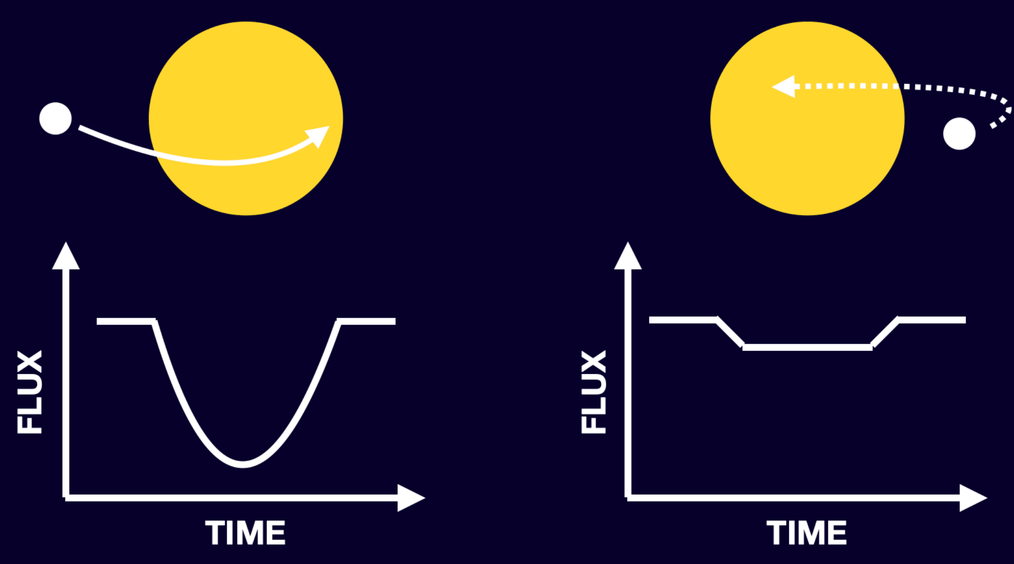
Investigating noise patterns in the JWST/MIRI detector

Prune C. August, DTU Space



We use the **James Webb Space Telescope (JWST)** to observe the planet in eclipse, that is when it passes **behind the host star** wrt. the observer.

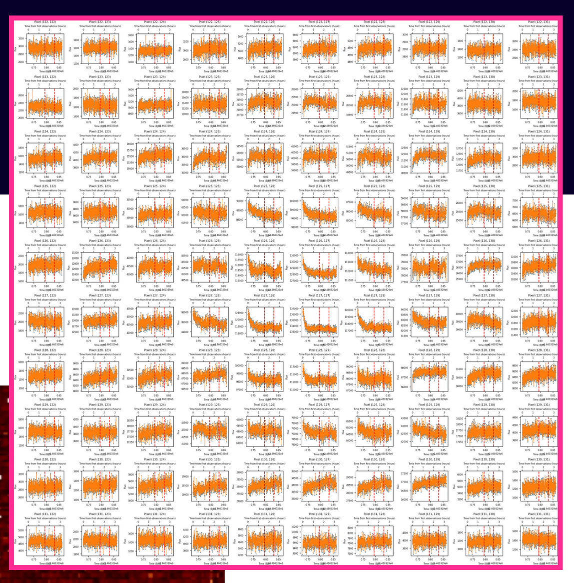
The **eclipse depth** contains information about the **atmospheric and surface properties of the planet.**

