WINTER: a new time-domain near-IR facility

Wide-Field INfrared Transient ExploreR

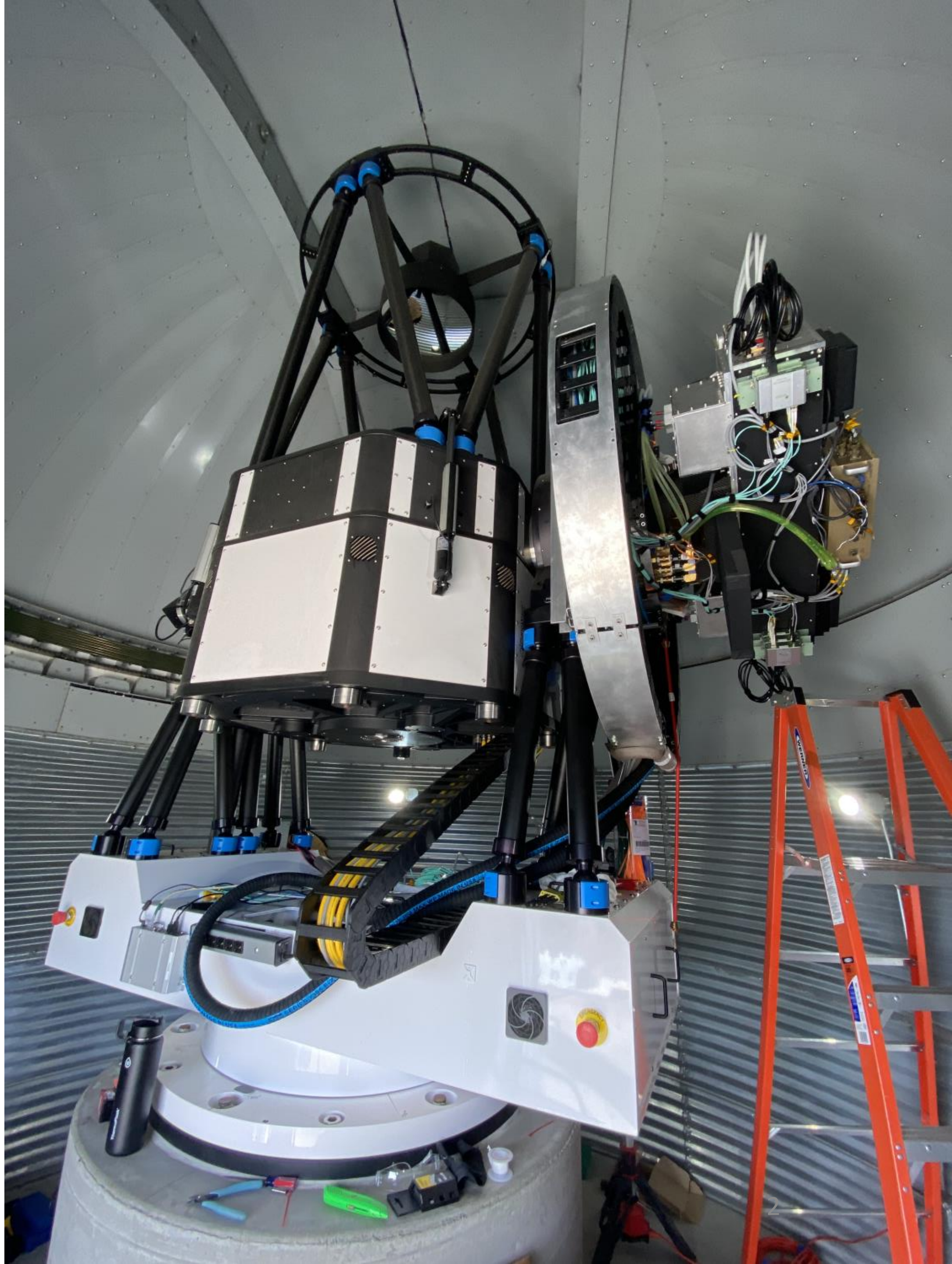
Danielle Frostig, MIT

The Transient and Variable Universe

6/20/23

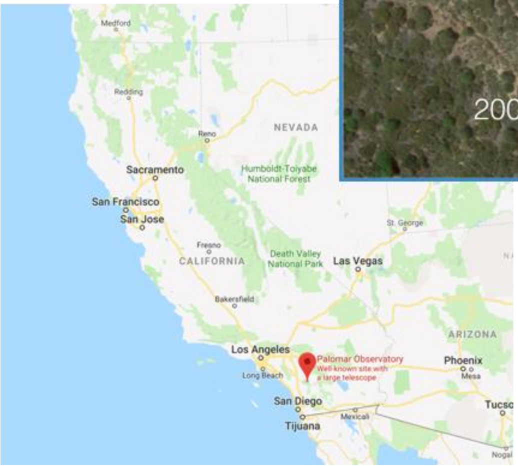
Outline

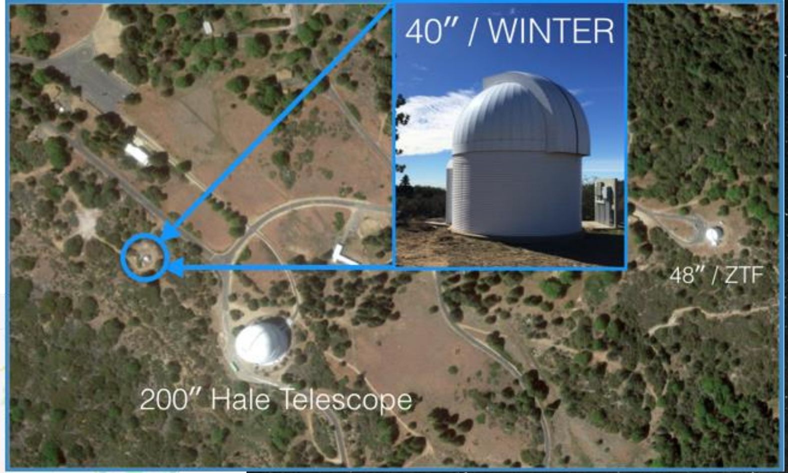
- Intro to WINTER
- Science goals
- How we're achieving them:
  - InGaAs detectors
  - Fly's-eye design
  - 1-meter robotic telescope
- First light last week
- Next steps

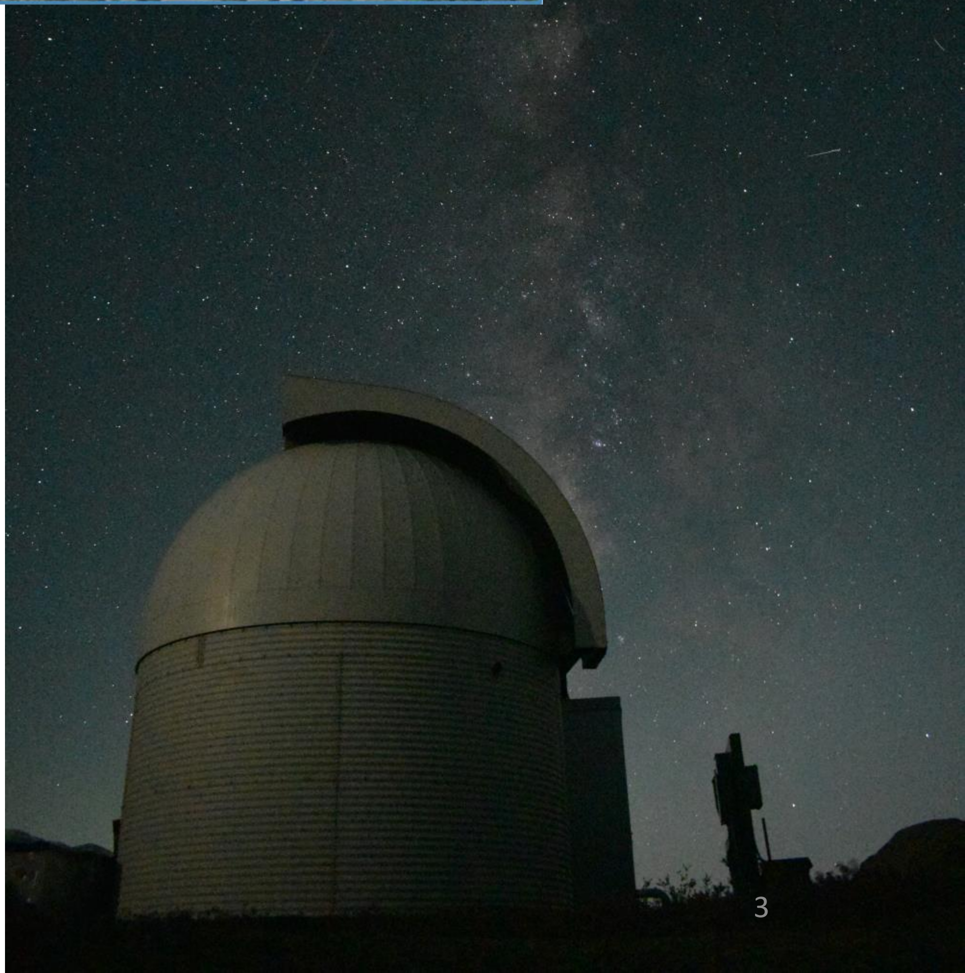


WINTER

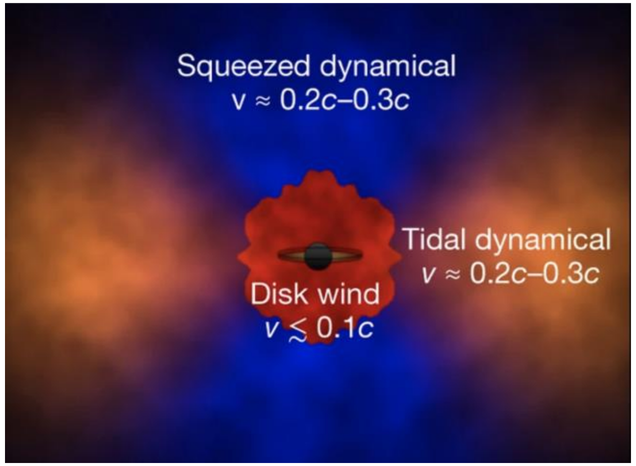
- Seeing-limited all-sky survey
- Dedicated 1-meter robotic telescope
- 1.19 x 1.02 deg^2 FOV
- Near-infrared Y, J, and short-H (0.9-1.7 μm)
    - Survey to J=21 mag
- Development of InGaAs detectors as cheaper alternative for near-IR astronomy
- Designed for multi-messenger astronomy, probing dusty environments, and near-infrared static sky science



