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ERNAZIONALE
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ISAS - INTERNATIONAL SCHOOL FOR ADVANCED STUDIES

THESIS FOR THE ATTAINMENT OF
"MAGISTER PHILOSOPHIAE"

DETECTION OF TIME VARIABILITY FROM SYNTHETIC IMAGES

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Academic Year: 1984/85

TRIESTE

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1] INTRODUCTION

1.1] Astrophysical importance of variable object detection and study in the M8, M20 nebular region.

Variable object detection from 2-D photographic plates is one of the important tasks for having information about stellar and extended source time variability and which supports, as an example in the first case, star formation and stellar evolution, in the other case astrophysics of active galactic nuclei and quasars.

The region under study contains two emission nebulae, known as Lagoon Nebula (M8,[1950] =18 01.6, = -24 20), Trifid Nebula (M20,[1950] =17 58.9, =-23 02), two open clusters namely NGC 6530 ([1950] =18 01.6, =-22 35) embedded in M8, NGC 6531 ([1950] =18 01.8, =-24 20) and a large amount of field stars.

Variable stars study in this region goes back to the 1950's. F.W. Walker (1) made the first three colour photometric observations of the NGC 6530, to V=16 magnitudes, which indicates that the colour- magnitude diagram, like that of the NGC 2264, consists of a main sequence extending from O5 to about A0 below which the stars lie above the main sequence. Like NGC 2264, it has been found that a large number of faint T Tauri stars occur in the cluster. The presence of the T Tauri stars and the agreement of the colour-magnitude diagram and the luminosity function with those of NGC 2264 indicate that these two objects are very similiar in composition and added weight to the interpretation of the colour-magnitude diagrams of both clusters as indicating that the clusters are so young that the fainter stars are still in the process of gravitational contraction.

His observations shown that variable stars are concentrated within the outline of the complex of bright stars and nebulosities in the vicinity of NGC 6530. This concentration shows that these stars are definetively members of the group. The presence and distribution of variable stars in NGC 6530 imply (i) that the physical membership of the cluster extends to extremely faint stars and (ii) that the physical limits of the cluster extend far beyond the obvious concentration of stars to which the designation NGC 6530 usually refers. According to his determinations, 41 % of the variables show H-alfa emission. For the stars in the Orion nebula cluster it is found 47 %, and for NGC 2264 36 %, which suggests that the variable and H-alfa emission stars are similiar in nature.

In the same year G. H. Haro (2) made a stellar study of the same region including emission nebula S188. He gave lists and descriptions of the H-alfa emission stars found in and around the emission nebulae M8, M20, and S188. Except for the Be stars associated with the nebulae and the background emission line objects, the stars found in this survey are believed to be T Tauri-like stars in the nebulae. He noted that direct photographs give the strong impression that M8 , the fainter nebula involved in S188 and probably M20 as well, are all associated with the same obscuring matter and thus are all at the same distance. This impression seems to be supported by the photometric and spectroscopic data available.

Another variable star study had been done by G. C.

Kilambi (3), in 1972 with photographic UBV observations of the galactic cluster NGC 6530. In his work a star is considered variable if it shows changes bigger than or equal to 0.1 magnitudes in each bandpass. Tables and a list of variables found in NGC 6530 and in the field around the cluster, was given. He had reported that most of the variables have amplitudes between 0.2 and 0.3 magnitudes in all three bandpasses. Altogether 109 stars were found to be variables in his analysis on each plate, out of which 53 stars are actual members of NGC 6530. Again it is interesting that nearly 20 % of the stars which were considered constant at the time of Walker's photometry turn out to be variable. For NGC 6530 33 % of all stars in and around the cluster region for which photometry exists at present turn out to be variable. But due to the lack of sufficient observational material, no variable has been established as a periodic one. It is likely that the percentage of variables will increase once we recognize low amplitude variables. His conclusion was, that 75 % of the cluster members for which B-V = 0.7 magn. are variables. This high percentage could be due to shell activity or some other mechanism prominent during pre main sequence evolution.

1.2] <u>Definition of the problem in order to detect variable objects.</u>

Whenever a picture is converted from one form to another, e.g. copied, scanned, transmitted, or displayed, the quality of the output picture may be lower than the input. Many enhancement techniques are designed to compensate for the effects of a specific (known or estimated) degradation processes. This approach is generally known as image restoration and makes an extensive use of filtering theory.

The standard image processing functions are followings:

1)Display,

2)Rototranslation,

3)Scaling,

4)Histogram manipulation,

5)Arithmetics,

6)Filtering for enhancement.

The images under study were secured on photographic plates with the 61 cm. Schmidt telescope of Catania observatory. Because of the optical characteristics of the Schmidt camera system, after a defined angular radius from the telescope axis pixels are distorted.

Another well known problem is photometric(intensity) registration of the plates which are taken in different observational conditions. This is unavoidable because of the instrumental and observational variations such as emulsion on the plates, reflectivity of the mirrors , variation of the zenith angle etc.

Then the problem can be defined as follows: For searching the time variability of a set of pixels of the same region (or regions) recorded on the plates we must transport the mentioned pixels to a common reference system by rototranslation and scaling (geometric registration) and lastly by a photometric registration of them, to get a homogeneous data set named data cube. In other words it is necessary to eliminate all the effects which cause variability but the real physical variability between two set of pixels.

1.3]A procedure for testing automated geometric and photometric registration of the images.

In this work a procedure for the simulation of the best algorithm is searched for the automated detection of time variability of point-like sources, from photographic-like synthetic images in available software environments.

Procedure for testing the geometric registration algorithms is involving these main lines:

i)Generation of a stellar field.

ii)Geometric operation on the coordinates of the image, in order to get a geometrically distorted image, such as in the case of Schmidt plates.

iii)Geometric registration of the second image onto the third one with the defined linear transformation coefficients.

iv)Testing the difference between first(template) and the third(registered) image.

v)Then repeating these steps with different signal to noise ratios with available software. A scheme describing the geometric registration tests is given in Fig.1(a,b,c)

For the photometric(intensity) registration following steps are carried out:

i)Generation of a stellar field.

ii)Generation of another stellar field with the same coordinates of stars but different background and intensity values. Assumed relation for one selected intensity value on the stellar profile is given with the below formula.

$$I(2)=I(1)*Constant1+Constant2 \qquad (1)$$

iii)Next step is finding these constants from generated two images by means of standard stars and stationary background. And rescale intensity values to generate the third image.

iv)With these new values generate photometrically registered image.

v)Lastly test the difference between first(template) and third(registered) image.

vi)Then repeat the same steps with different signal to noise ratios. A scheme describing the photometric registration test is given in Figure 1.2.

As seen from the schemes, nearly all types of image processing functions are used in order to make homogeneous the data and eliminate the variability arising from geometric and photometric characteristics of the images.

2]SOFTWARE USED FOR THE SIMULATION OF GEOMETRIC AND PHOTOMETRIC REGISTRATION TESTS.

2.1]Synthetic image generation.

In idp/OAT [ASTRONET] software environment synthetic images are generated by Program IMAGE. It's documentation is given below:

Program IMAGE

Method: The Program IMAGE generates a stellar field (up to 10 star profiles) with Gaussian stellar profiles and stationary background. This program is a modified version of Programs SINTHIM [PATRAS] written by Dr. P. Santin (4) for more general purposes.

Synthetic image is stored in a two dimensional array. Program prompts for Noise generation, so it is possible to generate standard normal noise.

Parameters:

File name: For generation of a standard ASTRONET image, a name for the image frame up to 10 characters. (Character)

Image dimension: Dimension of the image frame, up to 512 pixels. Program uses square images. (Integer)

Noise generation: Prompt for generation of standard normal noise. (Character)

Number of the objects: Number of the two dimensional gaussian stellar profiles to be generated. (integer)

Center coordinates(X,Y): Center coordinates of the two dimensional gaussian profiles in pixel units. (Real)

Sigma(X,Y): Sigma value for defining the gaussian profiles in X and Y directions. (Real)Approximately SIGMA=2.345*FWHM.

Peak intensity:Amplitude for the gaussian profile,at the center coordinates of the profile.(Real)

Noise sigma:If noise is needed sigma value of the standard normal distribution of the noise.(Real)

Seed:A large odd number for random number generator.(Integer)

Two dimensional output standard image is generated with a message.

Notes:i)The formula for generating two dimensional gaussian profiles are given below.

S(i,j)=BCG+AMP * EXP(-(Y-YO)**2/(2.* SIGMA(Y)**2))
*EXP(-(X-XO)**2/(2.* SIGMA(X)**2)) ....(2)

In this formula i,j are the integer coordinates of the image up to image dimension,BCG is the Background value,AMP is the peak intensity of the profile in center coordinates at XO and YO.

ii)Standard image generation is performed by means of FILECREATE procedure of ASTRONET software environment(5).Image is stored and moved from the disk with %VAL procedure of DEC VAX.

iii)Noise generation is performed with the use of random number generator ,which has a Box distribution between values 0 and 1.This flat distribution is changed to normal standard distribution by the use of Central-Limit Theorem; by superimposing 12 samples of mentioned Box distribution.Fig(2.1) shows the effect of superimposing samples of Box distribution.Table(2.1) gives the calculated values for standard normal noise generation.

In order to run programs in STARLINK environment with the images which are generated in ASTRONET environment a conversion program STARCONV [PATRAS] is used. This program is just a image-format conversion program with ASTRONET to STARLINK environment. Also with the same program, conversion from STARLINK to ASTRONET environment can be done. Program prompts:

Type of conversion, Input file name, Image type(Real or Integer image), Complete image or a defined portion of the image to be converted, Output file name for the converted environment and lastly a Normalization factor.

This procedure of geometric and photometric registration tests couldn't be carried out in Munich Image and Data Analysis(MIDAS) environment, although this environment is present, because of the lack of a image conversion program. But MIDAS environment will be available for the real images.

2.2] Display of the images in ASTRONET and STARLINK environments.

For the display purposes of the images in ASTRONET environment program ISOLEVEL [PATRAS] is used. This program scans the whole image by taking a box of four pixels and connecting them with a vector. The points in the sides of this box are that have the input level. Program computes the values within the pixels by linear interpolation. At the end of the program after the desired levels are loaded hardcopy on the one of the available printing machines is also available.

In STARLINK environment programs used for display purposes and their short description is given below.

These routines either display images on the ARGS or modify an existing display. Note that they act upon the ARGS assigned to ARGSDEVICE.

Program ADISP

Function: It displays an image on the ARGS at a specified center after suitable scaling.

Use: This is the major routine used to look at data. Note the use of the LOG parameter and remember that by choosing suitable values for PVLO and PVHI a negative display is generated.

User Parameters:

IMAGE: The 2-d Starlink image to be displayed. It may be of any size, but no more than 512*512 pixels will be visible.

XC/256/: The x co-ordinate on the ARGS where the CENTER of the image will be located.

YC/256/: The y co-ordinate on the ARGS where the CENTER of the image will be located.

PVLO/Min. value/: Data with this value are scaled to zero.

PVHI/Max. value/: Data with this value are scaled to 255, which is the largest value to be displayed by the ARGS.

Normally Defaulted Parameters:

TRIM/TRUE/: If TRUE, values outside the range PVLO to PVHI are set to those values. If FALSE then PVLO and PVHI are ignored and the values reduced to 16 bits. This may cause them to wrap around on the ARGS.

LOG/FALSE/: If TRUE then logarithmic scaling is used between the defined limits, otherwise linear scaling is use.

Program APAN

Function: ARGS Trackerball/Cursor PAN AND ZOOM general package.

Execution continues until button 4 is pressed. Button 3 increases the X and Y zoom factors, button 2 decreases the X and Y zoom factors, button 1 resets the zoom factors and image position. Zoom factors allowed are 1, 2, 4, 8, 16

RETURNED: IX, IY position of cursor on image.

Programs LUTREAD, LUTCOL, LUTROT

These routines all prepare or load look-up-tables into the ARGS. Each is a 3x256 Starlink .BDF file, and is loaded into the ARGS assigned to ARGSDEVICE.

i)LUTREAD

Function: This program sends a colour look up table to the ARGS.

Parameters:

LUT/FRAME(R)/: Colour look up table

LIMITS/VALUE/0,255: Range in ARGS lookup table onto which LUT is to be mapped.

LOG/VALUE/FALSE: TRUE if a log scale is to be used.

The lasttwo are connection file defaulted.

ii)DSCL Procedure LUTCOL

Function: Reads standard coloured lookup table using ASPIC program LUTREAD The second and third parameters to LUTREAD may be given as the first and second to this procedure. See documentation to LUTREAD

iii) LUTROT

Function: Rotate entries 1-255 in the LUT by means of the Tracker Ball. Press button 1 to reset LUT, press button 4 to exit. The table offset is returned to DSCL.

Parameters:

KTABLE/FRAME(R)

OFFSET/VALUE

NOARGS/ERROR/ARGS IS ASSIGNED TO ANOTHER USER

Program WRHIST

Function: It computes, lists and stores the histogram of a frame.

Use: It may used to give a quick listing of a histogram (with a low value of NUMBIN) or to store a histogram away to be plotted by HISTPLOT.

Parameters:

INPUT: The input Starlink frame of any dimension.

HMIN: Minimum. The data value corresponding to the first bin of the histogram.

HMAX: Maximum. The data value corresponding to the last bin of the histogram.

NUMBIN: HMAX-HMIN+1. The number of bins in the histogram. Note that if QUIET=false (default) all of these bins will be typed on the terminal.

HGRAM: If present this is the name of a 1-D frame to store the histogram. It is also the name of a descriptor in the INPUT frame, to which it is also written.

Normally Defaulted Parameters:

QUIET/F: By default the histogram is listed on the terminal. If TRUE no such listing is produced, which is desirable if the histogram contains many bins.

Error messages: BADINP/ERROR/BAD INPUT FRAME

Program HISTPLOT

Function: It produces a 1-D plot from a Starlink image using descriptor items HMIN and HMAX, if present, to convert the array subscript into physical units.

Use: It was written to plot meaningful histograms from the file created by WRHIST (qv).

Parameters:

INPUT: This is the Starlink image used for input. It should be 1-D.

DEVICE: This is the graphics device to be used. It may be any GKS device as specified in SGP 26.

YRANGE: (Min., Max)This defines the vertical limits for plotting.

XRANGE: (Min., Max.)This allows selection of part of the horizontal range to be plotted.

AXES: (Lin,Lin)This allows definition of or logarithmic axes in both X (first) and Y. Note that logs and zeros do not go well together!

SIZE: This is the size of the plot, but is only used if the the selected device does not have a cursor.

2.3]Operation on the images

In order to get a geometrically distorted image Program OPERATOR is used.

Method: This program simply rotates, translates and/or scales the given coordinates of the objects on the plate; with respect to the axis center according to the below formula.

X(new)=M[(X-XO)cosO+(Y-YO)sinO]

Y(new)=M[-(X-XO)sinO+(Y-YO)cosO] ....(3)

This three operation can be done either one by one or altogether. Then program calculates the linear trnsformation coefficients which are given with the formula (4a).

X'=C(1)+C(2)*XO+C(3)*YO

Y′=C(4)+C(5)*XO+C(6)*YO ....(4a)

where C(1)=[(-X*C(2))-(Y*C(3)],C(2)=M*cosO,C(3)=M*sinO and C(4)=[(-X*C(5))-(Y*C(6))],C(5)=-M*sinO,lastly C(6)=M*cosO.

These linear transformation coefficients are tested in the STARLINK environment with the use of programs XYKEY,XYLIST,XYFIT. Their documentation is given below:

Program XYKEY

Function: To enter X,Y positions and their corresponding character identifiers into a file from the keyboard.

Method: The program prompts for successive entries of X,Y positions and identifiers which are entered into the output file. A 'null' entry terminates the input. Identifiers may be defaulted and are then replaced by a number sequence.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

ILEVEL(2): An integer from 1 to 3 to control the printing of informational messages. If ILEVEL is 2 or more, informational messages are printed. If ILEVEL is 1, printing is supressed.

INPUT(null): An optional input file containing an existing X,Y list. If this file is supplied, any further entries made via this program will be added to the input list as though the input list had previously been entered during the same run of the program. If it is not supplied, the program will commence with a completely empty list of X,Y positions.

MAXENTRY(See Description): An integer specifying the maximum number of entries which may be made in the output file (counting the number of different identifiers as the number of entries). If no INPUT list is given, this parameter defaults to 100, but may take values from 1 to 1000000. If an INPUT list is supplied, it defaults to 100 more than the number of entries in the input list, but may be set to any value from 1 more than the number of input entries to 1000000.

XYPOSN: The program uses this parameter to prompt repeatedly for input entries for the X,Y list. The user should enter a character string giving the X and Y positions followed by an optional identifier of up to 20 characters. If the identifier is omitted, the program generates one in the form ' N' , where N is a count of the number of times the identifier has been defaulted. N may be reset at any time by entering a position with an identifier in the form ' NN' , where NN is the new value for N; subsequent entries with the identifier omitted will increment N by 1 each time.

If the number of different identifiers entered reaches the value specified in MAXENTRY, the program ceases to prompt for new input values and generates an output list.

If an identifier is given which corresponds to one already entered, the new X,Y position will replace the old position in the list.

OUTPUT: An output file for the output X,Y list.

TITLE: A title (up to 30 characters) for the output list. The run time default is blank, unless an INPUT file was given, in which case it is the title of the input X,Y list.

Errors: The program may access the following error parameter(s) to indicate error conditions:

NOLIST: ***OUTPUT LIST HAS NO ENTRIES

No entries were given at the keyboard and no input file was given ,so there are no entries in the output list. No output dataset is created.

WHAT: ***NOT UNDERSTOOD

A value for the parameter XYPOSN could not be translanted into a valid list entry, you will be prompted to enter the value again.

Program XYLIST

Function: To list a file of X,Y positions, identifiers and possibly magnitudes.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

INPUT

Program XYFIT

Function: To obtain a linear position transformation which relates one set of X,Y positions to another with minimum mean square error. The type of transformation may be specified and aberrant points may be rejected.

The program is intended for general use in aligning images using a set of reference positions. It will adjust automatically to varying numbers and positioning of reference positions as well as to the presence of erroneous positions.

Method: The two input lists of positions 'A' and 'B' are compared to match positions with the same identifiers. A linear transformation is then computed which maps the 'A' positions on to the corresponding 'B' positions with least squared error. The type of transformation may vary from a shift of origin to a complete 6 parameter transformation involving shift, rotation, stretch and shear; the user may specify which is required.

Having obtained a transformation, the the standard deviation of the transformed 'A' positions from the corresponding 'B' positions is found (the RMS alignment error) and the most mis-aligned point is also identified. This point is rejected if it deviates by more than NSIGMA standard deviations and the transformation is re-evaluated. This iteration is repeated up to MXREJECT times, or until no further points are rejected.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

ILEVEL(2): An integer from 1 to 3 to control the printing of results.

1: Printing is supressed.

2: Details of the fit obtained are printed.

3: A table of the positions and alignment errors is also printed, identfying those positions which have been rejected.

INPUTA: The input list 'A' of X,Y positions.

INPUTB: The input list 'B' of X,Y positions.

FITTYPE(4): An integer from 1 to 4 specifying the type of linear transformation required:

1: A shift of origin only.

2: A shift of origin and a rotation.

3: A shift, rotation and magnification.

4: A full 6 parameter transformation: shift, rotation stretch and shear.

NSIGMA(1.0E10):A real value specifying the number of standard deviations at which aberrant points are rejected. The connection file default is such as to cause all points to be accepted.

MXREJECT(See Description):An integer not less than zero giving the number of rejection iterations required. This value thus sets an upper limit to the number of points which may be rejected. The connection file default is a value sufficiently large that all points may be rejected if they lie outside the NSIGMA threshold.

