# Correlating the Sky

## A look into the JCMT-Transient Data Reduction and Calibration methods

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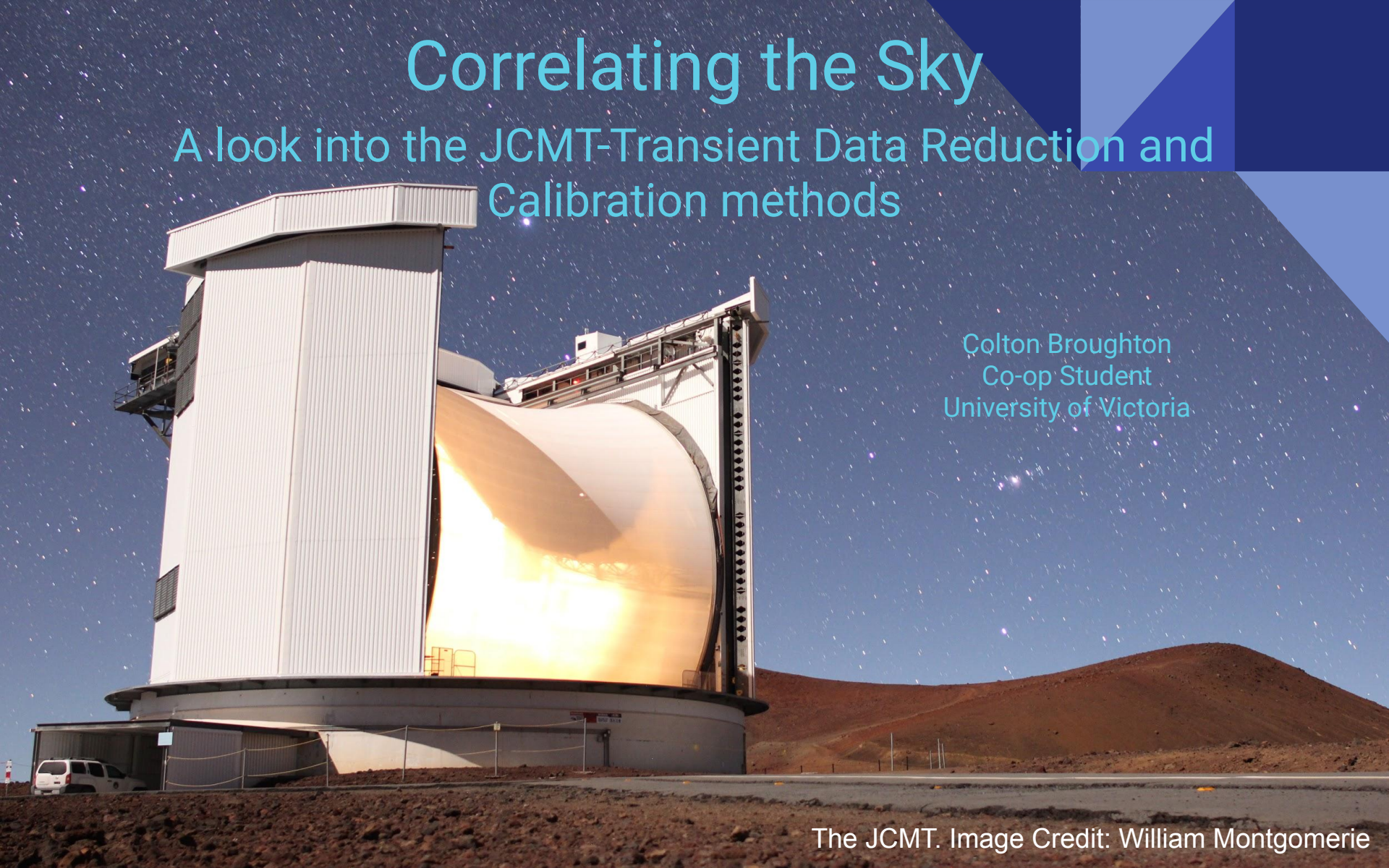


The JCMT. Image Credit: William Montgomerie

# Intro to the JCMT Transient Survey

**8 Regions < 500 pc (GBS)** | **4 Year Survey** | More on this later

**182 Protostars, 800 Disk sources** | **One Month Cadence**

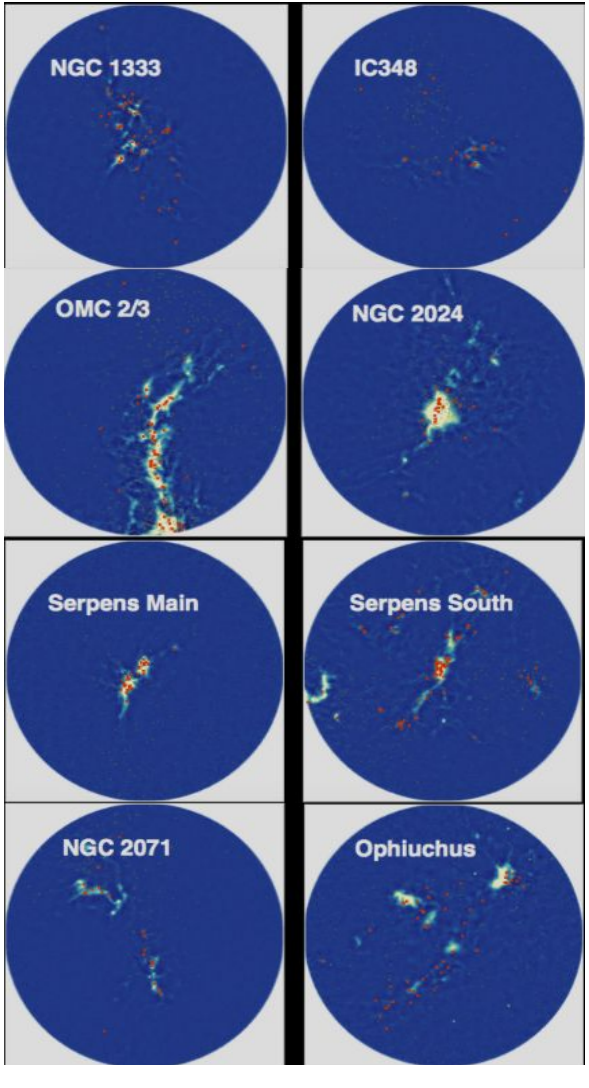
***Luminosity problem*** Kenyon et al (1990):
*Protostars are an order of magnitude too faint for steady mass accretion.*

Details?

