Robotic Telescopes in the Age of 'Big Data'

Fraser Lewis
Faulkes Telescope Project (DFET)
National Schools' Observatory
The Open University

LaSciL

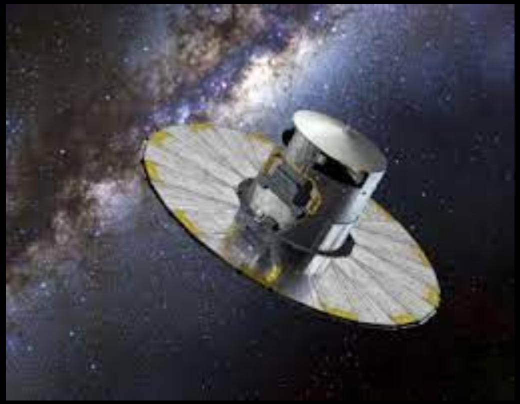
Summer 2021 – Summer 2023

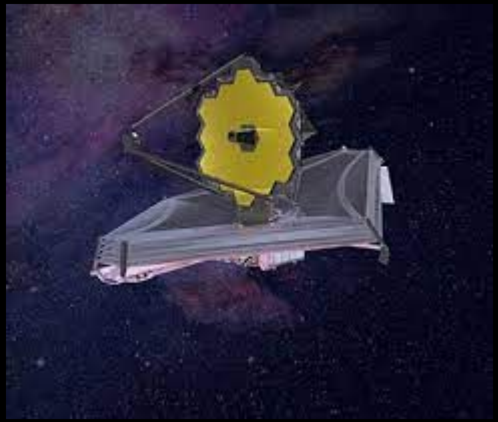
We will support teachers with high quality digital tools around online learning (during and post-pandemic), data archives, 'big data'

Allow teachers to capitalise on students interest in science and encourage careers in STEM

Co-funded by the Erasmus+ Programme of the European Union

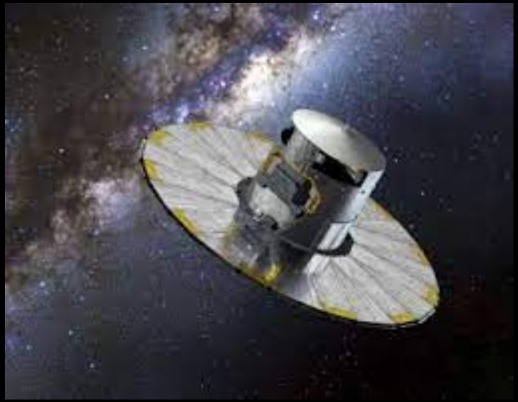
Big Data

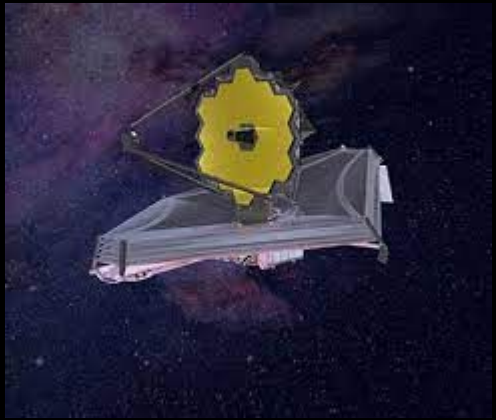




Big Data

Gaia DR3 (June 22) will contain data on 1.8 billion stars





JWST - 50 GB per day over 10 – 20 years

SKA radio array creating an exabyte per day

Rubin Observatory will produce 20 TB per night totalling 100 petabytes over 10 year survey

In 2016 CERN generated 49 petabytes of data

Project Results

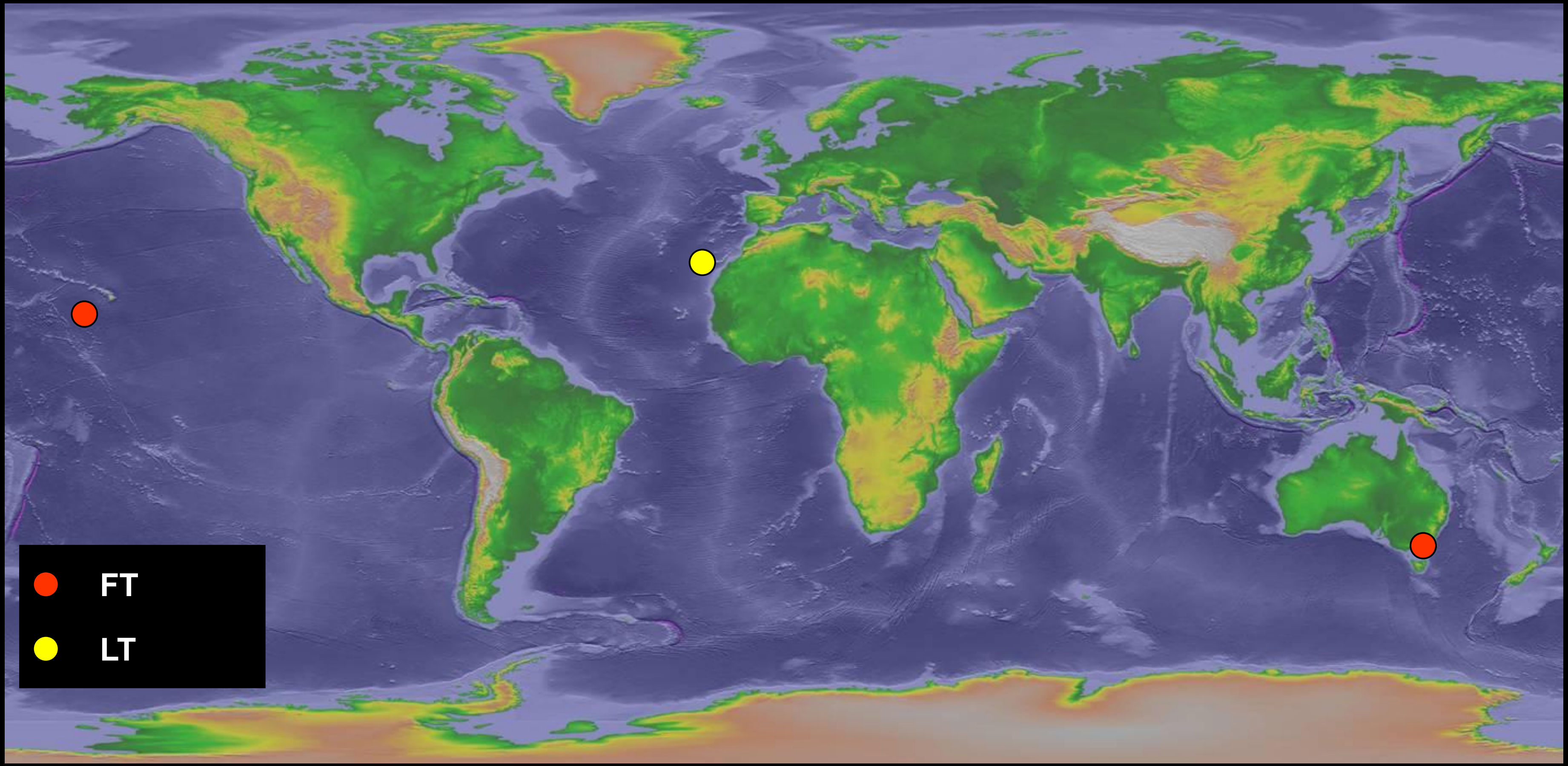
Our focus at FT is on finding resources which we can use to provide us with suitable targets and projects

e.g. supernovae, stellar clusters, variable stars, asteroids/comets

Our colleagues in NUCLIO are creating complementary resources around analysis and interpretation of these types of datasets

Robotic telescopes allow us to obtain images from (several) distant good quality sites

Only 3 * 2-metre telescopes that do this for education (in both queue-scheduled and real-time)



Why Use Robotic Telescopes ?

More Efficient Use of Limited Resource

Removes Human “Thinking Time”

