Imperial Astrophysics
PhD Open Day
Welcome!

Dave Clements
What Happens Today

• Brief intro about the group and overall applications process

• Brief presentations on each proposed project

• Breakout rooms to meet potential supervisors and ask questions

• Breakout room with current PhD students (and no supervisors) so you can ask what the place is really like - warts and all!
Introduction to the group

Prof Andrew Jaffe
(on behalf of Head of Group
Prof Alan Heavens)
The Imperial Astro Group

- Cover a wide range of research interests
  - Cosmology to the Sun
  - Planet formation to the search for life
- Wide range of techniques and facilities
  - Numerical modelling
  - Data analysis
  - Space missions
- Ground-based observing - small & large facilities
Life at Imperial in Physics/Astrophysics

- Astrophysics is one of 10 groups in the Physics Department
  - Close ties to other groups, especially:
    - Theory, High-Energy Physics, Space/Atmospheric
- ~13 staff & fellows, ~5 postdocs, ~20 students, 
  ~5 visitors/associates
  - Weekly group seminars, journal clubs
  - sub-groups (cosmology, particle astro, ...) also have ~weekly meetings, discussions, donuts
  - Department-level events (colloquia, etc)
  - coffee, lunch, social events (XMas party, games nights), ...
Planet formation, white dwarfs, brown dwarfs

The Atmosphere of the Sun
Cosmic Shear and large-scale structure

Euclid telescope

Microwave background radiation

Deep surveys

21cm radiation

Square Kilometre Array
Astrostatistics

ICIC
Imperial Centre for Inference & Cosmology
More on projects later
Now something about the application process
Applications

• Must use the College application form found on the Imperial Website

• A research proposal is not needed, just a preference for supervisor or area of study

• Entry requirements:
  
  • Master’s degree in a related subject either a postgraduate MSc or an undergraduate MSci/MPhys

  • A minimum of a 2.1 (or overseas equivalent) for your first degree

  • College requires proof of competence in English. If your first degree was taken overseas in a non-English speaking country, you need to provide an acceptable result in a recognised English language test

  • Two references should be provided, at least one of which should be academic. Forms are provided as part of the online application process
Funding

• We expect 2-3 STFC funded PhD places for 2022 entry. These cover fees and maintenance for UK students.

• Applications for STFC places should reach us by 16 Feb with interviews (probably remote) taking place on 2 March

• International students may be eligible for STFC funding in some cases

• Initial offers about a week after interviews, deadline for acceptance 31 March

• If you can’t get an STFC award there are scholarships available, some via the single selection process, some via separate application

• A scholarship finding tool is available on the IC application page
Any questions?
Projects
The unobserved first billion years: The Epoch of Reionization

Much unknown about first galaxies, first black holes, cosmology

Solution: new field of low-frequency 21cm radio observations
Jonathan Pritchard

Exploring the topology of the epoch of reionization with the 21cm signal

Gaussian statistics - power spectrum
Non-Gaussian statistics - bispectrum, etc
Topological data analysis: Betti number, Minkowski Functionals, etc

Interested in whether there are robust ways for measuring and interpreting them for 21cm observations

Figure 14: Evolution of the VR-complex of the dataset \(D\), as \(\varepsilon\) increases.

\(b_k\) is the \(k\)th Betti number of the corresponding complex. In this simple case, we can check our conclusions from the barcode diagram by directly computing Betti numbers for relevant values of \(\varepsilon\), using the technique described in Section 2.2.5. The result is shown in Figure 14. Indeed, we now see the two holes which we found in the barcode diagram, for relevant values of \(\varepsilon\). Furthermore, we conclude that no more interesting topological features occur once \(\varepsilon\) reaches 7.

\[ \text{Points} \quad \text{Simplices} \quad \text{Betti number, } b_k \]

Measure of holes and filaments in medium

Murugan & Robertson [arXiv:1904.11044]
Dusty star-forming galaxies are objects that form stars rapidly (100s of Msun per year) but they are so dusty this can’t be seen in the optical

- Rare in the local universe but may make up ~1/2 the SFR at cosmic dawn (z~2.5)

- What triggers this activity, what role do they play in galaxy evolution, why are they forming stars so rapidly?