- Collected using SCUBA-2
- Determine if any sources are varying
- ... Any variations we observe in the envelope can be traced back to the protostar to determine the variation in the mass accretion of the star. (DJ 2013)

Has it found anything?

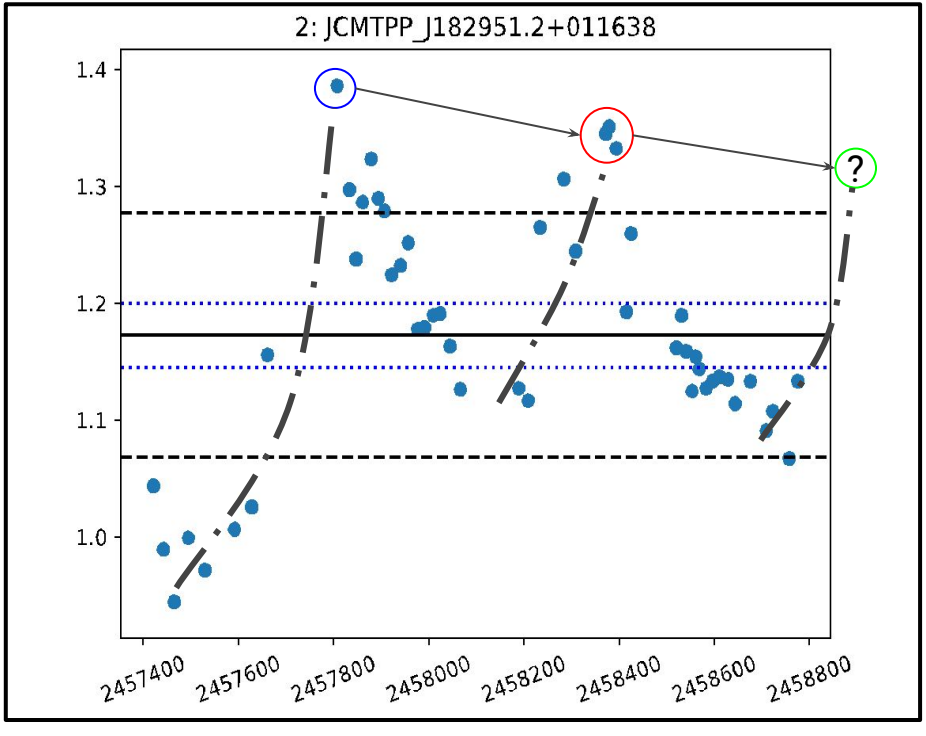
- EC-53 and many other variables (*Yoo, H; et al 2017 ApJ*)
- JW-566 a sub-mm flare (*Mairs, S; et al 2019 ApJ*)

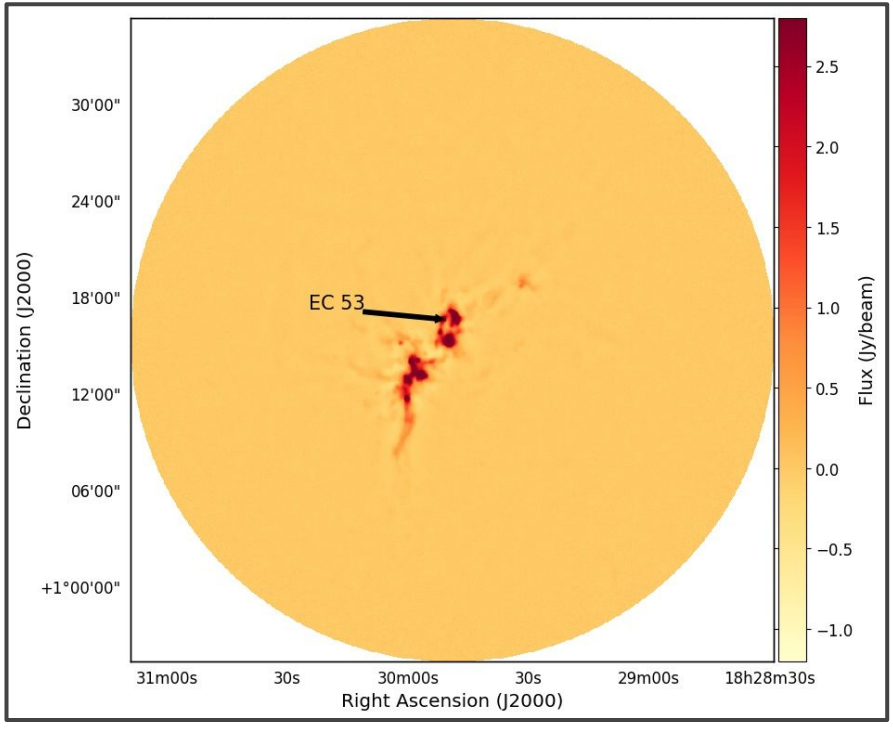


# EC-53 in Serpens Main

- 1.5 times the quiescent brightness
- Suspected binary with a giant planet in its ring
- EC53 was also observed in NIR and confirmed periodic.

