Fernández Moroni, G., Estrada, J., Cancelo, G. et al. “Sub-electron readout noise in a Skipper CCD fabricated on high resistivity silicon,” Exp Astronomy (2012) 34: 43. https://doi.org/10.1007/s10686-012-9298-x

Summary of this article:

When working on the Skipper CCD, the most important aspect to keep in mind was the readout noise in the output stage because that is currently the main limitation when trying to use CCDs for detecting low signals for trying to differentiate the energy between two very similar signals. Readout noise is caused by electrical noise changing the pixel value during various stages in the CCD readout process such as the output amplifier, the readout system, and the bias and clock signals used to collect the charges. The readout out process is used by the CCD to recover and digitize the value of each pixel and so an addition of electronic noise is really changing the value of the collected charge and thus altering the signal seen by the detector.

In 2010 the Lawrence Berkeley National Lab developed the Skipper CCD on a high resistivity, n-type silicon. The detector is a square made up of 1022 by 1024 pixels that have a 15 µm width. These pixels are placed in four quadrants that each have an amplifier at the corner of the chip/detector. One of the main differences with the Skipper CCD is that the floating diffusion output stage (where the charge is dumped before being read by the amplifier) has a much smaller capacitance (and thus higher voltage) than the current fabricated CCDs. Noise created within the output stage depends directly on the capacitance so a design with minimized capacitance will experience less noise. In the current models, the floating diffusion node has a voltage

$$\Delta V = \frac{\Delta Q}{C_J + C_{PFD} + C_{IN}}$$

where the total capacitance made up of the capacitance at the junction between the floating diffusion and the bulk (C_J), the parasitic capacitance at the node (C_{PFD}), and the capacitance of the output amplifier (C_{IN}). Through a new design, the Skipper CCD has a total capacitance that really only relies on C_{PFG} and C_{IN} thus reducing the read out noise.
[Add more info about other ways the Skipper CCD has changed to have lower readout noise]

Ways I think I will use this article:

This article was the first article published on the new Skipper CCD design so I can use it to talk about the critical changes that were made from the currently fabricated CCDs.

Tiffenberg, J., M. Sofo Haro, J. Estrada, et. al. “Sensei: A novel search for a hidden-sector dark matter.” *Fermi National Lab.* URL: http://home.fnal.gov/~javiert/sensei/materials/SENSEI-summary.pdf

Summary of this article:

Sensei is the research and development project at Fermilab that created and tested the Skipper CCD (in conjunction with LBL Micro Systems Lab). This project is made up of particle theorists and experimentalists that are after the main goal of producing a new ultra-sensitive detector to search for the dark matter particles that make up 85% of the universe’s matter. Some of these particle candidates (called hidden-sector) lie within the eV-to-GeV range of masses which has been an underexplored possibility until recently. With the new sensitivity that the Skipper CCDs have to signal, this area of searching for hidden-sector particle candidates is now a reality. One way that the Skipper CCD can change the dark matter search is when the dark matter scatters of bound electrons in the silicon CCD, one or a few free electrons will be created and detected. Before the Skipper CCD, signals of only a few electrons could not be accurately read because of noise being larger than the signal.

Ways I think I will use this article:

This article is a short, one page summary of the work that the SENSEI group is doing at Fermilab, but it has some great information about where the project is currently and the future plans. I plan on looking up the DAMIC-1K project that is mentioned in this article and talk more about future use of the Skipper CCDs in the conclusion of my paper. This article also does a good job of succinctly talking about who was involved with creating the skipper CCD so that could be used as part of my introduction to the Skipper CCD.