
# Stellar Variability in Crowded Fields

Preliminary results

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*On behalf of the TVS Stellar Variability in Crowded Fields TF*

# Goals

- Create metrics to determine the success of the pipeline. These will be based on the recovery of:
  - periods
  - magnitudes
  - distance scale determinations
  - precision on astrometric solutions.
- Identify the optimal available code for the science requirements (primarily pulsating stars) and optimize it if necessary.

# Project and People

- Stellar Variability in Crowded Fields is one of the TVS task forces
- Strictly connected with the DDF/MS TF: *RR Lyrae stars in the inner bulge*

- Kelly Hambleton (Villanova University)
- Giuseppe Bono (Univ. Tor Vergata)
- Michele Fabrizio (ASI Science Data Center)
- Giuliana Fiorentino (INAF-OABO)
- Alessia Garofalo (INAF-OABO)
- Davide Magurno (Univ. Tor Vergata)
- Silvia Marinoni (ASI Science Data Center)
- Paola Marrese (ASI Science Data Center)
- Tatiana Muraveva (INAF-OABO)

# How the group is organized

- Weekly zoom call
  - Contact with the LSST people working on the pipeline: R. Lupton, C. Slater, E. Bellm
- Discussion of the past week results
- Planning of the next week work and tasks assignment

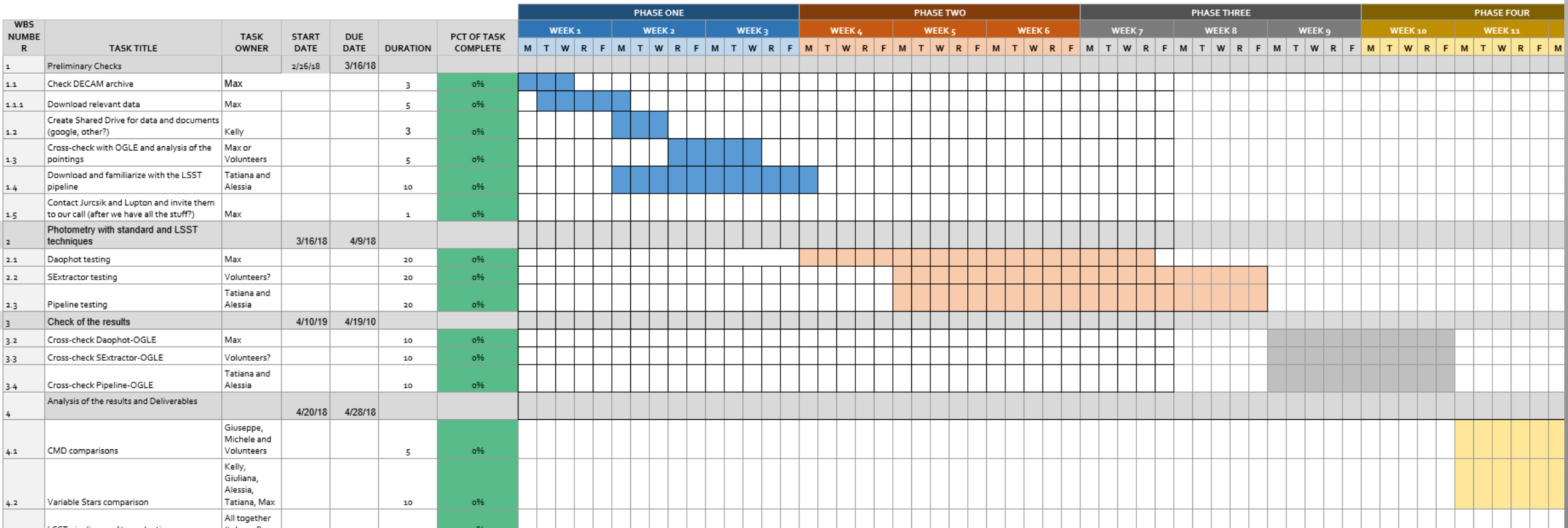
# Timeline

## GANTT Stellar Variability in Crowded Fields

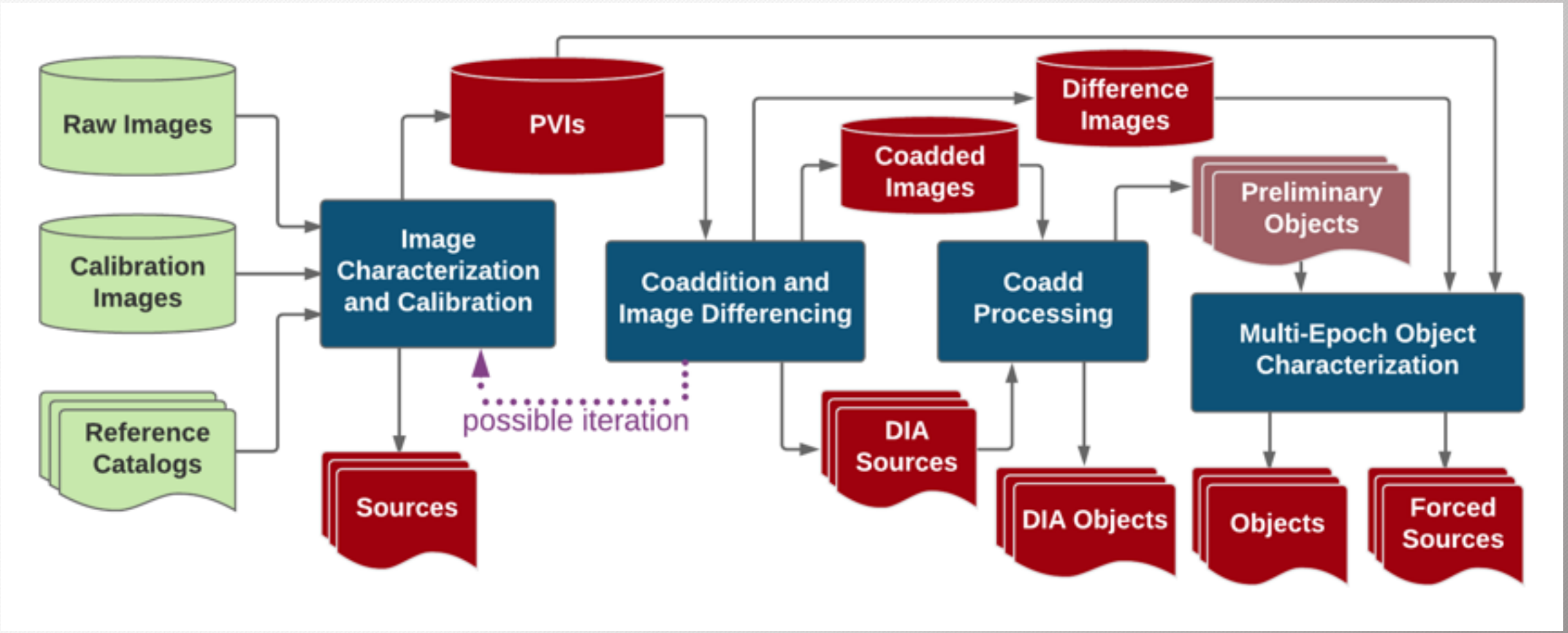
| | | | |
|---|---|---|---|
| PROJECT TITLE | Stellar Variability in Crowded Fields | COMPANY NAME | LSST |
