

Astronomy 102
September 6, 2005



IC434

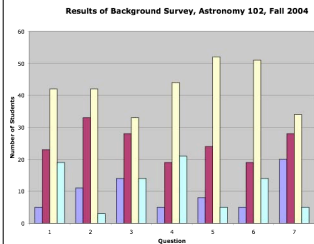
Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

Astronomy 102
September 6, 2005. Today's Topics.

- Course information:
 - Results of Survey
 - Astronomy 102 Homework
- Continuation of our discussion of how big is that:
 - Distances/sizes
 - Mass
 - Time
 - Velocity
 - Luminosity

Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

Astronomy 102, Fall 2005
Background Survey



- Questions:
1. Arithmetic
 2. Units
 3. Scientific notation
 4. Algebra
 5. Geometry
 6. Graphs
 7. Trigonometry

Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

How big is that? Units of Distance/Size

- The unit most frequently used in astronomy to specify the distances between and the sizes of astronomical objects is the light year (ly).
- One light year is the distance traveled by light in one year.
- Examples of distances and sizes in terms of light years:
 - Distance between stars in a galaxy: a few light years
 - Diameter of normal galaxies: a few tens of thousand light years
 - Distance between galaxies: a few million light years

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Units of Distance/Size

- It happens frequently that the units in which our observations are made are not the units we need to compare our observations with theories.
- To be able to compare the results of our observations with the predictions made by our theories we may need to carry out unit conversions.
- The principle of unit conversions relies on the fact that if we multiply the value of a certain observable by 1, the results of the multiplication does not change the value of our observable.

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Astronomical Distances

- NGC 4945 is a nearby spiral galaxy in the Centaurus Group of galaxies.
- Its distance from earth is about 12 Mly.
- The image shown here, shows and edge-on view of this galaxy.
- NGC 4945 has an unusual, energetic nucleus, indicating that it might house a large black hole.



Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Unit Conversions

- **Example:**
 - The mass of Vega is $2.5 M_{\odot}$.
 - What is its mass in pounds?
- **Solution:**
 - Convert the mass to grams:
 $\text{mass} = 2.5 M_{\odot} * (2.0 \times 10^{33} \text{ grams}) / (1 M_{\odot}) = 5.0 \times 10^{33} \text{ grams}$
 - Convert the mass to pounds:
 $\text{mass} = (5.0 \times 10^{33} \text{ grams}) * (1 \text{ pound}) / (454 \text{ grams}) = 1.1 \times 10^{31} \text{ pounds}$.
- **Facts:**
 - $1 M_{\odot} = 2.0 \times 10^{33} \text{ grams} \Rightarrow$
 $1 = (2.0 \times 10^{33} \text{ grams}) / (1 M_{\odot})$
 - $1 \text{ pound} = 454 \text{ grams} \Rightarrow$
 $1 = (1 \text{ pound}) / (454 \text{ grams})$

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

Let's take a break

- During the break you can
 - Ask questions
 - Talk to the stardust sitting next to you
 - Enjoy the image of two galaxies colliding, and be happy that the earth is not part of either galaxy.



Image: colliding galaxies, NGC 4038 and 4039 (Ohio State University)

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Times and ages in astronomy

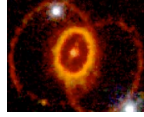
	seconds	hours	days	years
Earth's rotation period	8.64×10^4	24	1	
Moon's revolution period	2.42×10^6	672	28	
Earth's revolution period	3.16×10^7	8.77×10^3	365.25	1
Century	3.16×10^9			100
Recorded human history	1.6×10^{11}			5000
Milky Way Galaxy's rotation period (at Sun's orbit)	7.5×10^{15}			2.4×10^8
Age of the Sun and Earth	1.4×10^{17}			4.5×10^9
Total lifetime of the Sun	4.7×10^{17}			1.5×10^{10}
Age of the Universe	4×10^{17}			10^{10}

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Typical time spans

- Planetary revolution period: around 1 year
- Life expectancy, normal stars: around 10^{10} years
- Life expectancy, giant stars: $10^6 - 10^8$ years
- Rotation period of normal galaxies: $10^7 - 10^9$ years
- Important conversion factors:
 - 1 year = 3.16×10^7 seconds
 - 1 hour = 3600 seconds



The Mysterious Rings of Supernova 1987a
Credit: C. Burrows (ESA/STScI), HST, NASA



M100, 100 billion stars, 56 Mly from earth, Image: NASA

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Unit Conversions

- Example:
 - What is the typical lifetime of a human being in terms of hours?
- Solution:
 - Convert the lifetime to seconds:
lifetime = 75 years * (3.16×10^7 seconds)/(1 year) = 2.37×10^9 s
 - Convert the lifetime to hours:
lifetime = (2.37×10^9 s) * (1 hour)/(3600 s) = 6.6×10^5 hours.
- Facts:
 - 1 year = 3.16×10^7 seconds =>
 $1 = (3.16 \times 10^7 \text{ seconds}) / (1 \text{ year})$
 - 1 hour = 3600 s =>
 $1 = (1 \text{ hour}) / (3600 \text{ s})$