TRCOEFFS:An output parameter which contains the 6 coefficients of the linear transformation obtained, C(I),I=1,6. These transform the 'A' positions (XA,YA) according to:

XA'=C(1)+C(2)*XA+C(3)*YA

YA'=C(4)+C(5)*XA+C(6)*YA ....(4b)

so as to align with the 'B' positions.

Notes:If at any time the number or positioning of the data points becomes such that the required form of the transformation cannot be obtained, the value of FITTYPE is repeatedly reduced by 1 until it is possible to obtain a transformation. Unless printing is supressed, a message is printed indicating the type of transformation actually calculated.

Errors:The program may access the following error parameter(s) to indicate error conditions:

NOMATCH:***NO MATCHES FOUND BETWEEN THE INPUT LISTS.

No match could be found between any of the identifiers in the lists 'A' and 'B'. There are thus no data points to define the transformation.

Timing: Approximately proportional to the number of data points used and the number of rejection iterations performed.

2.4] Geometric registration programs.

For the geometric registration of the geometrically distorted images in ASTRONET environment Program REGISTER is used.

Program REGISTER

Method: This program computes the new intensity values of the output picture with the use of transformation coefficients. First reads the template image, then computes the REAL coordinates of the transformed image with transformation coefficients. Then with a predefined approximating method finds the corresponding pixel numbers in the template image and assigns each output pixel to this value of template image. Since a transformation is applied some pixels may stay outside the image frame program decides for the valid pixels by their numbers. For example if the output pixel number is grater than or equal to one and less than or equal to image dimension is a criterion for deciding if the output pixel is valid or not.

This program uses four different approximating methods in order to decide the corresponding pixel center of the template image:

Nearest pixel: Transformed pixel coordinates are generally a real number. In this mode simply, the nearest pixel center or nearest integer value of the input pixel assumed to be the output. So this value is assigned to the

output pixel.

Bilinear interpolation: This mode scans the input picture with a box of four neighbour pixels. And computes the output value of the pixel with linear interpolation in both X and Y directions, then the average value of these two interpolations is assigned to the output pixel.

2nd degree Polinomial interpolation: In this mode scanning of the input picture is done with 9 neighbour pixels. And output pixel value is calculated with the 2nd degree Lagrangian interpolation in both X and Y directions, lastly by avareging them.

3rd degree Polinomial interpolation: This mode is similiar to the previous one but scanning of the input picture is done with 16 pixels. And 3rd degree Lagrangian interpolation is used.

This program will be modified with bicubic Spline interpolation mode.

Parameters:

Input file name: Template picture which will be scanned through a selected mode.

Image Dimension: Dimension of the input image, square image.

Output file name: Output name for the registered image.

Transformation coefficients: Linear transformation coefficients defining the transformation.

Mode selection: An integer 1 to 4 for the selection of the aproximation which will be used.

Output: Geometrically registered image with a message.

For testing the methodologies used for geometric registration in STARLINK environment Program RESAMPLE is used.

Program RESAMPLE

Function: To resample an image so as to move the features to different locations within the image matrix. The program is intended for achieving alignment of features between images.

Method: The input image is resampled at a set of points defined by a linear transformation acting on the positions of the pixels of the output image. The transformation is given by a set of coefficients C(I),I=1,6. If X,Y are the coordinates of a pixel in the output image, the pixel is assigned the value of the input image at the location:

X'=C(1)+C(2)*X+C(3)*Y

Y'=C(4)+C(5)*X+C(6)*Y

Since this is not usually an integer (i.e. pixel centre) position, interpolation is necessary within the input image. This may use the nearest-neighbour, linear interpolation between the 4 nearest pixels, or a 'uniform interpolation' method.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

INPUT: The input image.

TRCOEFFS: The set of 6 coefficients C(I) giving the linear transformation to be used.

METHOD(LINEAR): One of the following, specifying the method to be used in resampling the input image:

i)NEAREST - use the nearest neighbouring pixel.

ii)LINEAR - use a linear interpolation between the 4 nearest pixels.

iii)UNIFORM - use the 'uniform interpolation' method, which uses a variably weighted mean of the nearest 9 pixels. (See notes section for details.) Abbreviations are acceptable.

CONSERVE(FALSE):A logical parameter which controls the automatic rescaling of the output image to conserve the total data sum. If CONSERVE=FALSE, the output image values are the interpolated values from the input image. If CONSERVE=TRUE, the output image is rescaled (via the descriptor items BSCALE and BZERO) by dividing by the area reduction factor which the resampling transformation introduces between the input and output images. In this way, the total data sum within a resampled image feature is unchanged.

NPIXOUT(See Description):The number of pixels per line in the output image. The default is the number of pixels per line in the input image.

NLINEOUT(See Description):The number of lines in the output image. The default is the number of lines in the input image.

OUTPUT:The output image.

TITLE:A title (30 characters) for the output image. The run time default is the title of the input image.

Notes:- The criterion used to determine whether an output pixel is valid or not is whether the corresponding position in the input image is valid. If it is not, i.e. it lies outside the input image or within an invalid input pixel, the output pixel is invalid. Otherwise an output value is calculated.

- Note that in going from the input to the output, image features undergo a position transformation given by the inverse of that given in TRCOEFFS.

- The METHOD=NEAREST option is the most rapid method and may be used to extract sections from images, reduce their size, etc., where it is not necessary to interpolate between pixels.

- The METHOD=LINEAR option is a general purpose method of interpolation when it is necessary to evaluate the input image between pixel centres.

- Using a simple linear interpolation method introduces a degree of smoothing or resolution degradation and adjacent output pixels are no longer independent. With the LINEAR option, this effect depends on the resampling phase (i.e. the distance to the nearest pixel centre in the X and Y directions) - being least near a pixel centre (single pixel used) and greatest when interpolating near a pixel corner (4 pixels used). This changing smoothing effect may result in an image where the local pixel to pixel noise level varies with position in a way which depends on how it was resampled. Such an image cannot subsequently be processed by a program which uses the local noise level to perform its task (FFCLEAN or STACK using the MODE option, for example). When such programs cannot be run prior to resampling the image, the METHOD=UNIFORM option provides a solution. This method uses a weighted mean of (up to) the nearest 9 pixels, but adjusts the weights according to the resampling phase in such a way that the resolution degradation (measured by the reduction in pixel to pixel noise level) remains uniform and equal to the worst-case LINEAR method. This corresponds to a reduction in pixel to pixel noise level by a factor of 2, equivalent to a smoothing introduced by averaging over 4 pixels.

Timing: Approximately proportional to the area of the output image. The time is also increased if the transformation employed involves significant image rotation. The interpolation time increases depending on the METHOD option in the order NEAREST, LINEAR, UNIFORM.

2.5] Photometric registration of the images.

In this part of the work again Program Image is used for the generation of the template image. In the second run of this program gaussian stellar profile parameters and background values are scaled in order to get the photographic-like effects. Background and peak intensities of the stellar profiles in these two images are found with the use of Programs STARFIT, and STARMAG. Their documentation is given in the following lines.

Another Program SCALING gives the scaling factors of these two images which are generated first, for background and peak intensities of the gaussian stellar profiles; by accepting the background and peak intensity values found from STARFIT and STARMAG for the template and second image and by assuming stationary background and standard stars in the image.

Then a modified version of Program IMAGE is used to perform the photometric rescaling of the second image. This program prompts peak intensity values of the scaled image and scaling factors derived from program SCALING.

Program STARFIT

Function: To find a set of parameters describing a model star image, which can be used when performing stellar photometry using STARMAG.

The model has a radial profile:

D=A*exp(-0.5*(r'/sigma)**GAMMA) ....(5)

where r' is calculated from the true radial distance from the star centre, r, allowing for image ellipticity. The program combines a number of star images specified by the user and determines a mean seeing disk size (SEEING), radial fall-off parameter (GAMMA), axis ratio (AXISR) and axis inclination (THETA) of a model star image.

Method: Marginal profiles of each star image are formed in 4 directions, inclined at 45 degree intervals. A gaussian curve and background is fitted to each profile. Using the resulting 4 gaussian centres, a mean centre is found for each star.

The 4 gaussian widths of all the stars are combined, using a weighted average with rejection of erroneous data, and from the 4 average widths the seeing disk size, axis ratio and axis inclination are calculated.

The data surrounding each star is then binned into isophotal zones which are elliptical annuli centred on the star - the ellipse parameters being those just calculated. The data in each zone is processed to remove erroneous points and to find an average value. A gaussian profile is fitted to these average values and the derived amplitude is used to normalise the values to an amplitude of unity. The normalised values are put into bins together with the corresponding data from all other stars and this binned data represents a weighted average radial profile for the set of stars, with the image ellipticity removed. Finally a radial profile is fitted to this data, giving the radial profile parameter GAMMA and a final re-estimate of the seeing disk size.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

ILEVEL(2): An integer from 1 to 3 controlling the printing of results.

1: Printing is supressed.

2: Results are printed, giving the number of stars used and the mean profile parameters.

3: A table, giving details of the seeing and ellipticity of each star image used is also printed. This table indicates if any star could not be used.

IMAGE: The input image containing the stars to be fitted.

INPUT: An input list of X,Y positions for the stars to be used in the fit.

ISIZE(15): An integer from 3 to 101 specifying the side of the square area to be used when forming the marginal profiles for a star image. This should be sufficiently large to contain the entire star image. If an even value is given, the next largest odd number is used instead.

RANGE(4.0): The number of image profile widths ('sigma' in the equation above) out to which the radial star profile is to be fitted. (There is an upper limit of 50 pixels to the radius at which data is actually used.)

DEVICE(NONE): A parameter specifying a graphical output device on which to produce a plot of the mean radial profile of the stars and the fitted function. Any GKS supported plotting device may be specified. Abbreviations are acceptable. The default (NONE) produces no plot.

SEEING: An output parameter giving the seeing disk size: the full width at half maximum across the minor axis of a star image.

AXISR: An output parameter giving the axis ratio of the star images: the ratio of the major axis length to that of the minor axis.

THETA: An output parameter giving the inclination of the major axis of the star images to the X axis (increasing pixel number direction). This value is in degrees, X through Y being considered positive.

GAMMA: An output parameter giving the radial fall-off parameter in the equation above.

Notes:- The values of the parameters SEEING, AXISR, THETA and GAMMA are in a form for direct use with the program STARMAG.

- The stars used to determine the mean image parameters should be chosen to represent those whose magnitudes are to be found using STARMAG, and to be sufficiently bright, uncrowded and noise-free to allow an accurate fit to be made.

Errors: The program may access the following error parameter(s) to indicate error conditions:

NOSTARS: ***NO STAR IMAGES FOUND

No image features at the positions given resembled star images sufficiently closely to allow their centres and widths to be determined. There is thus no data on which to base a fit.

NOFIT: ***RADIAL PROFILE FIT COULD NOT BE OBTAINED

There is insufficient data in the final average radial profile or the profile differs too much from the form expected (a gaussian) for a fit to be obtained.

Timing: Approximately proportional to the number of stars used and the image area which each occupies.

Program STARMAG

Function: To determine the integrated brightness and magnitude of star images by fitting a 2 dimensional surface to the data. The program is intended for images which have been previously linearised and spatially calibrated, although it is not necessary for the background to have been subtracted. The method assumes that all star images have the same shape, and some inaccuracy will result if this is not the case.

Method: Each star image is located by forming marginal profiles in the X and Y directions, subtracting a background estimate and fitting a gaussian of a specified width. Having thus located the centre of each star image, the surrounding data is binned into iso-photal zones, which are circular or elliptical annuli centred on the star. The data in each zone is processed to remove aberrant values and a radial star profile and background is then fitted to the binned data. The integrated brightness is obtained from the integral of the fitted function.

The full form of the fitted star surface is:

D=A*exp(-0.5*(r'/sigma)**GAMMA)+B ....(6)

A is the star central amplitude, B the background and sigma the profile width. The parameter GAMMA determines the rate of radial fall-off in the star profile and is normally set around 2, corresponding to a gaussian profile. The effective radial distance r′ is derived from the true distance from the star centre r, allowing for ellipticity in the star image.

The user must supply the axis ratio of the ellipse, the inclination of the major axis to the X axis, the FWHM seeing across the minor ellipse axis and the radial profile parameter GAMMA. These parameters remain constant throughout a run. The program calculates the centre, the central amplitude, the background and the integrated magnitude for each star.

Parameters: The program uses the following parameter(s). Connection file defaults, if present, are shown in brackets after the parameter name.

ILEVEL(2): An integer from 1 to 3 to control the printing of results.

1: Printing is supressed.

2: Results are printed for each star sucessfully fitted.

3: The table also includes stars not successfully fitted, together with appropriate error messages.

IMAGE: The input image containing the stars.

INPUT: An X, Y list of approximate positions of stars to be fitted.

SEEING: The seeing disk size: the full width at half maximum across the minor axis of a star image.

AXISR(1.0): The axis ratio of the star images: the ratio of the major axis length to that of the minor axis. This value should lie in the range 1.0 to 2.0.

GAMMA(2.0): The radial profile parameter which determines the rapidity of the radial fall-off in a star's brightness. The value 2.0 corresponds to a gaussian profile. The value of GAMMA should lie in the range 1.0 to 5.0.

RANGE(3.5): The number of image profile widths ('sigma' in the equation above) out to which the radial star profile is fitted, after binning into iso-photal zones. (There is an upper limit of 50 pixels to the radius at which data is actually used.)

ZEROMAG(0.0): The zero point of the magnitude scale. The calculated magnitude of a star image is:

MAG= -2.5*log10(brightness) + ZEROMAG .....(7)

where 'brightness' is the integrated brightness of the star.

OUTPUT: The output X,Y list containing the accurate centre positions of the stars which were successfully fitted and their magnitudes. These results may be listed using XYLIST.

TITLE: A title (30 characters) for the output list. The run-time default is the title of the input list.

Notes:- Values for the parameters SEEING, AXISR, THETA and GAMMA may be determined using the program STARFIT.

- Although the program will handle invalid pixels, the results may be unreliable if there is a significant number of these within a star image. The program also makes an attempt to reject blemishes during the radial binning process, but this process will not be efficient if many blemishes occur close to a star centre.

Errors: The program may access the following error parameter(s) to indicate error conditions:

NOLIST: ***OUTPUT LIST CONTAINS NO DATA

No stars were successfully fitted, so there are no results in the output list.

Messages: In addition to Starlink error parameters, the list of results may contain (if ILEVEL=3) the following error messages, indicating why stars could not be fitted:

STAR CENTRE NOT FOUND

TOO LITTLE DATA TO FIND STAR

TOO LITTLE DATA TO FIT STAR

FIT GIVES NEGATIVE BRIGHTNESS

Timing: Approximately proportional to the number of stars fitted and the area of image which each star occupies.

2.6] Test of the registrations.

In order to test the goodness of registration, we must make a comparision between the first(template) and third(registered) images. This comparison is done by finding the magnitudes, peak brightness of the stellar profiles and background in these two images. Another test is performed with program ROOTMSQER.

Program ROOTMSQER

Function: This program calculates the root mean square error between two images and generates a percentage error file, an image frame which is the percentage of intensity difference in registered image.

Method: Program scans two images pixel by pixel and then calculates the root mean square error according to equation

RMSQER=SQRT(SUM/NPIX) .... (8)

where

SUM=(Image1(i,j)-Image2)**2 and i,j are the image coordinates, NPIX total pixel number.

Then program generates a difference image frame with the scanned images which is another measure of the difference between two input images. In other words this is the percentage of the difference in intensity between two images pixel by pixel.

Parameters:

Input File Name: Template image file name.

Input File Name: File name of the image which will be compared with the template image.

Output File Name: File name of the output error frame

Note: Output error frame is a standard ASTRONET image.

3]RUN OF THE PROGRAMS AND RESULTS.

3.1]Results of the geometric and photometric registration tests.

After the construction of the procedure with the available software environments registration tests are performed. Geometric registration tests are done with four different signal to noise retios, in order to see how the registration algorithms behave with the noise. Same flag values of the STARLINK registration programs are used for the registration programs which are written in ASTRONET environment. It is found that tests with different flag values are not comparable with the program ROOTMSQER. In the first tests seeing value which is calculated with Program STARFIT was taken randomly. STARFIT is giving one of the error messages in the presence of the noise; because of this it was not possible to calculate seeing values with the noise. And in order to control seeing value all through the procedure same sigma parameter is chosen for the star profiles. After the calculation of the seeing value in signal to noise ratio infinite the same value is used for all geometric registration tests. STARMAG parameter zeromag is chosen 28. magnitudes for the convenience. During the tests with noise all other parameters of this program is defaulted except seeing value.

Figure 3.1(a,b) gives the ISOLEVEL output of the template image and geometrically distorted image respectively. Their data and other characteristics are given in the Table 3.1(a,b). Because of the very large output only signal to noise ratio equal 10. test output is given. Complete tests are also performed with the signal to noise ratio 1.,3. and infinite. Table 3.2 gives the data of linear transformation which is applied to second images for registration. As it is seen from the table there is a truncation error for the registered coordinates which must be equal to the data given in table 3.1(a). Program XYFIT output is slightly different from Program OPERATOR output so XYFIT transformation coefficients are used which gives the error of alignment. Figure 3.2(a,b) gives the ISOLEVEL output of the geometrically registered images respectively in ASTRONET and STARLINK environments, with nearest pixel approximation. Figure 3.2(c,d) gives the 2nd degree and 3rd degree polinomial interpolation cases in ASTRONET. Their data is given in Table 3.3(a,b,c,d) with the same order. Nearest pixel registrations in both environments are directly comparable. But for the polinomial cases there are no available programs in STARLINK . Lastly Figure 3.3(a,b) gives the geometrically registered images in ASTRONET and in STARLINK environments with Bilinear interpolation ,figure 3.3(c) is the STARLINK uniform interpolation case. All these three registered images are comparable ,although results of the ASTRONET Bilinear case is slightly different from other two. Data of these registered images are given in Table 3.4(a,b,c)

Figure 3.4 gives the ISOLEVEL output of the percentage error file and it's histogram for ASTRONET nearest pixel registration. Figures 3.5 to 3.7 similiar output for ASTRONET bilinear, polinomial 2nd degree and 3rd degree and 3.8 to 3.10 for STARLINK nearest bilinear and uniform geometric registrations. Peak percentage error is the smallest in

ASTRONET bilinear case. All error histograms are similiar ,but gives slightly high peak values both in ASTRONET and STARLINK bilinear cases. This can be seen from isolevel diagrams too. Comparison of the same error frames with the same error isolevel; for bilinear cases in both environments with other algorithms shows that other methods have more dense error frames which supports above conclusion.

Table 3.5 gives the root mean sqare errors, average magnitude differences (template - registrated) and variance of the magnitude differences in all available registration methods; for four signal to noise ratios. Again the above conclusion holds for these parameters. Root mean square error is the smallest in the cases of bilinear interpolation registrations. Slight difference between STARLINK and ASTRONET bilinear registrations are due to the truncation error. Also it is evident that with the increasing noise uniform interpolation gives the smallest root mean square error.

According the results of the Table 3.5 bilinear, uniform and polinomial 2nd degree methods are chosen for the detection of the time variability tests.

Photometric registration tests are performed with three different signal to noise ratios, S/N=4., 10., and infinite. Table 3.6(a,b,c) is giving the data for the noiseless case, and Table 3.7(a,b,c) for the S/N=4. case. Also average magnitude difference with respect to their template and its variation is given. Figures 3.11 and 3.12 gives ISOLEVEL output for these two cases of photometric registration respectively.

As an example these to extreme cases are chosen to see the error variance which is in the best case 0.0004 and the worst case 0.0294 . It is found that even in the high noise case variance of the difference of magnitudes respect to template is much smaller than geometric registration case. Same conclusion also holds for the root mean sqare errors.

