December 8th, 2018

Troy Invitational

Astronomy C

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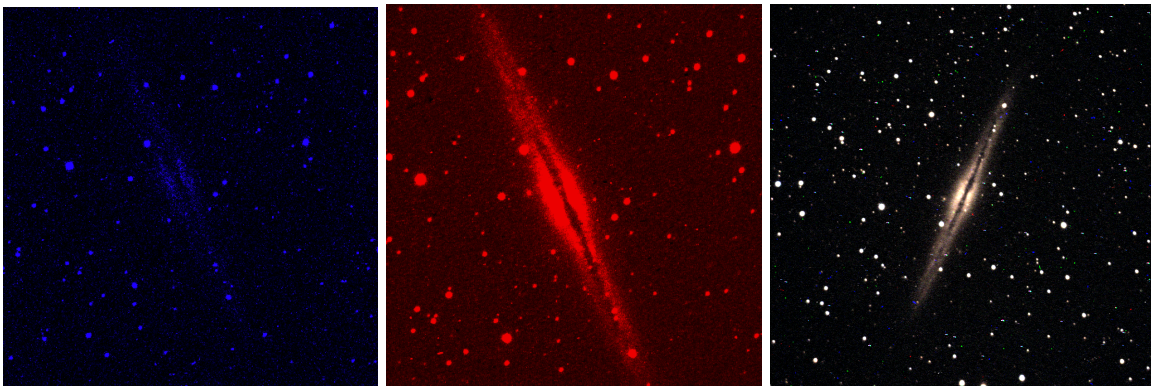
Supervised by: Maggie Zhang

Team Number: _____
Team Name: _____
Team Members: _____

Directions:
Each sub question is worth two points. Only the answer sheet will be scored.
Questions? Email me at asher13a@gmail.com!
Good Luck!

Contents

Question 1: NGC 891



(a) B-band Image (b) R-band Image (c) RGBH Composite

Figure 1: Images of NGC 891 that I captured while Maggie Zhang and Milena Matthew were sleeping in New Mexico this past summer

1. NGC 891 is a Sa galaxy with a measured rotational velocity of 225 kms^{-1} and an apparent B-band apparent magnitude of 9.37 after correcting for extinction.
   (a) What galaxy is this said to resemble?
   (b) What is mostly responsible for the red and green blue dots in the RGBH Composite (possibly best shown on cover)?
   (c) What is the absolute magnitude of NGC 891?
   (d) What is its distance in light years?
   (e) Would you expect the observed $\frac{M_\odot}{L_\odot}$ to be higher or lower than expected for Sa galaxies? Why?
   (f) Explain why the galaxy appears more luminous in the R-band than the B-band.

Question 2: Almost Free Points

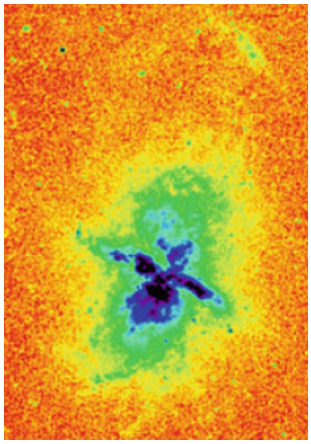


Figure 2: The relative surface brightness of a nearby galaxy

2. Galactic outflows are rare at low redshifts, yet we have one nearby.
   (a) Which DSO is shown in Figure 2? What wavelength is this?
   (b) What are two sources of kinetic energy that are causing this outflow?
   (c) What is this object's estimated star-formation per square kiloparsec (SFR/A) if the starburst region has a radius of 400 pc?
   (d) How many orders of magnitude larger is this than that of the Milky Way?

Question 3: The Initial Mass Function

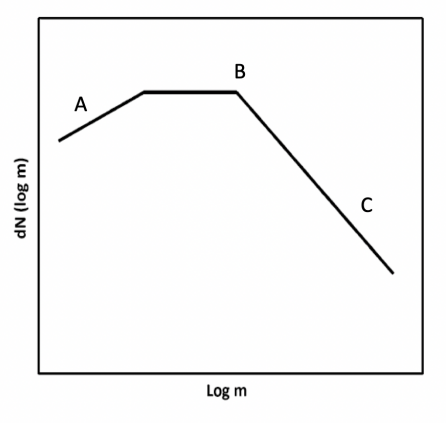


Figure 3: A schematic of the Initial Mass Function (IMF) for star formation

3. Star formation in stellar populations:

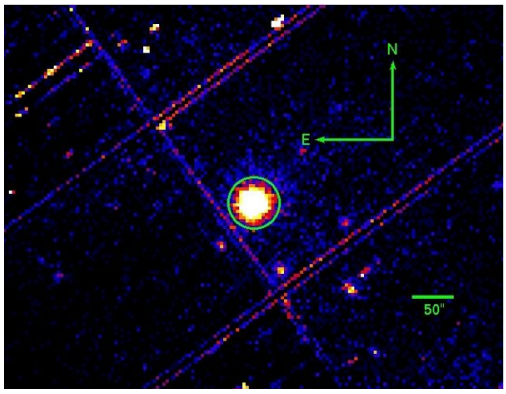
   (a) Which letter represents where one expects to find the sun?