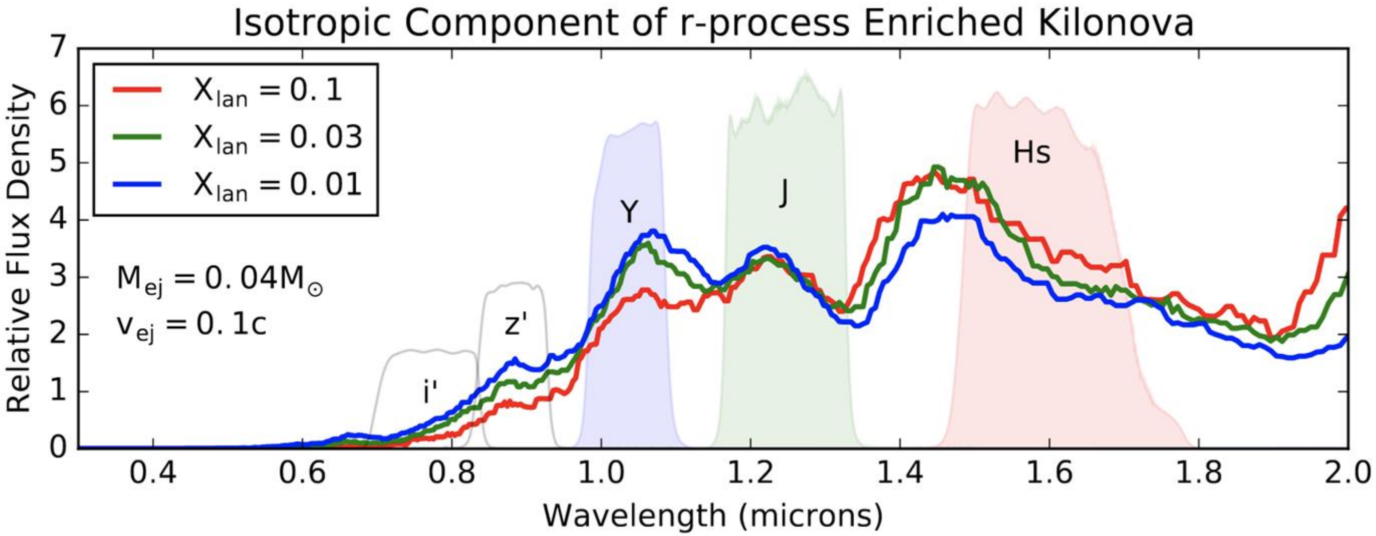




Designed for kilonova discovery



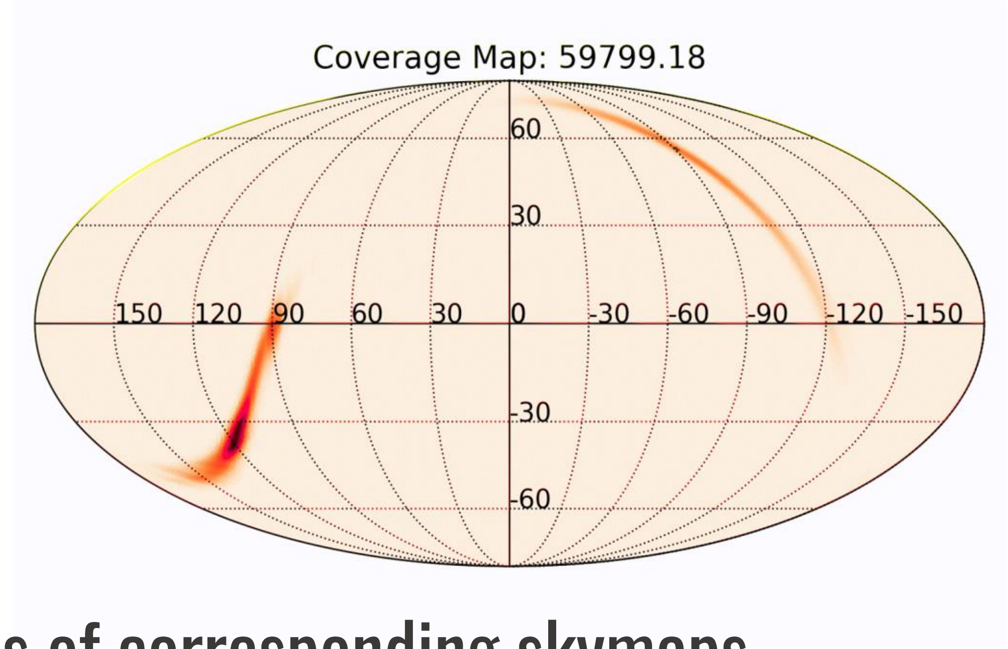
Kasen et al. 2017



Simcoe et al. 2019
with data from Kasen et al. 2017

- IR component should be longer lived (~2 weeks) and isotropic

Simulated search for kilonovae



- Simulated suite of kilonovae and 2 kinds of corresponding skymaps
- Realistic tiling with WINTER for a year of observing during O4

An Infrared Search for Kilonovae with the WINTER Telescope. I
Binary Neutron Star Mergers
Frostig et al. — ApJ 2022

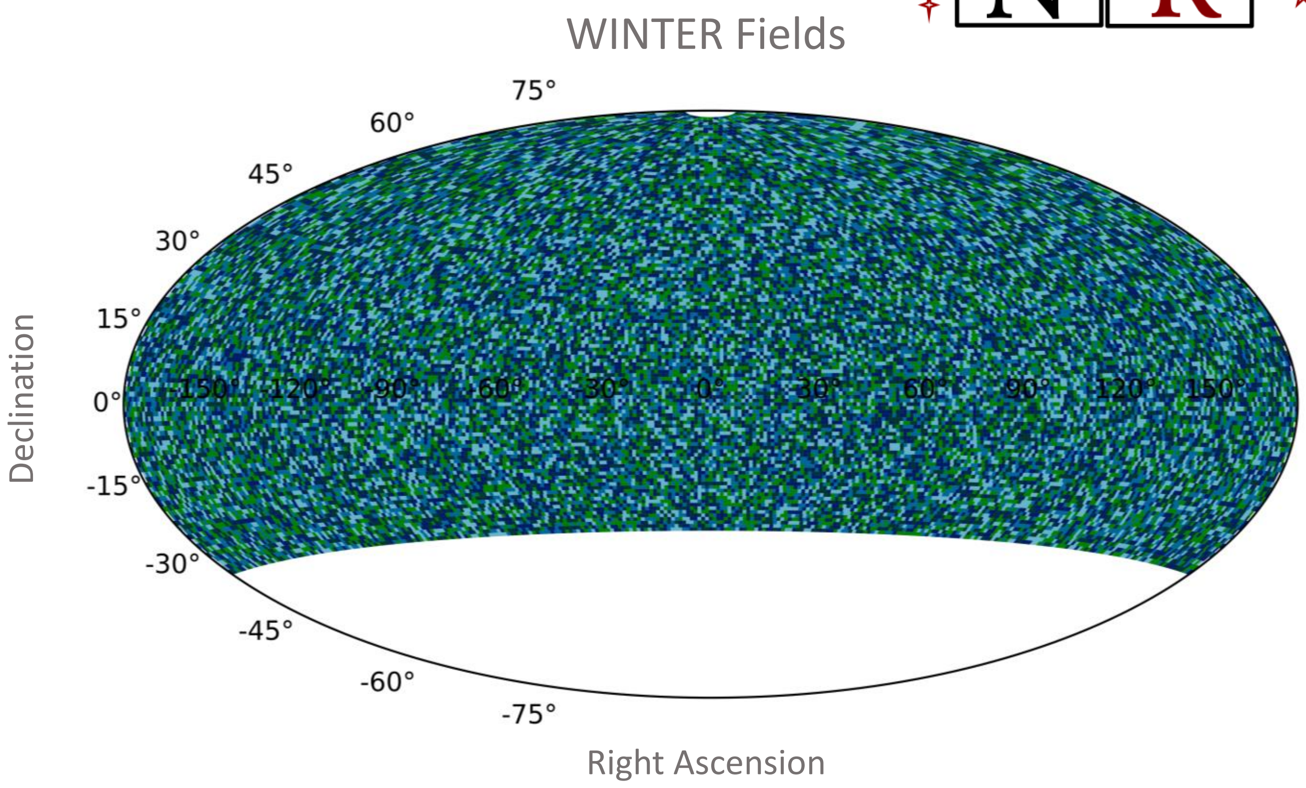
WINTER independently discovers up to 5 kilonovae in a “realistic” year

Rate	GW triggers	EM Accessible	Localized	Discovered			
				Bulla		Kasen	
	Events	Events	Events	Φ [°]	Events	X_{lan}	Events
Pessimistic	3^{+3}_{-2}	2^{+2}_{-2}	1^{+1}_{-1}	30	0^{+1}_{-0}	10^{-2}	0^{+2}_{-0}
				45	0^{+1}_{-0}	10^{-3}	0^{+2}_{-0}
				60	0^{+1}_{-0}	10^{-4}	0^{+1}_{-0}
						10^{-5}	0^{+0}_{-0}
Realistic	16^{+6}_{-5}	11^{+5}_{-5}	5^{+3}_{-3}	30	1^{+2}_{-1}	10^{-2}	2^{+3}_{-2}
				45	1^{+2}_{-1}	10^{-3}	3^{+2}_{-2}
				60	1^{+2}_{-1}	10^{-4}	1^{+2}_{-1}
						10^{-5}	0^{+1}_{-0}
Optimistic	33^{+7}_{-7}	23^{+5}_{-7}	10^{+4}_{-4}	30	3^{+1}_{-2}	10^{-2}	6^{+3}_{-4}
				45	3^{+2}_{-2}	10^{-3}	6^{+4}_{-3}
				60	3^{+2}_{-2}	10^{-4}	2^{+2}_{-2}
						10^{-5}	1^{+1}_{-1}