3.2]Detection of time variability test

In the last part of the work detection of time variability from photographic-like synthetic images for point-like sources is performed. Infact this was the real astronomical and astrophysical task. For this aim one template and eight image frames which are containing 4 standard stars, stationary background and one variable star which has a known form of intrinsic light variation, are generated. Figure 3.13(a,b,c) gives three dimensional graphics of the template plate, first plate and registered plate without noise. Figure 3.13(d) is the ISOLEVEL output for error file and Figure 3.13(e) is the three dimensional graphics of the error file. Figure 3.14(a,b,c) gives the three dimensional graphics of the same images with S/N=10. with the same order. Image frames also includes photometric and geometric degradation together. So two registration steps used respectively. Images first photometrically registered then this photometrically registered image is geometrically registered onto a common reference system. Table 3.8 gives the data for the template plate. Table 3.9(1,2) gives the first plate and registered plate respectively, data for all other following plates are given in the same order up to Table 3.9(15,16) which corresponds to the last plate. All generated image frames are transported geometrically and photometrically onto the template frame. In the tables for the registered images the magnitudes and their difference with template is given for four different methods which are selected with geometric registration tests. Namely 1 corresponds to ASTRONET bilinear, 2 to STARLNK uniform, 3 to STARLINK bilinear and 4 to ASTRONET Polinomial 2nd degree case.

It is found that minumum magnitude difference is generally for the bilinear cases. Figure 3.15 gives the theoretical light curve of the variable star superimposed with four different tests. These experimental curves fit well to describe the model curve specially for a relatively high noise level such as S/N=10. Figure 3.16(a,b,c,d) gives experimental curves for the methodologies. Theoretical light curve of the variable star is chosen as a gaussian and lastly deviations of the experimental curves from this model curve is computed in order to see the limiting magnitude amplitude for detection of variability which is smaller than .1 magnitudes. Figure 3.17(a,b,c,d) gives the deviations from the model curve, average magnitude difference , it's variance, maximum and minumum deviations from the model curve.

Table 3.10 contains the variance of the magnitude differences for all the available data for all applied methodologies. As a conclusion bilinear geometric registration algorithms gives the best result for detection of time variability which can be seen from the last line of the table as a global variance for all data set.

3.3] <u>Concluding remarks</u>

From all the tests performed in order to construct a procedure for geometric and photometric registrations for detection of time variability in photographic-like results as a final conclusion is given as follows:

i)Geometric registration causes the biggest intensity loss for images. This loss of intensity is proportional to increasing noise.

ii)Polinomial interpolation algorithms did not give significantly better results corresponding to bilinear interpolation algorithms.

iii)Photometrical registration tests showed that intensity loss and error for estimating the magnitudes are much more smaller than geometric case.

iv)For detection of variability limiting magnitudes are determined which is smaller than .1 magnitudes with the available software environments.

Second part of the planned work can be caried out with real images in a standard image processing environment MIDAS. In this work standard magnitudes for reference stars found from signal to noise ratio infinite plates. But for the real images standard star catalogues will be used.

According to the researches done so far, region under study is containing probably many undetected young variable stars. From the results of this work it is found that it will be possible to detect variable stars with amplitudes smaller than .1 magnitudes and possibly some periodic ones with available plates.

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(2) G.H. HARO Ap.J., Vol:125,654

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Figure and table captions.

Figure 1.1(a,b,c) Schematic description of geometric registration procedure in STARLINK and ASTRONET environments.

Figure 1.2 Schematic description of photometric registration procedure in STARLINK and ASTRONET environments.

Figure 2.1 Standard normal noise generation, effect of oversampling. M=1,6, 12

Table 2.1 Standard normal noise generation with oversampling of Box distribution. M is number of sampling.

Figure 3.1(a,b) Geometric registration test. ISOLEVEL output for template image(a) and geometrically distorted image(b).

Table 3.1(a,b) Data of the images given in figure 3.1(a,b)

Table 3.2 Data of the linear transformation to the registered image.

Figure 3.2(a,b,c,d) ISOLEVEL output for geometrically registered images in ASTRONET (a), in STARLINK (b) with nearest pixel algorithm and ASTRONET polinomial second degree (c), third degree (d) algorithms.

Table 3.3(a,b,c,d) Data of the images given in figure 3.2(a,b,c,d)

Figure 3.3 ISOLEVEL output fot geometrically registered images in ASTRONET (a) and in STARLINK (b) with bilinear interpolation algorithms, in STARLINK (c) with uniform interpolation algorithm.

Table 3.4(a,b,c) Data of the images given in figure 3.3

Figure 3.4 ISOLEVEL outputs for error files of nearest pixel registration in ASTRONET environment and it's histogram generated by program WRHIST.

Figure 3.5 Same output as fig. 3.3 for ASTRONET bilinear case.

Figure 3.6 Same output as fig. 3.3 for ASTRONET 2nd degree polinomial case.

Figure 3.7 Same output as fig. 3.3 for ASTRONET 3rd degree polinomial case.

Figure 3.8 Same output as fig. 3.3 for STARLINK nearest pixel case.

Figure 3.9 Same output as fig. 3.3 for STARLINK bilinear case.

Figure 3.10 Same output as fig. 3.3 for STARLINK uniform case.

Table 3.5 General results from all geometric registration tests for four different S/N ratios.

Figure 3.11(a,b,c) Photometric registration test. ISOLEVEL output for template (a), photometrically scaled (b) and registered images (c) without noise.

Table 3.6(a,b,c) Data of the images given in fig. 3.11.

Figure 3.12(a,b,c) Photometric registration test. Same as figure 3.11 but S/N=4.

Table 3.7(a,b,c) Data of the images given in fig. 3.12

Figure 3.13(a,b,c) Three dimensional graphics of the template (a) , first plate (b) and registered plate (c) without noise, (d) error file of the registration and three dimensional graphics of the error file (e).

Table 3.8 Detection of time variabilty test. Data of the template image.

Figure 1.1(a)

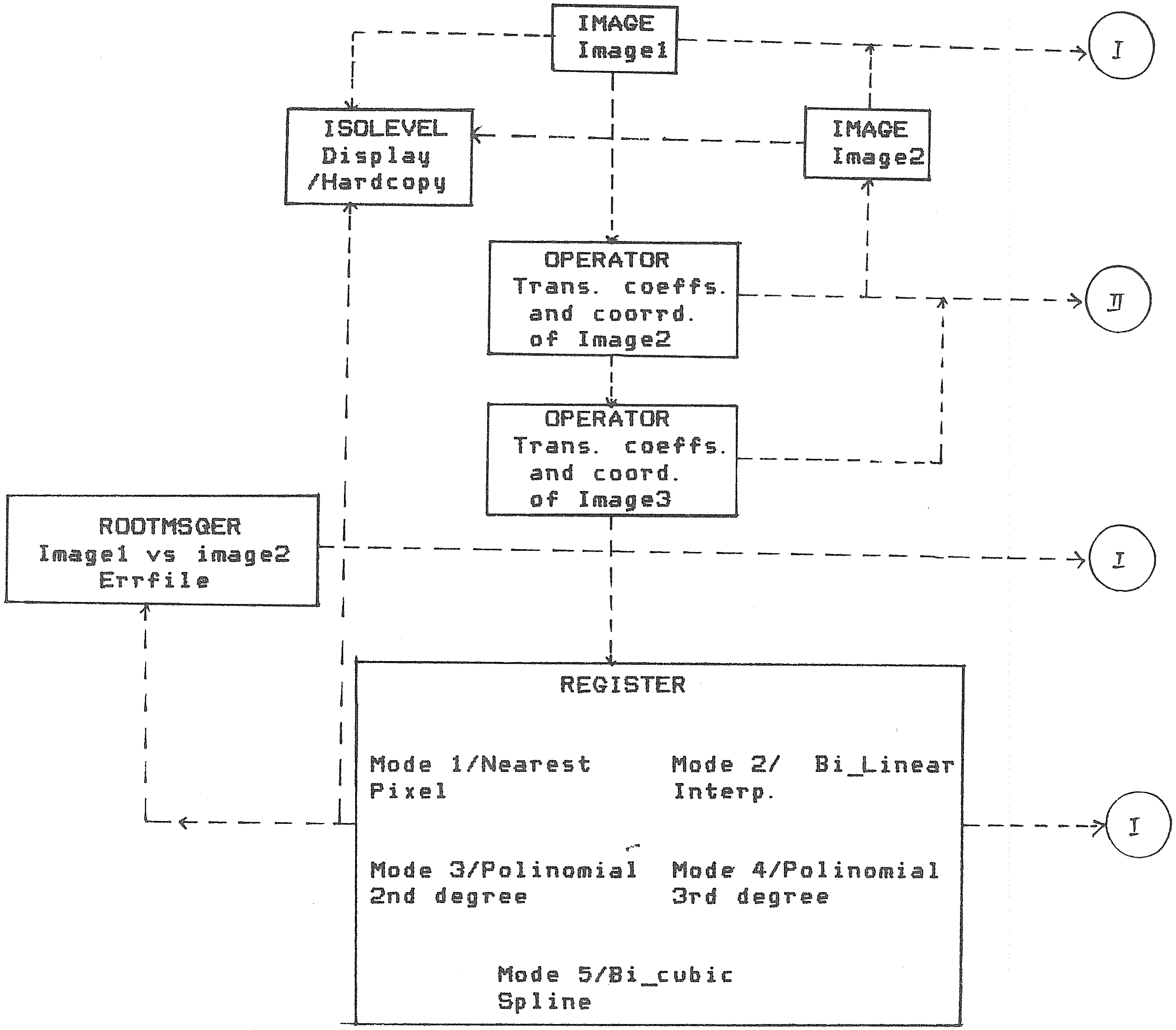


IMAGE
Image1
ISOLEVEL
Display
/Hardcopy
IMAGE
Image2
OPERATOR
Trans. coeffs.
and coorrd.
of Image2
OPERATOR
Trans. coeffs.
and coord.
of Image3
ROOTMSQER
Image1 vs image2
Errfile
REGISTER
Mode 1/Nearest
Pixel
Mode 2/ Bi_Linear
Interp.
Mode 3/Polinomial
2nd degree
Mode 4/Polinomial
3rd degree
Mode 5/Bi_cubic
Spline
I
II
I
I

Figure 1.1(b)

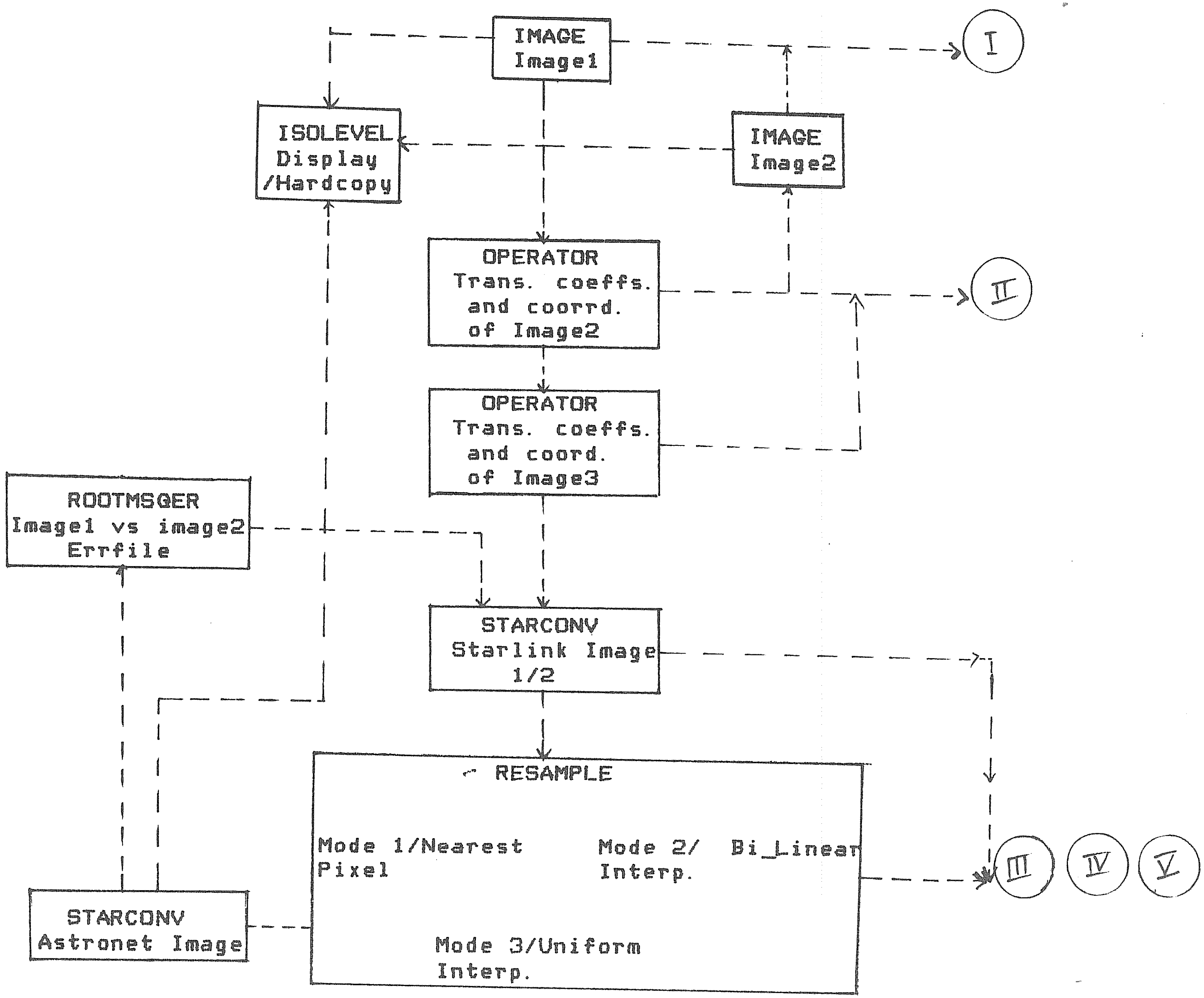


IMAGE
Image1
ISOLEVEL
Display
/Hardcopy
IMAGE
Image2
I
OPERATOR
Trans. coeffs.
and coorrd.
of Image2
II
OPERATOR
Trans. coeffs.
and coord.
of Image3
ROOTMSQER
Image1 vs image2
Errfile
STARCONV
Starlink Image
1/2
RESAMPLE
Mode 1/Nearest
Pixel
Mode 2/ Bi_Linear
Interp.
Mode 3/Uniform
Interp.
STARCONV
Astronet Image
III
IV
V

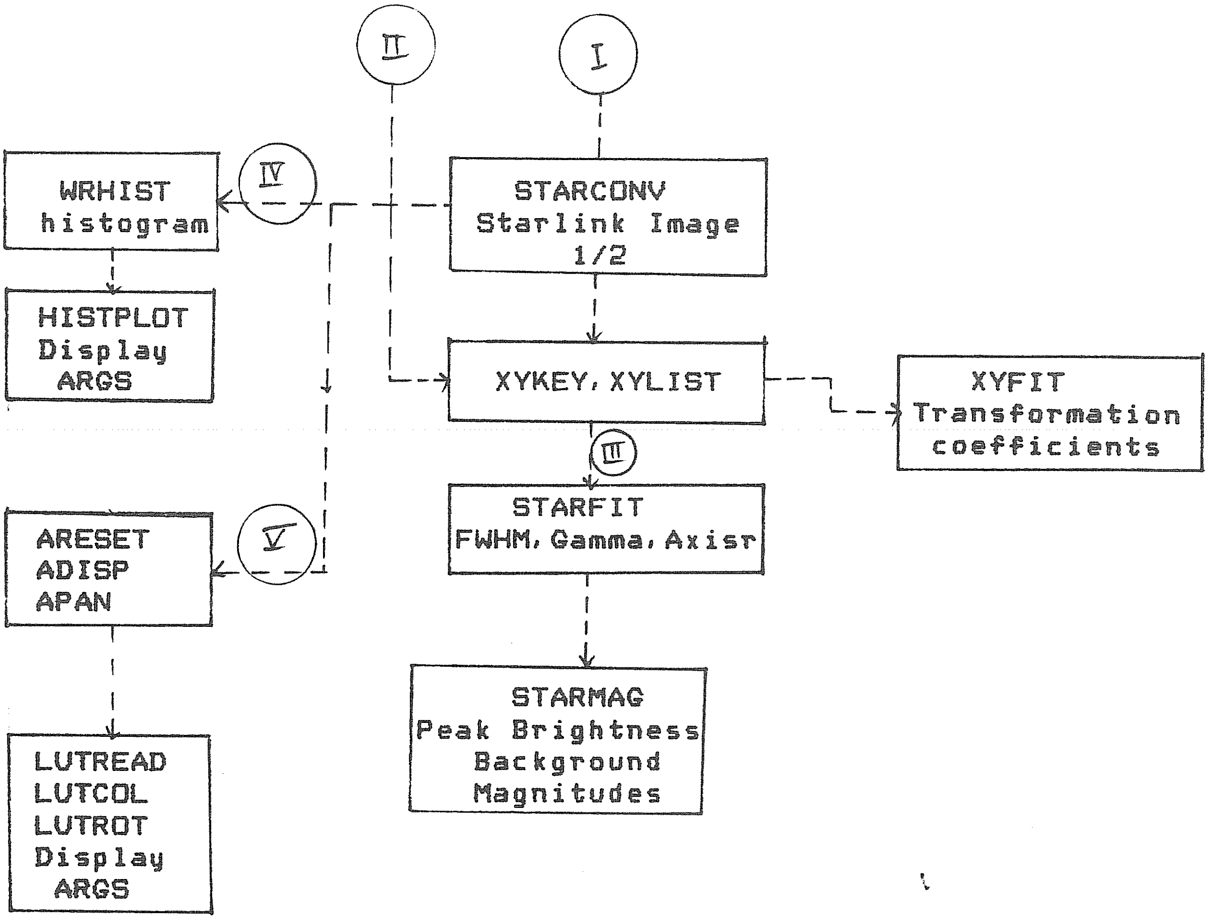

II
I
IV
WRHIST
histogram
STARCONV
Starlink Image
1/2
HISTPLOT
Display
ARGS
XYKEY, XYLIST
XYFIT
Transformation
coefficients
III
STARFIT
FWHM, Gamma, Axisr
V
ARESET
ADISP
APAN
STARMAG
Peak Brightness
Background
Magnitudes
LUTREAD
LUTCOL
LUTROT
Display
ARGS

Figure 1.1(c)

