Report on the differences in exposure quality from the UKST Hα survey - The case for completion to A grade.

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Abstract

The Hα survey of the southern galactic plane currently underway by the UK Schmidt Telescope (UKST) produces films whose quality depends not only on the fine grained emulsion and telescope optics but also on the seeing at the time of observation. Bad seeing can create poorer resolution and decrease the magnitude of the dimmest images in the resulting exposure. Survey exposures are carefully examined by eye and are subjectively given a grade: A; B or C depending on their quality, according to a precise set of grading guidelines. These subjective gradings require a quantitative description to highlight the loss of scientific data that would be incurred should the project be completed only to B grade. The aim is to create as homogeneous a survey as possible, ideally completed to A grade.

1 Introduction.

The aim of this project was to create a quantitive assessment, explaining the difference in depth and resolution between 'A' and 'B' grade exposures from the UKST Hα survey. The fields used in this project to provide the data for analysis were Hα survey fields 527 and 678, fields which were given subjective gradings in A and B. The details of these subjective gradings and field locations are shown in table 1. Hα survey fields are 6 degrees across, this report shall analyse only the centre of each field with a diameter of 0.76 degrees. Table 1 suggests that the A grade exposure in 678 is of better quality than 527 and its B grade exposure is of worse quality than the 527 counterpart. One of the aims of this project is to see how accurate these subjective gradings are. The difference in quality between A and B grades can be witnessed through many different forms of analysis as will be shown in this report. However a simple visual inspection of these fields leaves one in no doubt as to the quality gap between an A and a B grade exposure. Figures 1 and 2 depict sub images of A and B grade exposures for fields 527 and 678 respectively. These figures are 256 pixel (172 arcseconds) square images and the difference between them is clear to see. The quotient image (A divided by B) is also included to highlight the differences between the two grades. Notice in the quotient images the black signals, corresponding to the positions of dim stars; these imply that the A grade exposure receives a stronger signal than the B grade for these stars. It is notable that for the larger stars, these black signals are replaced by a grey signal with a white halo. The grey indicates a complete cancellation between the images and the white halo corresponds to the spreading out of the light on a B grade exposure. The complete cancellation in larger images gives an indication that pixel saturation is achieved for these objects. This is an issue which will be addressed subsequently in this report.

2 Resolution

The resolution of a telescope describes its ability to separate adjacent objects - it is a measure of the fine detail and structure that may be seen. The potential to see this fine detail can be destroyed

Field	Subjective Grading	RA of field centre (1950) (HMS)	Declination of field centre (1950)(deg)	Exposure number
527	A2/A1	08 00 00	-36	Hα18745
527	BI3	08 00 00	-36	Hα17850
678	A0	08 06 00	-28	Hα18749
678	BIE4	08 06 00	-28	Hα17935

Table 1: Table to show details of the fields used in this report.