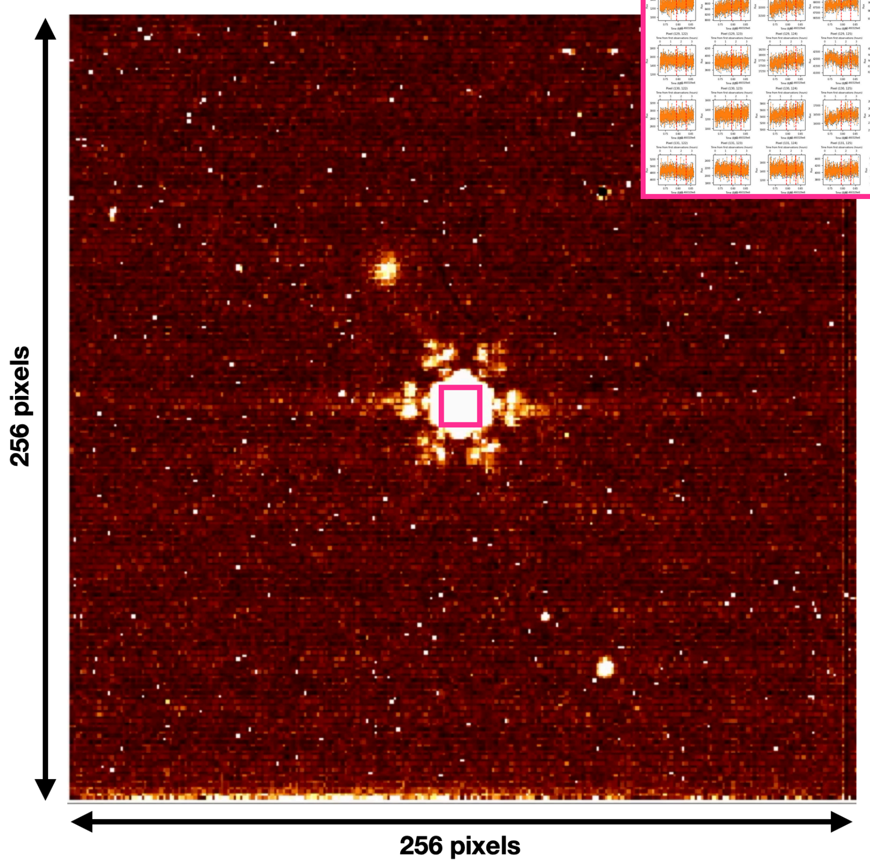
1. SCIENTIFIC CONTEXT

Because planets are small and emit very little light compared to their host stars, these signals are also very small (~100ppm). Any **systematics in the lightcurve** can **compromise the possibility to measure them properly**.

Additionally, **all the instruments on the JWST are new**. There hasn't been enough time and datasets yet to be able to build a **community knowledge** and understanding of most **systematics and noise sources**.

2. THE DATA



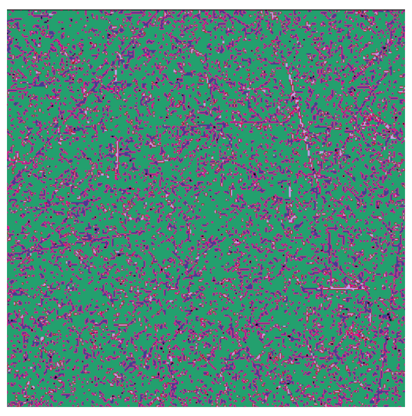


The dataset comprises, in total, **964 integrations** of **256x256** px images of the star around the eclipse event.

Each of these **pixel light-curves** are extracted, including the background, then **passed into Fourier space and normalised**.

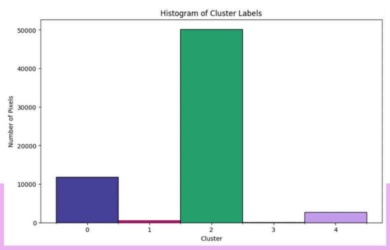
The resulting power spectra are then passed into clustering algorithms. In this case, we **mostly relied on KMeans clustering**.

