Stars for Schools in 2022

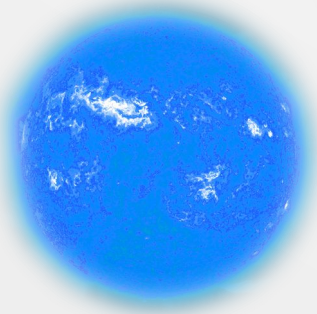
Robert Izzard
and many friends

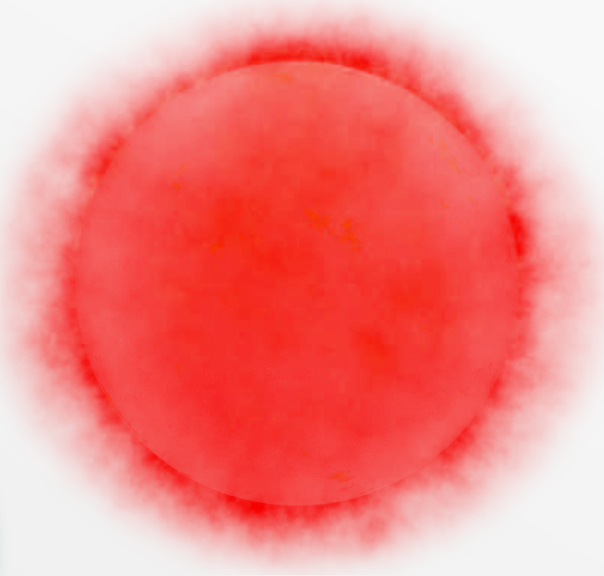
UNIVERSITY OF SURREY

Science & Technology Facilities Council

Stars for Schools

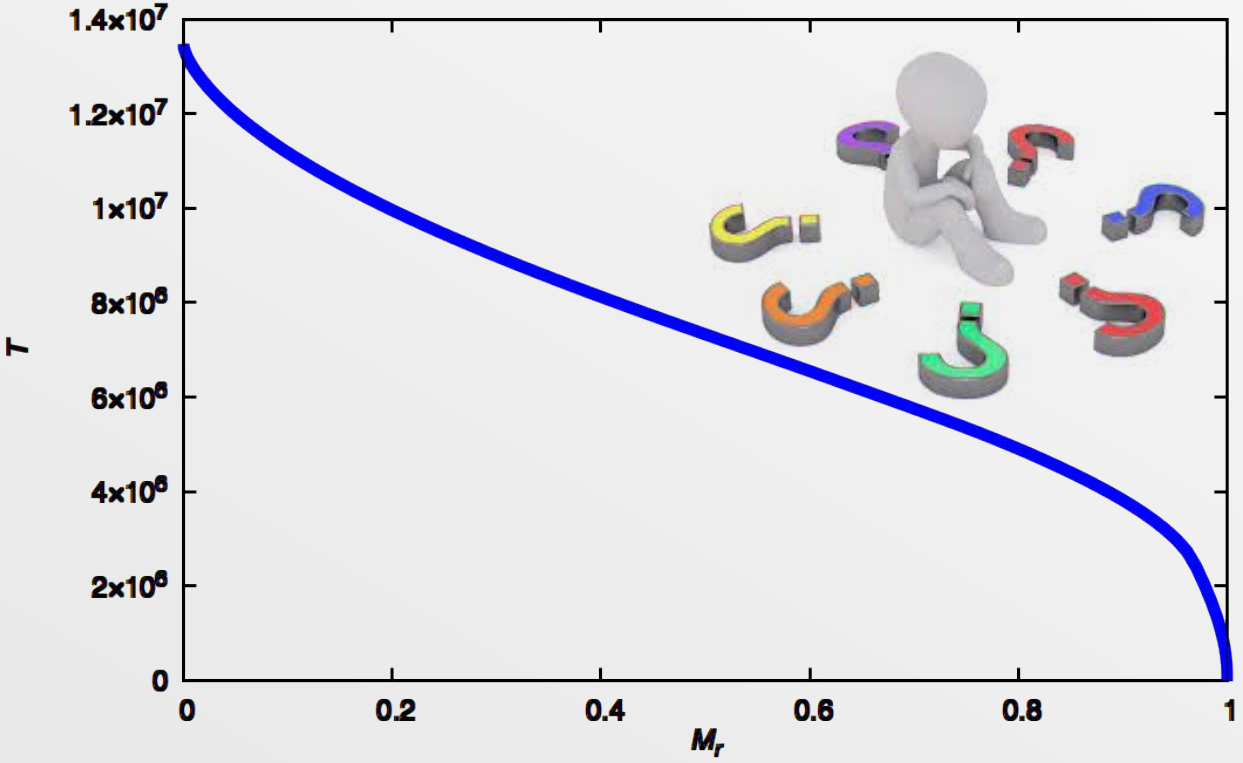
- The *Window to the Stars* software
- Making it work on the Raspberry Pi
- Bringing the project to schools
- Future plans

