Year 2 Astro Projects

Project Descriptions

2020

These projects are designed to reflect the different aspects of modern astronomy, and are designed, as much as possible, to be like the real thing. The demonstrators are all active researchers, working in areas reflected in the projects and can provide real insights into cutting-edge research and guide your work in interesting directions.

Two types of projects are available this year:

1. Observatory Projects – where you take your own data at the observatory and analyse it. There are two observatory projects this year, one involves observing an open star cluster, and one involves observing an eclipsing binary star.

2. Data Analysis Projects – using data that already exists (from satellites or other surveys). There are 2 data analysis projects this year, one uses data from the Local Cluster Substructure Survey (LoCuSS), and one uses data from the Kepler satellite.

There are two observatory projects and two data analysis projects available. We anticipate limiting the number of student groups per project to a maximum of 3. This helps to balance the load across the demonstrators and minimise the risk of bad weather, thus ensuring a good experience for the students. **It is therefore possible that you do not do your first choice project. If any projects are over-subscribed, we will assign the relevant groups to those projects randomly.**

Bad weather in January and February can severely limit the opportunities to obtain new observational data. Therefore all Observatory Projects will be based on an archival dataset allowing students to begin their project immediately after Christmas. If weather permits, additional data will be obtained for these projects.

A lot of modern astronomy now uses data taken by satellites or from large scale all-sky surveys. Here the astronomer does not take the data themselves, but rather downloads from a data archive and then proceeds to do something novel and intelligent. An example of this is the Kepler satellite, which has discovered lots of new planets, but also observed many tens of thousands of stars with unprecedented photometric accuracy. This mode of discovery will only grow in the future, for example, through the Large Synoptic Survey Telescope (LSST) that will begin operations in 2021. The LoCuSS dataset is an example of the type of data that will be available in the future from LSST.

The advantage of this approach is that instantly you have access to some of the best datasets available to anyone. A Y2 Astro Project that uses data from a public archive can therefore expect to go further with the scientific analysis than a project that uses data from our own observatory.

On the other hand, taking your own data at the Observatory is very rewarding and instructive, and helps to reinforce what you learn in the Observational Astronomy module. It also helps to prepare you for the Y3 Observatory Laboratory module that only offers Observatory-based projects.

Y2 students opting for an Observatory-based project can therefore expect to develop their observing, data processing, and data analysis skills. However they will likely get less far in the analysis and scientific interpretation than students doing a analysis projects. Equally high marks are possible for both kinds of project.. the choice between them is matter of taste and priority for students.

Project 1: The Age and Structure of a Star Cluster

Most stars are believed to have been born in star clusters. Many of these clusters dissolve away with time (as stars escape), but some remain bound and become globular clusters.

The project involves taking imaging data, in at least two wavebands, of one or more star clusters from Wast Hills. Then reducing and analysing the data to find constraints on the age of a star cluster and the evolution of the stars in the cluster. The important point about star clusters is that all of the stars are at basically the same distance from the Earth and are all of the same age (star clusters are believed to form very rapidly). The age of a star cluster can be determined by measurement of the magnitude of stars turning off the main sequence in the Hertzsprung-Russell (H-R) diagram.

You will need to select star clusters that can be observed from the Wast Hills observatory (you need to make sure the clusters are not too large for the field of view of the telescope or too distant) and estimate the exposure times required and when the targets rises and sets.

Take observations in three different bands (for example B, V and R band) and then analyse the data with the IRAF package.

The main science goal is to determine the magnitude and colour indices (for example $B - V$) of the stars and plot them on a H-R diagram (or a colour-colour diagram). The colour index will be a proxy for the temperature of the star, and the magnitude will be a proxy for the luminosity of the star. From this, derive the age of the cluster by extracting the magnitude from stars turning off the main sequence and fitting isochrones.

The cluster reddeining can be determined by adjusting a Zero Age Main Sequence (ZAMS) to the observed colour-colour diagram for the cluster (usually $B - V$ vs. $U - B$ though other combinations are possible). Then, keeping this value fixed, adjusting the distance and age using the observed colour-magnitude digaram and tabulated (Padova) isochrones.

Other interesting aspects can include location the centre of the cluster and the fall off in density of stars (accounting for projection effects).

