Panoptic Astronomical Networked OPtical observatory for Transiting Exoplanets Survey (PANOPTES)

Website:**projectpanoptes.org**
Google group: **projectpanoptes**

Olivier Guyon (Subaru Telescope, Univ. of Arizona)
Josh Walawender (Subaru Telescope)
Mike Butterfield (GEOST)

… on behalf of PANOPTES project team

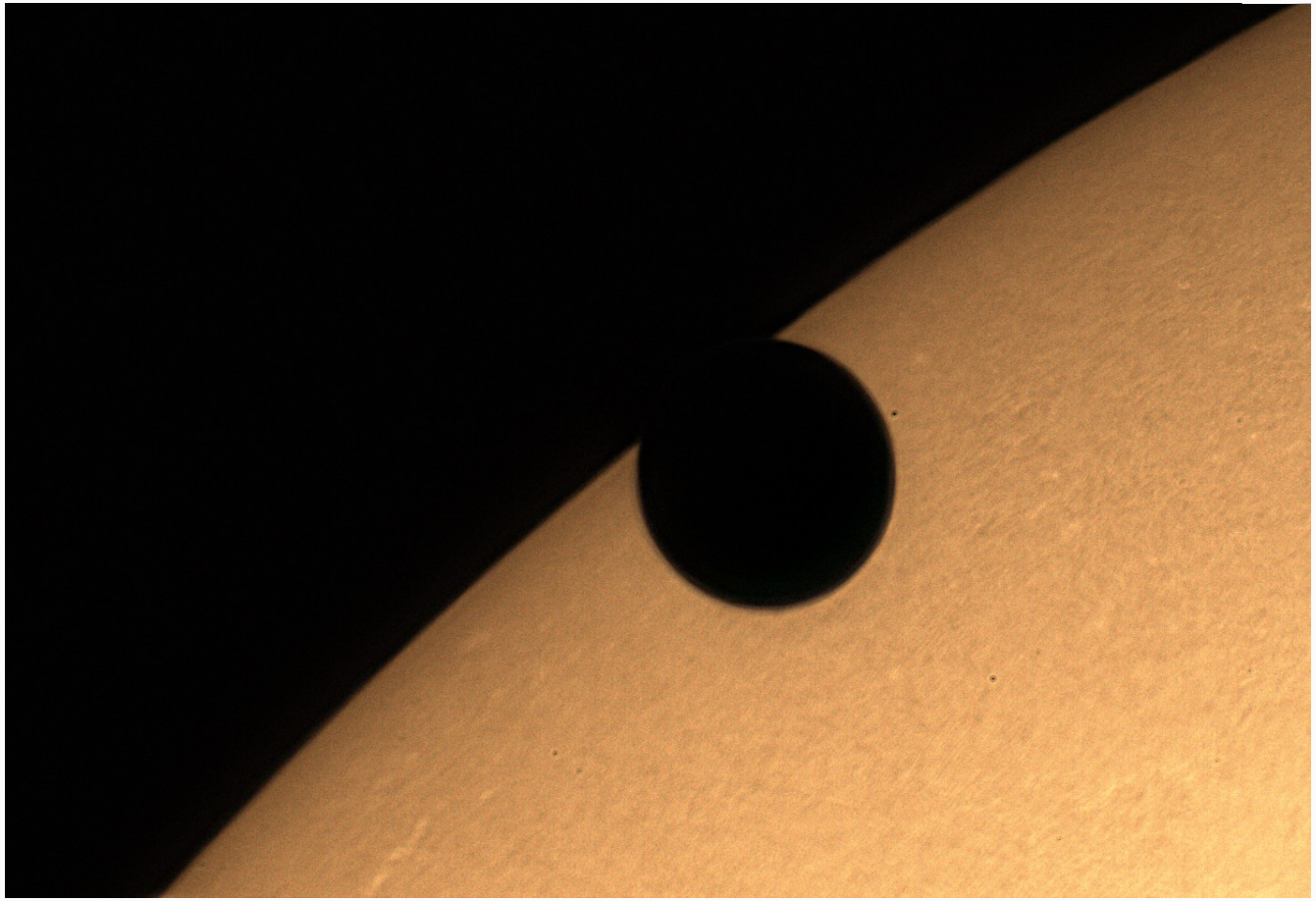
Project PANPOPTES overview & goals

Establish a world-wide network of small cameras to monitor, quasi-continously, a large fraction of the sky to detect exoplanet transits.

Enable amateur astronomers / citizen scientists and schools to discover a large number of exoplanets.

The PANOPTES data can also enable other discoveries (comets, variable stars, supernovae, asteroids)...
You come up with new ideas/projects and test them !

Exoplanet transits



Transit of Venus
June 2012

Jupiter-type planets create ~1% transit depth

Efficient & cost-effective approach

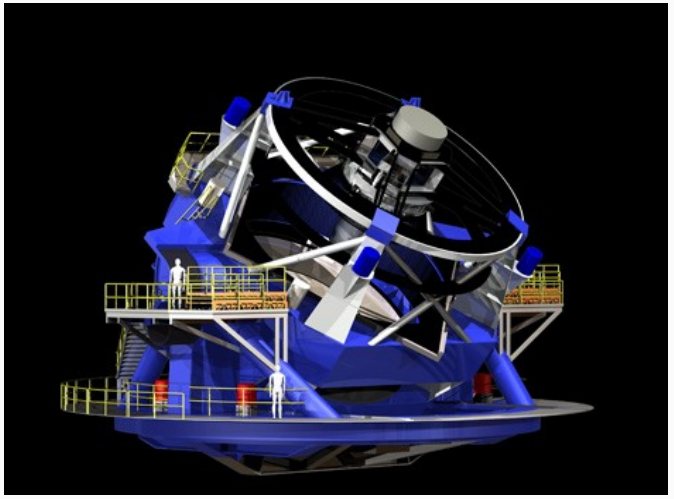
PANOPTES-type survey performance is quantified by total etendue:
Etendue = # units x collecting area x field of view

We should trade # of units, collecting area and field of view to maximize etendue

PANOPTES uses DSLR camera + 85mm F1.4 lenses
PANOPTES unit = few $1000s
1 camera+ lens = 150 sq deg x 0.003 sq meter = 0.43 sq deg sq meter
→ **~0.2 sq deg sq m / $1000**