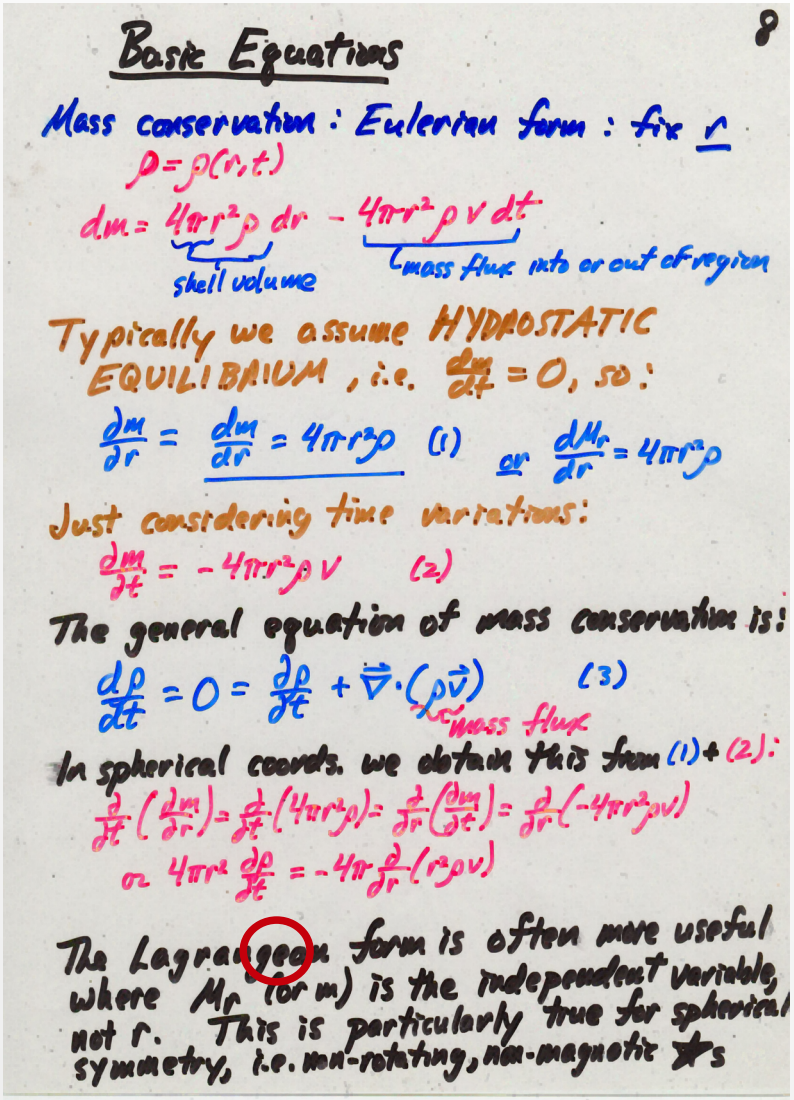




Stellar evolution software

- What is it and what does it do?
  - Solves stellar structure equations…
  - To give us internal models of stars





Confusing *FORTRAN*

```
do jx = 1, 10
    do jq = 1, kt
       do iq = 1, kr
          fspl(1, 1, jq, iq, jx) = cs(iq, jq, jx)
       end do
    end do
     do ir = 1, kr
       do it = 1, kt
          mat(1, it) = fspl(1, 1, it, ir, jx)
       end do
       call spline ( kt, tfm, mat )
       do it = 1, kt - 1
          fspl(2, 1, it, ir, jx) = mat(2, it)
          fspl(3, 1, it, ir, jx) = mat(3, it)
          fspl(4, 1, it, ir, jx) = mat(4, it)
       end do
    end do
end do
```

… modern codes are still like this!

2005: *TWIN* stellar code

- Based on Peter Eggleton's original ***TWIN*** code
- Fast, low-CPU usage compared to competition
- One can simulate a star "in 2000 lines of FORTRAN" (77?)
- Utrecht version of ***TWIN*** → modern(ish) FORTRAN 95

  → Documented, human-readable code, tested
- Many (then) new features supported
- But still all **command line**

