**Major Project**

**On**

# Development of Photometric Data Pipeline in IDL

**By**

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**May 2008**

**Major Project**

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# Development of Photometric Data Pipeline in IDL

Submitted in partial fulfillment of the requirements

For the degree of

**Master of Technology in Computer Science & Engineering**

By

**Tejasvee Gupta**
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Under Guidance of

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This is to certify that Dissertation entitled

**Development of Photometric Data Pipeline in IDL**

Submitted by

Tejasvee Gupta

has been accepted toward fulfillment of the requirement
for the degree of
Master of Technology in Computer Science & Engineering

| | |
|---|---|
| Dr. S. N. Pradhan | Prof. D. J. Patel |
| Professor | Head of Department |

Prof. A. B. Patel
Director, Institute of Technology

*CERTIFICATE*

This is to certify that the work presented here by **Mr. Tejasvee Gupta** entitled "Development of Photometric Data Pipeline in IDL**"** has been carried out at **Physical Research Laboratory, Ahmedabad** during the period **September 2007 – May 2008** is the bonafide record of the research carried out by him under my guidance and supervision and is up to the standard in respect of the content and presentation for being referred to the examiner. I further certify that the work done by him is his original work and has not been submitted for award of any other diploma or degree.

**Dr. Abhijit Chakraborty**

Astronomy & Astrophysics Division,
Physical Research Laboratory, Ahmedabad.

**Date:**

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# ABSTRACT

This project develops an algorithm for the Data Pipeline in IDL. Series of images observed in a single night or over many nights are processed. And the variations in the stars magnitude during the period of observation are identified.

In the first part of the project the starting steps to identify the stars randomly from an image are performed. The language used to develop the algorithm is IDL. The prime aim of data pipeline is to detect photometric variability in stars that could be due to various astronomical reasons.

Initially the densely populated images are used. For the images chosen the stars are identified with their pixel position. Next their magnitudes are calculated. This experiment has been repeated for a few images to check the compatibility of program with different images.

Finally a series of image is used as input to this program. The stars and their magnitudes are identified. And also the variations among these stars are identified.

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# Chapter 1

# INTRODUCTION

## 1.1 General

There is vast number of researches going on the astronomical data. This project is also based on the analysis of astronomical data. Here an available data from the sources issued by Astronomical resources is being analyzed to detect the presence of stars and individually identify each star and find its attributes.

Like our Solar system has a star called Sun, there are many other stars present in the universe. Unlike Sun they might also have planets revolving around them. The stars being the source of light are bright and easily visible. On the other hand the other celestial body reflects the light of the stars nearby and hence is less bright.

Archival data for research work are available on the sites for astronomical researches. One such image of a galaxy is used here to be analyzed in the initial phase. This image displays thousands of stars. The analyses to be done need some working environment so here IDL (Interactive data language) will be used. IDL, short for interactive data language is a programming language that is a popular data analysis language among scientists.

The work that is to be done in first phase is to identify the stars from the images and calculate there magnitudes of luminosity.

In the later phase this developed procedure is applied to a series of images. The images are taken over intervals for a particular location. The magnitudes obtained are compared to observe the variations among these stars. The observations also helps to identify if a star may be having celestial bodies revolving around them.

## 1.2 Motivation

There has always been the greed of discoveries in the astronomical world. One such topic is extra solar planets.

An extra solar planet or exoplanet, is a planet beyond solar system. As of April 2008, 287 exoplanets have been detected. The first confirmed detections were made in 1990s; since 2000, more than 15 planets have been discovered every year. It is estimated that at least 10% of sun-like stars have planets. The discovery of extra solar planets sharpens the question of whether some might support extraterrestrial life.

Planets are extremely faint light sources compared to their parent stars. They usually have a less than a millionth of their parent star’s brightness. In addition to the intrinsic difficulty of detecting such a faint light source, the parent star causes a glare that washes it out. For those reasons, current telescopes can only directly image exoplanets under exceptional circumstances. Specifically it may be possible when the planet is especially large (considerably larger than Jupiter), widely separated from its parent star, and hot so it emits intense infrared radiation. The vast majority of known exoplanets have been discovered through indirect methods. One such method is transit method.

If a planet crosses (or transits) in front of its parent star, then the observed brightness of star drops by a small amount. The amount by which the star dims depends on its size and on the size of the planet. This project is also contributes some effort in doing the transit search.

## 1.3 Scope of the Work

Photometry is a technique of astronomy concerned with measuring the flux or intensity of an astronomical object. This project also does same kind of procedure that leads to the transit search. The change in relative magnitudes helps to identify the stars with celestial bodies/planets around it.

This kind of algorithm is also developed by other users/researchers but they are not released for public use. This project is also such a kind. But this algorithm can be used as a generalized algorithm for the transit search.

## 1.4 Organization of report

- Chapter 2 gives a few characteristics of the working environment.
- Chapter 3 describes the already existing various methods for detecting the presence of extra solar planets. Also this chapter gives the details of the procedure used in this project to identify the stars with possibility of planets around them. The various modules used to support this procedure are also described.
- Chapter 4 gives the flowchart of the development of main program and the detailed steps.
- Chapter 5 shows the derived results of the programs. Also the concluding graph is included that will give the final conclusion of the project.
- Chapter 6 gives the conclusion of the program.

# Chapter 2

# About the Development Tool

## Working Environment

**IDL**, short for **interactive data language**, is a programming language that is a popular data analysis language among scientists. IDL is often confused, at the acronym level, with another (unrelated) "IDL": the Interface description language.

IDL is vectorized, numerical, and interactive, and it is commonly used for interactive processing of large amounts of data (including image processing). The syntax includes many constructs from FORTRAN and some from C.

As most other array programming languages, IDL is very fast doing vector operations (sometimes as fast as a well-coded custom loop in FORTRAN or C) but quite slow if elements need processing individually. Hence part of the art of using IDL (or any other array programming language, for that matter) for numerically heavy computations is to make use of the inbuilt vector operations.

As a computer language, IDL:

-is dynamically typed.

-has a single namespace

- was originally single threaded but now has many multi-threaded functions and procedures.
- has all function arguments passed by reference ("IN-OUT")
- has named parameters called keywords which are passed by reference.
- provides named parameter inheritance in nested routine calls, by reference or value.
- does not require variables to be predeclared.
- provides only COMMON block declarations to share global values among routines.
- provides a basic form of object-oriented programming.
- implements a persistent, global heap of pointer and object variables.
- compiles to an interpreted, stack-based intermediate p-code (à la Java VM).

- provides a simple and efficient index slice syntax to extract data from large arrays.
- provides various integer sizes, as well as single and double precision floating point real and complex numbers.
- provides composite data types such as character strings, homogeneous-type arrays, and simple (non-hierarchical) record structures of mixed data types.

