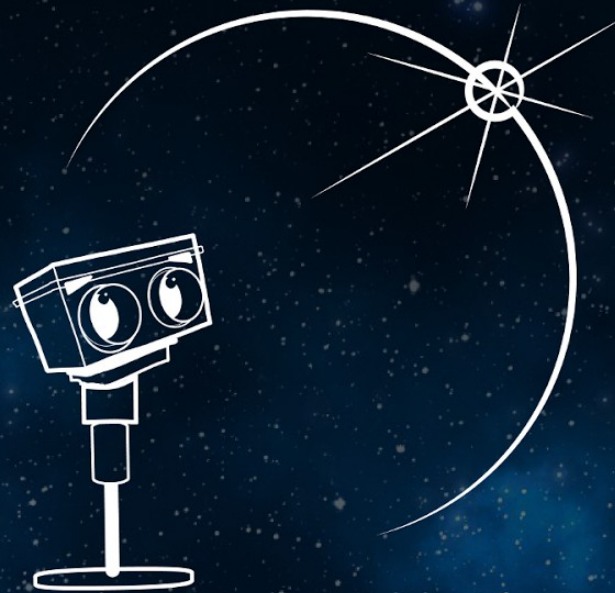


Panoptic Astronomical Networked Observatories for a Public Transiting Exoplanets Survey

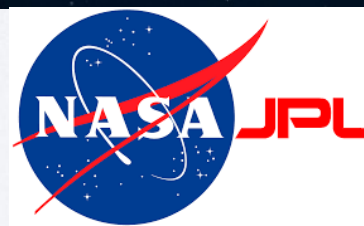


PROJECT PANOPTES
DISCOVER NEW WORLDS

MacArthur
Foundation



MACQUARIE
University
SYDNEY • AUSTRALIA



Google Cloud Platform

PANOPTES

- PANOPTES is a low cost robotic observatory which uses commercial off the shelf (COTS) technology.
- Anyone can build a PANOPTES unit. You (Students!) can discover exoplanets!



PANOPTES GOALS

- Blend of research and outreach/citizen science.
- Research: Establish a world wide network of automated cameras to monitor a large fraction of the sky to **detect exoplanet transits**.
- Outreach: Enable citizen scientists and schools to **participate in all aspects of the science**, from data collection to data analysis.
- PANOPTES can potentially support other science (variable stars, supernovae, asteroids, etc.). **We want users to come up with new projects.**



LOW-COST HARDWARE

DSLR cameras

Canon Rebel DSLR (\$400-500)
has 18 MP



Rokinon 85mm f/1.4 is ~\$300



ETENDUE COMPARISON

Etendue = (N units) x (collecting area) x (FOV)

	Aperture Diameter	Area	Field of View	Approximate Cost	Etendue	Etendue per \$
	(m)	(m ²)	(deg ²)	(\$)	(m ² deg ²)	(m ² deg ² / M\$)
LSST	8.4	45.8	9.6	120,000,000	440.6	3.7
Pan-STARRS (PS2)	1.8	1.91	7.1	8,000,000	13.5	1.7
0.6 meter CDK	0.60	0.23	0.28	130,000	0.07	0.5
Celestron C14	0.35	0.09	0.13	40,000	0.01	0.3

ETENDUE COMPARISON

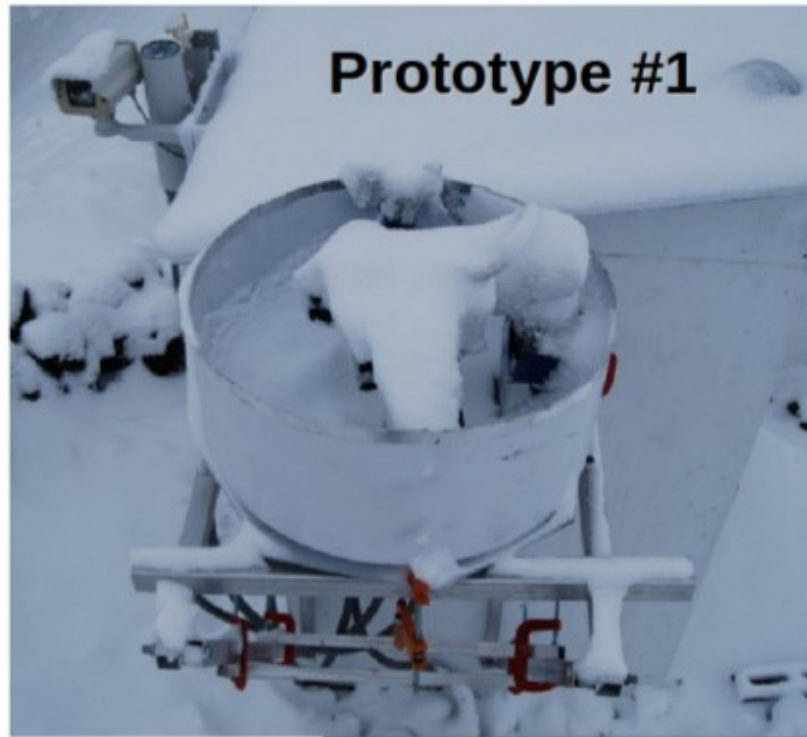
Etendue = (N units) x (collecting area) x (FOV)

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Celestron C14	0.35	0.09	0.13	40,000	0.01	0.3
Panoptes (1 camera)	0.061	0.0029	150.0	5,000	0.43	86.9
Panoptes (2 cameras)	0.061	0.0029	150.0	5,800	0.87	149.7
Panoptes (4 cameras)	0.061	0.0029	150.0	7,200	1.74	241.3

- Does not account for pixel count / resolution.

PANOPTES HISTORY

Needed to demonstrate: Low Cost & reliability, high precision photometry



PANOPTES HISTORY

- Project Started in late 2010
- First prototype on Mauna Loa.
 - Canon DSLR with 85mm lens, amateur telescope mount



PANOPTES HISTORY

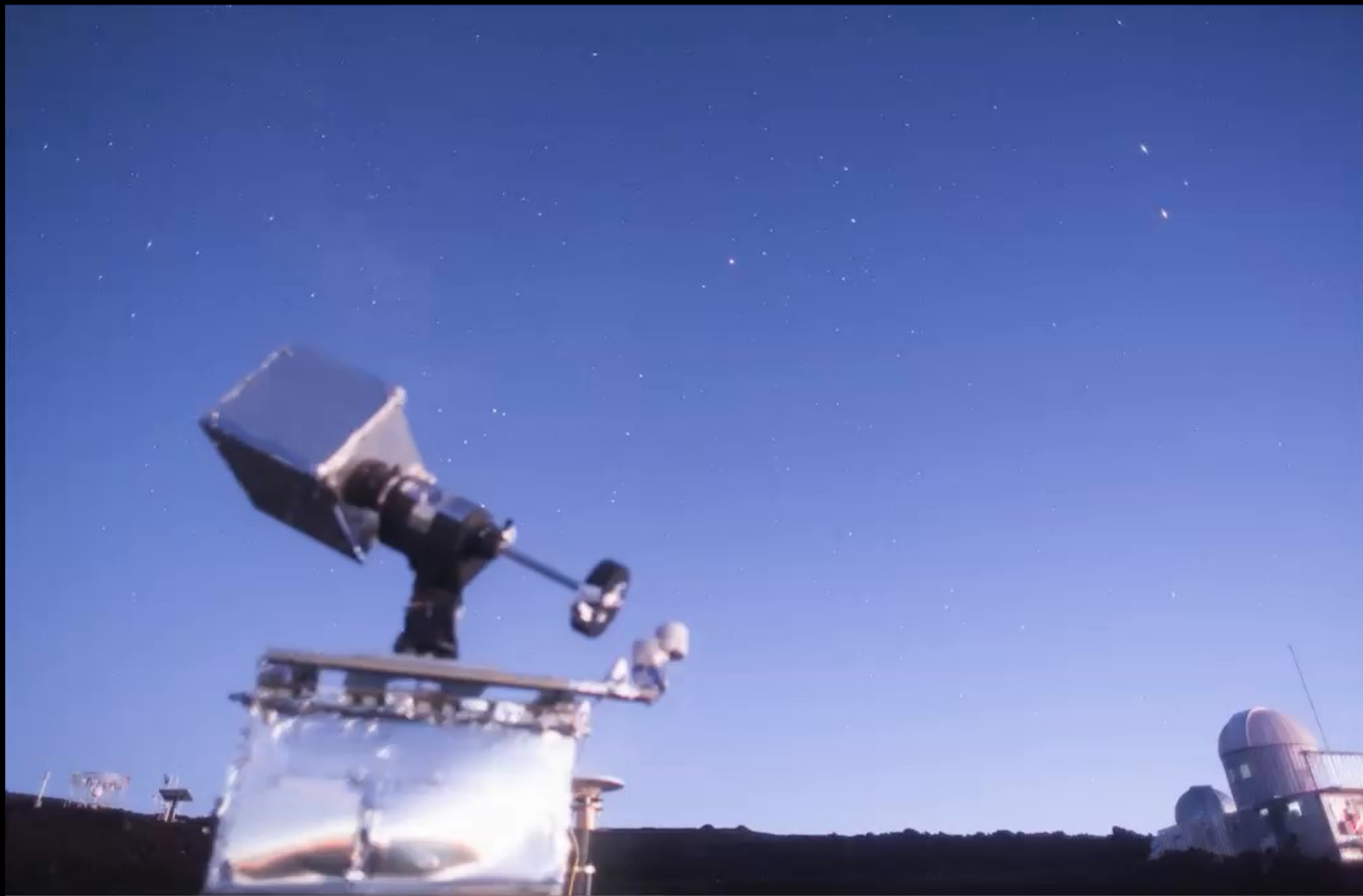
Cost is kept down by not using a dome



PANOPTES HISTORY

- Prototype #3
 - Four cameras co-mounted.





