The Kilonova Data Challenge

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What are Kilonovae?

Kilonovae are rare transient astronomical events that occur when two dense objects such as neutron stars merge. As a result of this event, an enormous amount of energy and light is produced. This includes phenomena such as strong gravitational waves and intense gamma-ray bursts. Thus far, the only astronomical event classified as a kilonova was GW170817, found in 2017.
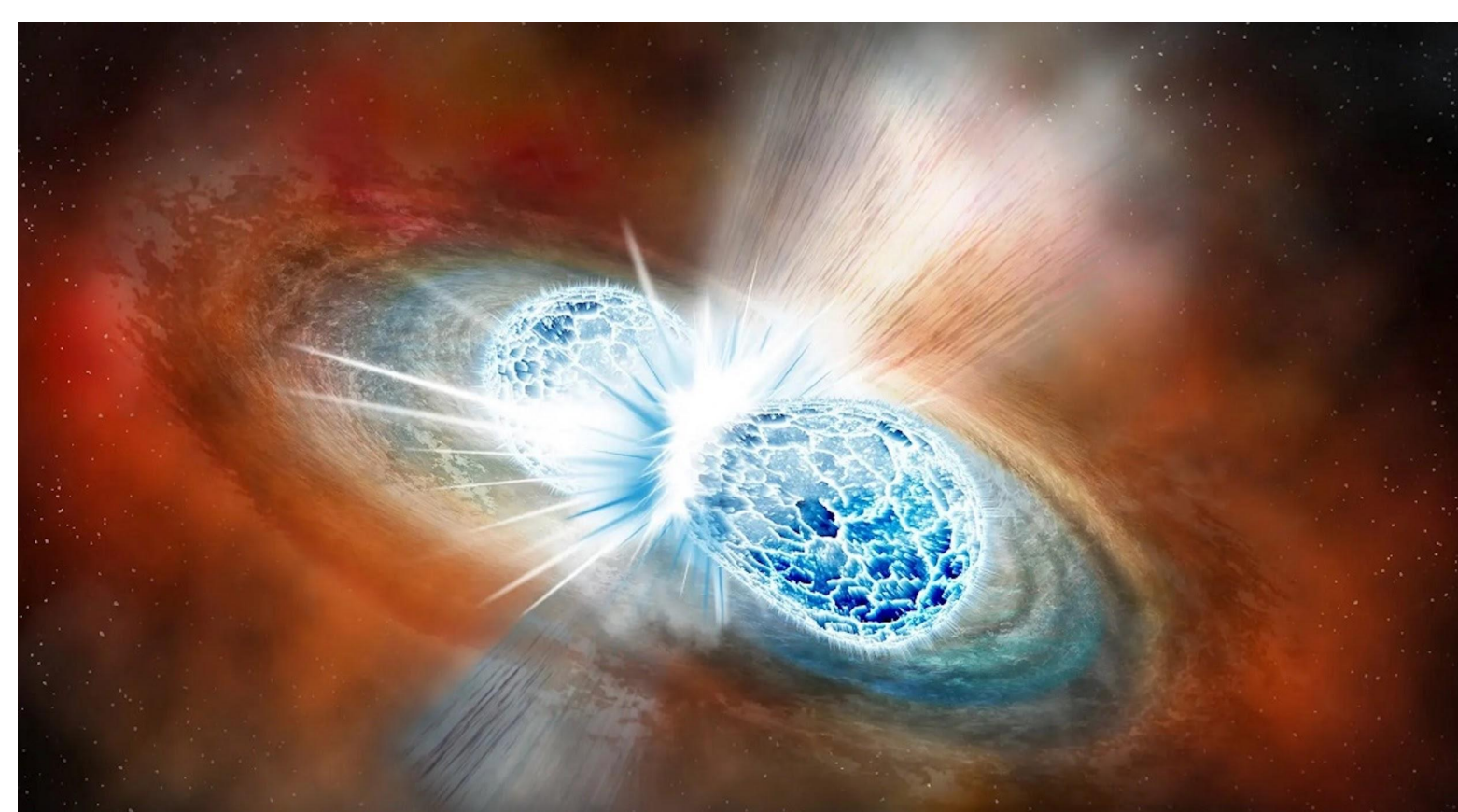
Fig 2. This is an illustration of GW170817 as the two neutron stars merged. Credited to the Chandra X-Ray Observatory at Nasa.