# Chapter 3

# PROCEDURE

## 3.1 Detection methods

Exoplanets have been discovered through indirect methods:

- **Astrometry**: Astrometry consists of precisely measuring a star's position in the sky and observing the ways in which that position changes over time. If the star has a planet, then the gravitational influence of the planet will cause the star itself to move in a tiny circular or elliptical orbit about their common center of mass.
- **Radial velocity or Doppler method:** Variations in the speed with which the star moves towards or away from Earth — that is, variations in the radial velocity of the star with respect to Earth — can be deduced from the displacement in the parent star's spectral lines due to the Doppler effect[. This has been by far the most productive technique used.
- **Pulsar timing:** A pulsar (the small, ultra dense remnant of a star that has exploded as a supernova) emits radio waves extremely regularly as it rotates. Slight anomalies in the timing of its observed radio pulses can be used to track changes in the pulsar's motion caused by the presence of planets.
- **Transit method:** If a planet crosses (or transits) in front of its parent star's disk, then the observed brightness of the star drops by a small amount. The amount by which the star dims depends on its size and on the size of the planet.
- **Gravitational microlensing:** Microlensing occurs when the gravitational field of a star acts like a lens, magnifying the light of a distant background star. Possible planets orbiting the foreground star can cause detectable anomalies in the lensing event light curve.
- **Circumstellar disks:** Disks of space dust surround many stars, and this dust can be detected because it absorbs ordinary starlight and re-emits it

as infrared radiation. Features in dust disks may suggest the presence of planets.

- **Eclipsing binary:** In an eclipsing double star system, the planet can be detected by finding variability in minima as it goes back and forth. It is the most reliable method for detecting planets in binary star systems.
- **Orbital phase:** Like the phase of the Moon and Venus, extrasolar planets also have phases. Orbital phases depend on inclination of the orbit. By studying orbital phases scientists can calculate particle sizes in the atmospheres of planets.
- **Polarimetry:** Stellar light becomes polarized when it interacts with atmospheric molecules, which could be detected with a polarimeter. So far one planet has been studied by this method.

Not counting a few exceptions, all known extrasolar planet candidates have been found using ground-based telescopes. However, many of the methods can yield better results if the observing telescope is located above the restless atmosphere. COROT (launched in December, 2006) is the only active space mission dedicated to extrasolar planet search. Hubble Space Telescope has also found or confirmed a few planets. There are many planned or proposed space missions such as Kepler, New Worlds Mission, Darwin, Space Interferometry Mission, Terrestrial Planet Finder, and PEGASE.

## 3.2 Procedure

This project is also a part of transit search method. The variations in magnitudes of stars will help to identify the stars with possibility of planets around them.

The Astronomical Data Pipeline reduction will include the following issues

i. Determine the mean FWHM of stars in the field.

ii. Extracting stars from the field with accurate x,y pixel position of the image.

iii. Determine the median flux of all stars in a large square degree FOV Image, the total number of stars may vary from 1000 to 10000 or even more.

iv. Determine the magnitude of the extracted stars and normalizing the stars magnitudes with respect to the median flux determined by step1.
v. Repeating the above 4 steps for a series of images observed in a single night and/or over several nights and determining the variations in the stars magnitudes during the period of observations.

For the first phase of this project a single image of the m36 galaxy is used to do the calculations. This image is available from the astronomical data resources. Later in the further phases the images of a same location will be analyzed to observe the variations. The variability in stars may be due to various astrophysical reasons:

- extra solar planet transit
- gravitational micro-lensing phenomena
- stellar activity
- eclipsing binaries
- nova, etc

**Figure 3.1** Image of the m36 cluster

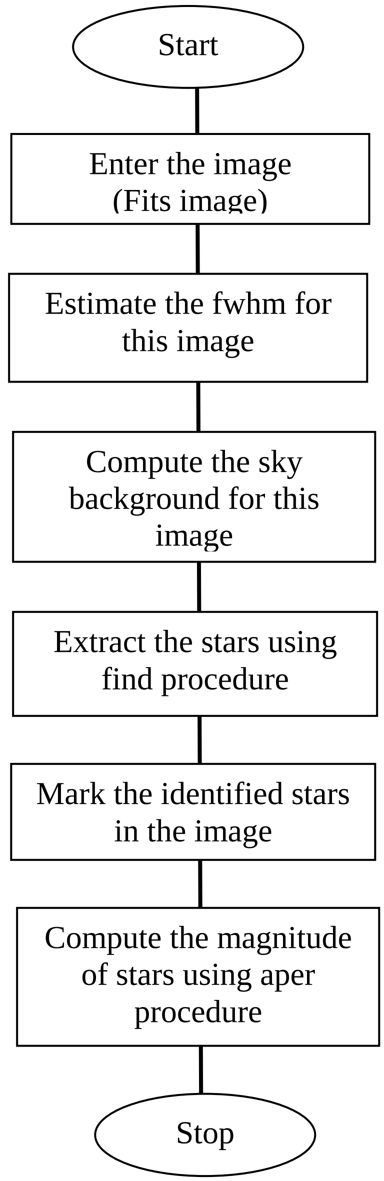


**Figure 3.2** Flowchart of Steps Followed

### 3.3 Need for FWHM

Stars are point sources. However the image formed of stars by focusing through a lens is not a point but a blurred spot. Thus point sources emit light which is processed by the optical system, because of diffraction; this light is smeared out into some sort of blur spot over a finite area on the image plane rather than focus to a point. When this patch is scanned the distribution of intensities can be described by a mathematical function. This function is known as the point spread function (PSF) of the lens. It is the impulse response of the system whether it is optically perfect or not. In a well corrected system, apart from a multiplicative constant the PSF is the Airy irradiance distribution function centered in the Gaussian image point. The value of the spread function depends only on the displacement of that location from the particular image point on which the PSF is centered.

For an object spread across an area or several pixels the object is no more just a point. We must therefore give a precise meaning to the term ‘co-ordinates’ or ‘position’. In order to determine the co-ordinate of the object, the centre of area is chosen as the representative position. The centre of area is estimated by the centre of mass or centroid of the object. Also determining the position of a star by just taking best give the precision of measurement to one pixel. It is therefore highly preferable to determine the centre of mass or centroid.

When the image of space is taken, then it is seen that due to high luminosity bright stars can shadow faint neighbors. In a crowded image like the one in fig1 there are over thousands of stars. The stars those are bright are easily visible, but some of them are not.

So here we use PSF fitting to identify bright good stars. Each star is identified or scanned individually and its magnitude is calculated. All the stars above a threshold values are selected.

The area under the curve will give the magnitude of the stars.