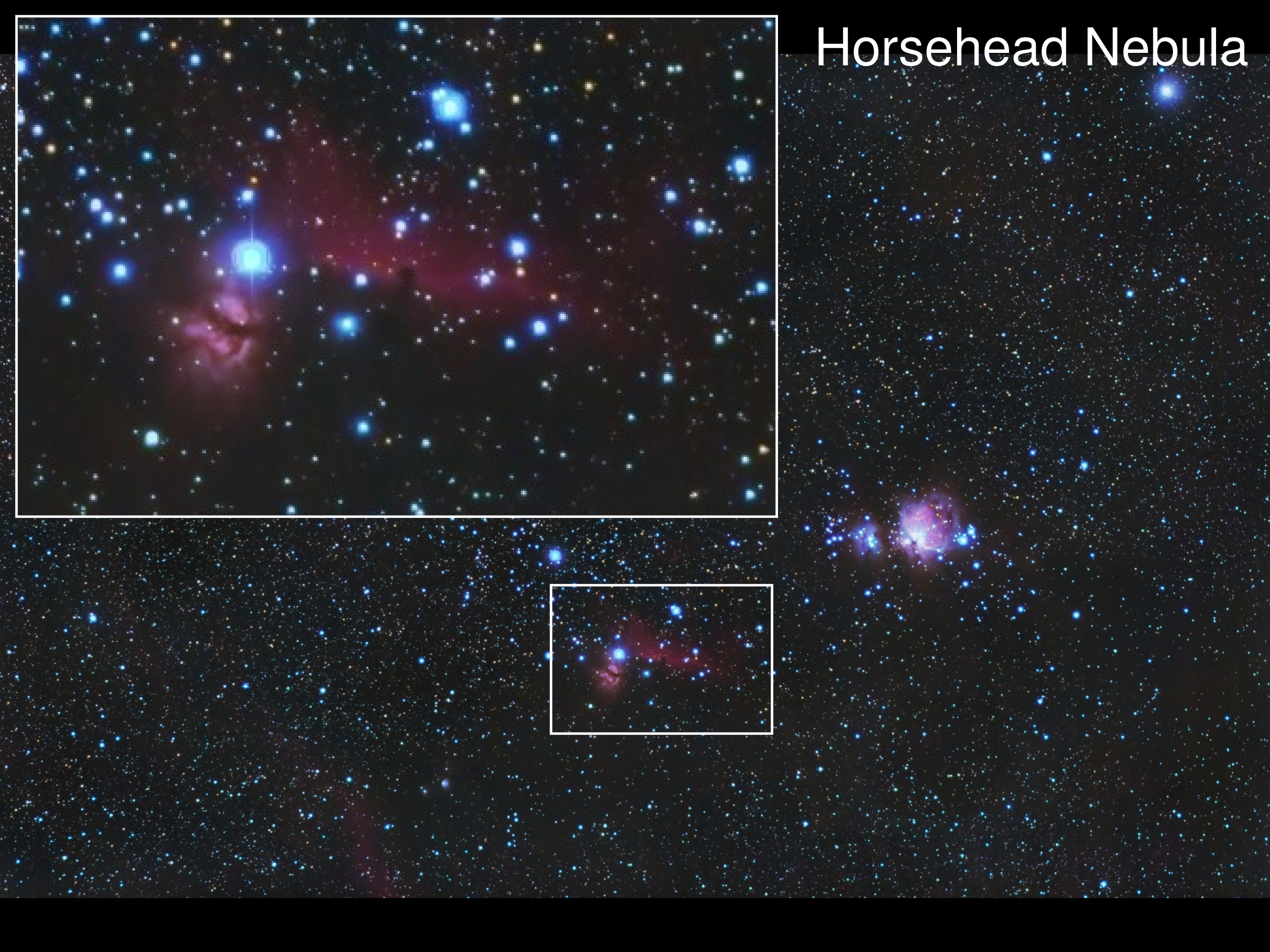


Comet Lovejoy and Geminid meteor - single 10 minute exposure

Orion's Belt



Horsehead Nebula



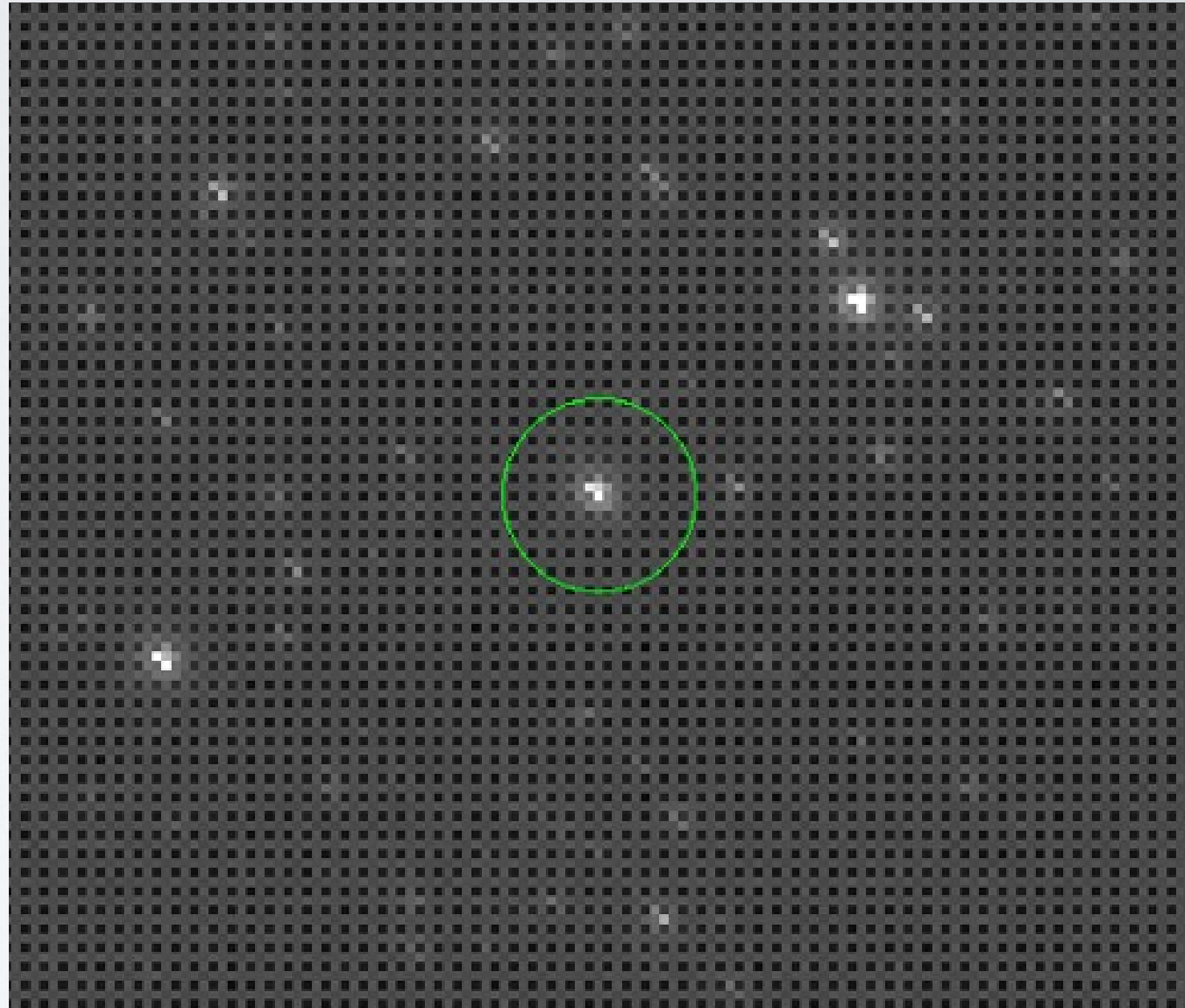
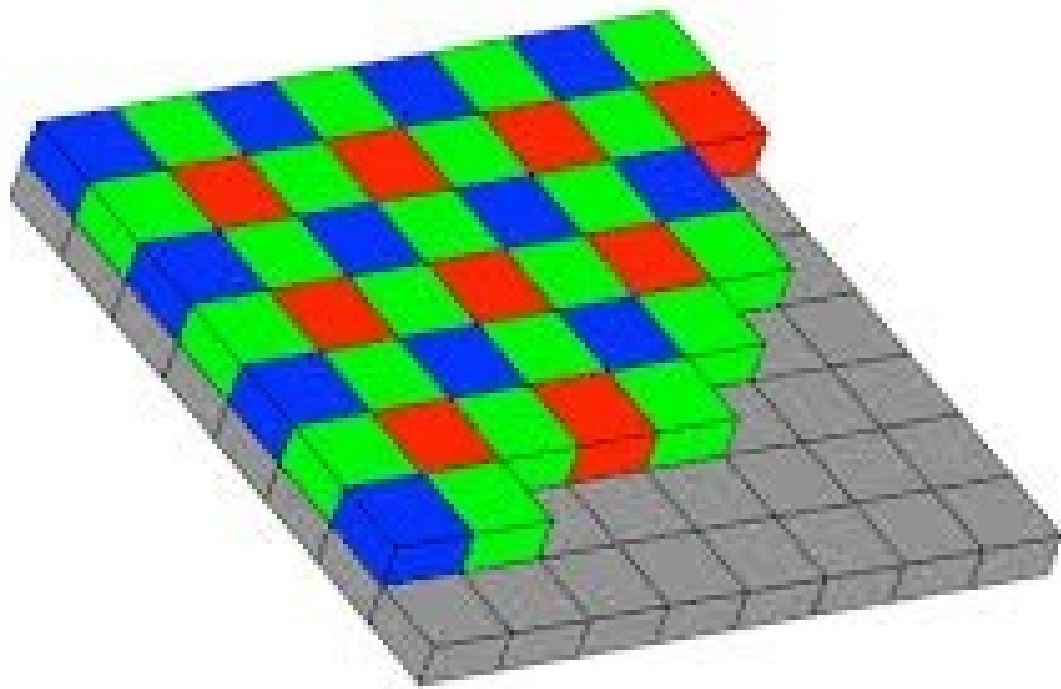
Orion Nebula