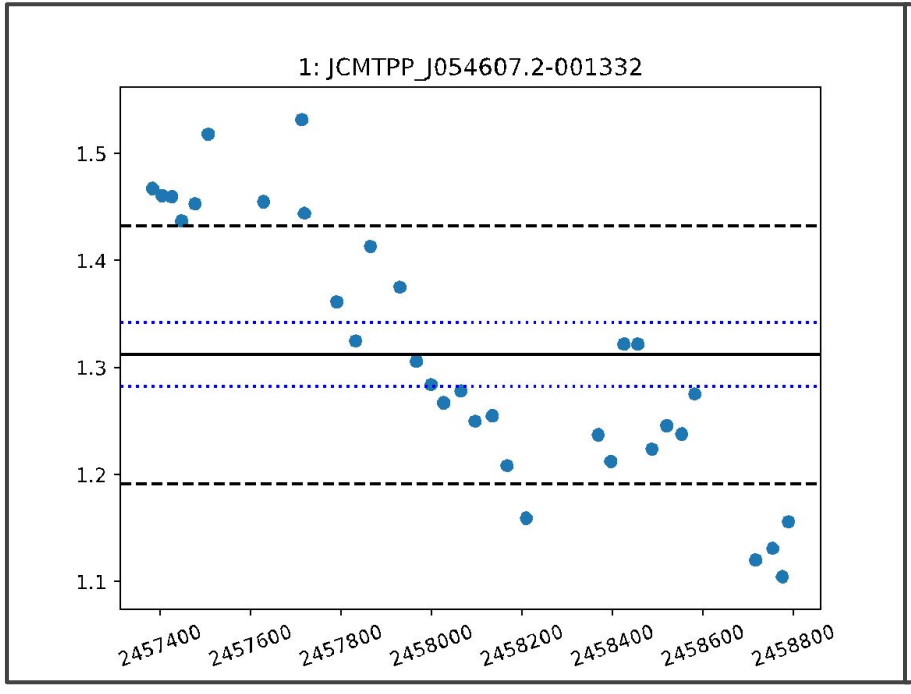
Light curve as of Nov. 12, 2019, periodicity becoming apparent.

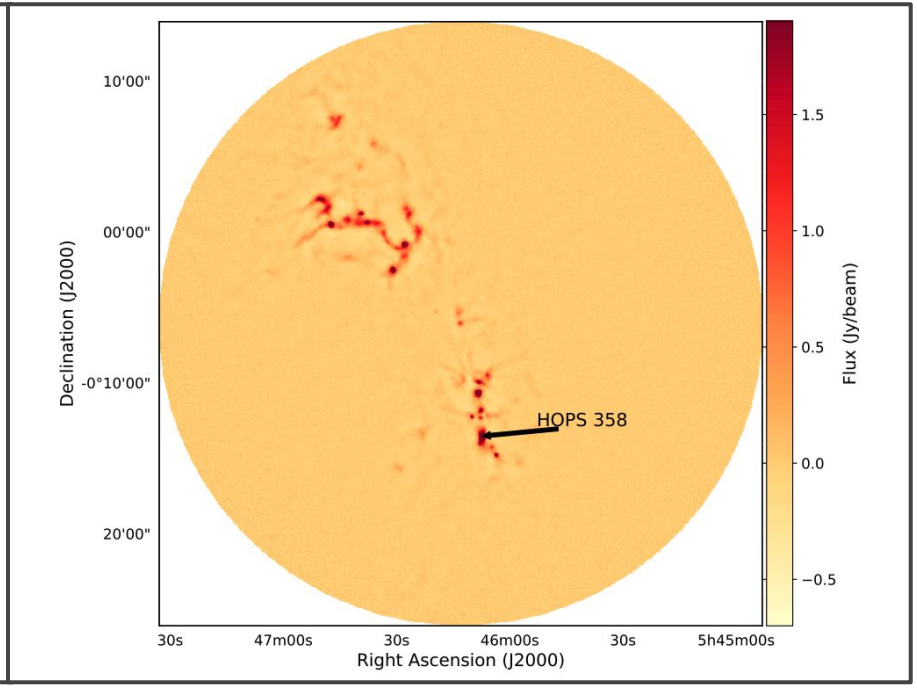


# A Variable Detected via Automation:

**HOPS 358 in NGC 2068 (PACS Bright Red Source, Stutz et al. 2013)**
~30% decline in sub-mm flux over 2 yrs
An estimated 75% decline in accretion