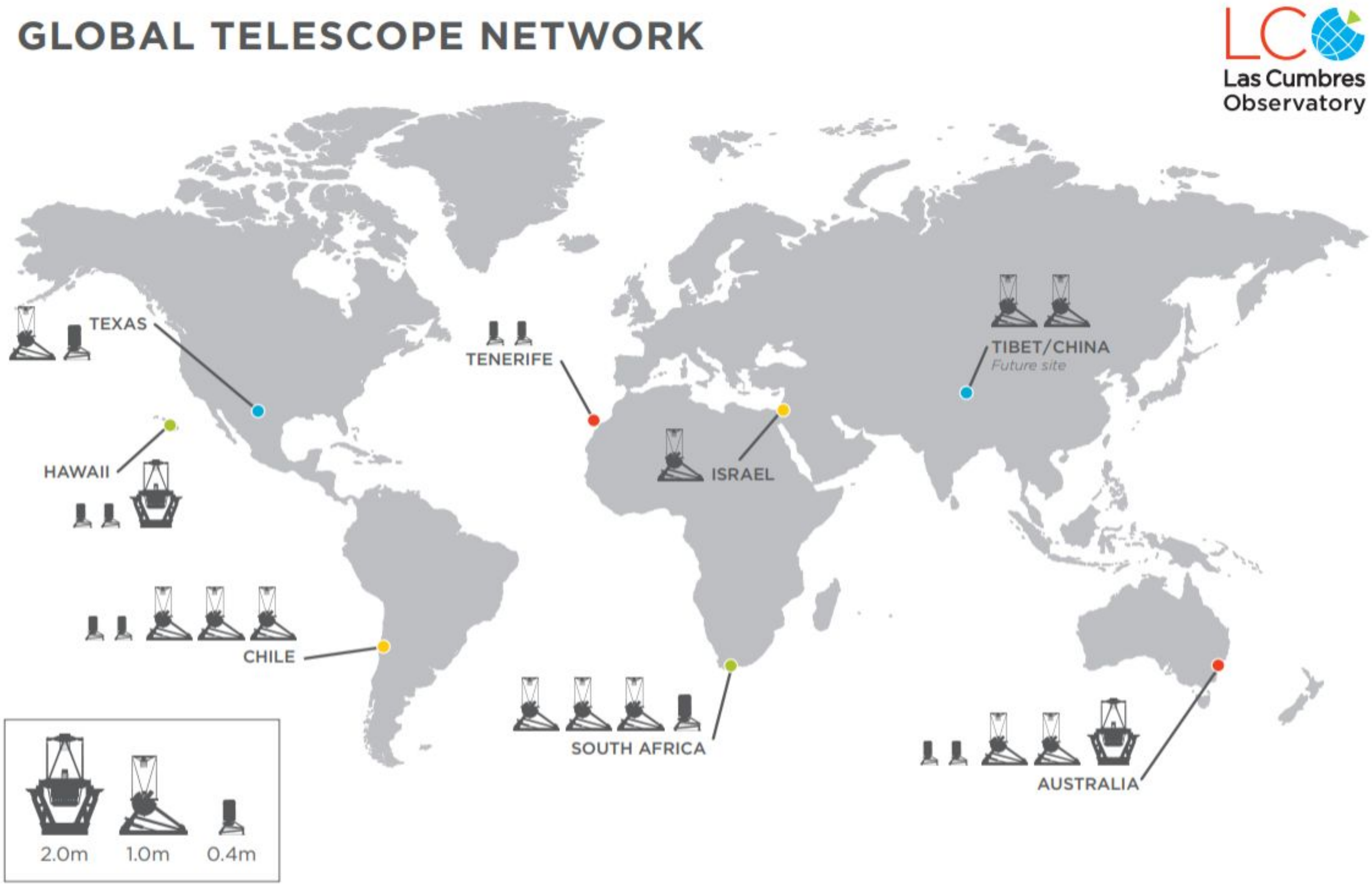
Rapid Response to Targets of Opportunity (ToO)

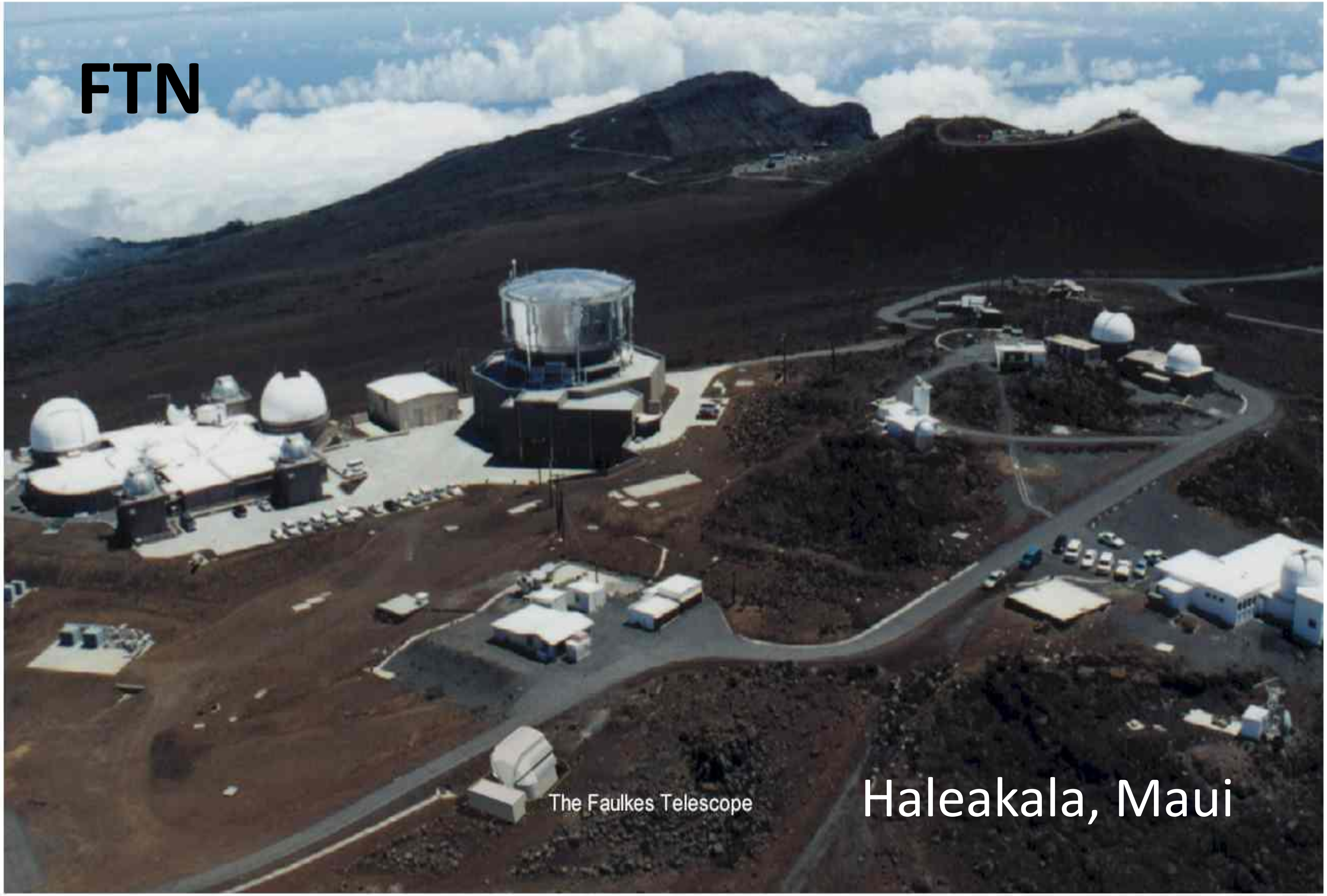
Provides Telescope Time and Access to Students and Teachers

Saleable Resource To Amateurs

Stops Astronomers Flying to Sunny Places

GLOBAL TELESCOPE NETWORK




FTN
The Faulkes Telescope
Haleakala, Maui


LCOGT ELP sitecam 2013-01-03 21:40:03
LCOGT


14/09/2012 12:40


SN2016adj - Centaurus A (NGC5128)
1,0 meter, 30 s, 2016.02.18;23:44UT
LCOGT, Siding Spring (Australia)
Faulkes Telescope Project
Clube de Astronomia da E.S.Adolfo Portela
Álvaro Folhas (2016)

Astronomy is Great and Easy to Inspire People

But it’s often a small part of the curriculum

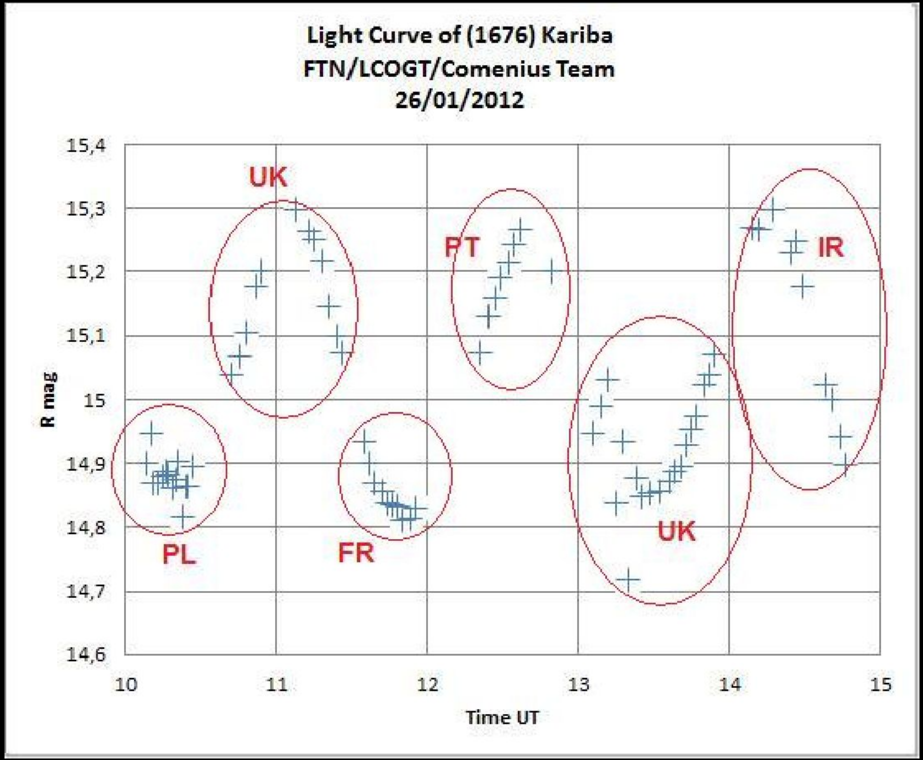
So we introduce maths, IT, chemistry, biology … and we encourage schools to collaborate, especially internationally

Jan 2012 – 6 schools from UK, Ireland, Poland, Portugal and France observed asteroid Kariba over 5 hrs