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Speeds in astronomy

	cm per second	km per second	miles per hour
NYS Thruway speed limit	3.0×10^3	3.0×10^{-2}	65
Earth's rotational speed at the equator	4.7×10^4	0.47	1050
Speed of Earth in orbit	3×10^6	30	
Speed of Sun in orbit around center of Milky Way	2.2×10^7	220	

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Speeds in astronomy



Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Luminosity (total power output) in astronomy



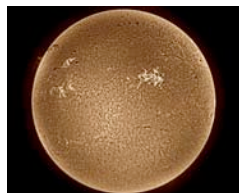
Credit: Courtesy CFA, TRACE Team, NASA

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that? Luminosity (total power output) in astronomy

- The luminosity of an object is the rate with which it generates energy.
- Most of the energy generated by stars is emitted in the form of light.
- The brightness of a star depends both on its luminosity and on its distance from the observer.



Brown Sun Bubbling
Credit & Copyright: Robert Gendler

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

How big is that?

Luminosity (total power output) in astronomy

	ergs per second	watts	Solar luminosities
100 W light bulb	1.0×10^9	100	
150 horsepower car engine	1.2×10^{12}	1.2×10^5	
Large city	10^{15}	10^8	
H bomb (1 megaton, 0.01 s)	4.2×10^{21}	4.2×10^{14}	1.1×10^{-12}
Sun	3.8×10^{33}	3.8×10^{26}	1
Largest stars	4×10^{38}	4×10^{31}	10^5
Milky Way galaxy	4×10^{43}		10^{10}

Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

How big is that?

Luminosity (total power output) in astronomy

- Normal stars: around one solar luminosity (L_{\odot})
- Giant stars: thousands to hundreds of thousands of L_{\odot}
- Normal galaxies: $10^9 - 10^{10} L_{\odot}$
- Quasars: $10^{12} - 10^{13} L_{\odot}$
- Conversion factors:
 - $1 L_{\odot} = 3.8 \times 10^{33}$ erg/s = luminosity of the Sun
 - 1 watt = 10^7 erg/s

Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

Astronomical rates

Why do we care?

- The velocity of an object is the rate with which its position changes.
- The radius of the Earth's orbit around the Sun is 1.5×10^{13} cm. What is its orbital speed (assumed constant)?
 - The distance traveled by the earth in 1 year is $(2\pi r) = 9.4 \times 10^{13}$ cm.
 - The total distance in terms of miles is $(9.4 \times 10^{13} \text{ cm}) \times (1 \text{ km}/10^5 \text{ cm}) \times (1 \text{ mile}/1.61 \text{ km}) = 5.9 \times 10^8$ mile.
 - It takes 1 year to travel this distance, or 1 year $\times (3.16 \times 10^7 \text{ s}/1 \text{ year}) \times (1 \text{ hour}/3600 \text{ s}) = 8.8 \times 10^5$ hour.
 - The velocity of the earth is $5.9 \times 10^8 \text{ mile} / 8.8 \times 10^5 \text{ hour} = 67,000$ mph.
 - We are really going fast!

Frank L. H. Wolfs Department of Physics and Astronomy, University of Rochester

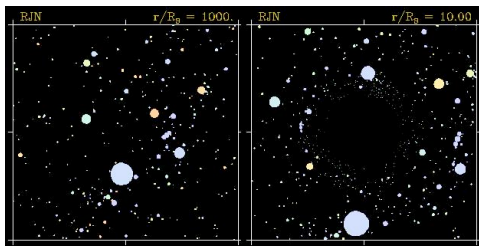
Astronomical rates Why do we care?

- The luminosity of a star tells us something about the rate of energy loss of the star.
- If we make assumptions about the total energy that can be generated by the star, its luminosity will tell us something about the expected life time:
 - Our sun was created with an energy supply of 2×10^{51} erg
 - The solar luminosity is 3.8×10^{32} erg/s
 - Assuming the sun keeps losing energy at this rate, its lifetime will be $(2 \times 10^{51} \text{ erg}) / (3.8 \times 10^{32} \text{ erg/s}) = 5.3 \times 10^{17} \text{ s} = 1.7 \times 10^{10}$ year
 - The sun was formed 4.5 billion years ago, and you can expect that it will still shine by the time you graduate!

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester

Astronomy 102 On Thursday we will travel to a black hole



Too Close to a Black Hole
Credit & Copyright: Robert Nemiroff (MTU)

Frank L. H. Wolfs

Department of Physics and Astronomy, University of Rochester