| PROJECT MANAGER | Each of us | DATE | February 23, 2018 |

| WBS NUMBER | TASK TITLE | TASK OWNER | START DATE | DUE DATE | DURATION | PCT OF TASK COMPLETE |
|---|---|---|---|---|---|---|
| 1 | Preliminary Checks | | 2/26/18 | 3/16/18 | | |
| 1.1 | Check DECAM archive | Max | | | 3 | 0% |
| 1.1.1 | Download relevant data | Max | | | 5 | 0% |
| 1.2 | Create Shared Drive for data and documents (google, other?) | Kelly | | | 3 | 0% |
| 1.3 | Cross-check with OGLE and analysis of the pointings | Max or Volunteers | | | 5 | 0% |
| 1.4 | Download and familiarize with the LSST pipeline | Tatiana and Alessia | | | 10 | 0% |
| 1.5 | Contact Jurcsik and Lupton and invite them to our call (after we have all the stuff?) | Max | | | 1 | 0% |
| 2 | Photometry with standard and LSST techniques | | 3/16/18 | 4/9/18 | | |
| 2.1 | Daophot testing | Max | | | 20 | 0% |
| 2.2 | SExtractor testing | Volunteers? | | | 20 | 0% |
| 2.3 | Pipeline testing | Tatiana and Alessia | | | 20 | 0% |
| 3 | Check of the results | | 4/10/19 | 4/19/10 | | |
| 3.2 | Cross-check Daophot-OGLE | Max | | | 10 | 0% |
| 3.3 | Cross-check SExtractor-OGLE | Volunteers? | | | 10 | 0% |
| 3.4 | Cross-check Pipeline-OGLE | Tatiana and Alessia | | | 10 | 0% |
| 4 | Analysis of the results and Deliverables | | 4/20/18 | 4/28/18 | | |
| 4.1 | CMD comparisons | Giuseppe, Michele and Volunteers | | | 5 | 0% |
| 4.2 | Variable Stars comparison | Kelly, Giuliana, Alessia, Tatiana, Max | | | 10 | 0% |
| | | All together | | | | |