Efficient & cost-effective approach

For comparison (ignoring detector efficiency, which can change etendue by ~factor 2):



LSST (8.4m diam, 3.5 deg FOV):
350 sq deg sq m for $600M
0.006 sq deg sq m / $1000
(340x less efficient than PANOPTES)

Celestron 14 + Hyperstar + 27mm CCD + dome
4 sq deg x 0.1 sq m for ~$40,000
0.01 sq deg sq m / $1000
(20x less efficient than PANOPTES)

Efficient & cost-effective approach

Distributed network of low-cost units (DSLR cameras + lenses) is not only a great way to involve public and amateur astronomers, it also **makes sense scientifically:**

Lots of small units is most efficient way to carry out survey

Geographical coverage is essential for time and sky coverage

→ amateur astronomers, citizen scientists and schools can have significant impact in exoplanet discoveries
CHALLENGE: how to make it easy to participate, build network ?
This is what PANOPTES is working on right now.

Project PANPOPTES overview, goals

Scientific performance scales as number of units → We build simple low-cost units, easy to assemble to maximize participation

PANOPTES is open-source, open-hardware. Developed by amateur astronomers and citizen scientists

All design info and software is public, anyone can participate (hardware, software)

All data is public – we build tools / infrastructure to distribute it efficiently and process it

… membership is a loose boundary

Project PANOPTES history and early prototyping

2010: Astrophotography with DSLRs → quantitative analysis of DSLR performance shows it is potentially suitable for exoplanet transit

Dec 2010: 1st prototype unit deployed at Mauna Loa observatory (MLO)

Mar 2011-present : MLO unit observes robotically most nights to test hardware & software. 3 generations of prototypes:

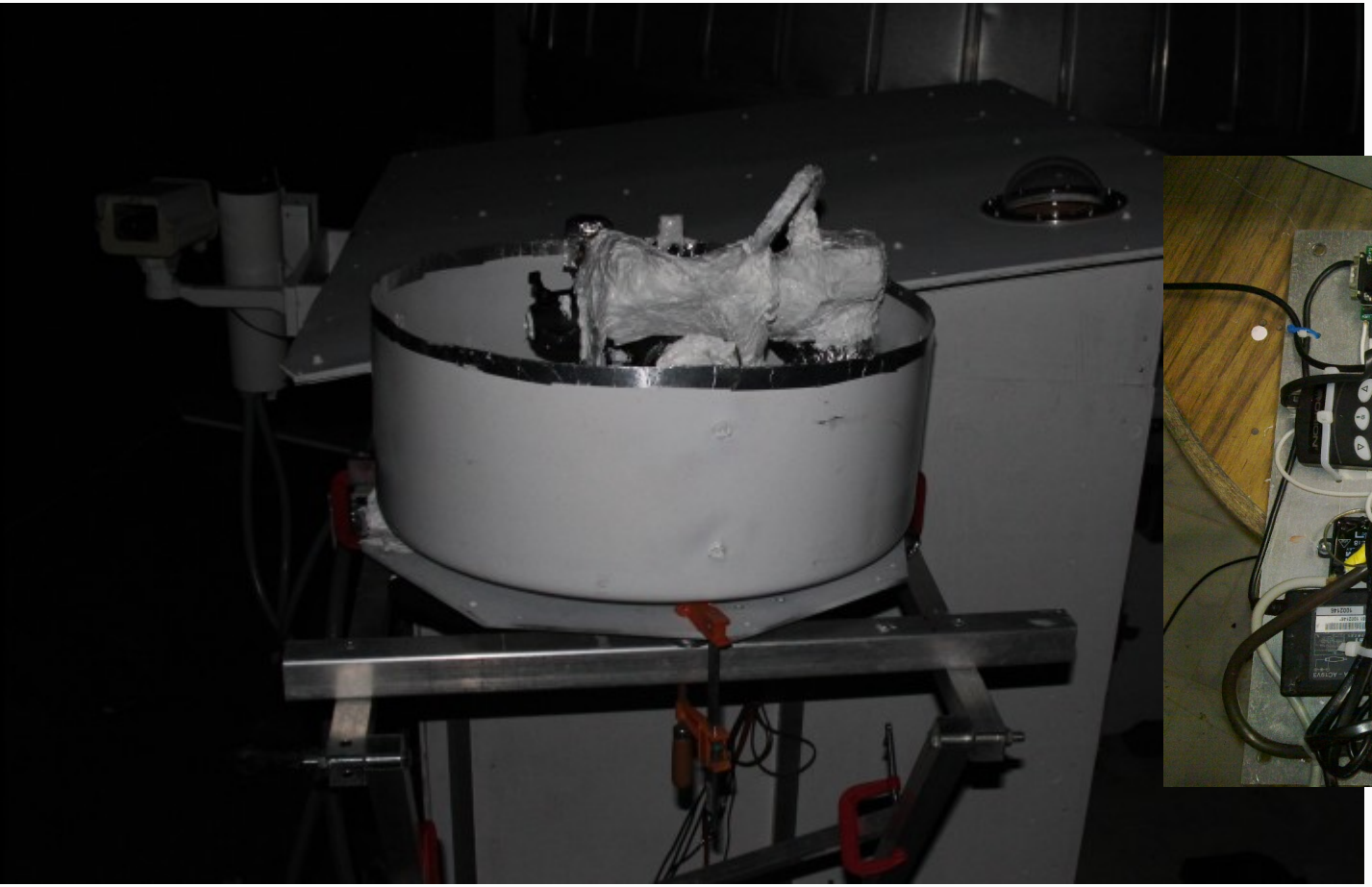
Gen 1 (March 2011 → July 2011): one DSLR camera, mounted on side of wooden building

Gen 2 (Sept 2011 → May 2013): two DSLR cameras, metal frame

Gen 3 (July 2013 → present): 4 DSLR cameras, new electronics enclosure

Jan 2013 – present: establish baseline, set up project and collaborations

MLO prototype #1 (2010 → 2011)