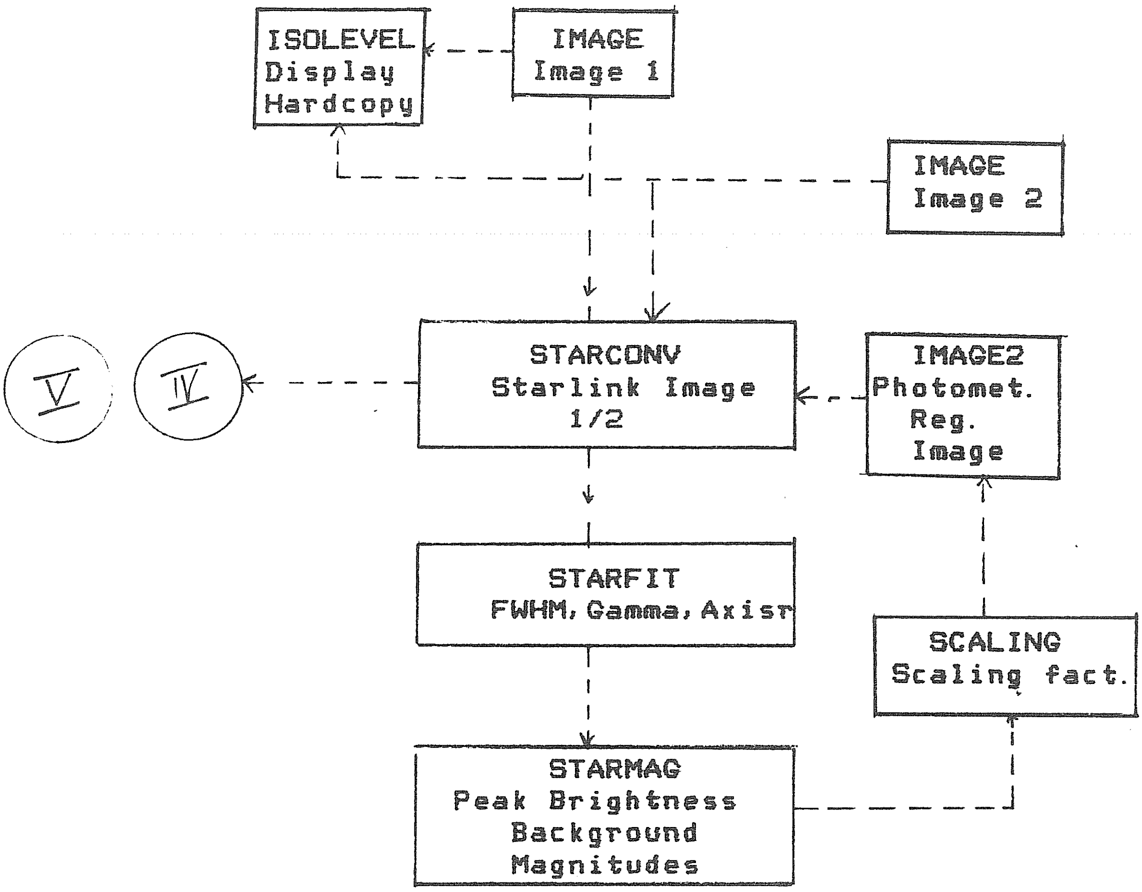

ISOLEVEL
Display
Hardcopy
IMAGE
Image 1
IMAGE
Image 2
STARCONV
Starlink Image
1/2
IMAGE2
Photomet.
Reg.
Image
V
IV
STARFIT
FWHM, Gamma, Axisr
SCALING
Scaling fact.
STARMAG
Peak Brightness
Background
Magnitudes

Figure 1.2

Figure 2.1

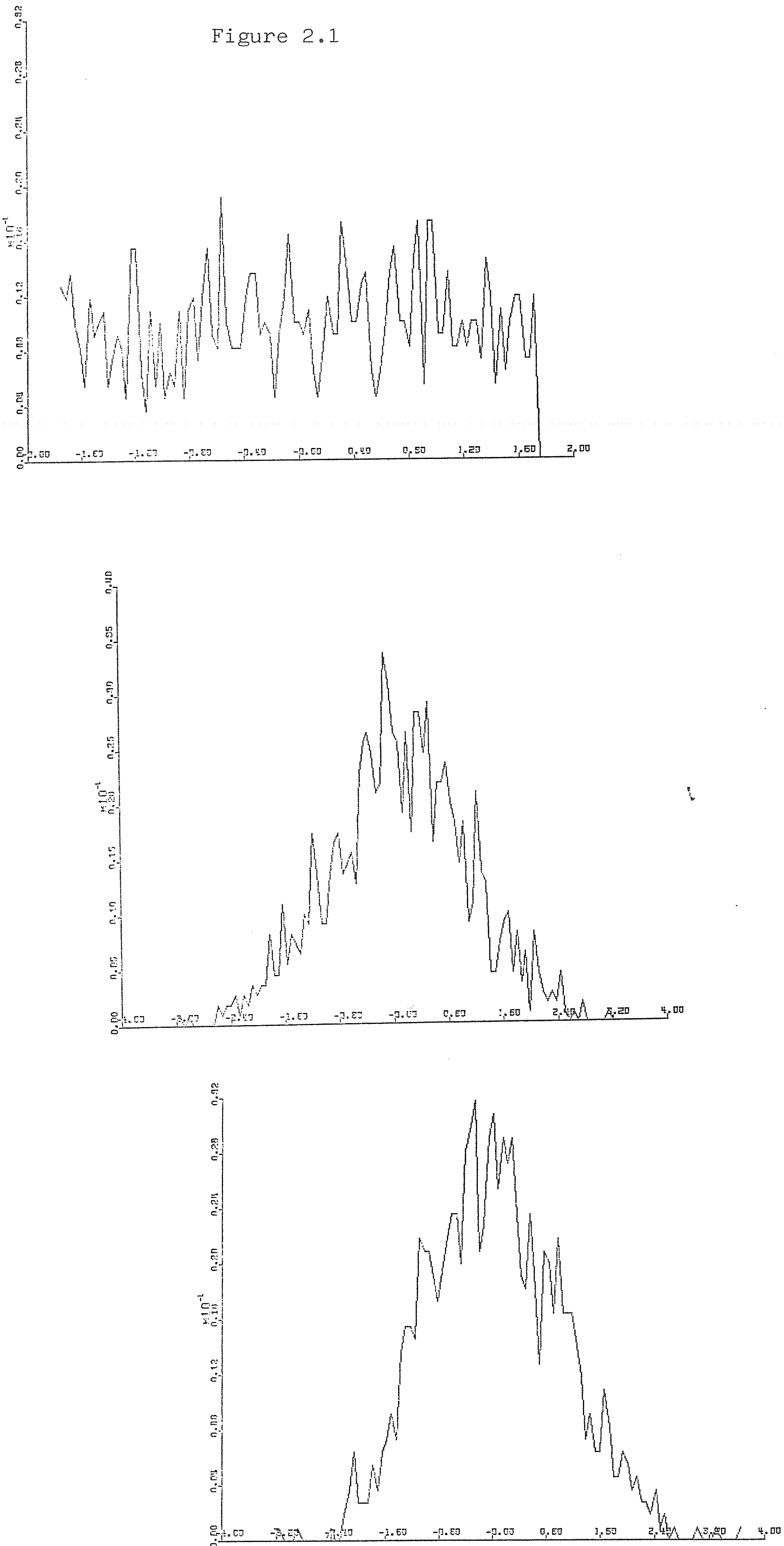


Table 2.1

M	μ	σ^2	σ
1	0.51063	0.81631E-01	0.28571
2	.99893	.15723	.39652
3	1.4975	.24084	.49075
4	1.9992	.31419	.56053
5	2.5052	.41249	.64226
6	2.9966	.49514	.70366
7	3.4912	.55446	.74462
8	3.9960	.63648	.79780
9	4.5048	.70483	.83928
10	5.0086	.76809	.87641
11	5.5195	.84648	.92005
12	6.0265	.93754	.96827

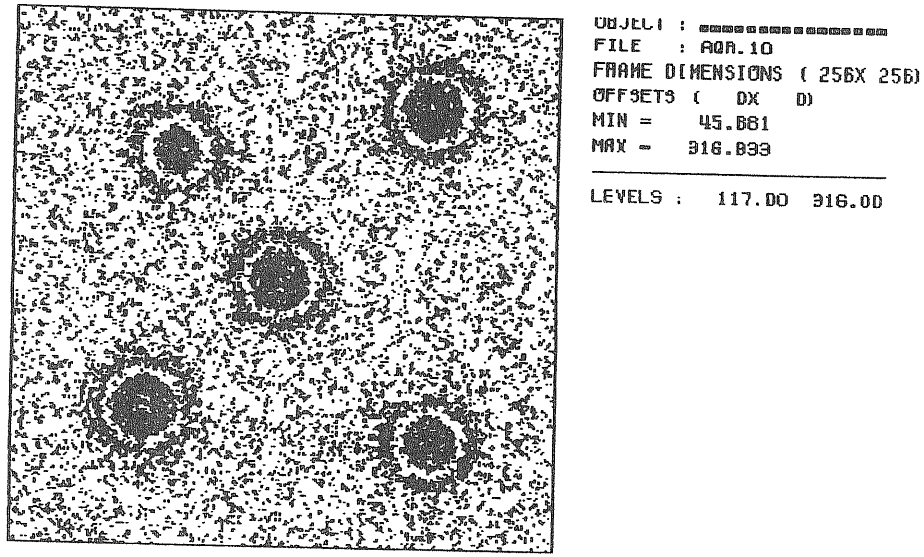


Figure 3.1(a)

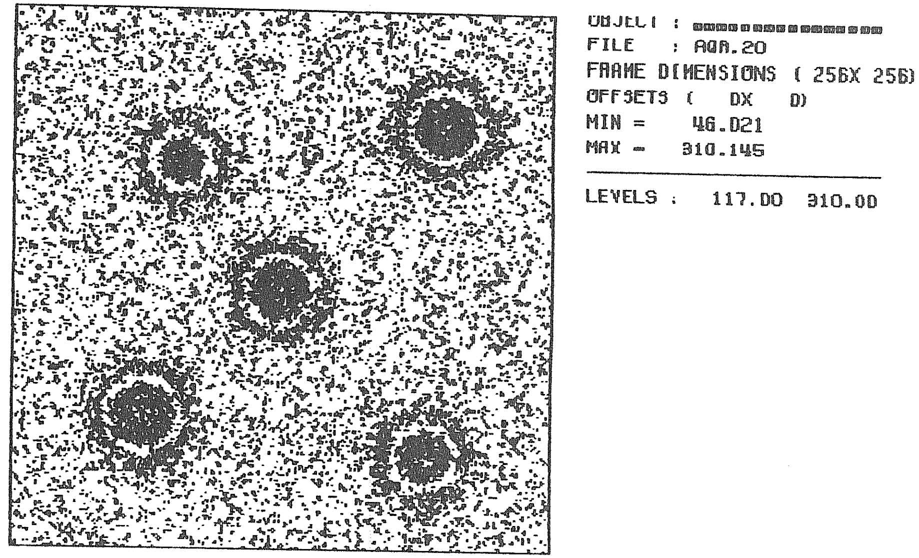


Figure 3.1(b)

Table 3.1(a)

File Name: AQR. 10   S/N=10.   Background=20.   Sigma noise=14.

Output from STARMAG
with DATA. 10

Object #	Coordinates X	Y	Sigma[X, Y]	Ampl.	Peak Brightness /Background	Magn.
1	64.	67.	10.	180.	1790. 3/1004. 9	12. 872
2	78.	189.	10.	102.	1037. 4/998. 74	13. 465
3	127.	128.	10.	158.	1589. 1/995. 04	13. 002
4	198.	52.	10.	123.	1228. 1/1003. 9	13. 281
5	198.	210.	10.	160.	1594. 9/1001. 9	12. 998

Gaussian FWHM
Seeing=23. 55

Levels for ISOLEVEL=317., 305., 267., 247., 227., 207., 187., 167., 117.

Table 3.1(b)

File Name:AQR.20   S/N=10.   Background=20.   Sigma noise=14.

Output from STARMAG
with DATA.20

Object #	Coordinates X	Coordinates Y	Sigma[X,Y]	Ampl.	Peak Brightness /Background	Magn.
1	63.56496	63.24477	10.	180.	1697.7/1019.3	12.930
2	80.75030	184.81216	10.	102.	945.54/1013.0	13.565
3	128.12723	122.56285	10.	158.	1417.2/1021.8	13.126
4	197.09967	44.74591	10.	123.	1001.7/1039.6	13.503
5	206.23207	202.52931	10.	160.	975.26/1096.4	13.532

Gaussian FWHM
Seeing=23.55

Levels for ISOLEVEL=310.,305.,267.,247.,227.,207.,187.,167.,117.

Scaling factor=.9998   Rotation angle=1.5

Translation[X,Y]=2.1

Table 3.2

Registration Tests

Scaling Factor=1.0002   Rotation Angle=-1.5

Translation[X,Y]=-2.1

#	X(new)	Y(new)
1	63.94473	67.05470
2	77.94472	189.05470
3	126.94471	128.05467
4	197.94473	52.05469
5	202.94472	210.05469

Transformation coefficients[ASTRONET]=

C(1)=2.04472   C(2)=.99986   C(3)=-.02618

C(4)=2.15468   C(5)=.02618   C(6)=.99986

Transformation coefficients[STARLINK]=

C(1)=2.10002   C(2)=.999857   C(3)=-.261821E-01

C(4)=2.09992   C(5)=.261822E-01   C(6)=.999858

RMSQ. alignment error=0.2974E-04

Figure 3.2

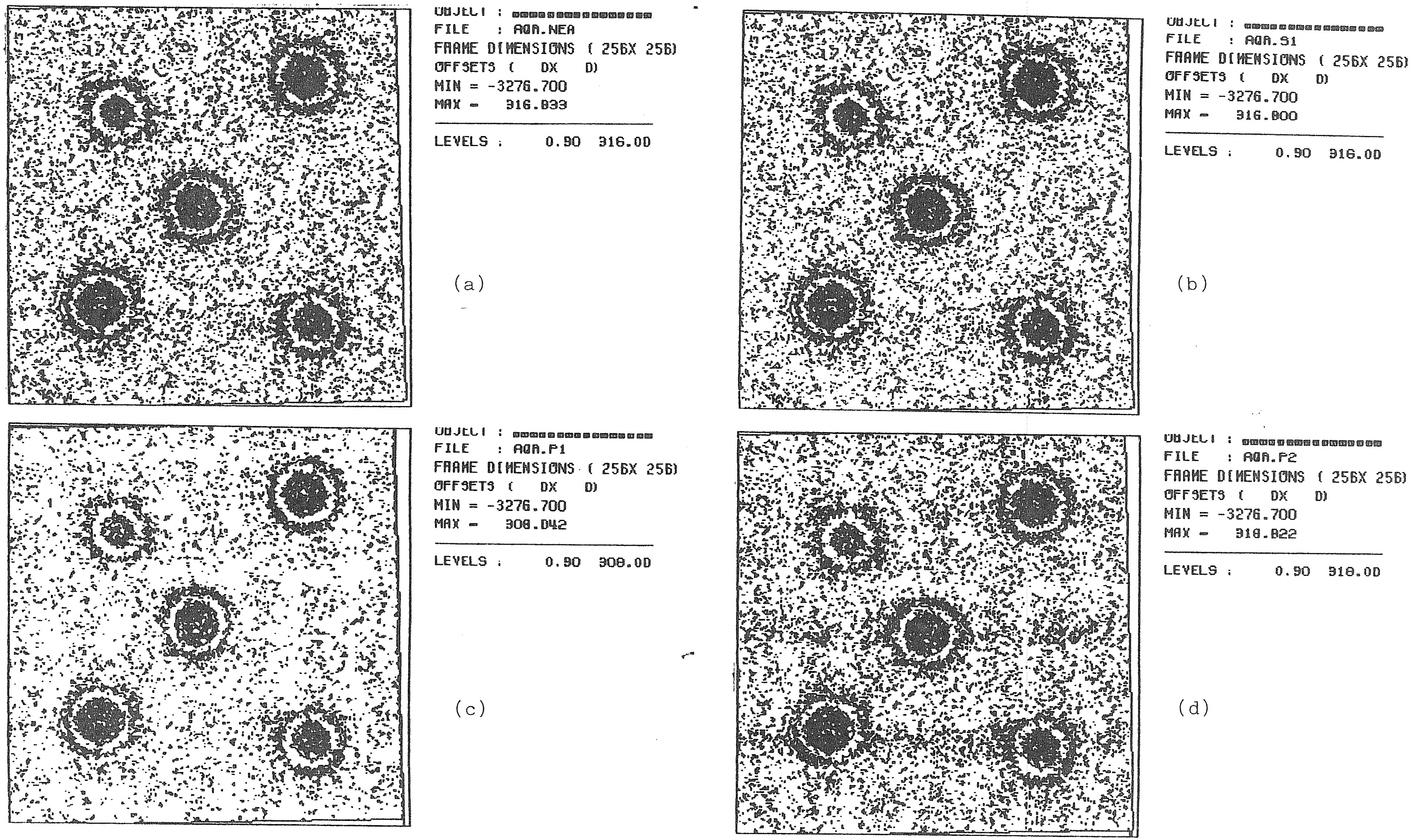

OBJECT :
FILE : AQA.NEA
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 316.833
LEVELS : 0.90 316.00
(a)
OBJECT :
FILE : AQA.S1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 316.800
LEVELS : 0.90 316.00
(b)
OBJECT :
FILE : AQA.P1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 308.042
LEVELS : 0.90 308.00
(c)
OBJECT :
FILE : AQA.P2
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 318.822
LEVELS : 0.90 318.00
(d)

Table 3.3(a)

File Name: AGR. NEA   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA. 10

Object #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	64.	67.	10.	180.	1686. 7/1020. 0	12. 937	-. 065
2	78.	189.	10.	102.	866. 72/1024. 0	13. 660	-. 195
3	127.	128.	10.	158.	1416. 7/1020. 9	13. 126	-. 124
4	198.	52.	10.	123.	1132. 5/1017. 6	13. 369	-. 088
5	198.	210.	10.	160.	1224. 2/1058. 5	13. 285	-. 237

Registration Algorithm: Nearest Pixel[ASTRONET]
Gaussian FWHM
Seeing=23.55

Root Mean Square Error of the Registration=21. 9990

Levels for ISOLEVEL=316. , 305. , 267. , 247. , 227. , 207. , 187. , 167. , 117.

Table 3.3(b)

File Name: AQR. S1 S/N=10. Background=20. Sigma noise=14.

Geometrically Registered Image

Output from STARMAG with DATA. 10

Object #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	64.	67.	10.	180.	1686. 7/1020. 0	12. 937	-. 065
2	78.	189.	10.	102.	866. 72/1024. 0	13. 660	-. 195
3	127.	128.	10.	158.	1416. 7/1020. 9	13. 126	-. 124
4	198.	52.	10.	123.	1132. 5/1017. 6	13. 369	-. 088
5	198.	210.	10.	160.	1224. 2/1058. 5	13. 285	-. 287

Registration Algorithm: Nearest Pixel[STARLINK]

Gaussian FWHM
Seeing=23.55

Root Mean Square Error of the Registration=21. 9991

Levels for ISOLEVEL=310., 305., 267., 247., 227., 207., 187., 167., 117.

Table 3.3(c)

File Name: AQR.P1   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA.10

Object #	Coordinates X	Y	Sigma [X,Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	64.	67.	10.	180.	1693.4/1019.3	12.932	-.006
2	78.	189.	10.	102.	865.67/1024.1	13.661	-.196
3	127.	128.	10.	158.	1413.6/1021.6	13.129	-.127
4	198.	52.	10.	123.	1133.0/1017.5	13.369	-.088
5	198.	210.	10.	160.	1231.3/1058.1	13.278	-.280

Registration Algorithm: Second Degree Polinomial Interpolation [ASTRONET]

Gaussian FWHM
Seeing=23.55

Root Mean Square Error of the Registration=20.6139

Levels for ISOLEVEL=308.,267.,247.,227.,207.,187.,167.,117.

Table 3.3(d)

File Name: AQR. P2   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA. 10

Object #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δ m
1	64.	67.	10.	180.	1689. 5/1024. 5	12. 935	-. 063
2	78.	189.	10.	102.	855. 30/1030. 3	13. 674	-. 209
3	127.	128.	10.	158.	1414. 7/1028. 2	13. 128	-. 126
4	198.	52.	10.	123.	1108. 8/1024. 5	13. 392	-. 111
5	198.	210.	10.	160.	1222. 6/1061. 5	13. 286	-. 288

Registration Algorithm: Third Degree Polinomial Interpolation [ASTRONET]

Gaussian FWHM
Seeing=23.\55

Root Mean Square Error of the Registration=21. 9512

Levels for ISOLEVEL=310. , 305. , 267. , 247. , 227. , 207. , 187. , 167. , 117.