  hand-hacked **input files**

  → **significant learning curve**

  → **impossible for most people**

Sick in Heidelberg and Switzerland

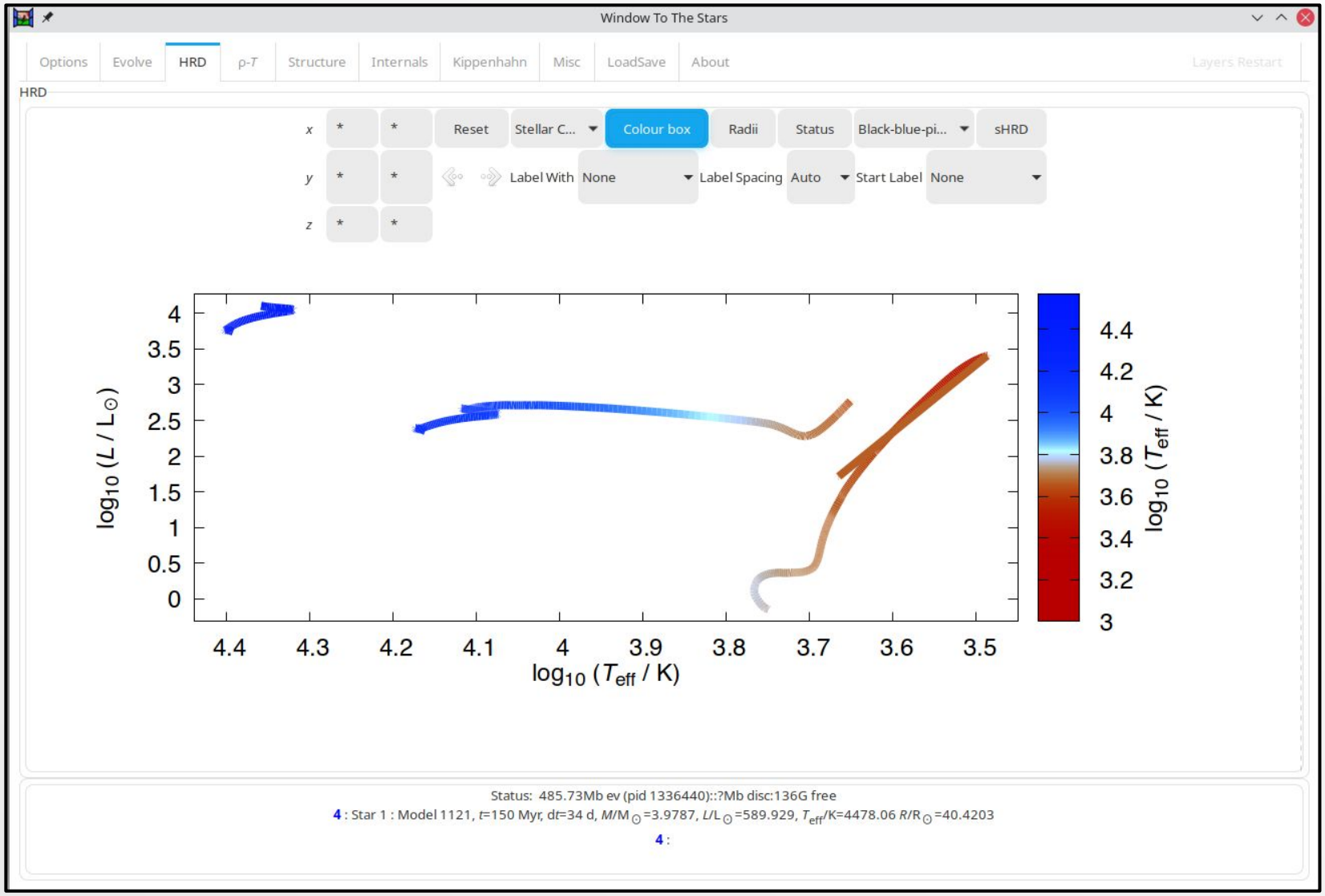
- 2005: Bronchitis from visiting kids in Heidelberg
- Smoking inlaws in Switzerland

→ endless coughing → not good

→ Locked in my room! **VERY BOLD**

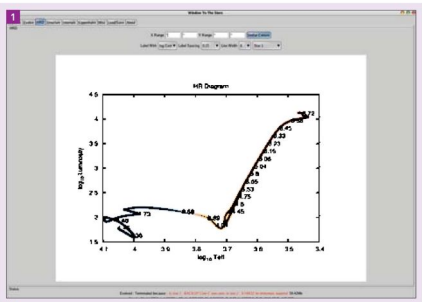
→ Decided to write ***Window to the Stars***

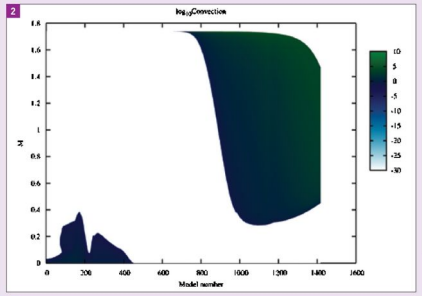
WTTS: A web browser to the stars

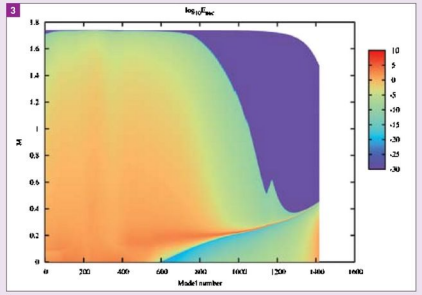


http://personal.ph.surrey.ac.uk/~ri0005/window.html

Papers in *New Astronomy*, *Astronomy and Geophysics*







Software provides Window to the Stars

Robert Izzard and Evert Glebbeek demonstrate the working of their user-friendly stellar modelling tool, Window to the Stars.

We have developed a graphical user interface, Window to the Stars (WTTS), to Peter Eggleton's TWIN single and binary stellar evolution code (Eggleton 1971, Eggleton and Kiseleva-Eggleton 2002). The project came about as a result of our frustration with a steep learning curve for what should be a simple exercise. With WTTS both professional astrophysicists and students benefit from a clear, simple interface to stellar evolution, so they can focus on the physics of the problem rather than non-essential computational details. WTTS is written using freely available software and can be downloaded, together with TWIN, from our website at http://www.astro.uu.nl/~izzard/window/. It has been tested on Linux and Mac OS X.

With a series of simple tabbed windows, the user is guided through the process of choosing initial conditions and physical parameters, e.g. mass and metallicity, for a stellar model. While every parameter of TWIN can be changed, it is not necessary to do so, hence novices can construct stellar models and experts can fine-tune theirs. Real-time help is provided for each option. Execution and termination of the stellar evolution code is handled transparently by WTTS. A suite of plotting tools is available to show quickly all aspects of the models, including a text log of model information, labelled and stellar-coloured Hertzsprung–Russell diagrams (figure 1), surface parameters (e.g. mass, luminosity, temperature and chemistry), internal structural details such as composition profiles, and 3-D surface plots of any stellar variable against two others (figure 4). Images and animations can be saved as PNG, GIF or PostScript files for direct inclusion in publications and websites.