   (b) How do most local conditions affect the IMF?

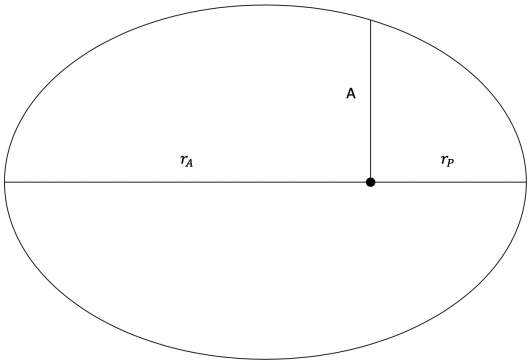
   (c) When does metallicity affect the IMF? How does it change the slope near C?

   (d) What is the relationship between the magnitude of the slope near C and the relative number of Type II supernova?

Question 4: Binary Practice



(a) Binary System



(b) Keplerian Orbit

Figure 4: Image and schematic of a close binary system

4. Close binary systems:
   (a) The object shown in image 1 resides in which DSO? What is the name of this object?
   (b) What is the classification for this type of binary?
   (c) What term is best used for to describe r_p for this type of binary?
   (d) (6 points) Derive an expression for A in terms of r_a and r_p.

Question 5: Investigating Metallicity

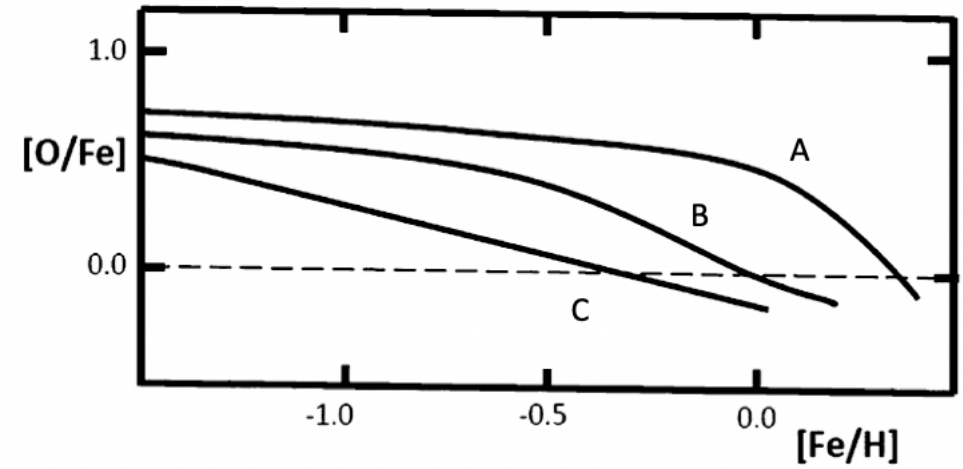
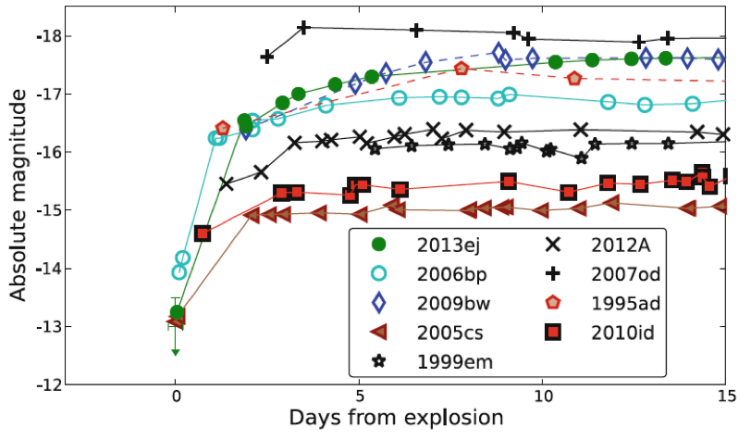


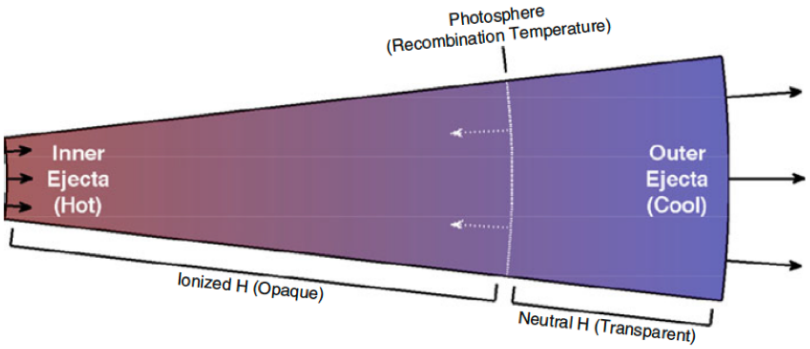
Figure 5: A schematic of the ratio of an alpha abundance to Iron as a function of Iron abundance in three different stellar populations

