**Details of the school**

**(I) Observational astronomy (Simon Driver)**

**1.Lecture**

1.1 Introduction of galaxy images for different galaxy types from both the nearby and distant Universe (the latest HST/JWST/Euclid images will be used for this).
1.2 Spectroscopic properties of galaxies and key information extracted from the properties.
1.3 Special talks from early-career researchers.

**2.Hands-on session**

2.1 Estimation of galaxy masses using observational data.
2.2 Derivation of galaxy distances using spectroscopic data.

**(II) Gravitational dynamics in the universe (Kenji Bekki)**

**1.Lecture**

1.1 From Kepler motions in two-body to rosetta orbits in N-body systems.
1.2 Physics of galaxy merging – the role of dynamical friction.
1.3 The roles of galaxy merging in galaxy formation – merging of supermassive black holes, morphological transformation, triggering starbursts.
1.4 Nbody simulations of galaxies and star clusters
1.5 Introduction of short projects after this summer school.

**2.Hands-on session (Evolution of satellite galaxies from 100 kpc to 0.01 pc)**

2.1 Analytical estimation of total masses (including dark matter) for the Galaxy and its satellite galaxies using rotation curves/virial theorem.

2.2. From 100 kpc to 1 kpc – the timescale of merging of a satellite with the Galaxy with/without dark matter due to dynamical friction against halo stars/gas + dark matter

2.3 From 1 kpc to 10 pc - the timescale of merging of a stellar nucleus (with MBH)

2.4 From 10 pc to 0.01 pc (or event to the Schwarzschild radius) - the timescale of merging of SBHHs due to dynamical friction within merging nuclei.

*** For 2.2- 2.4. both analytical models and simulations results will be used. ****
*** For analytical models, only pens and papers are necessary. ***

*** For simulation data analysis, plotting skills + laptop PCs are required. ***

**3. Summer projects (for multiple students) – from one week to one year!**

3.1 Dynamical friction of MBHs against gas in forming stellar nuclei (gas vs star dynamical friction comparison).
3.2 Destruction of stellar nuclei by sinking MBHs. – origin for the diverse nuclear structures in galaxies.
3.3 Ram pressure stripping and S0 formation.

*** Students will be able to use my own GPU clusters for these new simulations. ***

**(III) Cosmology and dark matter (Chris Power)**

**1. Lecture**

1.1 The expanding Universe – measuring distance, the cosmic distance ladder, the Hubble Law

1.2 The matter content of the Universe - the Big Bang, the primordial elements, the need for dark matter.
1.3
1.4 Where does cosmic structure come from? - the Cosmic Microwave Background, overview of top-down and bottom-up structure formation, how it connects to our theories of dark matter, the cosmic web?

1.5 How do galaxies fit into this picture? – dark matter halos, high level overview of the physics of galaxy formation, in particular star formation, black hole growth and feedback.

2. **Hands-on session – galaxies in the cosmic web – will require access to a computer and to manipulate data cubes using a python notebook**.

2.1 Load in a cosmological dark matter simulation and visualize the cosmic web in 3D in the 3 spatial coordinates – look at projections in 2D.

2.2 Overlay the distribution of galaxies (either from a semi-empirical model, like a halo occupation distribution, or a semi-analytical model, like Shark) – apply different luminosity/colour cuts to highlight how galaxies of different masses/luminosities/colours trace the cosmic web – what trends are apparent?

2.3 Overlay the distribution of dark matter halos – what is the relationship between galaxies and their associated dark matter halos?

2.4 Now visualize the cosmic web – now using projected spatial coordinates in 2 dimensions and introducing redshift along the third dimension. Investigate (by eye) the Finger of God effect.

**3.Summer projects (TBC)**