The Virgo Cluster of Galaxies



DSLR PHOTOMETRY



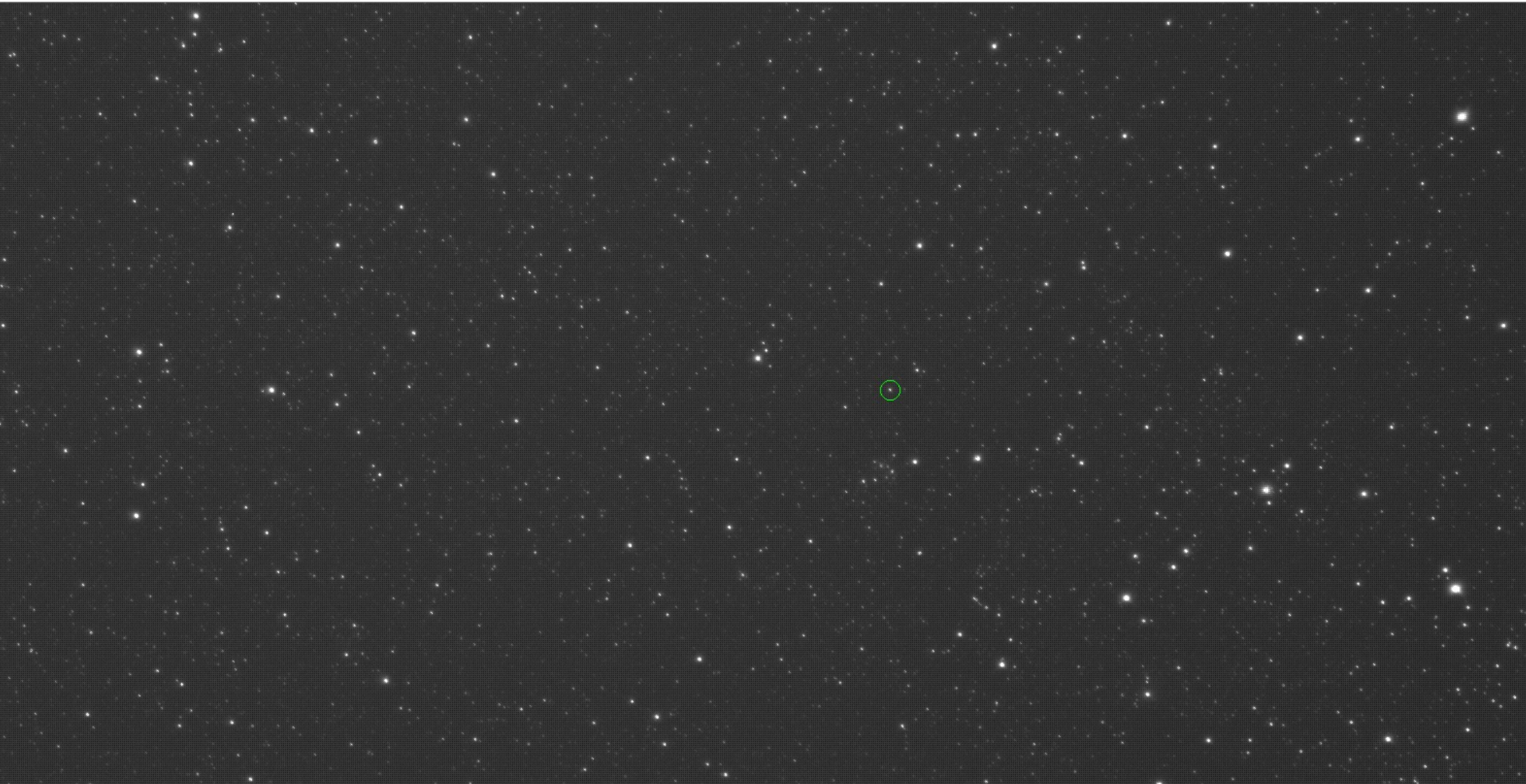
Test on HD54743 (V=9.35)

1 min cadence



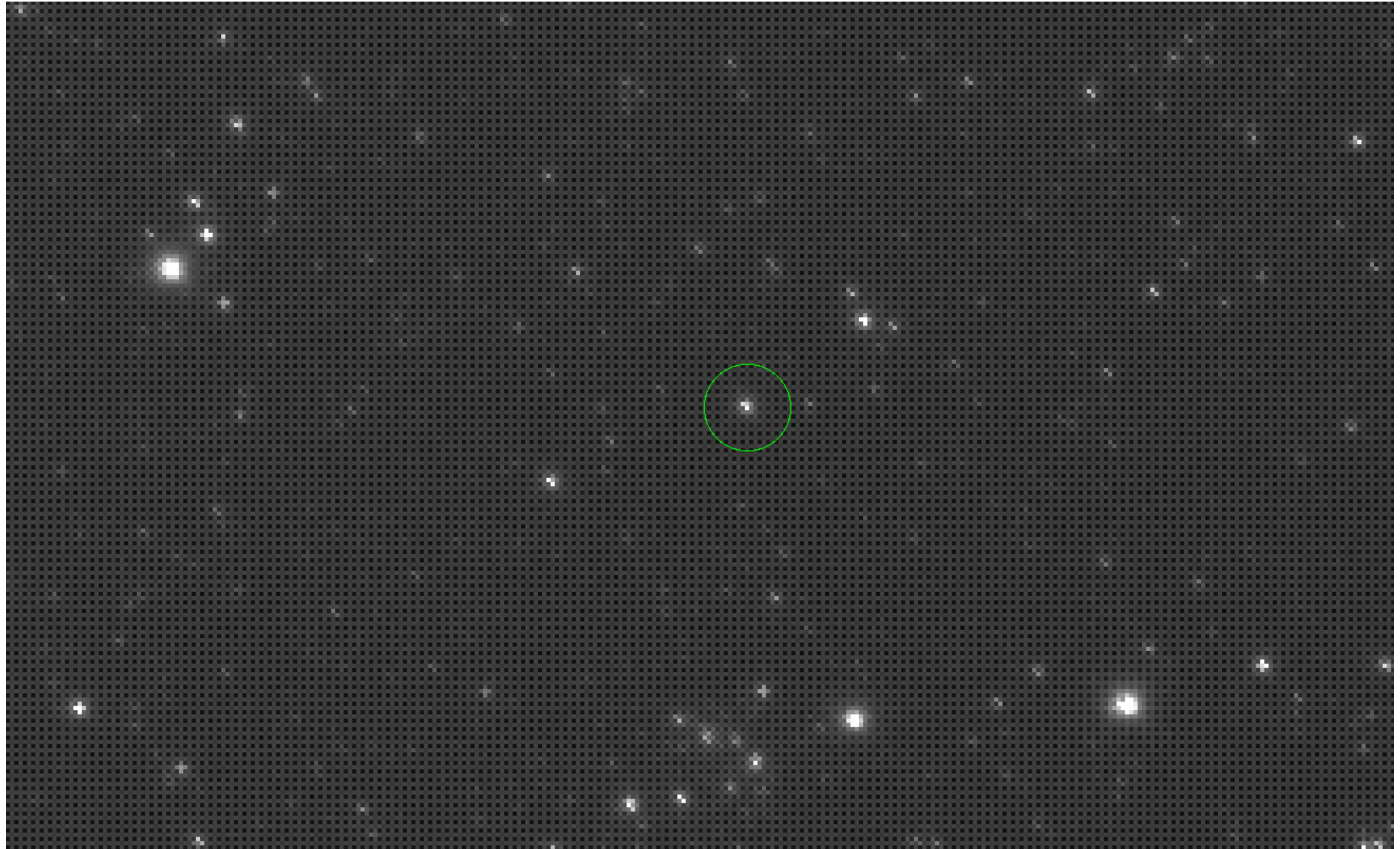
Test on HD54743 (V=9.35)