The images presented here as figures 1–4 show how Window to the Stars can be used to analyse the results of the TWIN stellar evolutionary code. Shown is an evolutionary sequence starting from the merger of a $0.59\,M_\odot$ and a $1.29\,M_\odot$ star. The merged star is "puffed up" from excess energy after the merger until it settles down as a $1.74\,M_\odot$ star on its main sequence. It is no ordinary star, as it has a non-standard chemical profile, so it evolves a little differently from a normal main sequence star. Mergers such as these are thought to lead to "blue stragglers" in globular clusters.

Window to the Stars is being used to study stellar merger remnants at the University of Utrecht, and as a teaching aid at the University of Nijmegen. We plan to develop the WTTS software further, to include fully binary star evolution, enhanced nucleosynthesis and the ability to use different stellar evolution codes with a single user interface.●

Robert Izzard and Evert Glebbeek, Sterrenkundig Institute, Universiteit Utrecht, The Netherlands.

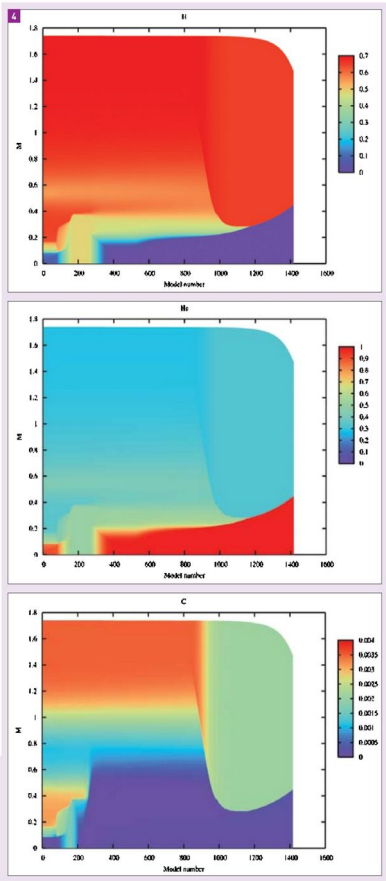
References
Eggleton P P 1971 *MNRAS* **151** 351.
Eggleton P P and Kiseleva-Eggleton L 2002 *ApJ.* **575**
http://www.astro.uu.nl/~izzard/window/

1: Evolution track in the Hertzsprung–Russell (log luminosity vs log effective temperature) diagram of a typical stellar merger remnant, up to the helium flash at the tip of the giant branch. The numbers along the track mark the model number in the calculation. The first 250 or so models show the post-collisional relaxation towards the main sequence.

2: Convection zones in the merger remnant, blue/green colours are the convective regions, white regions are radiative. A convection zone develops in the centre during the relaxation phase, mixing hydrogen into the core. The main sequence lasts from about model 250 to 450, after which the convective core disappears. Around model 700 the surface convection zone moves inwards to the edge of the burning shell while the star becomes a red giant.

3: Regions of nuclear energy generation inside the star (red regions have the most nuclear burning, blue the least). The post-main-sequence hydrogen-burning shell develops by model 800 (the red band at about $M=0.2$). Towards the end of the run energy generation in the core starts to rise again, eventually leading to the helium flash.

4: Abundances of hydrogen, helium and carbon by mass fraction. Matter from the progenitor stars was not completely mixed during the collision, leading to a hydrogen-depleted region outside the core (between $M=0.5$ and $M=0.6$). Convection mixes the region below $M=0.4$, bringing fresh hydrogen into the core. When the dredge-up moves in (around model 700) it mixes the hydrogen-depleted layers.



https://ui.adsabs.harvard.edu/abs/2006A%26G....47d..28I%2F/abstract
https://arxiv.org/abs/astro-ph/0607611

