

Imperial College  
London

Department of Physics  
Space, Plasma and Climate Community

**PhD Open Day 2023**

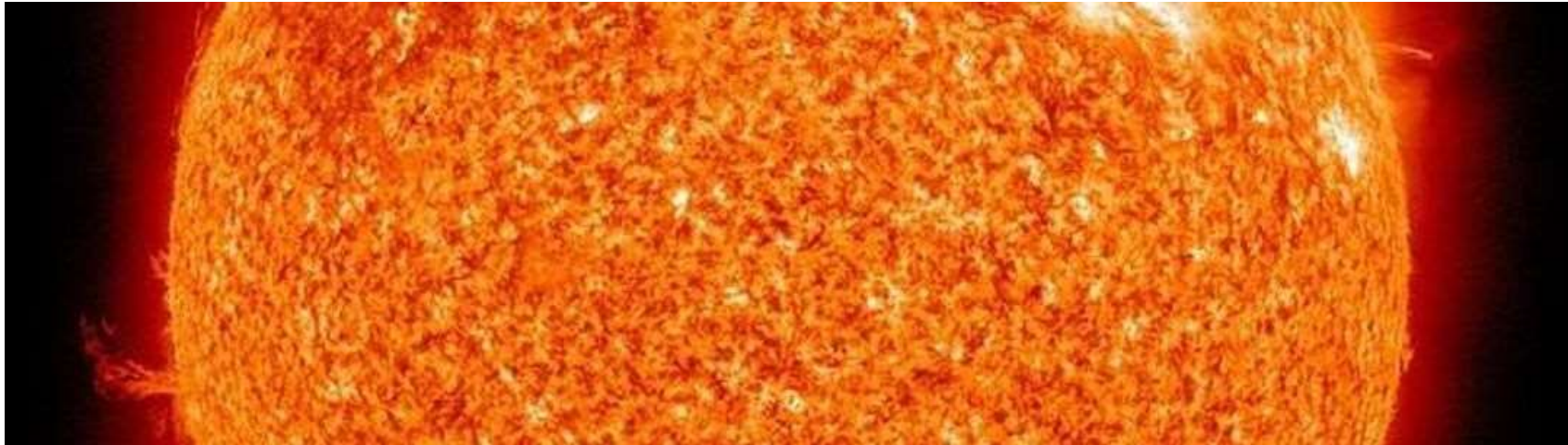
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# Schedule

- Intro by Prof Stuart Mangles, Community Head
- Short (1-2 min) presentations by PhD supervisors
- “Life as a PhD student in SPC” by Anna Tippett, Cara Waters and Nic Mitchell
- 1pm: Lunch and socialising
- 2pm: Optional lab visits

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## The Space, Plasma and Climate Community



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## Who are we?

**36 Academic Staff**

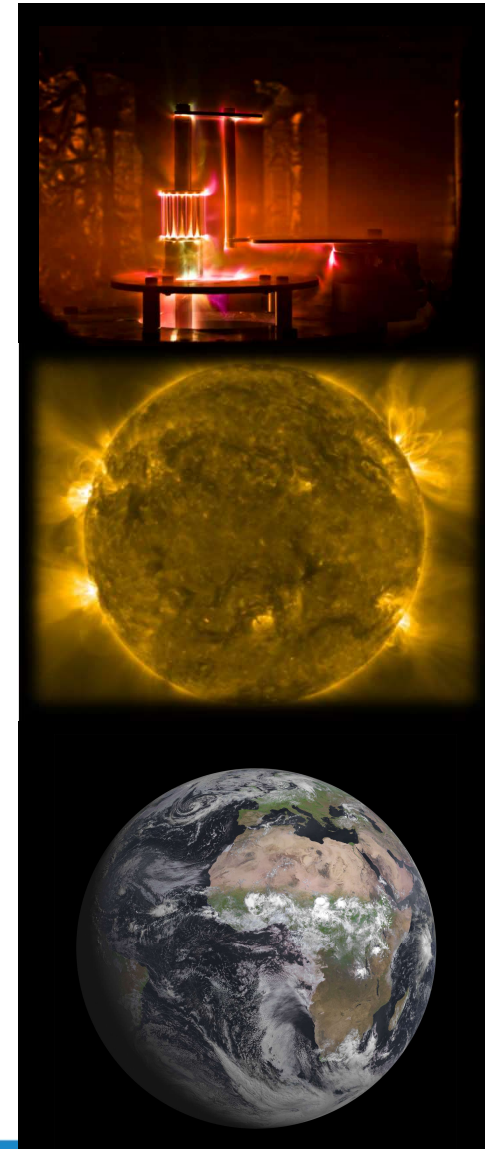
**20 Technical and support staff**

**40 Postdoctoral Research Staff**

**60 PhD students**

In the Space, Plasma and Climate Community, our exciting research spans the physics of plasmas in the laboratory and occurring naturally in space, atmospheric physics, and solar system science.

This includes the quest for fusion energy, understanding changes in our planet's climate system and the drive to predict hazardous space weather.



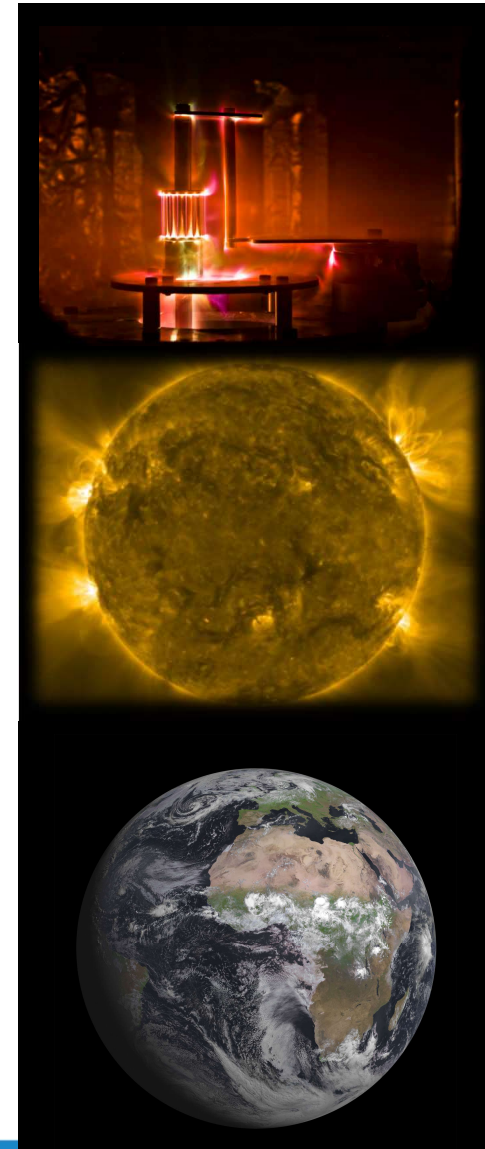
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## Who are we?

We study processes from the bottom of the ocean to the edge of the solar system, and from inside planets to the surface of blackholes

We use theory, simulation and measurements to improve our understanding of fundamental physics processes and complex multi-scale systems

We design, build and operate experiments and instruments that take measurements in the lab, on aircraft, in Earth orbit, and across the solar system



## Plasma

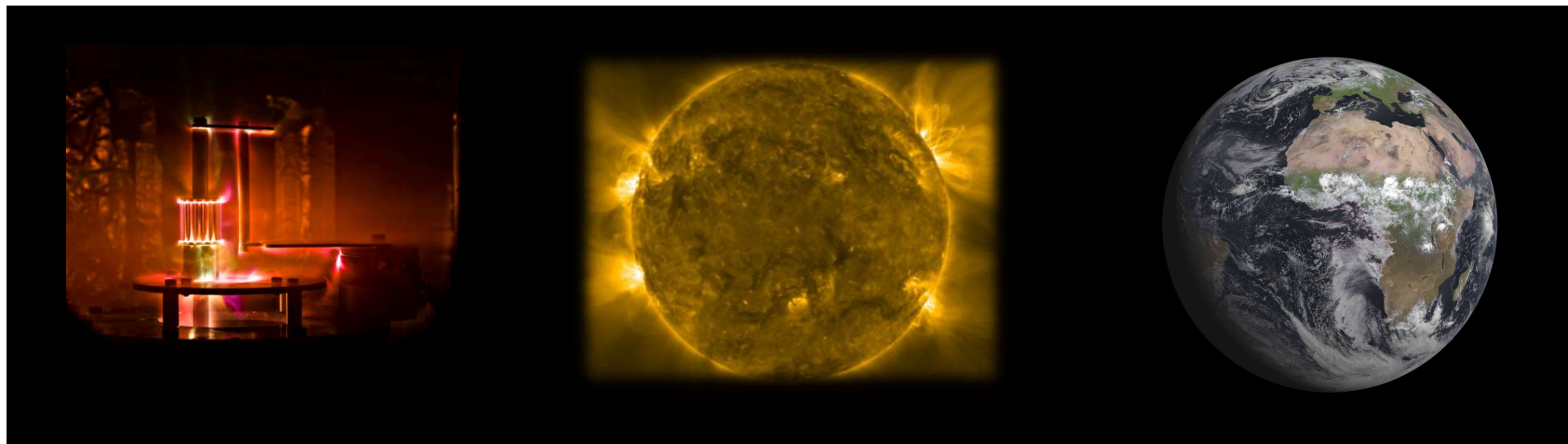
Fusion  
Laboratory astrophysics  
Plasma accelerators  
High Energy Density Physics