1 min cadence



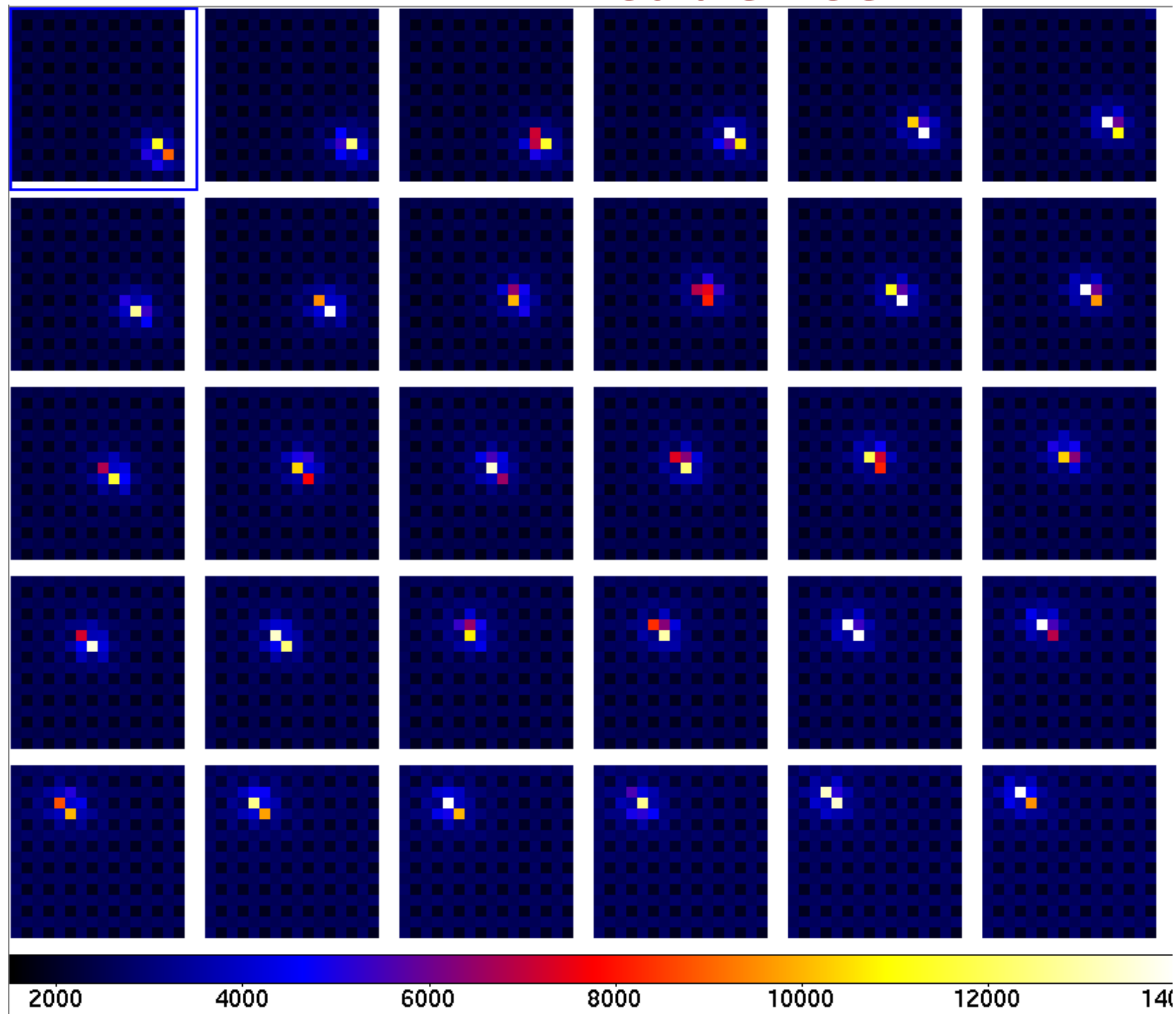
Test on HD54743 (V=9.35)

1 min cadence



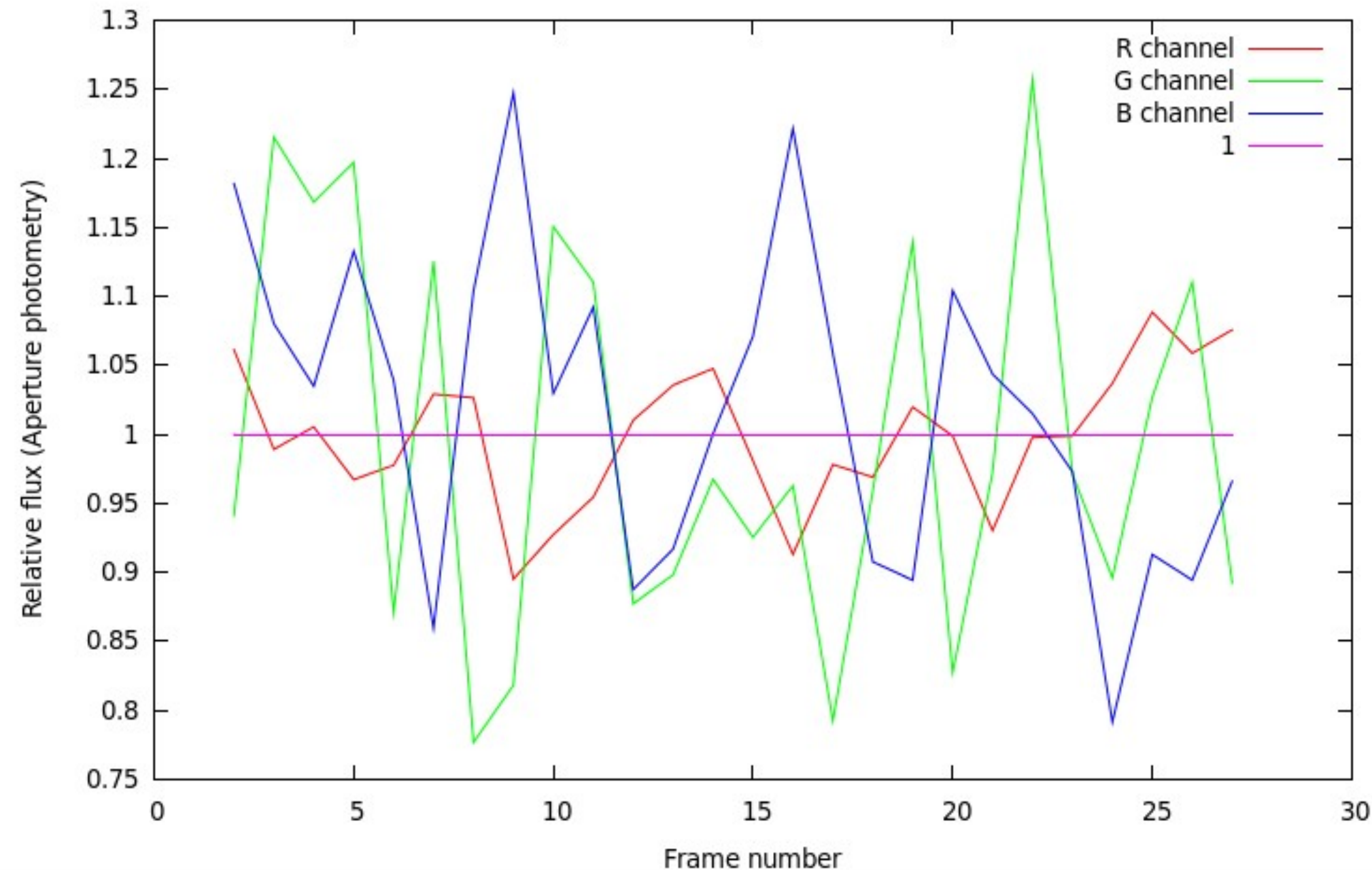
Test on HD54743 (V=9.35)