5. For this analysis, assume that core collapse SNe produce significant amounts of alpha elements and that low-mass binary systems produce a significant amount of iron peak elements.
   (a) What are the alpha elements? How are they produced?
   (b) What are the iron peak elements? How are they produced?
   (c) Based on given information, would you expect iron peak elements to be produced earlier or later in a stellar population's lifetime? Why?
   (d) Would you expect alpha-element/iron ratios to be higher or lower for stars formed earlier in a stellar population's lifetime? Why?
   (e) The turnover in the relation shown above reveals information about the star formation and enrichment rate. Of the three shown above, which population has the highest initial star formation? Why?
   (f) Some of the stellar populations above correspond to galactic structures. Which population contains stars found in the Milky Way bulge? Which population would likely contain stars found in Dwarf galaxies?

Question 6: Estimating the IIP Plateau



(a) R-band light curves of Type IIP SNe



(b) Recombination front

Figure 6: Observations and diagrams of Type IIP SNe

6. In the wake of a Type IIP SNe, the cooling of the ejecta forms a temperature gradient. The location inside the envelope where recombination equals the recombination temperature of hydrogen is called the recombination front. At this point in the SN, assume radiation is the sole contributor to observed luminosities.

   (a) What causes the ionized hydrogen inside the recombination front to be opaque?

   (b) How does the radius of the recombination front change as the envelope expands?

   (c) What is the approximate luminosity, in solar luminosities, of SN 2005cs's plateau?

   (d) If the recombination temperature of hydrogen is 3,000K, what is the radius of the recombination front, in solar radii?

Question 7: Einstein's playground

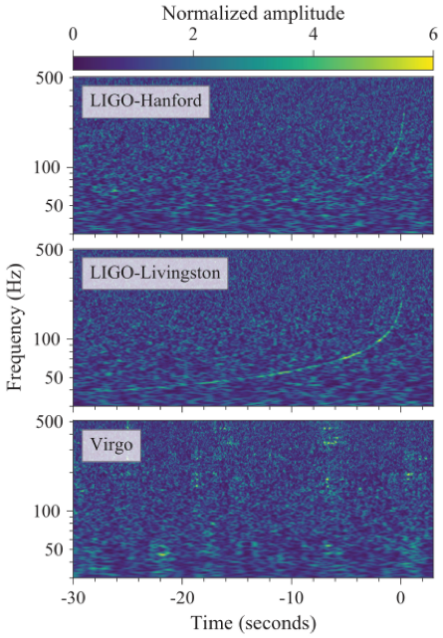


Figure 7: Confirmation of Einstein's theory

7. On August 17, 2017, LIGO detected a neutron star merger.

   (a) What was the name of the gravitational wave component of this event? In what constellation did it originate?

   (b) What type of event is thought to have accompanied this event in the electromagnetic spectrum?

   (c) A drop in X-ray emission since the event suggests that this event produced what type of compact object?

   (d) General relativity: How will the frequency of light from the edge of the event horizon change as it escapes the potential well? What is this phenomenon known as?

   (e) Special relativity: Will time measured near the event horizon be faster or slower than proper time on a distant clock? What is this phenomenon known as?

Question 8: Do you really know Parallax?

8. A nearby RR Lyrae is observed from Earth to have a recessional velocity of 10 km/s. Four months later, the star is found to have traveled an angular displacement of 0.4 arcseconds across the sky. Twelve months after the initial observation, the star's angular displacement is 0.2 arcseconds. Assume the displacements lie along the same line.

   (a) Do we have to consider the dynamical local standard of rest (LSR)? What is the term for the sun's velocity relative to this?

   (b) Determine the velocity of this star, in km/s.

   (c) Determine the component of the star's velocity in the direction of the change of the Earth's position over the first four months, in km/s.

   (d) Determine the parallax angle after four months, in arcseconds.

   (e) Determine the distance to this star, in pc.

   (f) What is the apparent magnitude of this object?

   (g) What is the nearest super massive black hole to this star?

Answer Sheet A: Questions 1-4

1. (a) _____
   (b) _____
   (c) _____
   (d) _____
   (e) _____
   (f) _____
   _____
2. (a) _____
   (b) _____
   (c) _____
   (d) _____
3. (a) _____
   (b) _____
   _____
   (c) _____
   _____
   (d) _____
4. (a) _____
   (b) _____
   (c) _____
   (d) _____

Answer Sheet B: Questions 5-8

5. (a)
   (b)
   (c)
   (d)
   (e)
   (f)
6. (a)
   (b)
   (c)
   (d)
7. (a)
   (b)
   (c)
   (d)
   (e)
8. (a)
   (b)
   (c)
   (d)
   (e)
   (f)
   (g)