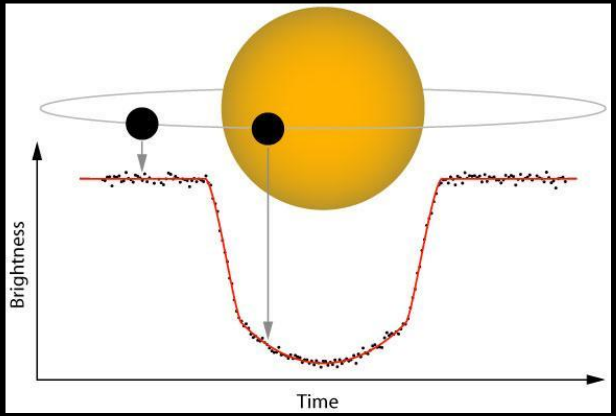
‘Met up’ on Skype for advice and student questions

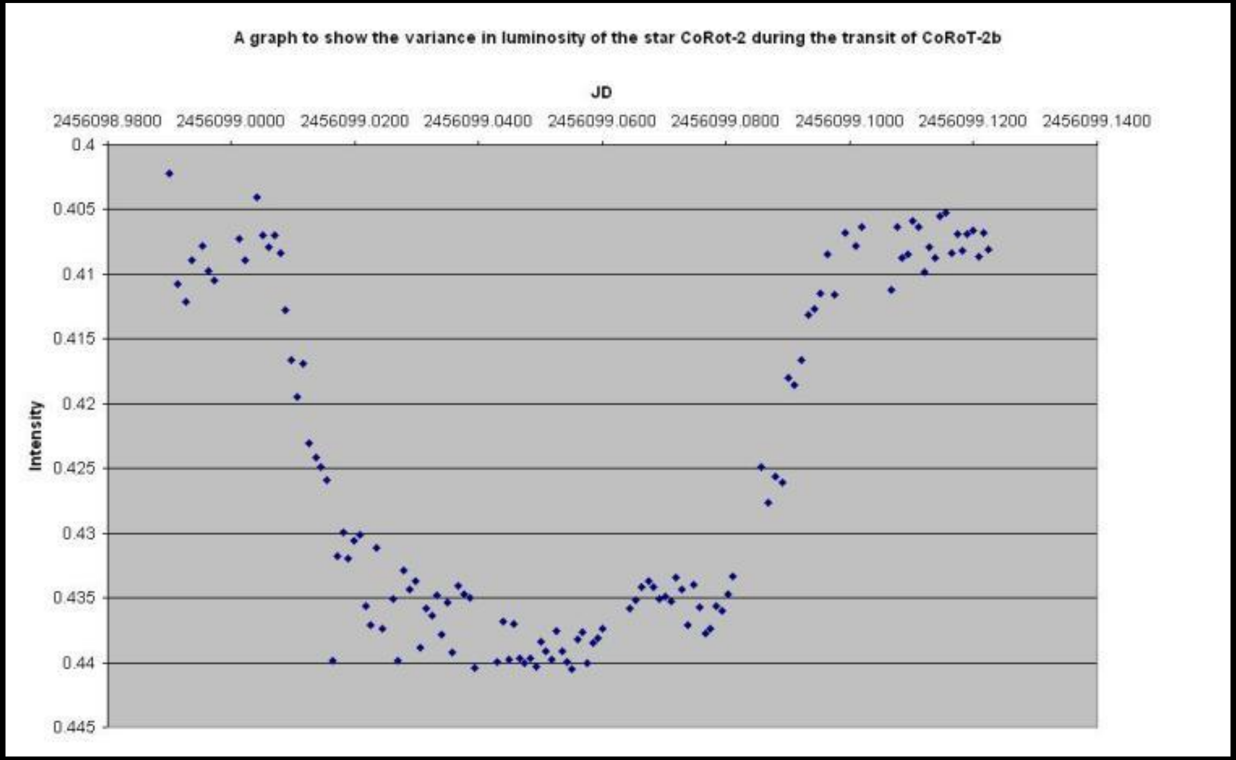
Students used SalsaJ to produce a lightcurve