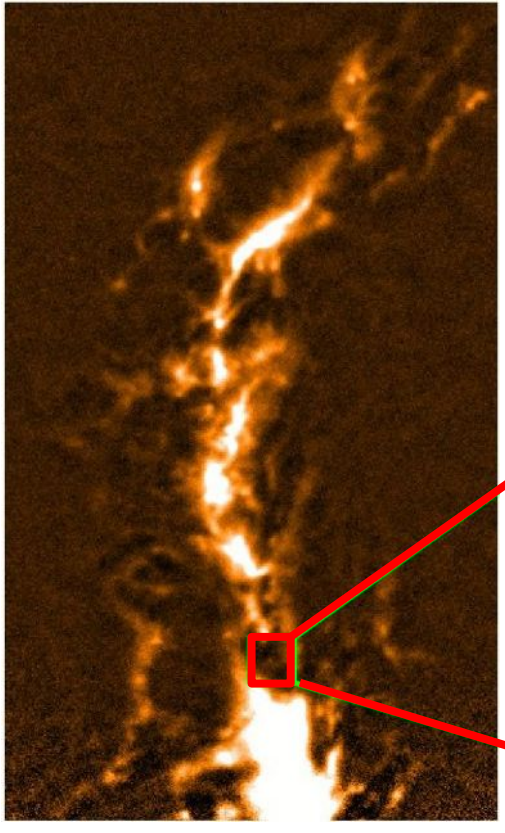


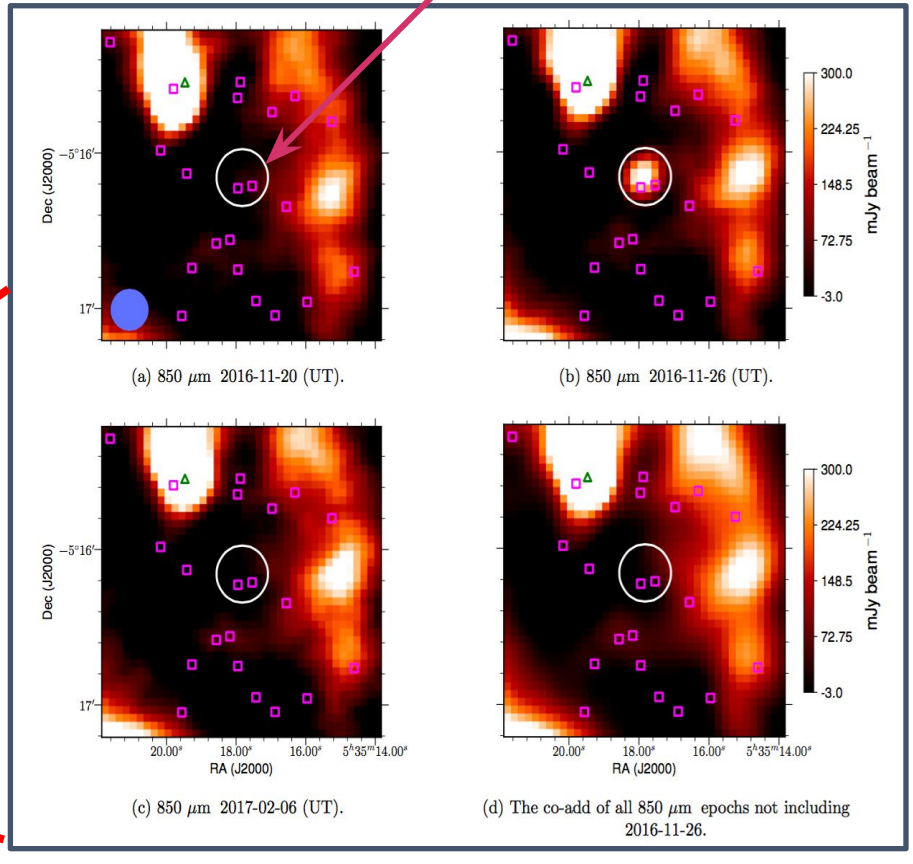
# Sub-mm Flares in JW-566

Searching for sources that appear in *only one* epoch: Mairs et al. 2019 ApJ

- Observed in only one epoch
- Large burst ~30x the noise level of 10 mJy/bm
- Did not appear in the CoAdd of all the epochs excluding the 2016-11-26 epoch
- Was not evident 6 days prior



Location of T Tauri binary JW 566

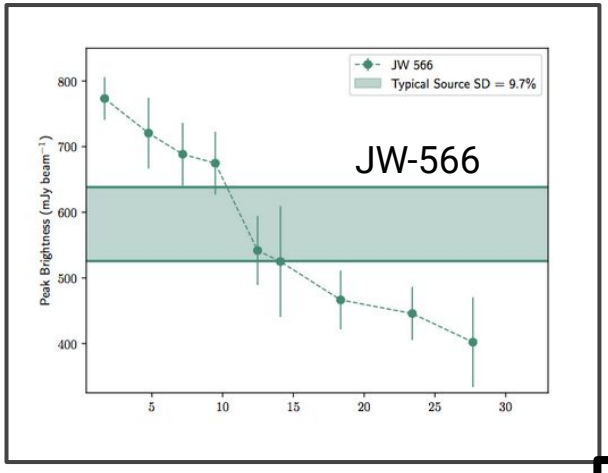



(a) 850 $\mu$m 2016-11-20 (UT).

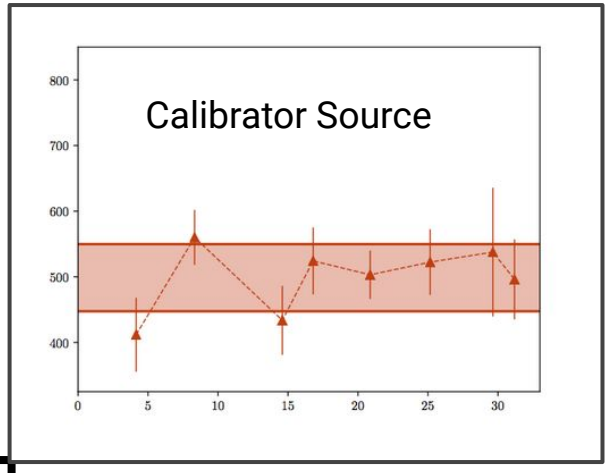
(b) 850 $\mu$m 2016-11-26 (UT).

(c) 850 $\mu$m 2017-02-06 (UT).

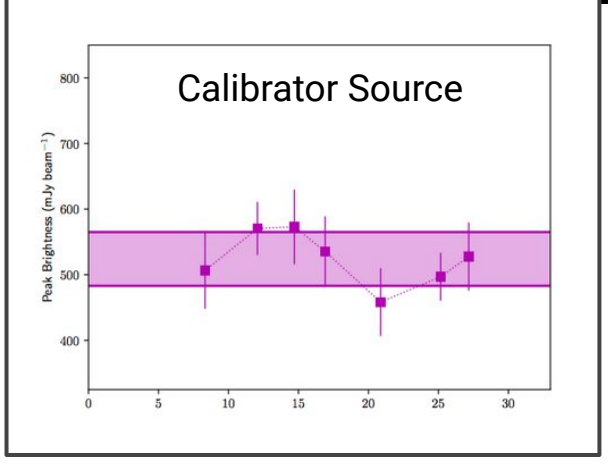
(d) The co-add of all 850 $\mu$m epochs not including 2016-11-26.

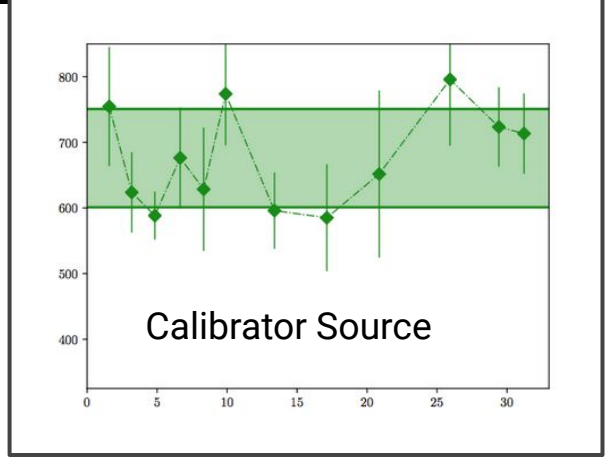



50% decline!