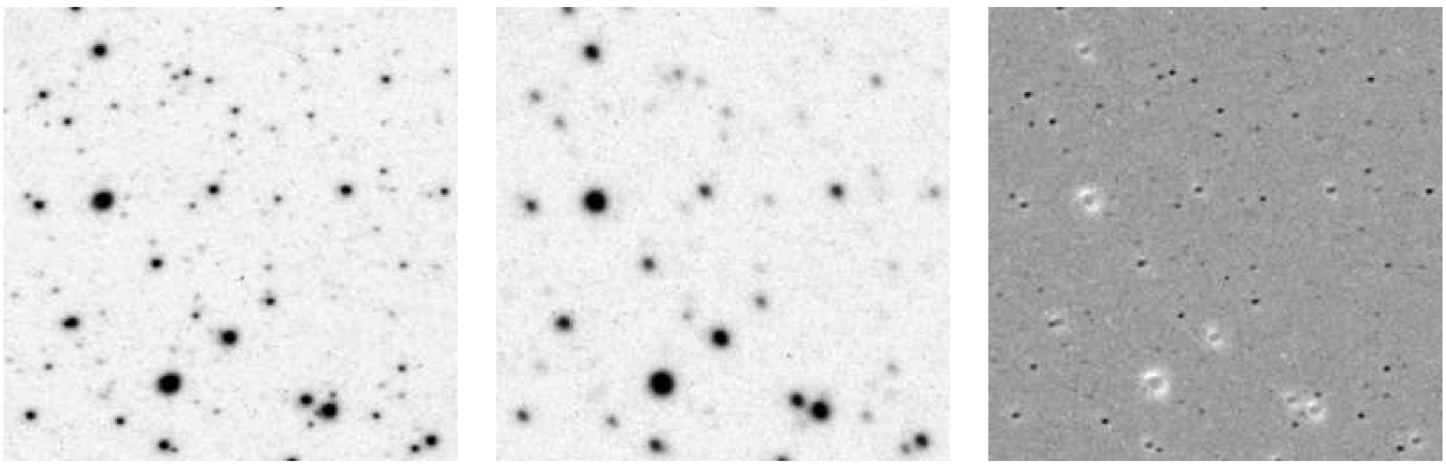

Figure 1: 256x256 images for 527; A is left, B is middle, the quotient image (A/B) is on the right. In the quotient image, black represents a positive signal for A over B, white indicates the opposite.

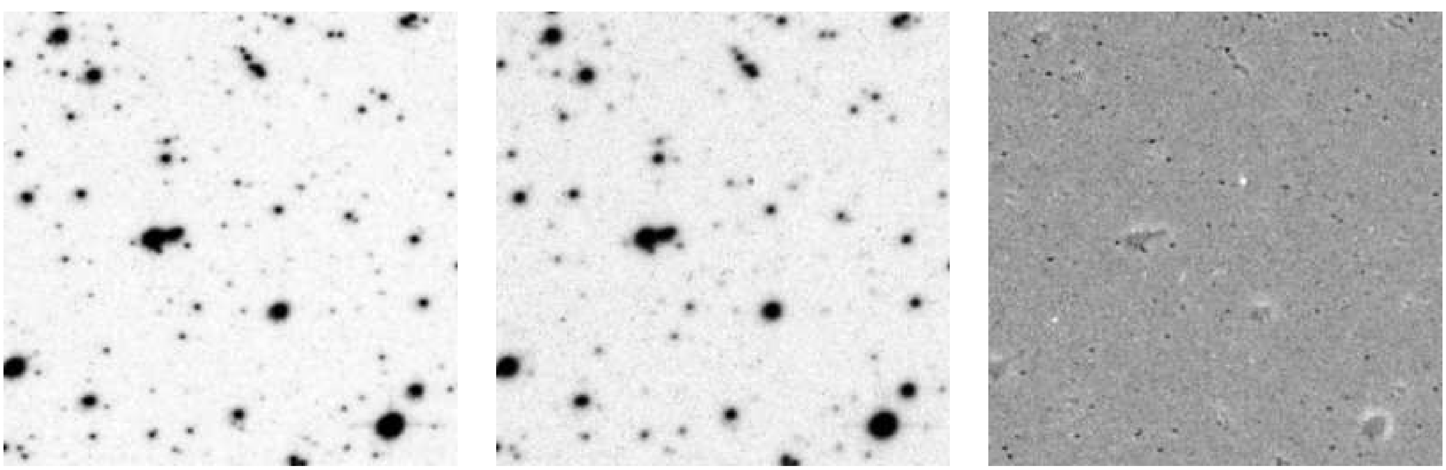

Figure 2: 256x256 images for 0678; A is left, B is middle, the quotient (A/B) is on the right.

by poor seeing in the atmosphere. Detail is essential for new astronomy and one would wish to maximise it. A study into the differences in resolution was conducted to show why the A grade images of figures 1 and 2 are superior.

2.1 Merged Objects

Seeing in the atmosphere causes images recorded by UKST exposures to become blurred and spread out as can be seen in the B grades of figures 1 and 2. Occasionally two objects which are close together in an A grade exposure will appear merged together as one object in a B grade because of this effect. An example of this effect is shown in figure 3.