Asteroid rotation



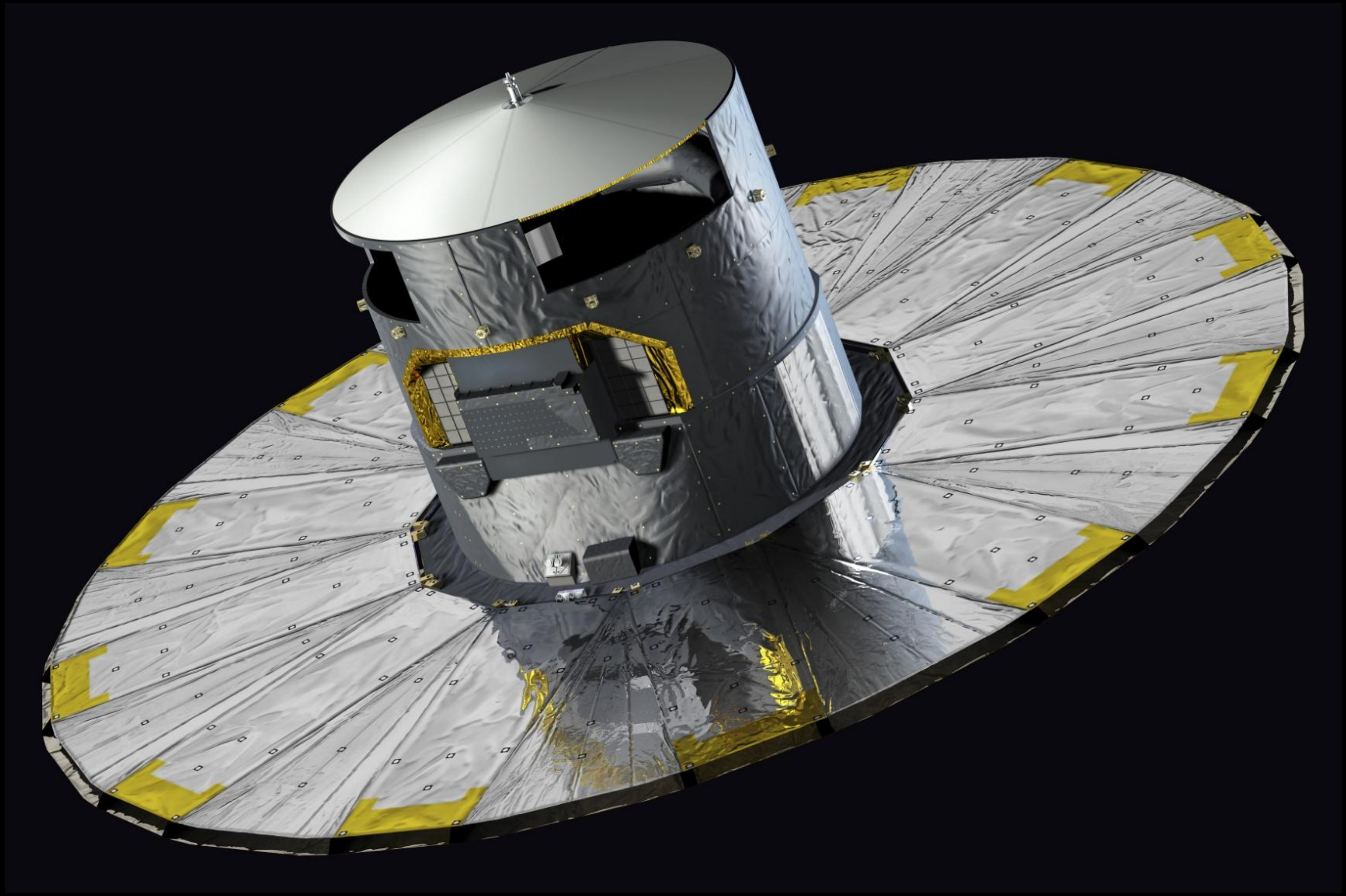
Exoplanet transits



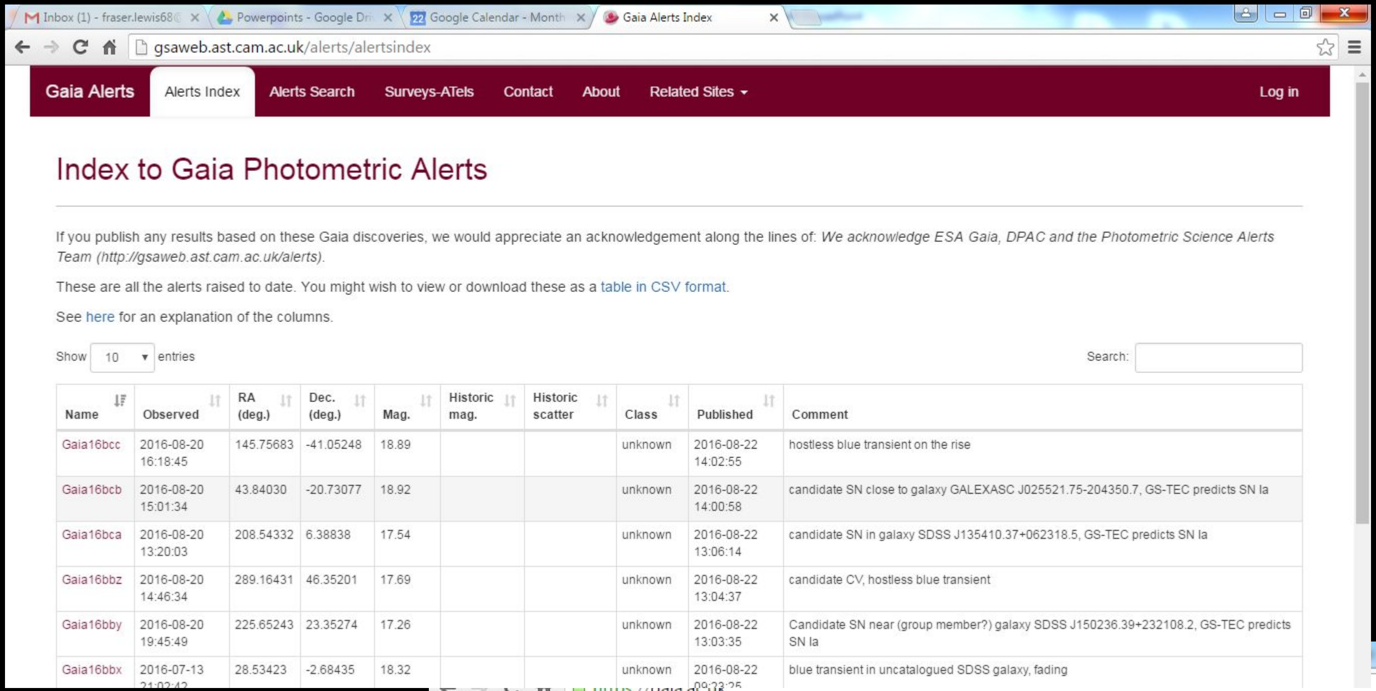


CoRot 2b: David Hardy & Thomas Ham (Cardiff schools), July 2012

Gaia Transient Follow-up



http://gsaweb.ast.cam.ac.uk/alerts/alertsindex


gsaweb.ast.cam.ac.uk/alerts/alertsindex

Gaia Alerts | Alerts Index | Alerts Search | Surveys-ATels | Contact | About | Related Sites | Log in

Index to Gaia Photometric Alerts

If you publish any results based on these Gaia discoveries, we would appreciate an acknowledgement along the lines of: *We acknowledge ESA Gaia, DPAC and the Photometric Science Alerts Team (http://gsaweb.ast.cam.ac.uk/alerts).*

These are all the alerts raised to date. You might wish to view or download these as a table in CSV format.

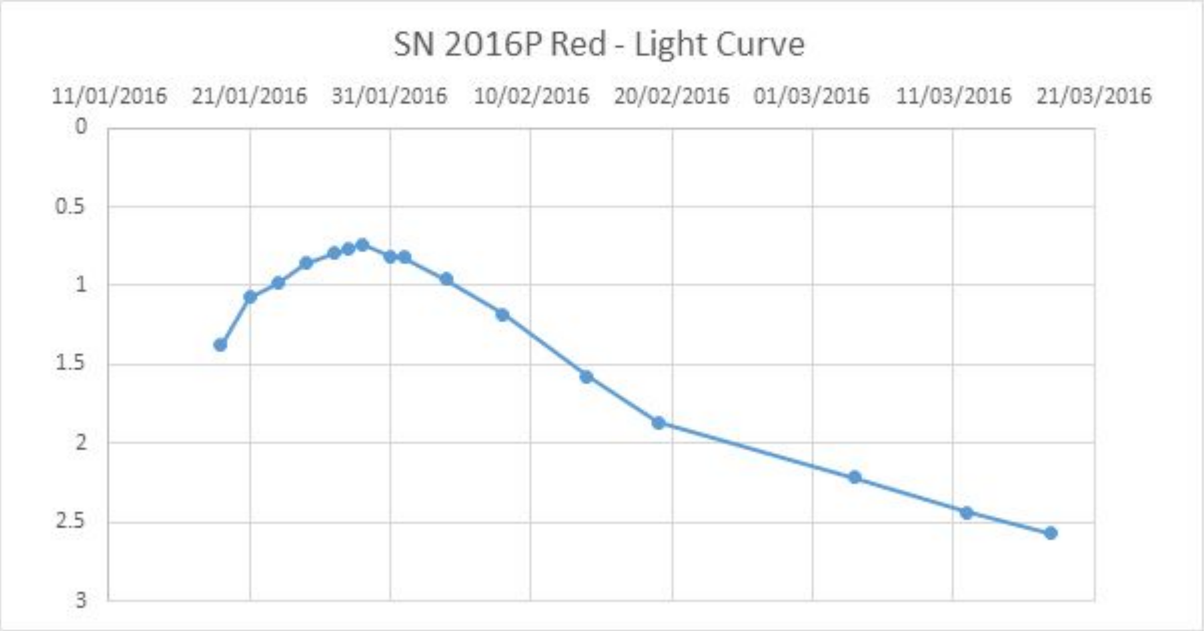
See here for an explanation of the columns.

Show 10 entries

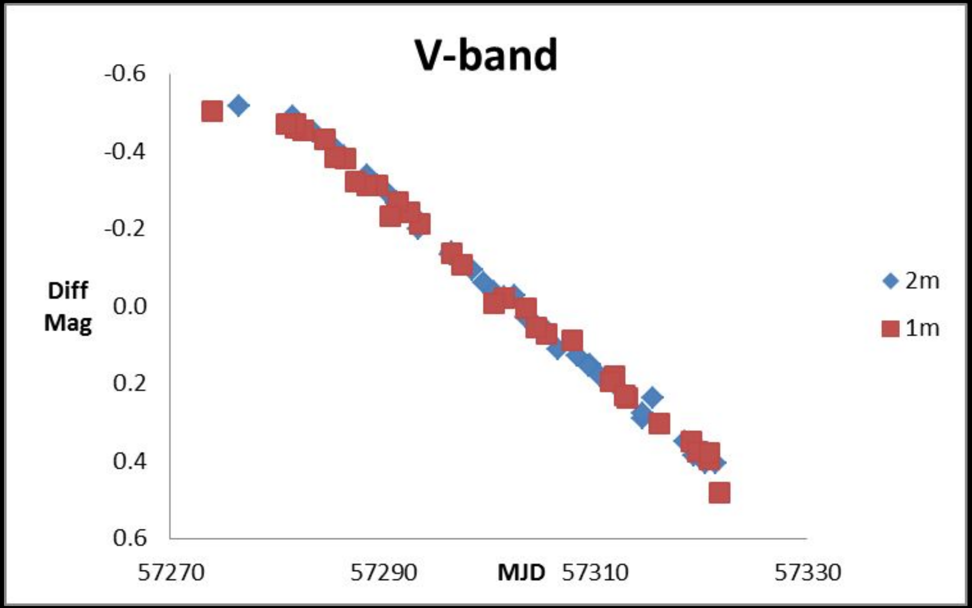
Search:

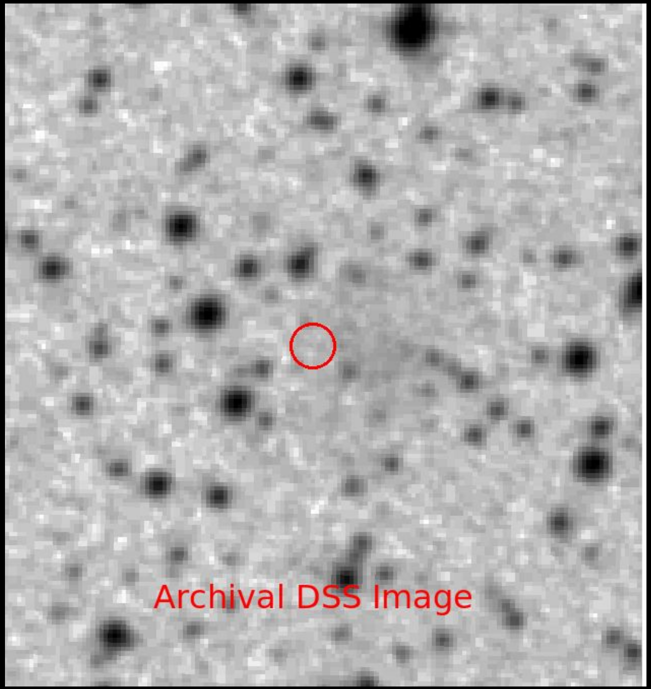
Name	Observed	RA (deg.)	Dec. (deg.)	Mag.	Historic mag.	Historic scatter	Class	Published	Comment
Gaia16bcc	2016-08-20 16:18:45	145.75683	-41.05248	18.89			unknown	2016-08-22 14:02:55	hostless blue transient on the rise
Gaia16bcb	2016-08-20 15:01:34	43.84030	-20.73077	18.92			unknown	2016-08-22 14:00:58	candidate SN close to galaxy GALEXASC J025521.75-204350.7, GS-TEC predicts SN Ia
Gaia16bca	2016-08-20 13:20:03	208.54332	6.38838	17.54			unknown	2016-08-22 13:06:14	candidate SN in galaxy SDSS J135410.37+062318.5, GS-TEC predicts SN Ia
Gaia16bbz	2016-08-20 14:46:34	289.16431	46.35201	17.69			unknown	2016-08-22 13:04:37	candidate CV, hostless blue transient
Gaia16bby	2016-08-20 19:45:49	225.65243	23.35274	17.26			unknown	2016-08-22 13:03:35	Candidate SN near (group member?) galaxy SDSS J150236.39+232108.2, GS-TEC predicts SN Ia
Gaia16bbx	2016-07-13 21:02:42	28.53423	-2.68435	18.32			unknown	2016-08-22	blue transient in uncatalogued SDSS galaxy, fading