## Space

Space plasma physics  
Planetary physics  
Space weather  
Space instrumentation

## Climate

Global and regional climate  
Ocean-atmosphere coupling  
Aerosol and cloud interactions  
Greenhouse gas sources and cycles  
Wildfires and tropical cyclones



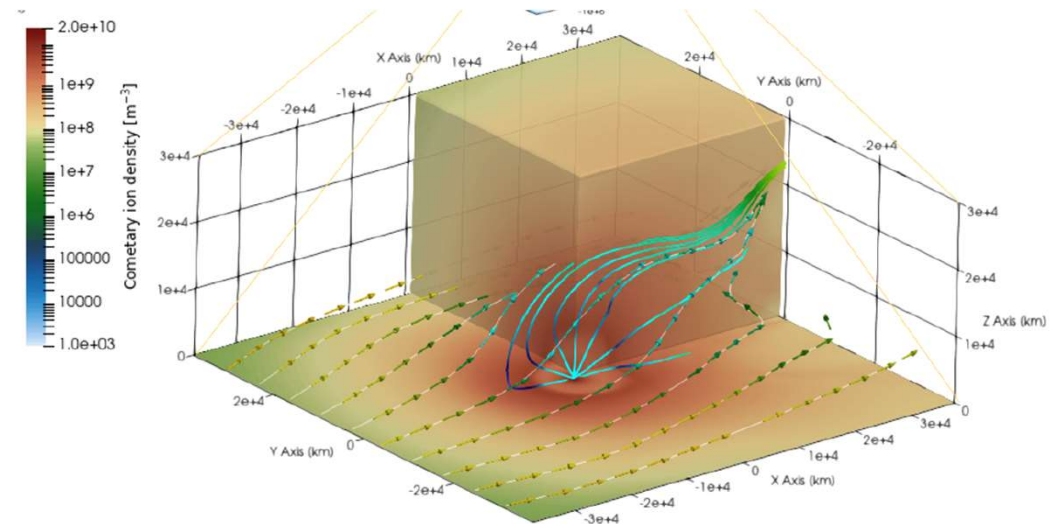
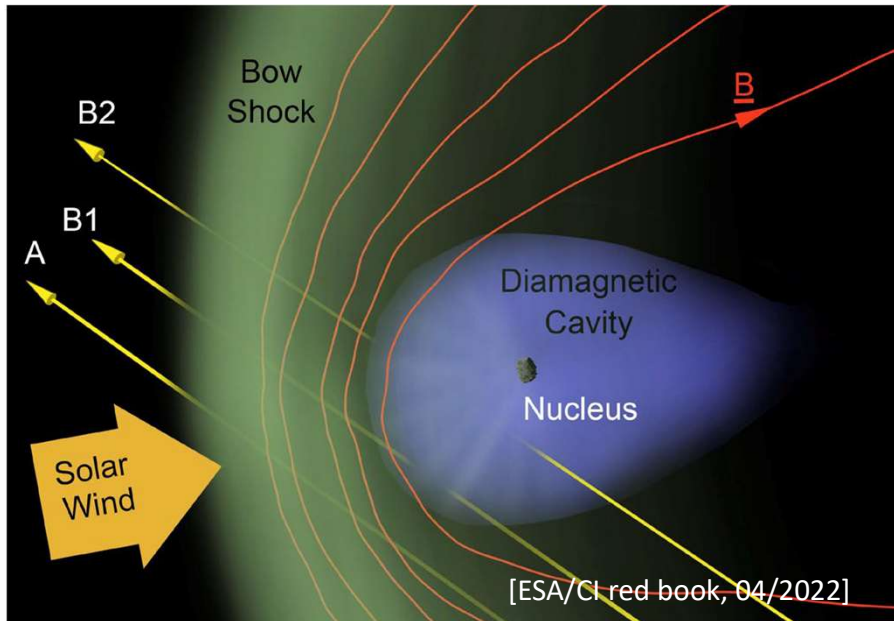
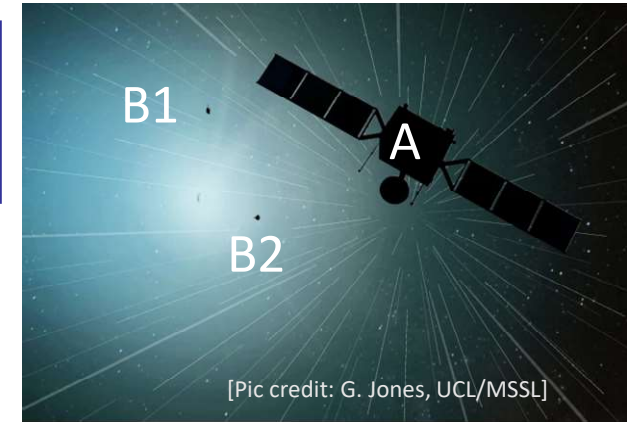
# PhD projects in Space Physics

<b>Galand</b>	Exploring the diversity of solar wind-cometary interaction
<b>Horbury</b>	Formation and evolution of the solar wind
<b>Dougherty</b>	Electromagnetic Sounding of Ocean Worlds
<b>Mueller-Wodarg</b>	Development of a Uranus Upper Atmosphere Model
<b>Simpson</b>	Probabilistic joint inversion of geophysical and physicochemical data from Iceland

# Exploring the diversity of solar wind-cometary interaction

SUPERVISOR: Marina Galand [[m.galand@imperial.ac.uk](mailto:m.galand@imperial.ac.uk)]

- **What?** - Natural plasma lab
- **Why?** - ESA Comet Interceptor (launch 2029)
- **Aim?** - To assess how the interaction of the solar wind with the cometary plasma evolves under  $\neq$  interplanetary and cometary cdt
- **How?** - Multi-fluid MHD modelling (Giotto, Rosetta)



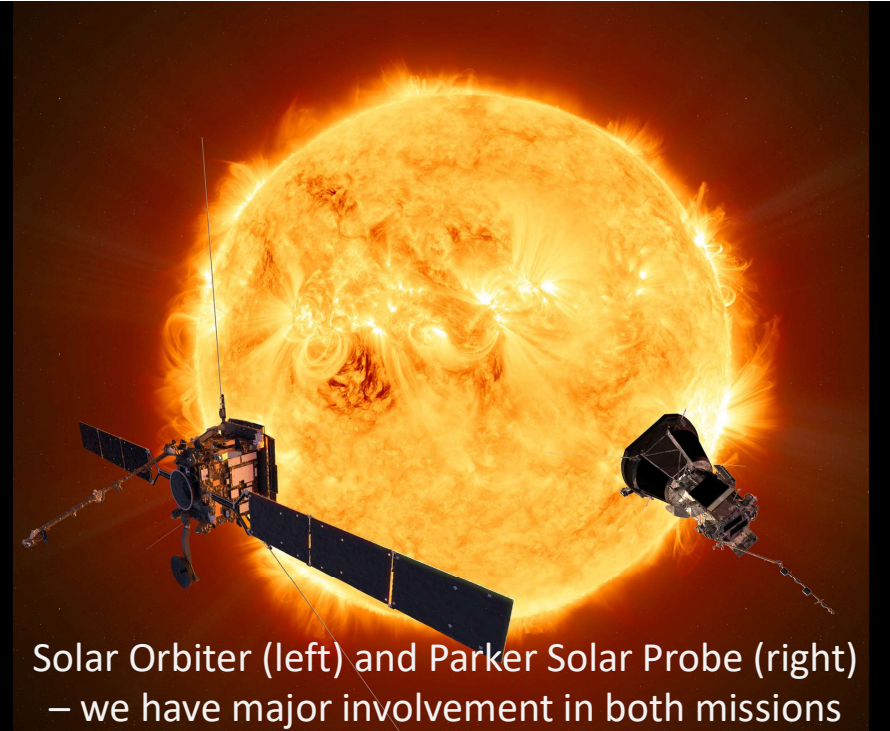
[Cushen, MSc Thesis, 2023]