PHASE ONE: WEEK 1, WEEK 2, WEEK 3
PHASE TWO: WEEK 4, WEEK 5, WEEK 6
PHASE THREE: WEEK 7, WEEK 8, WEEK 9
PHASE FOUR: WEEK 10, WEEK 11



# Where are we in the LSST Data Release?



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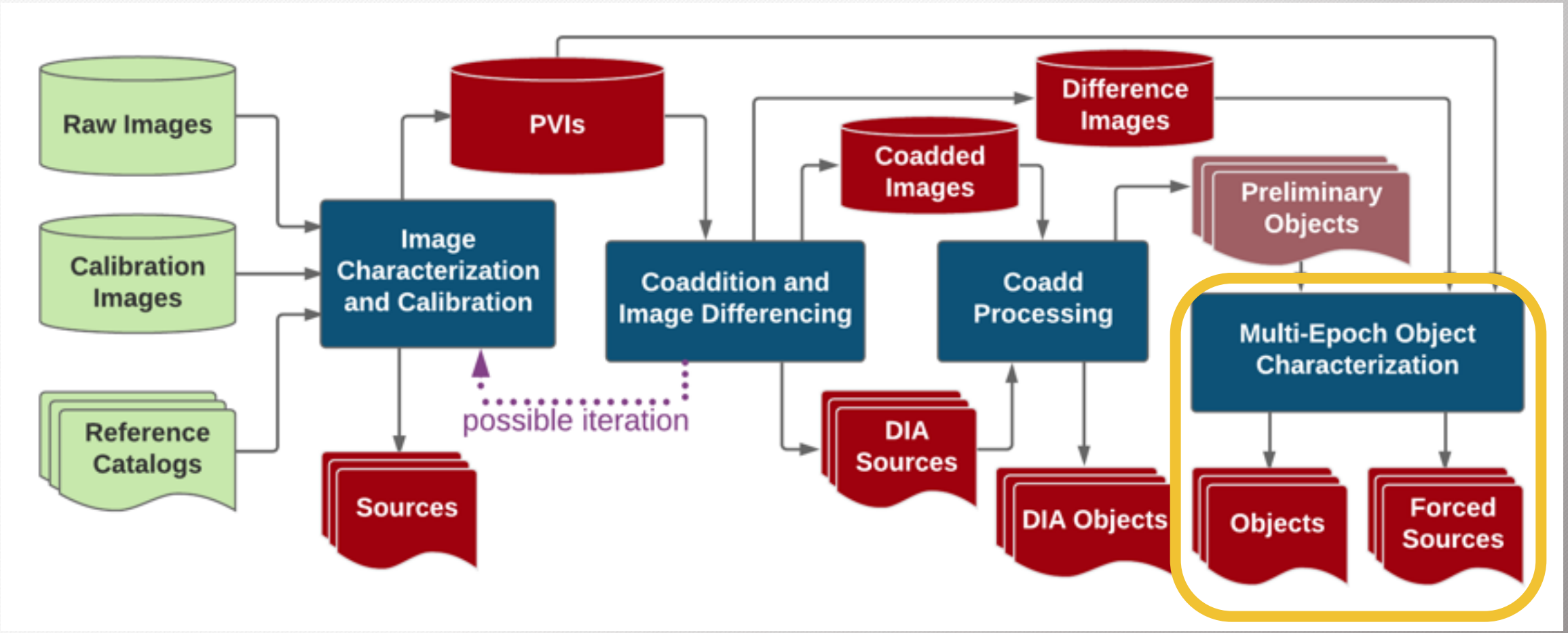