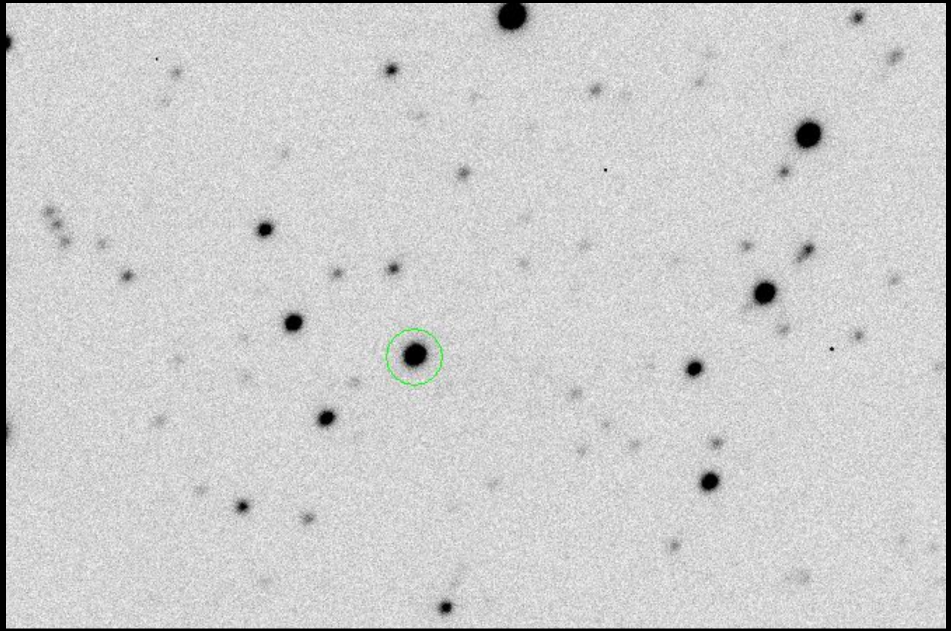
SN2016P (Type Ic)

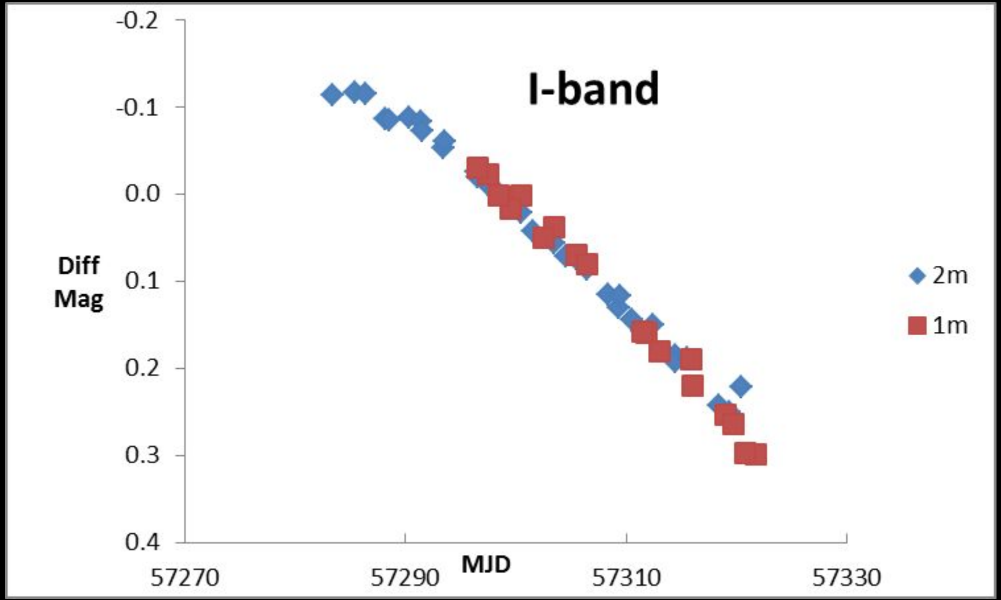


ASASSN-15oz (~250 images in 4 filters over 7 telescopes on 5 sites)



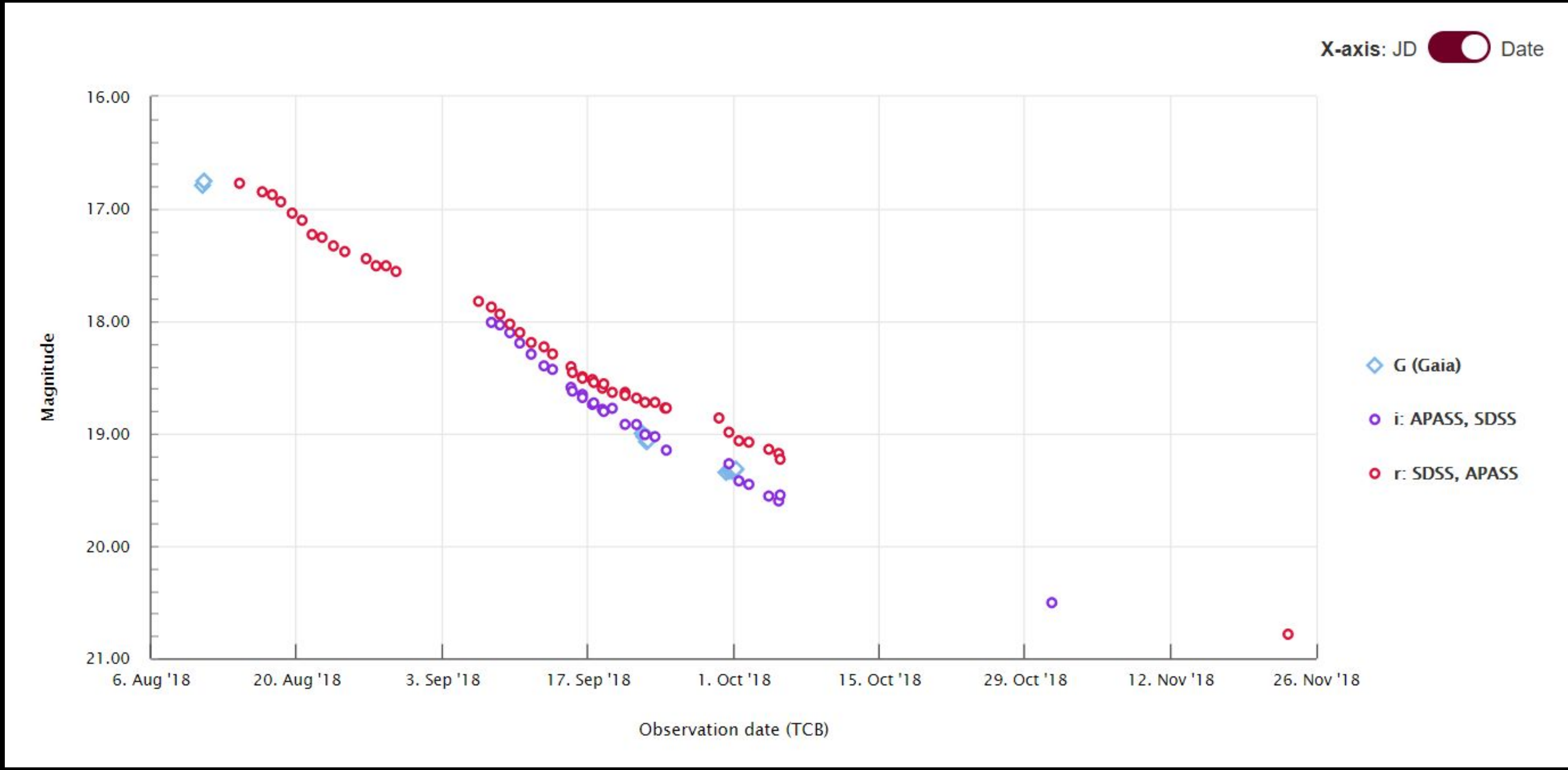


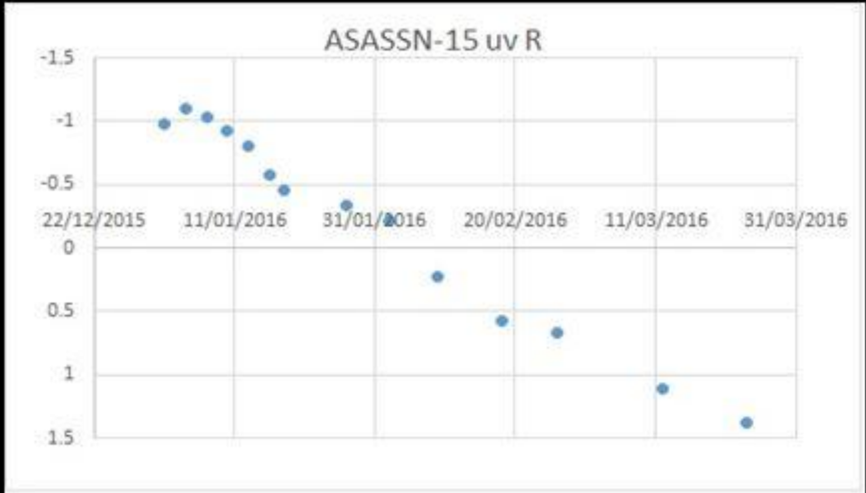




Gaia18ccw

Type Ia SN (selected by committee at a conference in 2018 !)