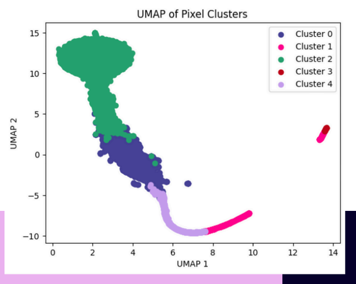
3. CLUSTERING

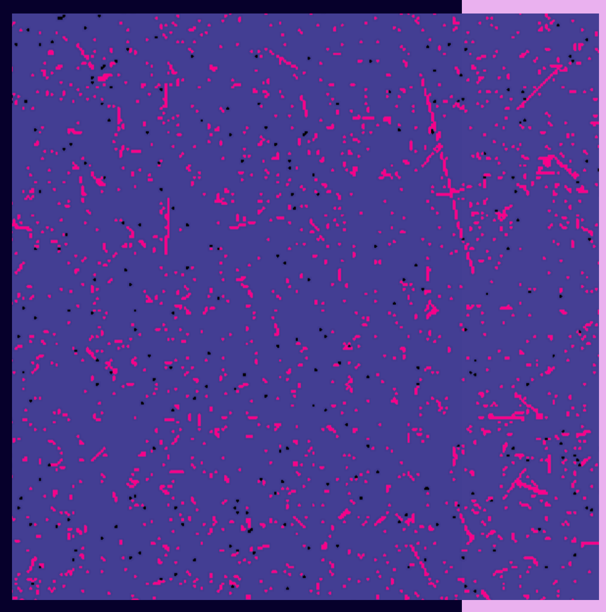


There is **some structure**, and KMeans returns very **unbalanced clusters**.

But overall the MIRI detector is pretty **homogeneous. No major frequency patterns** jump out.

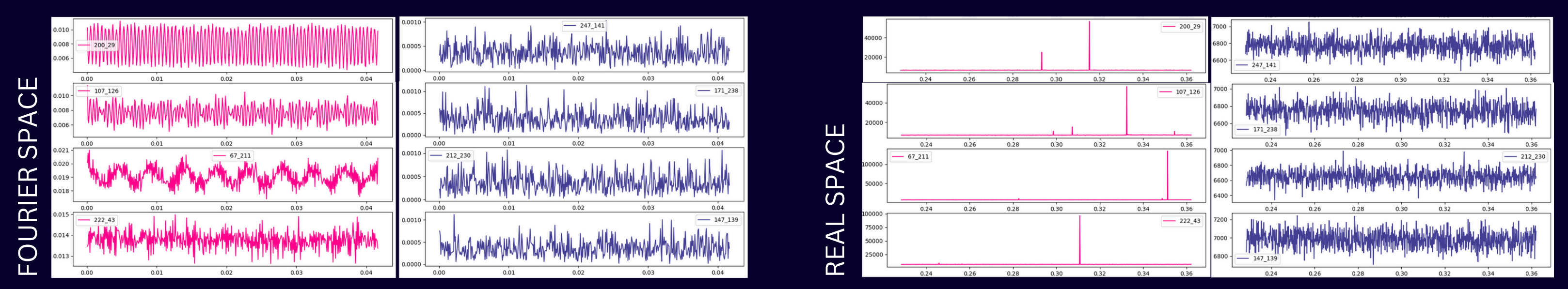






Using **2 clusters**, most pixels are sorted into cluster 1, while some form a second cluster, with some shapes and structure on the detector.

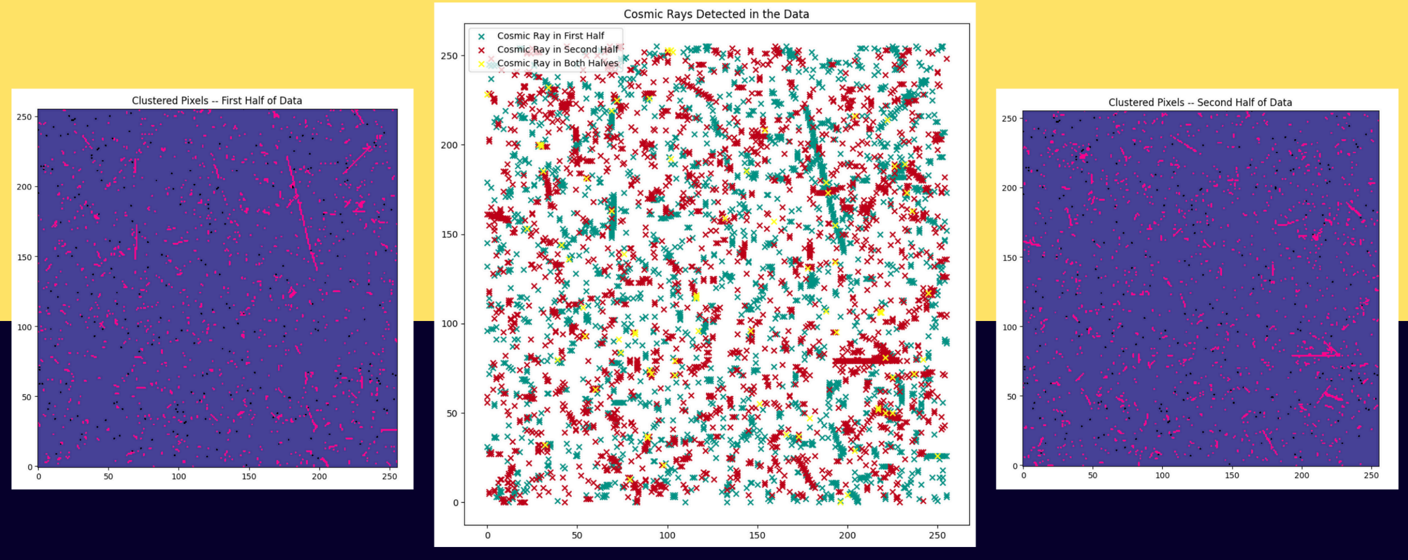
When looking at the individual pixels, their FTs have **larger amplitudes** and **distinct patterns** compared to the cluster 1 "random noise" signals.