Frostig et al. 2022, ApJ

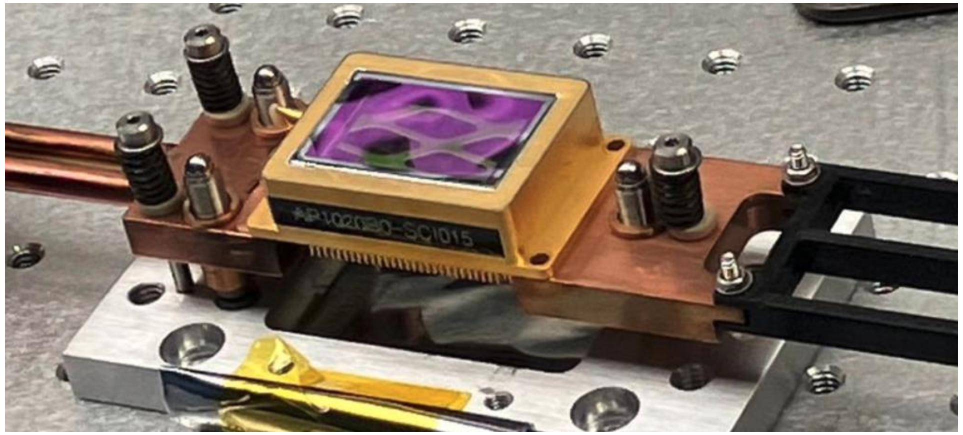
IR Targets that Aren't Kilonovae

- Can penetrate dusty environments
  - Supernovae and classical novae
  - Dust echoes of stars tidally disrupted around black holes
- Transits
  - Transiting planets around low-mass stars
- Static Sky Science:
  - High-redshift QSOs
  - Brown Dwarfs
  - Galactic Structure
- Seeing-limited, infrared time-domain survey
  - Compliment the Vera Rubin Observatory optical observations
  - Preparation for the Nancy Roman Telescope



InGaAs detectors

- Infrared detectors: ~0.9 to 1.7 μm
- Commonly used in defense applications
- Alternative to HgCdTe sensors like the H2RG (JWST, Gemini, Keck, etc.)
- InGaAs (compared to HgCdTe):
  - Cheaper (<½ the cost per pixel)
  - Higher operational temperatures (250 K vs 77 K)
  - Noisier
    - Higher read noise
    - Higher dark current
    - Lower dark current at a given temperature



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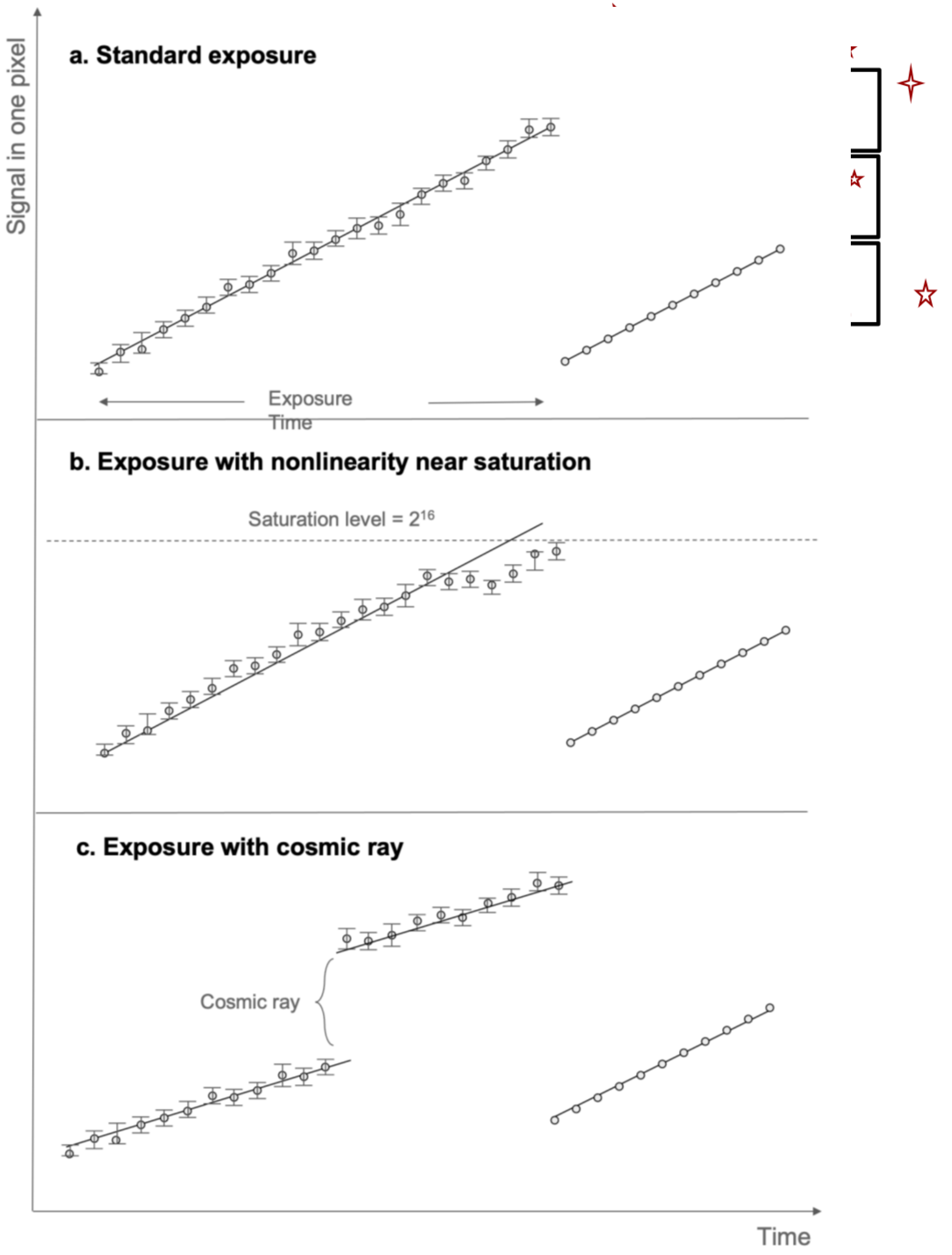
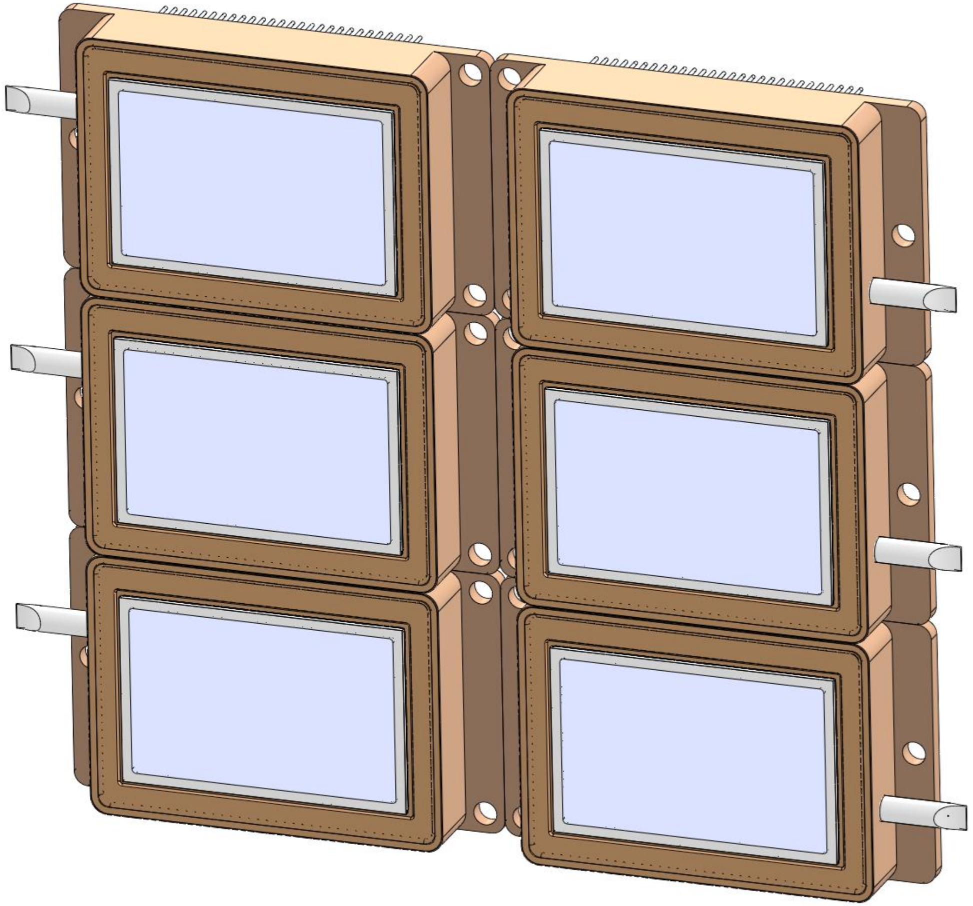


Fly's-eye optics to cover 1 square degree



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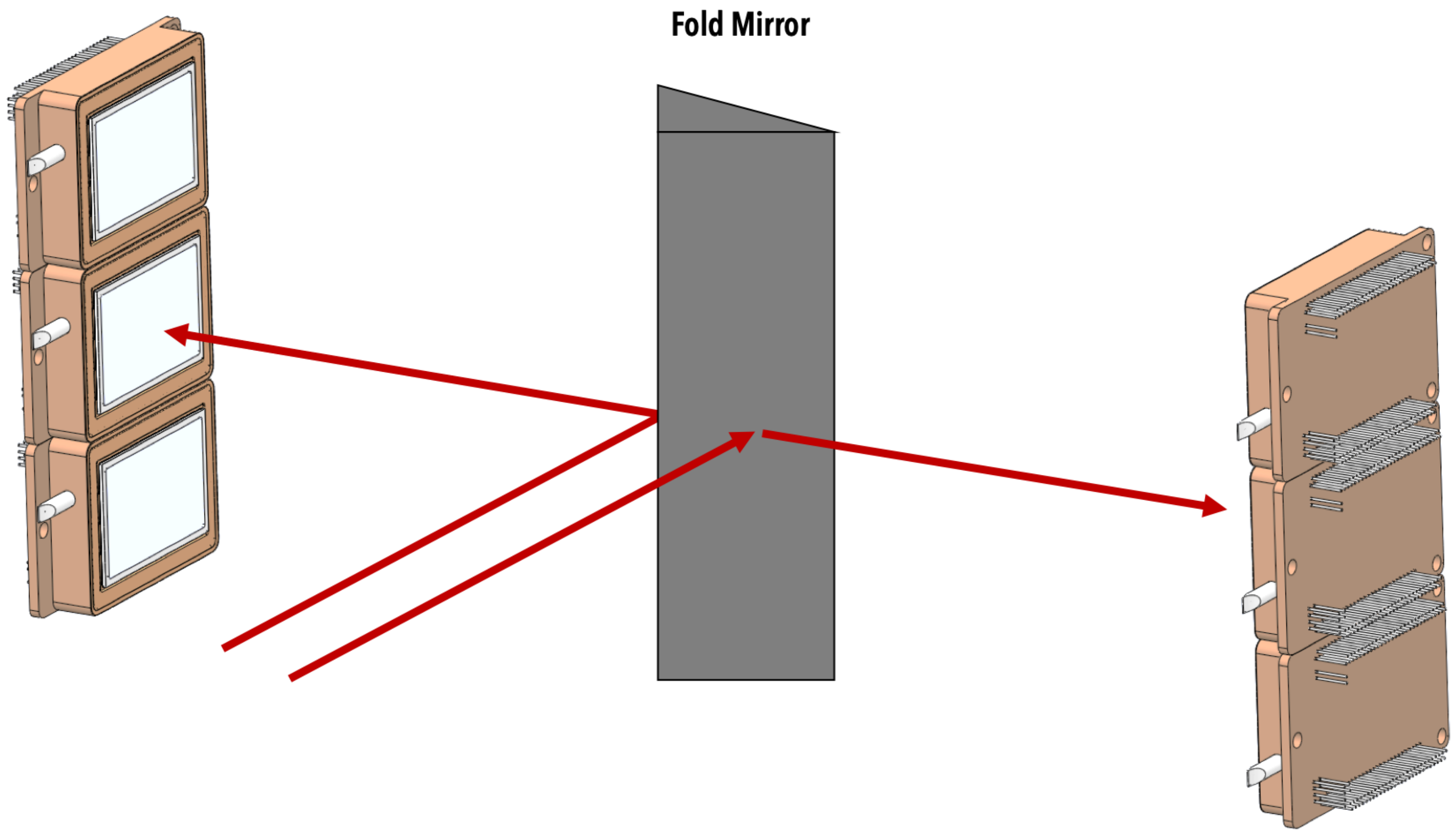