30 minute epoch observation broken into ~5 minute bins



# Where do I fit in to the project?

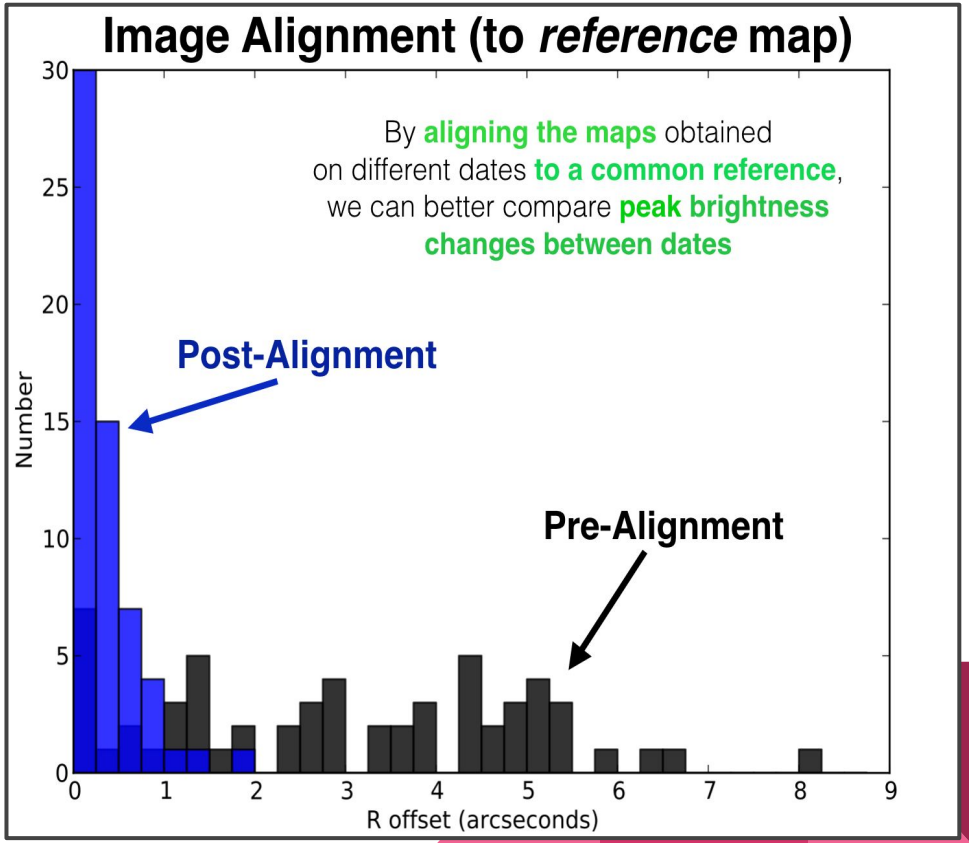
# Calibrating the Data:

JCMT:

- Alignment was between 0 and 8 arc seconds between subsequent maps.
- Primary cause of high offset is due to the telescope pointing

Steve Mairs:

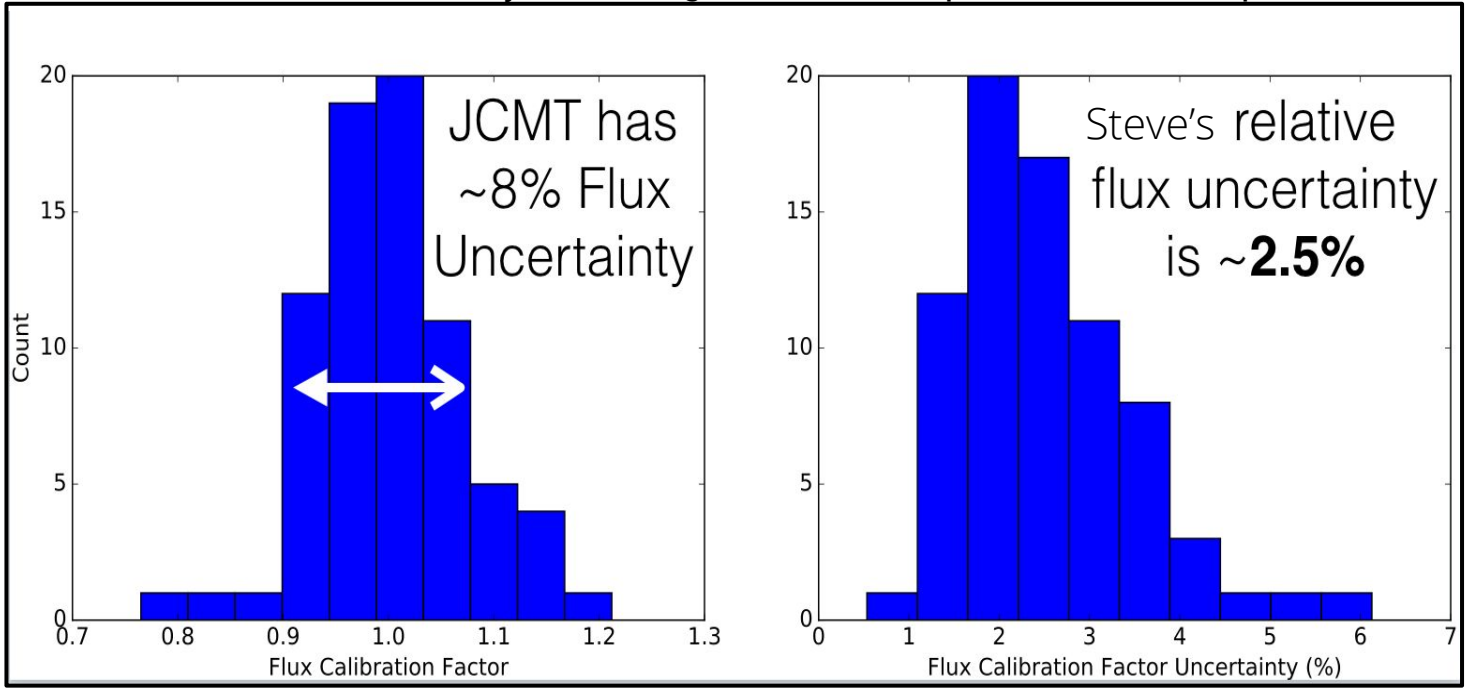
- Used a family of compact luminous (~200 mJy/bm) to calibrate epoch offsets.
- Relative Offsets: ~1” or 1/3rd of a px