Figure 3.3

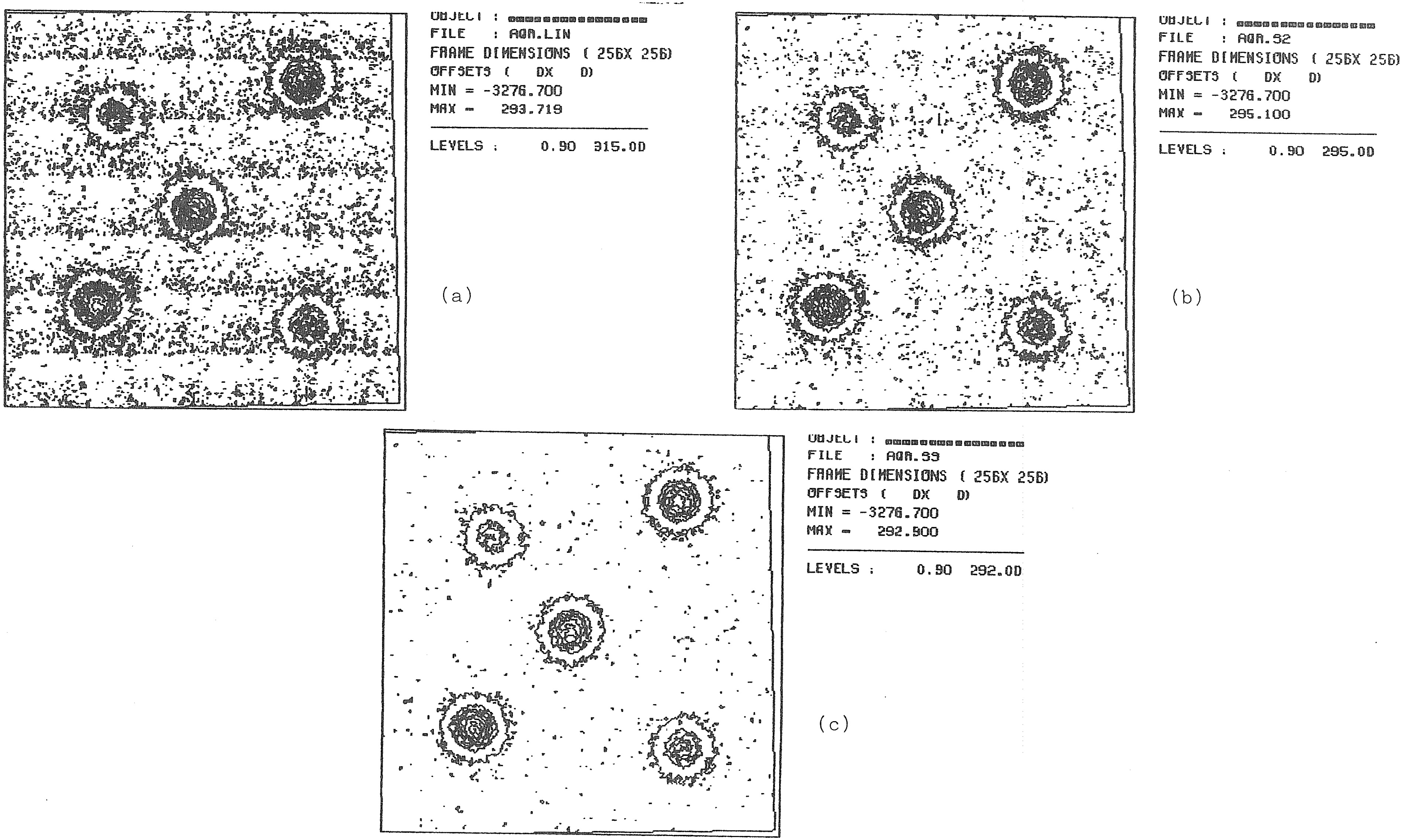

OBJECT :
FILE : AQA.LIN
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 293.719
LEVELS : 0.90 315.0D
(a)
OBJECT :
FILE : AQA.52
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 295.100
LEVELS : 0.90 295.0D
(b)
OBJECT :
FILE : AQA.53
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -3276.700
MAX = 292.900
LEVELS : 0.90 292.0D
(c)

Table 3.4(a)

File Name: AQR.LIN   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA.10

Object #	Coordinates X	Y	Sigma [X,Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	64.	67.	10.	180.	1702.0/1042.1	12.927	-.055
2	78.	189.	10.	102.	882.95/1042.5	13.640	-.175
3	127.	128.	10.	158.	1442.6/1037.5	13.107	-.105
4	198.	52.	10.	123.	1154.4/1033.2	13.349	-.068
5	198.	210.	10.	160.	1264.0/1073.8	13.250	-.252

Registration Algorithm: Bi_Linear Interpolation[ASTRONET]
Gaussian FWHM
Seeing=23.55

Root Mean Square Error of the Registration=19.9896

Levels for ISOLEVEL=293.,267.,247.,227.,207.,187.,167.,117.

Table 3.4(b)

File Name: AQR. S2   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA. 10

Object #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δ m
1	64.	67.	10.	180.	1691. 8/1019. 6	12. 933	-. 061
2	78.	189.	10.	102.	864. 27/1024. 5	13. 663	-. 198
3	127.	128.	10.	158.	1411. 1/1022. 2	13. 130	-. 128
4	198.	52.	10.	123.	1131. 5/1017. 9	13. 370	-. 089
5	198.	210.	10.	160.	1229. 7/1058. 5	13. 280	-. 282

Registration Algorithm: Bi_linear Interpolation[STARLINK]

Gaussian FWHM
Seeing=23.55

Root Mean Square Error of the Registration=21. 9991

Levels for ISOLEVEL=295. , 267. , 247. , 227. , 207. , 187. , 167. , 117.

Table 3.4(c)

File Name: AQR. S3   S/N=10.   Background=20.   Sigma noise=14.

Geometrically Registered Image   Output from STARMAG with DATA. 10

Object #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	64.	67.	10.	180.	1690. 2/1020. 4	12. 935	-. 063
2	78.	189.	10.	102.	862. 80/1024. 5	13. 665	-. 200
3	127.	128.	10.	158.	1409. 3/1022. 5	13. 132	-. 130
4	198.	52.	10.	123.	1130. 3/1018. 2	13. 371	-. 090
5	198.	210.	10.	160.	1230. 9/1058. 1	13. 279	-. 281

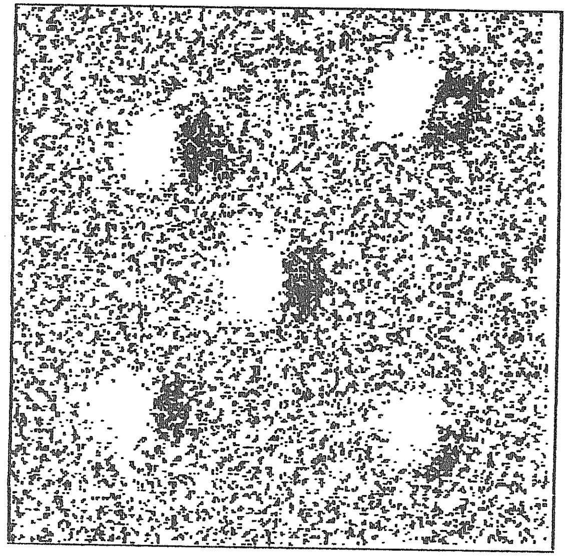
Registration Algorithm: Uniform Interpolation[STARLINK]

Gaussian FWHM
Seeing=23. 55

Root Mean Square Error of the Registration=18. 3218

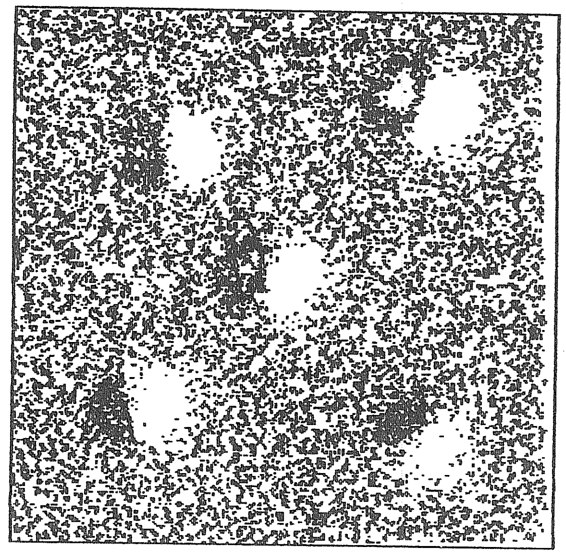
Levels for ISOLEVEL=292. , 267. , 247. , 227. , 207. , 187. , 167. , 117.

Figure 3.4



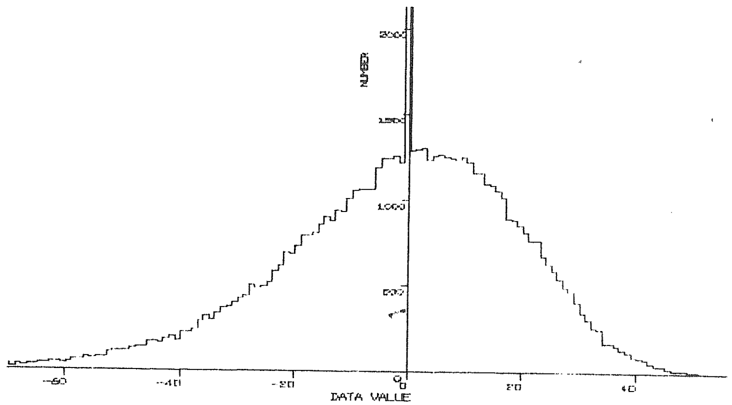
OBJECT :
FILE : ERR.NEA
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -158.896
MAX = 56.190

LEVELS : 20.00 20.00



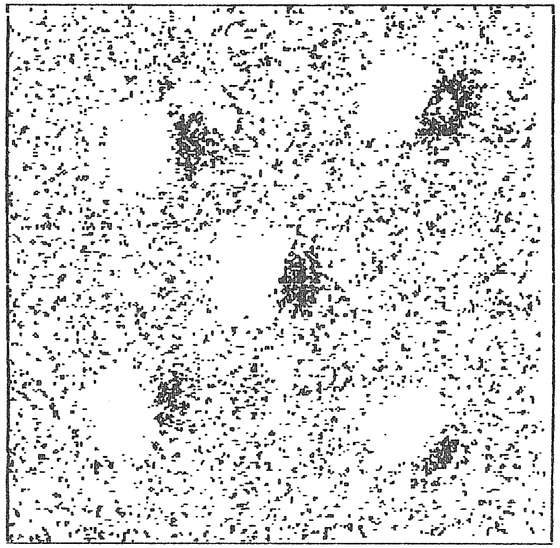
OBJECT :
FILE : ERR.NEA
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -158.896
MAX = 56.190

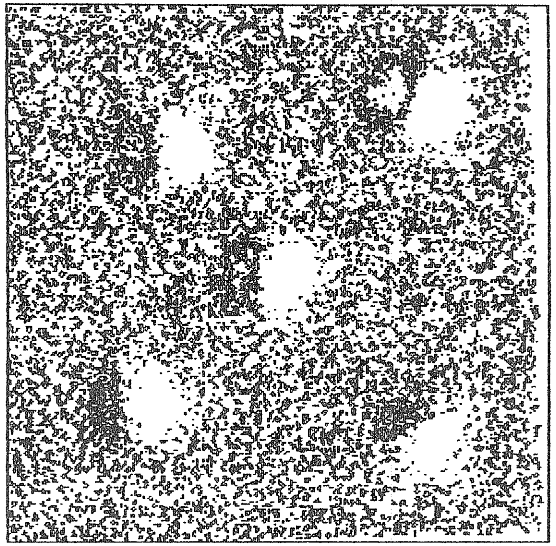
LEVELS : -20.00 -20.00

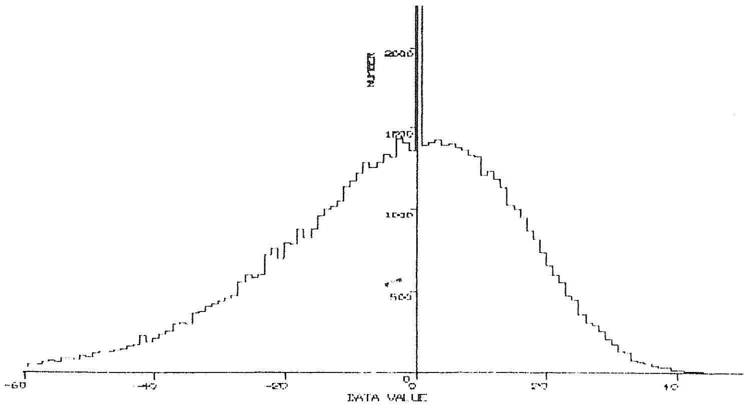


err.h1

Figure 3.5

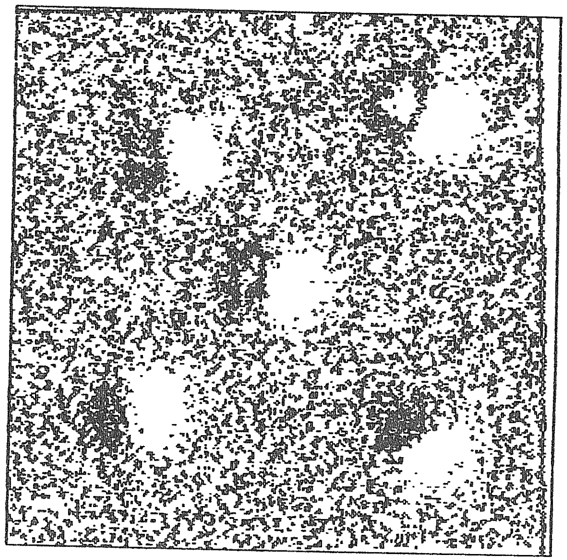






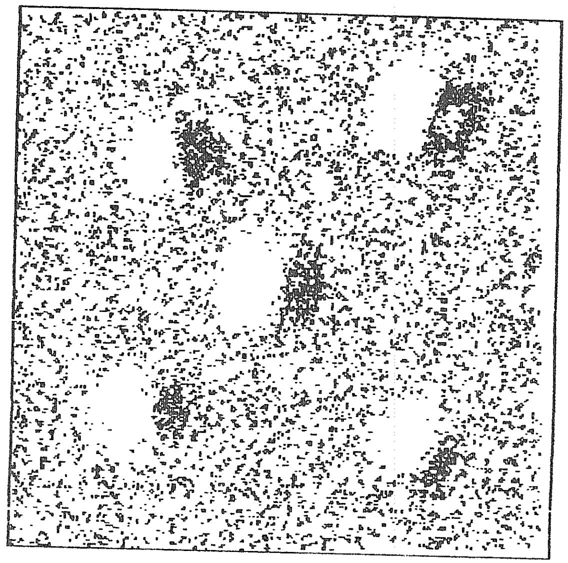
err h2

Figure 3.6



OBJECT : ▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪
FILE : EAA.P1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -181.140
MAX = 49.431

LEVELS : -20.DO -20.DO



OBJECT : ▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪
FILE : EAA.P1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -181.140
MAX = 49.431

LEVELS : 20.DO 20.DO

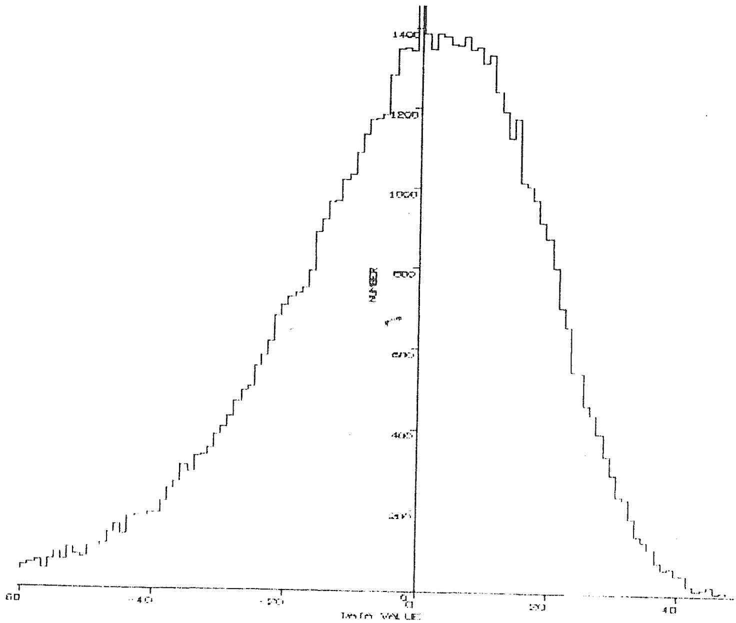
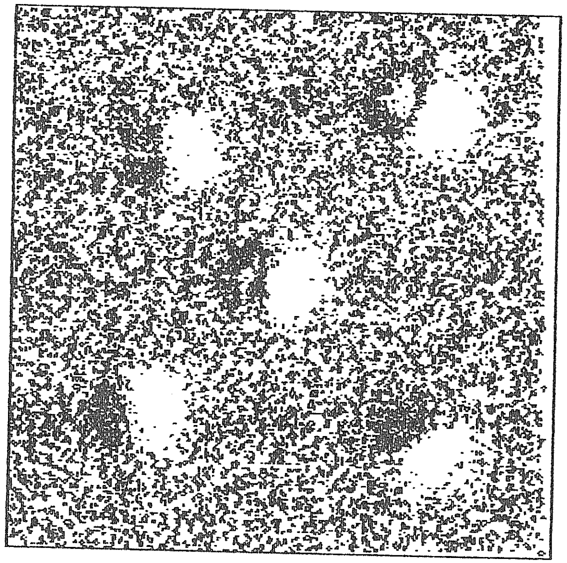
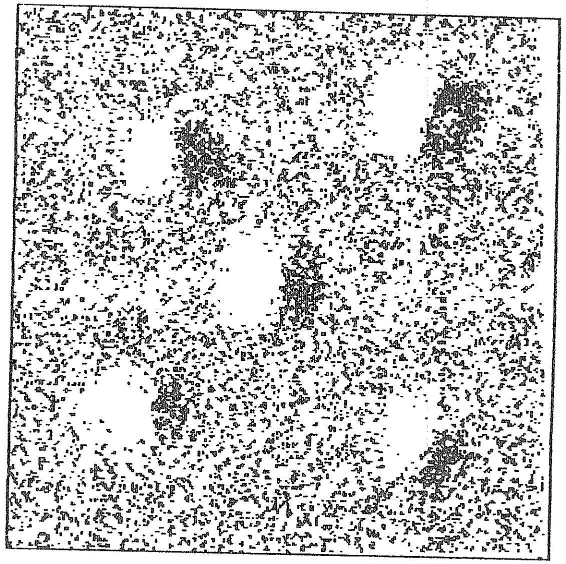


Figure 3.7



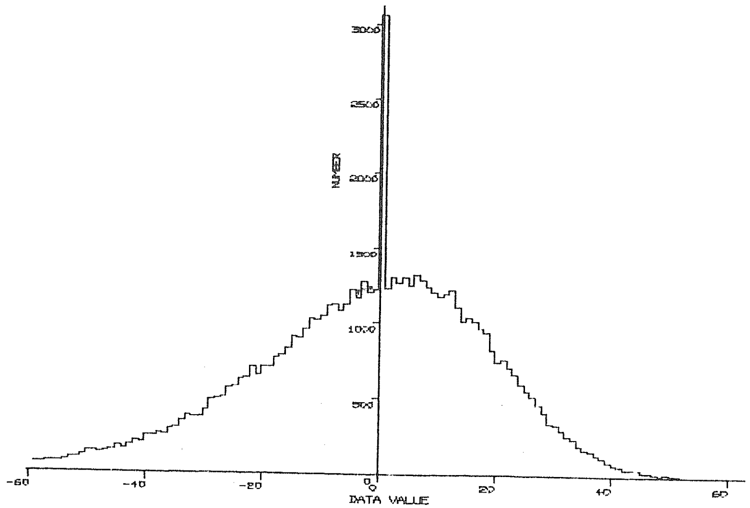
OBJECT :
FILE : ERR.P2
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -131.289
MAX = 63.046