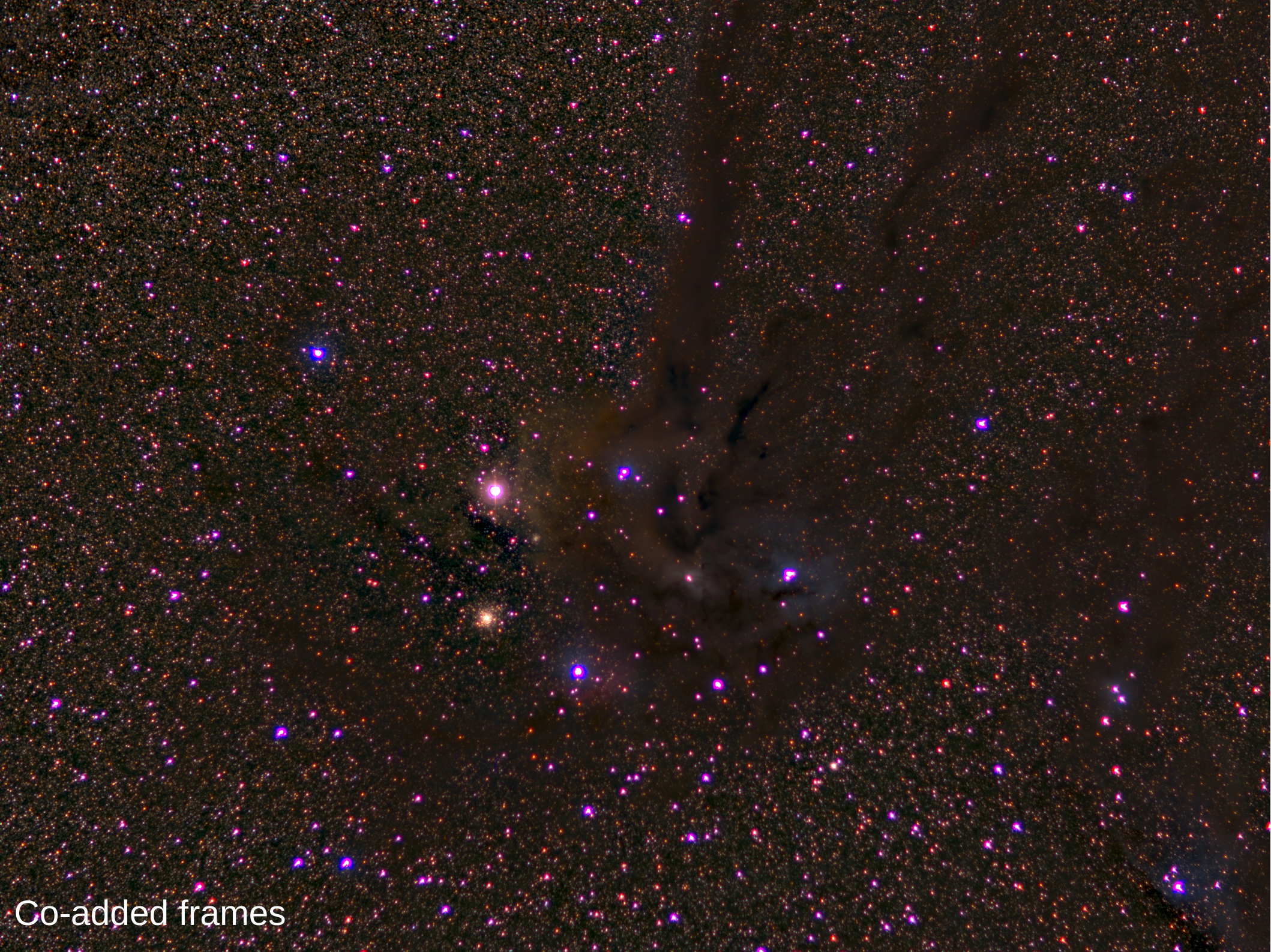


EOS camera + 85mm F1.2 lens + modified Orion Atlas EQ-G mount
Mounted on side of wooden building
Camera and mount sealed for protection, points down during bad weather
Electronics located below mount
Autonomous software, including weather monitoring

362 sec, ISO 100, no processing (no flat-fielding or dark subtraction)

Bottom left corner of previous frame

What is this ?


Co-added frames

Detail

MLO prototype #1: lessons learned

Low-cost DSLR-based system with no dome works and is reliable/durable !

Minor issues: ***proper sealing of cables is essential, plan for power outage > 10hr, don't mount your system on a wooden panel***