# Flux Calibration:

Steve:

- A new subset of sources with flux >500 mJy/bm Were used for flux calibration.
- Compared ratio of two sources over all epochs in a region. If the standard deviation of those pairs were less than 6% they're considered non-varying and are used as calibrators.
- A flux factor is then made by the average of all source pair ratios in a map



# Cross Correlation:

Using a **fast fourier transform Cross-correlation** method:

- We are able to **quickly compute** the cross-correlation between a reference map and a subsequent epoch map.
- We then determine the **distance between the peak of the offset and the centre** of the maps
- This offset is the offset between each epoch to the reference map.
- After a radial offset is determined we can then **realign the maps**.

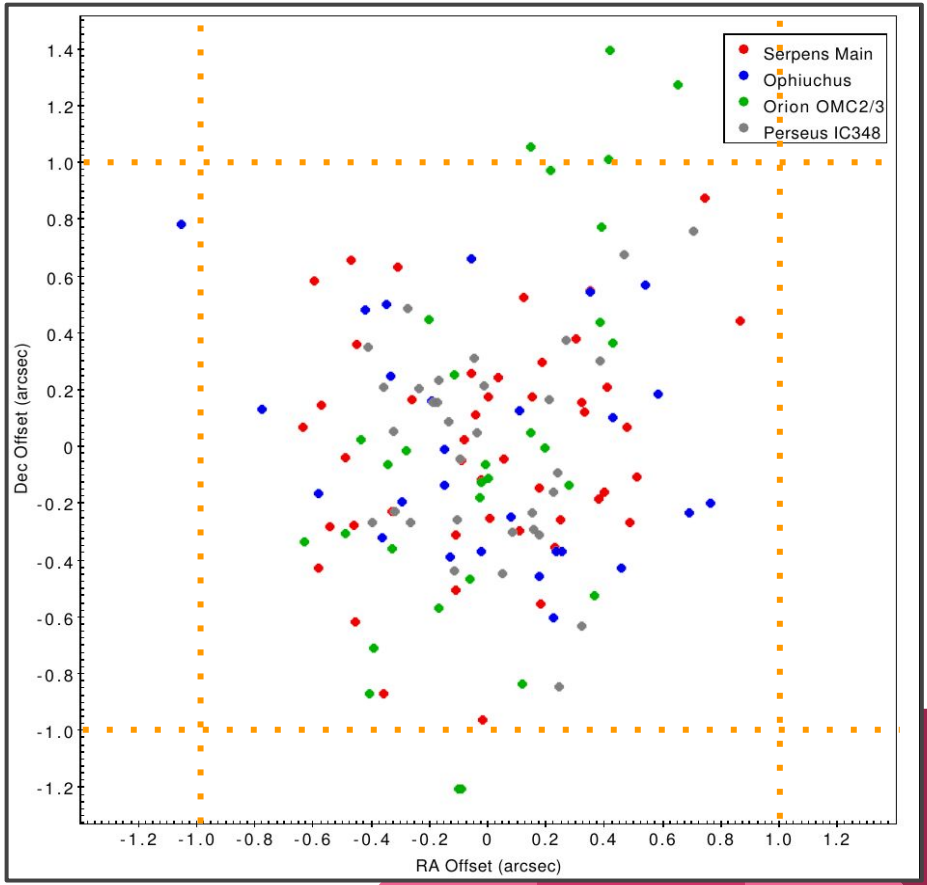
This method has agreed with the calibration done by Steve.

- All of the **offsets lie within the errors** of Steve's calibrations.
- Orion has more North South Structure which causes issue with our Declination offsets. However, it is still within ½ a pixel.
- Some minor tweaks may get use a better than current offset calibration
  - ➢ However for the time being, this is a great way to cross check that the calibrations in the pipeline are good.

Benefits of this method:

- Uses the entirety of the information in the maps, Steve only uses nicely behaving sources.