ASASSN-15 uv R
-1.5
-1
-0.5
0
0.5
1
1.5
22/12/2015
11/01/2016
31/01/2016
20/02/2016
11/03/2016
31/03/2016


SN 2016P Red - Light Curve
11/01/2016
21/01/2016
31/01/2016
10/02/2016
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01/03/2016
11/03/2016
21/03/2016
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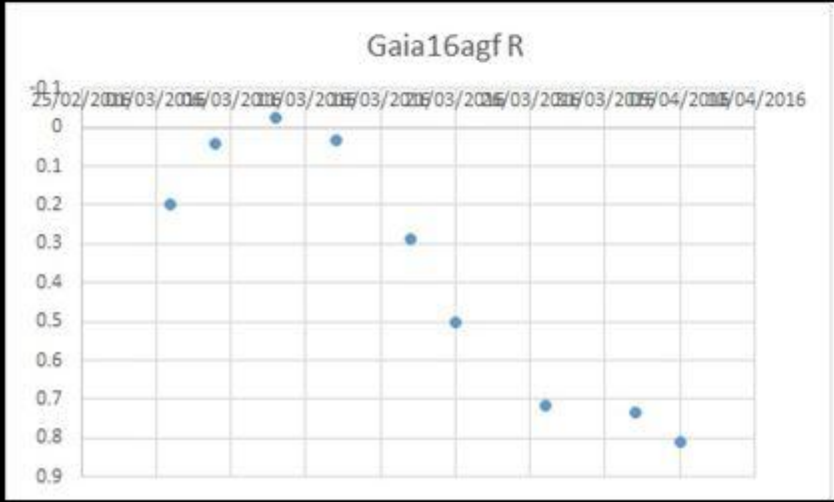
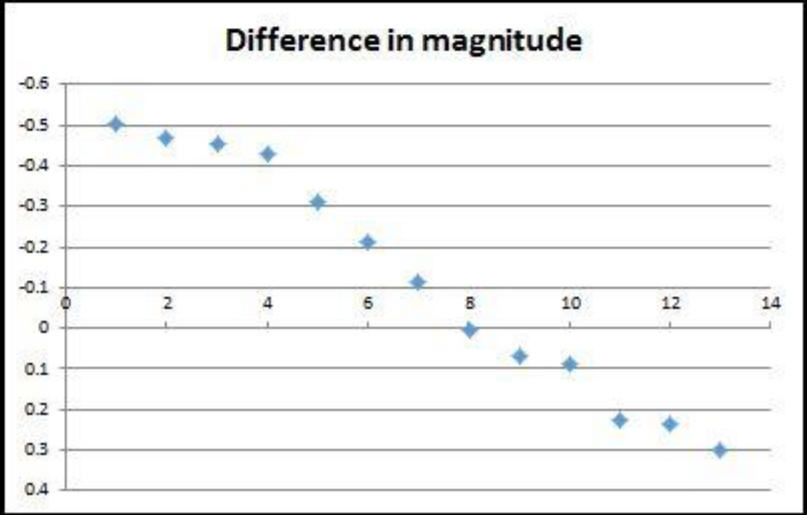
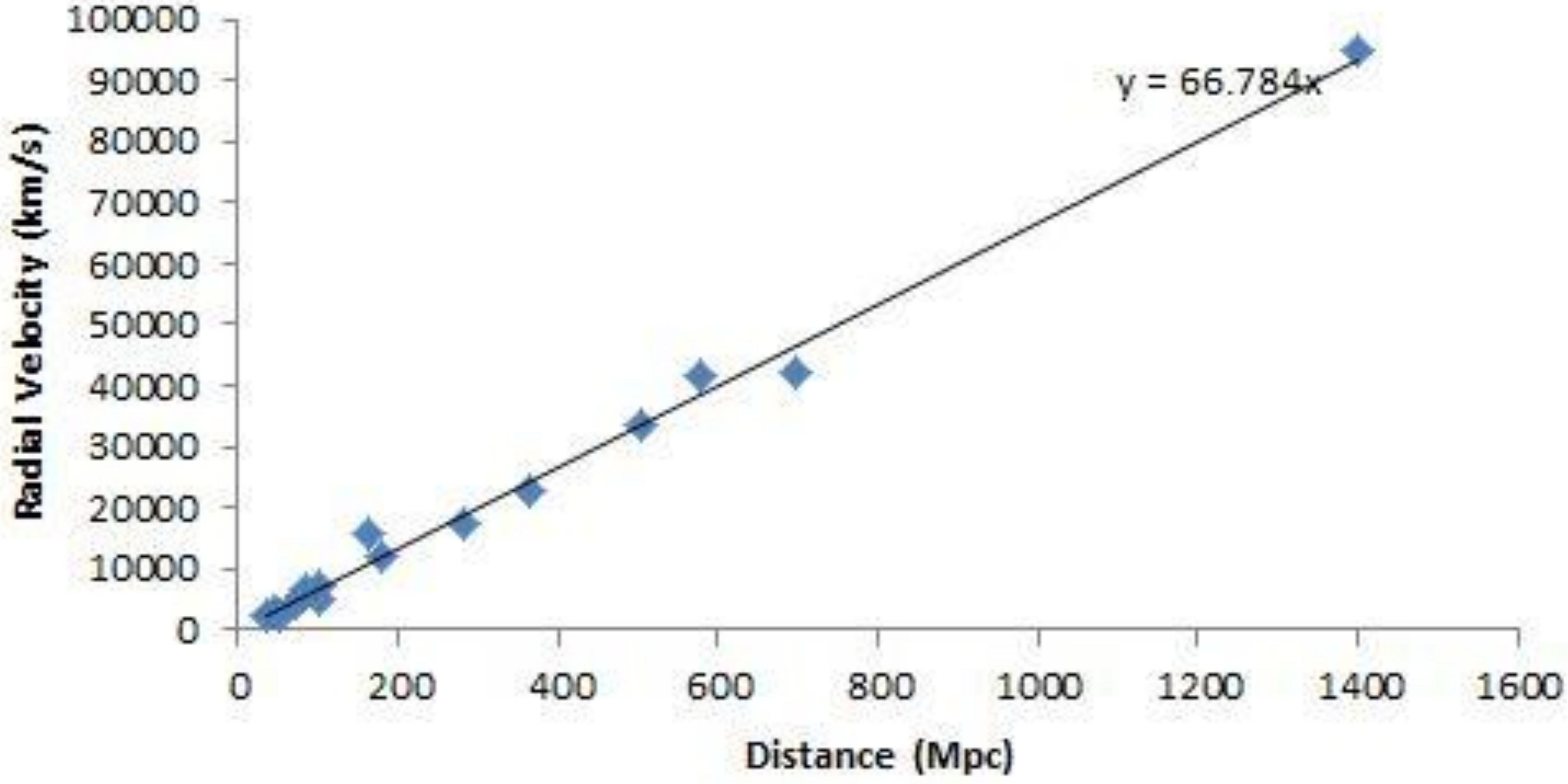
0.5
1
1.5
2
2.5
3


Gaia16agf R
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


Difference in magnitude
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0
2
4
6
8
10
12
14

Hubble Diagram



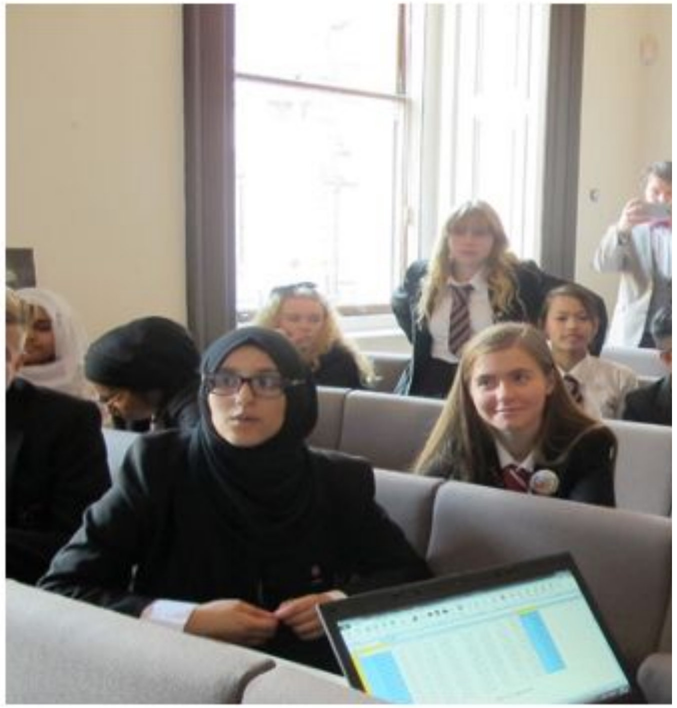
Eastbury Community School give Gaia astronomers a lesson in how to plot a Supernova lightcurve at the Royal Astronomical Society

THE INSTITUTE for RESEARCH in Schools

Eastbury Community School students in action.