MLO prototype #1: lessons learned

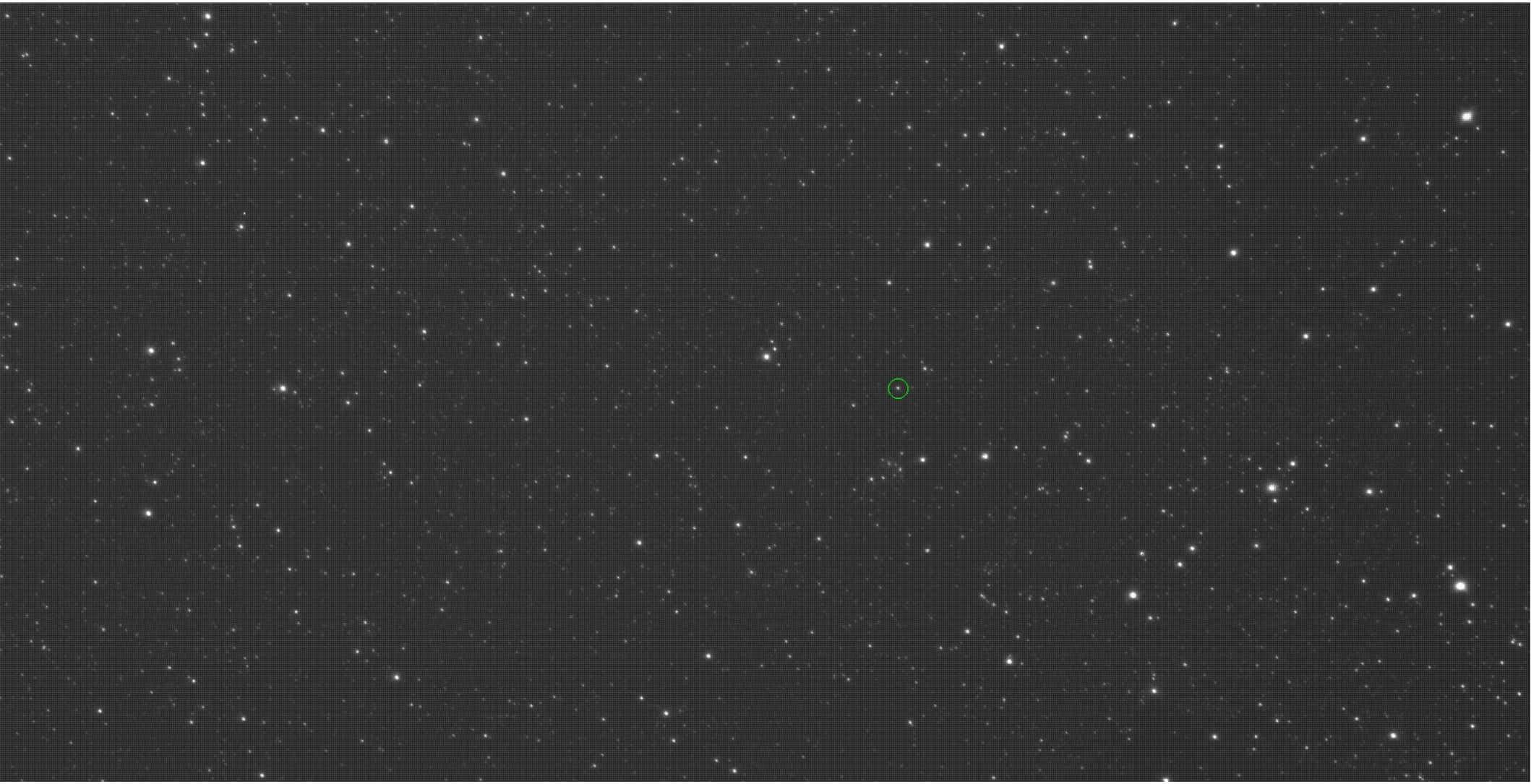
Precision photometry is possible with DSLRs <u>without defocusing</u>

We developed an image correlation based algorithm to reach percent level photometry on minute timescale (transit of giant planets: ~1%, 2hr long)

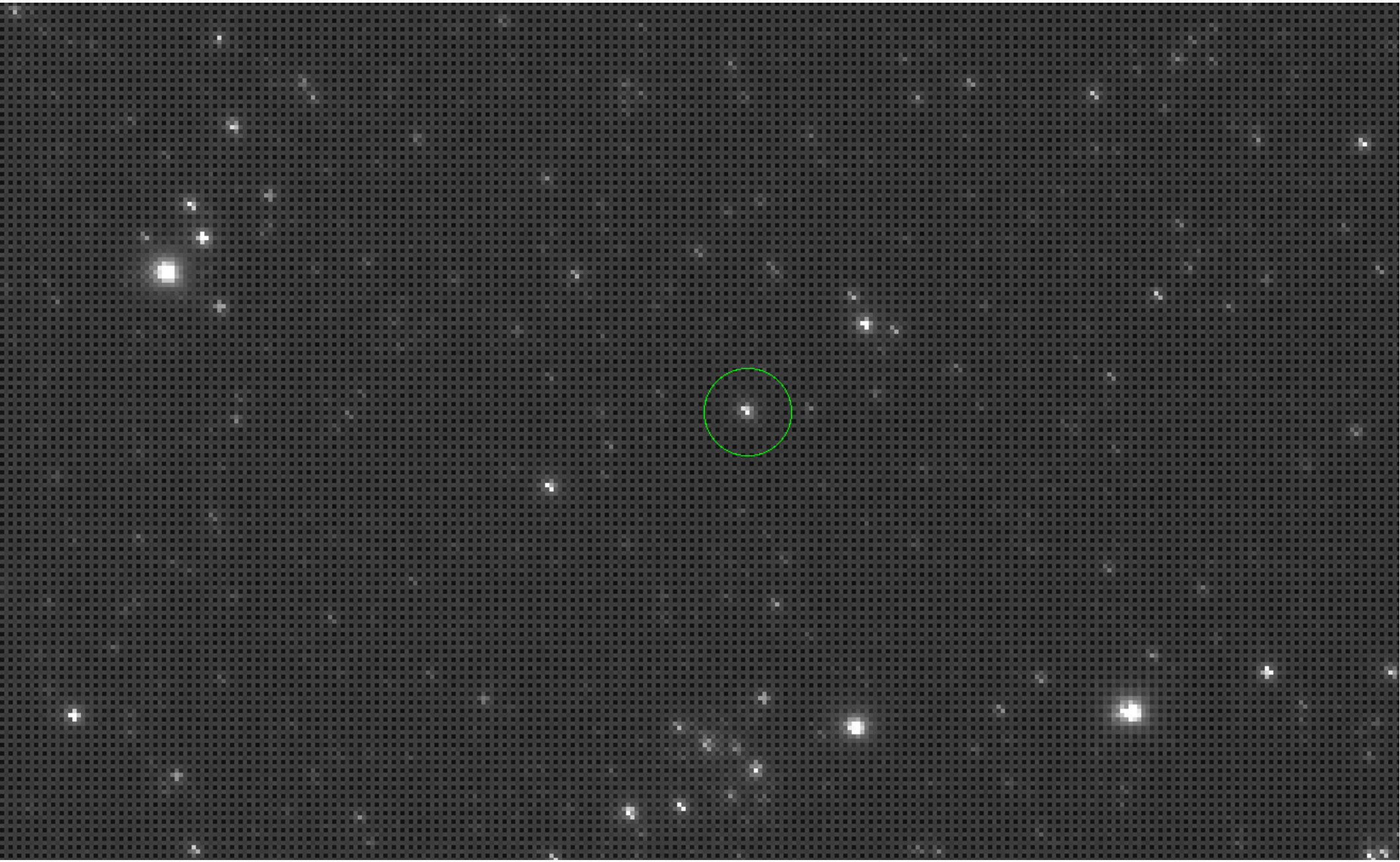
Challenge: interaction between star images and color pixels is hard to figure out, and creates ~20% modulation in total flux captured from frame to frame