- A particular issue is their role in galaxy cluster formation
- Expect protocluster cores to be most apparent at $z \sim 6$, but recent observations finding them at $z \sim 4$ & lower with SFRs too high

- Herschel/Planck selection finds candidates but need confirmation, and properties fully examined to see how they fit galaxy formation & evolution models

- Getting the observations to do this will be the job of this PhD
DC & Ingo Mueller-Wodarg: Molecules in Venus

• Discovery of phosphine in the atmosphere of Venus by JCMT & ALMA was a surprise

• Suggests unexpected chemistry or even life!

• Awarded 200 hours of JCMT long term time over 3 years to follow this up & examine variation of phosphine & other molecules

• This is a large international project in which the student will play an important role in reducing and analysing the data
- Produce variability plots with hour to year timescales
- More sensitive PH3 data will allow altitude of absorption to be measured
- Will also work on modelling the atmosphere of Venus and the chemistry underway in it
- Examining variability of PH3 & other molecules may provide indicate the origin of PH3
Theory PhDs in Exoplanets, Planet Formation and Accretion Discs

James Owen
Possible project areas

Accretion Disc Structures

Physics of planetary accretion

Atmospheric dynamics on hot exoplanets

Young Exoplanets

Accretion discs around white dwarfs
Current data \implies Nearly every star harbours one or more planets \implies billions of planets in galaxy

Most of these exoplanets are of a type not found in the Solar System:

**Earth to super-Earth sized rocky planets orbiting very close to the central star**
(in orbits smaller than Mercury’s! see example above left)

**OPEN QUESTION: How Do These Small Close-In Planets Form?**
Vital for understanding planet formation in general, and also for understanding planet habitability

Planes form out of the **discs of gas and dust**
around newborn stars

Our work so far: **Steady-state model of gas** in the disc close to the star

**BUT** must include:
- Time-evolution of disc!
- Dust grains to form solid planets!

\implies **Dynamical co-evolution of gas and dust**
**Step 1. Dynamical Co-evolution of Gas and Dust: Hydrodynamical Simulations**

Dust-gas interactions make grains drift radially inwards, fragment, grow, and vertically settle. Grains accumulate in the inner disc regions.

Accumulated large grains form clumps via dust-gas instabilities, finally producing **planetesimals** (10-100 km sized rocky bodies).

![Dust grain clump](image)

**Step 2. Growth of Planetesimals into Planets: N-Body Simulations**

Planetesimals grow via collisions aided by gravitational interactions, ultimately forming a distribution of **planets**.

First time **all** these processes will be studied **together** in detail, to construct the **first end-to-end planet formation model**.

**Require of student:** solid knowledge of university-level hydrodynamics; programming skill (e.g., in python) desirable; Experience in numerical sims a plus.
The Earliest Stages of Planet Formation

Richard Booth
r.booth@imperial.ac.uk

- ALMA images of millimetre-size dust grains show signposts of planets
- But how do these grains evolve and how do they make their way into planets?

Left:

Simulations of spirals and rings:

Signposts of planets?

I build theory and simulations to learn what these latest observations tell us about how planets form
The Earliest Stages of Planet Formation

Richard Booth
r.booth@imperial.ac.uk

- ALMA measures dust properties and disk composition
- James Webb will start measuring exoplanet compositions this year

Project Goals:
- Understand how the early stages of planet formation affect the properties of discs, including their composition
- Understand what this means for the properties of planets
Solar and Stellar Activity

– Spectral modelling of active stars

- Solar spectral irradiance modelling
  → climate
- Stellar brightness variations
  → stellar `pollution’ in transit spectroscopy
  → use of transits to test spot/facular models
  → irradiation of exoplanets

Other interests
- Stellar surface mapping / Doppler imaging
- Galactic plane surveys

Group members:
Rinat Tagirov, Blake Chang, Luke Johnson
Stellar variability modelling

Surface features leave imprint in lightcurves
1. Quantify effect on exoplanet radius retrievals
2. Use observations to test spot & facular models

Why now?
- JWST + ground-based transit spectroscopy
- First models for spots and faculae on stars other than Sun
- Role of metallicity, activity level, $T_{\text{eff}}$