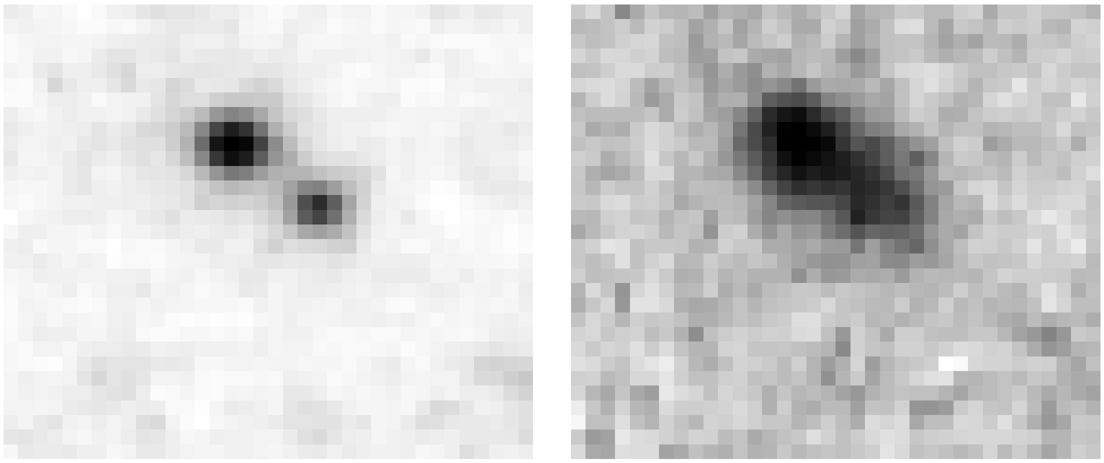

Figure 3: 64x64 images for field 527; A is left, B is right. They show two objects distinct on the A grade but merged together in the B.

An investigation was carried out to find the maximum angular separation objects on an A grade could have for the objects to be merged on a B grade exposure. Clearly, this separation would be different for each field and so the study was performed independently for each one. The application PISA[1] was used to find objects in a chosen region. An investigation was undertaken to find which threshold and minimum number of pixels should be used to ensure that: All objects were detected and no spurious noise peaks were confused to be objects. Spurious noise peaks were taken to be objects whose area cut was below the minimum number of pixels inputted to PISA. The origin of these noise spikes is likely to be due to small dust particles settling on the emulsion or else other small scale physical errors in the emulsion such as tiny scratches.

It was found that a threshold of 95 (intensity units above the background) and a minimum number of 8 pixels best suited both of the 527 fields and the A grade of the 678 field. For the remaining B grade (678 field) a threshold of 120 and a minimum of 9 pixels were used to safely detect all images with no mistakes. With all images detected the package CURSA[2] was invoked to read in PISA returned data as a catalogue. By visually examining the images, object pairs with a small angular separation on an A grade were noted. The same area was then compared with the B grade to see if the two images had merged or remained distinct. Tables 2 and 3 show just a few of the object separations found on the A grade which either resulted in a merged B image or two distinct objects remaining. The separation is measured in pixels, where 1 pixel = 0.6714 arcseconds, between the image centres. These values are tabulated against the R equivalent magnitudes of the stars involved. A description of how these magnitudes are calculated is given in section 3 of this report.

In both examples if two objects are separated by $\geq$ 13 pixels then the separated images in A will remain distinct in B with reasonable confidence. Since this method of finding the gap takes the

[1] "Position Intensity and Shape Analysis" by Starlink
[2] "Catalogue and Table Manipulation Applications" by Starlink

distance as being from image centre to centre it is clear that for large, merged, objects this gap will be comparatively large despite the fact that the separation of image edges may be similar to that of smaller objects. This is part of the reason that two objects can be distinct in a B grade with a smaller separation than it takes for two other objects to be merged.

Field	Some A grade separations found for objects still to be distinct in B (pixels)	A grade magnitude of first star(R equivalent)	A grade magnitude of second star(R equivalent)
527	6.641	17.168	16.321
527	6.714	16.615	16.381
527	7.515	16.364	15.753
527	8.134	15.937	15.172
527	12.192	15.418	13.513
527	12.490	16.015	14.498
678	7.205	17.646	16.151
678	7.310	18.422	18.135
678	8.157	18.685	16.987
678	8.310	17.067	16.601
678	10.943	15.259	14.622
678	16.062	14.386	13.282

Table 2: Table to show examples of the degree of separation required in an A grade exposure for the objects to be found still distinct in a B grade.

It is clear from tables 2 and 3 that the angular separation required for objects to merge in a B grade depends upon the R equivalent magnitude of the objects. In a field of only 0.76 degrees it is difficult to find a large number of objects which are distinct in A but merged in B, it would be desirable to find a larger selection of such objects and plot initial separation against magnitude. With such a graph it would be possible to estimate whether two objects, in a certain field, would be split in a B grade or not - based on their R equivalent magnitudes. Tables 2 and 3 do suggest, however, that star pairs in the 527 field pair more easily in a B grade than they do in the 678 field. However, this is a small sample and additional work will be required to provide a fuller understanding.

