Team name: KEY Team number: KEY

Answer Page: Section A (1 point each)

1. (a) 1
   (b) Third instance of binary system with massive star and compact object in supernova aftermath
2. (a) S Doradus
   (b) One of the brightest
3. (a) Luminous Blue Variables/S Doradus Variables
   (b) AG Carinae, Image 4
   (c) Wolf-Rayet Star
4. 14, 4, 10, 5
5. (a) Sharpless 171
   (b) It will be very difficult for stars to form within the nebula as the gas will be too thinly dispersed and unable to collapse.
6. (a) Jellyfish Nebula, Sharpless 248
   (b) The motion of the central neutron star is shown via a wake of material
   (c) The motion of the neutron star is not aligned with the direction of the remnant's center
   (d) The supernova was offset from the center of expansion of the gas or fast-moving nebular gas has influenced the path of the material wake.
7. (a) C
   (b) C
   (c) I
   (d) I
   (e) K
8. (a) Image 5
   (b) This is usually only possible in a black hole x-ray binary, not one containing a neutron star like Circinus X-1
9. (a) Image 12
   (b) Speckle Interferometry
10. (a) Left is Geminga, right is PSR B0355+054
    (b) Energetic emissions from the magnetic poles
    (c) Geminga is being viewed along its "equator" so the jets point perpendicular to our line of sight, while in PSR B0355+54 they are aimed at the Earth

11. Image 2

12. Eddington Limit, may be exceeding due to a funneling of infalling material along the pulsar's magnetic field lines

13. (a) SN 1987A
    (b) Neutron star

14. (a) Radio-quiet pulsar
    (b) Unlike other pulsars, it's not visible in the standard radio spectrum.
    (c) Pulsar radio emission usually occurs at magnetic poles, and Geminga's magnetic field is not oriented along Earth's line of sight

15. 11, 14, 8, 13, 6

16. (a) ASASSN-15lh
    (b) It is lacking in hydrogen and helium
    (c) Wolf-Rayet Star

17. Image 15

18. (a) Image 13
    (b) Uneven ejection of materials at the poles compared to the equator of the dying star, concentrated in jets of material

Team name: KEY Team number: KEY

Answer Page: Section B (1 point each)

19. (a) Temperature
    (b) Kelvin
    (c) Luminosity and absolute magnitude
    (d) Logarithmic
    (e) G
    (f) B, E
    (g) C
    (h) A
    (i) J
    (j) I

20. (a) Cepheid
    (b) Neutron Star
    (c) Hubble's law
    (d) Eclipsing binary
    (e) HII region
    (f) Gravitational waves/radiation
    (g) Type Ic supernova
    (h) Iron (Fe)
    (i) Semiregular variable
    (j) Magnetar

21. (a) Neutron Stars
    (b) Direction to Earth
    (c) Macronova
    (d) Afterglow
    (e) R-process

Team name: KEY Team number: KEY

Answer Page: Section C (2 points each)

22. (a) O
    (b) 6.1 (5.5 - 6.7) Solar Radii
    (c) 0.12 (0.07 - 0.17) g/cm^3
    (d) -6.9 (-6 - -8)
    (e) 2.4 (2 - 3) kpc
    (f) 0.42 (0.3 - 0.5) milli-arcseconds
    (g) It has a convective interior and radiative envelope

23. (a) 457 (400 - 500) km/s
    (b) 6.5 (6 - 7) Mpc
    (c) 121.7 (121.6 - 121.8) nm
    (d) 4.3 (4 - 4.5) Gpc
    (e) 14 (13.5 - 14.5) Gyr

24. (a) 0.41 (0.35 - 0.45) Years
    (b) 5
    (c) 0.83 (0.8 - 0.85) AU
    (d) 60.5 (50 - 70) km/s
    (e) 1.5 $\times 10^{46}$ (1-2 $\times 10^{46}$) kg m^2/s