Megan Greet (Head of physics), Jamie Paton (teacher) and sixteen students from Eastbury Community School were delighted to be invited to the Royal Astronomical Society on Wednesday to demonstrate that teenagers really can carry out genuine scientific research. In partnership with the Institute for Research in Schools, led by Becky Parker, Eastbury were selected as the pilot school to analyse data from the Gaia project. This is a wonderful opportunity to enhance the enrichment work being

Eastbury Community Sch
a lesson in how to plot a
the Royal Astronomical S



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Eastbury Physics
@EastburyPhysics

Follow

Us giving presentation @RoyalAstroSoc on supernovae found in data from #GaiaMission provided by @ResearchInSch

Datasets on Type Ia SNe

Background material

How to do photometry using JS9 (online tool) inc. screencasts

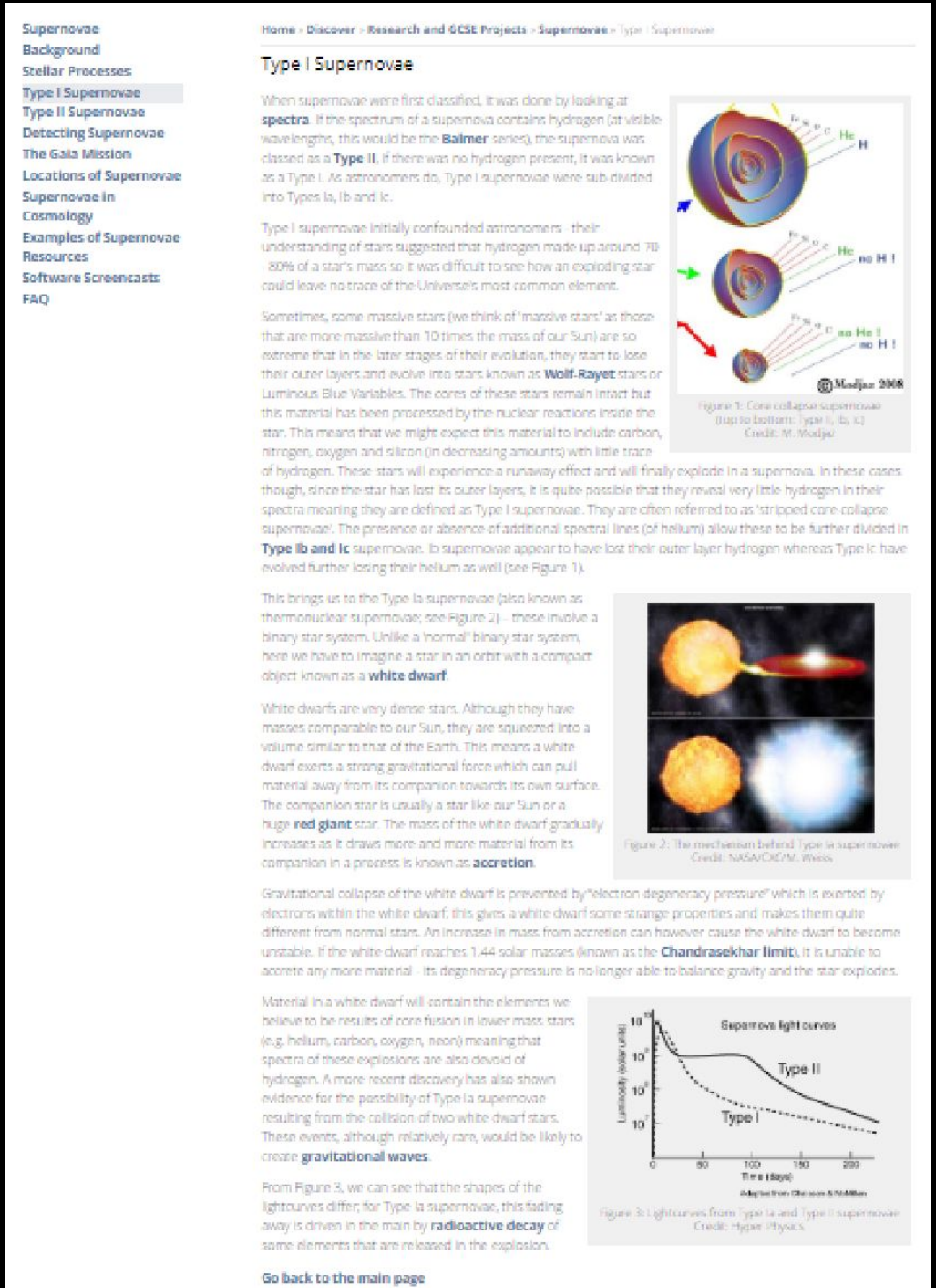
Put your values into an Excel sheet

Calculate the peak brightness and use that to calculate the distance to the host galaxy

Plot your data on the Hubble plot and calculate the age of the Universe !

Use Gaia to add new objects

https://www.schoolsobservatory.org/discover/projects/supernovae/



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Type I Supernovae

When supernovae were first classified, it was done by looking at **spectra**. If the spectrum of a supernova contains hydrogen (at visible wavelengths, this would be the **Balmer** series), the supernova was classed as a **Type II**. If there was no hydrogen present, it was known as a Type I. As astronomers do, Type I supernovae were sub-divided into Types Ia, Ib and Ic.

Type I supernovae initially confounded astronomers - their understanding of stars suggested that hydrogen made up around 70-80% of a star's mass so it was difficult to see how an exploding star could leave no trace of the Universe's most common element.

Sometimes, some massive stars (we think of 'massive stars' as those that are more massive than 10 times the mass of our Sun) are so extreme that in the later stages of their evolution, they start to lose their outer layers and evolve into stars known as **Wolf-Rayet** stars or Luminous Blue Variables. The cores of these stars remain intact but this material has been processed by the nuclear reactions inside the star. This means that we might expect this material to include carbon, nitrogen, oxygen and silicon (in decreasing amounts) with little trace of hydrogen. These stars will experience a runaway effect and will finally explode in a supernova. In these cases though, since the star has lost its outer layers, it is quite possible that they reveal very little hydrogen in their spectra meaning they are defined as Type I supernovae. They are often referred to as 'stripped core collapse supernovae'. The presence or absence of additional spectral lines (of helium) allow these to be further divided in **Type Ib and Ic** supernovae. Ib supernovae appear to have lost their outer layer hydrogen whereas Type Ic have evolved further losing their helium as well (see Figure 1).

Figure 1: Core collapse supernovae (top to bottom: Type II, Ib, Ic) Credit: M. Modjaz

This brings us to the Type Ia supernovae (also known as thermonuclear supernovae; see Figure 2) - these involve a binary star system. Unlike a 'normal' binary star system, here we have to imagine a star in an orbit with a compact object known as a **white dwarf**.

White dwarfs are very dense stars. Although they have masses comparable to our Sun, they are squeezed into a volume similar to that of the Earth. This means a white dwarf exerts a strong gravitational force which can pull material away from its companion towards its own surface. The companion star is usually a star like our Sun or a huge **red giant** star. The mass of the white dwarf gradually increases as it draws more and more material from its companion in a process is known as **accretion**.

Figure 2: The mechanism behind Type Ia supernovae Credit: NASA/CXC/M. Weiss

Gravitational collapse of the white dwarf is prevented by "electron degeneracy pressure" which is exerted by electrons within the white dwarf; this gives a white dwarf some strange properties and makes them quite different from normal stars. An increase in mass from accretion can however cause the white dwarf to become unstable. If the white dwarf reaches 1.44 solar masses (known as the **Chandrasekhar limit**), it is unable to accrete any more material - its degeneracy pressure is no longer able to balance gravity and the star explodes.

Material in a white dwarf will contain the elements we believe to be results of core fusion in lower mass stars (e.g. helium, carbon, oxygen, neon) meaning that spectra of these explosions are also devoid of hydrogen. A more recent discovery has also shown evidence for the possibility of Type Ia supernovae resulting from the collision of two white dwarf stars. These events, although relatively rare, would be likely to create **gravitational waves**.

From Figure 3, we can see that the shapes of the lightcurves differ; for Type Ia supernovae, this fading away is driven in the main by **radioactive decay** of some elements that are released in the explosion.

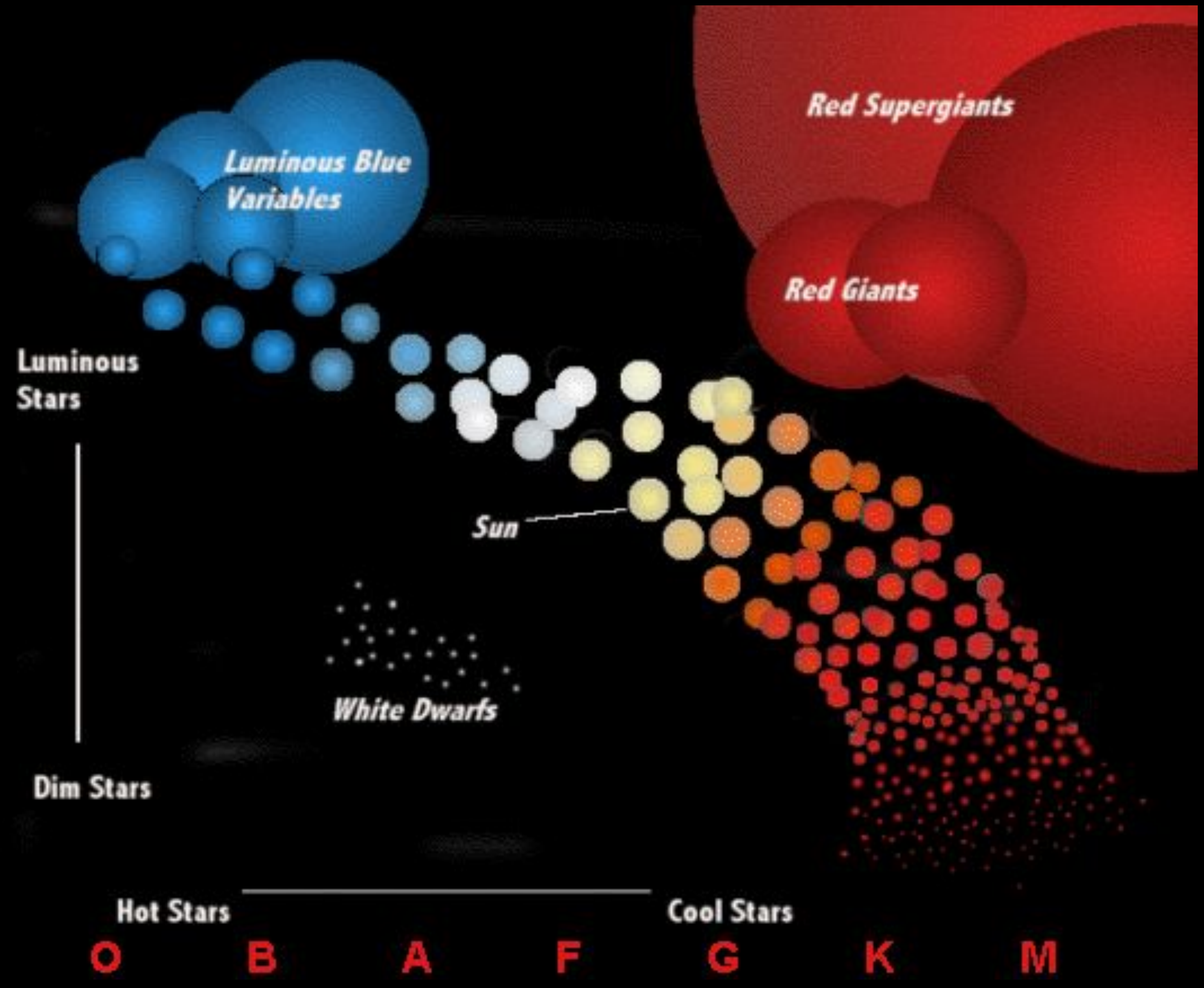
Figure 3: Lightcurves from Type Ia and Type II supernovae Credit: Hyper Physics