Fig 1. An illustration of what a Kilonova would look like as two neutron stars collide. Credited to Robin Dienel/Carnegie Institution for Science.
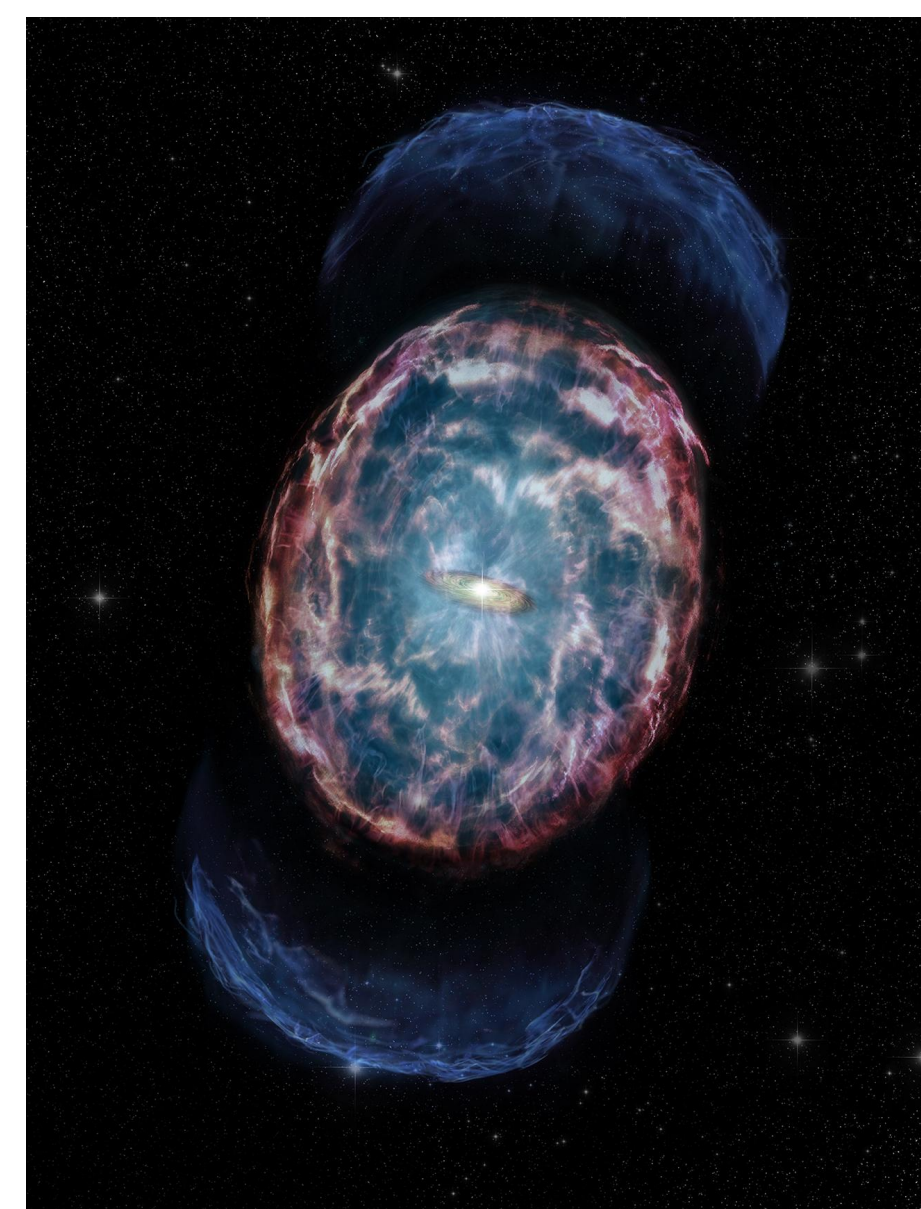
What Is The Kilonova Data Challenge?

The Kilonova Data Challenge (KDC) is a project to determine how well the current LSST pipelines can recognize kilonovae. The KDC is using a simulated data set by DESC (The Dark Energy Science Collaboration) known as DC2. This data set covers 300-sq-deg of the sky in six optical bands. With this image set, we are able to use synthetic source injection to add kilonovae into the images; and subsequently test out our ability to search for them. With this information, we will be able to exercise how to find kilonovae in advance of real LSST data.