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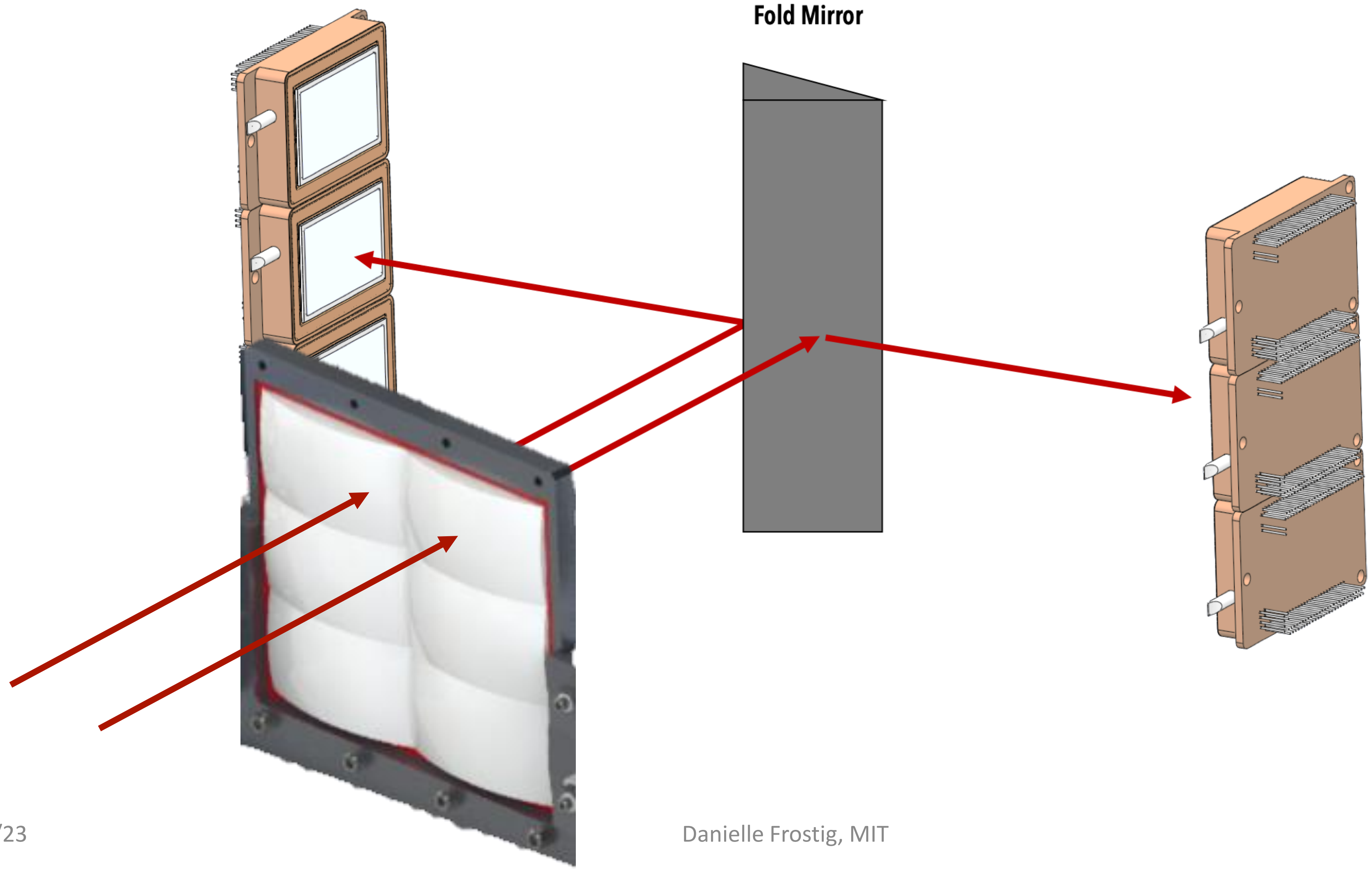

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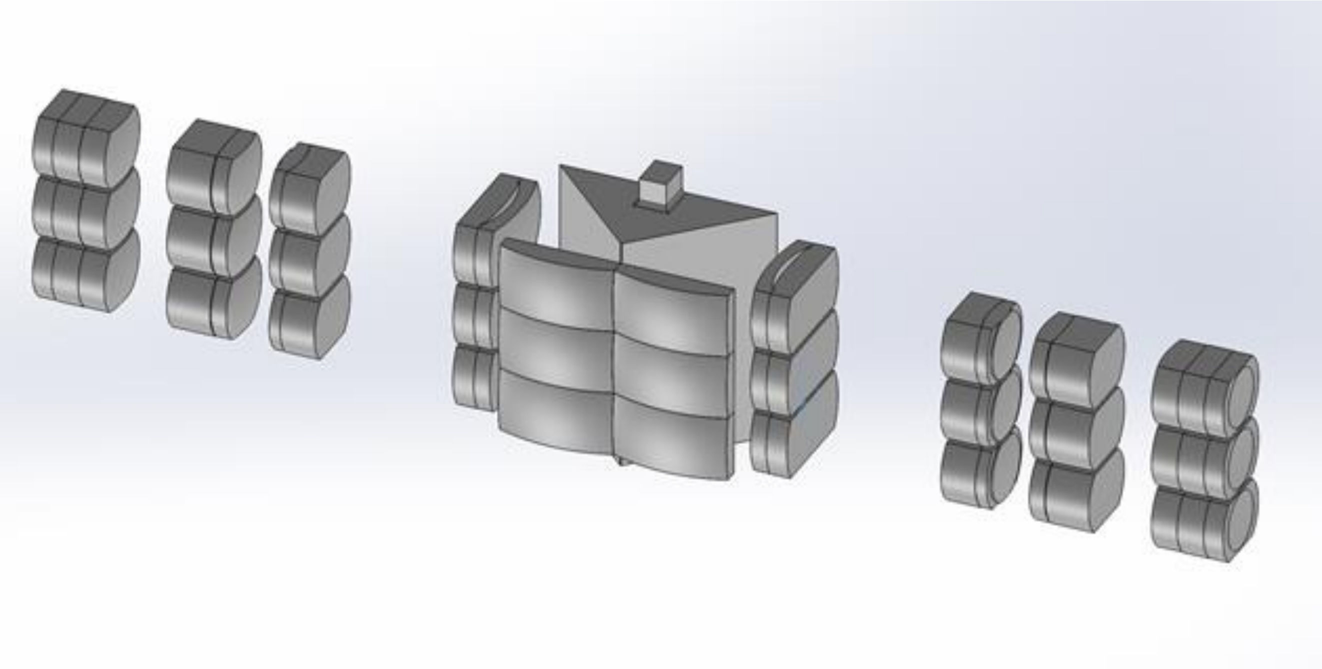
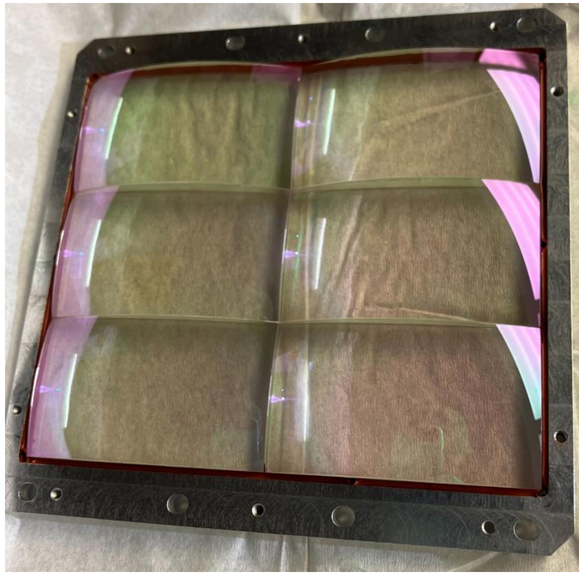
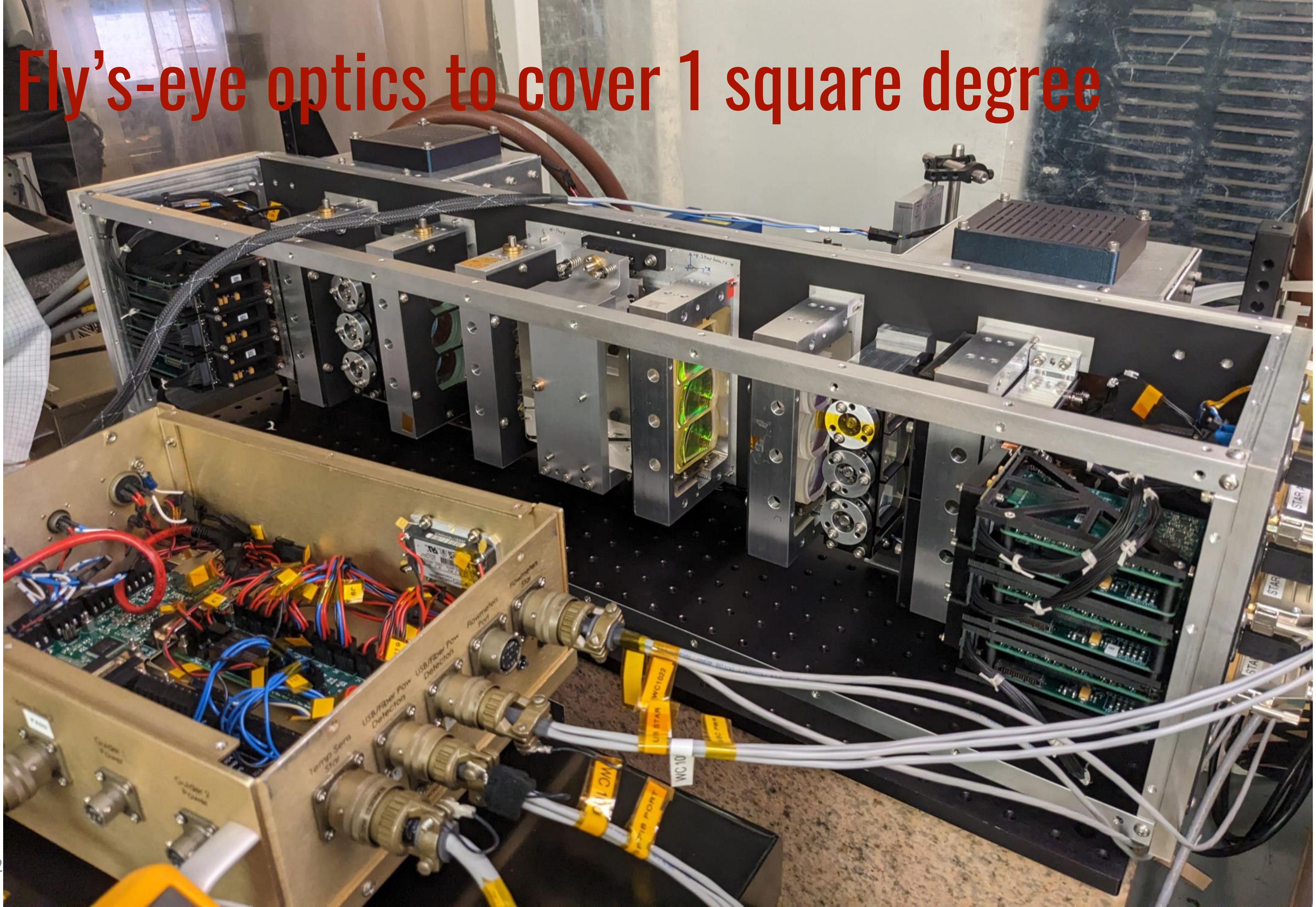