LEVELS : -20.00 -20.00



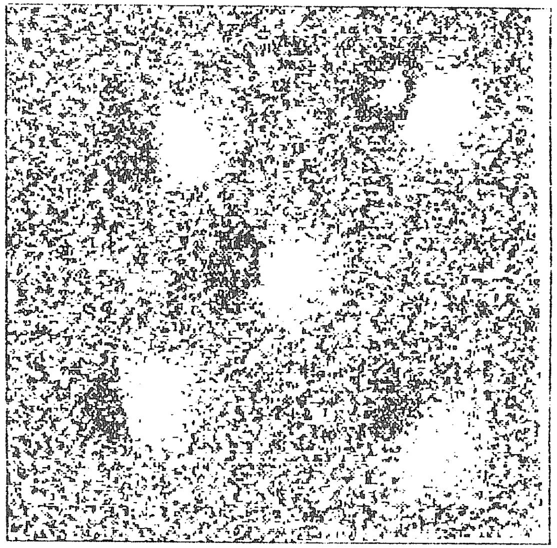
OBJECT :
FILE : ERR.P2
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -131.289
MAX = 63.046

LEVELS : 20.00 20.00



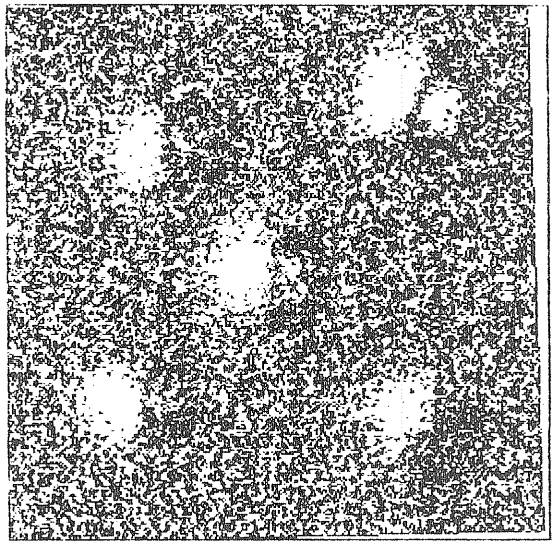
err.h4

Figure 3.8



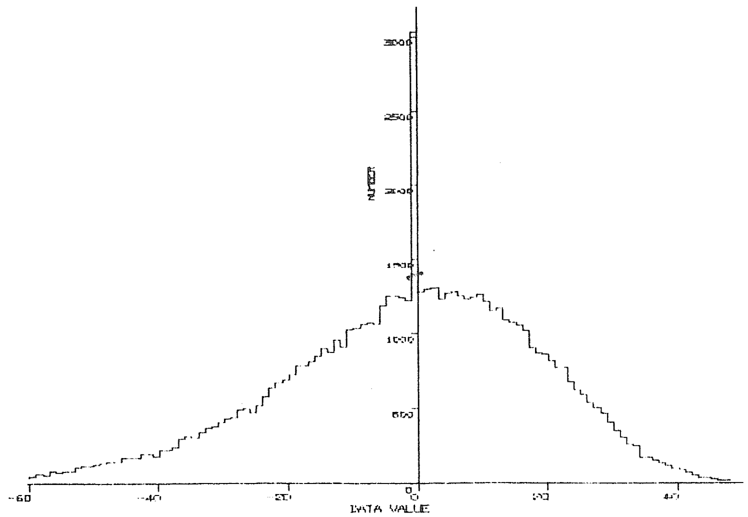
OBJECT : ■■■■■■■■■■■■■■■■■
FILE : EAR.ST1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX 0)
MIN = -136.691
MAX = 6394.194

LEVELS : -20.00 20.00



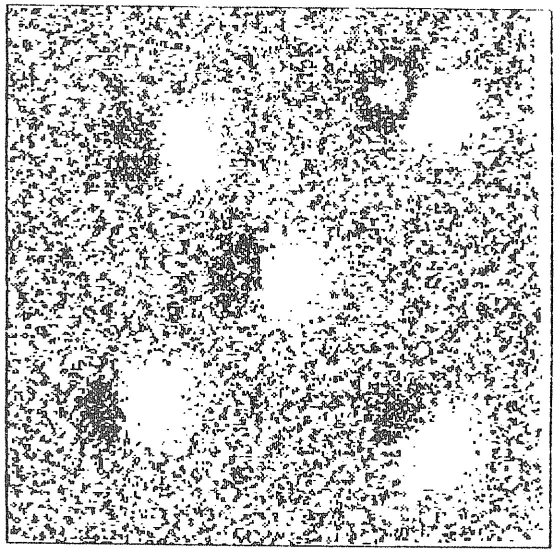
OBJECT : ■■■■■■■■■■■■■■■■■
FILE : EAR.ST1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX 0)
MIN = -136.691
MAX = 6394.194

LEVELS : 10.00 10.00



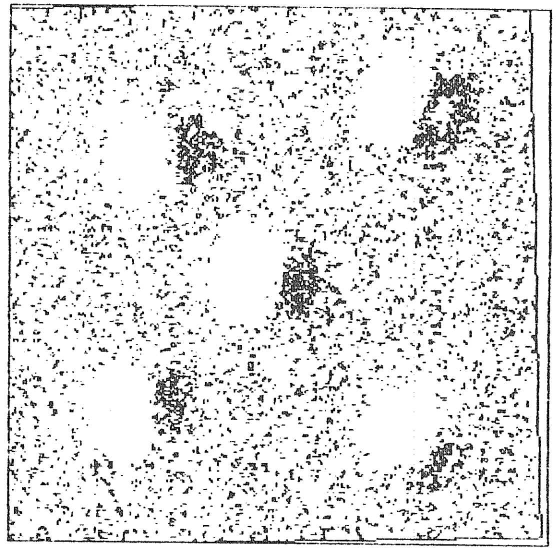
err.sh1

Figure 3.9



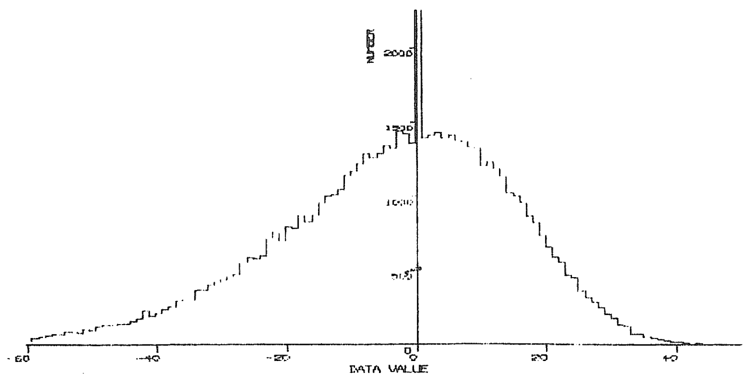
OBJECT :
FILE : ERR.52
FRAME DIMENSIONS (256X 256)
OFFSETS (0X 0)
MIN = -118.789
MAX = 6394.194

LEVELS : -20.00 -20.00



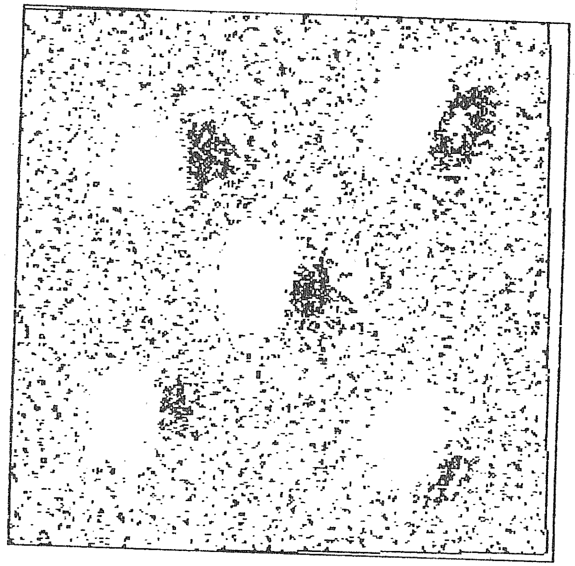
OBJECT :
FILE : ERR.52
FRAME DIMENSIONS (256X 256)
OFFSETS (0X 0)
MIN = -118.789
MAX = 6394.194

LEVELS : 20.00 20.00



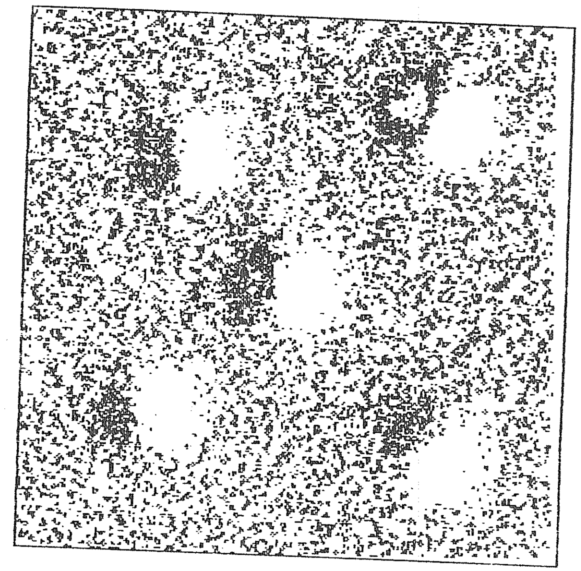
err.sh2

Figure 3.10



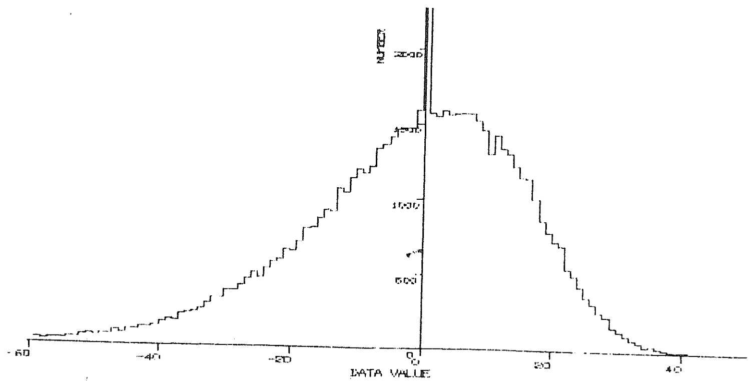
OBJECT :
FILE : ERR.59
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -116.845
MAX = 6394.194

LEVELS : 20.00 20.00



OBJECT :
FILE : ERR.59
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = -116.845
MAX = 6394.194

LEVELS : -20.00 -20.00



err sh3

Table 3.5

Geometric Registration Test Results

	1	2	3	4	5	6	7
$S/N=\infty$							
RMSQ error	9.48804	8.99152	9.63605	9.34483	9.48803	9.41495	9.40226
Average Δm	-.1522	-.1282	-.1510	-.1384	-.1522	-.1518	-.1396
Var. Δm	.0907	.0839	.0893	.1031	.0907	.0891	.0886
S/N=10.							
RMSQ error	21.9990	19.9896	20.6138	21.9512	21.9914	19.3221	18.3219
Average Δm	-.1458	-.1310	-.1502	-.1594	-.1518	-.1516	-.1536
Var. Δm	.0875	.0822	.0877	.0891	.0902	.0892	.0873
S/N=3							
RMSQ error	67.0959	60.3292	61.8807	67.1013	67.0964	57.2466	53.4202
Average Δm	-.1490	-.1176	-.1630	-.1590	-.1570	-.1530	-.1540
Var. Δm	.0970	.0867	.0850	.0910	.0920	.0940	.0920
S/N=1							
RMSQ error	197.6016	177.1067	181.8359	197.6792	197.6021	167.7335	156.3135
Average Δm	-.1630	-.0920	-.1570	-.2020	-.1630	-.1580	-.1600
Var. Δm	.1120	.1250	.0970	.1150	.1120	.1060	.1050

Figure 3.11

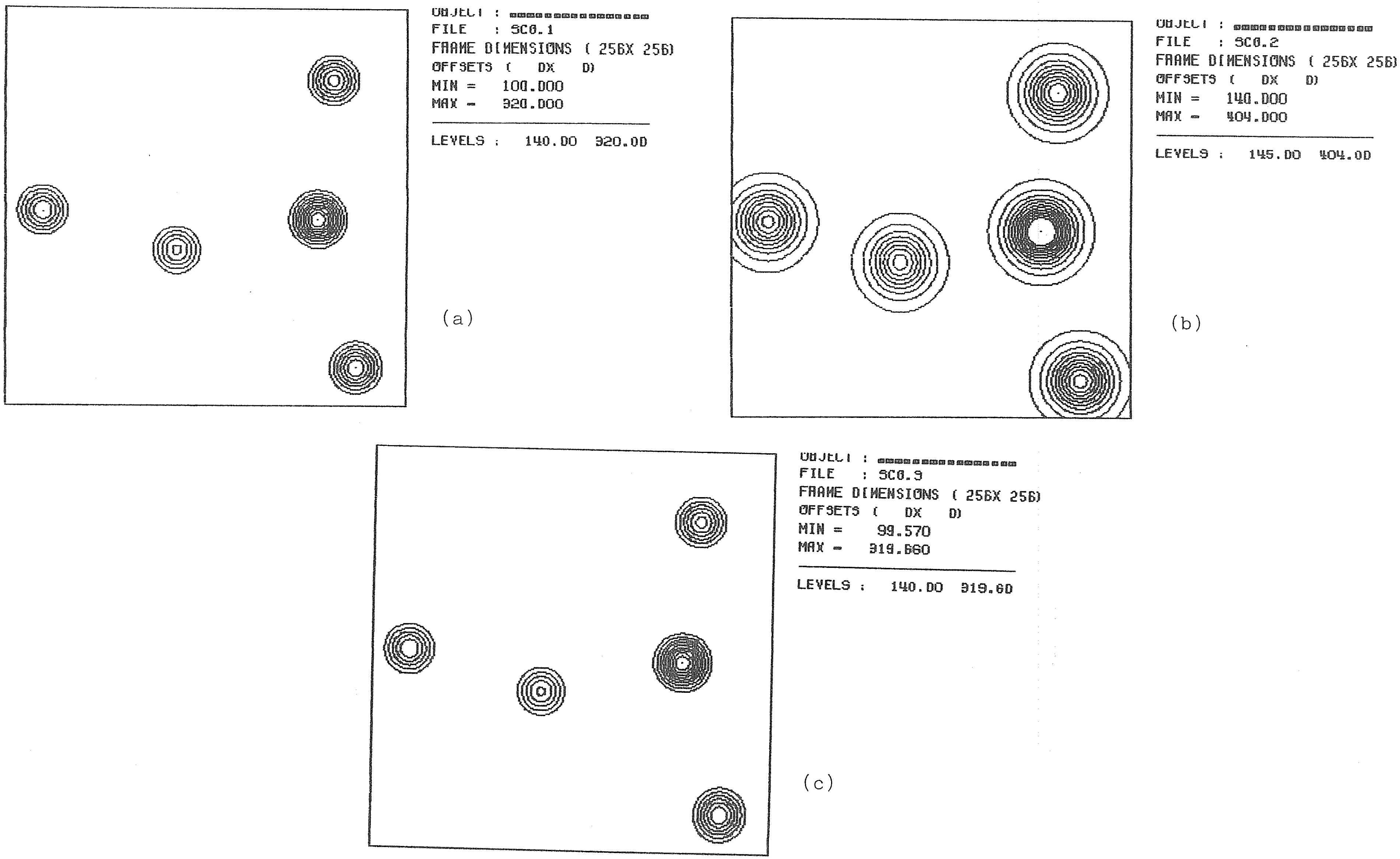

OBJECT :
FILE : SC0.1
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 100.000
MAX = 320.000
LEVELS : 140.00 320.00
(a)
OBJECT :
FILE : SC0.2
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 140.000
MAX = 404.000
LEVELS : 145.00 404.00
(b)
OBJECT :
FILE : SC0.3
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 99.570
MAX = 319.660
LEVELS : 140.00 319.60
(c)

Table 3.6(a)

File Name: SCO.1   S/N=∞ Background=20.   Sigma noise=0.

Output from STARMAG
with DATA.SC1

Object #	Coordinates X	Coordinates Y	Sigma[X,Y]	Ampl.	Peak Brightness /Background	Magn.
1	25.	125.	10.	140.	1400.6/999.6	13.137
2	110.	100.	10.	125.	1250.4/999.64	13.260
3	210.	210.	10.	150.	1500.7/999.58	13.062
4	200.	120.	10.	220.	2201.0/999.41	12.647
5	225.	25.	10.	160.	1600.7/999.56	12.992

Gaussian FWHM
Seeing=23.55

Mean axis ratio=1.

Gamma=1.997

Levels for ISOLEVEL=320.,300.,280.,260.,240.,220.,200,180.,160.,140.

Table 3.6(b)

File Name: SCO. 2   S/N= ∞ Background=28.   Sigma noise=0.

Scaling factor for Intensity=1. 2

Scaling factor for Background=1. 4

Output from STARMAG with DATA. SC1

Object #	Coordinates X	Coordinates Y	Sigma[X, Y]	Ampl.	Peak Brightness /Background	Magn.
1	25.	125.	12.	168.	1680. 5/1399. 4	12. 543
2	110.	100.	12.	150.	1500. 2/1399. 5	12. 666
3	210.	210.	12.	180.	1800. 4/1399. 4	12. 468
4	200.	120.	12.	264.	2640. 6/1399. 1	12. 052
5	225.	25.	12.	192.	1920. 6/1399. 2	12. 398

Gaussian FWHM Seeing=28. 27

Mean axis ratio=1.

Gamma=1. 997

Levels for ISOLEVEL=404. , 340. , 320. , 300. , 280. , 260. , 240. , 220. , 200, 180. , 160. , 140.

Table 3.6(c)

File Name: SCO. 3   S/N= ∞ Background=19. 914   Sigma noise=0.

Photometrically Registered Image   Output from STARMAG with DATA. sc1

Obj. #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	25.	125.	10. 048	140. 067	1401. 3/999. 35	13. 127	0. 010
2	110.	100.	10. 048	125. 031	1250. 8/995. 41	13. 250	. 010
3	210.	210.	10. 048	150. 061	1501. 4/995. 34	13. 052	. 010
4	200.	120.	10. 048	220. 090	2201. 9/995. 18	12. 636	. 011
5	225.	25.	10. 048	160. 079	1601. 5/995. 30	12. 982	. 010

Average Δm =0. 0102

Variance Δm=0. 0004

Scaling factor for Intensity[Output from SCALING]=1. 19978

Scaling factor for Background[Output from SCALING]=1. 39992

Gaussian FWHM
Seeing=23. 66

Root Mean Square Error of the Registration=0. 38934

Levels for ISOLEVEL=310. , 305. , 267. , 247. , 227. , 207. , 187. , 167. , 117.