2.2 Area Cuts and Light Distribution.

From a simple examination of figures 1 and 2 it is clear that the light distribution of the stars is different in an A grade than in a B grade. An investigation was performed and the area of stars was compared for common objects in A and B grades over a range of magnitudes. Plots of image area against image area for the same stars in A and B grades are shown in figure 4.

The plots of figure 4 are quite different, it is clear that the difference between A and B grades is more extreme in the 527 field where intense objects are quickly blurred out and occupy a larger area on the film. Figure 4 shows that for both fields, the A grade exposure provides a far more reliable visual representation of stars.

Field	Some A grade gaps for objects found to be merged in B (pixels)	A grade magnitude of first star(R equivalent)	A grade magnitude of second star(R equivalent)
527	3.238	18.752	18.470
527	5.799	17.176	16.232
527	6.970	16.918	16.385
527	7.188	16.524	15.717
527	7.700	19.211	17.091
527	9.266	14.983	14.863
527	10.450	15.429	13.513
527	10.922	14.594	13.013
678	6.570	18.892	16.021
678	7.472	18.129	15.616
678	7.740	18.114	14.332
678	7.742	18.178	14.243
678	12.668	18.077	13.431

Table 3: Table to show examples of some of the degrees of separation found on an A grade where the equivalent images on a B grade are merged into one.

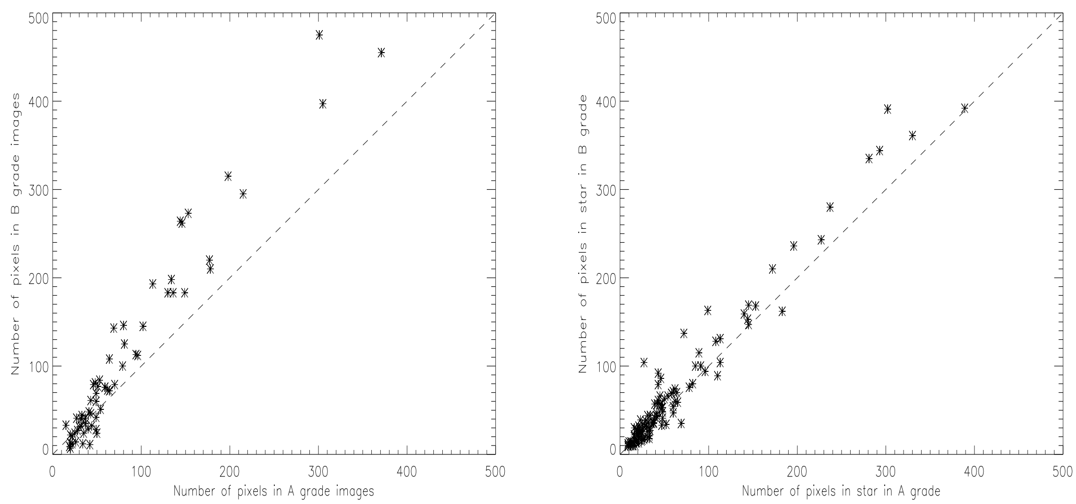

Figure 4: Graphs to show how area (pixels) changes in A and B as objects become larger and more intense. Field 527 is on the left and 678 is on the right.

2.3 Elliptical Objects

Both of the fields used in this project come from within the galactic plane, hence the vast majority of images seen on them are stars. However, elliptical objects are observed on the A grade exposures due to two objects which have not been properly resolved; in the same way as was seen in the B grade exposures in the previous section. Were these objects outwith the galactic plane then small elliptical objects like these could well be galaxies. Therefore, if these objects can be observed in the A grade as elliptical but not in the B grade then the B grade exposures would be far less well equipped to detect faint galaxies if it were so required. An investigation was carried out into this effect and the results are shown in table 4.

Field	Grade (A/B)	Object size (pixels)	Ellipticity	Angle (deg)
527	A	134	0.363	91.9
527	B	182	0.160	67.4
527	A	50	0.445	161.4
527	B	54	0.105	69.3
527	A	164	0.509	79.4
527	B	270	0.237	104.9
527	A	172	0.358	115.8
527	B	158	0.220	25.2
678	A	118	0.289	72.4
678	B	128	0.265	89.0
678	A	797	0.353	123.4
678	B	850	0.306	123.3
678	A	272	0.276	89.1
678	B	286	0.225	87.9
678	A	390	0.307	86.3
678	B	463	0.267	83.8
678	A	86	0.327	59.6
678	B	93	0.218	63.4

Table 4: Table to show ellipticities of objects detected in A grade compared to those in B grade.