The surface plot view of the m36 galaxy when plotted against intensities is as shown below:

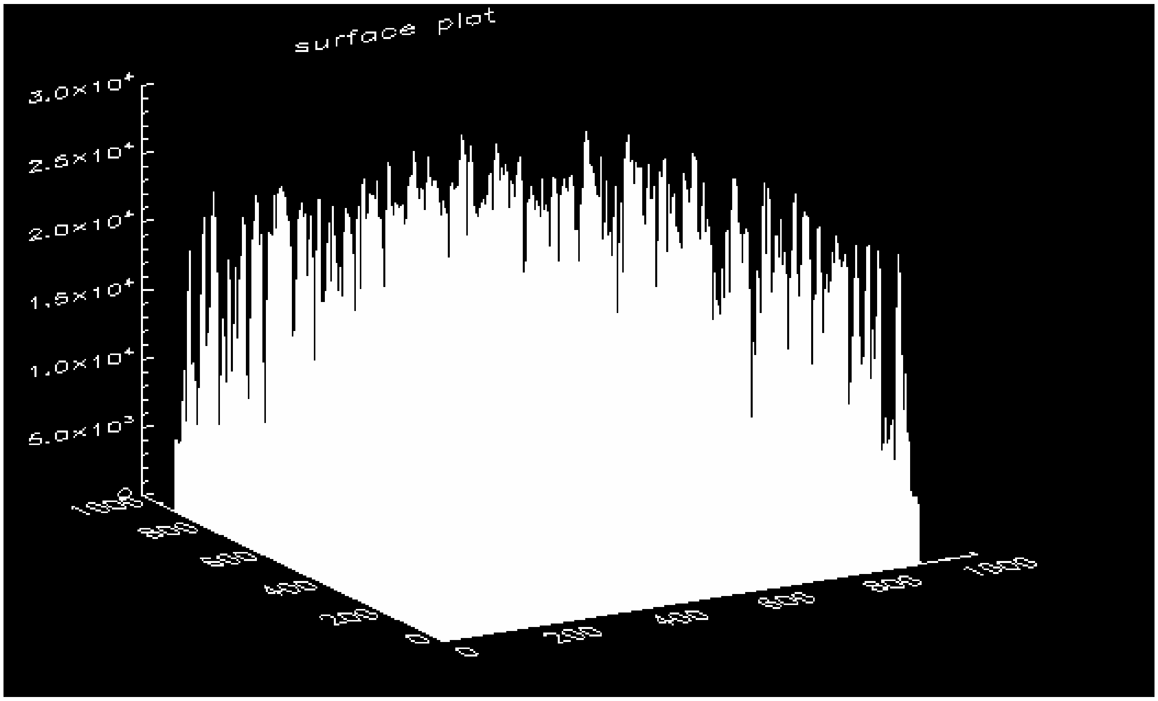


**Figure 3.3** Surface plot of m36.fits

### 3.4 FWHM

A **full width at half maximum** (**FWHM**) is an expression of the extent of a function, given by the difference between the two extreme values of the independent variable at which the dependent variable is equal to half of its maximum value.

Now here we select a window which is less populated. By looking at image we can search for a star which is isolated and the area around is less populated.

Then we fit a Gaussian on that window. For that particular window there will be a Gaussian curve which will be having some maximum peak value. That is the stars maximum intensity.

Now we need to calculate the centroid position and the FWHM in this window. For a Gaussian distribution function the functional form of the curve is given by,

$$f_g(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-a)^2}{2\sigma^2}}$$

Here a=mean and σ=standard deviation.

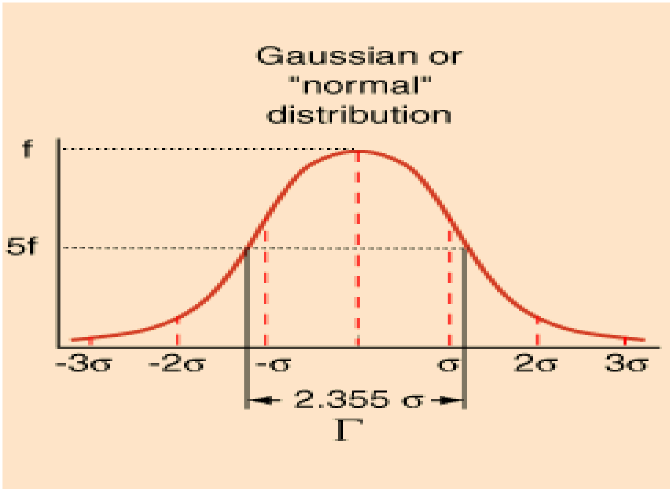


**Figure 3.4** Gaussian Curve

$$f(x) = Ce^{(-x^2/2\sigma^2)}$$

Let x=h at half the max height

$$0.5C = Ce^{(-h^2/2\sigma^2)}$$

Taking log on both the sides

$$\ln(0.5) = -h^2/2\sigma^2$$

$$h^2 = -2\ln(0.5)\sigma^2 = 2\ln 2\sigma^2$$

The Full Width Half Maximum of the peak is

FWHM= $2\sqrt{2\ln 2\sigma} = 2.355\sigma$

### 3.5 Extraction of stars

Now here we need to find out a few characteristics of the image before we start the job. Here we need to first find out the background characteristics. The mmm procedure helps us to obtain these characteristics. The three basic terms that was calculated are skymod, sigma and skew. Skymode is the scalar giving the estimated mode of sky values. Sigma is the scalar giving the standard deviation of the peak in the sky histogram. Skew is the scalar giving the skewness of the peak in the sky histogram. Now here for us sigma will be of use.

First we select randomly few distinct stars which are easily visible and are far apart at different places. We find their FWHM and then use the approximate FWHM for further analysis. Here to find the FWHM we use the Gaussian 2D fitting. The procedure returns a 7 element array. A window is created containing the star selected. Then this window is passed as an input to the procedure. The third and fourth elements in the output array are the width of the Gaussian in the X and Y direction. The fifth and the sixth element of the output array give the centre of the ellipse supplied as the input. This way we get FWHM for few randomly selected stars.

So now we are having an approximate value of FWHM as well as sky background to use for further calculations. From various readings 8 is the average FWHM that will be used in further calculations. Because the FWHM ranges from 2 to 18 for different stars. Now we find the stars in the entire image. This is done by the find procedure. The input to the find procedure is the entire array of images. The procedure also asks for approximate FWHM. Then a minimum value above background for threshold is also needed. This value is 3 times approximately the sigma value. After this an array is also supplied to the procedure. After execution an array of the identified stars is stored in passed empty array. Now I have marked this pixel positions so that the stars can be easily visible. The image in fig 4 shows the identified stars.