Figure 3.12

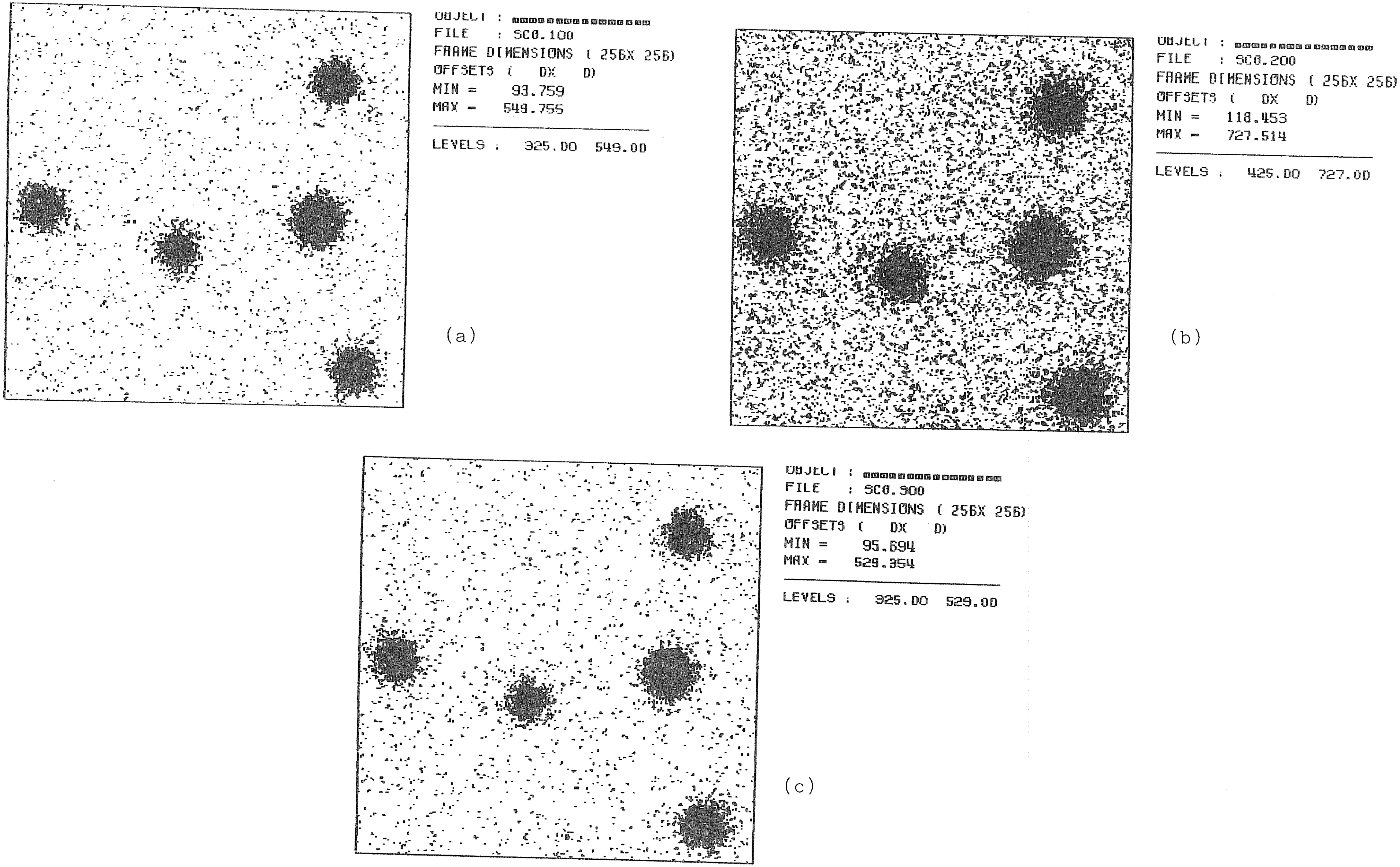

OBJECT :
FILE : SC0.100
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 93.759
MAX = 549.755
LEVELS : 325.00 549.00
(a)
OBJECT :
FILE : SC0.200
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 118.453
MAX = 727.514
LEVELS : 425.00 727.00
(b)
OBJECT :
FILE : SC0.300
FRAME DIMENSIONS (256X 256)
OFFSETS (DX D)
MIN = 95.694
MAX = 529.354
LEVELS : 325.00 529.00
(c)

Table 3.7(a)

File Name: SCO.100 S/N=4. Background=50. Sigma noise=39.750

Output from STARMAG with DATA.SC1

Object #	Coordinates X	Y	Sigma[X,Y]	Ampl.	Peak Brightness /Background	Magn.
1	25.	125.	10.	140.	1392.8/2507.4	13.154
2	110.	100.	10.	125.	1265.7/2501.8	13.258
3	210.	210.	10.	150.	1466.6/2504.3	13.098
4	200.	120.	10.	220.	2166.2/2504.3	12.674
5	225.	25.	10.	160.	1603.3/2499.0	13.001

Gaussian FWHM Seeing=23.55

Levels for ISOLEVEL=549.,500.,475.,450.,425.,400.,375.,350.,325.

Table 3.7(b)

File Name: SCO. 200   S/N=4.   Background=71.   Sigma noise=44. 322

Scaling factor for Intensity=1. 115

Scaling factor for Background=1. 42

Output from STARMAG
with DATA. SC1

Object #	Coordinates X	Y	Sigma[X, Y]	Ampl.	Peak Brightness /Background	Magn.
1	25.	125.	11. 15	156. 10	1581. 0/3546. 9	12. 780
2	110.	100.	11. 15	139. 36	1387. 4/3553. 3	12. 922
3	210.	210.	11. 15	167. 25	1636. 0/3563. 3	12. 743
4	200.	120.	11. 15	245. 30	2430. 1/3559. 7	12. 313
5	225.	25.	11. 15	178. 40	1733. 7/3563. 0	12. 680

Gaussian FWHM
Seeing=26. 15

Levels for ISOLEVEL=727. , 700. , 650. , 600. , 550. , 500. , 475. , 450. , 425.

Table 3.7(c)

File Name: SCO. 300   S/N=4.   Background=50. 095   Sigma noise=39. 496

Photometrically Registered Image   Output from STARMAG with DATA. sc1

Obj. #	Coordinates X	Y	Sigma [X, Y]	Ampl.	Peak Brightness /Background	Magn.	Δm
1	25.	125.	10. 045	142. 430	1420. 2/2511. 6	13. 123	0. 031
2	110.	100.	10. 045	124. 992	1249. 8/2505. 6	13. 262	-. 004
3	210.	210.	10. 045	147. 388	1454. 9/2510. 6	13. 097	. 001
4	200.	120.	10. 045	218. 929	2166. 8/2514. 4	12. 664	. 010
5	225.	25.	10. 045	156. 191	1519. 1/2516. 9	13. 050	-. 049

Average Δm =-0. 0022

Variance Δm=0. 0294

Scaling factor for Intensity[Output from SCALING]=1. 10999

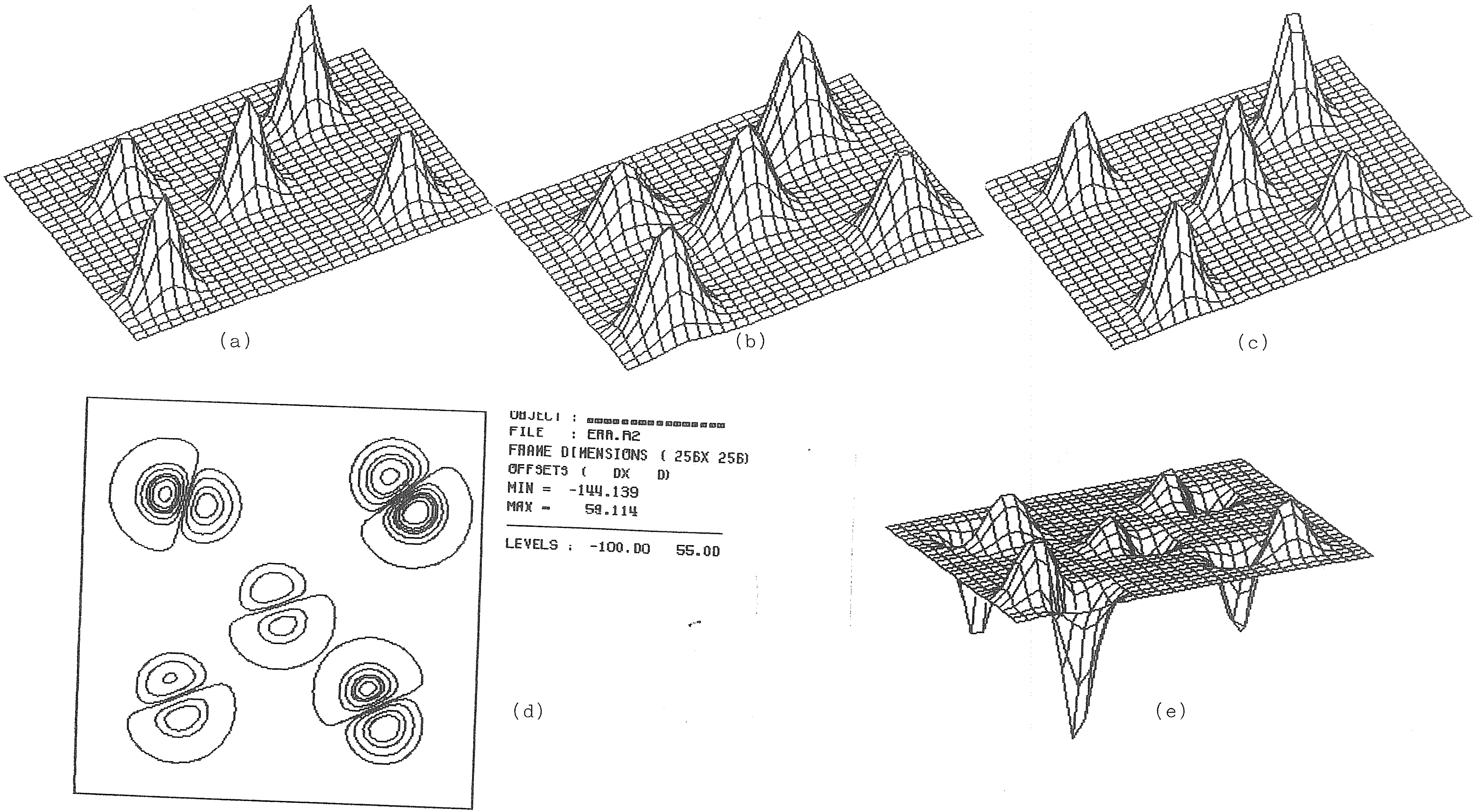
Scaling factor for Background[Output from SCALING]=1. 42021

Gaussian FWHM Seeing=23. 57

Root Mean Square Error of the Registration=0. 65317

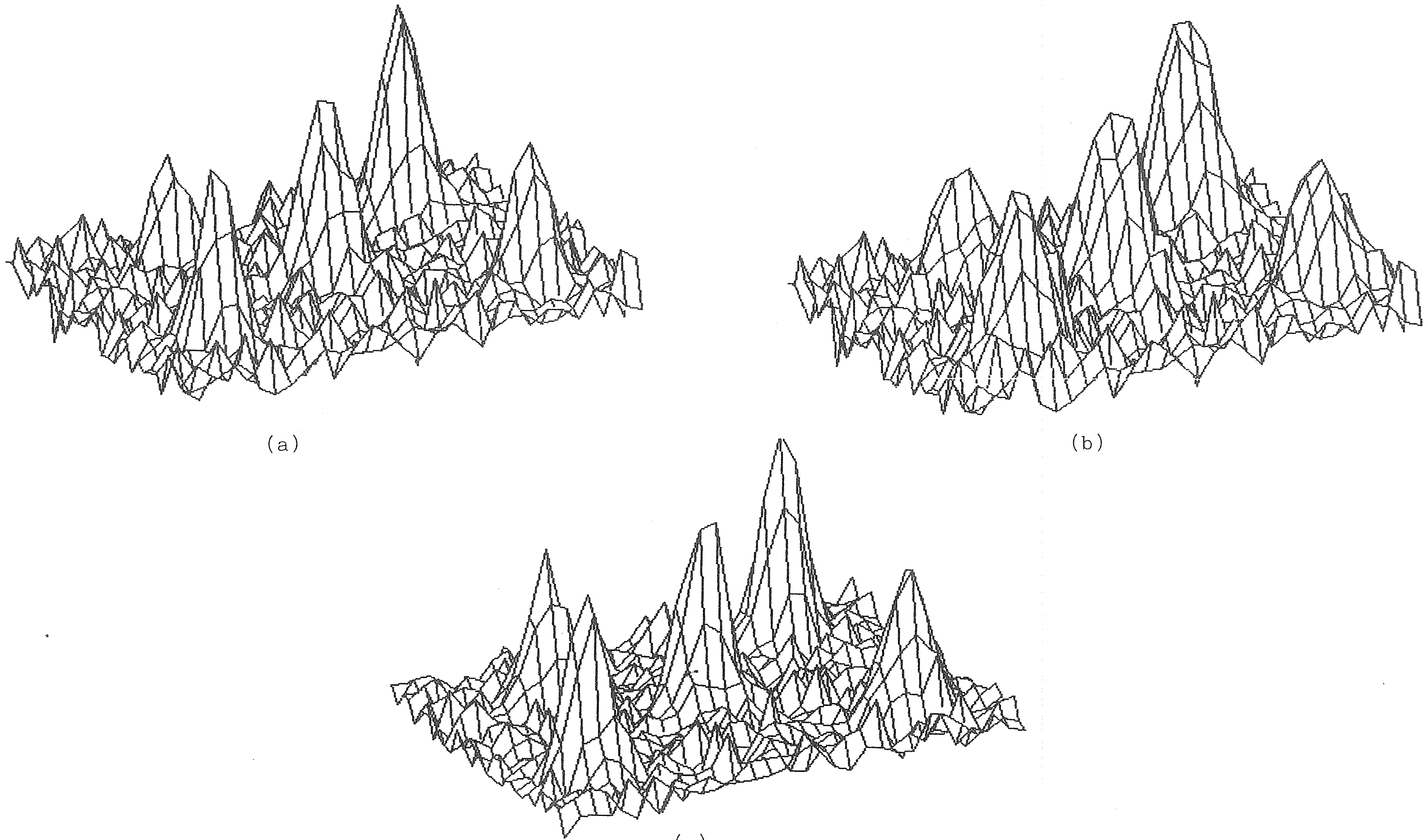
Levels for ISOLEVEL=549. , 500. , 475. , 450. , 425. , 400. , 375. , 350. , 325.

Figure 3.13



(a) (b) (c) (d) (e)

Figure 3.14



(a) (b) (c)

Table 3.8

File Name: AQR. 10   S/N=10.   Background=20.   Sigma noise=14.
Template Image

Output from STARMAG
with DATA. 10

Object #	Coordinates X	Coordinates Y	Sigma[X,Y]	Ampl.	Peak Brightness /Background	Magn.
1	64.	67.	10.	180.875	1813.3/998.34	12.859
2	78.	189.	10.	102.	1022.7/997.21	13.480
3	127.	128.	10.	158.	1583.6/995.51	13.006
4	198.	52.	10.	123.	1208.2/1001.6	13.300
5	198.	210.	10.	160.	1595.6/1001.5	12.998

Gaussian FWHM
Seeing=23.45

Table 3.9(1)

File Name: AQR.20   S/N=10.   Background=24.   Sigma noise=20.29

Scaling factor for Intensity=1.4

Scaling factor for Background=1.2

Output from STARMAG with DATA.20

Object #	Ampl.	Peak Brightness /Background	Magn.
1	254.625	1697.7/1019.3	12.930
2	142.8	945.54/1013.0	13.565
3	221.2	1417.2/1021.8	13.126
4	172.2	1001.7/1039.6	13.503
5	224.0	975.26/1096.4	13.532

Transformation coefficients=

C(1)=2.10002   C(2)=.999857   C(3)=-.261821E-01

C(4)=2.09992   C(5)=.261822E-01   C(6)=.999858

Table 3.9(1)

File Name: AQR. 20   S/N=10.   Background=24.   Sigma noise=20. 29

Scaling factor for Intensity=1. 4

Scaling factor for Background=1. 2

Output from STARMAG
with DATA. 20

Object #	Ampl.	Peak Brightness /Background	Magn.
1	254. 625	1697. 7/1019. 3	12. 930
2	142. 8	945. 54/1013. 0	13. 565
3	221. 2	1417. 2/1021. 8	13. 126
4	172. 2	1001. 7/1039. 6	13. 503
5	224. 0	975. 26/1096. 4	13. 532

Transformation coefficients=

C(1)=2. 10002   C(2)=. 999857   C(3)=-. 261821E-01

C(4)=2. 09992   C(5)=. 261822E-01   C(6)=. 999858

Table 3.9(3)

File Name: AQR.30   S/N=10.   Background=28.   Sigma noise=19.1

Scaling factor for Intensity=1.3

Scaling factor for Background=1.4

Output from STARMAG
with DATA.30

Object #	Ampl.	Peak Brightness /Background	Magn.
1	236.85	2364.6/1401.3	12.010
2	132.56	1330.3/1398.6	12.634
3	205.4	2060.2/1402.3	12.159
4	159.9	1578.6/1404.9	12.449
5	208.	2075.8/1404.7	12.151

Transformation coefficients=

C(1)=2.09989   C(2)=.987889   C(3)=-.224182E-01

C(4)=2.0999   C(5)=.224187E-01   C(6)=.987888

Table 3.9(4)

File Name: AQR.30   S/N=10.   Background=19.995 Sigma noise=14.45

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1.30231

Scaling factor for Background[Output from SCALING]=1.40269

Output from STARMAG
with DATA.10

Obj.	METHODS							
#	1		2		3		4	
	Mag.	Δm	Mag.	Δm	Mag.	Δm	Mag.	Δm
1	12.892	-.033	12.899	-.040	12.900	-.041	12.898	-.039
2	13.593	-.113	13.620	-.140	13.619	-.139	13.618	-.138
3	13.061	-.055	13.084	-.078	13.081	-.075	13.080	-.074
4	13.357	-.057	13.358	-.058	13.360	-.060	13.358	-.058
5	13.170	-.172	13.189	-.191	13.188	-.190	13.188	-.190

Table 3.9(5)

File Name:AQR.40   S/N=10.   Background=30.   Sigma noise=16.45

Scaling factor for Intensity=1.1

Scaling factor for Background=1.5

Output from STARMAG
with DATA.40

Object #	Ampl.	Peak Brightness /Background	Magn.
1	225.432	2254.5/1499.2	12.424
2	112.2	1129.2/1495.6	13.175
3	173.8	1746.8/1500.1	12.701
4	135.3	1335.1/1502.7	12.993
5	176.	1756.1/1504.0	12.695

Transformation coefficients=

C(1)=2.09762   C(2)=.971607   C(3)=-.203519E-01

C(4)=2.09988   C(5)=.203524E-01   C(6)=.971604

Table 3.9(6)

File Name: AQR. 40   S/N=10.   Background=19.993   Sigma noise=14.90

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1.10320

Scaling factor for Background[Output from SCALING]=1.50067

Output from STARMAG
with DATA.10

Obj. #	METHODS 1		2		3		4	
	Mag.	Δm	Mag.	Δm	Mag.	Δm	Mag.	Δm
1	12.742	.117	12.748	.110	12.747	.112	12.746	.113
2	13.617	-.137	13.626	-.146	13.630	-.150	13.628	-.148
3	13.071	-.065	13.079	-.073	13.079	-.073	13.078	-.072
4	13.386	-.086	13.389	-.089	13.384	-.084	13.383	-.083
5	13.269	-.271	13.269	-.271	13.271	-.273	13.269	-.271

Table 3.9(7)

File Name: AQR. 50   S/N=10.   Background=34.   Sigma noise=24.25

Scaling factor for Intensity=1.6

Scaling factor for Background=1.7

Output from STARMAG
with DATA.50

Object #	Ampl.	Peak Brightness /Background	Magn.
1	344.0	3432.0/1704.3	11.154
2	163.2	1557.9/1719.8	11.976
3	252.8	2527.8/1706.9	11.486
4	196.8	1963.4/1705.0	11.761
5	256.	2559.2/1708.7	11.473

Transformation coefficients=

C(1)=1.09992   C(2)=.999602   C(3)=-.244293E-01

C(4)=1.10004   C(5)=.244298E-01   C(6)=.999601

Table 3.9(8)

