: Chap 1

- $10^{21}$ km
- $3 \times 10^{19}$ km
- $10^{18}$ km
- $10^{10}$ km
- $10^4$ km

09/04/12 – slide 18
The numbers encountered in this class are astronomical:

- The nearest star is \(41,000,000,000,000\) kilometers away

- The mass of the sun is \(2,000,000,000,000,000,000,000,000,000,000,000\) grams

Scientists have devised a more compact notation for dealing with such numbers called scientific notation.
Scientific Notation

41,000,000,000,000 kilometers
2,000,000,000,000,000,000,000,000,000,000,000 grams

There are really only two important parts to each of the numbers:

1. The leading digits – which establish the precision of the number itself
2. The number of digits – which sets the size or magnitude of the number

In Scientific notation:

4.1\times10^{13} \text{ and } 2.0\times10^{33}
Scientific Notation

The “×” is, as it appears, a multiplication:

\[ 10^2 = 10 \times 10 = 100 \]
\[ 10^3 = 10 \times 10 \times 10 = 1,000 \]
\[ 10^4 = 10 \times 10 \times 10 \times 10 = 10,000 \]
\[ 10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100,000 \]
\[ 10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000 \]

so \(4.5 \times 10^4 = 4.5 \times 10 \times 10 \times 10 \times 10 = 45,000\).
Counting zeros and moving the decimal place is a convenient way of carrying out the multiplication by powers of ten.

Example:
Want: \(10^3 \times 10^5\)

\[
10^3 \times 10^5 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^8
\]

The result of that long string of multiplication is that we add the exponents of the 10’s: \(3+5=8\)
Addition a bit more tricky:

\[ 10^3 + 10^5 = 10 \times 10 \times 10 + 10 \times 10 \times 10 \times 10 \times 10 = 1.01 \times 10^5 \]
Addition a bit more tricky:

\[10^3 + 10^5 = 10 \times 10 \times 10 + 10 \times 10 \times 10 \times 10 \times 10 = 1.01 \times 10^5\]

or

\[1,000 + 100,000 = 101,000 = 1.01 \times 10^5\]
Scientific Notation

Addition a bit more tricky:

\[ 10^3 + 10^5 = 10 \times 10 \times 10 + 10 \times 10 \times 10 \times 10 \times 10 = 1.01 \times 10^5 \]

or

\[ 1,000 + 100,000 = 101,000 = 1.01 \times 10^5 \]

or

\[ 0.01 \times 10^5 + 1.0 \times 10^5 = 1.01 \times 10^5 \]

Rule: add the prefix (mantissa) when power of ten (exponent) for the addends is the same.
1 light-year = \((\text{speed of light}) \times (1 \text{ year})\)

\[= 300,000 \frac{\text{km}}{\text{s}} \times \frac{365 \text{ days}}{1 \text{ year}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ s}}{1 \text{ min}}\]
Light-year in km

\[ 1 \text{ light-year} = (\text{speed of light}) \times (1 \text{ year}) \]
\[ = 300,000 \frac{\text{km}}{\text{s}} \times \frac{365 \text{ days}}{1 \text{ year}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ s}}{1 \text{ min}} \]
1 light-year  =  (speed of light) × (1 year)

= 300,000 km/s × \frac{365 \text{ days}}{1 \text{ year}} × \frac{24 \text{ hr}}{1 \text{ day}} × \frac{60 \text{ min}}{1 \text{ hour}} × \frac{60 \text{ s}}{1 \text{ min}}

= 9,460,000,000,000 km
Light-year in km

\[
1 \text{ light-year} = (\text{speed of light}) \times (1 \text{ year})
\]

\[
= 300,000 \frac{\text{km}}{\text{s}} \times \frac{365 \text{ days}}{1 \text{ year}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ s}}{1 \text{ min}}
\]

\[
= 9,460,000,000,000 \text{ km}
\]

\[
= 9.46 \times 10^{12} \text{ km}
\]
1 light-year = (speed of light) \times (1 \text{ year})