1 min cadence



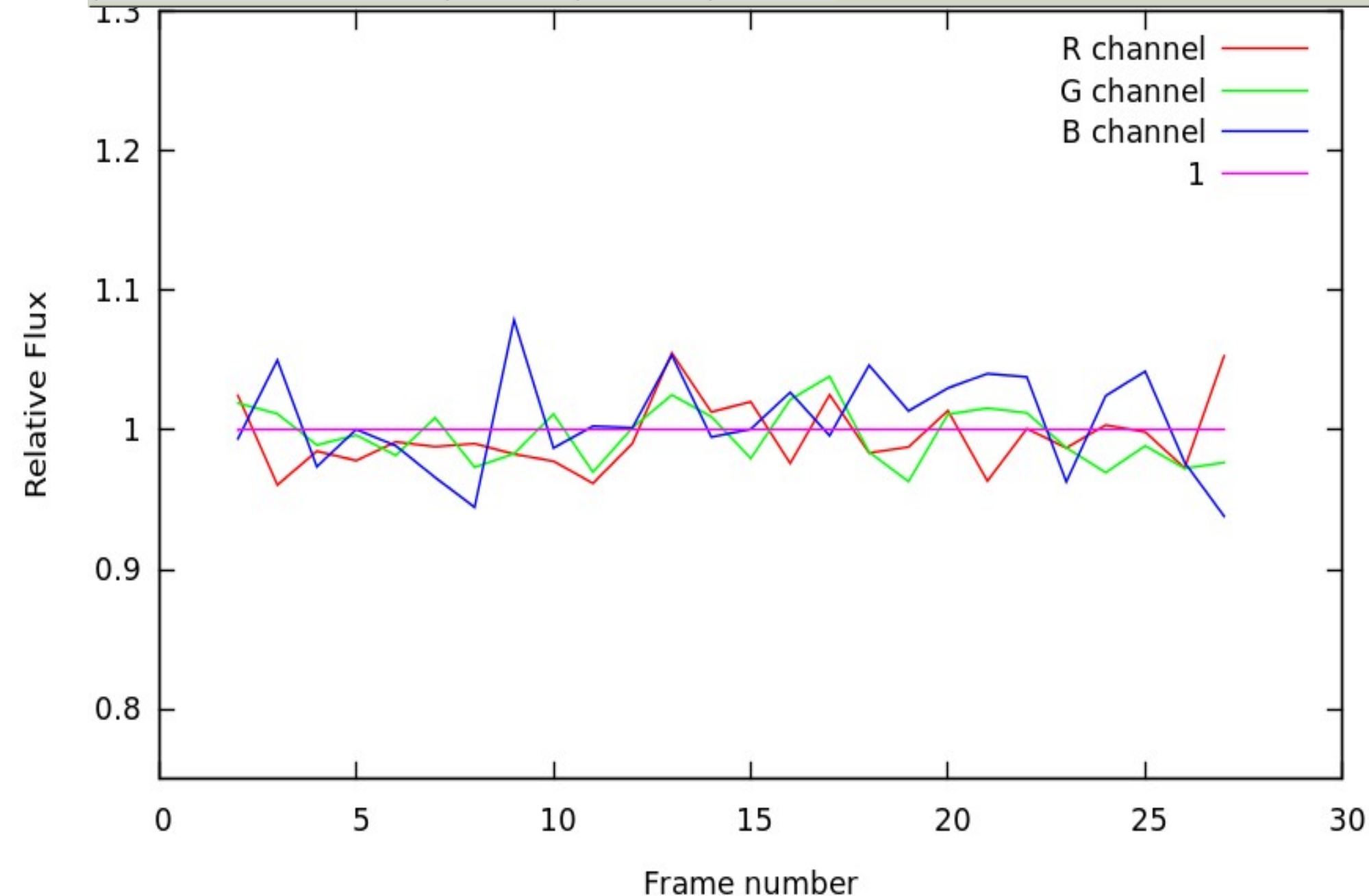
Precision photometry: Aperture photometry will not work !

	R channel	G channel	B channel
Average count (ADU)	5918.04	25990.6	6658.04
Standard Deviation	4.72%	13.56%	11.24%



Using PSF shape information to build reference PSF mitigates sampling errors

Error term	R channel	G channel	B channel	Notes
Atmospheric Scintillation	0.3%	0.3%	0.3%	
Photon Noise	2.79%	1.00%	2.24%	mV=9.35, includes background contribution (bright time, r=40arcsec mask)
Readout Noise	0.40%	0.23%	0.71%	
Flat field error	0.5%	0.4%	0.5%	Error term irrelevant with good tracking
Total (expected)	2.88%	1.14%	2.42%	
Achieved	2.48%	2.04%	3.51%	



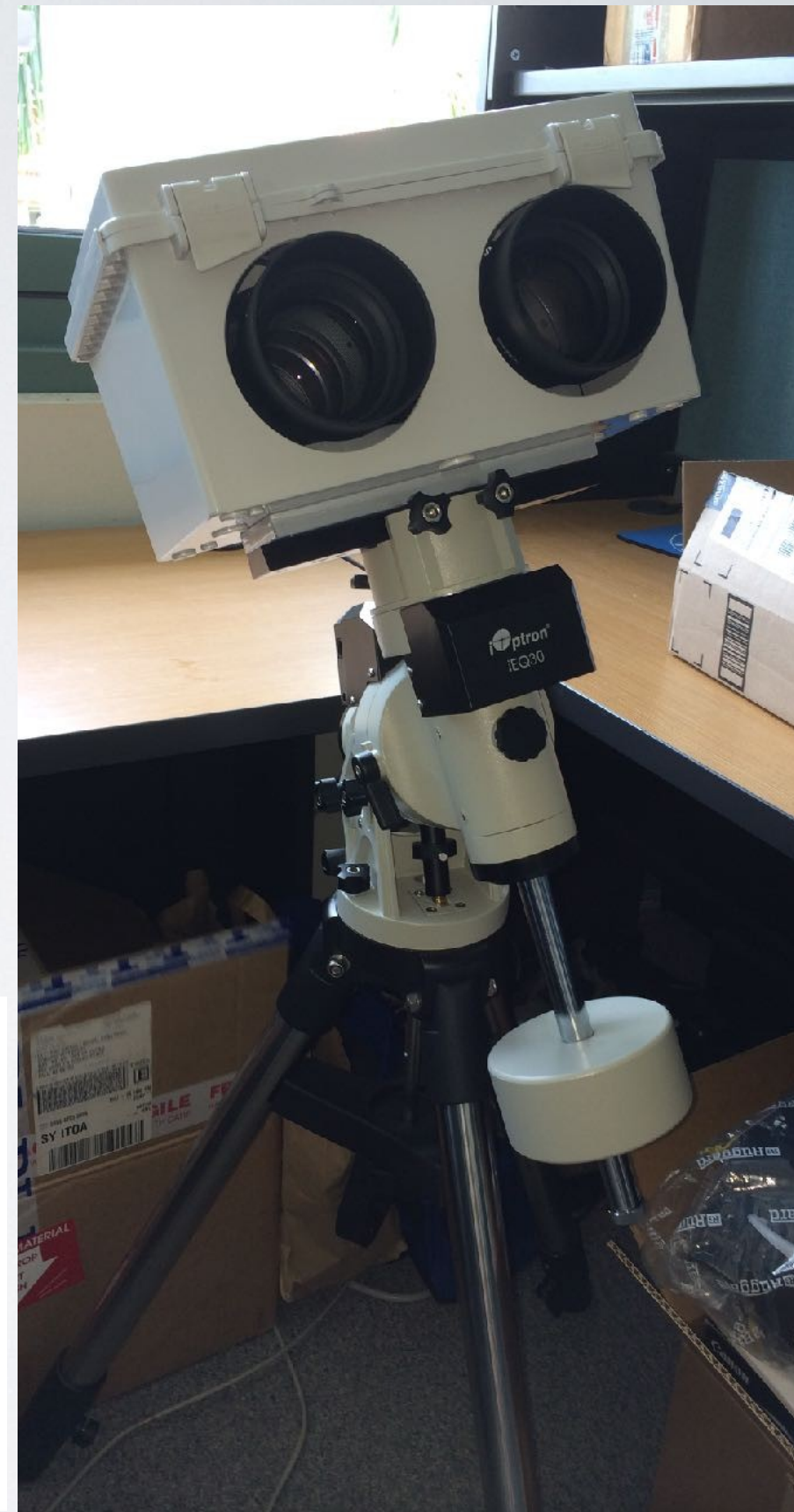
THE BASELINE UNIT

Take the lessons learned from the prototype and design a “baseline unit” which can be reproduced by non-experts