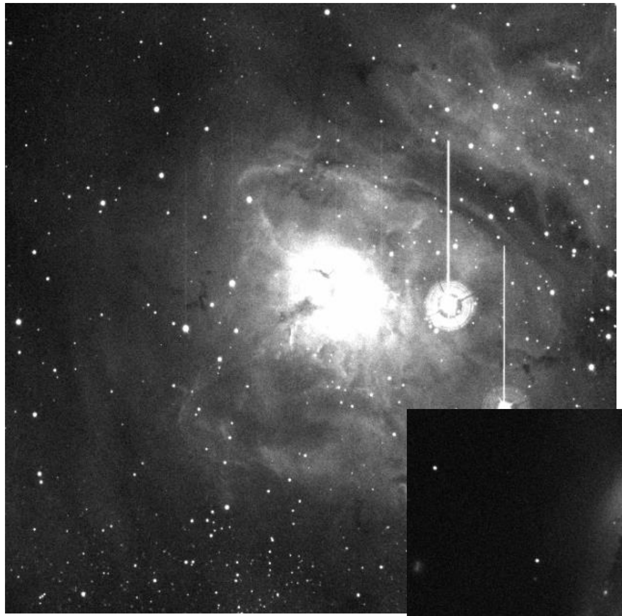


Lenses: collimate the telescope f/6 beam and demagnify 2x to get f/3

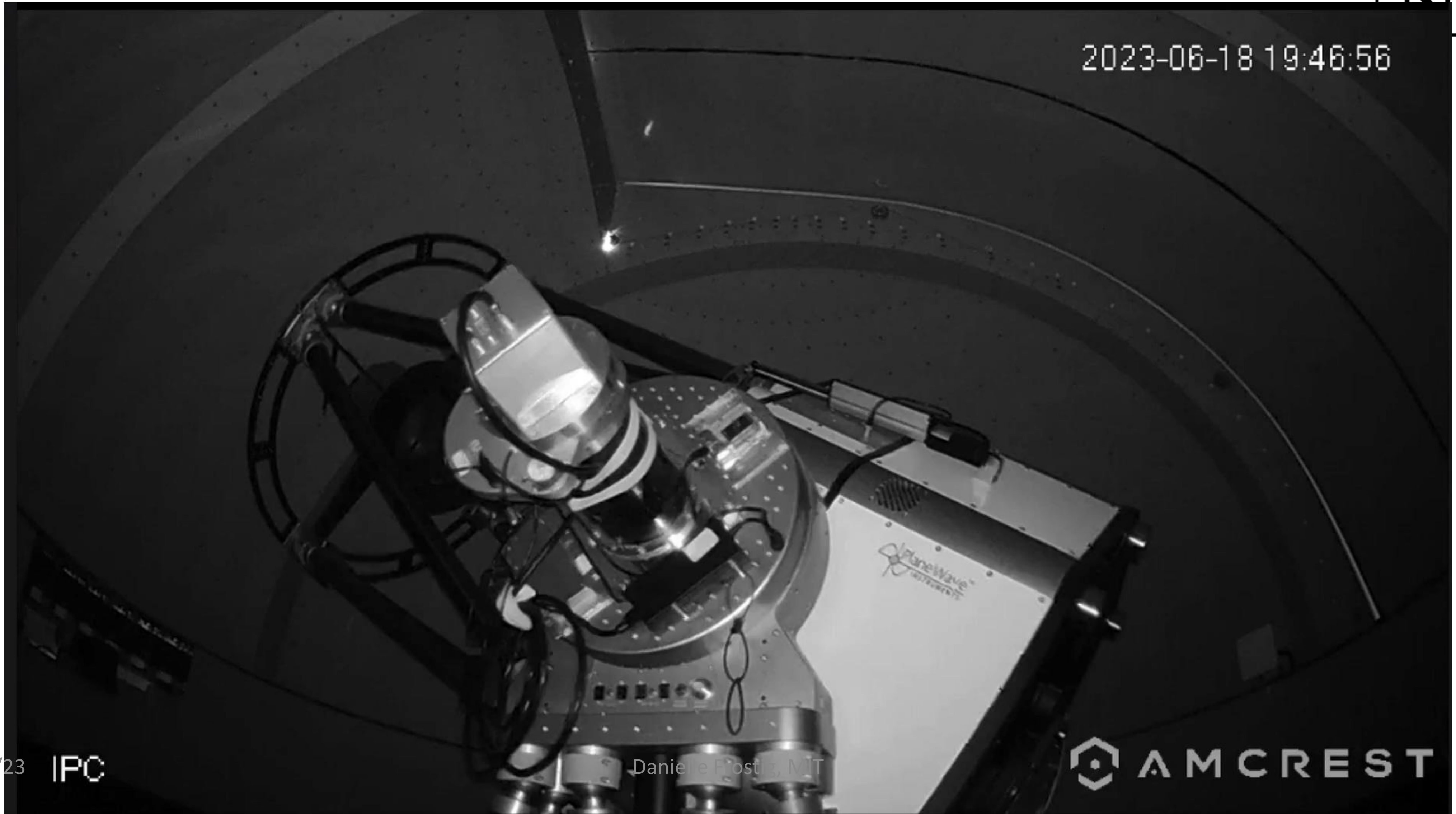
Fly's-eye optics to cover 1 square degree



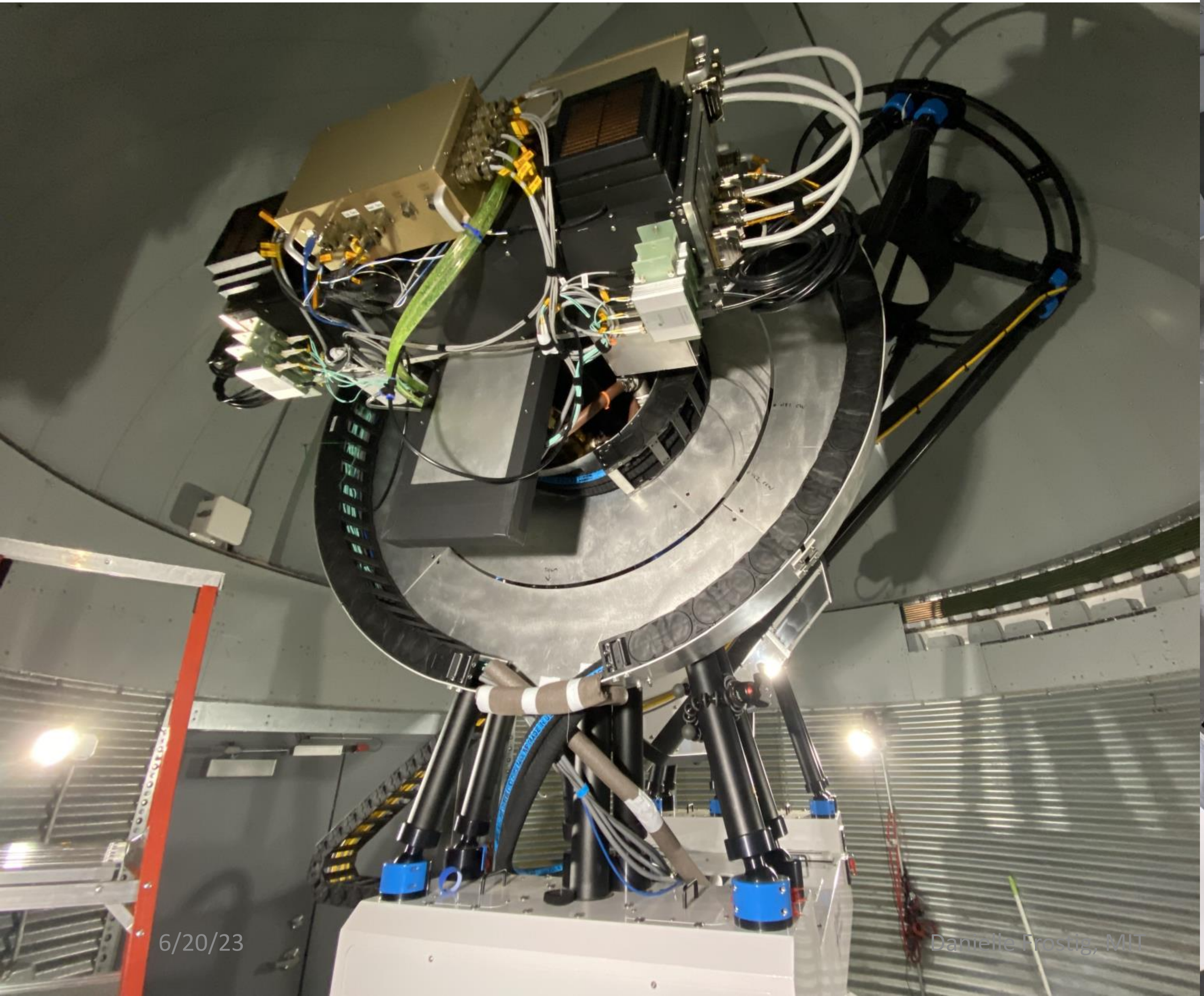
Robotic 1-meter telescope running for 2 years