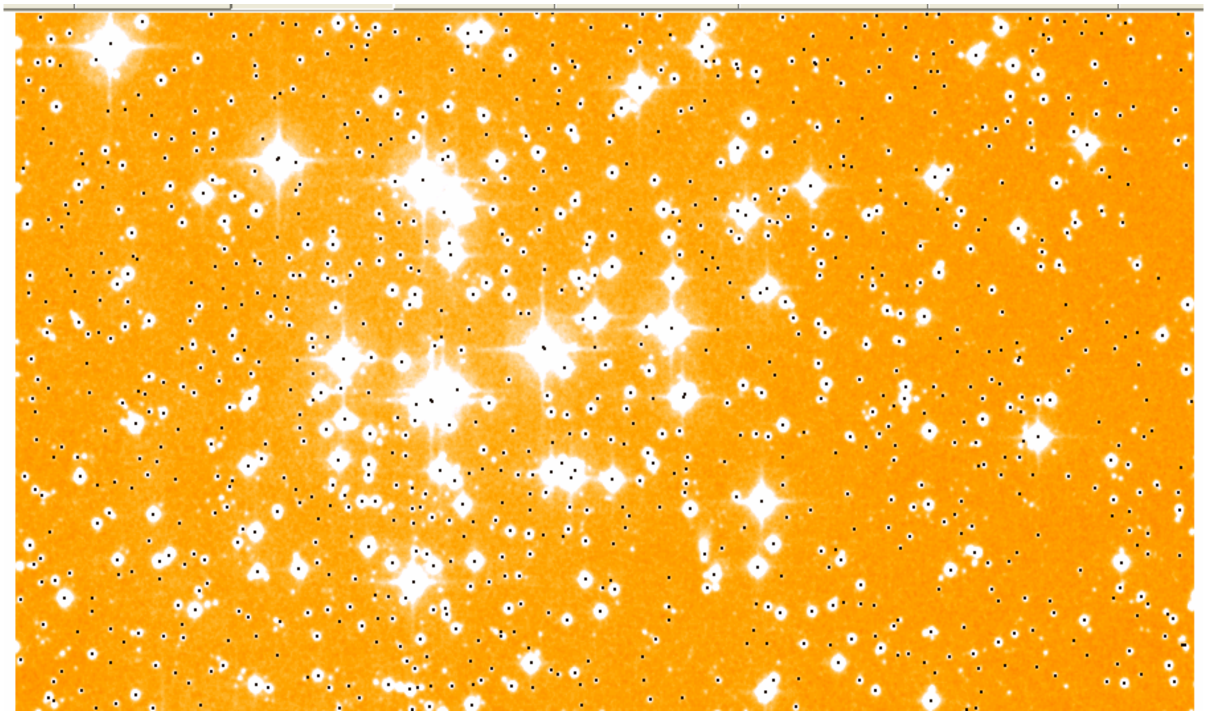

**Figure 3.5** Identified Stars

Here almost 1850 stars are identified in this image.

The mmm procedure

The procedure estimates the sky background in a stellar contaminated field. The input to this procedure is the vector containing the sky values. The outputs of the procedures are

Skymod – scalar giving the estimated mode of the sky value.

Sigma – scalar giving standard deviation of the peak in the sky histogram.

Skew – scalar giving the skewness of the peak in the sky histogram.

The algorithm used in mmm consists of roughly two parts:

1. The average and the sigma of the sky pixels are computed. These values are used to eliminate outliers, i.e. values with a low probability give a Gaussian with specified average and sigma. The average and sigma are then recomputed and the process is repeated up to 20 iterations.

2. The amount of contamination by stars is estimated by comparing the mean and median of the remaining sky pixels. If the mean is longer than the true sky value is estimated by 3*median-2*mean.

<u>The find procedure</u>

This procedure finds the positive brightness perbutations(I.e stars) in an image. It also returns centroids and shape parameters (roundness and sharpness). The inputs to this procedure are

Hmin – threshold intensity for a point source- should generally be 3 or 4 sigma above background.

Fwhm – FWHM to be used in the convolve filter

Sharplim – 2 element vector giving low and high cutoff for the sharpness statistic (default: [0.2, 1.0]). Change this default only if the stars have significantly larger or smaller concentration than a Gaussian.

Roundlim – 2 element vector giving low and high cutoff for the roundness statistics (default:[-1.0, 1.0]). Change this default only if the stars are significantly elongated.

The outputs of this procedure are:

X – Vector containing x position of all the identified stars.

Y – Vector containing x position of all the identified stars.

Flux – vector containing flux of identified stars as determined by Gaussian fit.

Fluxes are not converted to magnitude.

### 3.6 Finding the magnitude of identified stars

Now the next step is to find the magnitude of the identified stars. For this aper procedure is used. This procedure computes the concentric aperture photometry. The inputs to this procedure are the image array and the vector of x and y coordinates. The procedure returns the sky values and the magnitudes of the stars.

Now the figure 4 is a result of fwhm=8 and threshold above background=1000. The magnitudes of the stars are as follows.

**Table 3.1** Position and Magnitude of Stars for m36 cluster

| **Star** | **X** | **Y** | **Magnitudes** |
|---|---|---|---|
| 1019 | 342.45 | 471.81 | 17.511+-2.739 |
| 1020 | 711.75 | 471.86 | 13.723+-0.071 |
| 1021 | 476.39 | 473.57 | 10.618+-0.008 |
| 1022 | 495.03 | 472.50 | 9.684+-0.009 |
| 1023 | 82.13 | 473.75 | 12.197+-0.019 |
| 1024 | 206.53 | 475.00 | 13.731+-0.081 |
| 1025 | 290.23 | 475.43 | 13.135+-0.050 |
| 1026 | 47.02 | 476.73 | 11.416+-0.009 |

Now these same steps are also performed with a highly populated image to check if the program works for a large square degree field of view image. The image used is an archival data from the digitized sky survey site. The image is shown below