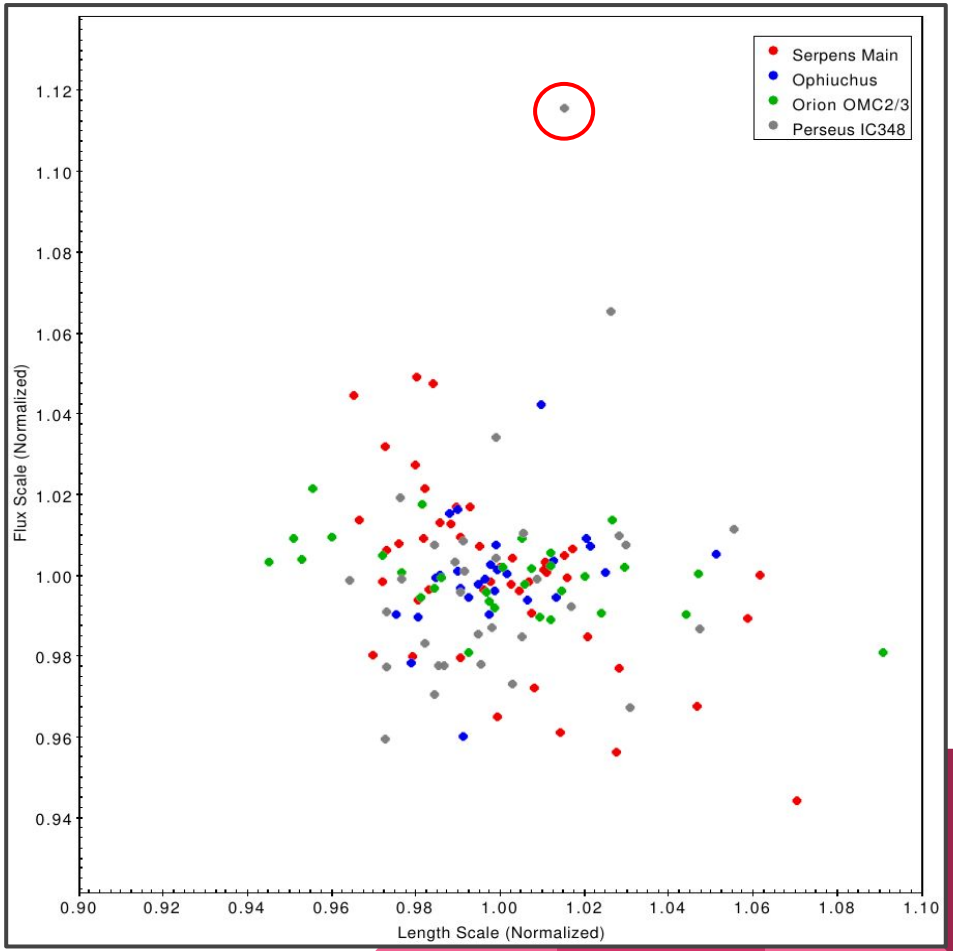
Steve Mairs' offset calibration



# Autocorrelation:

- Gaussian fit to the peak of the autocorrelation map
  - Used the size off the peak for calibrating the flux
  - Size of the gaussian for determining the beam scale
- Simple Gaussian Source Model:
  - Increase in **source power**: **~ Amp * Amp**
  - Increase in **source size**: **increased Area**

- Allows us to get a length scale for the size of the beam; something that Steve's method sweeps under the rug.
- Length scale could potentially allow us to calibrate our maps even further using information of the changing beam size.
- Outlier at the very top is in Perseus where there are only 3 calibrator sources, one of which might actually be varying.



# Next Steps

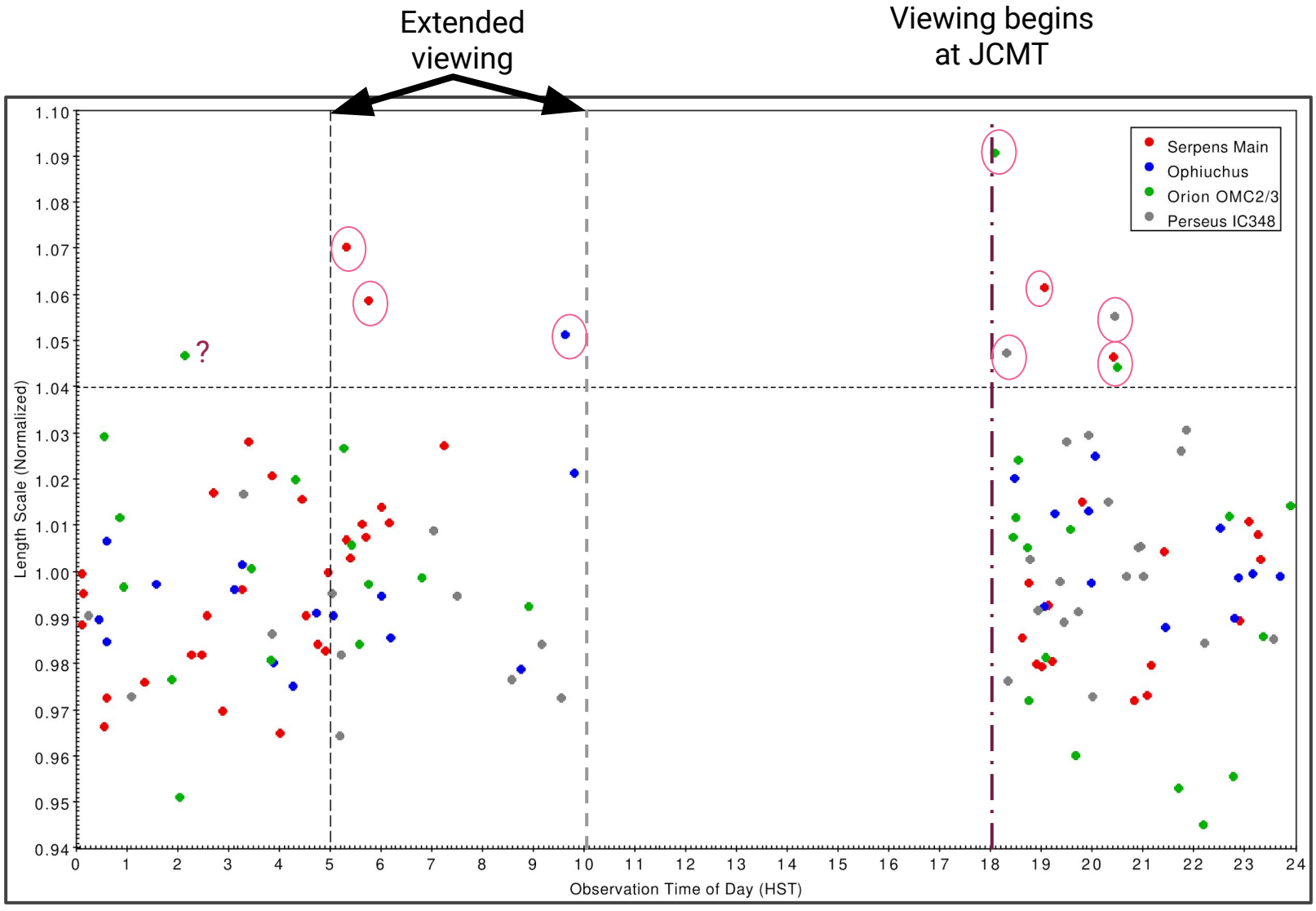
450 micron.