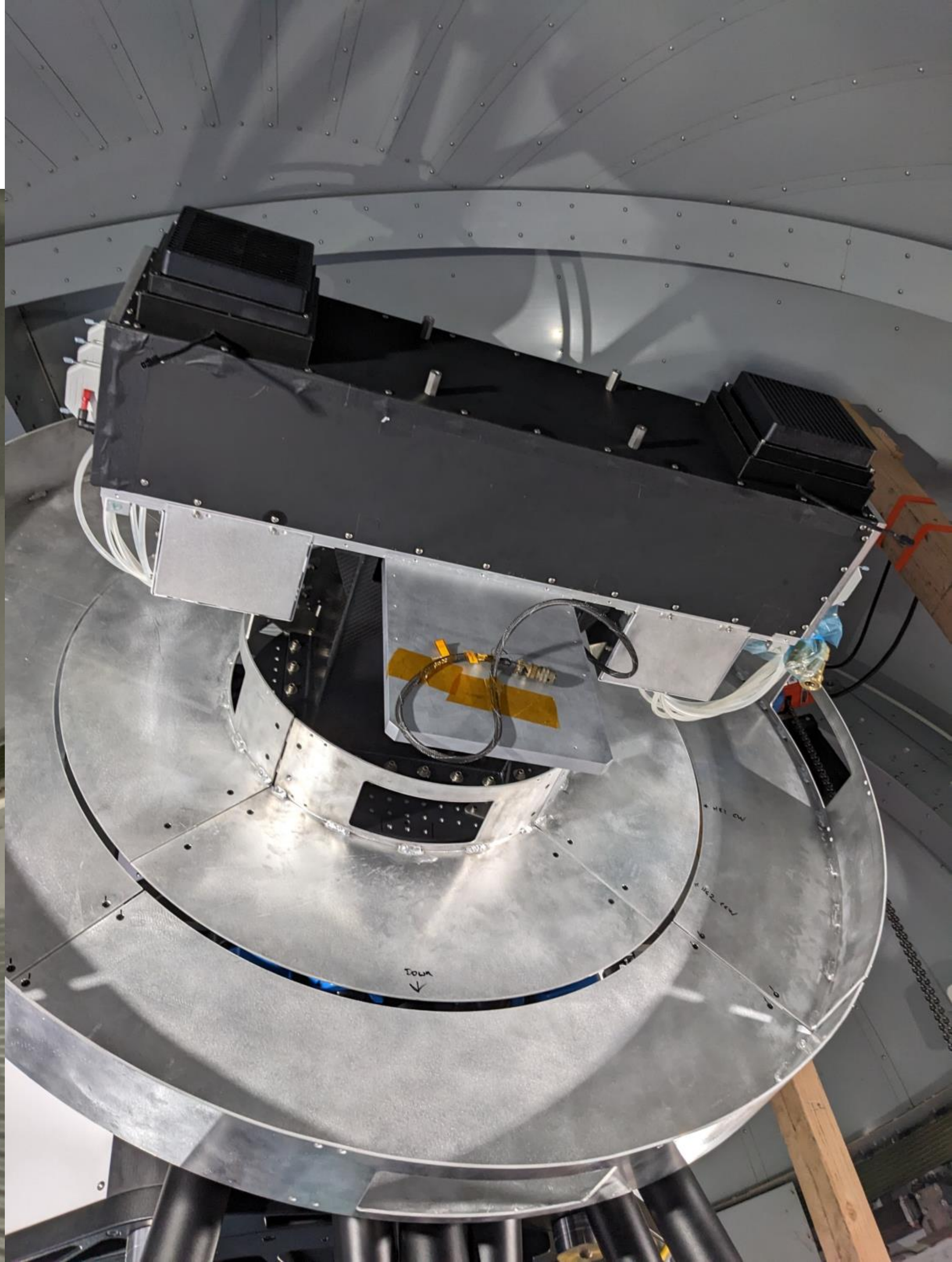


Robotic 1-meter telescope



Commissioning





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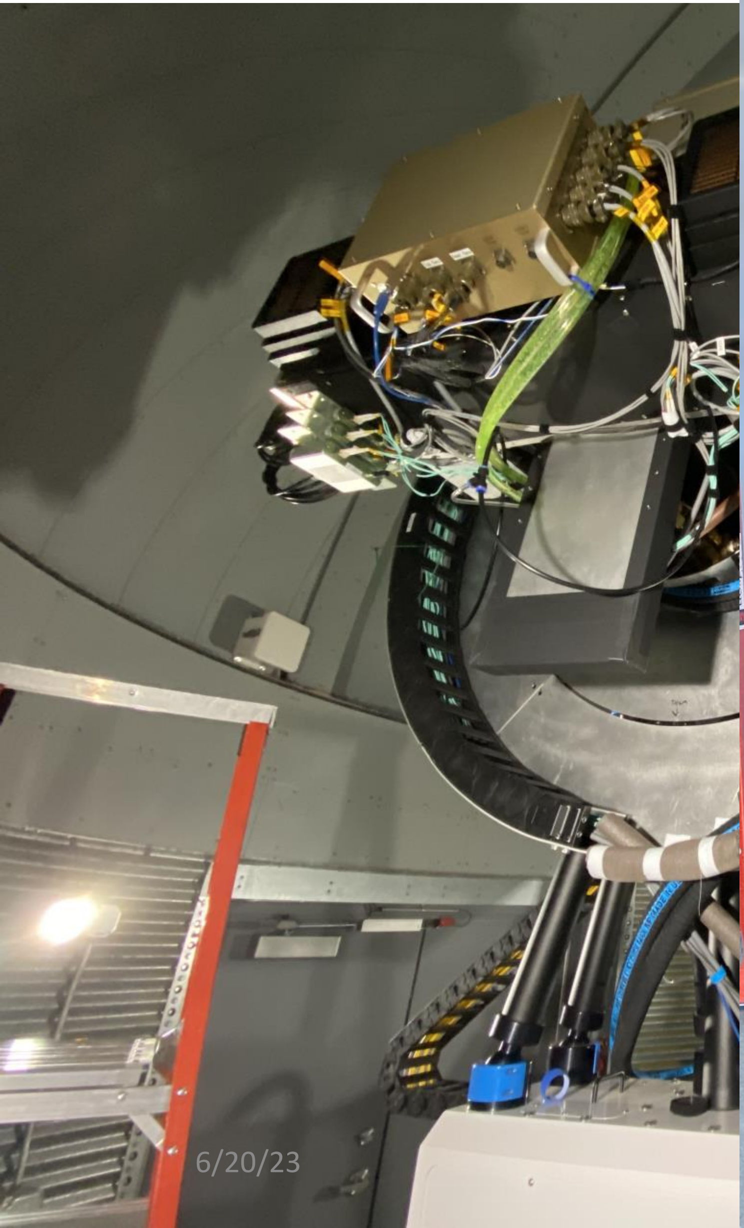
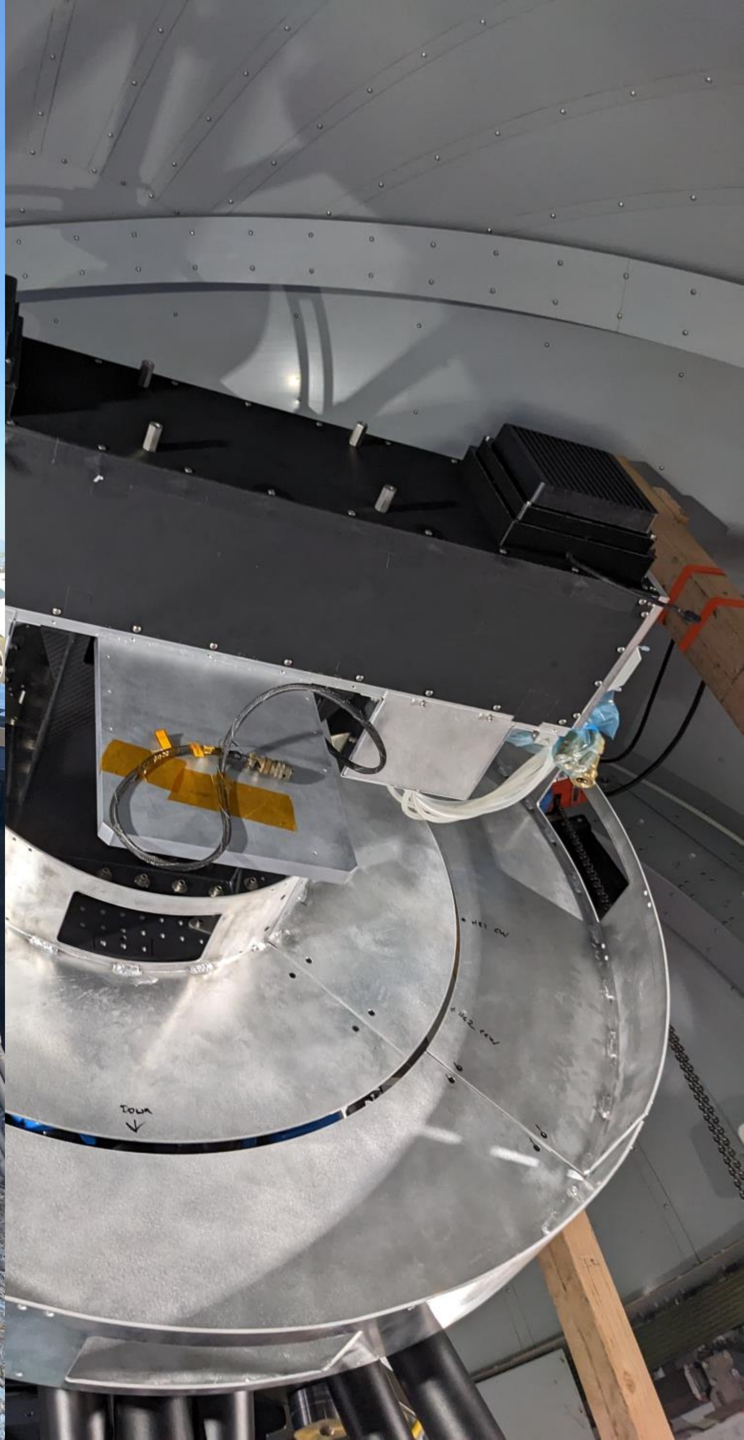