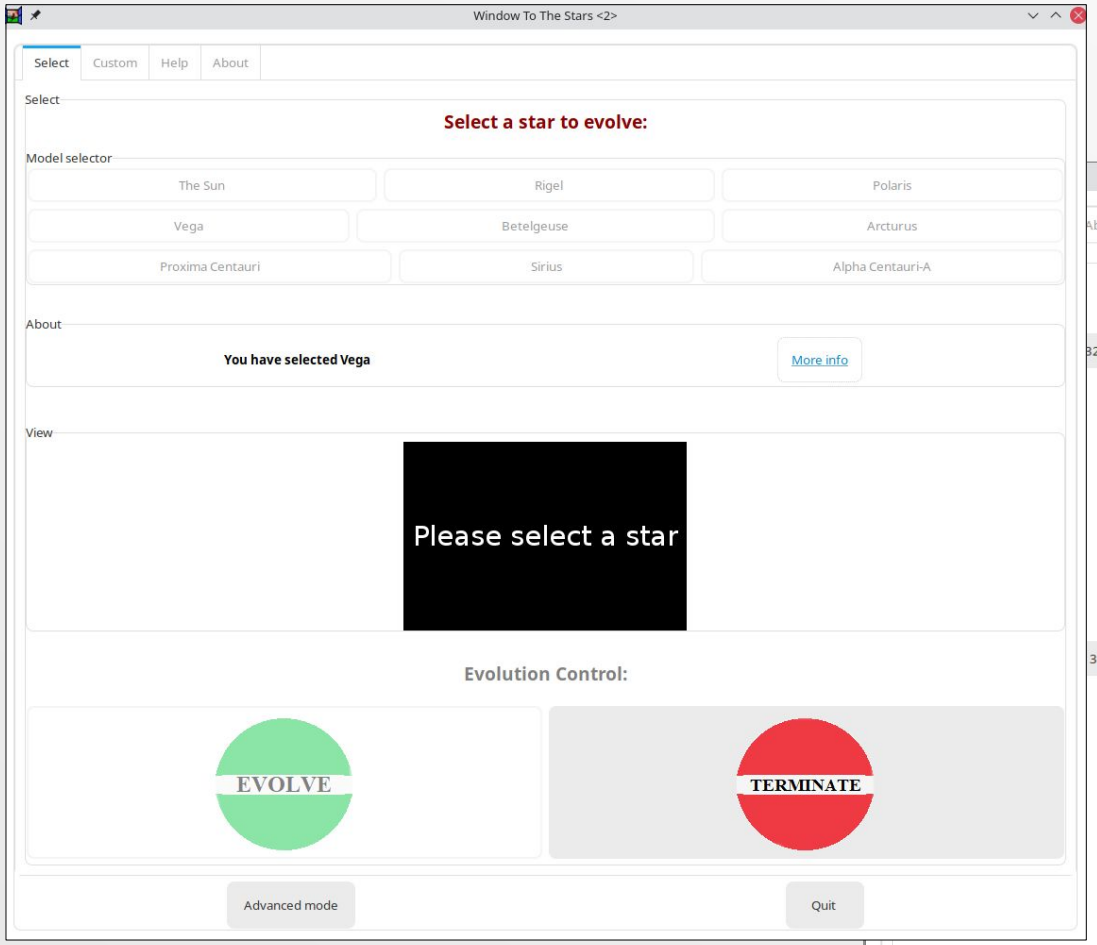
Undergraduate teaching

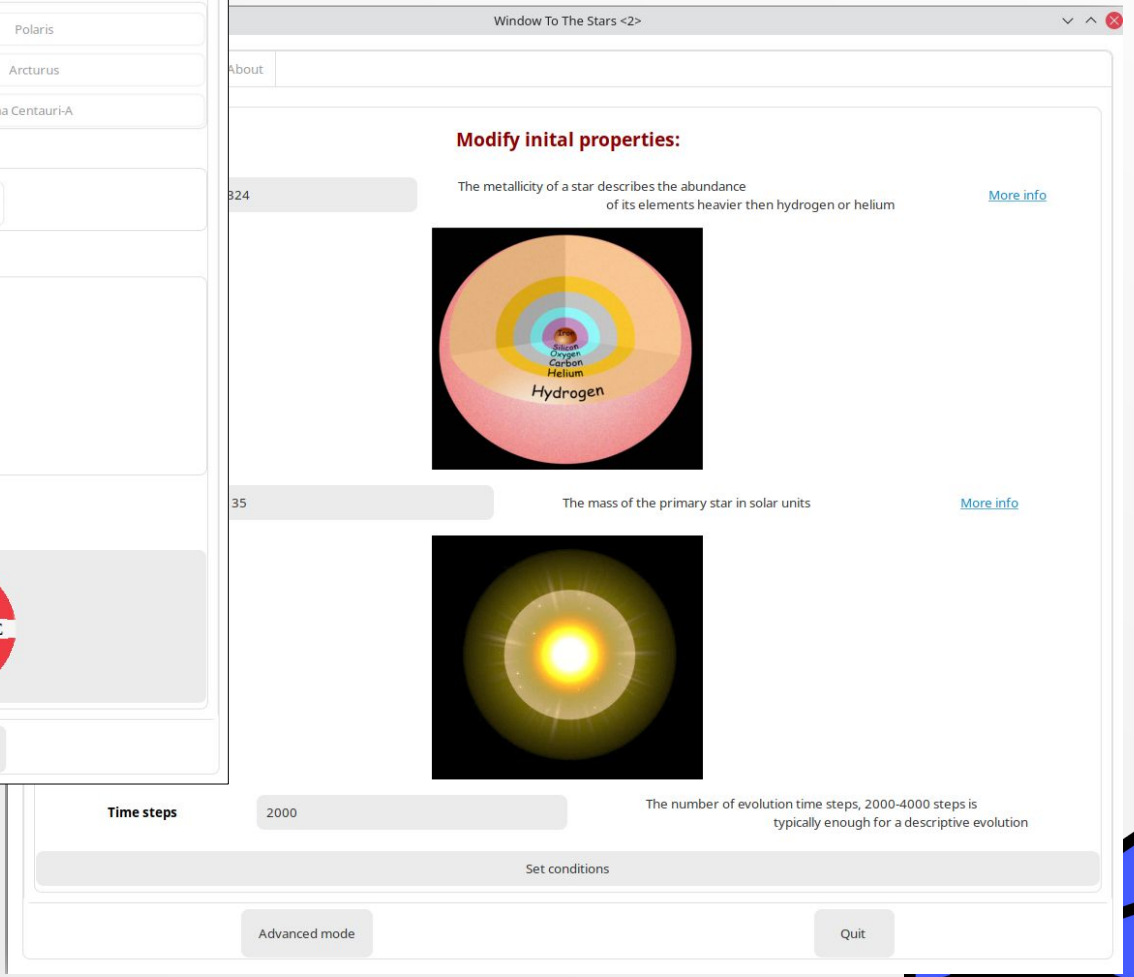
- Used in lab teaching in **Bonn**, **Monash**, **Sydney**, **Heidelberg** … also a high school in **Wisconsin** (!)