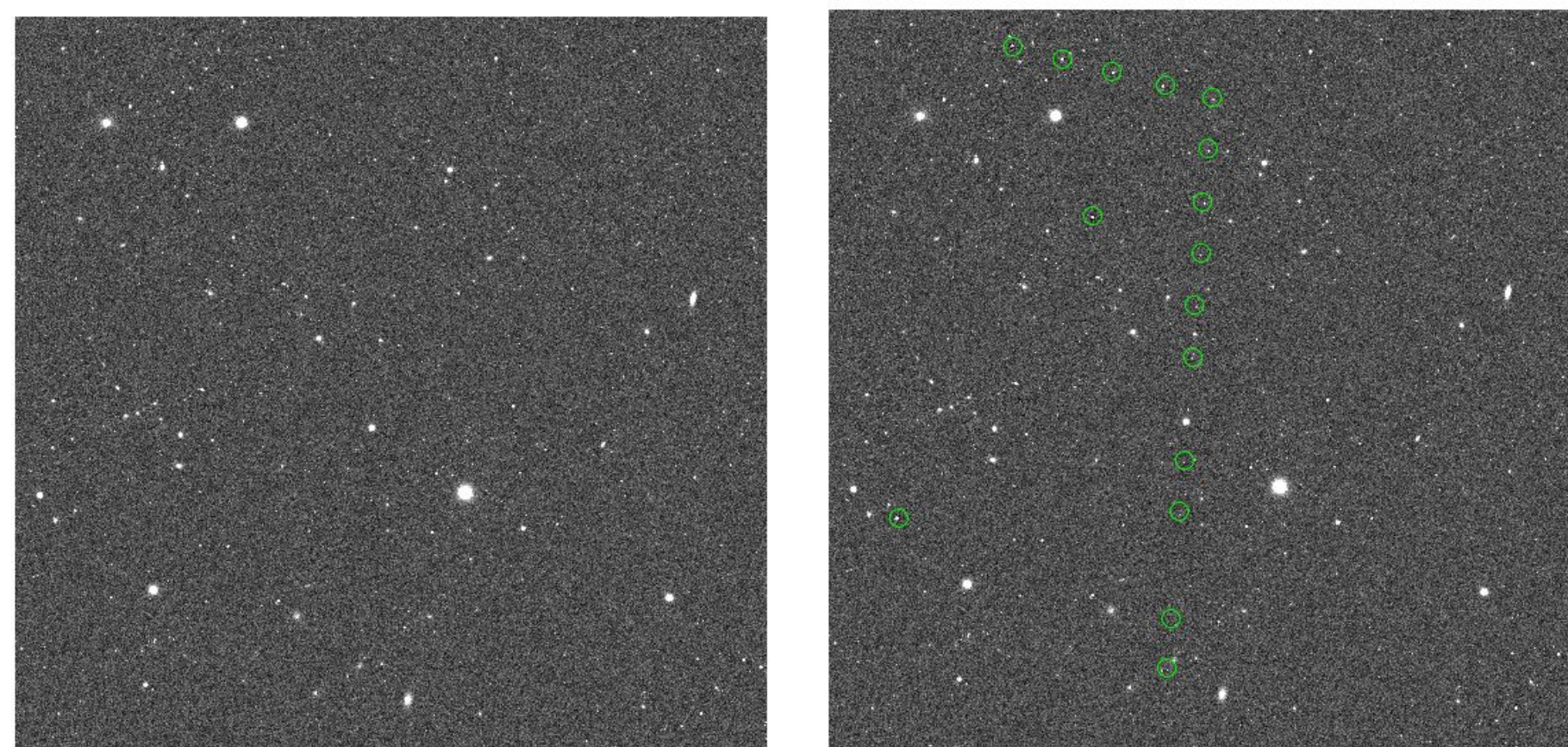Fig 3. A photo of the Rubin Observatory, captured by RubinObs/NSF/AURA/H. Stockebrand

Fig 4. A DC2 image without injected source (left) and with 20 injected sources (right). The green circles indicate the circles of the injected point sources.

