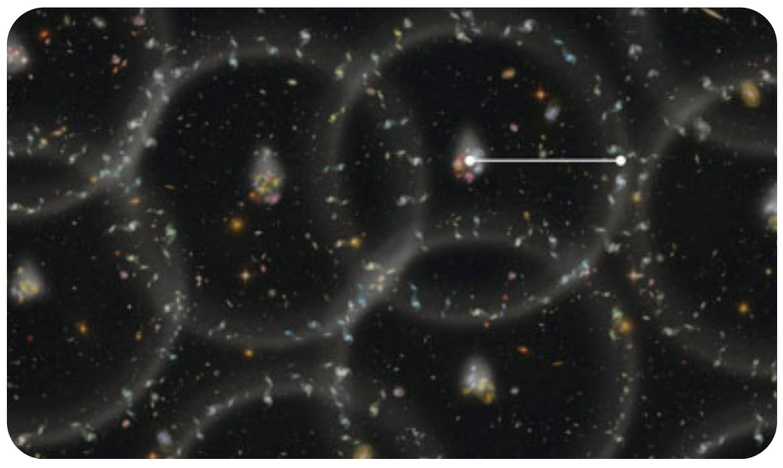
THE HIDDEN SIGNAL OF THE UNIVERSE

Nathan Romieux, Aurélien Verdier
Laboratory of Astrophysics, EPFL

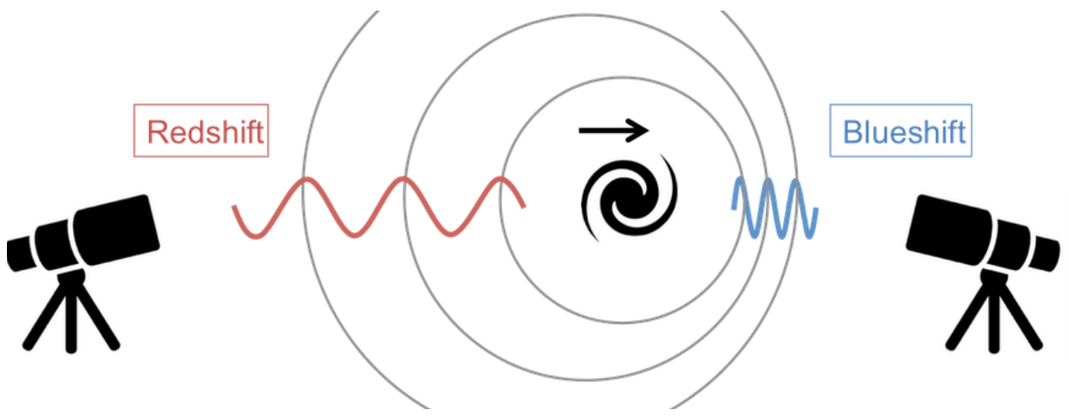
The Origin of the Standard Ruler

Frozen sound wave imprints, known as **Baryon Acoustic Oscillations** (BAOs), were left throughout the Universe **380,000 years** after the Big Bang as spherical shells with a **known initial radius**. As the Universe expanded, it stretched the space containing these structures, thereby increasing their physical radius over time. By measuring this stretched scale within the current distribution of galaxies, we can calculate the **expansion history** of the Universe.