Photometry: demonstration on HD54743

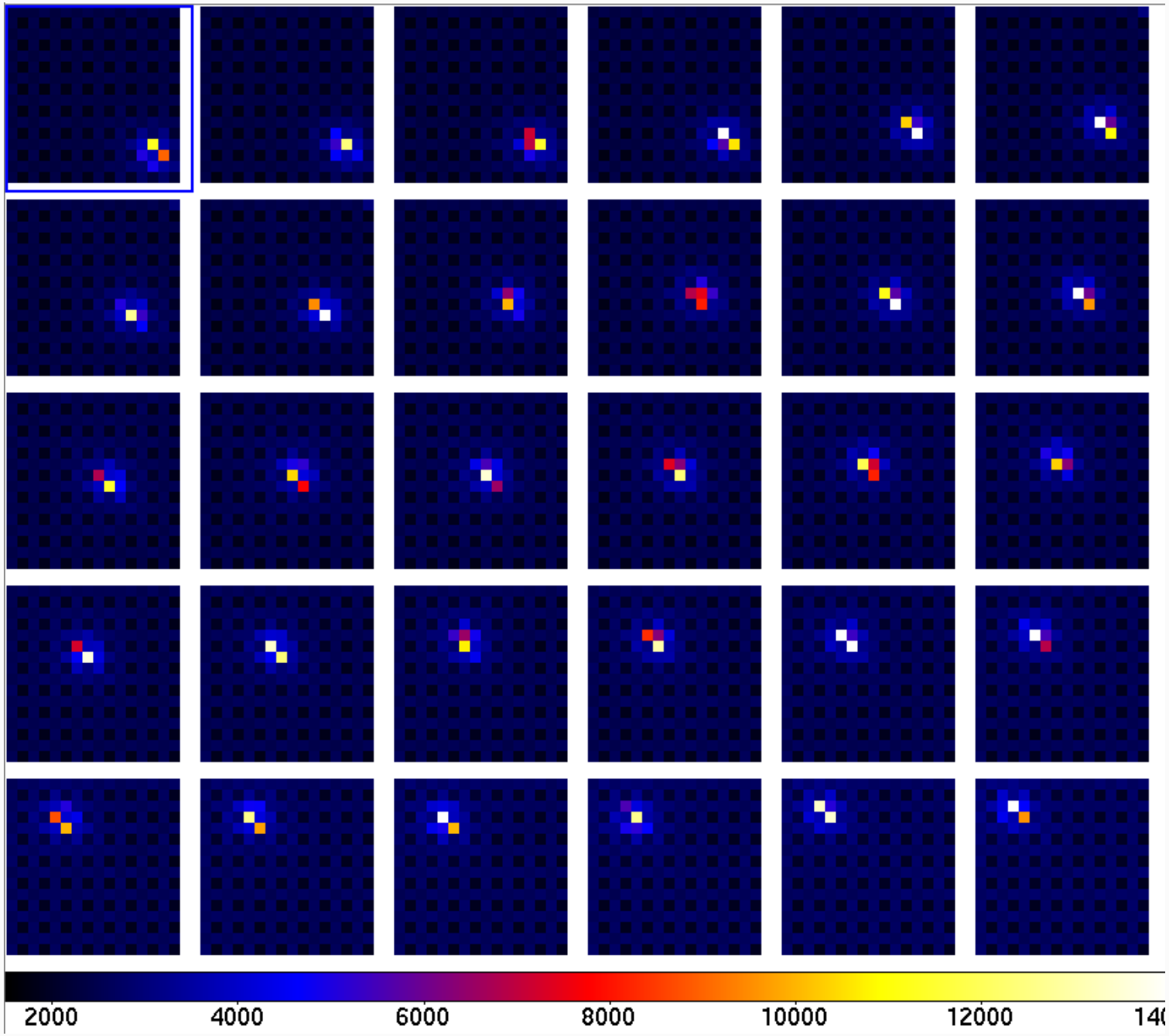
Photometry: demonstration on HD54743



Photometry: demonstration on HD54743



Photometry: demonstration on HD54743

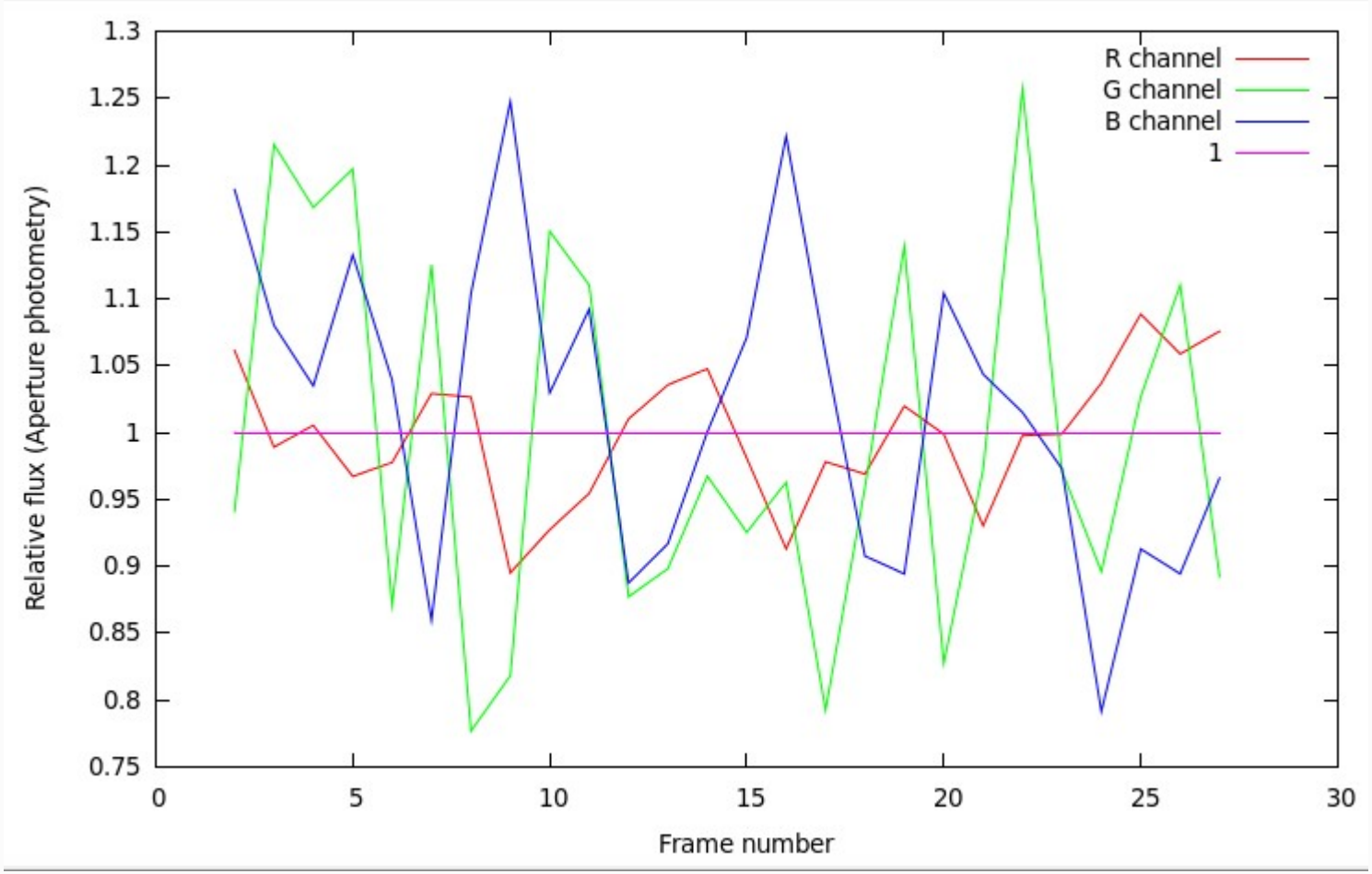


65 s / exposure

Tracking error moves star image across pixels from frame to frame

Photometry: demonstration on HD54743