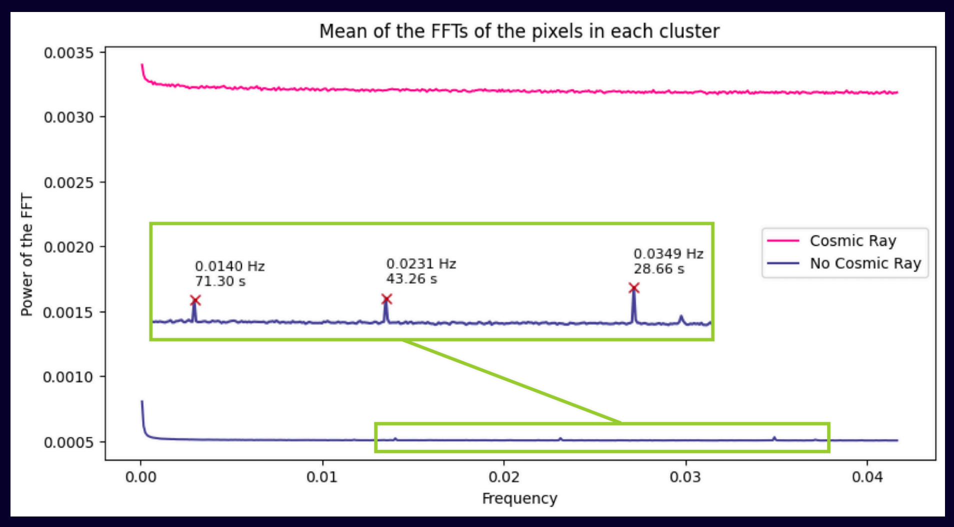
The original lightcurves reveal these as **pixels that get hit by strong "cosmic rays"** or other bright polluters.

4. VERIFICATION

Clipping out the cosmics does not impact the clustering's ability to pick up on pixels that were hit.



When the time series is **split into two halves**, the clustered pixels **match those that were hit in the corresponding half**. This means the perturbation of the pixels happens on timescales larger than one integration.



The mean FFT of regular pixels also revealed **3 peaks at specific frequencies**. It is important to note these are **not aliases of the sampling frequency**.

5. CONCLUSIONS

Instantanenous, bright polluters such as cosmic rays or asteroids flashing in front of the detector can **change the behaviour of the pixels.** This "shocking" of the pixels can be observed and **picked up beyond the actual event.**

Additionally, the pixels seem to have **common "resonance" frequencies** at **0.0140 Hz, 0.0231 Hz and 0.0349 Hz** (71.30 s, 43.26 s and 28.66 s). These might be **inherent to the MIRI detector or tied to some heating & cooling timescales from the telescope**.

More work on **multiple datasets** is needed to explore the noise properties of the JWST instruments at large. **ML techniques** might be helpful to **pick up patterns more efficiently and without much prior knowledge**.