As one would expect, the change in the shape of the object is most extreme for smaller objects. A visual example of this effect is provided of the first row of table 4. This can be seen in figure 5.

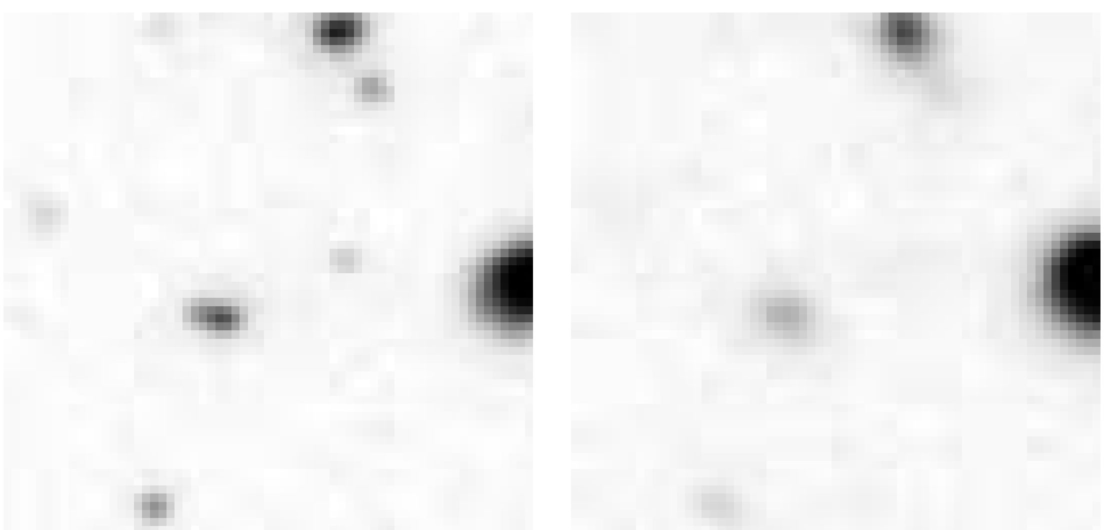

Figure 5: 64x64 images for field 527; A is left, B is right. Notice the elliptical object to the left of middle of the A image, seen to be far more circular in the B equivalent.

3 Depth

The most important difference between the A and the B grades, in terms of how much new astronomy can be done, is the difference in magnitude of the dimmest visible objects. The main aim of this project was to find the depth of each of the four images and the resulting differences between them.

A simple way to demonstrate the difference in depth between A and B grades is to run PISA on both of them and compare the number of objects found in a given area. Table 5 shows the fraction of objects found in an A grade which are also found in a B grade.

Field	Percentage of objects detected in A grade also detected by B grade
527	78.6
678	85.5

Table 5: Table to show the percentage of objects which are detected in an A grade exposure which are also detected by B.

Less objects are detected in a B grade exposure to a small degree due to objects merging but mostly because A grade exposures are capable of resolving dimmer objects. Table 5 is another example indicating that the quality difference between A and B grades of the 527 field is more extreme than that of the 678 field.

It does not make sense to consider the magnitude of objects in terms of their Hα emission, so instead we consider the "R equivalent" magnitude of an object. By pairing up the original Hα data with SUPERCOSMOS Survey data, available online, it is possible to discover objects' equivalent magnitudes in the Red part of the spectrum. To do this a logarithmic magnitude for the stars in the Hα data had to be created so that objects could be plotted against those in SUPERCOSMOS and a curve fitted relating one to the other.

PISA returns a value of intensity for each star, dependent on the background level of light. Clearly the same star should have the same magnitude regardless of whether it is in an A grade or a B grade. However, PISA will return a different intensity for the same star in an A grade as in a B grade. For bright stars the centre of the image may become saturated on the A grade, whereas on the B grade where the light is spread out this will be a less significant effect. In this type of situation one would expect PISA to return the bright stars from the B grade exposure with a higher intensity. Also for very dim stars, when the light is spread out in the B grade the light may be so dim that it is below PISA's threshold for detecting an image. In this kind of situation one would expect PISA to return stars in the A grade with a higher intensity. Figure 4 in section 2.2 demonstrates something of these effects. To sort this problem out a study of isolated, non-saturated, medium bright stars was carried out to find a conversion factor between all 4 fields so that the value for intensity meant the same thing throughout. Equation (1) was then applied to the stars from the Hα data to create a 'pseudo' magnitude.