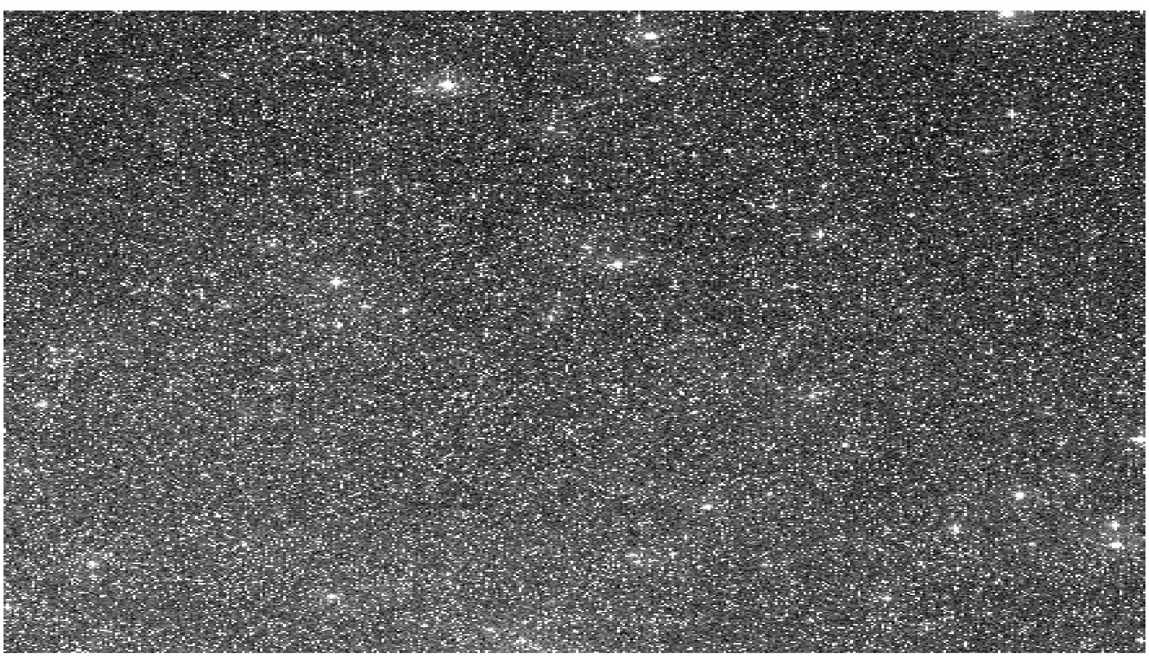

**Figure 3.6** dss29767a0bg.fits Image

As this image is very large (7055 x 7055) and also the size of stars for this image vary. It contains stars of different sizes. So according the program is modified to identify the stars. Here range of fwhm values was given so that both large and small stars could be identified. This way the program can also be used for images with different sizes of stars.

The results for this image are as under.

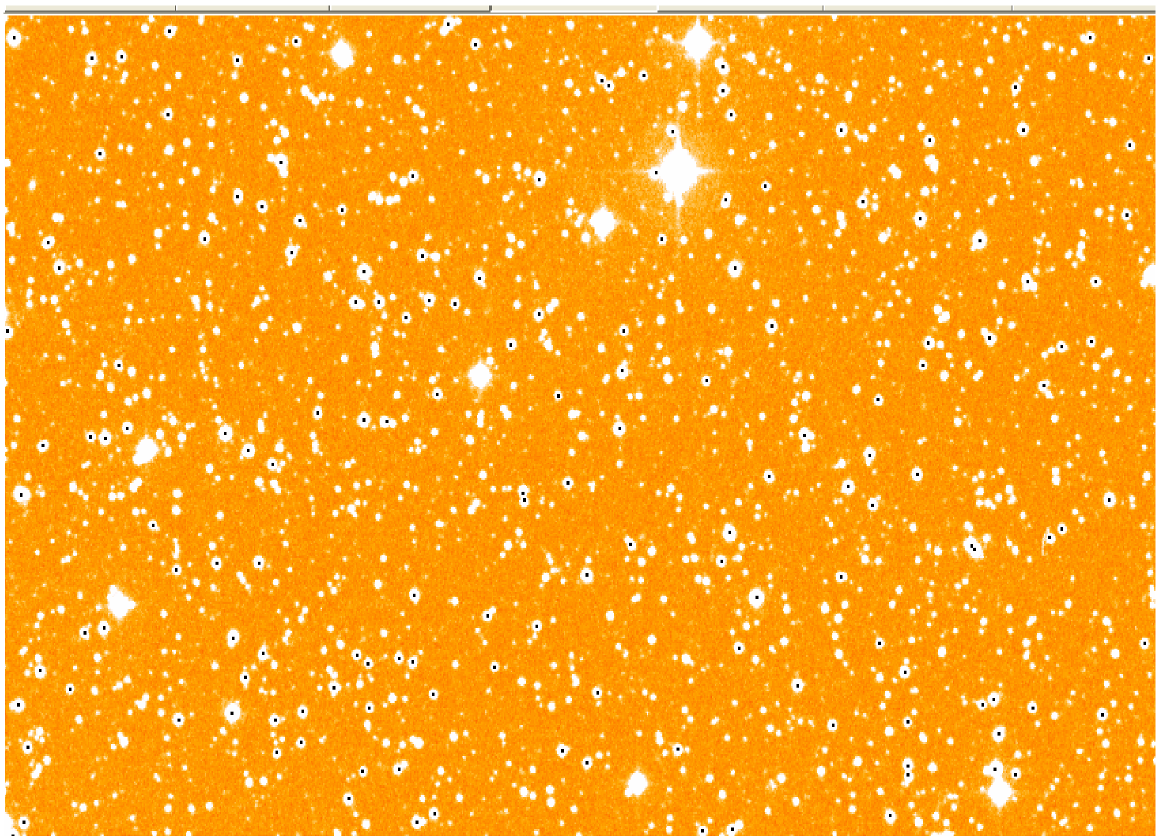

**Figure 3.7** Identifying stars(fwhm=8)

Now in fig 6, it can be seen that not all the stars are identified; only the stars between fwhm 4 to 8 are identified. By extending the range to 12 most of the stars can be identified.
The magnitudes of these stars are as under

**Table 3.2** Position and Magnitude of Stars for fwhm=8

| Star | X | Y | Magnitudes |
|---|---|---|---|
| 18000 | 2862.28 | 6927.41 | 10.659+-0.006 |
| 18001 | 3112.96 | 6926.97 | 11.955+-0.021 |
| 18002 | 1904.26 | 6927.85 | 11.743+-0.017 |
| 18003 | 2105.80 | 6927.78 | 12.209+-0.025 |
| 18004 | 428.04 6 | 929.09 | 11.674+-0.025 |
| 18005 | 2463.74 | 6929.26 | 11.791+-0.017 |
| 18006 | 6972.15 | 6928.70 | 11.977+-0.026 |
| 18007 | 33.88 | 6930.19 | 11.217+-0.013 |
| 18008 | 2986.10 | 6929.95 | 11.392+-0.014 |
| 18009 | 4401.88 | 6929.81 | 11.622+-0.017 |
| 18010 | 5326.95 | 6930.22 | 10.526+-0.006 |
| 18011 | 442.05 | 6931.02 | 11.237+-0.015 |
| 18012 | 3185.03 | 6932.04 | 10.789+-0.008 |
| 18013 | 754.85 | 6932.87 | 11.177+-0.012 |
| 18014 | 1324.99 | 6932.70 | 11.960+-0.021 |
| 18015 | 3503.99 | 6932.99 | 11.441+-0.013 |

# Chapter 4

## Development of Photometric Data Pipeline

The photometric data pipeline is actually a program that does the photometry of astronomical images and gives the desired output. The input to this program is a series of image. For this thesis work the input is the images of XO2 taken at intervals. The total duration between the first and last image is approximately four and half hours.

These images were taken by Dr Abhijit Chakraborty (PRL), at Mt Abu. The details of the images are shown in table 4.1.

**Table 4.1** Characteristics of XO2

| | |
|---|---|
| No of axis: | 2 |
| Axis length: | 1024 x 1024 |
| Object: | XO2 |
| Instrument/camera: | Apogee |
| Date of observation: | 06-03-2008 |
| Exposure time in seconds: | 60 |
| Latitude of image location: | 02 00 00 |
| Longitude of image location: | 07 00 00 |
| Focal length of telescope: | 15600 mm |
| Aperture diameter of telescope: | 1200 mm |
| Duration of the total images captured: | 4 hrs 26 minutes |

The input to this program is a text file having the name of the image file and the fwhm to be used for that image. For this project the image is having only two stars. The aim of this observation is to identify if any star is having any celestial body revolving around it. For this the required output is the magnitude difference between the two stars.