Comm

Next steps: data reduction pipeline

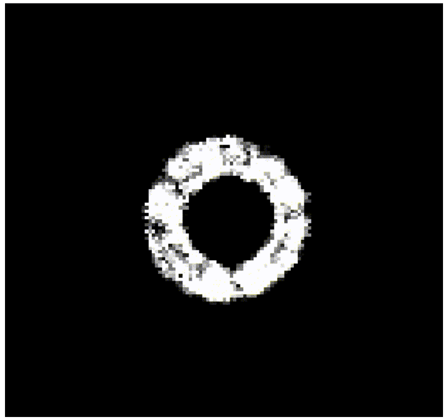
- Open-source, modular, python 3.11-based pipeline
- Process both SUMMER and WINTER images, with calibration, image subtraction, etc.
- Generation of a kafka alert stream of detected transients with low-latency (minutes)

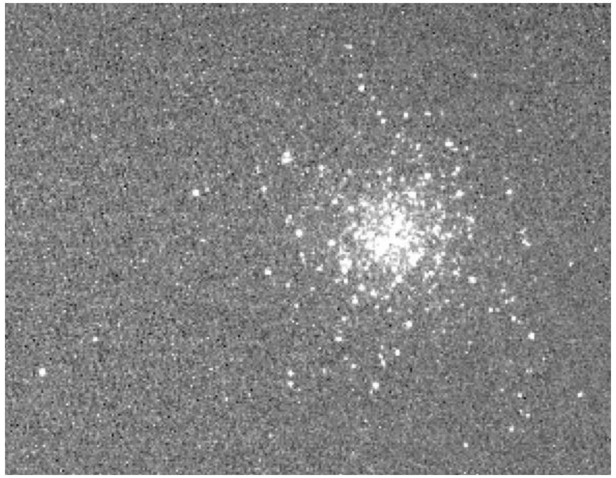
Viraj Karambelkar, Caltech

Robert Stein, Caltech

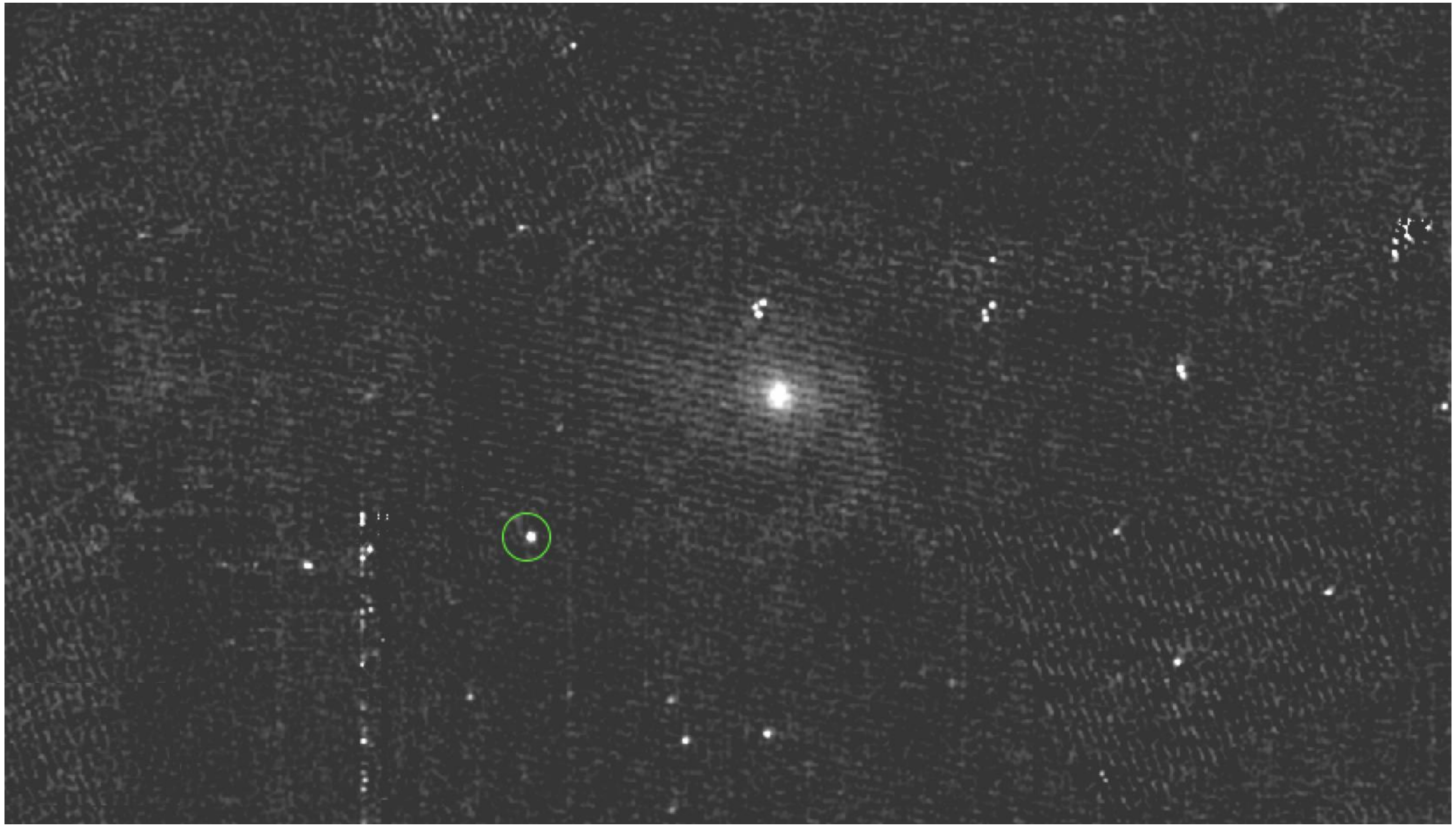
https://github.com/winter-telescope/mirar

Next steps: data reduction pipeline

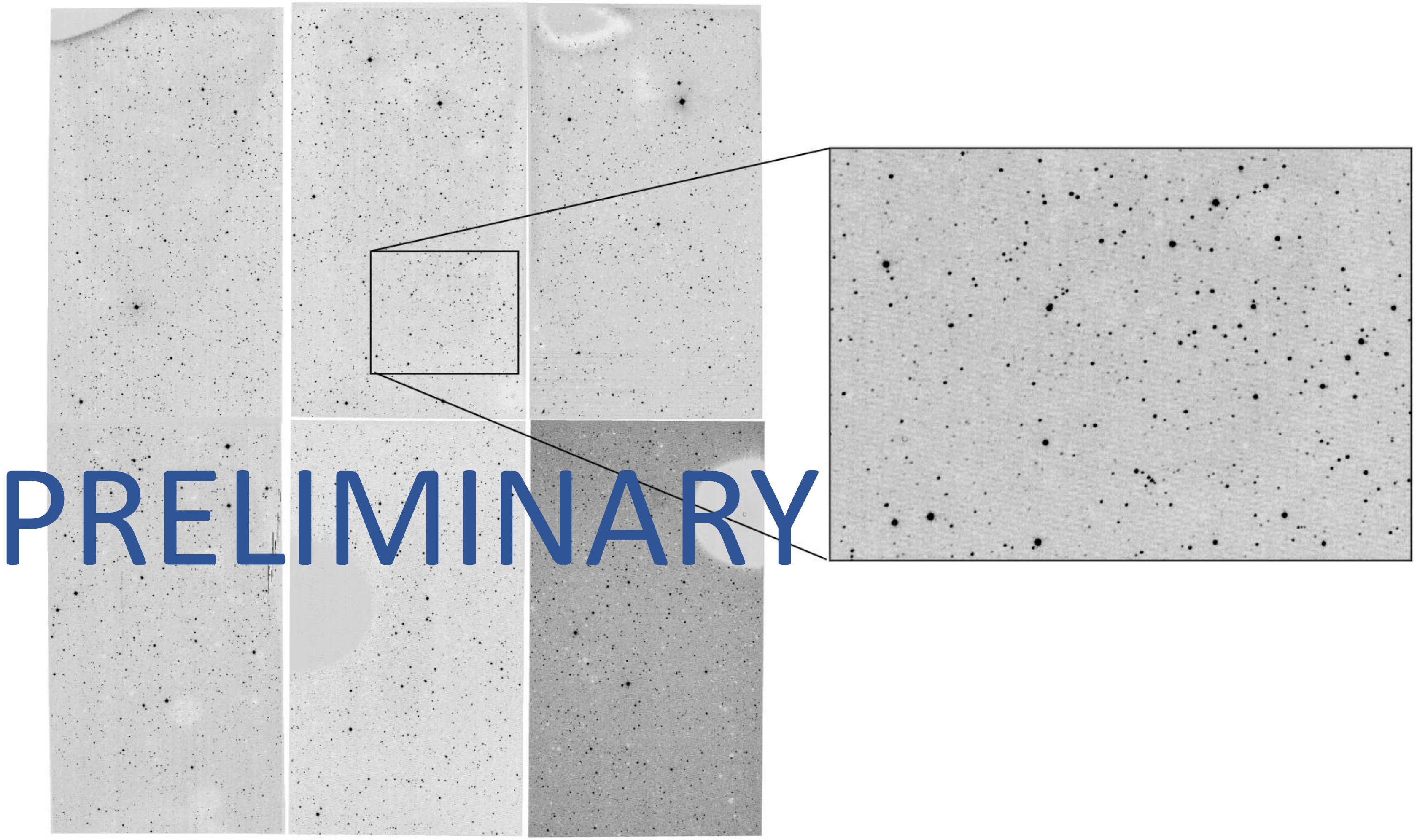




M13



M101


PRELIMINARY

Summary

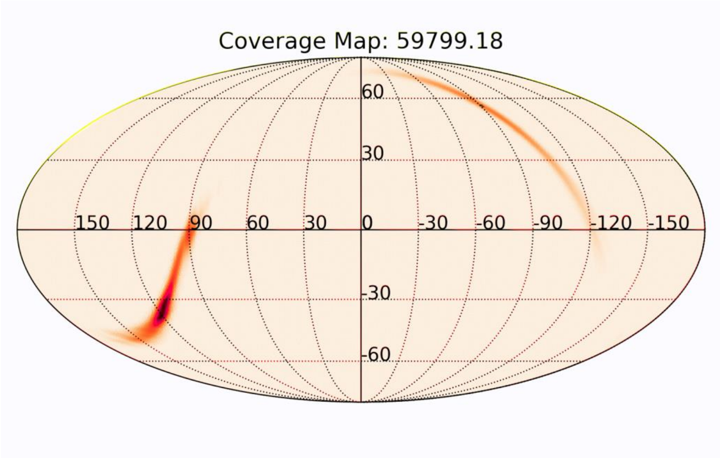
- WINTER is a new near-infrared survey telescope
- Covers > 1 deg^2 in Y, J, and Hs bands (0.9-1.7 microns)
- Fly's-eye optics tile 6 new-to-astronomy InGaAs detectors
- Near-infrared observations offer advantages over optical surveys
  - Kilonova are longer lived in near-IR
  - Probes of dusty environments and different physics
- On-sky!
  - Stay tuned for WINTER alerts.