Measuring total pixel counts does not work very well !



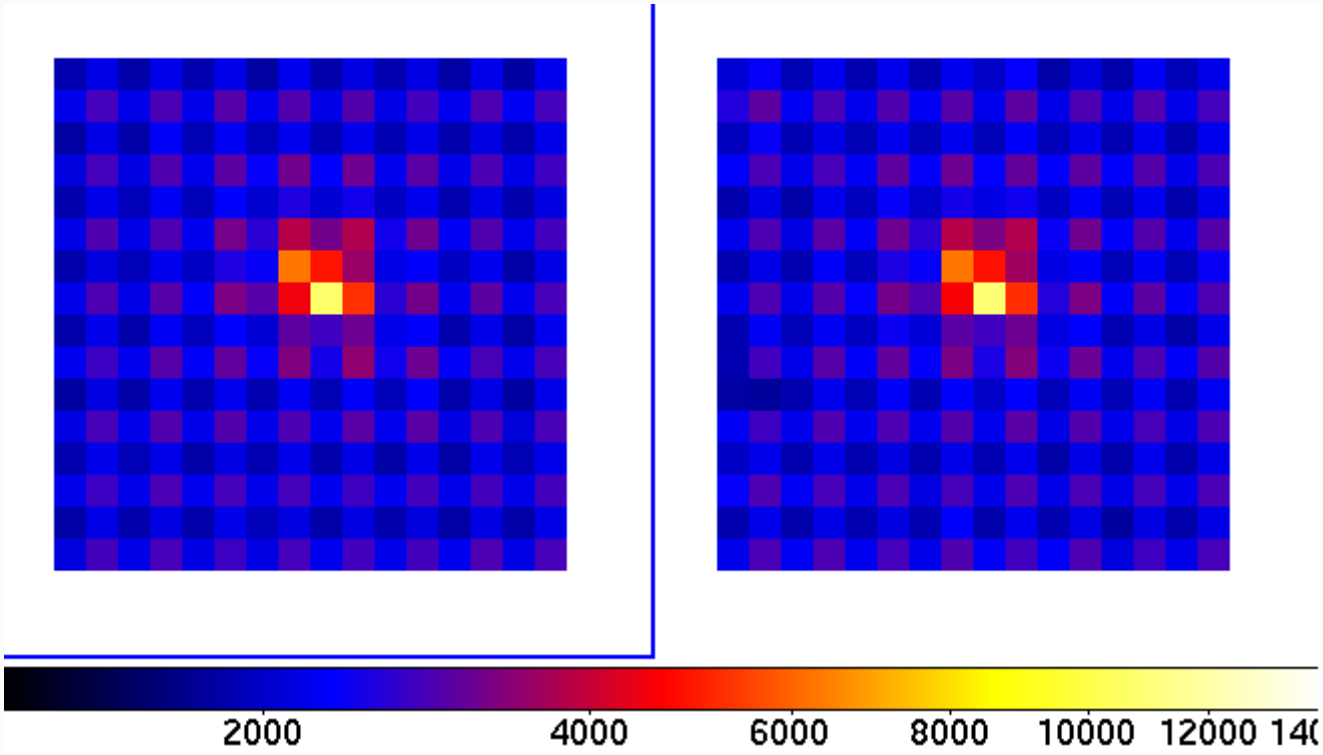
65 s / exposure

Tracking error moves star image across pixels from frame to frame

Photometry: demonstration on HD54743

There are lots of stars in each image
→ lets find star(s) for which the same errors occur, by looking for stars for which the image looks the same on each frame