# Formation and evolution of the solar wind

Tim Horbury

- The Sun is a star: we study the solar wind to understand stars and how the solar wind can affect our lives on Earth
- How is the solar wind formed? How does it change between the Sun and Earth?
- Use three spacecraft:
  - Parker Solar Probe, passes through corona
  - Solar Orbiter: corotation and high latitudes
  - IMAP: multi-spacecraft constellation near Earth, launching mid-2025
- Study the spatial and temporal scales of structures (switchbacks, patches, shocks, turbulence) as they evolve away from the Sun
- Mostly data analysis, some theory
- This is a STFC-funded project
- Sorry I can't be there. Questions? Contact Tim Horbury by email or Teams



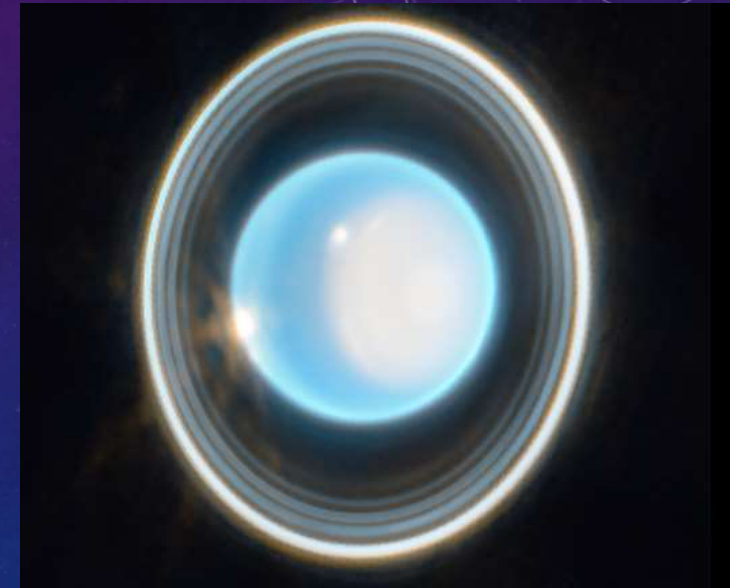
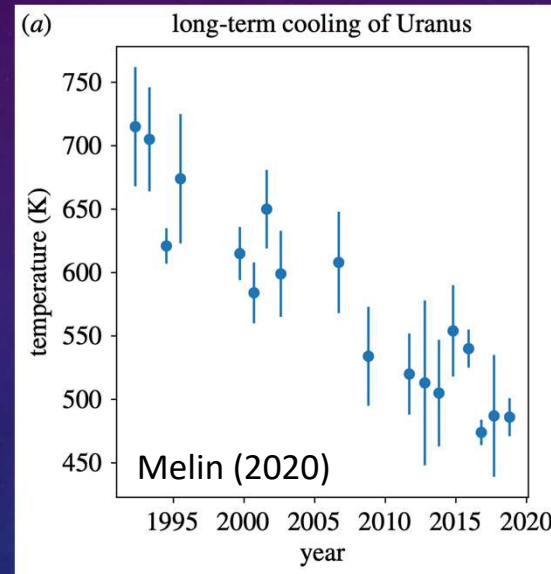
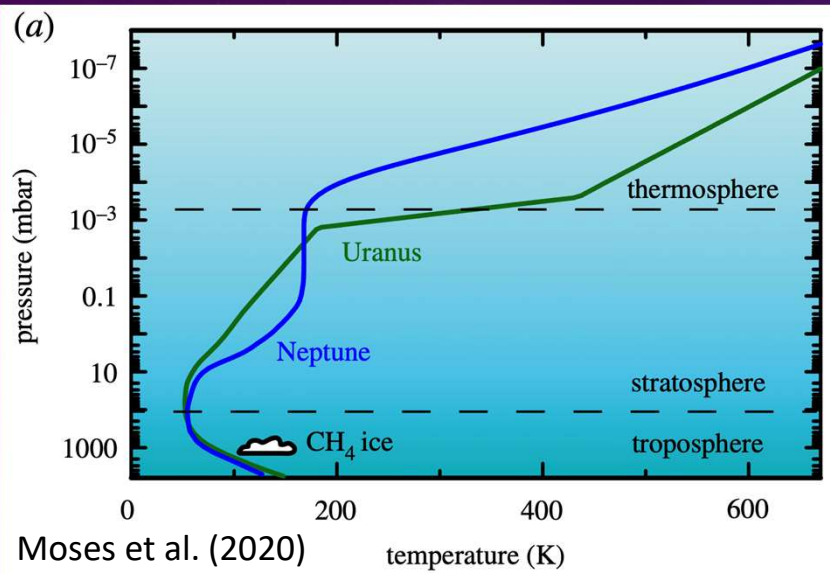
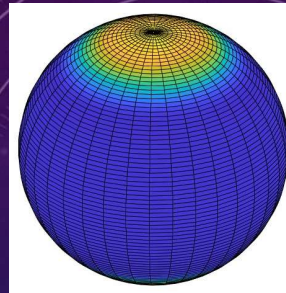
Solar Orbiter (left) and Parker Solar Probe (right) – we have major involvement in both missions



The IMAP flight instrument in our clean room on 6M: we will deliver it to NASA in early 2024

# DEVELOPMENT OF A URANUS UPPER ATMOSPHERE MODEL

Supervisor: Prof Ingo Mueller-Wodarg ([i.mueller-wodarg@imperial.ac.uk](mailto:i.mueller-wodarg@imperial.ac.uk))

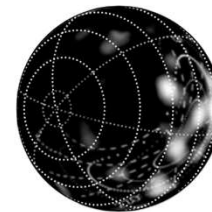


- Adaptation of existing Saturn/Jupiter Global Circulation Model to Uranus
- First ever 3-D upper atmosphere model for Uranus
- Need experience in coding & passion for topic

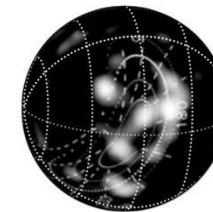
Southern aurora



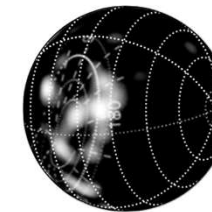
1985



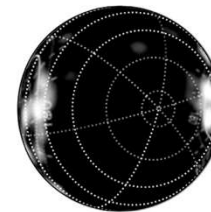
1995



2005



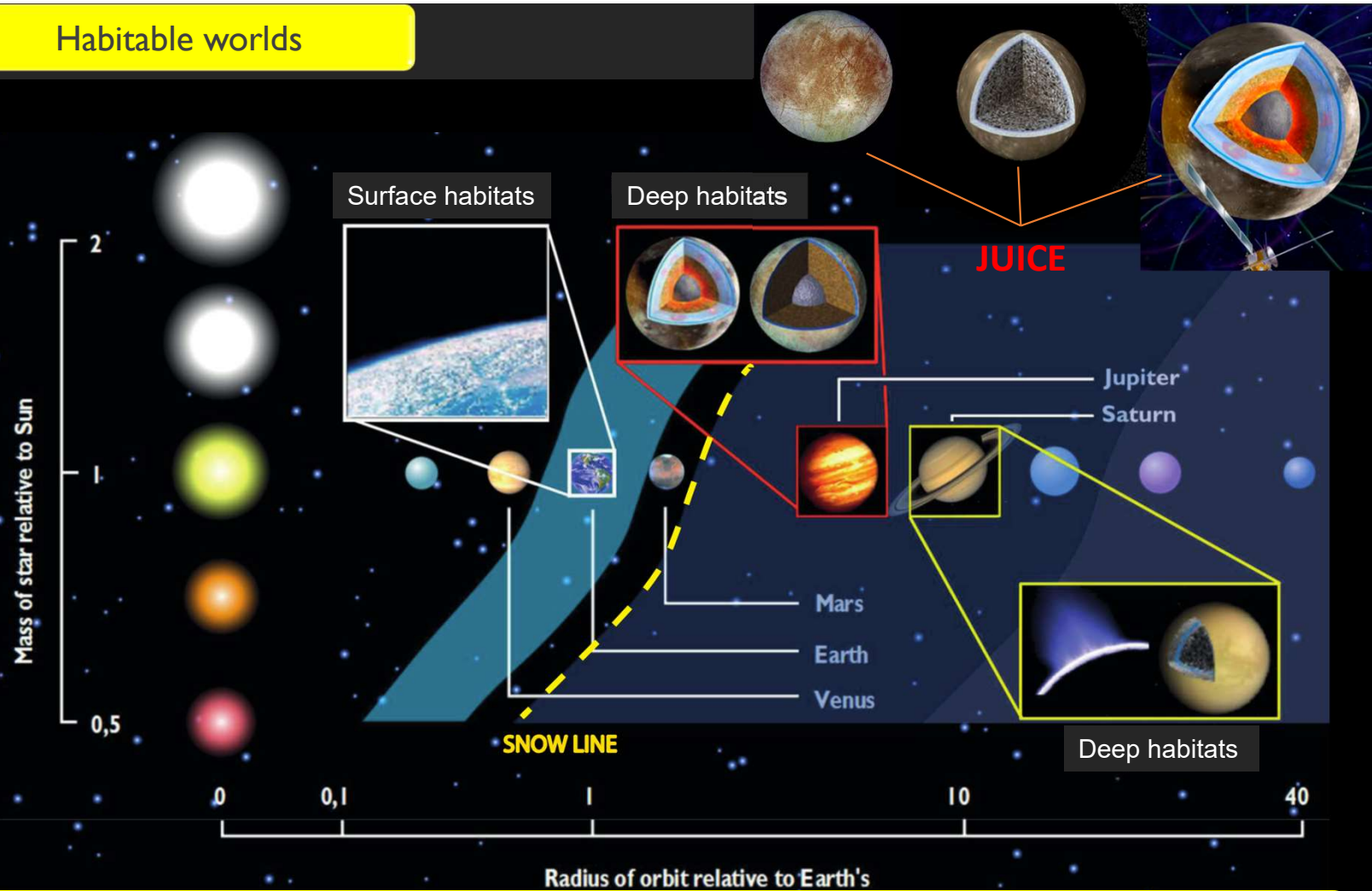
2015



2025

Melin (2020)