= \frac{300,000 \text{ km}}{s} \times \frac{365 \text{ days}}{1 \text{ year}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hour}} \times \frac{60 \text{ s}}{1 \text{ min}}

= 9,460,000,000,000 \text{ km}

\approx 9.46 \times 10^{12} \text{ km}

\approx 10^{13} \text{ km}
<table>
<thead>
<tr>
<th>Prefix</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>femto-</td>
<td>$10^{-15}$</td>
</tr>
<tr>
<td>pico-</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td>nano-</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>micro-</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>milli-</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>centi-</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>deci-</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>deka-</td>
<td>$10^0$</td>
</tr>
<tr>
<td>hecto-</td>
<td>$10^1$</td>
</tr>
<tr>
<td>kilo-</td>
<td>$10^2$</td>
</tr>
<tr>
<td>mega-</td>
<td>$10^3$</td>
</tr>
<tr>
<td>giga-</td>
<td>$10^6$</td>
</tr>
<tr>
<td>tera-</td>
<td>$10^9$</td>
</tr>
<tr>
<td>peta-</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>exa-</td>
<td>$10^{15}$</td>
</tr>
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</table>
Measuring distance

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Distance in meters (m)
# Energy Output

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Total Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Bang</td>
<td>$10^{68}$</td>
</tr>
<tr>
<td>Radio galaxy</td>
<td>$10^{55}$</td>
</tr>
<tr>
<td>Supernova</td>
<td>$10^{46}$</td>
</tr>
<tr>
<td>Sunlight (1 y)</td>
<td>$10^{34}$</td>
</tr>
<tr>
<td>Volcanic explosion</td>
<td>$10^{19}$</td>
</tr>
<tr>
<td>H-bomb</td>
<td>$10^{17}$</td>
</tr>
<tr>
<td>Thunderstorm</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Lightning flash</td>
<td>$10^{10}$</td>
</tr>
<tr>
<td>Baseball pitch</td>
<td>$10^{2}$</td>
</tr>
<tr>
<td>Typing (per key)</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Flea hop</td>
<td>$10^{-7}$</td>
</tr>
</tbody>
</table>

---

Read: Chap 1
Local motions

Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour
**Local motions**

- Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour
- Earth orbital speed (solar system) = 30 km/s = 170,000 km/hour = 67,000 miles/hour

---

Read: Chap 1
Local motions

- Earth rotates: speed = 0.5 km/s = 1,700 km/hour = 1,000 miles/hour

- Earth orbital speed (solar system) = 30 km/s = 170,000 km/hour = 67,000 miles/hour

- Sun’s orbital speed (Galaxy) = 200 km/s = 450,000 miles/hour
Stars in the local solar neighborhood move randomly relative to one another. . .

. . . while the galaxy’s rotation carries them around the galactic center at even higher speed.
Most of the galaxy’s light comes from stars and gas in the galactic disk and central bulge . . .

. . . but measurements suggest that most of the mass lies unseen in the spherical halo that surrounds the entire disk.
Discovery by Edwin Hubble in 1929

- All galaxies outside of our Local Group are moving away from us
- The more distant the galaxy, the faster it is moving
- Nothing special about our location in the Universe
Discovery by Edwin Hubble in 1929

- All galaxies outside of our Local Group are moving away from us
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Conclusion: We live in an expanding Universe!
Expanding Universe

Distances and Speeds as Seen from the Local Raisin

<table>
<thead>
<tr>
<th>Raisin Number</th>
<th>Distance Before Baking</th>
<th>Distance After Baking (1 hour later)</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 cm</td>
<td>3 cm</td>
<td>2 cm/hr</td>
</tr>
<tr>
<td>2</td>
<td>2 cm</td>
<td>6 cm</td>
<td>4 cm/hr</td>
</tr>
<tr>
<td>3</td>
<td>3 cm</td>
<td>9 cm</td>
<td>6 cm/hr</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Earth rotates around its axis once each day, carrying people in most parts of the world around the axis at more than 1,000 km/hr.