The Rubin Science Platform

The Rubin Science Platform (RSP) is an online platform that provides users access to Rubin data; which for now is just simulated data. To get a better understanding of the images, we have to see the full area the KDC would cover. Using the RSP, we developed a Jupyter notebook to display a set of calibrated exposures in a mosaic. In the notebook, we first imported the functions we would need; such as the display functions, matplotlib, the butler, etc. For reference, the butler's function is to retrieve images or catalogs from the database. We use this to call the images from DC2. Then define how many images we want to display. And lastly, we use the butler to call the calexp (calibrated exposure) images for the x number of different detectors.
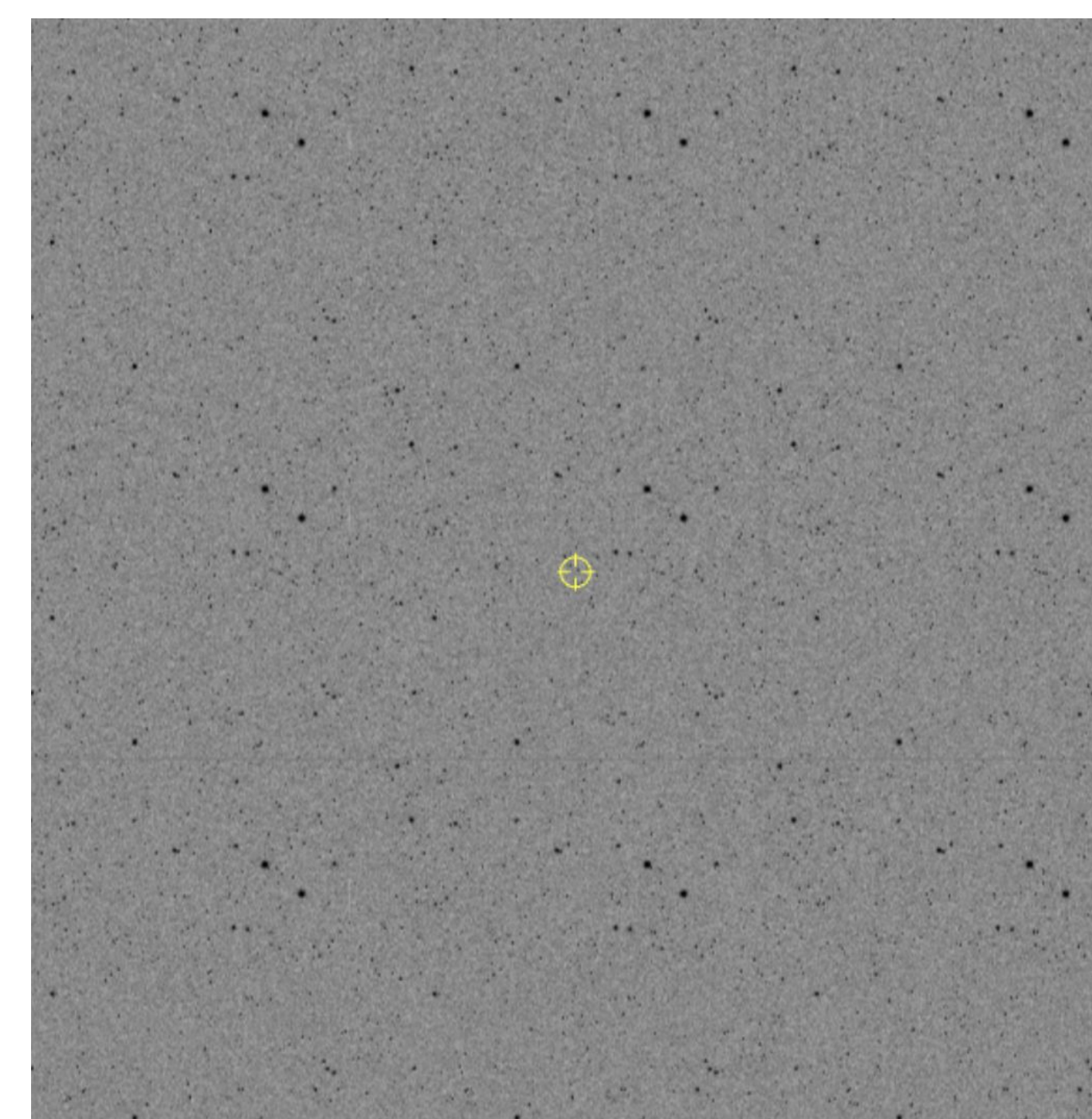
Fig 5. The output of the mosaic notebook. This is displaying 9 out of the 21 tiles needed to display 1 square degree.

This mosaic notebook accomplished the purpose of trying to visualize a larger area of the focal plane of the camera. After achieving our goal, this notebook was added to the DP0.2 Delegate Contributions.