Go back to the main page

The Hertzsprung-Russell Diagram (HRD; sometimes CMD)

A theoretical diagram showing the properties of a population of stars

Developed independently between 1911 and 1913 plotting brightness/luminosity (y-axis) against colour (i.e. temperature) or against spectral type (x-axis)


Red Supergiants
Luminous Blue Variables
Red Giants
Luminous Stars
Sun
White Dwarfs
Dim Stars
Hot Stars
Cool Stars
O B A F G K M

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The Colour Magnitude Diagram (CMD)

The Colour Magnitude Diagram (or CMD) is a plot of observational data (see Figure 1) which shows how a population of stars can be plotted in terms of their brightness (or luminosity) and colour (or surface temperature). The fact that we are able to interpret a star's colour as a measure of its temperature is based on the idea that stars can be considered as black-body sources, enabling us to use **Wien's Law**. It is this temperature which we can use to plot the star's **spectral type** on the x-axis.

The first work in this area was conducted, in 1911, by the Danish astronomer Ejnar Hertzsprung, who produced a graph of stars' magnitudes against their colours. Independently in 1913, the American Henry Russell, showed that there did appear to be some sort of relationship between a star's luminosity and its temperature, and that stars fell into distinct groups. Such a plot is now known as a Hertzsprung-Russell (or H-R) diagram. These theoretical diagrams have since been reproduced for stellar populations such as open and globular clusters and even for galaxies.

If all stars were alike, all those with the same luminosity would have equal temperature and we might expect hotter stars to always be brighter than cooler ones. The diagram below suggests that stars populate specific areas of the CMD. In fact, Figure 1 goes even further and overlays a set of lines denoting where stars of equal radii lie.

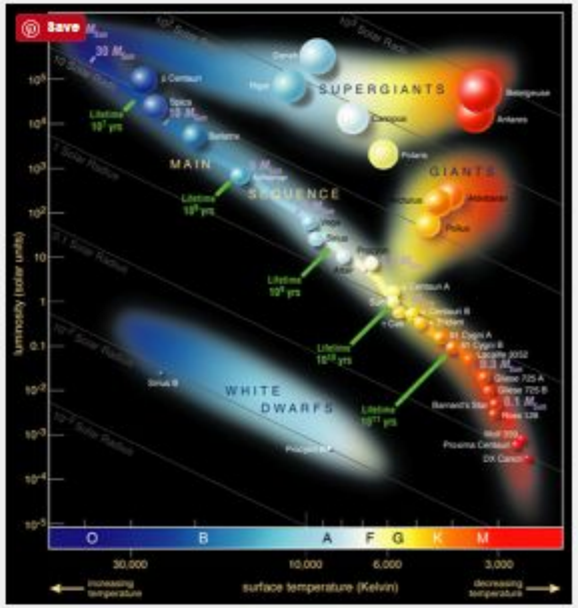


Figure 1: A colour magnitude diagram.
Credit: ESO (http://www.eso.org/public/images/)

There appear to be four distinct areas where the stars lie:

- A diagonal band of stars running from bright, blue stars to faint, red stars, known as the **main sequence**
- A horizontal strip of extremely bright stars with a range of colours from blue to red (denoting a range of temperatures from hot to cool), known as **supergiants**
- A grouping of red stars lying above (so brighter than) and to the right of the main sequence, known as **red**

Inquiry-based 'teacher-free' activity for students to learn about open clusters and HR diagrams as well as photometry (and all the nasty maths)

Can choose any one of 28 datasets or take their own observations with FT/LCO

https://www.schoolsobservatory.org/discover/projects/clusters/main

You can register for the FT Project (it's free, honest !)

UK and Ireland

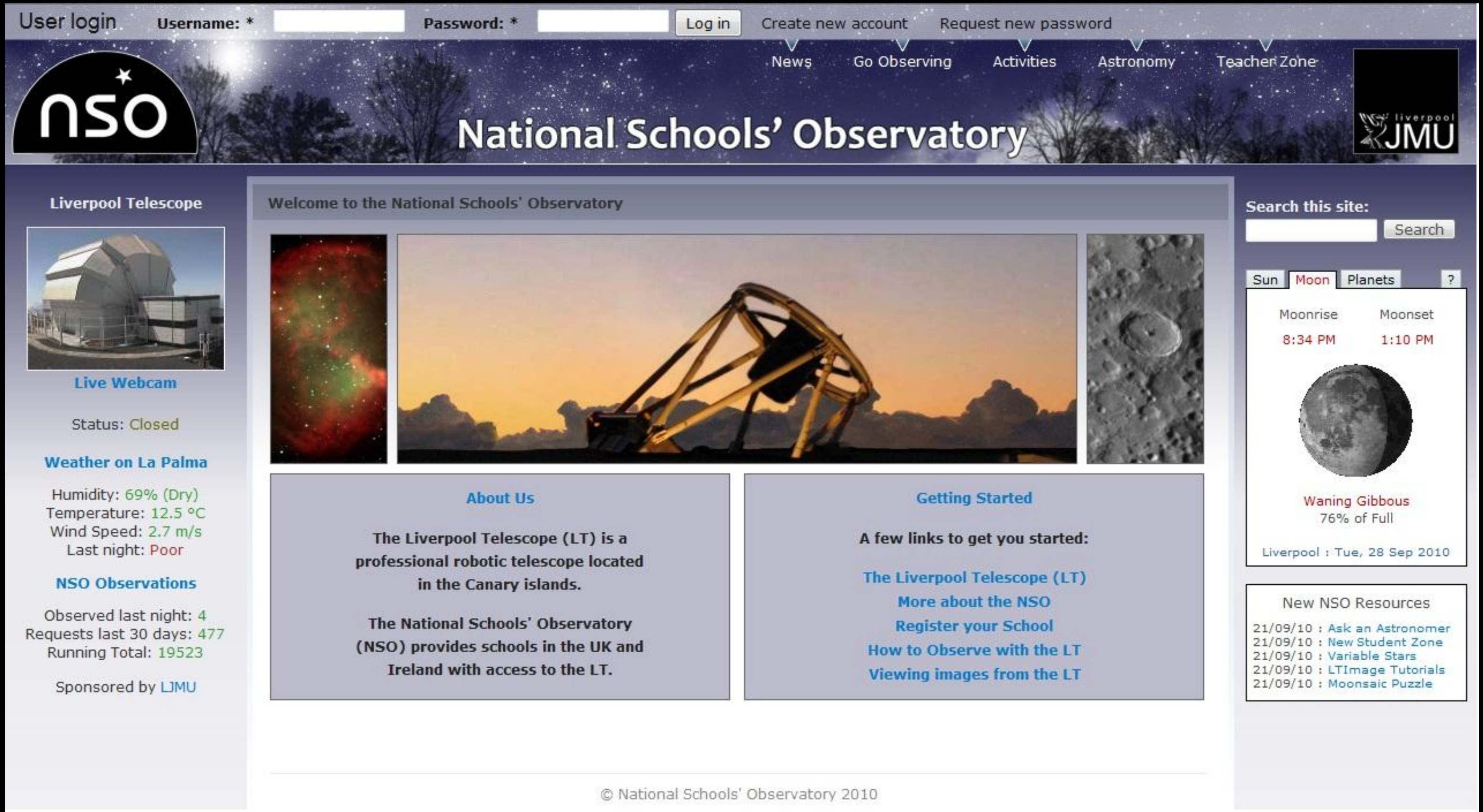
Email me: fraser.lewis@faulkes-telescope.com

Liverpool Telescope, La Palma

nso

LIVERPOOL JOHN MOORES UNIVERSITY

National Schools Observatory



Established (2004) to provide schools in the UK and Ireland with access to the Liverpool Telescope through a guided observing system, together with astronomy related content, news and learning activities.

FAULKES TELESCOPE

Please come find me or
e-mail me your ideas

fraser.lewis@
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