## Habitable worlds



Cosmic Vision: The quest for evidence of life in the Solar System must begin with an understanding of what makes a planet habitable

# Probabilistic Joint Inversion of Geophysical and Physicochemical Data

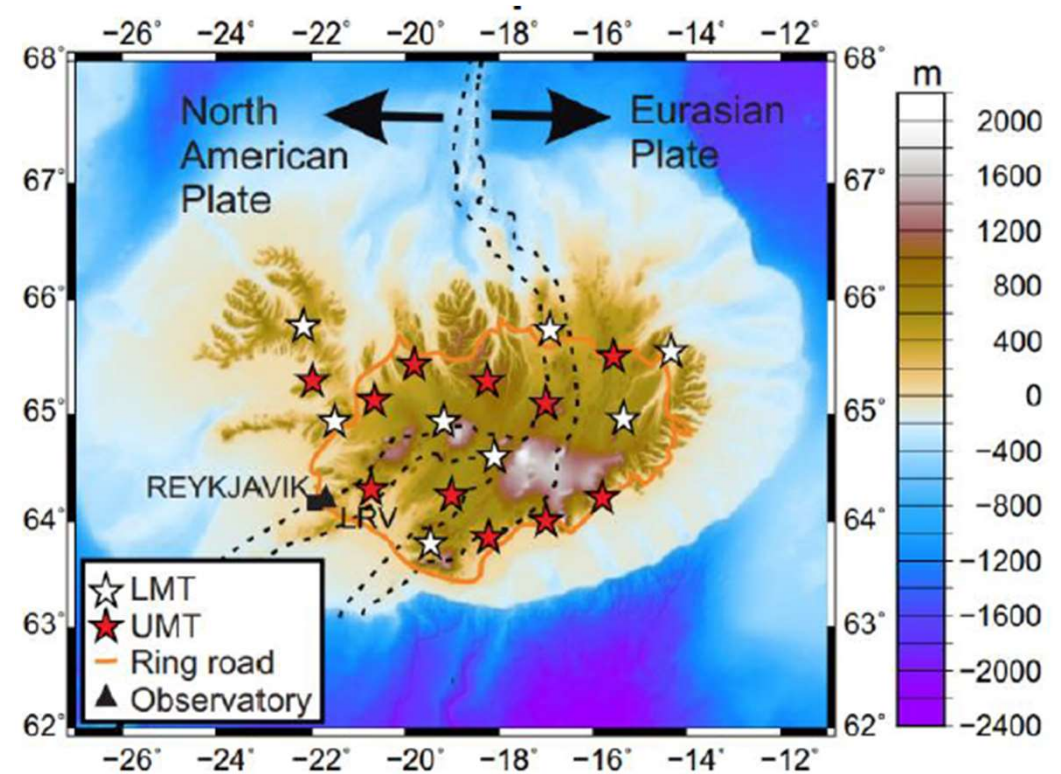
Supervisor: Fiona Simpson (f.simpson@ic.ac.uk)

Science and Solutions for a Changing Planet Doctoral Training Program



**Want to know about volcanism and space weather?**

Study magnetotellurics (MT) – an electromagnetic induction technique for imaging planetary interiors and recording magnetic storms.



- Fieldwork in Iceland (red and white stars on map).
- AI-aided computer modelling (joint inversion).
- Apply knowledge of physics to solve real-world problems.
- Make an impact: the more we know, the better we can forecast.

# PhD projects in Climate Physics

- |                  |   |
|------------------|---|
| <b>Toumi</b>     | A new global tropical cyclone model   |
| <b>Brindley</b>  | Capturing the spectral fingerprints of errors in weather and climate models   |
| <b>Ceppi</b>     | Why does climate sensitivity depend on the type of forcing?<br>Relating future jet stream changes to present-day observable variability |
| <b>Gryspeerd</b> | Observing aerosol-cloud interactions in a changing Arctic   |

# Ralf Toumi

**A new global tropical cyclone model**

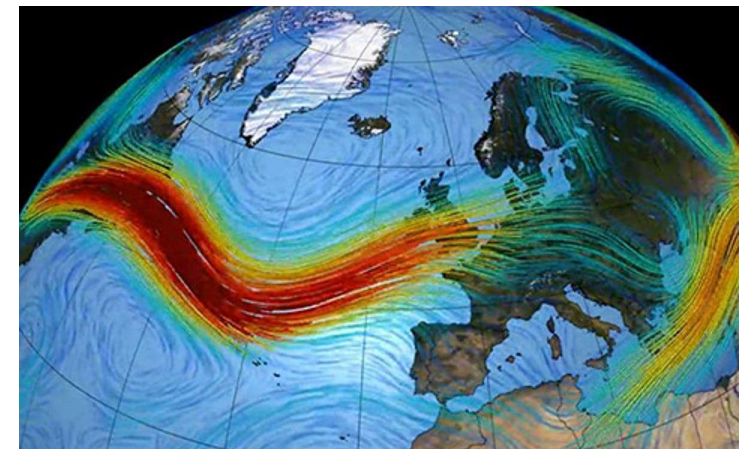
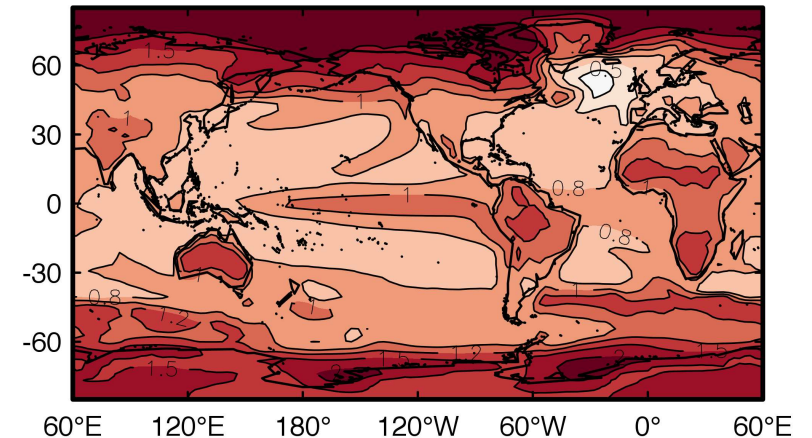
# Helen Brindley

**Capturing the spectral fingerprints of errors in weather and climate models**

# Projects in atmosphere & climate dynamics

Paulo Ceppi

- **Project 1: Dependence of climate sensitivity on forcing**
  - What determines the sea surface warming pattern in response to climate forcing?
  - How does this pattern affect the climate feedbacks and sensitivity?
  