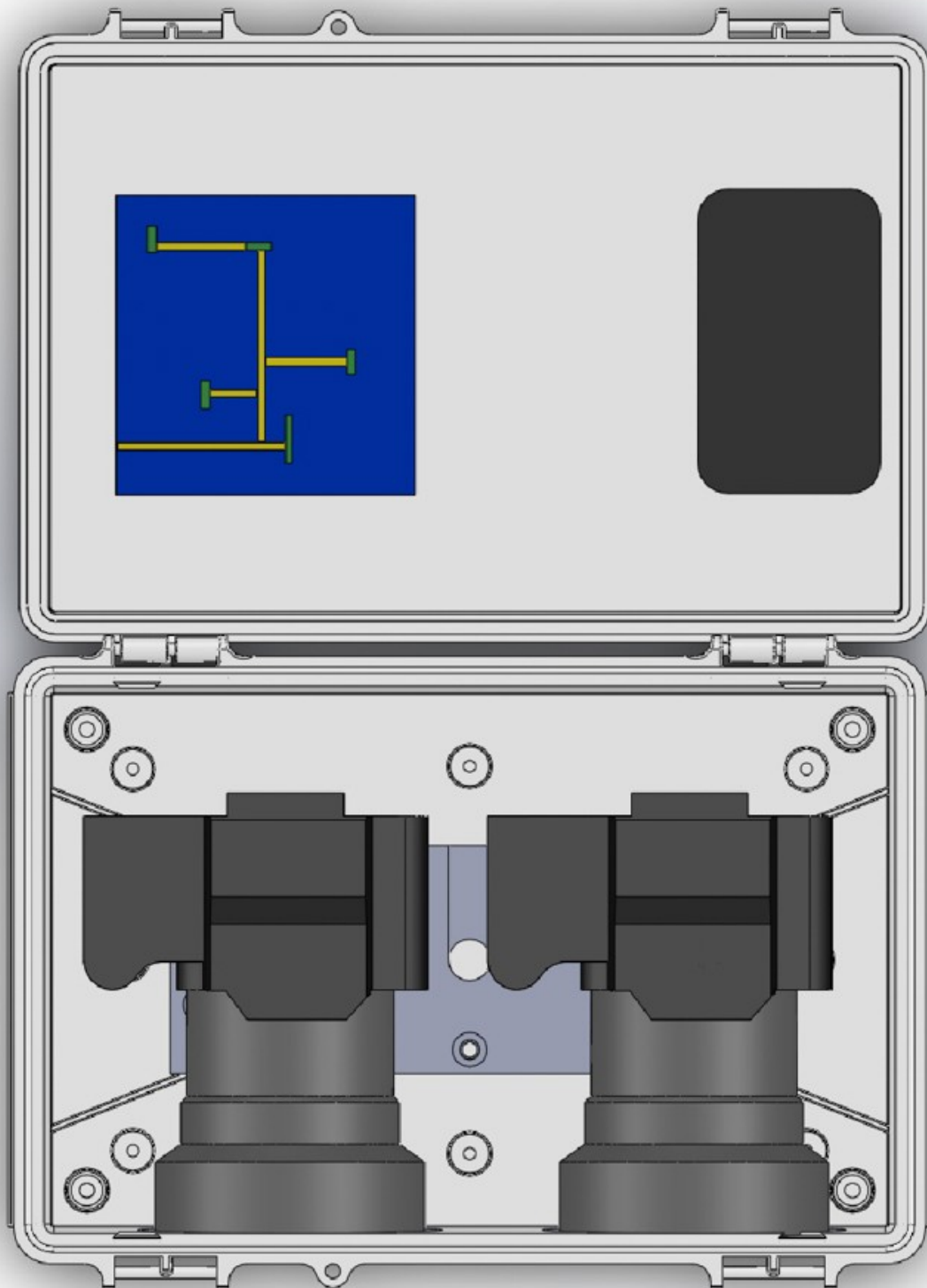
- We want amateurs and school groups to build and deploy their own units
- Open source hardware and software
- Goals:
 - Keep the design simple
 - Keep the cost low (\$4-5k)

HARDWARE

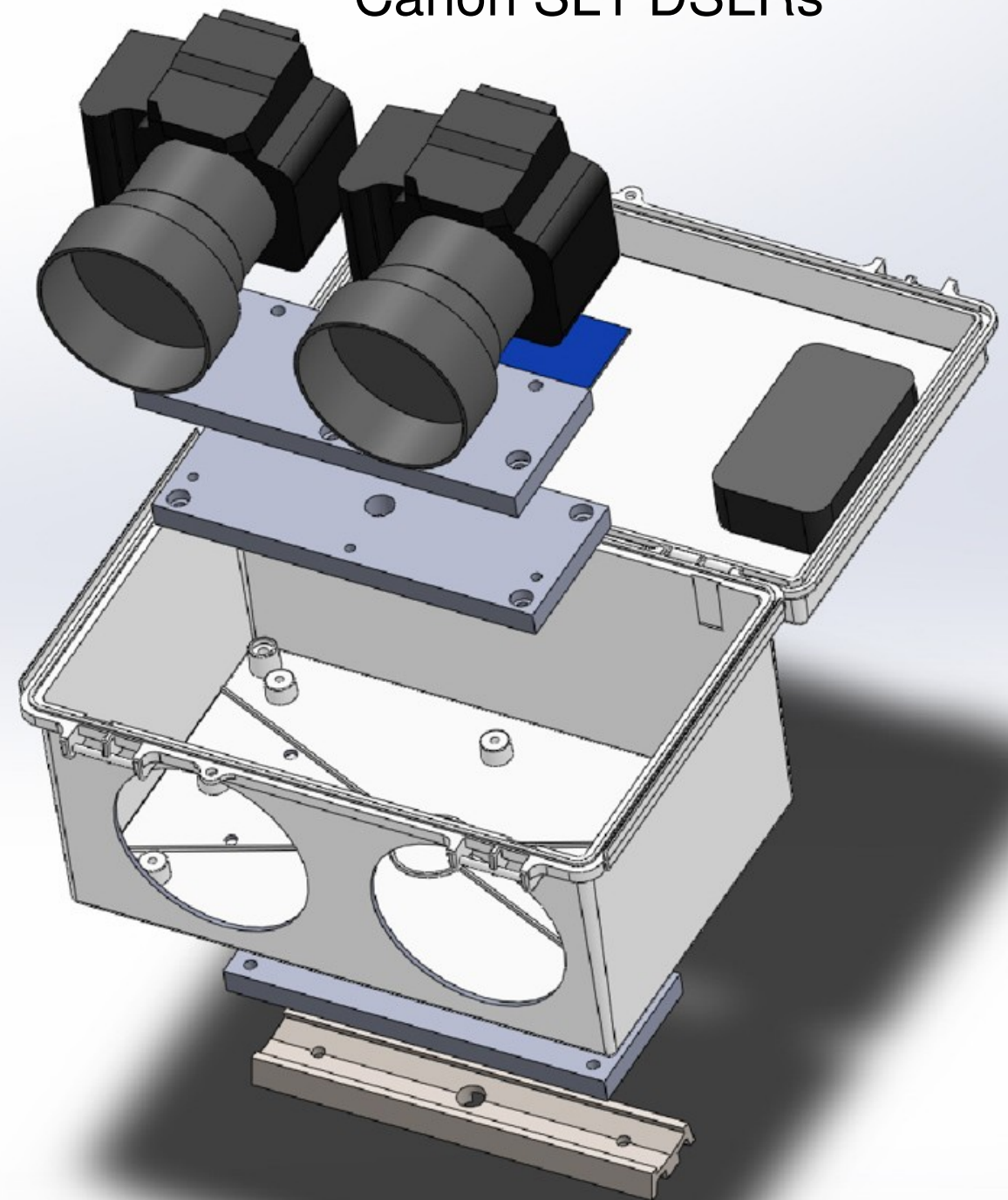
- Modularize the system. A PANOPTES “baseline unit” will consist of three items:
 - camera enclosure
 - mount
 - computer enclosure.
- The system becomes modular with a minimum of exposed cable runs.