Thanks!

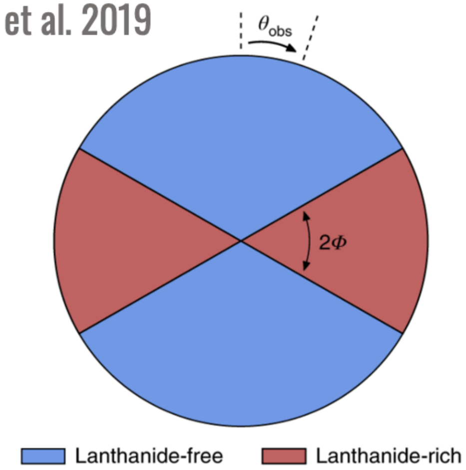
- WINTER @ MIT
  - Rob Simcoe (Co-I)
  - Gabor Furesz (Principal Research Scientist)
  - Nate Lourie (Project Scientist)
  - Erik Hinrichsen (Mechanical Engineer)
  - Drew Malonis (Electrical Engineer)
  - Kishalay De (Postdoc)
  - Kevin Burdge (Postdoc)
  - Danielle Frostig (PhD Student)
- WINTER @ Caltech
  - Mansi Kasliwal (Co-I)
  - Robert Stein (Postdoc)
  - Viraj Karambelkar (PhD Student)
  - Nicolae Ganciu (Observatory Staff)
  - John W. Baker (Observatory Staff)
  - Rick Burruss (Observatory Staff)
  - Jeffry Zolkower (Observatory Staff)

Extra slides

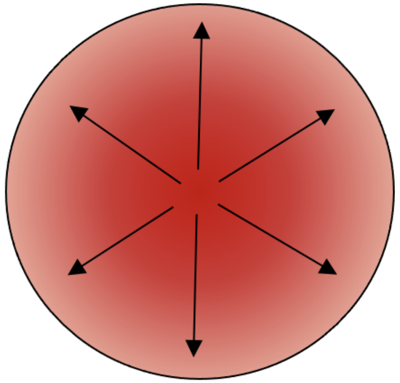
Simulated search for kilonovae

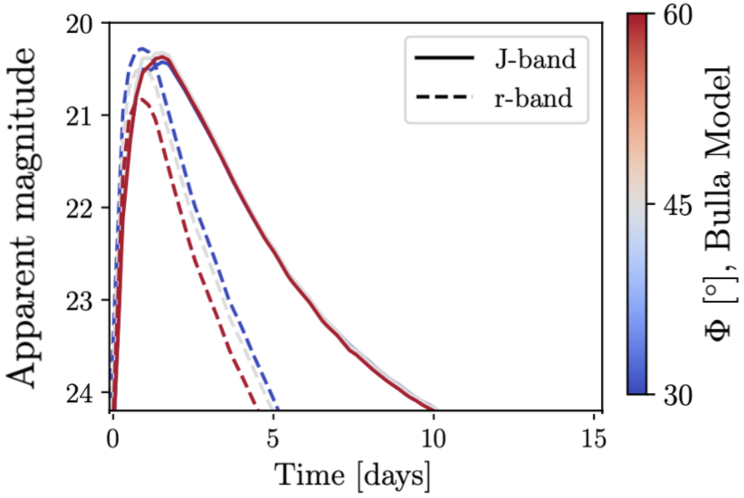


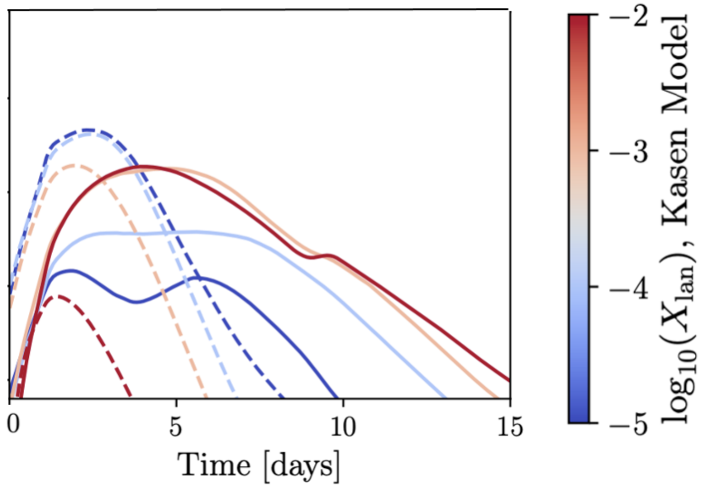
Bulla et al. 2019



Kasen et al. 2017







Frostig et al. 2022, ApJ

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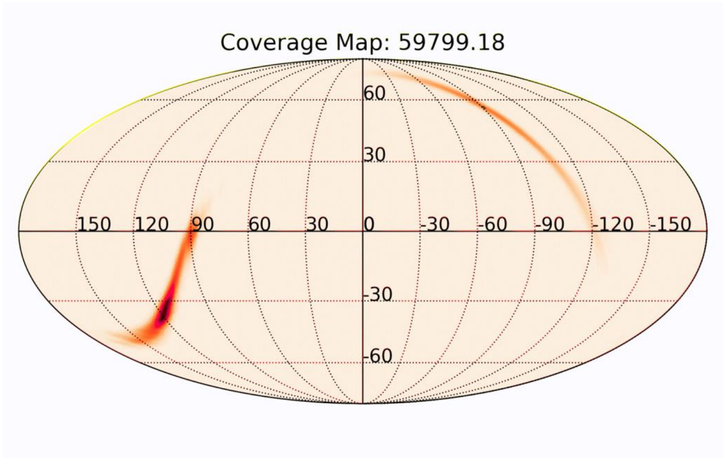

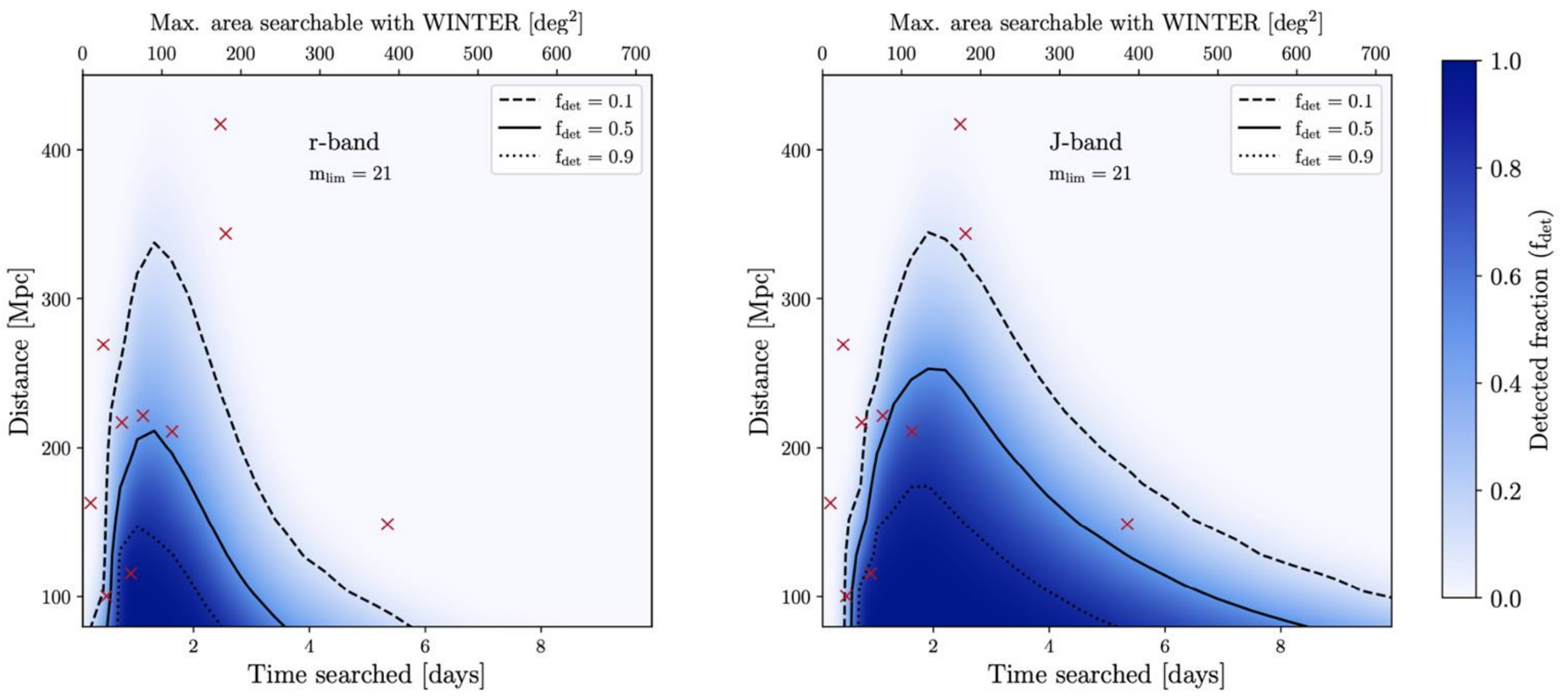

Frostig et al. 2022, ApJ


Starrett