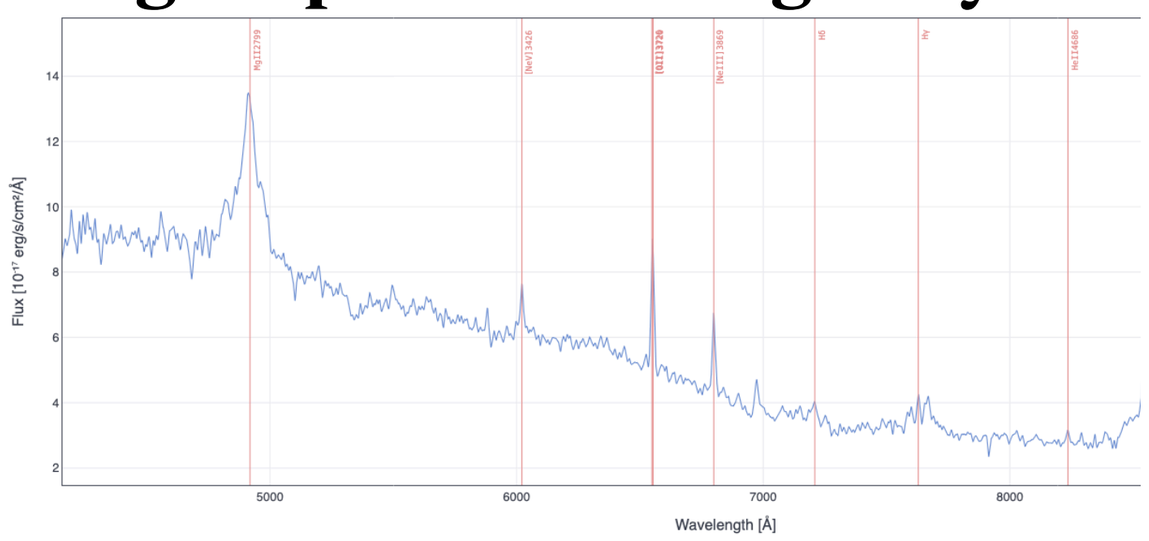


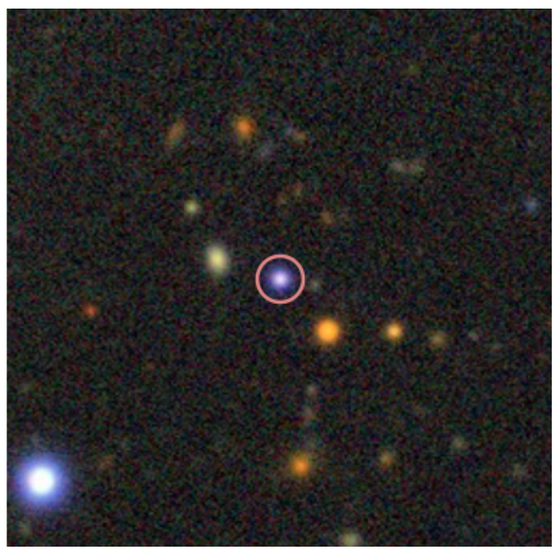
Redshift to map the universe

The redshift is related to the **galaxy's distance** by the following relationship, $D_C(z) = \frac{c}{H_0}\int_0^z \frac{dz'}{E(z')}$ with $E(z)$ a factor linked to the evolution of the **universe's content** and H_0 the **Hubble-Lemaître constant**.



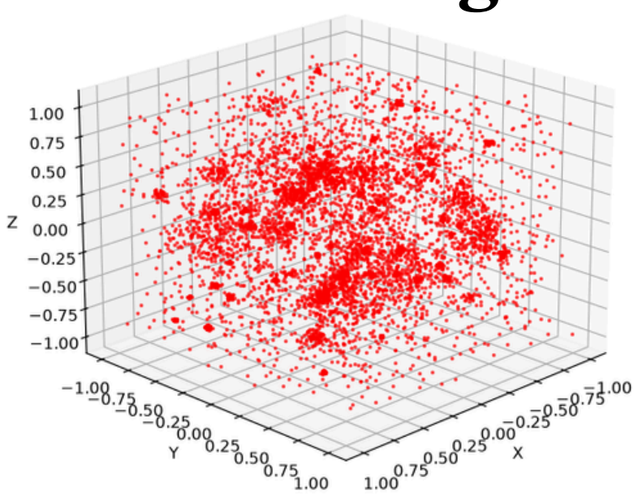
Light spectrum of a galaxy





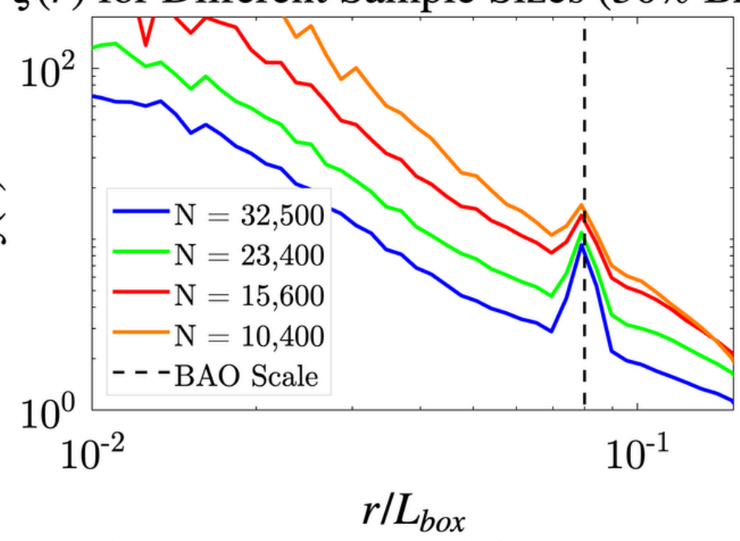
By recognizing specific spacings between **emission** or **absorption** features, one can determine the **galaxy type** and the extent to which the signal has been **redshifted** (shifted to the right). The galaxy observed here contains a highly **active black hole**, as evidenced by its unique **spectral signature**.

Statistical signal



Here is a **simulated universe** into which we have injected **spherical shells**, representing BAOs, to observe the limits of the signal's emergence.

Cluster Counter : $\xi(r)$ for Different Sample Sizes (30% BAO)



Fractal Structure : Power-law decay validates the hierarchical clustering.

BAO Signature : Peak confirms successful injection.

Detectability

Low Density : Requires unrealistic signal amplitude.

Realistic Signal (1–5%) : Requires massive N to reach SNR>3.

Result : High-density surveys are mandatory for detection.

Conclusion

This study mapped BAO detectability **thresholds** via simulations. We show **low-density** samples require artificially high signal amplitudes to extract the **correlation peak**. Conversely, real surveys achieve **100 times** higher densities, essential for detecting the faint cosmological signal **(1–5%)**. These results quantify the **trade-off** between **sample size** and **signal strength**, validating **massive surveys** to measure the BAO standard ruler.

contact : nathan.romieux@epfl.ch