UNIVERSITY COLLEGE LONDON

University Of London Observatory PHAS1510 – Certificate in Astronomy, 0910.01

PHAS1510-07: Palomar Sky Survey Prints

Name:________________________________

An experienced student should aim to complete this practical in 2 (and not more than 3) sessions.

1 Introduction

The 48-inch Schmidt telescope on Mount Palomar was designed with a large field of view so that the whole sky visible from Palomar could be surveyed in a reasonable time (some 10 years), to substantial 'depth' (i.e., to include relatively faint objects). The photographs were made on glass plates, from which contact prints were made.

We shall be studying several of these prints. Each is a 35-cm square contact print of the quality needed to do astronomical research. Please be extremely careful when handling these prints; hold them by the edges only and do not touch the photographic surface. When working with them, keep them in their transparent jackets and *do not write on paper that lies over the prints.*

Palomar prints come in pairs. For each region of the sky, one print is made from a blue-sensitive photographic plate, the other from a red-sensitive plate. In the upper left hand corner of each print is a small box containing important information; for example,

E-754 June 13/14 1955
$20^{h}33^{m}30^{s}$ $+42^{\circ}19'44''$

The single letter E or O denotes the sensitivity of the plate (red or blue, respectively; this nomenclature follows the designations used by Kodak for the relevant photographic emulsions); the following number is the sequential plate number (which is the same for the E and O plate of each pair). Then follows the date the plates were obtained, and finally, the right ascension and declination (1950.0) of the centre of the plate.

Each print covers 6° by 6° on the sky. The plate scale of 1.12 arcminutes per millimetre corresponds to roughly half a degree (the diameter of the Moon) per inch. Note that these prints are negatives; stars show up black, and the brighter the star, the larger is the image on the print.

Note: The following questions and suggestions are, to some extent, merely a guide to help you look at the Palomar prints and get a feeling for the immense richness of information in them. Spend part of your time looking for other features on the prints in preparation for Q. 10.

The Observatory has a complete set of Palomar prints, and film copies of the complementary ESO and Anglo-Australian Schmidt surveys of the Southern sky. Students are welcome to examine under proper supervision.

2 A Milky Way Field in Cygnus

The print pairs O/E-1099 and O/E-754 cover two adjacent regions in the Milky Way. You will see that there is an overlap of about 2.5 cm. The very bright star at the top of the 754 print and the bottom of the 1099 print is α Cyg (Deneb), an A2 supergiant that is the brightest star in Cygnus; it is also one of the most intrinsically luminous stars in our Galaxy ($M_V = -6.9$).

Work through the following sections, examining the prints and answering the first 9 questions in the spaces provided. Write complete answers to the questions, including your reasoning and, if relevant, sketches or additional notes from reference material. *When sketching, always include a scale and orientation, and label your diagram clearly.*

In answering the questions, use a coördinate system such that positions are defined in terms of their distances in millimetres parallel to the bottom and side of the prints, with the *inside* bottom left-hand corner of the black border as the origin; *e.g.*, Deneb has (x, y) coördinates (110, 325) on O/E-754, and (50,0) on O/E-1099). You can measure these coördinates with an ordinary ruler, or use the special overlay grids if you find this more convenient. (N.B. Indicate in your answer exactly how you have orientated the picture and where you have set the origin of the grid when taking your measurements. This is very important and helps the marker.)

2.1 Stars

Q. 1 Give the coördinates of (*i*) a red star (i.e., one that is brighter on the red sensitive print than on the blue one) and (*ii*) a blue star on O/E-1099. (Choose stars that are bright enough to be unambiguously identified by the markers; there are good examples of both red and blue stars in the central region of the prints. Note that most stars appear brighter on the O print, simply because blue-sensitive emulsions tend to be more sensitive than red-sensitive emulsions; your identification of a red star should take this average offset into account.)

(*i*)

(*ii*)

2.2 H II regions

H II regions (regions where the hydrogen gas is completely ionized) show up as black areas on the red-sensitive (E) prints. In these regions the atoms are ionized by far-ultraviolet radiation from nearby very hot blue stars, often occuring in clusters of stars. The free electrons often pass sufficiently close to a proton (hydrogen atom nucleus) to get captured by the proton. The electron will make one or more jumps between permitted orbits (energy levels), emitting photons; i.e., line radiation will be emitted. The strongest line emitted in the optical part of the spectrum is the Hα line, at a wavelength of 6563Å(656.3 nm), which lies in the red; hence H II regions show up most strongly on the red-sensitive prints. Some of the H II regions can also be recognised on the blue-sensitive prints, because of emission in the blue from fainter lines of hydrogen and from lines of elements such as oxygen.

H II regions surround hot, young stars. Therefore, these regions must themselves be quite young. They are expanding slowly, because they are heated by their ionizing stars (so that the pressure inside the H II region is greater than the pressure outside). As the gas density decreases consequently with time, their surface brightness (*i.e.*, their darkness on the negative prints) also decreases.

Q. 2 Identify (i.e., give the coördinates of) a couple of prominent H II regions on each of the two sets of prints . By considering their surface brightness, which would you judge to be the youngest H II region?