The conversion factors applied to the intensities returned from PISA are shown in table 6.

$$magnitude = -2.5 * log(correctedintensity) + 28 \quad (1)$$

Field	Grade (A/B)	Conversion Factor Applied to Intensity
527	A	1.020
527	B	1.795
678	A	1.000
678	B	1.119

Table 6: Table to show the conversion factors used to correct the intensity returned by PISA.

Where 28 is a nominal constant added on to make the pseudo magnitude roughly equal to what one would expect (around 20 at the weakest).

An area of SUPERCOSMOS data was then downloaded from the SSS online[3] data for each of the two fields. The data from SUPERCOSMOS was then manually paired with the Hα data and the previously created pseudo magnitudes were compared to the R equivalent magnitudes for the same objects. These were plotted against one another and a least squares fit was done to provide a fitted polynomial to the data. This was done for each field and the results are shown in figure 8.

A subimage of the data extracted from SUPERCOSMOS online is shown in figures 6 and 7 plotted with the equivalent area of the Hα data in A and B grade for each field. Note that although the SSS images show the dim objects from the Hα survey more clearly, the resolution is not as good as it is in an Hα survey A grade.

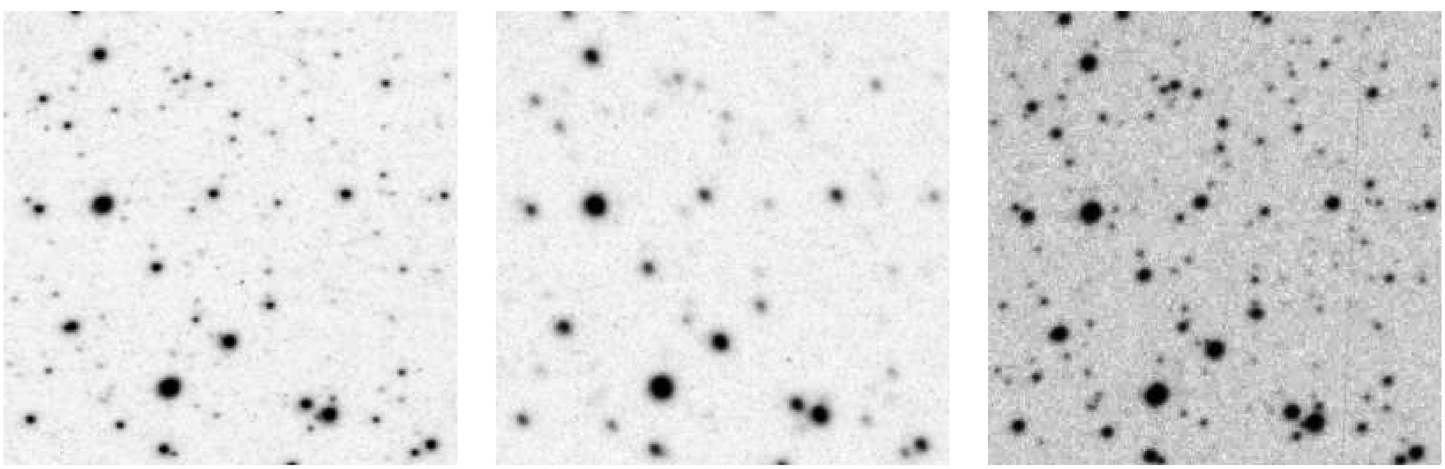

Figure 6: 256x256 images for 527; A is left, B is middle, the SSS image is on the right for the same area.

With these data it was then possible to ascribe to the stars, in the original Hα fields, an R equivalent magnitude. Stars were paired up in a 256x256 pixel area and the R equivalent magnitudes were plotted against one another for the same stars in A and B grade. The results are shown depicted for both fields in figure 9.

Although These plots do not tell us explicitly the depth of view they are however interesting. The graphs highlight very nicely the relative differences of A and B between the two fields.