We will then use this(ese) star(s) as reference for photometry

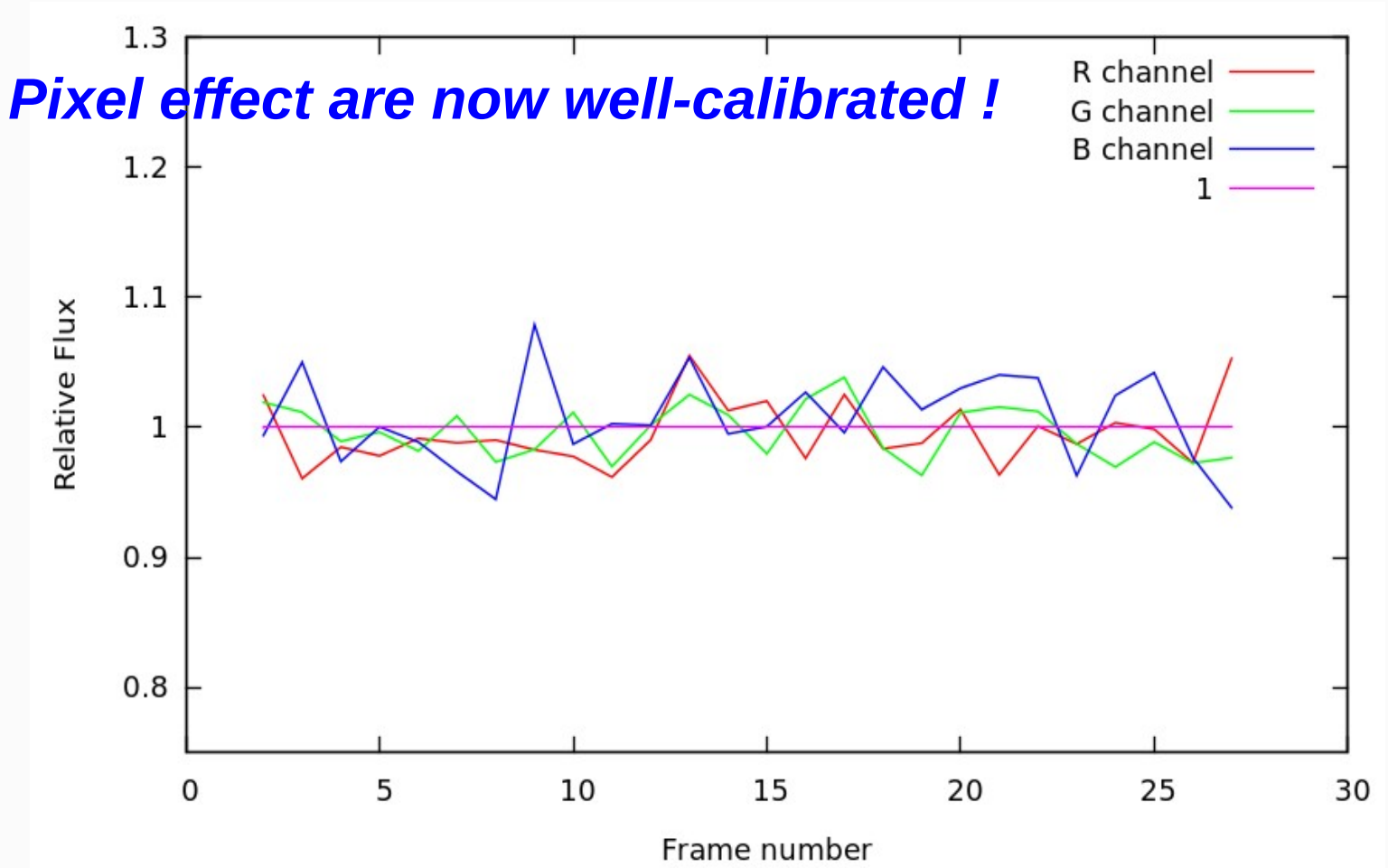


Test: remove one of the image of our target star and use reference star(s) to re-build it

Left: actual image #15 of HD54743

Right: reconstructed image #15 using reference(s)

Photometry: demonstration on HD54743



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%**	

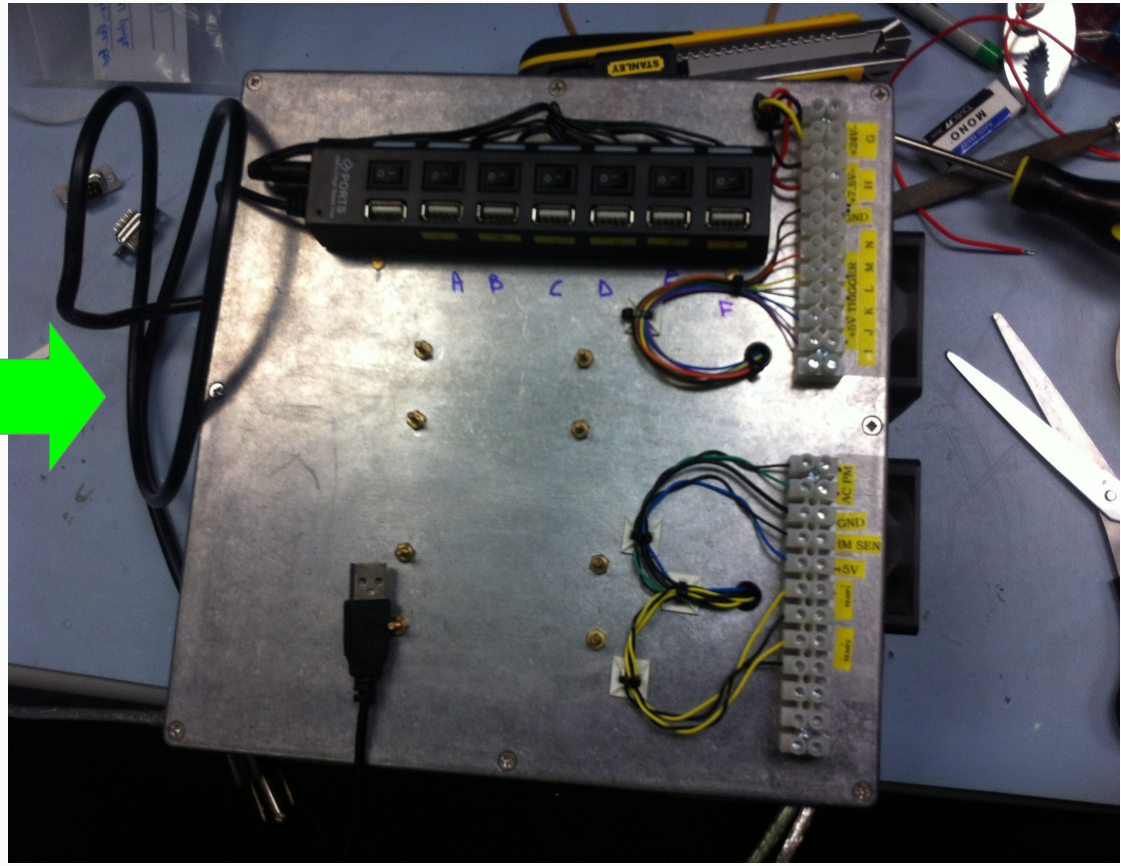
MLO prototype #2

Mounted on metal frame → better tracking
Two cameras: comparing with and without IR-blocking filter
Conclusion: we do not advise to remove IR-blocking filter

MLO prototype #3

4 cameras:
- comparing Canon F1.2 lens (~$2000) with Rokinon F1.4 ($300)
    Conclusion: we will use Rokinon lens for baseline
- can the mount support 4 cameras ? → Yes

MLO prototype #3



Rokinon 85mm F1.4 image quality

The Baseline Unit

We envision the PANOPTES project moving forward in 3 phases.