- Very good tutorial class. **Would love to explore more about *WTTS*!!!**
- The instructor for the lab was very helpful in installing everything, even late at night.
- We always had a nice morning, even though it was so early.
- The supernova simulation was the most epic experiment – period!
- All in all we gained deeper insight into stars. Furthermore, we realized that *WTTS* is a **really mighty instrument** which is able to plot more then we ever thought. And most importantly, we had much fun.
- The course was **a lot of fun**!
- We learned to interpret diagrams which is very useful for any type of scientist, and are now able to use the program *Window to the Stars* in a useful way.
- **This whole lab course helped me very much with understanding the principles of stellar evolution.** I often wonder what would change in *X* when I change *Y* ? … *WTTS* gave me the possibility to actually test that!
- While stars evolved and were analysed we always had a nice coffee **talk about England and whiskey** (sic).

“Simple-user mode”

Summer project with Gemma Kerr and Michael Armstrong





Public events

with ↓ Michael Armstrong, ↓ Gemma Kerr, Giovanni Mirouh ↘

Dark Matter Day, Surrey

Royal Society Summer Exhibition, London

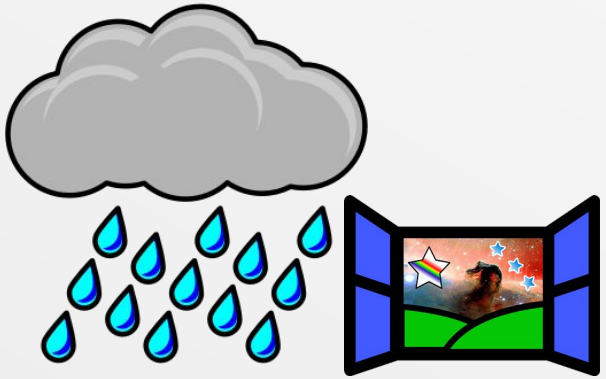
World Space Week, Guildford

Public events

Weekly astronomy nights at Institute of Astronomy, Cambridge

Holly Preece →

- Also university open days
- Very popular → *especially when it rains!*



→ … to schools?

- **“Security”** issues – really a problem?
- **“Runs on Linux”** ↔ lack of time/expertise/understanding

- IT support very limited, especially for non-Windoze
- Solutions? → **Raspberry Pi** and **Virtualbox**

Raspberry Pi solution

1. Technology improved: Raspberry Pi 3 and 4
2. Cheap solution in a tiny box!
3. Easy to burn an SD Card → “just works”

→ Surrey + LEHS

- Surrey outreach → local schools
- ***Lady Eleanor Holles School***, in Hampton (SW London)

People and activities at LEHS

- **Andy "Mr" Brittain**

  STEM coordinator, physics teacher, inspiration!

- Analyzing data from the Spitzer Telescope to identify targets JWST
- Participating in CERN@School
- National Schools' Observatory STEM club
- World Space Week Schools Art Competition
- Space Sounds Project: a joint venture w/ QMU/Reach Academy/LEH
- Entering BPhO, UK Space Design and Big Bang competitions
- Staging a Moon Rock Exhibition at LEH
- Trips to CERN, Thorpe Park, Dungeness Nuclear Power Station
- Lecture visits to University College London, The Royal Institution and the IOP
- Exoplanet naming project for students in the Junior and Senior School
- Exhibiting at the Royal Society Student Conference
- Isaac Embedded School

The students at LEH are a source of tremendous scientific power, and their output has yet to reach maximum intensity.

And a few weeks later...

The Covid-19 lockdown began ...

Lockdown work: a new course!

- Convert previous lab courses →

  schools course for 15-18 yr olds

- Not a small challenge! (esp. during Covid)
- Help from:

Rahul Kakaiya

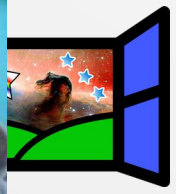
Surrey/Imperial

Sabana Ghale

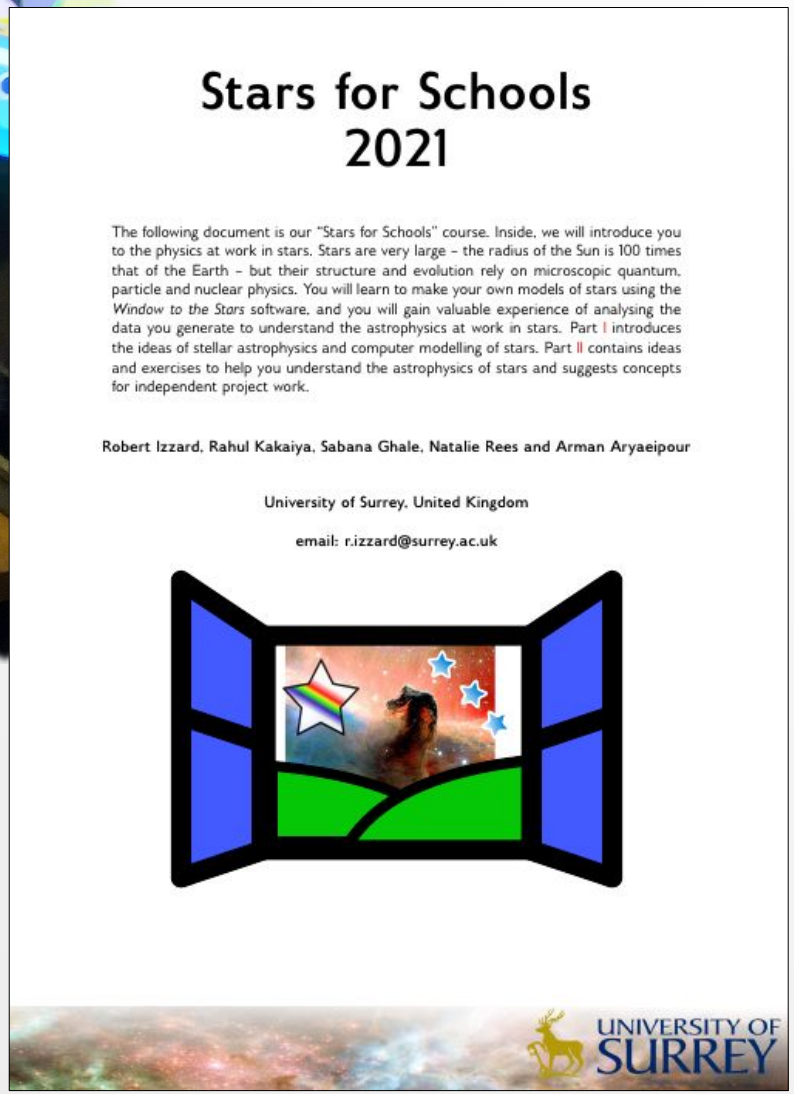
Surrey (BSc)

Natalie Rees, Arman Aryaeipour

PhDs Surrey



Course guide:
written with lockdown guest editor



Stars for Schools
2021

The following document is our "Stars for Schools" course. Inside, we will introduce you to the physics at work in stars. Stars are very large – the radius of the Sun is 100 times that of the Earth – but their structure and evolution rely on microscopic quantum, particle and nuclear physics. You will learn to make your own models of stars using the *Window to the Stars* software, and you will gain valuable experience of analysing the data you generate to understand the astrophysics at work in stars. Part I introduces the ideas of stellar astrophysics and computer modelling of stars. Part II contains ideas and exercises to help you understand the astrophysics of stars and suggests concepts for independent project work.

Robert Izzard, Rahul Kakaiya, Sabana Ghale, Natalie Rees and Arman Aryaeipour

University of Surrey, United Kingdom

email: r.izzard@surrey.ac.uk

UNIVERSITY OF SURREY

What's in the course?

Part I: Introduction and software

1 What are stars?
2 Modelling stars on your PC
3 Installing and running Window to the Stars
4 The Window to the Stars software
5 Layers in *WTTS*

Introduction
+ Physics
+ Maths
+ Computing

Part II: Stellar projects

6 The nuclear thermostat
7 The distance to stars
8 The beginning of nuclear astrophysics
9 Making chemical elements in stars
10 Dating star clusters
11 Project reporting → probably **for the first time**

New ideas:
+ Astrophysics
+ Maths/stats
+ Python

Academic level

1. **Who** are we aiming at? → **15-18 years**
   - 15-16 → GCSE level, school years 10 and 11
   - 17-18 → A level, school years 12 and 13, “sixth form”

2. **No calculus** allowed!
   - Before A-level (age <16) **no calculus**
   - Even at A-level, avoid calculus
   - But, leave it in as extra material

$$\frac{\mathrm{d}P}{\mathrm{d}r} = -\frac{GM\rho}{r^2}$$

3. Mix **physics** and **maths** with **Python** coding
   - Most students will have never programmed before
     → this is a great way to get them started
     → fundamental to the project work