- **Project 2: Relating future jet stream changes to observable variability**
  - Future jet stream changes very uncertain
  - Theory relating unforced (natural) variability to forced response
  - Important for regional climate and extremes





# Observing aerosol-cloud interactions in a changing Arctic

Edward Gryspeerdt, Helen Brindley (Imperial)

Jennie Thomas (CNRS/IGE), Louis Marelle (CNRS/LATMOS)

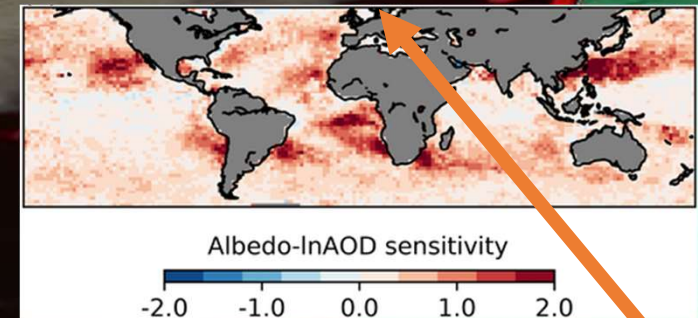
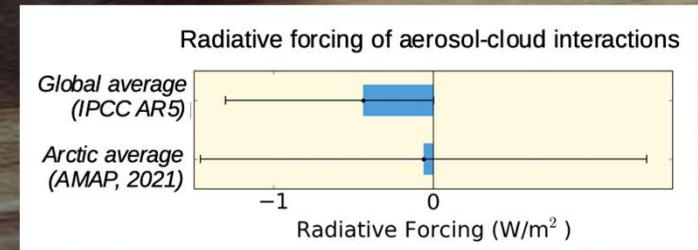
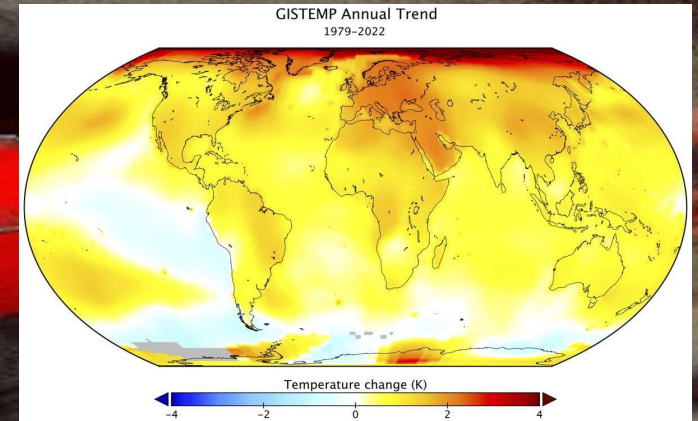


Sophie Anna Rodrigo Ollie



George Rebecca Geoff

Where are Arctic clouds sensitive to aerosol?  
How can we improve climate projections in the Arctic?  
What is the sign of aerosol-cloud interactions in the Arctic?



Arctic often ignored in aerosol-cloud studies

# PhD projects in Plasma Physics (Part 1)

- |                   |  |
|-------------------|--|
| <b>Lebedev</b>    | Radiation driven heat transfer experiments   |
| <b>Chittenden</b> | Predictions for scaling Inertial Fusion and High Energy Density Physics experiments to M4<br><br>Magneto-hydrodynamic effects in High Energy Density Plasmas and Inertial Confinement Fusion |
| <b>Tubman</b>     | PhD in magnetic fields in laser-produced plasmas with relevance to Inertial Confinement Fusion   |
| <b>Mangles</b>    | Quantum electrodynamics with laser wakefield accelerators  |

# Amplifi Prosperity Partnership 1

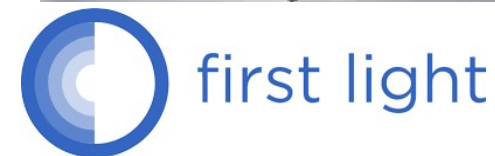
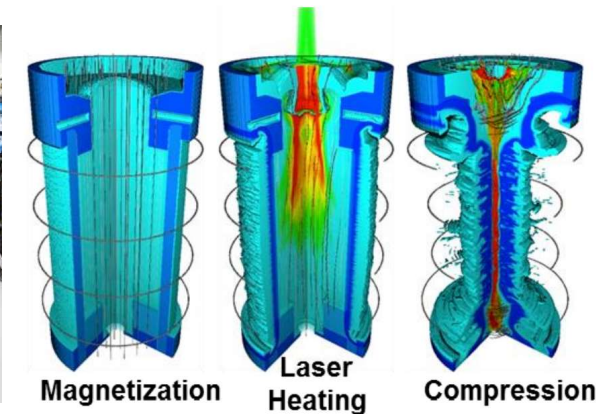
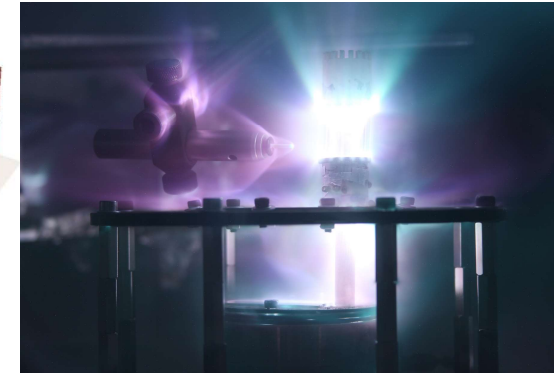
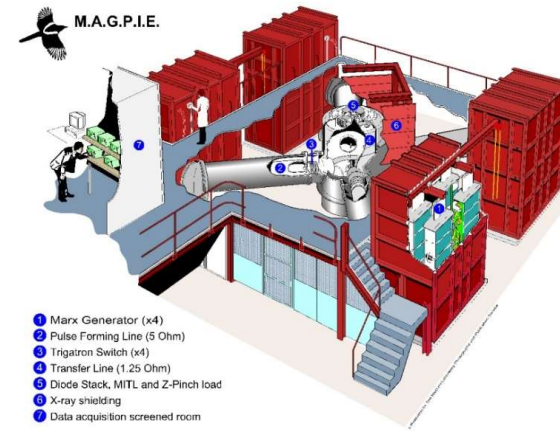
## Supervisor Prof. Sergey Lebedev

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A collaboration between First Light Fusion, Imperial College, Oxford, York and Machine Discovery to explore physics underlying Projectile Fusion

One experimental PhD in 2024, mainly on **MAGPIE**

- Utilise radiation driven ablation platform to make heat transfer measurements between plasmas of different materials and across complex interfaces
- Use multitude of diagnostics including Thompson scattering and X-ray absorption spectrometry
- Possibly expand to other facilities – Cepage, M3 and laser facilities / synchrotrons (ESRF)



# Amplifi Prosperity Partnership 2

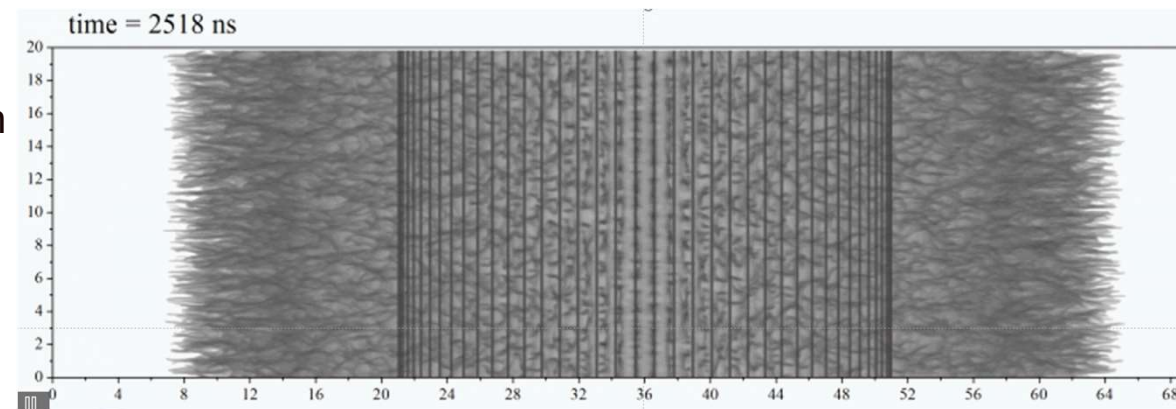
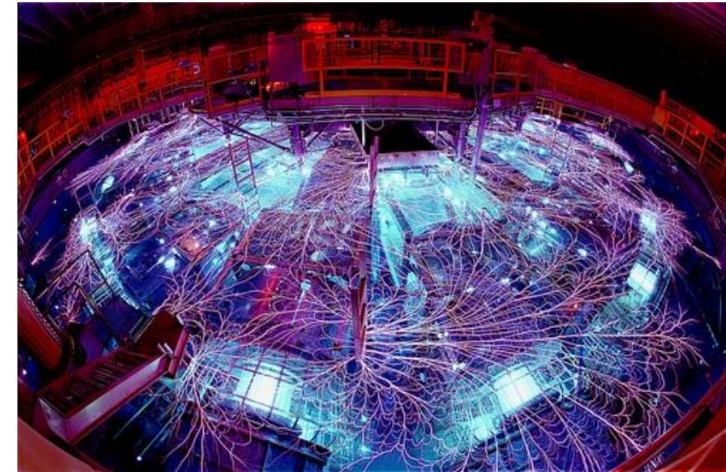
## Supervisor Prof. Jeremy Chittenden

Imperial College  
London

A collaboration between First Light Fusion, Imperial College, Oxford, York and Machine Discovery to explore physics underlying Projectile Fusion