This work can be also be used for other images for observing some other results. This program has been made a general algorithm for doing the transit search.

The output is written in a text file giving the magnitude difference and the errors in the magnitude of stars. This text file is used as an input for another module that plots a graph of the magnitude difference.

# Chapter 5

# Output

## 5. Results

### Snapshot of IDL Software

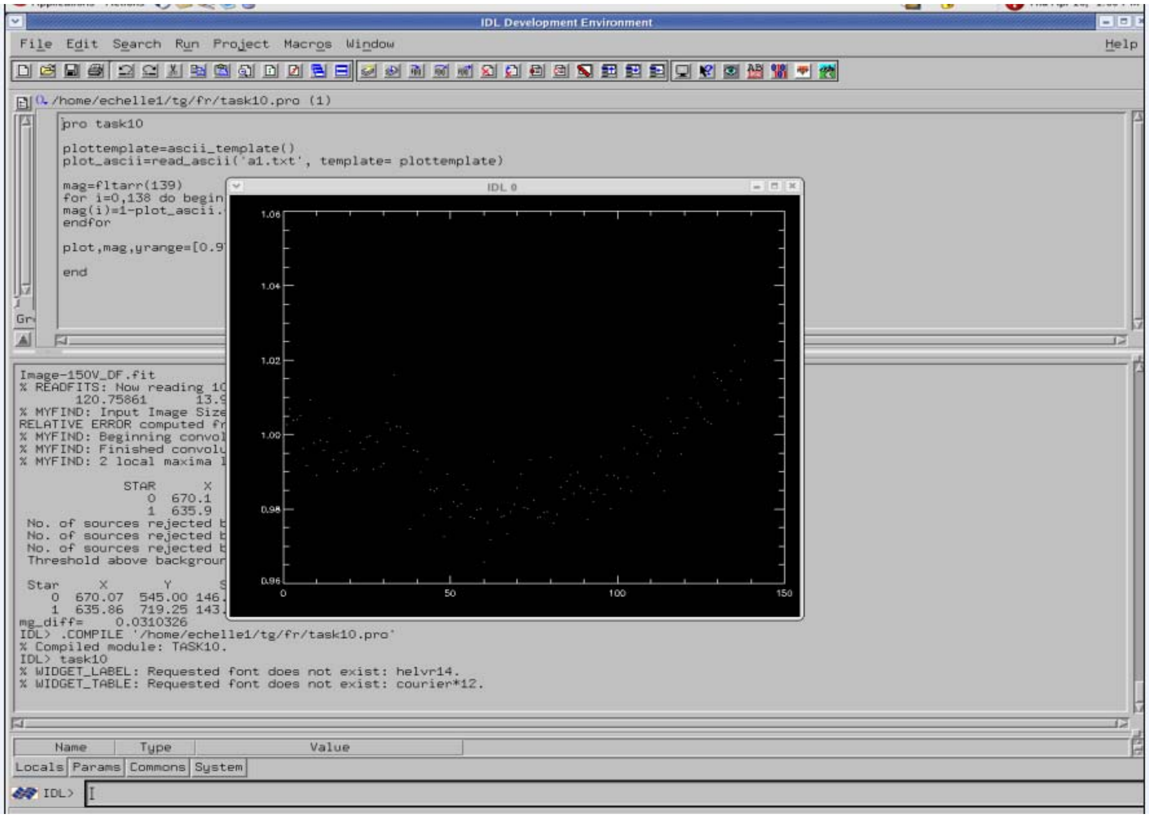


**Figure 5.1** Snapshot of working environment

For an individual image of the series of image.

**Figure 5.2** Image-009v_df.fit

The flux of the two stars and their position in the image are as shown below.

**Table 5.1** Flux and position of identified stars

| STAR | X | Y | FLUX |
|---|---|---|---|
| 0 | 676.3 | 534.7 | 8738.9 |
| 1 | 641.7 | 709.1 | 7997.7 |

The magnitude of the two stars with the error in magnitudes is as shown below.

**Table 5.2** Magnitude and position of identified stars

| STAR | X | Y | MAGNITUDE |
|---|---|---|---|
| 0 | 676.3 | 534.7 | 10.549+-0.002 |
| 1 | 641.7 | 709.1 | 10.579+-0.002 |

Magnitude Difference = 0.0308819

**Output file**

column data:- Image , Star1 coordinates(x,y) , Star2 coordinates(x,y) , Magnitude difference , Error in magnitudes( star1 & star2)

**Table5.3** Position and magnitude difference if the stars in all the images

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Image-009V_DF.fit | 676.276 | 534.921 | 641.722 | 709.187 | 0.031197 | 0.001949 | 0.001965 |
| Image-010V_DF.fit | 675.735 | 533.3 | 641.175 | 707.779 | 0.037245 | 0.00201 | 0.002237 |
| Image-011V_DF.fit | 680.387 | 530.111 | 645.791 | 704.352 | 0.033156 | 0.001613 | 0.001623 |
| Image-012V_DF.fit | 680.581 | 529.249 | 646.006 | 703.831 | 0.036258 | 0.001565 | 0.00162 |
| Image-013V_DF.fit | 674.999 | 528.303 | 640.613 | 702.508 | 0.036036 | 0.001512 | 0.00154 |
| Image-014V_DF.fit | 667.763 | 537.584 | 633.116 | 711.811 | 0.034785 | 0.001545 | 0.001578 |
| Image-015V_DF.fit | 650.545 | 537.668 | 616.005 | 711.776 | 0.043702 | 0.001691 | 0.001652 |
| Image-016V_DF.fit | 657.866 | 535.029 | 623.286 | 709.265 | 0.048401 | 0.001594 | 0.001634 |
| Image-017V_DF.fit | 667.693 | 533.057 | 633.154 | 707.455 | 0.030569 | 0.001698 | 0.001744 |
| Image-018V_DF.fit | 681.146 | 530.217 | 646.563 | 704.685 | 0.04241 | 0.001616 | 0.001623 |
| Image-019V_DF.fit | 680.202 | 539.377 | 645.807 | 713.597 | 0.05098 | 0.001726 | 0.001756 |
| Image-020V_DF.fit | 676.362 | 538.452 | 641.917 | 712.767 | 0.041514 | 0.001714 | 0.00178 |
| Image-021V_DF.fit | 672.059 | 537.054 | 637.486 | 711.333 | 0.04424 | 0.001702 | 0.001721 |
| Image-022V_DF.fit | 676.006 | 535.653 | 641.53 | 709.961 | 0.041857 | 0.001632 | 0.001642 |
| Image-023V_DF.fit | 676.236 | 534.017 | 641.639 | 708.386 | 0.03554 | 0.00165 | 0.001682 |
| Image-024V_DF.fit | 677.239 | 532.929 | 642.727 | 707.196 | 0.046748 | 0.001714 | 0.00177 |
| Image-025V_DF.fit | 680.542 | 542.124 | 645.992 | 716.309 | 0.049995 | 0.001632 | 0.0016 |
| Image-026V_DF.fit | 674.952 | 541.625 | 640.37 | 715.92 | 0.044892 | 0.00149 | 0.001547 |
| Image-027V_DF.fit | 674.986 | 541.185 | 640.578 | 715.044 | 0.047655 | 0.001405 | 0.001446 |
| Image-028V_DF.fit | 675.254 | 539.957 | 640.891 | 714.277 | 0.044383 | 0.001433 | 0.001473 |
| Image-029V_DF.fit | 674.818 | 546.021 | 640.36 | 720.274 | 0.039027 | 0.001557 | 0.001608 |
| Image-030V_DF.fit | 663.589 | 544.429 | 629.233 | 718.701 | 0.049747 | 0.001576 | 0.001584 |