This paper presents a published analysis of an open cluster and provides ideas and pointers of things you can do with your data:

`http://arxiv.org/abs/1507.05968`

Project 2: Photometry of Eclipsing Binaries or Extrasolar Planets

Many stars show photometric variations and the origin of this variability may have several causes, both intrinsic to the star (such as pulsations) or due to a companion passing in front of the star – either another star (so it is an eclipsing binary) or a planetary transit:

Eclipsing Binaries

Short period eclipsing binaries are good targets. Obtaining the ephemeris (i.e. the times of eclipses) is important for these systems (particularly if the system is evolving and the binary period is changing). The project involves observing a bright eclipsing binary to obtain the time of eclipse. Some suitable objects include VW Cep, V345 Gem, T Aur, V523 Cas, BW Dra, HT Cas, AN UMa, DV UMa (or other objects of your choice). It is also possible to focus on contact binaries, for example the W UMa type systems.

The goal is to obtain the time of the primary or secondary eclipses in their lightcurves. Several have very short binary periods (3 hours) so that observation of two consecutive eclipses can be made and the ephemeris derived consisting of the period and a reference time of one of the minima. Other sources have longer periods (up to 7 hr), and for these, the literature ephemeris available can be used to predict the approximate time of eclipse, and the exact time measured. An extension to the project would consist of fitting the data in the archive, including the point, you have obtained to produce an improved ephemeris and to see whether there is any evidence of period change.

Transiting Planets

Related to eclipsing binaries, here the object that passes in front of the star is a planet, and the eclipses are referred to as transits. The observations are more challenging – the transit dip is only 1 per cent (so great care is needed to observe standard stars, to calibrate the stellar brightness), and the transit last for ~ 2 hours in an orbit of 4 days (so great care must be taken as to the timing of the observation, otherwise you see a non-varying star). Use the extrasolar planet encyclopedia (see below) to determine which planetary objects are accessible at Wast Hills and work out when a transit event will occur, and make sure that th transit is large enough to be detected at Wast Hills (depths of 1 per cent or more). Having obtained the transit data, work out the size of the planet and details of the transit event from the data.

There may not be any transiting planets accessible on observing nights, and the project relies on there being good weather at the time of transit. The planet part of the project is therefore very risky, and is normally considered an extension to the eclipsing binary project described above. If you are interested in concentrating only on the planet aspects of this project, you are encouraged to discuss with GPS well before submitting your project choices.

http://exoplanet.eu/ The Extrasolar Planets Encyclopaedia
A useful database for transit timings can be found at: *http://var2.astro.cz/ETD/*

Project 3: Galaxy transformation in galaxy clusters

As blue star forming (typically spiral) galaxies fall in to the gravitational potential well of a massive galaxy cluster their star formation rate declines and they end up as “red and dead” elliptical galaxies. The physical processes responsible for this decline in star formation and the timescales on which it happens is a hotly debated topic.

Over the last decade, here in Birmingham, we have built a survey called the Local Cluster Substructure Survey” (LoCuSS) that aims to investigate this problem with an unprecedented multi-wavelength dataset. We have observed a sample of galaxy clusters all the way from X-ray to radio wavelengths, and in particular have compiled catalogues of the galaxies in these clusters that include photometric measurements at ultraviolet, optical/near-infrared, and far-infrared wavelengths. Our publications are among those in the thick of the debate as to how quickly star-formation is “quenched” (e.g. Haines et al. ApJ, 806, 101).

The main aim of this Y2 project is to learn how to use multi-wavelength catalogues and to explore the properties of galaxies that are in the process of transforming from star-forming to passive. Potential directions that students could pursue include:

- Where do “green valley” galaxies (those with colours intermediate between blue star-forming galaxies and red passive galaxies) live?
- How to find red spiral galaxies, and what can we learn from them?
- What fraction of ongoing star formation in cluster galaxies is obscured by dust?
- How do cluster-cluster mergers affect the transformation of galaxies?

Depending on the question that the project focuses on, and the progress made, it may be possible to use X-ray and weak-lensing mass maps to further explore the cluster properties.

Project 4: Determining the Weather on an Extrasolar Planet

The Kepler satellite has provided extremely high quality photometry of a large number of stars located in a small region of the sky in the constellation of Lyra. This data can see extremely small variations in the light from the star (parts per million) – caused by stellar pulsations, or eclipsing binaries or planets passing in front of the star.

This project will concentrate on bright transiting extrasolar planets. In addition to the main transit (as the planet passes in front of the star) we can also see the secondary transit, as the hot planet passes behind the star. In addition, we can see (after some data processing) reflected light from the planet and lies behind the star (but is not yet occulted by the star). The degree of this reflected light depend on the albedo of the planet (which in turn depends on the cloud cover of the planet).

Initially we shall focus on one particular objects (Kepler-7b), but may extend to look at other possible candidates. The goal is to determine the albedo of the planet and see if we can see any variation in the albedo of the planet.

This will require developing your own code (in either C++ or Matlab) to analyse the lightcurve. A big issue will be how you deal with the noise on the lightcurve and fit the data.