It can be observed that for the field 527 ,the trend of the curve created by the stars slips away from the 1:1 ratio dotted line far quicker than it does for the field 678. This difference is due to

[3]from the website http://www-wfau.roe.ac.uk/sss/

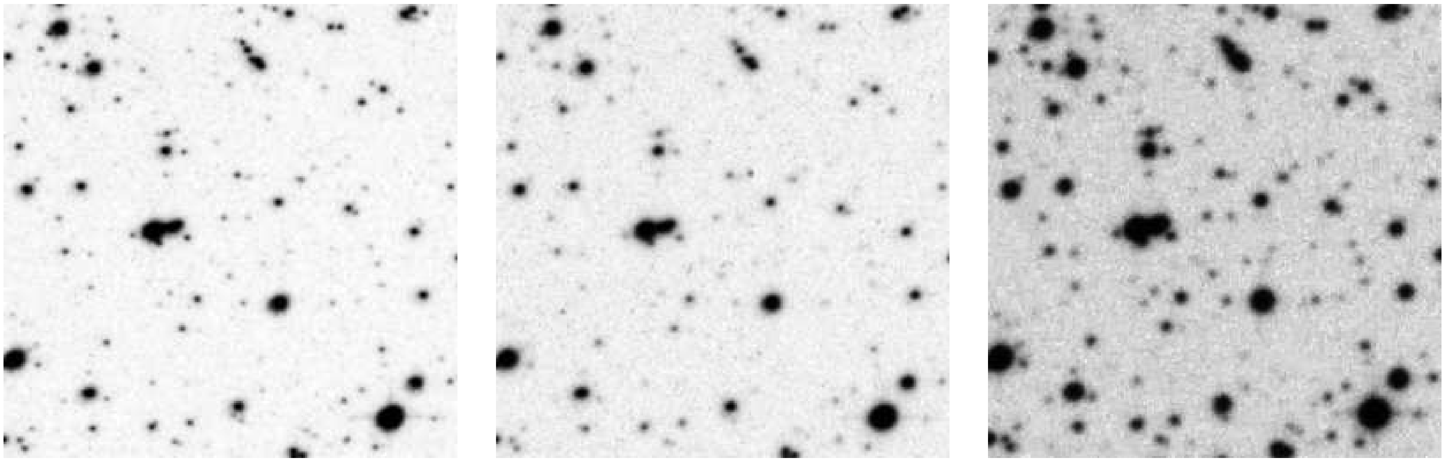

Figure 7: 256x256 images for 678; A is left, B is middle, the SSS image is on the right for the same area.

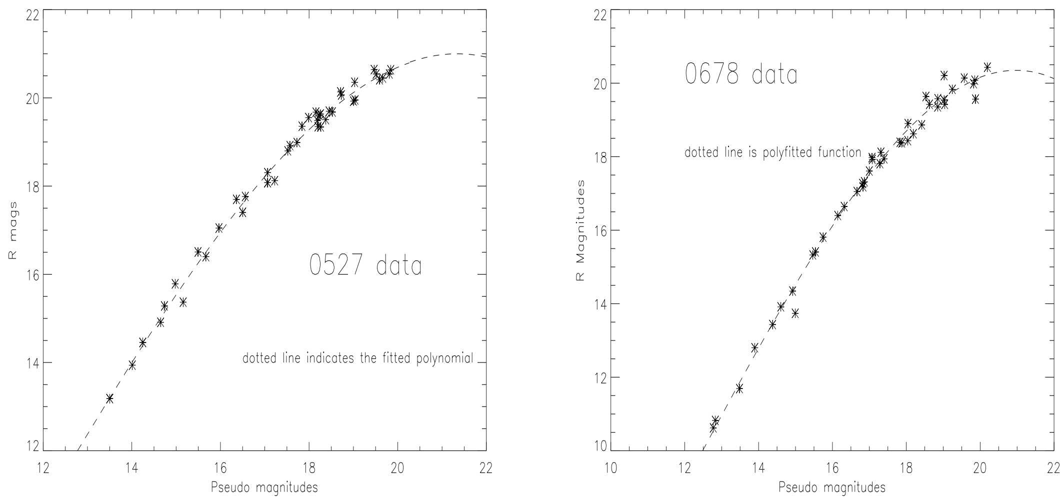

Figure 8: R equivalent magnitude versus pseudo magnitude for the Hα data and a polynomial fitted function to relate the two.

saturation, as was discussed before. It appears that for the 527 field the A grade exposure gets saturated at a far greater rate than its B equivalent; producing a curve which draws quickly away from the 1:1 ratio line with decreasing magnitude (increasing intensity). For the 678 field the A and B grades appear to be closer together, since the drop away from the 1:1 ratio line is much less; clearly the stars are becoming saturated at roughly the same rate in A and B. These suggests that the difference in quality is greater between the A and B grades of the 527 field than for the 678 fields, in direct contradiction to the subjective gradings originally ascribed to them. It is however, important to note that the original gradings were based on the entire field rather than the 0.76 degree subsection used in this report. There may be discrepancies in quality over the rest of the field which can account for the original gradings.