**Graph of magnitude Difference**

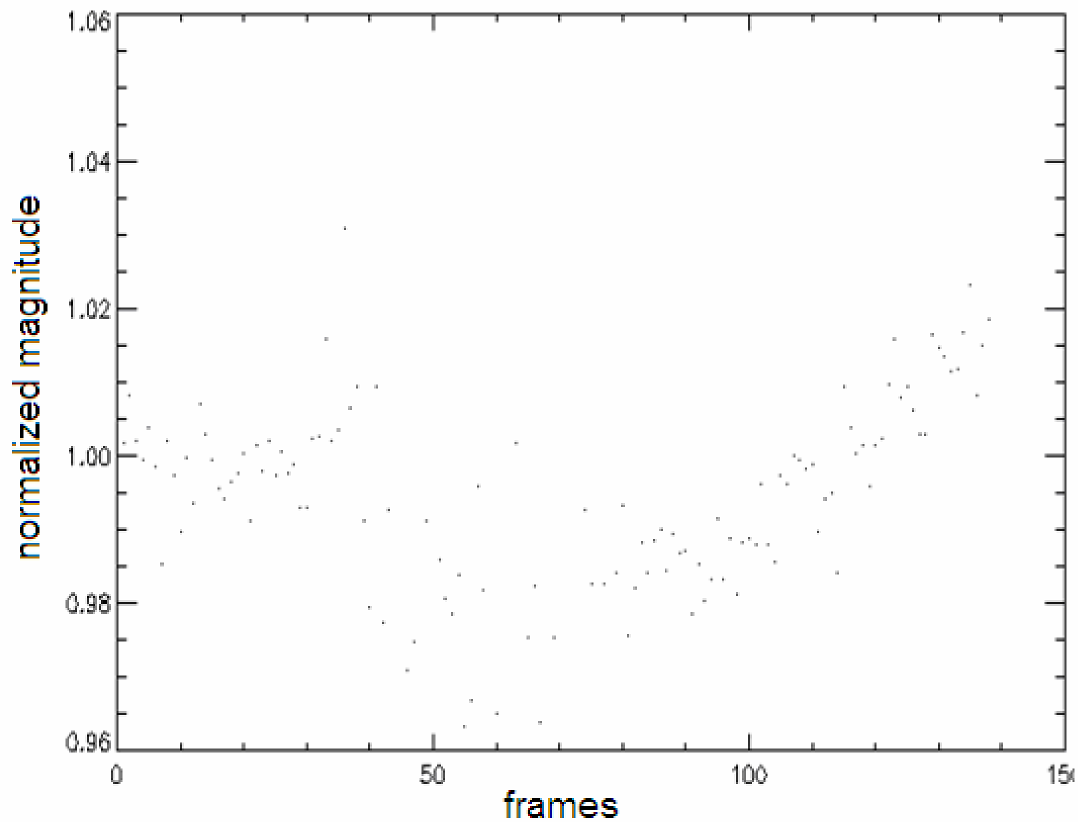


**Figure 5.3** Result Graph

# Chapter 6

# Conclusion

This project is a basic step to the transit search method of identifying the possibility of planets around a star. The project is divided into two phases. In the first phase, individual images of some astronomical position are processed to identify the position of stars and their magnitudes.

Next a series of images were applied for the same procedure. From the analysis done for the image that was having only two stars it was found that one was having the possibility of planets. From figure 5.3 it was observed that the magnitude difference of the two stars was variable and not consistent. The brightness of the second star cannot increase, so if magnitude change increases it can be said that first star must be having decrease in the brightness. Hence the possibility of exoplanets around first star is concluded.

# REFERENCES

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# Appendix A

**Photometry**

Many people are interested in astronomy because it is visually exciting. The many marvelous pictures of celestial objects taken using large telescopes on the ground or in space are certainly the most visible manifestation of modern research astronomy. However, to do real science, one needs far more than pictures. Pictures are needed as a first step in classifying objects based on their appearance (morphology). To proceed past this initial stage of investigation, we need quantitative information- i.e. measurements of the properties of the objects. Observational astronomy becomes science only when we can start to answer questions quantitatively: How far away is that object? How much energy does it emit? How hot is it?

The most fundamental information we can measure about celestial objects past our solar system is the amount of energy, in the form of electromagnetic radiation, which we receive from that object. This quantity we will call the flux. The science of measuring the flux we receive from celestial objects is called photometry. As we will see, photometry usually refers to measurements of flux over broad wavelength bands of radiation. Measurement of flux, when coupled with some estimate of the distance to an object, can give us information on the total energy output of the object (its luminosity), the object's temperature, and the object's size and other physical properties.

If we can measure the flux in small wavelength intervals, we start to see that the flux is often quite irregular on small wavelength scales. This is due to the interaction of light with the atoms and molecules in the object. These "bumps and wiggles" in the flux as a function of wavelength are like fingerprints. They can tell us lots about the object– what it is made of, how the object is moving and rotating, the pressure and ionization of the material in the object, etc. The observation of these bumps and wiggles is called spectroscopy. A combination of spectroscopy, meaning good wavelength resolution, and photometry, meaning good flux calibration, is called spectrophotometry. Obviously, there is more information in a spectrophotometric scan of an object compared with photometry spanning the same wavelength range. Why would one do low wavelength resolution photometry rather than higher resolution spectrophotometry or spectroscopy, given the fact that a spectrum gives much more information than photometry? As we will see, it is much easier to make photometric observations of faint objects than it is to make spectroscopic observations of the same object. With any given telescope, one can always do photometry of much fainter objects than one can do spectroscopy of. On a practical note, the equipment required for CCD imaging photometry is much simpler and cheaper than that needed for spectroscopy. With low cost CCDs now readily available, even small telescopes can do useful photometric observations, particularly monitoring variable objects.