One computational PhD in 2024 on **Gorgon / Chimera**

- First Light Fusion is building M4, the worlds largest pulsed power facility – 50MA, 400ns
- PhD will use 3D magneto-hydrodynamic simulations to examine scaling of different high energy density physics experiments to 50MA
- Exploring how inertial fusion experiments might reach ignition and high energy gain
- New opportunities for research in laboratory astrophysics, nuclear physics and planetary science



first light



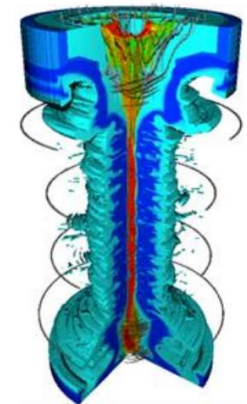
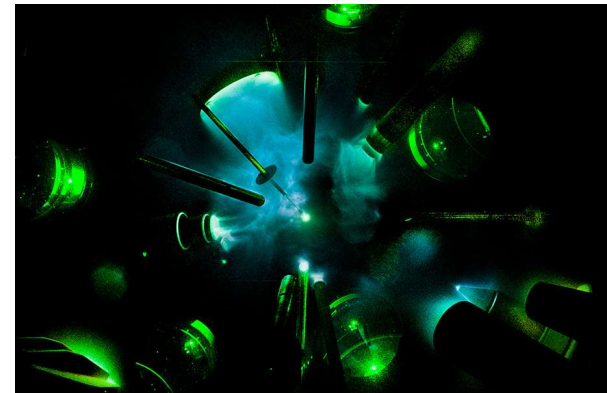
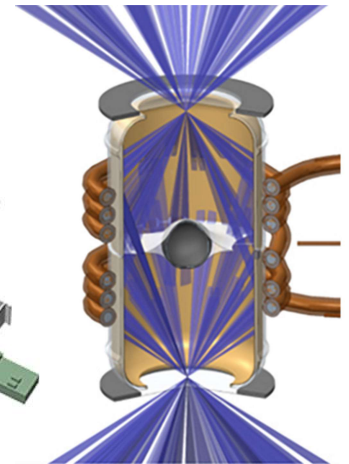
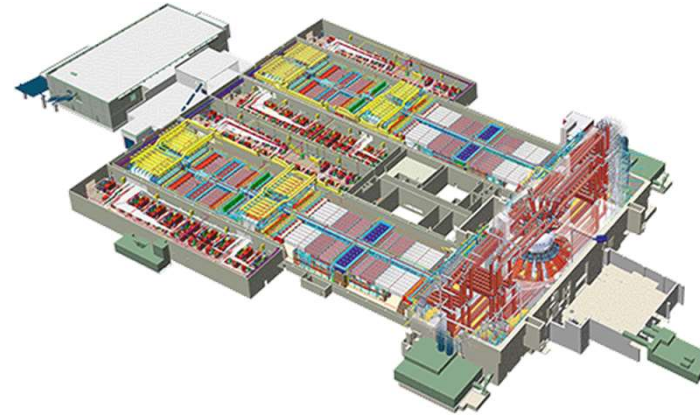
Machine Discovery

# Magnetised Inertial Fusion & Higher Energy Density Physics

## Supervisor Prof. Jeremy Chittenden

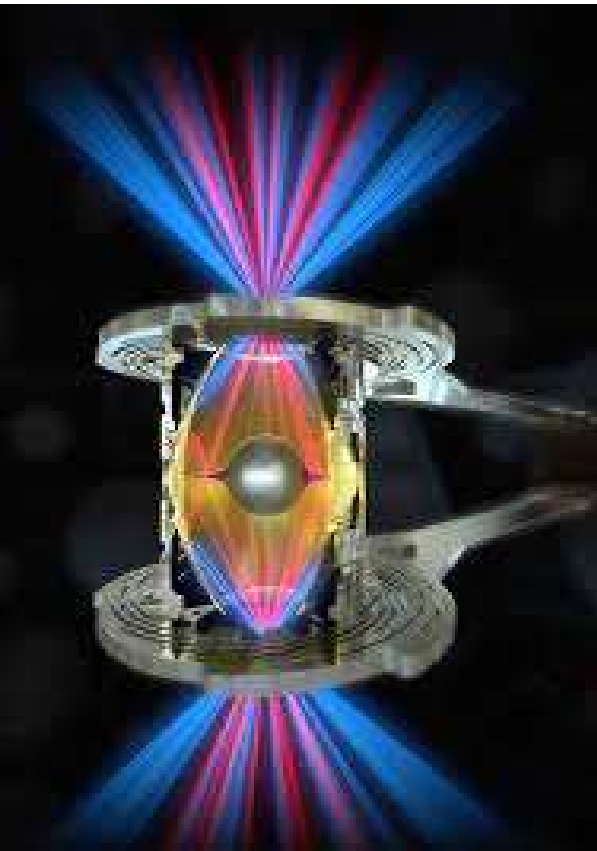
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- In Inertial Confinement Fusion magnetic fields suppress thermal conduction losses enabling 'ignition'
- Magnetic fields are compressed in imploding fusion targets up to 10,000 Tesla
- Magnetic fields are spontaneously generated in High Energy Density Plasmas driven by intense lasers.
- Magnetised Liner Inertial Fusion (MagLIF) uses the Lorentz force to drive the implosion of a cylinder of fusion fuel
- PhD will use 3D magneto-hydrodynamic simulations to model experiments on the National Ignition Facility, the Omega Laser and Sandia's 'Z' generator

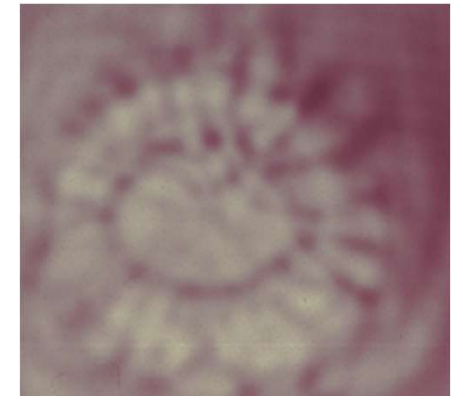


# Magnetic fields in laser-produced plasmas - with relevance to ICF

Supervisor: Ellie Tubman



- Magnetic fields produced in locations of steep, non-parallel temperature and density gradients.
- We know little about the fields created under extreme conditions of the hohlraum- incredibly complex geometry
- Simpler experiments will be performed at the Orion, Omega and NIF laser systems to break-down hohlraum components.
- New diagnostics will be developed for these facilities.
- Astrophysical phenomena can also be explored- such as shock waves.

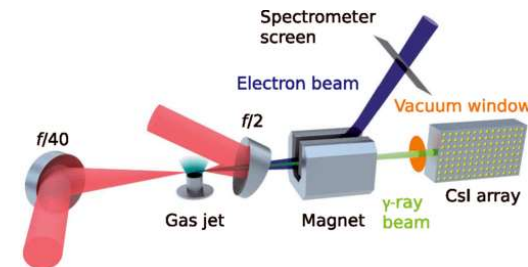


## Quantum Electrodynamics with Laser Wakefield Accelerators

### QED physics in strong fields:

LWFA electron beam + high intensity laser

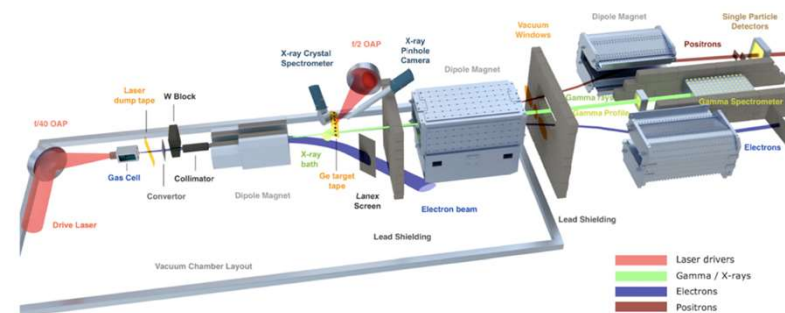
- non-linear Compton Scattering, Radiation Reaction, and non-linear Breit-Wheeler pair production
- processes that occur on quasars, magnetars
- See Cole PRX 2018



### Photon-Photon Physics

Gamma rays + dense X-ray fields:

- Two photon Breit Wheeler, Light by light scattering
- processes that occur as radiation traverses the universe
- See Kettle NJP 2021