Phase 1: The current group develops the “Baseline Unit” which will serve as a well-documented common point of reference for all future evolution of PANOPTES

The Baseline Unit

We envision the PANOPTES project moving forward in 3 phases.

Phase 2: A core group of “expert” users (professional and amateur astronomers) build their own baseline units with their own modifications if they choose.

The Baseline Unit

We envision the PANOPTES project moving forward in 3 phases.

Phase 3: We begin to actively recruit users and groups at all levels, especially schools. The “core” group from phase 2 now helps to support new users.

We want to create a user community for PANOPTES.

The Baseline Unit

What makes the Baseline different? What are our goals?

1) Simplify, simplify.
• Simple systems tend to be more reliable.
• Simple systems are easier for others to build, understand, and improve upon.

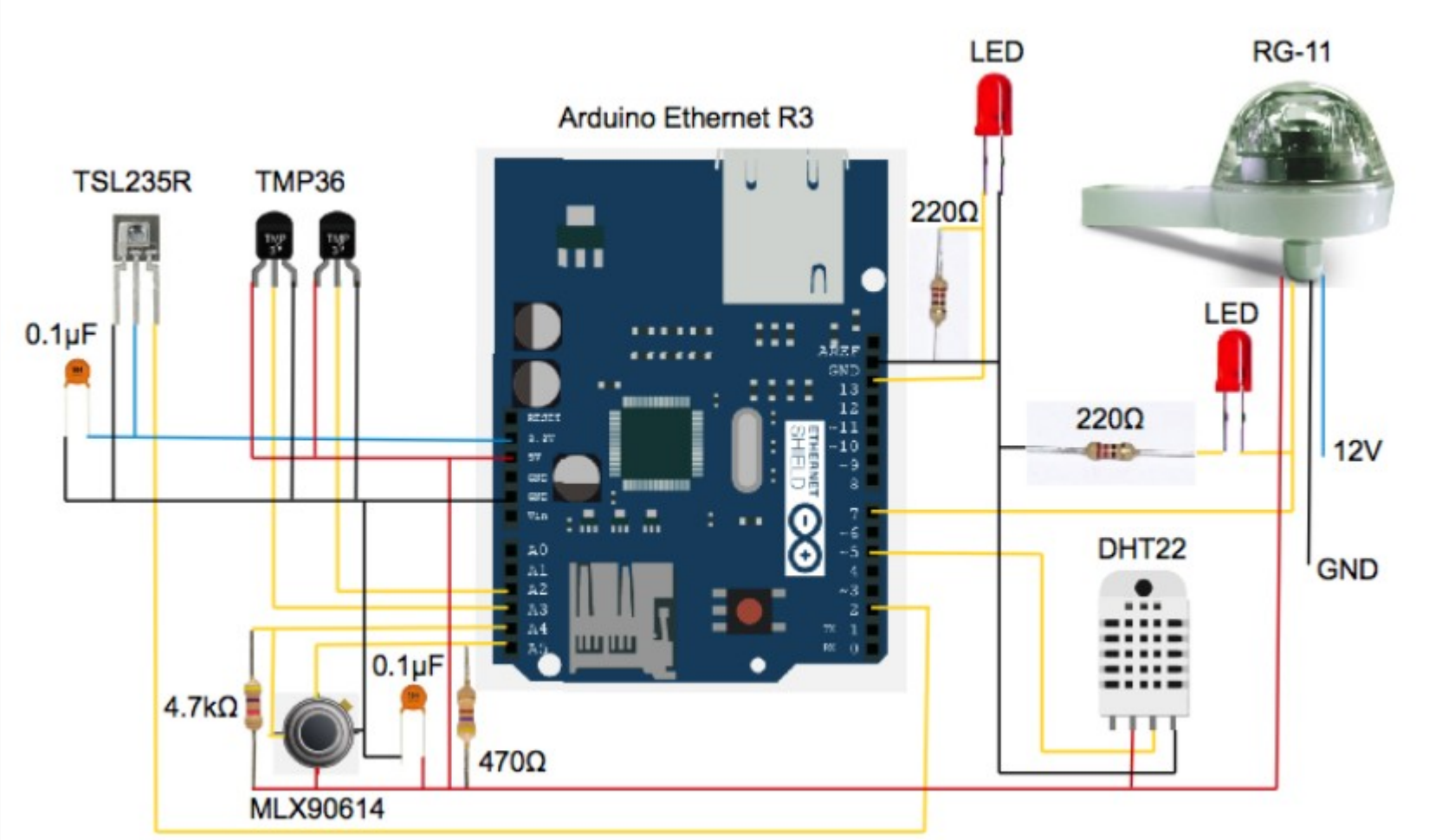
"Perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away."
-Antoine de Saint Exupéry

The Baseline Unit

Replace all digital and analog I/O with Arduino boards.

“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.”

The Baseline Unit: Weather monitoring



Design and code for weather station by undergraduate student Hannah Dalgleish.

The Baseline Unit: Mount homing

Instead of adding home and limit switches to the mount, we will use an accelerometer (or IMU) controlled by an Arduino board

The Baseline Unit

House all electronics in a weatherproof case. Thus a PANOPTES “unit” consists of three items:
1) the electronics case
2) the mount
3) the camera enclosure.

The system becomes modular with a minimum of exposed cable runs.

How to participate ?

PANOPTES participation is **open to all.**
You can participate at many levels:
Write code, build a unit, process data, improve hardware, start new type of hardware, follow-up of interesting targets with a larger telescope, provide a site or data storage

Email us as info@projectpanoptes.org

- Let everyone know how you can help, ideas you have to make things better
- Help up advertise the project.
- Help others to solve technical issues.