**Magnitudes**

Optical astronomers almost always use something called the (astronomical) magnitude system to talk about several different kinds of measurements, such as the observed brightness (power fluxes, or energy received per unit time per unit area) of stars and the luminosity (total power output in EMR) of stars. The historical roots of the magnitude system go way back to the first star catalog, compiled by a Greek named Hipparchus some 2200 years ago. Hipparchus divided the stars into six brightness classes, and he called the stars that appeared brightest (to the naked eye, of course, there being no telescopes back then) first magnitude stars, and the faintest visible stars the sixth magnitude stars.

Much later, when astronomers were able to make more exact measurements of the brightness of stars, they found that the Hipparchus magnitude scale was roughly logarithmic. That is, each magnitude step corresponded to a fixed brightness ratio or factor. The first magnitude stars are roughly 2.5 times as bright as the second magnitude stars, the second magnitude are roughly 2.5 times as bright as the third magnitude stars etc.

Based on the Hipparchus magnitude system, but using modern brightness measurements, astronomers decided to define a magnitude system where 5 magnitudes corresponds to exactly a factor of 100 in brightness or flux. Thus, each magnitude is exactly 1001/5 (which is equal to 102/5) or about 2.512 times as bright as the next.

$$m1 - m2 = -2.5\log10\ (f1/f2)$$

Clearly, if the flux ratio is 100, the magnitude difference is 5. Equation is the fundamental equation needed to define and deal with magnitudes.

Note that we can rearrange the equation to give the flux ratio if the magnitude difference is known:

$$f1/f2 = 10^{-0.4\ (m1-m2})$$

The most common use for magnitudes is for expressing the apparent brightness of stars. To give a definite number for a magnitude of a star (instead of just the magnitude difference between pairs of stars), we must pick a starting place, or zero point, for the magnitude system. To oversimplify somewhat (see note at end of previous chapter and chapter entitled “Standard Stars for Photometry”) we pick the star Vega, and say it has magnitude of 0.00. Then the magnitude of any other star is simply related to the flux ratio of that star and Vega as follows:

$$m1 = -2.5\log10\ (f1/f_{Vega})$$

The magnitude of Vega does not appear, because it is defined to be 0.00. These magnitudes are called apparent magnitudes, because they are related to the flux of the star, or how bright the star appears to us. Absolute magnitude is related to the true brightness or luminosity of an object. To derive an object’s absolute magnitude, one must measure the apparent magnitude, and also know the distance to the object and the amount of any obscuring dust between us and the object.

Table below gives apparent visual magnitudes for some selected celestial objects, spanning the range from brightest to dimmest. Also given are limits of several sized telescopes, either using the human eye as the detector (visual use) or a good CCD. The faintest star detectable with a given telescope and CCD depends on many factors- the exposure time, the sky brightness, and the seeing. The CCD magnitude limits quoted are for dark sky, good seeing, and minimum positive detection of the object. The limits of a detection and measurement of stars using CCDs is discussed in later chapters.

Table below shows the at first perplexing nature of magnitudes- brighter objects have smaller magnitudes, and indeed objects brighter than Vega (one of the brighter stars visible in the night sky) have negative magnitudes. Also never forget that the magnitude scale is a logarithmic scale for example, the Sun is about 15 magnitudes brighter than the full moon. From equation 4.1, we see that this means that the Sun is about a million times as bright as the full moon.

| **Object** | **V Note** |
|---|---|
| Sun | 26.7 |
| Full Moon | 12.0 |
| Venus | 4.7 at brightest |
| Sirius | 1.4 α Canis Major |
| Vega | 0.0 α Lyra |
| Castor | 0.0 α Gemini |
| Deneb | 0.1 α Cygnus |
| Altair | 0.2 α Aquila |
| Polaris | 0.6 α Ursa Minor |
| Pollux | 1.0 α Gemini |
| Betelgeuse | 1.5 α Orion |
| Aldebaran | 1.5 α Taurus |
| Antares | 1.9 α Scorpius |
| Naked eye limit | ~6.5 dark sky |
| Visual limit -6 inch telescope | ~13 dark skies |
| CCD 5 minutes - 6 inch telescope | ~16 dark sky (S/N=5) |
| HST | ~30 deep field |

### Overview of FITS Data Format

FITS was originally developed in the late 1970's as an archive and interchange format for astronomical data files. In the past decade FITS has also come into wide use as an on-line file format that can be directly read and written by data analysis software. FITS is much more than just another image format (such as JPG or GIF) and is primarily designed to store scientific data sets consisting of multidimensional arrays and 2-dimensional tables containing rows and columns of data.

A FITS file consists of one or more Header + Data Units (HDUs), where the first HDU is called the `Primary HDU', or `Primary Array'. The primary array contains an N-dimensional array of pixels, such as a 1-D spectrum, a 2-D image, or a 3-D data cube. Five different primary data types are supported: unsigned 8-bit bytes, 16 and 32-bit signed integers, and 32 and 64-bit single or double precision floating point reals. FITS can also store 16 and 32-bit unsigned integers.

Any number of additional HDUs may follow the primary array; these additional HDUs are called FITS `extensions'. There are currently 3 types of extensions defined by the FITS Standard:

- Image Extension - a N-dimensional array of pixels, like in a primary array
- ASCII Table Extension - rows and columns of data in ASCII character format
- Binary Table Extension - rows and columns of data in binary representation

Every HDU consists of an ASCII formated `Header Unit' followed by an optional `Data Unit'. For historical reasons, each header or data unit must be an exact multiple of 2880 bytes long. Any unused space at the end of the header or data unit is padded with fill characters (ASCII blanks or NULs depending on the type of unit).

Each header unit consists of any number of 80-character keyword records which have the general form:

KEYNAME = value / comment string

The keyword names may be up to 8 characters long and can only contain uppercase letters, the digits 0-9, the hyphen, and the underscore character. The keyword name is (usually) followed by an equals sign and a space character (= ) in columns 9 - 10 of the record, followed by the value of the keyword which may be either an integer, a floating point number, a character string (enclosed in single quotes), or a Boolean value (the letter T or F).

The last keyword in the header is always the `END' keyword which has no value or comment fields. There are many rules governing the exact format of a keyword record (see the FITS Standard for details) so it is generally better to rely on standard interface software like CFITSIO to correctly construct or parse the keyword records rather than directly reading or writing the raw FITS file.

Each header unit begins with a series of required keywords that specify the size and format of the following data unit. A 2-dimensional image primary array header, for example, begins with the following keywords:

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                  440 / length of data axis 1
NAXIS2  =                  300 / length of data axis 2
```

The required keywords may be followed by other optional keywords to describe various aspects of the data, such as the date and time of the observation. Other COMMENT or HISTORY keywords are also frequently added to further document the contents of the data file.

The data unit, if present, immediately follows the last 2880-byte block in the header unit. Note that some HDUs do not have a data unit and only consist of the header unit.