## PhD projects in Plasma Physics (Part 2)

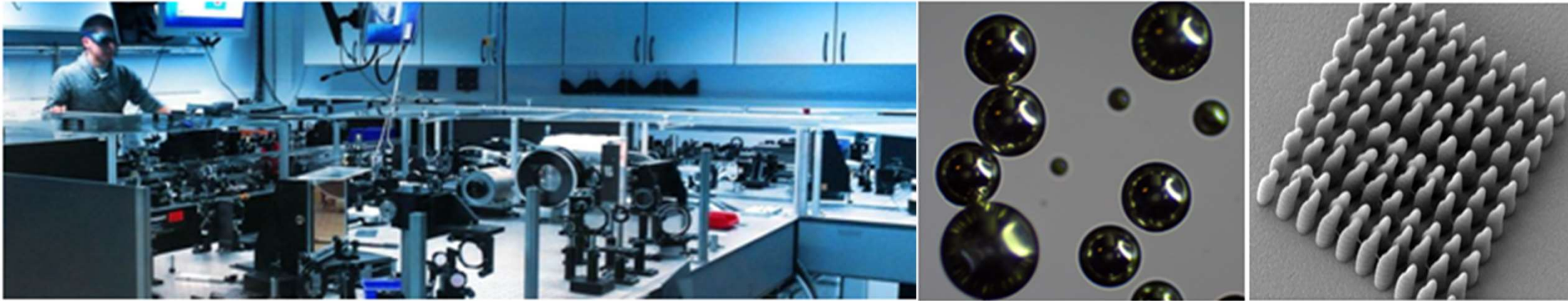
<b>Smith</b>	Ultra High-Intensity OPCPA Laser Systems and Light-Matter Autocorrelation
<b>Kagan</b>	Transport and shocks in non-ideal, dense plasmas Interplay between kinetic effects and magnetic fields at plasma interfaces
<b>Kingham</b>	Fluid and kinetic modelling of ELM burn-through in tokamak exhaust
<b>Najmudin</b>	Plasma based Accelerators



**Roland Smith and Mary Matthews**

**Ultra High-Intensity OPCPA Laser Systems and Light-Matter Autocorrelation**

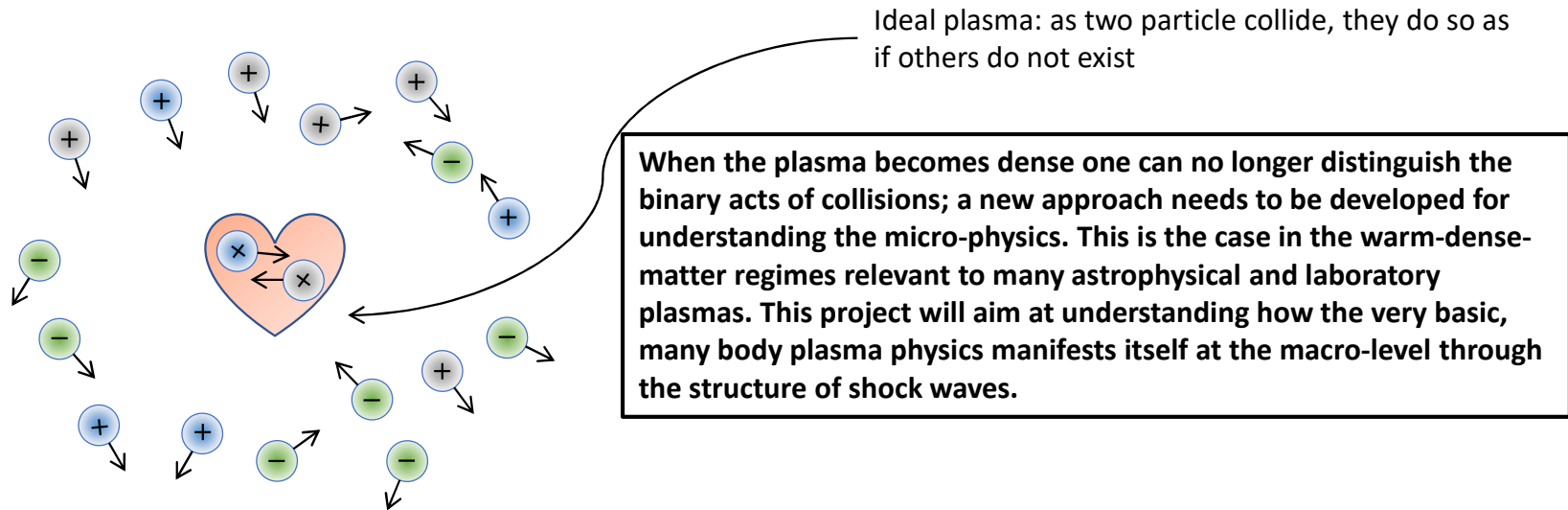
**PhD - Co-funded by EPSRC and The Rutherford Appleton Laboratory**



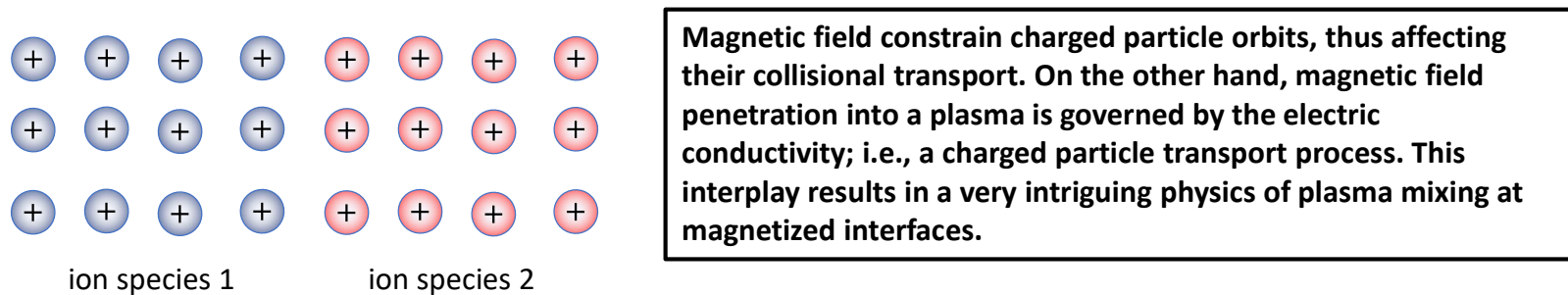
- **Optical Parametric Chirped Pulse Amplification (OPCPA) allows us to build ultra-high power lasers that deliver TW – PW peak powers at very high contrast (low optical noise).**
- **This project aims to improve the OPCPA technique as part of a 20 PW upgrade of the Vulcan laser at RAL, and also harness the coupling between light and virtual photons in a non-linear crystal to enable a new type of sub-picosecond resolution time measurement of exotic particles.**

# Grigory Kagan: g.kagan@imperial.ac.uk

## Transport and shocks in non-ideal, dense plasmas:



## Interplay between kinetic effects and magnetic fields at plasma interfaces:



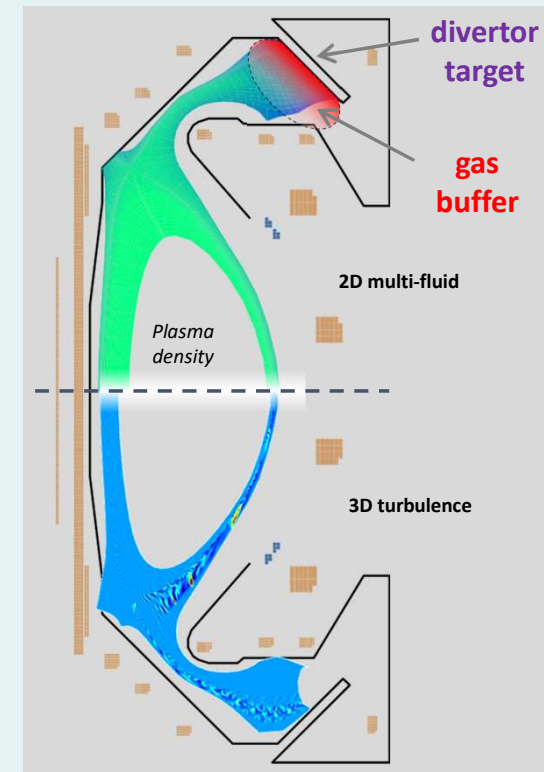
# Modelling of ELM burn-through in tokamak exhaust

*Dr Robert Kingham*

- MCF – Computational & Theoretical
- 50% funded by UKAEA
- ELMs → Edge Localized Modes  
→ power spikes to 'divertor'
- Explore **kinetic effects** in transport:  
1D3V VFP-Boltzmann code
- Assess & improve reduced models  
for 2D fluid codes (SOLPS)