Beam Calibration; Smoothing the data to a common beam size and then performing flux calibrations. Possibly creating a new reduction and calibration flow of:

1. Cross-correlating the maps to align to a reference
2. Convolving the maps to a common beam size
3. Relative flux calibration of maps

Establishing these methods into the pipeline, if only as a cross check for Steve's current methods.

Other...


Extended viewing
Viewing begins at JCMT
Serpens Main
Ophiuchus
Orion OMC2/3
Perseus IC348
?
Length Scale (Normalized)
Observation Time of Day (HST)
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

# Conclusion:

The Autocorrelation and cross-correlation methods of calibrating the maps is an effective tool for cross-checking the pre-existing calibration to ensure it is doing an effective job.

Expanding on these methods could lead to an efficient, and quick, way to calibrate the 850 micron data for the JCMT transient Survey. The implementation of these methods, as they are now, can calibrate to at least as good as the much more involved method of source family calibration methods outlined by Steve Mairs.

It is unclear whether or not these methods will be as effective on the 450 micron data but it is a task outlined for future research. Additionally the effect of convolving the maps to a common beam as a “Beam Calibration” method will also be investigated.

**The JCMT-Transient Survey was extend through until the beginning of 2023. Increasing the time baseline to 7 years at the end of the survey!**

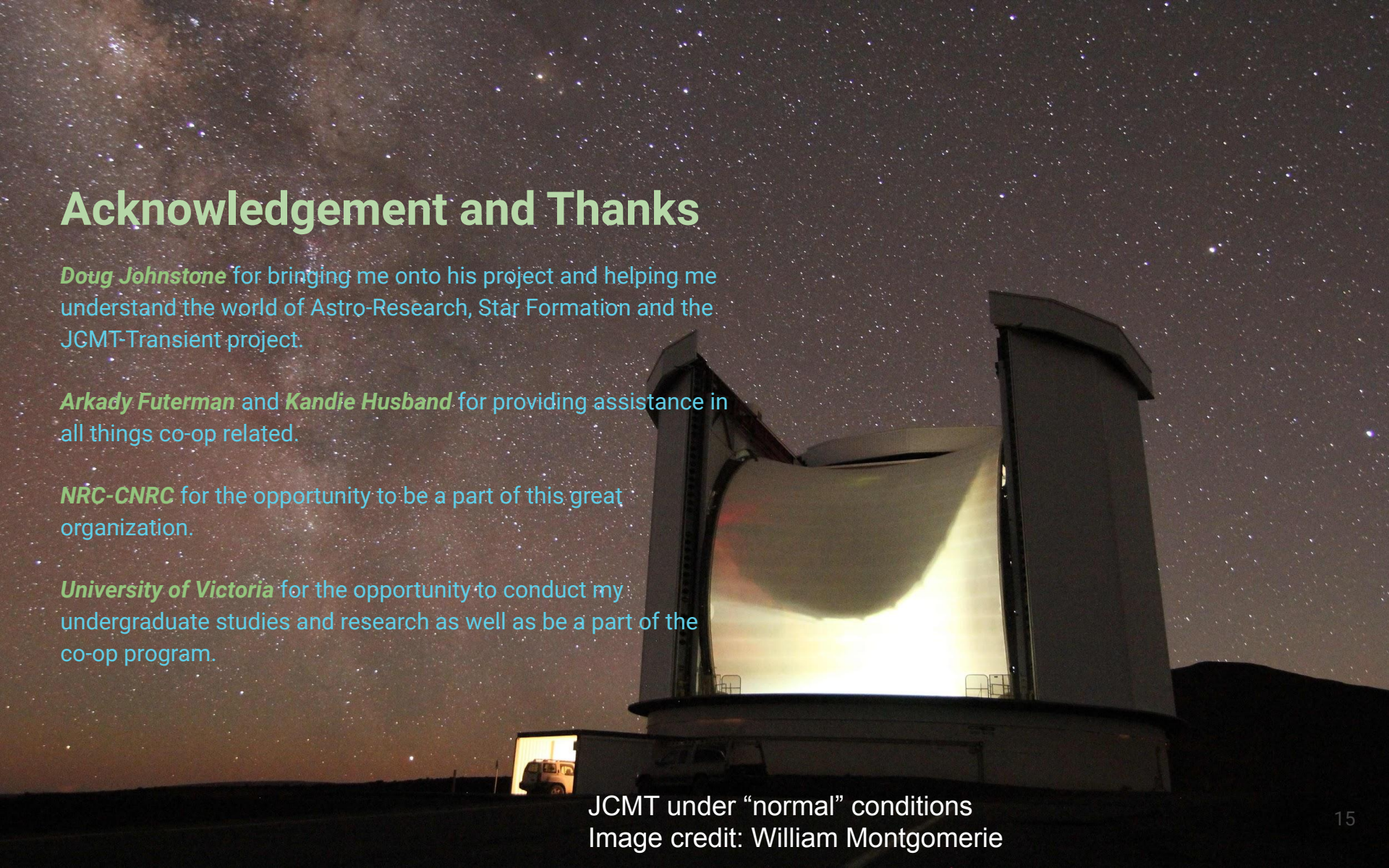
# Acknowledgement and Thanks

***Doug Johnstone*** for bringing me onto his project and helping me understand the world of Astro-Research, Star Formation and the JCMT-Transient project.

***Arkady Futerman*** and ***Kandie Husband*** for providing assistance in all things co-op related.

***NRC-CNRC*** for the opportunity to be a part of this great organization.

***University of Victoria*** for the opportunity to conduct my undergraduate studies and research as well as be a part of the co-op program.



JCMT under “normal” conditions
Image credit: William Montgomerie