CAMERA ENCLOSURE



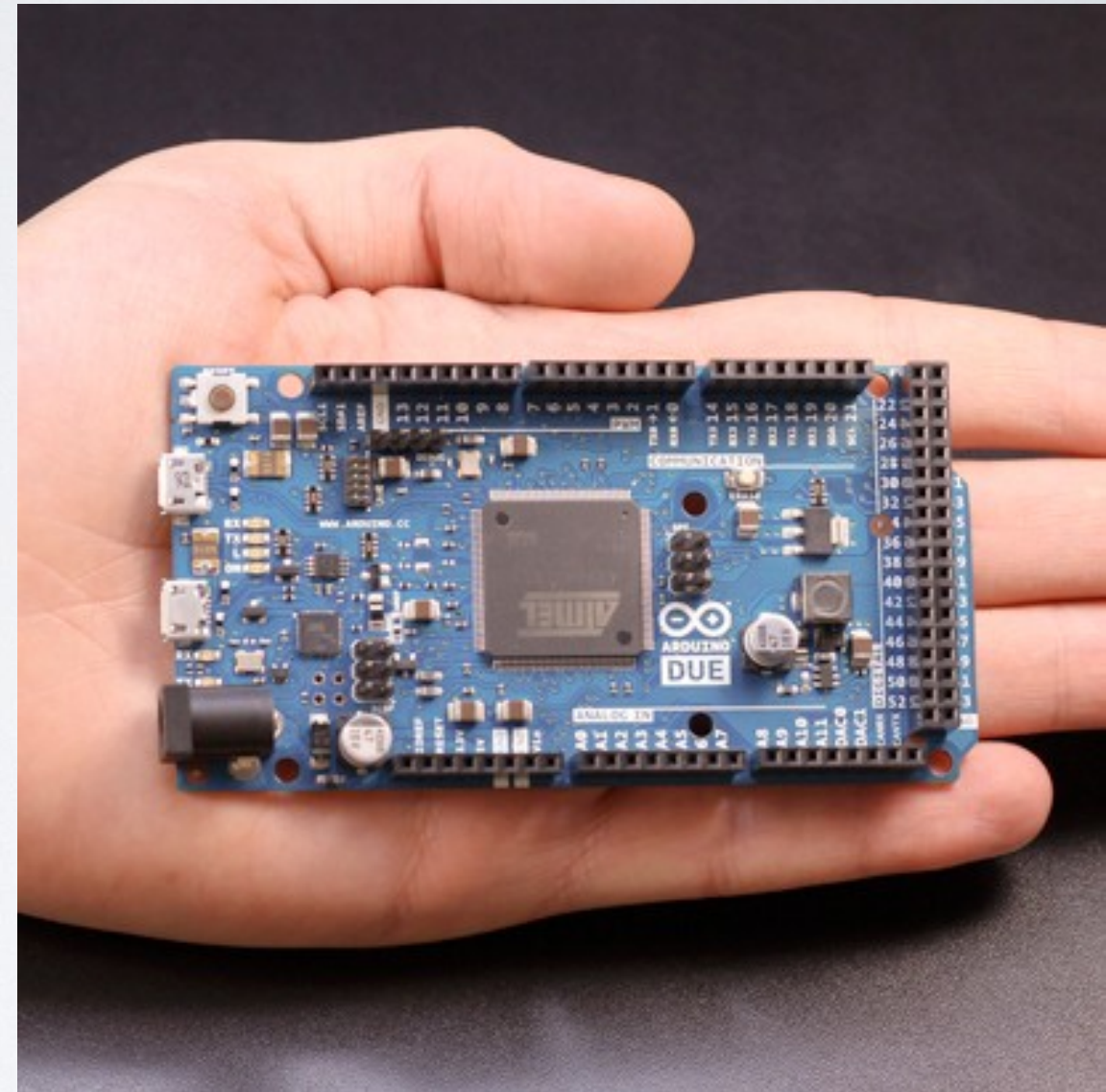
Canon SL1 DSLRs



ELECTRONICS

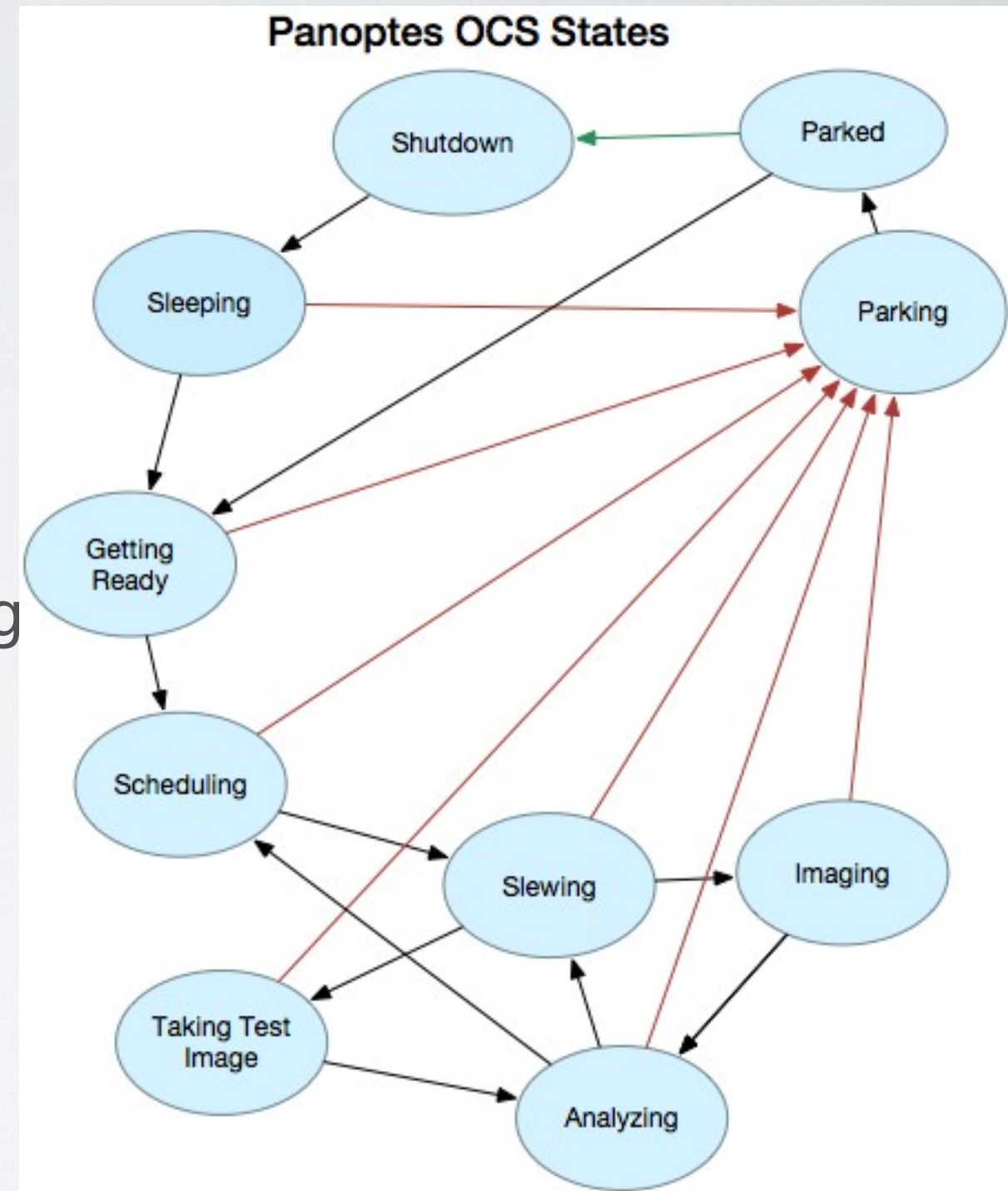
- Replace digital and analog i/o boards with Arduino.

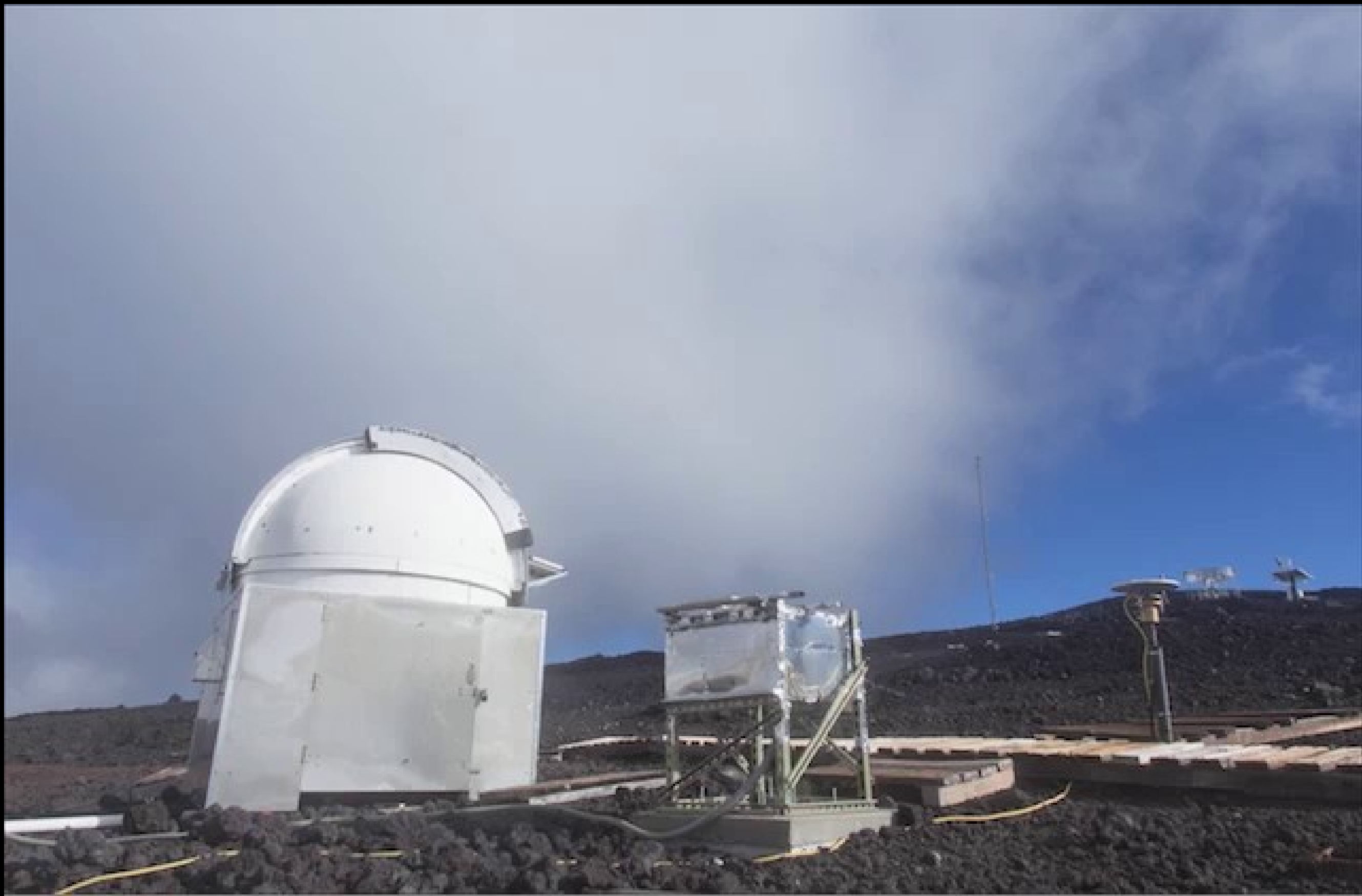
“Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's **intended for artists, designers, hobbyists** and anyone interested in creating interactive objects or environments.”