Earth orbits the Sun once each year, moving at more than 100,000 km/hr.

The Solar System moves relative to nearby stars, typically at a speed of 70,000 km/hr.

The Milky Way Galaxy rotates, carrying our Sun around its center once every 230 million years, at a speed of about 800,000 km/hr.

Our galaxy moves relative to others in the Local Group; we are traveling toward the Andromeda Galaxy at about 300,000 km/hr.

The universe expands. The more distant an object, the faster it moves away from us; the most distant galaxies are receding from us at speeds close to the speed of light.
Gas (mostly hydrogen) settles in the disk of galaxies

This gas fragments into dense knots, forms stars

The stars fuse hydrogen into helium and heavier elements, generating energy

The star explodes!

Galaxy: a huge “island” of stars moving around a common center and held together by gravity.
Origin of the elements

- Gas (mostly hydrogen) settles in the disk of galaxies
- This gas fragments into dense knots, forms stars
- The stars fuse hydrogen into helium and heavier elements, generating energy
- The star explodes!

Nebula: an interstellar cloud of dust and/or gas
Gas (mostly hydrogen) settles in the disk of galaxies

This gas fragments into dense knots, forms stars

The stars fuse hydrogen into helium and heavier elements, generating energy

The star explodes!

Star: generates heat and light through nuclear fusion
Origin of the elements

- Gas (mostly hydrogen) settles in the disk of galaxies
- This gas fragments into dense knots, forms stars
- The stars fuse hydrogen into helium and heavier elements, generating energy
- The star explodes!

Supernova: fusion fuel exhausted, the star explodes
Origin of the elements

- Gas (mostly hydrogen) settles in the disk of galaxies
- This gas fragments into dense knots, forms stars
- The stars fuse hydrogen into helium and heavier elements, generating energy
- The star explodes!
Time for Earth to make one rotation: 1 day
**Time scales**

- Time for Earth to make one rotation: 1 day
- Time for Earth to orbit the Sun: 1 year
- Time for Earth to make one rotation: 1 day
- Time for Earth to orbit the Sun: 1 year
- Time for Uranus to orbit the Sun: 84 years
Time scales

- Time for Earth to make one rotation: 1 day
- Time for Earth to orbit the Sun: 1 year
- Time for Uranus to orbit the Sun: 84 years
- Time for Sun to Orbit the Galaxy:

\[
\text{Time} = \frac{2\pi \times 28,000 \text{ light years}}{200 \text{ km/s}}
\]
Time scales

• Time for Earth to make one rotation: 1 day
• Time for Earth to orbit the Sun: 1 year
• Time for Uranus to orbit the Sun: 84 years
• Time for Sun to Orbit the Galaxy:

\[
\text{Time} = \frac{2\pi \times 28,000 \text{ light years}}{200 \text{ km/s}} = \frac{28,000 \text{ light years}}{220 \text{ km/s}} \times \frac{9.46 \times 10^{12} \text{ km}}{1 \text{ light year}} \times \frac{1 \text{ year}}{3.15 \times 10^7 \text{ s}}
\]
Time scales

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  \]

  \[
  = 2.4 \times 10^8 \text{ year} = 240 \times 10^6 \text{ year}
  \]

Read: Chap 1
Time scales

- Time for Earth to make one rotation: 1 day
- Time for Earth to orbit the Sun: 1 year
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- Time for Sun to Orbit the Galaxy: 240 million years
- Time for Milky Way to collide with Andromeda Galaxy: 10 billion years
Time scales

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- Time for Uranus to orbit the Sun: 84 years
- Time for Sun to Orbit the Galaxy: 240 million years
- Time for Milky Way to collide with Andromeda Galaxy: 10 billion years
- Time for light to get to us from the most distant galaxy: 14 billion years