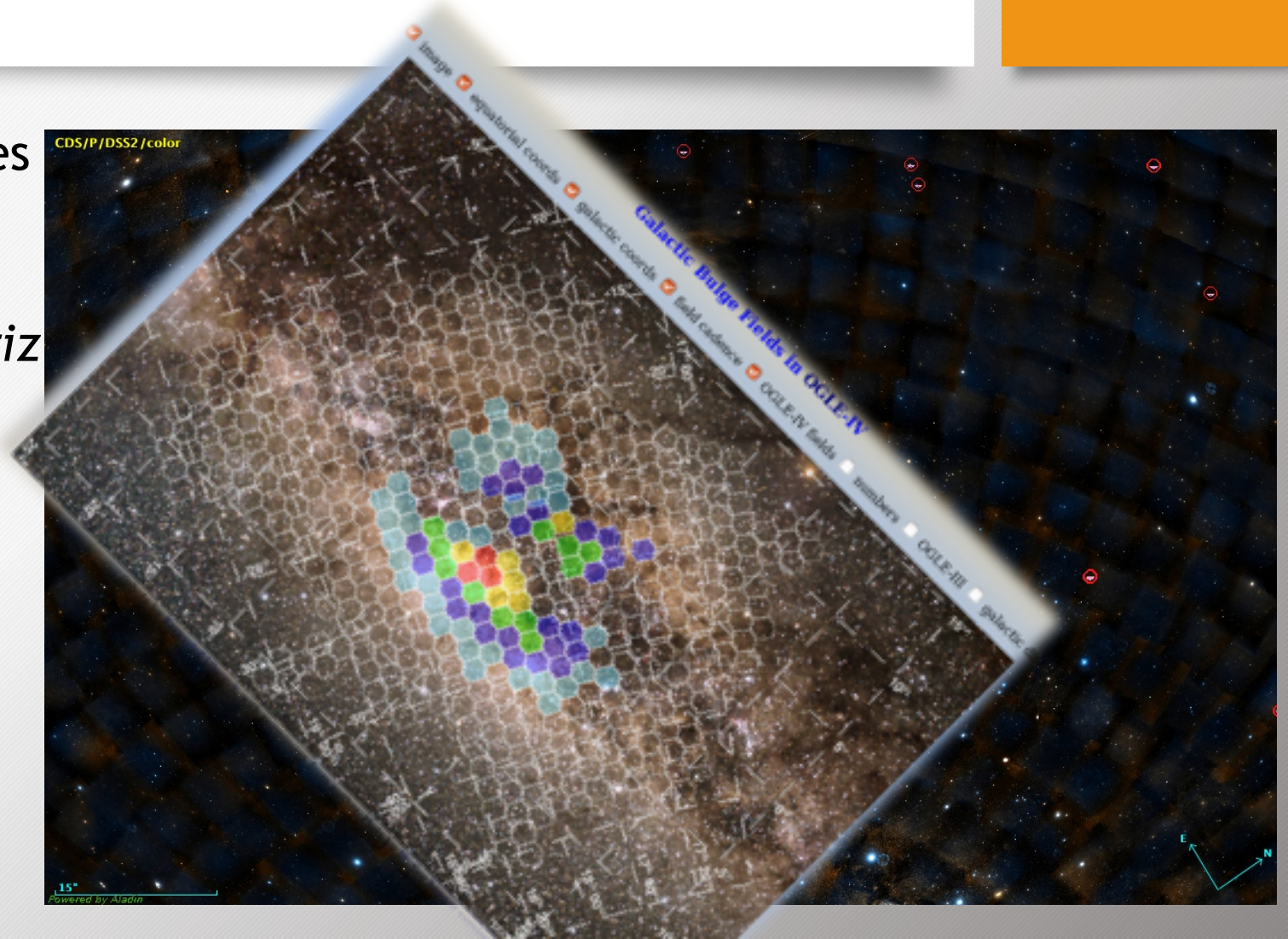
# The ideal benchmark

- We need a robust, high quality and deep dataset
- Severe crowding
- Time-series
- Large Field
- “Level 3” data product already available: calibrated images
- Known variables