File Name: AQR. 50   S/N=10.   Background=19.992 Sigma noise=15.11

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1.59987

Scaling factor for Background[Output from SCALING]=1.70721

Output from STARMAG
with DATA. 10

Obj.	METHODS							
#	1		2		3		4	
	Mag.	Δm	Mag.	Δm	Mag.	Δm	Mag.	Δm
1	12.714	.145	12.718	.141	12.718	.141	12.717	.142
2	13.630	-.150	13.638	-.158	13.638	-.158	13.636	-.156
3	13.077	-.071	13.106	-.100	13.104	-.098	13.102	-.096
4	13.374	-.074	13.387	-.087	13.385	-.085	13.385	-.085
5	13.201	-.203	13.225	-.227	13.224	-.226	13.223	-.225

Table 3.9(9)

File Name: AQR. 60   S/N=10.   Background=24. 2   Sigma noise=17. 54

Scaling factor for Intensity=1. 15

Scaling factor for Background=1. 21

Output from STARMAG with DATA. 60

Object #	Ampl.	Peak Brightness /Background	Magn.
1	253. 0	2527. 2/1211. 3	12. 204
2	117. 3	1185. 7/1204. 7	13. 050
3	181. 7	1827. 7/1210. 0	12. 555
4	141. 45	1400. 8/1211. 8	12. 844
5	184.	1835. 1/1213. 8	12. 551

Transformation coefficients=

C(1)=1. 00382   C(2)=. 999733   C(3)=-. 174987E-01

C(4)=0. 841274   C(5)=. 182545E-01   C(6)=1. 00051

Table 3.9(10)

File Name: AQR. 60   S/N=10.   Background=20. 003 Sigma noise=15. 19

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1. 15500

Scaling factor for Background[Output from SCALING]=1. 21013

Output from STARMAG with DATA. 10

Obj. #	METHODS 1		2		3		4	
	Mag.	Δ m	Mag.	Δ m	Mag.	Δ m	Mag.	Δ m
1	12. 680	. 174	12. 694	. 165	12. 694	. 165	12. 693	. 116
2	13. 549	-. 069	13. 569	-. 089	13. 567	-. 087	13. 565	-. 085
3	13. 048	-. 042	13. 073	-. 067	13. 058	-. 052	13. 071	-. 070
4	13. 375	-. 075	13. 373	-. 073	13. 365	-. 065	13. 370	-. 070
5	13. 140	-. 014	13. 142	-. 144	13. 143	-. 145	13. 141	-. 143

Table 3.9(11)

File Name:AQR.70   S/N=10.   Background=31.6   Sigma noise=24.53

Scaling factor for Intensity=1.75

Scaling factor for Background=1.58

Output from STARMAG
with DATA.70

Object #	Ampl.	Peak Brightness /Background	Magn.
1	376.25	3739.1/1596.6	10.867
2	178.5	1720.5/1620.2	11.710
3	276.5	2687.1/1633.7	11.226
4	215.25	2122.0/1592.4	11.482
5	280.	2781.5/1594.6	11.188

Transformation coefficients=

C(1)=2.19995   C(2)=1.00170   C(3)=-.244807E-01

C(4)=2.19988   C(5)=.244816E-01   C(6)=1.00171

Table 3.9(12)

File Name: AQR. 70   S/N=10.   Background=19.966 Sigma noise=15.16

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1.71900

Scaling factor for Background[Output from SCALING]=1.61016

Output from STARMAG with DATA.10

Obj.	METHODS							
#	1		2		3		4	
	Mag.	Δm	Mag.	Δm	Mag.	Δm	Mag.	Δm
1	12.682	.177	12.697	.162	12.694	.162	12.696	.163
2	13.650	-.170	13.667	-.187	13.666	-.186	13.666	-.186
3	13.100	-.094	13.111	-.105	13.111	-.105	13.110	-.104
4	13.347	-.047	13.347	-.047	13.347	-.047	13.347	-.047
5	13.193	-.195	13.213	-.215	13.215	-.217	13.213	-.215

Table 3.9(13)

File Name: AQR. 80   S/N=10.   Background=25. 80   Sigma noise=13. 18

Scaling factor for Intensity=. 877

Scaling factor for Background=1. 29

Output from STARMAG
with DATA. 80

Object #	Ampl.	Peak Brightness /Background	Magn.
1	179. 732	1793. 3/1290. 6	13. 165
2	89. 45	896. 5/1290. 5	13. 917
3	138. 56	1387. 9/1292. 9	13. 443
4	107. 87	1071. 6/1287. 4	13. 724
5	140. 32	1409. 6/1288. 2	13. 426

Transformation coefficients=

C(1)=. 998471E-01 C(2)=. 999810 C(3)=-. 195460E-01

C(4)=. 998770E-01 C(5)=. 195467E-01 C(6)=. 999810

Table 3.9(14)

File Name: AQR.80   S/N=10.   Background=20.381   Sigma noise=14.95

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=.87710

Scaling factor for Background[Output from SCALING]=1.28900

Output from STARMAG
with DATA.10

Obj. #	METHODS 1		2		3		4	
	Mag.	Δm	Mag.	Δm	Mag.	Δm	Mag.	Δm
1	12.740	.119	12.756	.103	12.754	.105	12.754	.105
2	13.551	-.071	13.549	-.187	13.549	-.069	13.548	-.068
3	13.055	-.049	13.064	-.058	13.063	-.057	13.061	-.055
4	13.369	-.069	13.376	-.076	13.375	-.075	13.374	-.074
5	13.114	-.116	13.133	-.135	13.132	-.134	13.132	-.134

Table 3.9(15)

File Name: AQR.90   S/N=10.   Background=75.60   Sigma noise=21.341

Scaling factor for Intensity=1.45

Scaling factor for Background=3.78

Output from STARMAG with DATA.90

Object #	Ampl.	Peak Brightness /Background	Magn.
1	278.29	2778.9/3782.9	11.597
2	147.9	1467.5/3786.9	12.290
3	229.1	2281.0/3791.4	11.812
4	178.3	1753.5/3789.7	12.097
5	232.0	2313.1/3787.0	11.796

Transformation coefficients=

C(1)=.100366   C(2)=.998746   C(3)=-.230230E-01

C(4)=.83787E-01   C(5)=.225929E-01   C(6)=.999159

Table 3.9(16)

File Name: AQR. 90   S/N=10.   Background=19. 998 Sigma noise=14. 67

Geometrically and Photometrically Registered Image

Scaling factor for Intensity[Output from SCALING]=1. 44408

Scaling factor for Background[Output from SCALING]=3. 78793

Output from STARMAG
with DATA. 10

Obj. #	METHODS 1		2		3		4	
	Mag.	△ m	Mag.	△ m	Mag.	△ m	Mag.	△ m
1	12. 813	. 046	12. 816	. 043	12. 808	. 051	12. 815	. 044
2	13. 539	-. 059	13. 569	-. 089	13. 559	-. 079	13. 565	-. 085
3	13. 065	-. 059	13. 075	-. 069	13. 055	-. 049	13. 073	-. 067
4	13. 390	-. 090	13. 397	-. 097	13. 367	-. 067	13. 394	-. 094
5	13. 172	-. 174	13. 174	-. 176	13. 143	-. 145	13. 175	-. 177

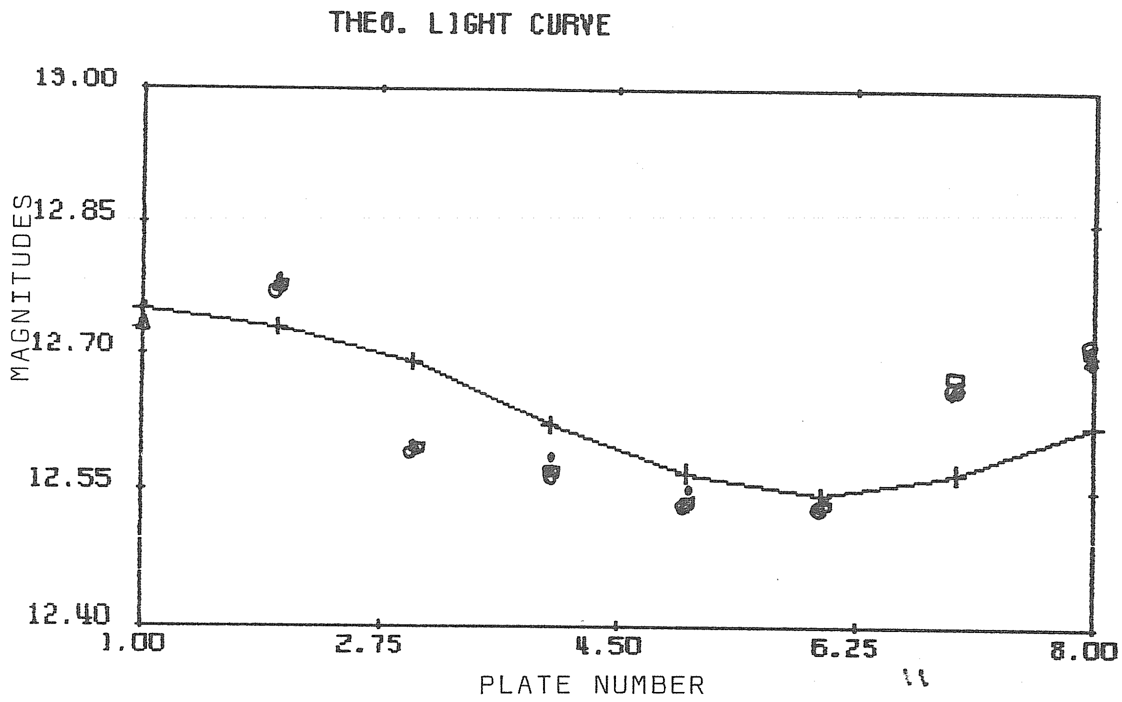

THEO. LIGHT CURVE
13.00
12.85
12.70
12.55
12.40
MAGNITUDES
1.00
2.75
4.50
6.25
8.00
PLATE NUMBER

Figure 3.15

Figure 3.16

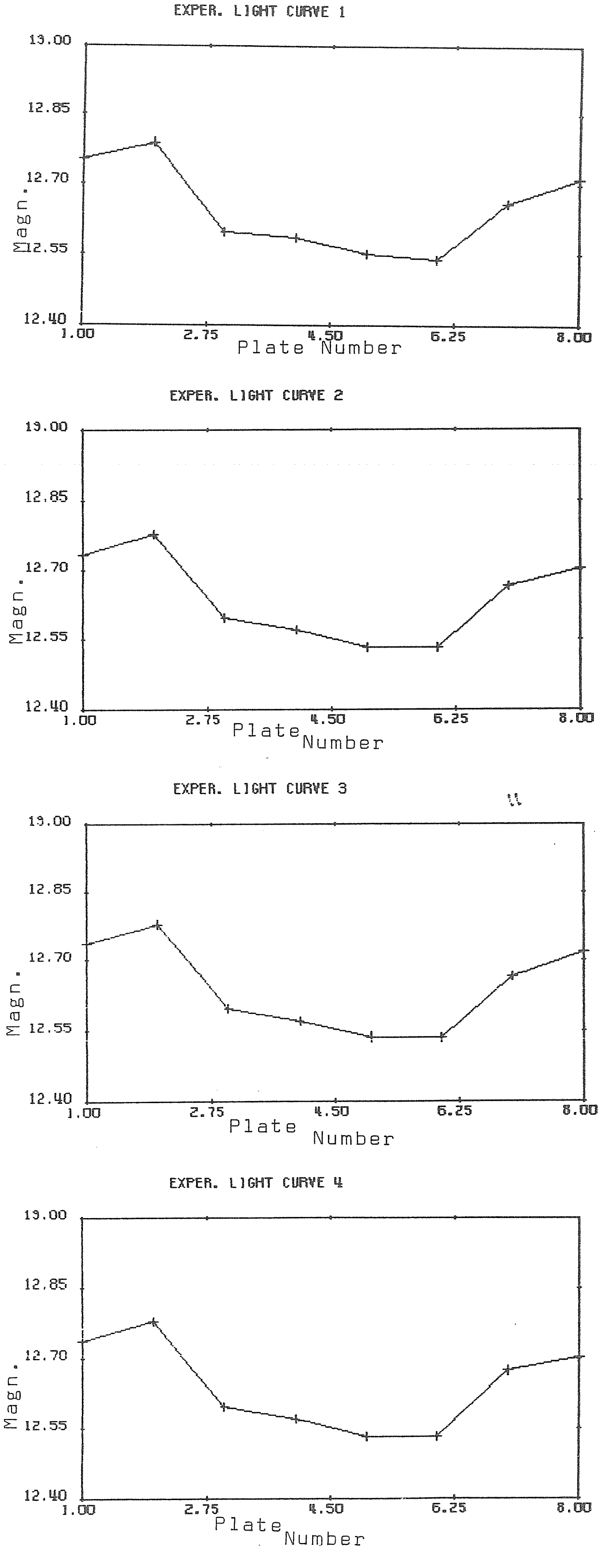
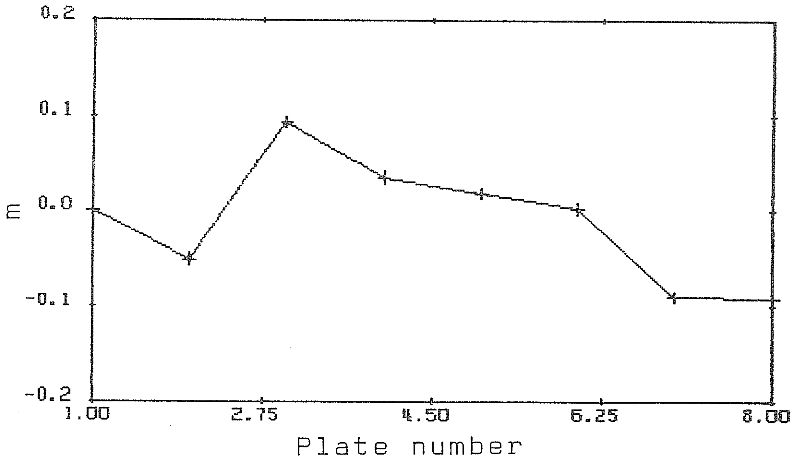
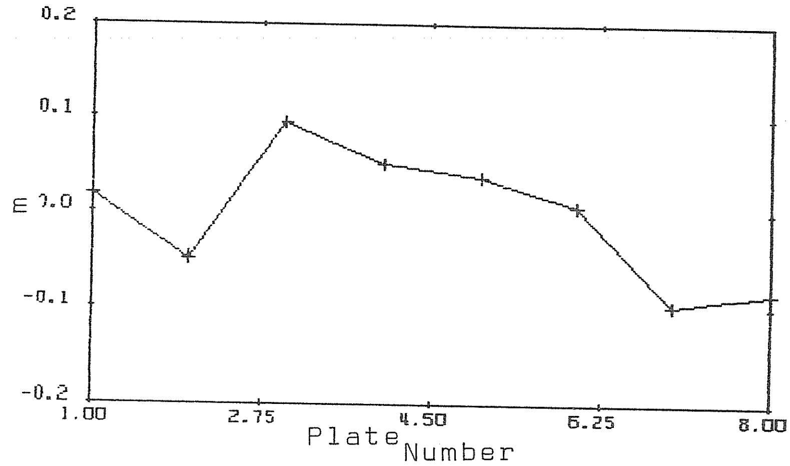

EXPER. LIGHT CURVE 1
13.00
12.85
12.70
12.55
12.40
Magn.
1.00
2.75
4.50
6.25
8.00
Plate Number
EXPER. LIGHT CURVE 2
13.00
12.85
12.70
12.55
12.40
Magn.
1.00
2.75
4.50
6.25
8.00
Plate Number
EXPER. LIGHT CURVE 3
13.00
12.85
12.70
12.55
12.40
Magn.
1.00
2.75
4.50
6.25
8.00
Plate Number
EXPER. LIGHT CURVE 4
13.00
12.85
12.70
12.55
12.40
Magn.
1.00
2.75
4.50
6.25
8.00
Plate Number

Figure 3.17

Ave. Δm=-.01126
Var. Δm= .0650
Max. Δm=.094
Min. Δm=-.098 (a)

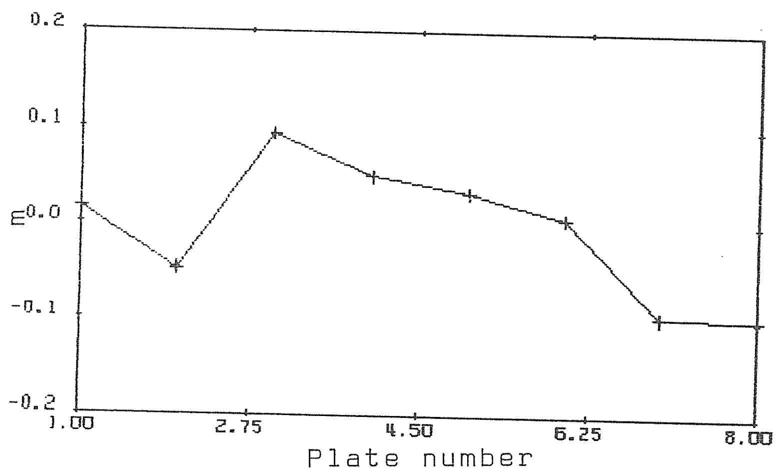


Ave. Δm=-.00299
Var. Δm=.06735
Max. Δm=.093
Min. Δm=-.098 (b)



Ave. Δm=-.00603
Var. Δm=.06978
Max. Δm=.094
Min. Δm=-.099

(c)



Ave. Δm=-.00474
Var. Δm=.0694
Max. Δm=.094
Min. Δm=-.108

(d)

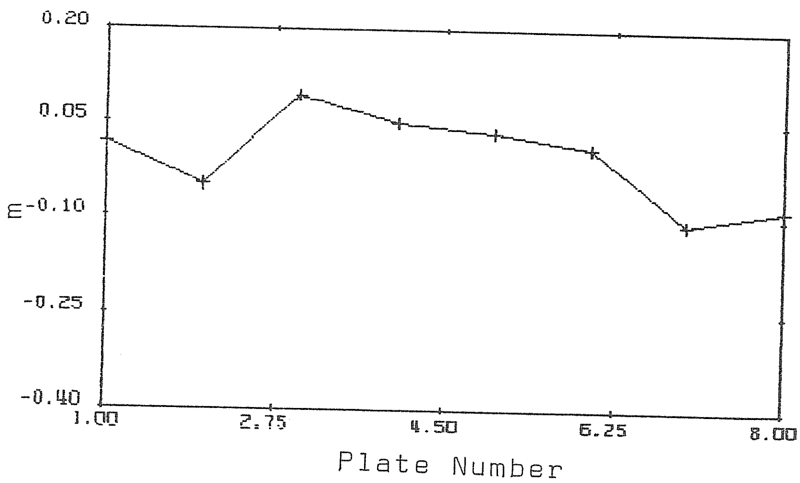


Table 3.10

PLATE #	METHODS 1	2	3	4
1	.0797	.0844	.0848	.0842
2	.0554	.0606	.0601	.0608
3	.0926	.0898	.0919	.0914
4	.0638	.0639	.0645	.0644
5	.0850	.0848	.0918	.0857
6	.0682	.0768	.0773	.0768
7	.0283	.0345	.0343	.0351
8	.0543	.0506	.0458	.0521
Var. Δm over plates	.06591	.06818	.06881	.06881

STAR #	METHODS			
1	.0517	.0598	.0634	.0591
2	.0472	.0328	.0356	.0331
3	.0165	.0248	.0204	.0234
4	.0603	.0609	.0661	.0605
Var. Δm over stars (ref.)	.04394	.04458	.04641	.04402
GLOBAL VAR. Δm	.05492	.05638	.05746	.05641