a) i) An eclipsing binary is detected by its luminosity / time graph. This shows a large dipping decrease in luminosity when the brighter star moves behind the less luminous star, and a smaller decrease when the less luminous star moves behind the brighter star.

ii) The total mass of a binary star system can be calculated by observing the systems radius (r) and period (T) and then applying the formula:

$$m_1 + m_2 = \frac{4\pi^2 r^3}{G T^2}$$

where $m_1 + m_2$ is the total mass and G is the universal gravitational constant.

The radius and period of orbit are determined in a number of ways depending on the way the binary is detected, either astrometrically (a wobble is observed in a star indicating another non-visible

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star), spectroscopically (Doppler effect shows stars moving towards and away periodically), visually (stars can be resolved by telescope) and eclipsing as shown in (i).

b) i) Proxima Centauri

ii) $$\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$$

$$\frac{I_R}{I_P} = 100^{(11.01 - 10.37)/5}$$

$$= 100^{0.128}$$

$$= 1.803017741$$

∴ Ross 154 is 1.8 (1dp) times brighter than Proxima Centauri.

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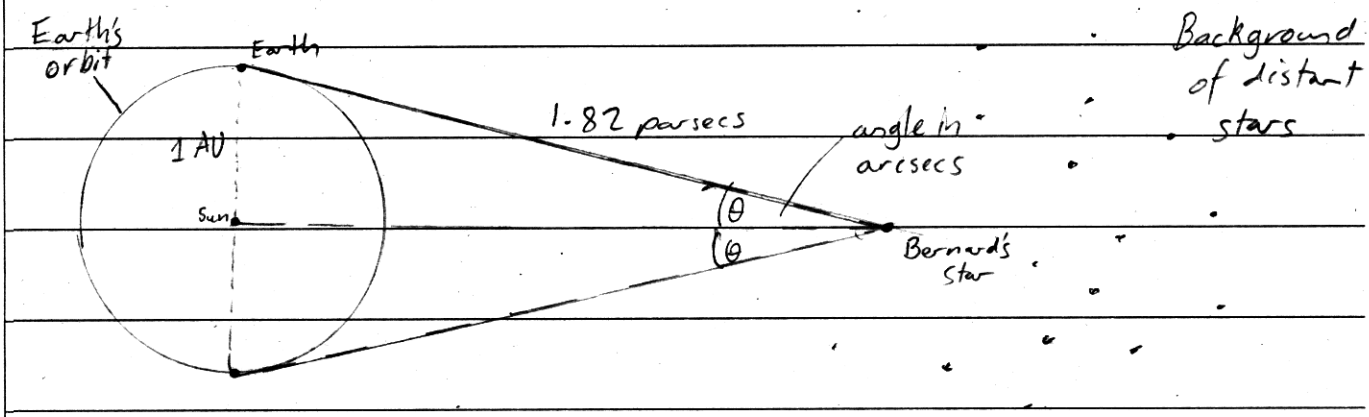
iii)



$p = \frac{1}{d}$

$= \frac{1}{1.82}$

$= 0.549450549$

$= 0.55$ arcsecs

Astronomers would measure the position of Bernard's star against it's background when at opposite sides of Earth's orbit. The parallax angle would then be used to calculate the distance, in parsecs to Bernards star. The parallax angle in this case would be 0.55 arcseconds (2 dp).

c) i) White dwarfs would be at position S. This is because they are small, hot white coloured stars that are not very luminous. Position S best shows these factors.

ii) A white dwarf is the extremely dense remnant of a larger stars core. The gravitational pull inwards is equalised by the pressure outwards due to its density enabling a white dwarf to remain stable.

iii) The proton-proton (p-p) chain reaction takes place in less massive and cooler main sequence stars. It involves four hydrogen atoms combining by fusion to create a helium nucleus. This is done by the following reactions:

$$^{1}_{1}H + {}^{1}_{1}H = {}^{2}_{1}H + e^{+}$$

$$^{1}_{1}H + {}^{2}_{1}H = {}^{3}_{2}He$$

$$^{3}_{2}H + {}^{3}_{2}H = {}^{4}_{2}He + 2\,{}^{1}_{1}H$$

PTO

The fusion reactions release energy as this occurs, in the form of electromagnetic waves.

$^{2}_{1}H$ = heavy hydrogen

$^{3}_{2}He$ = light helium

e^{+} = positron

d) Adaptive optics is a fast system to compensate for the atmospheric effects on light coming from celestial objects. As light passes through the atmosphere it diffracts causing images to be distorted slightly reducing resolution of a telescope. By using adaptive optics, light is sampled 1000 times each second with a wavefront sensor and a controlling computer causes mechanical alterations to be made to the mirror in order to counteract the atmospheric effects on the light. By using this system resolution can be improved significantly allowing ground based astronomy to be much more

accurate than previously.

The Resolution of a telescope is also affected by abberations, or imperfections, in the mirror itself. Though these can be reduced they can not be eliminated. Active optics is a system which allows the ~~mirror shape to be changed~~ distortion which results from abberations to be counteracted. This is done by a slower system than adaptive optics and used in large new optic telescopes in order to improve resolution.

The sensitivity of a telescope is affected by the surface area of the ~~lens~~ objective mirror or lens. ~~to very large~~ This means that very large telescopes are much more useful for ~~ground~~ astronomy. To achieve large mirror diameter ~~on~~ the cost is large, increasing at a rate proportional to the mirrors diameter. Developments in mirror manufacture and design have allowed cheaper, large diameter mirrors

to be made. ~~Technologies now for designs that~~ Recent designs include very thin mirrors with honeycomb composite backing to support the thin structure, rotating mercury mirrors and rotating the molten glass as it sets in order to create concave shape therefore reducing costs. These recent developments have allowed the sensitivity and resolution of individual telescopes to be increased.

By making improvements in the design of ground based telescopes, resolution and sensitivity can be improved by counteracting distortion factors and reducing costs of large mirrors. This enables increased accuracy of ~~and the continued relevance of~~ ground based astronomy, ensuring astronomers can gain the best information possible about the celestial objects studied.