DP0.2 Delegate Contributions GitHub Repository: https://github.com/rubin-dp0/delegate-contributions-dp02/tree/main/view_mosaic

Displaying Images in DP0.2

The Data Image Preview 0.2 (DP0.2) simulated image set was created in anticipation of the start of Rubin operations. We wanted to view these images and highlight where kilonova are in the galaxy images. To do so we created a galaxy_viewer notebook in the RSP. In this notebook, we define the image along with the tract and patch. And then we create the coadd function, which is a stack of several single exposure images. Now using synthetic source injection, we found a visit and band. Lastly, we defined an image and set the right ascension and declination. This produced a large image, displaying the galaxy we chose to host the kilonova (Fig 6). To see the host galaxy more closely, we used a cutout coadd to augment the image, and zoom in on the location (Fig 7). This notebook was also added to the DP0.2 Delegate Contributions.
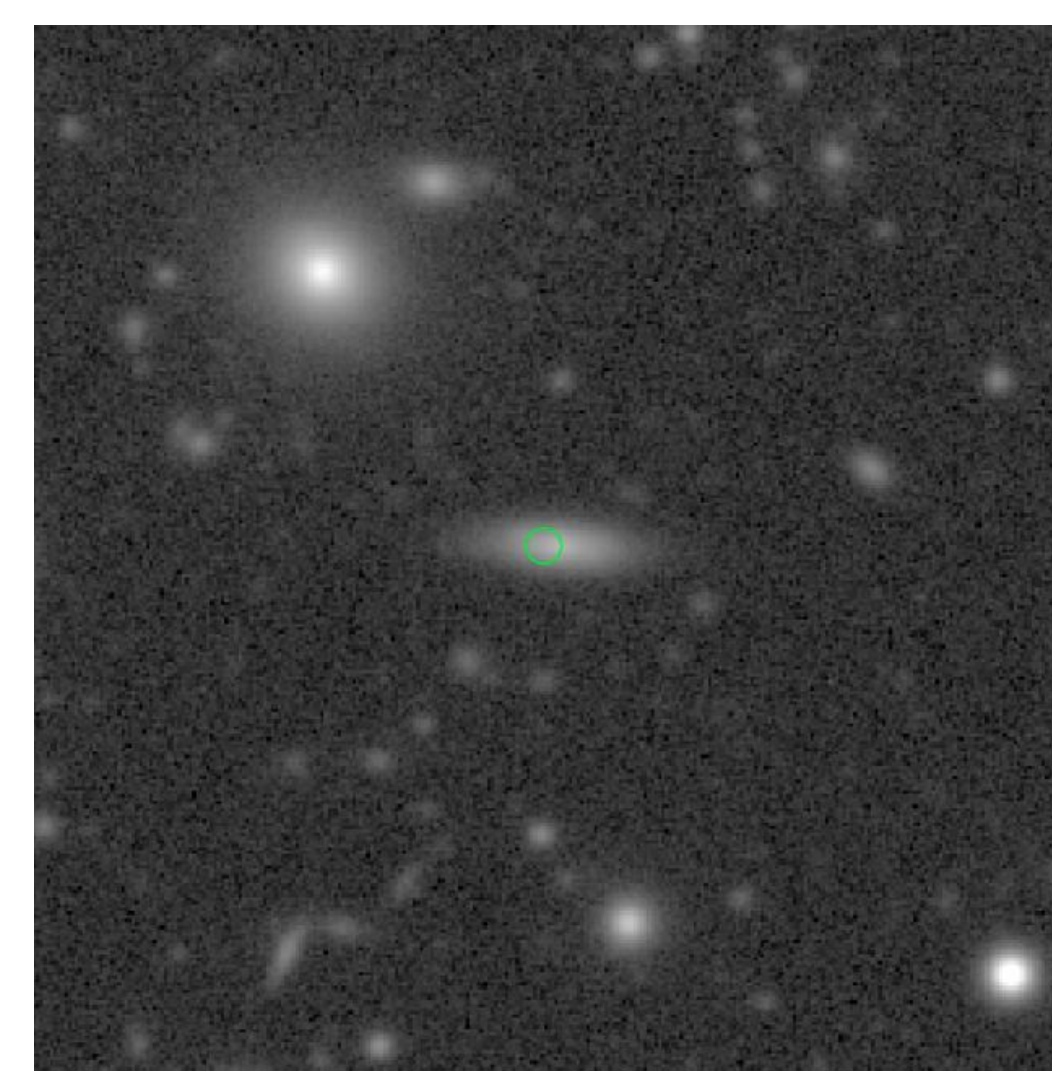
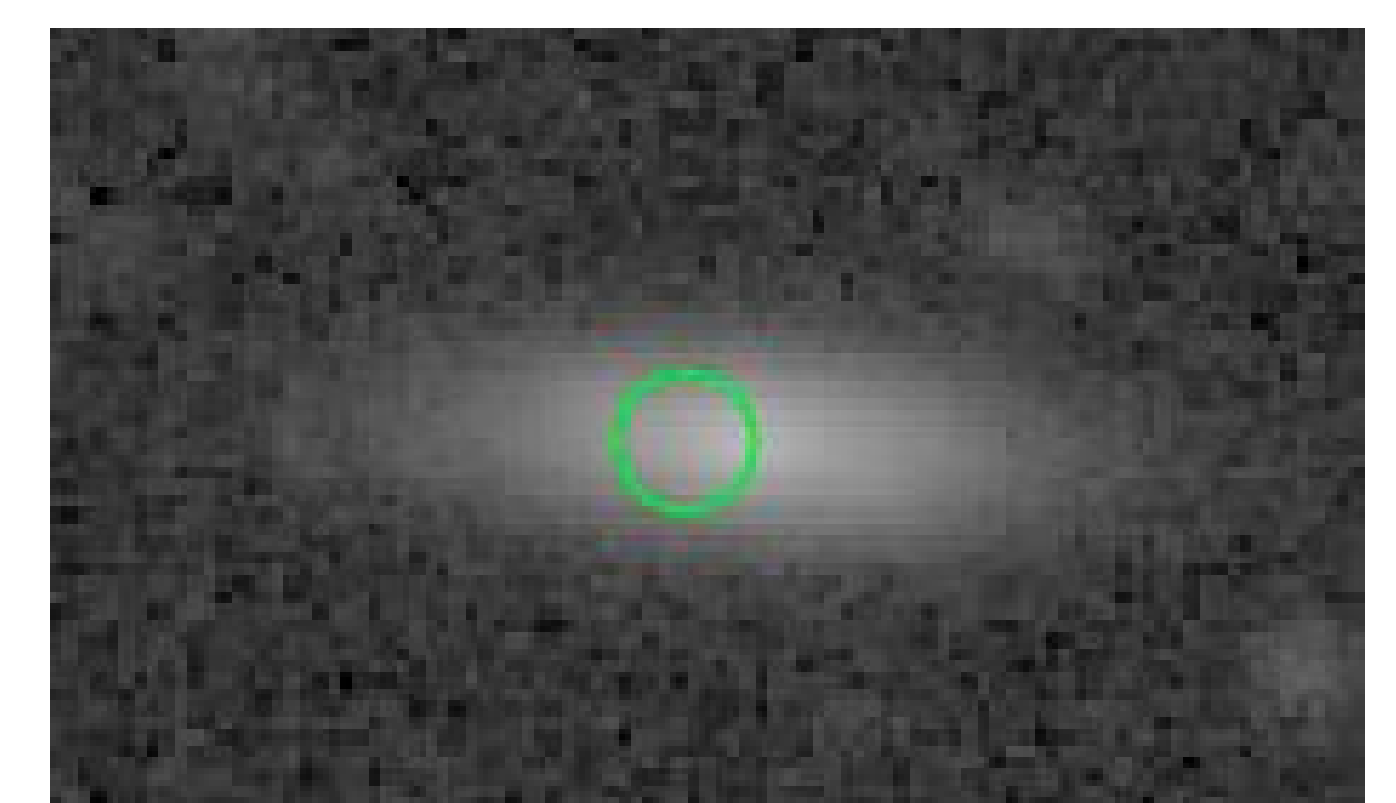Fig 6. This is a full view of the galaxy_viewer notebook output.

Fig 7. This zoomed in output of the galaxy_viewer notebook.

Results

Thus far, we have built several critical notebooks which brought us closer towards achieving our goals. Going forward, we will continue development on these; and on ideas that will bring us closer to a clear result. For Rubin, this will give us an idea of what to expect. Hopefully, it will give us some sense of what to look for when doing kilonova searches with Rubin.

Acknowledgments

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