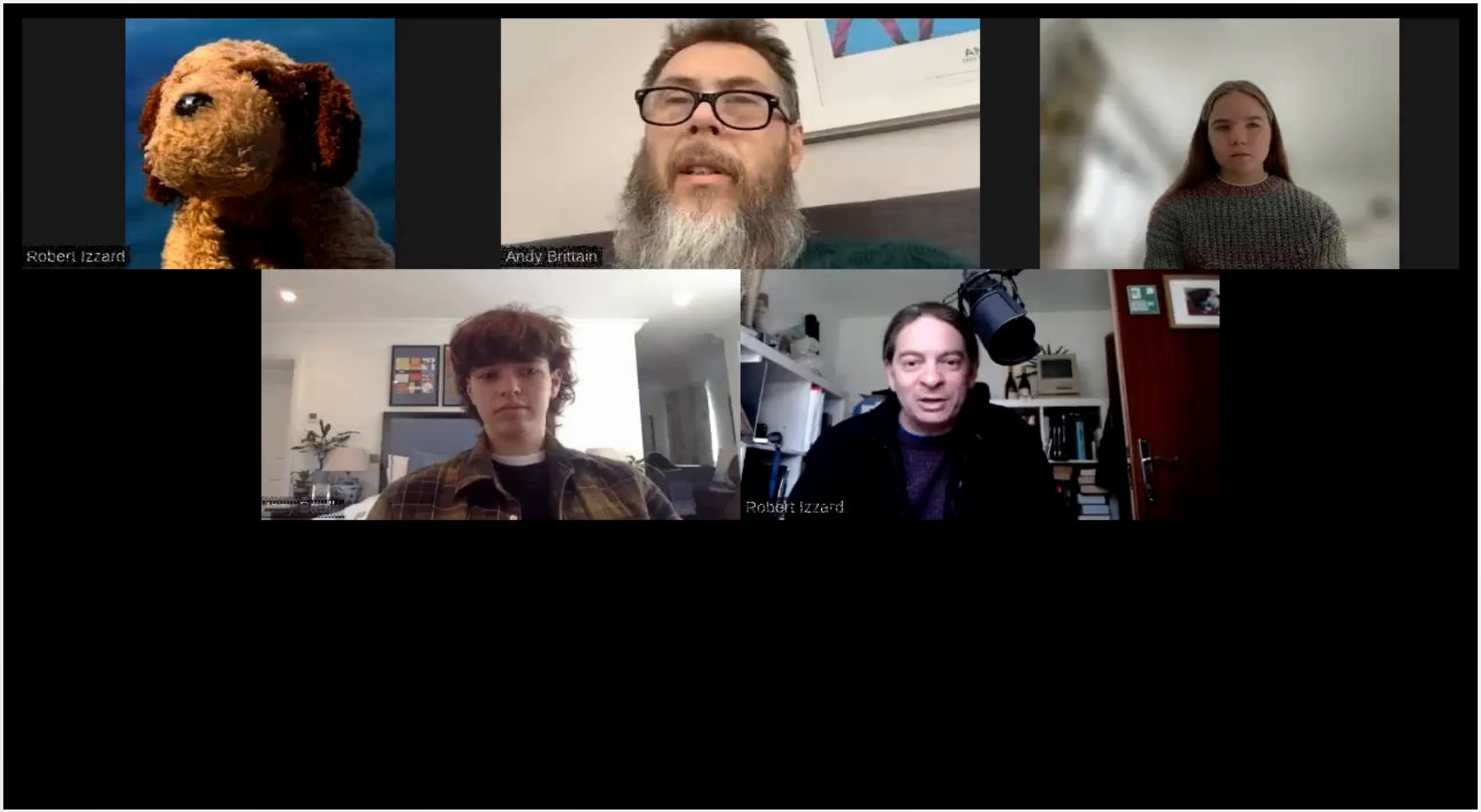
LEHS launch

- **Six** students
- **Extra** to the curriculum → runs in **parallel** to classes
- **Initial launch** *M$ Teams* meeting
- **Weekly** virtual meetings with Sabana or me
- Half-term and term-end **catchup**
- We provided **educational** and **tech**. support

  → tech support for home PCs ↔ *Virtualbox*

  → others use **Raspberry Pis**

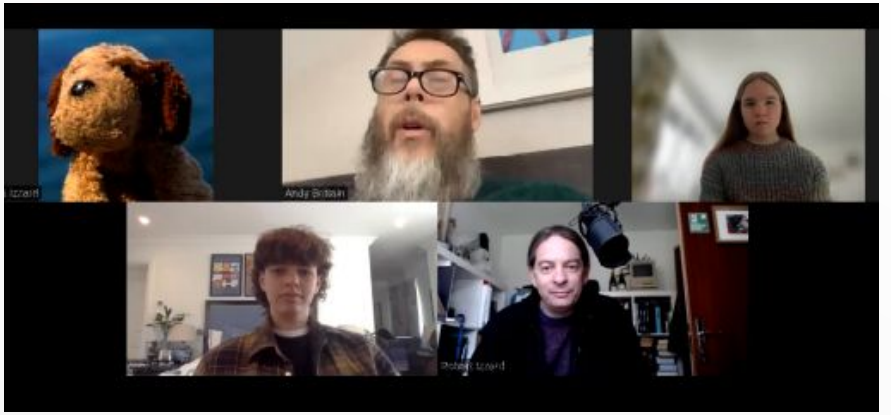
School feedback



Andy Brittain, Abi Dawes, Isabella Baulk

from Lady Eleanor Holles school, London

Feedback



Andy Brittain, Abi Dawes, Isabella Baulk, Björn

- **The years before exams**
- **Maths** is ***not*** too **hard**
- Documentation, software → **good**
- The ***Python*** coding is **really useful** to bond subjects
- Extending to other schools as much a **mental** as **time** and **money** challenge.
- “it's really been amazing”

  → **much to celebrate**!

Future of the programme

- Working with Andy Brittain to extend the programme to younger students (11-15yr).
- Extend to more schools. Needs an academic network: Surrey contacts haven't worked out, so trying other routes, e.g. ***Royal (Astronomical) Society***
- UK ***STFC*** application: We can't do it without the money, so we can't do it to get the money, etc. but are trying again…
- ***Royal Society*** application in progress
- **Hochschulwettbewerb**

  "Unser Universum"

  … decision next week!

Many thanks

In approximately chronological particular order:

Evert Glebbeek and Peter Eggleton for *TWIN*

Holly Preece, Tom Comerford, Giovanni Mirouh

Rahul Kakaiya, Gemma Kerr, Michael Armstrong

Sabana Ghale, Arman Aryaeipour, Natalie Rees

Heather Campbell, Sam Weston

Andy Brittain and the physics students at LEHS

Useful links

http://personal.ph.surrey.ac.uk/~ri0005/

http://personal.ph.surrey.ac.uk/~ri0005/window.html

http://personal.ph.surrey.ac.uk/~ri0005/stars_for_schools.html

Paper:
https://arxiv.org/abs/astro-ph/0607611

Raspberry pi image:
https://zenodo.org/record/3627232