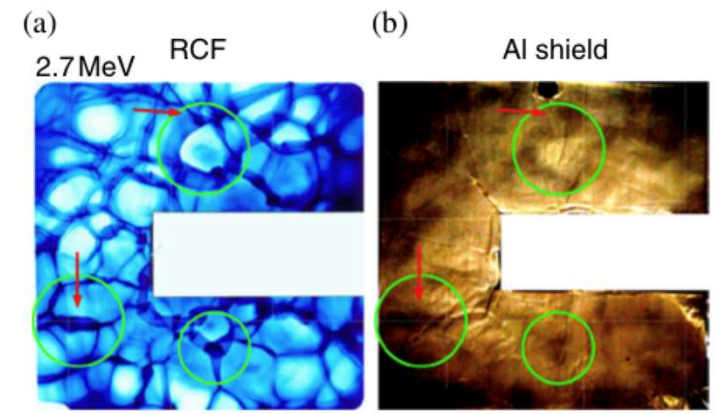
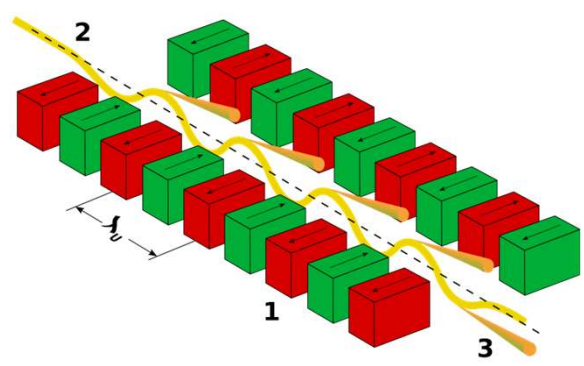
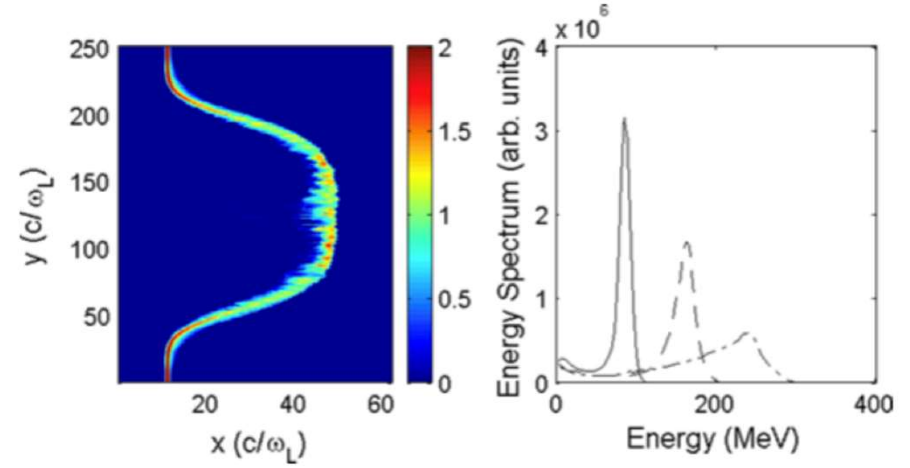
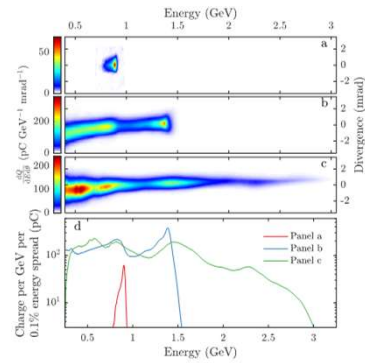
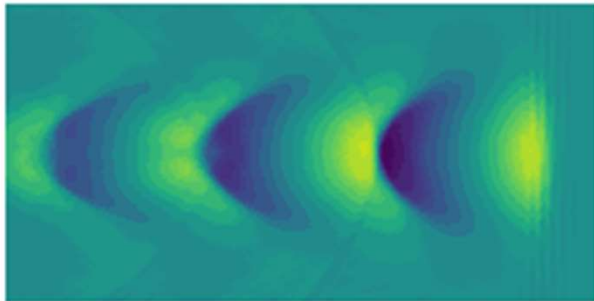
Detail of Super-X divertor showing particle exhaust path



# Plasma Accelerators can be < 1000x smaller than conventional accelerators

Project 1: Free Electron Laser based on laser wakefield acceleration

Project 2: Radiation pressure acceleration of thin foils

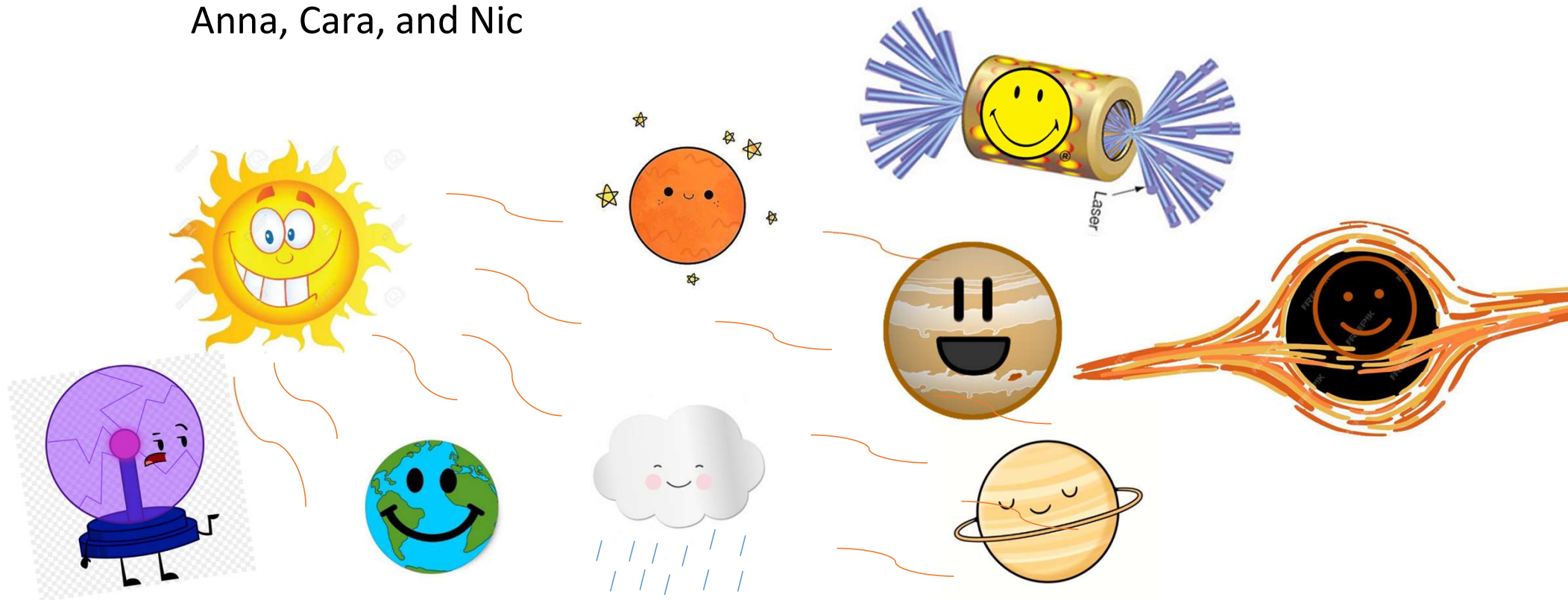


Supervisor: Zulfikar Najmudin

# Life as a PhD Student in SPC

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London

Anna, Cara, and Nic



# Why SPC?

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- World-leading research
- Everyone is friendly!
- Diverse mix of areas
- > 45 PhD students
- Lots of social events

# Day-to-Day

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- Shared office space with other PhD Students
- PG lectures (2-3h/week)
- Weekly group talks + seminars
- Undergraduate teaching – lots of opportunities!
  - Labs
  - Tutorials
  - Note-taking
  - Exam invigilation
  - Etc...
- Outreach opportunities (Imperial lates, schools, external events...)



# Life at Imperial

Imperial College  
London

- Shops/cafés/restaurants/bars
- >340 clubs + societies
- Low cost sports facilities
  - £30/year gym
- Central London!
- Lots of training + support:
  - Student reps
  - Welfare advisor
  - Graduate school
    - Over 100 free courses – professional + research skills
  - Many other college services

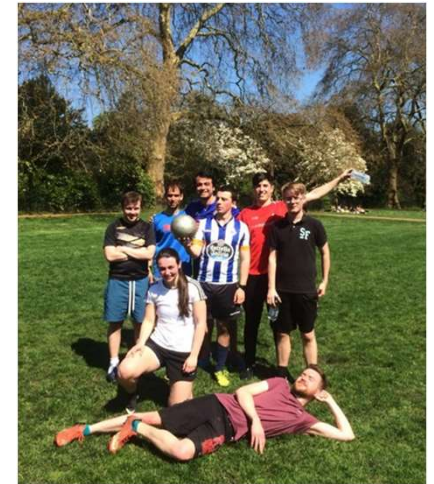




# Social Stuff

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- Welcome party
- Christmas dinner + party
- Summer BBQ
- Departmental events
- Lots more!



# PhD Perks... (Travel!)

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- Conferences/Summer schools
- Research placements
- Internships