2.3 Filaments

Filaments appear as wispy streaks across the prints. They are prominent on E-1099, and are again very red due to the Hα emission line. However, usually there are no blue stars near enough to photo-ionize them. What, then, could cause the ionization? One suggestion is that the gas in the filaments is colliding at high speed with other interstellar gas that is cold and thus not visible on the prints; it is the energy of the collisions which ionizes the atoms. Another suggestion is that the gas was ionized by a burst of radiation from a supernova. The gas has not had time to cool down and is still shining, though the supernova faded long ago. Behind the dust clouds that form the Milky Way rift on print 754 (see below) there is a radio and an X-ray source, an indication that a supernova may indeed have occurred there.

Q. 3 Overlay prints E-1099 and E-754, using Deneb (α Cyg) to align the overlapping sections. The filaments on these prints appear to be slightly rounded; this may be because they have been formed by the blast wave from a supernova travelling outwards radially from its source. Make a *rough* estimate of the apparent centre from which the filaments appear to have been blasted or heated (give a sketch if convenient, or use negative coördinates if necessary) – a precise answer is impossible.

2.4 Reflection nebulae

Dust reddens the starlight passing through it by scattering the blue light in all directions. (The same phenomenon occurs in the Earth's atmosphere, explaining why the daytime sky is blue and sunsets are red.) If the dust is close to a star then we will see the blue *reflected* light as a blue nebulous region surrounding the star. The star in this case cannot be *very* hot, otherwise it would form an H II region instead.

Q. 4 Would you expect the reflection nebulae to show up best on the O or E prints? Find some reflection nebulae on O/E-754 and write down their coördinates. (This is quite difficult because of the dominance of H II regions. Hint: try looking mid-way up the print, towards the right.)

2.5 Planetary nebulae

At the end of their lives, stars like the Sun first become red supergiants, then eject their outer layers, forming a slowly expanding shell of gas surrounding a very hot blue star: a planetary nebula (PN). (Some examples of PN images are given in reference 4, pages 141–146.) The central star has plenty of far-ultraviolet photons to ionize the gas, producing emission lines much like those from an H II region. Once again, the Hα emission line is strong in the red, but (mainly) oxygen emission lines produce only a *very* faint blue image.

Q. 5 Give the coördinates of the planetary nebula on E-1099 (it is practically invisible on O-1099). *Hint*: this particular planetary nebula is only a couple of mm in diameter, but has a well defined circular edge – quite different to the H II regions – and is quite easy to recognize once found. It was, in fact, discovered by examining this photograph.

Sketch the PN after inspection under the magnifier.

2.6 Interstellar dust clouds

Interstellar dust clouds are found in many directions, mainly along and near the Milky Way. Print 754 shows part of the "rift" in the Milky Way in Cygnus. Stars in front of the dust cloud are unaffected by it, while stars behind the dust cloud are obscured (and reddened). Some clouds are so thick and dense that virtually no starlight can penetrate; all the stars seen in the direction of such a cloud are foreground objects.

Q. 6 Identify two or three dust regions on the E-754 print. Two examples are given for guidance; remember that the prints are negatives, so that dark areas on the prints are bright and vice versa; thus dust lanes are *whiter* areas on the prints. *Hint:* when a dust lane lies in front of an extended bright object, such as an H II region, it can be identified and its structure seen more easily.

(30,100) (260,40)

Q. 7 Of the two dust clouds at (30,100) and (260,40), which is the nearer? How do you judge this? Explain your reasoning fully.

Q. 8 In which direction is there more nearby dust: in the "rift" running down the centre of E-754, or in the upper half of E-1099? How do you know this?

2.7 Globules

Sometimes the very dense absorbing dust clouds are clearly separated from anything else, and may well have very sharp edges. They show up very distinctly against H II regions, with which they are often associated, as small dark (i.e., white!) shapes on the red prints. Occasionally these small dust clouds have rounded shapes and have angular sizes which are comparable to the stellar images on the plate. We call these small, dense dust clouds 'globules'.

Q. 9 Locate the smallest globule you can find. Record its position and sketch it after inspection under a magnifier. Given that individual prints sometimes have defects of similar size to the globules, how can you check that the patch you picked is not a print defect?

[If you have access to a WWW browser, you might be interested in examining what globules in some H II regions (*e.g.*, M16) look like at high spatial resolution, as observed with the *Hubble Space Telescope*; see ref. 3 below.]

2.8 Other features

Q. 10 The preceding questions cover much of what is *astrophysically* interesting in the prints. Identify and briefly comment on any other features of interest. (Look at ref. 1 for background material on some of the defects which may be apparent on the prints.)

References

1. Notes to the Palomar Observatory Sky Atlas, California Institute of Technology, 1954.

2. Freedman, R.A. & Kaufmann, W.J., *Universe,* 7th edition; various sections in Chapter 20, particularly 20–2, 20–8.

3. WWW addresses (URLs):
   Space Tel. Science Institute: `http://oposite.stsci.edu/pubinfo/nebulae.html`
   See also: UK HST Support Facility: `http://www.ast.cam.ac.uk/HST/`

4. Murdin, P., Allen D.A. & Malin, D., "Catalogue of the Universe" (Cambridge University Press)