SOFTWARE: POCS

- PANOPTES Observatory Control System (POCS)
- State machine
- Written in python
- Uses community supported code (e.g astropy)
- open source:
<https://github.com/panoptes/POCS>

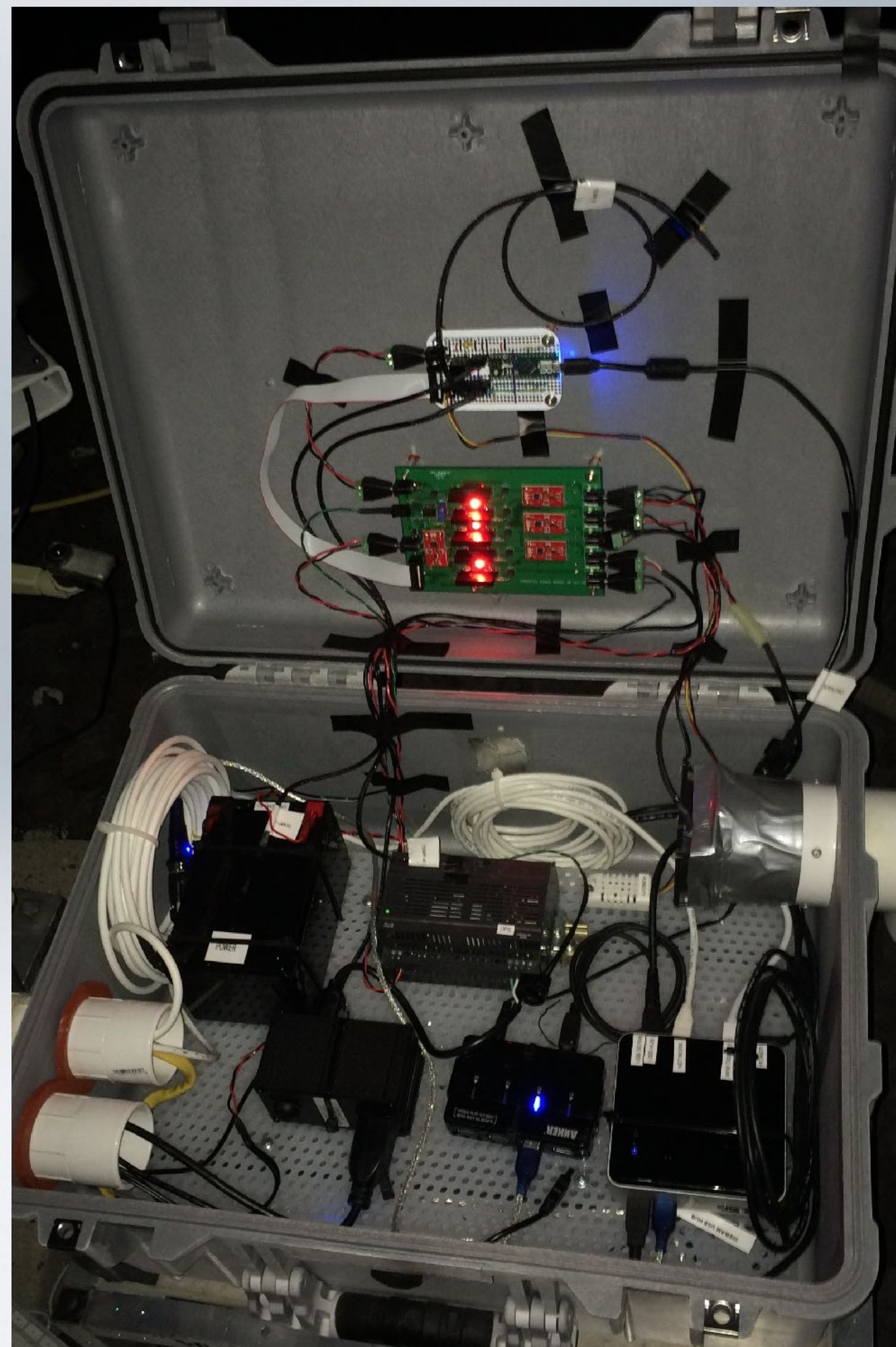












PAN001



PANOPTES COMMUNITY

- Our goal is to build a community of PANOPTES users
 - Get teams to help each other and continue development
- Our biggest challenges are not scientific, technological, or financial, they are **social**:
 - We need to build a social network of amateur scientists.

PANOPTES COMMUNITY

Phases:

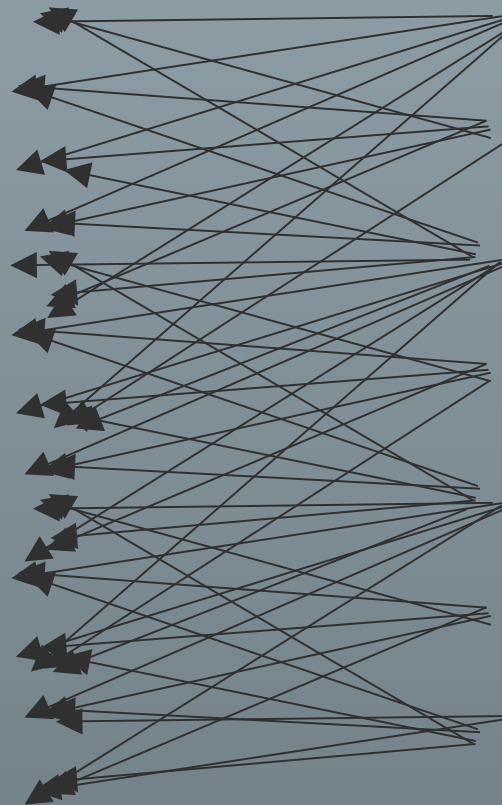
- Design / Prototype
- Build
- Maintenance
- Data Acquisition
- Science
- ...

Areas:

- Individual Unit
- PANOPTES Network
- Project-wide

Audience:

- HS Students
- Undergrads
- Grad Students
- Amateur Astronomers
- Career Astronomers
- Educators
- Anyone



PANOPTES COMMUNITY

- Open Source / Science / Data
- Citizen Science

*We must recognize that a critical feature of “citizen science” is the **enabling of amateurs to make authentic contributions** to the research topic in question: this in turn should drive us to **seek out those tasks that cannot be done by other means.***

Marshall, Lintott, Fletcher (2015)
“Ideas for Citizen Science in Astronomy”
Annual Review of Astronomy and Astrophysics, 53

WHO ARE WE?

- Current team includes people based at:
 - Subaru Telescope
 - W. M. Keck Observatory
 - Macquarie University
 - NASA JPL
 - Google
 - along with our first beta testers



PARTICIPATION

- PANOPTES participation is open to all.
 - Anyone interested in participating by contributing to the social, technological, or scientific aspects of the system is encouraged to contact us.
- email: info@projectpanoptes.org
- web: www.ProjectPanoptes.org
- Social:
 - Google Groups: Project Panoptes
 - Google+: Project Panoptes
 - Software: <https://github.com/panoptes>