To find the difference in depth of view between A and B grade fields the application CURSA was again used, this time to plot the number of objects in different magnitude bins. A larger field of 1024 square pixels was used and the number of objects found per 0.05 R equivalent magnitude

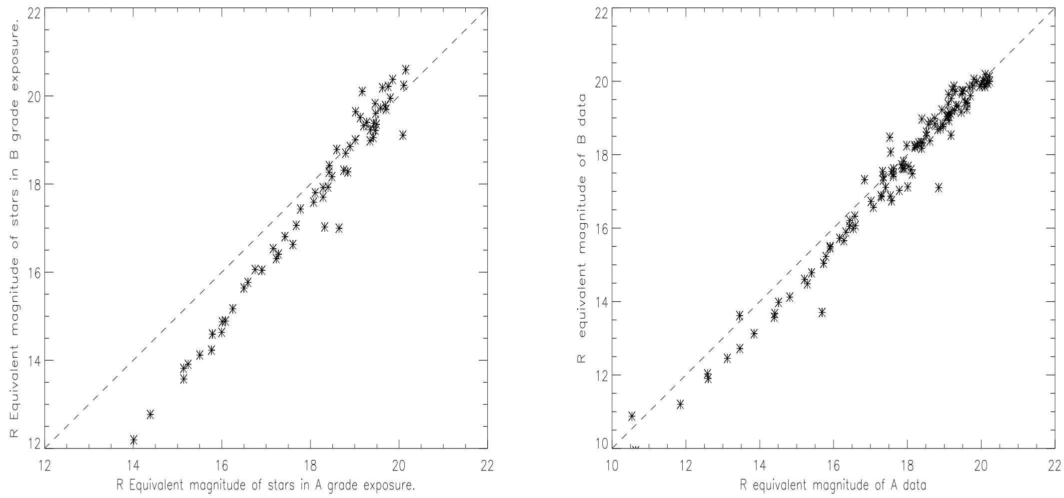

Figure 9: Graph to show the R equivalent magnitude of the same stars on A and B grade exposures, for the field 527 on the left and 678 on the right.

interval was plotted as a histogram. One would expect there to be an increasing number of objects at higher magnitudes and a sharp peak above which few objects were found, this peak would be the limit of magnitude. Plots were made for all four images and these are included in the appendix.

The R equivalent magnitude corresponding to the peak of each histogram was found by zooming in on the area of interest and the results are shown in table 7. Since this is a histogram the peak was taken to be the middle of the histogram bin, therefore there is an inherent error of 0.025 magnitudes in these results.

Field	Grade (A/B)	Peak of Histogram (R equiv. magnitude)
527	A2/A1	20.77 ± 0.025
527	BI3	20.42 ± 0.025
678	A0	20.62 ± 0.025
678	BIE4	20.42 ± 0.025

Table 7: The depth of each of the four original images measured in R equivalent magnitudes.

From table 7 it is clear that both B grade exposures have close to the same limit in terms of depth but the A grades do not. The A grade in the 527 field has the capability of resolving stars an extra 0.15 magnitudes fainter than the 678 field equivalent. Table 8 shows explicitly the difference in depth between the A and B grade exposures in both fields.

Field	Difference in depth between A and B(R equiv. magnitude)
0527	0.35 ± 0.05
0678	0.20 ± 0.05

Table 8: Differences in depth between A and B grades in both fields.

4 Summary.

The principal differences found between A and B grade exposures in the Hα survey are as follows.

• Two distinct A grade objects will become merged on a B grade if their angular split is small considering their R equivalent magnitudes.

• There is a significant loss of information on the structure of small, elliptical objects in a comparison between A and B.

• The subjective gradings ascribed to exposures in the Hα survey can be inconsistent on a small scale.

• An A grade exposure sees around 0.3 (R equivalent) magnitudes deeper than its B grade counterpart.

These differences are clearly not the same for each of the two fields I examined, and the differences will vary for every field in the survey. The data provided is an estimate based only on the two fields in the report but the results can be extended with reasonable confidence to the entire Hα survey.

5 Conclusion.

The difference in quality between A and B grade exposures in the Hα survey is very clear from a simple visual analysis. In this report the variations in resolution and maximum magnitudes that create these clear visual disparities have been found. The loss of scientific data that would be incurred were the project to be completed only to B grade is very apparent. This report recommends that the project be fully completed to A grade.