# Test Dataset: the Galactic bulge

- DECam calibrated archive images (NOAO 2013A-0719, PI: Saha, 4156 images)
- More than 50 epochs per band with exposures > 10s, in the *ugriz* bands
- Project designed to detect RR Lyrae stars

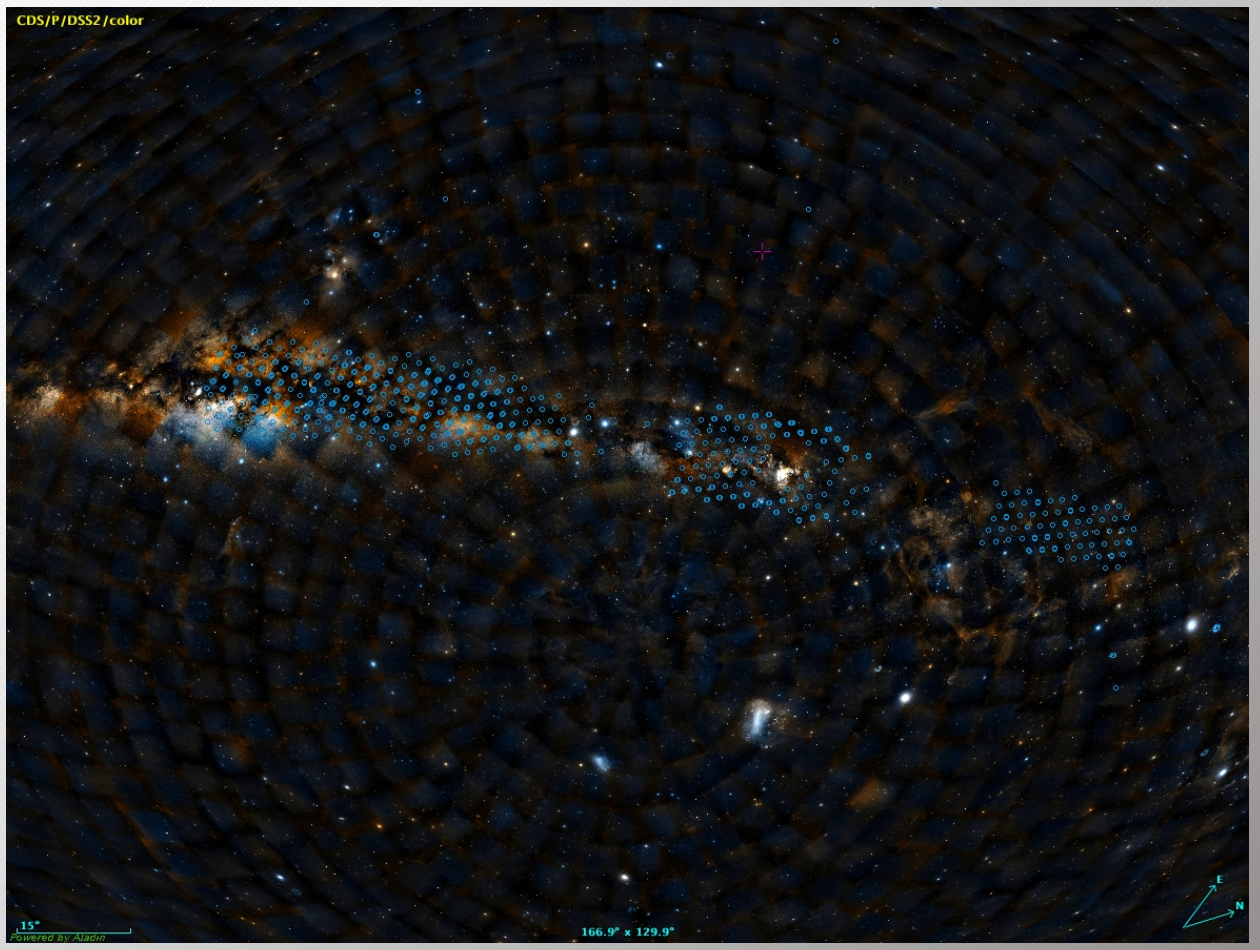
- Known variables from OGLE IV
- Local standards from DECam Plane Survey (DECaPS)



# Other data

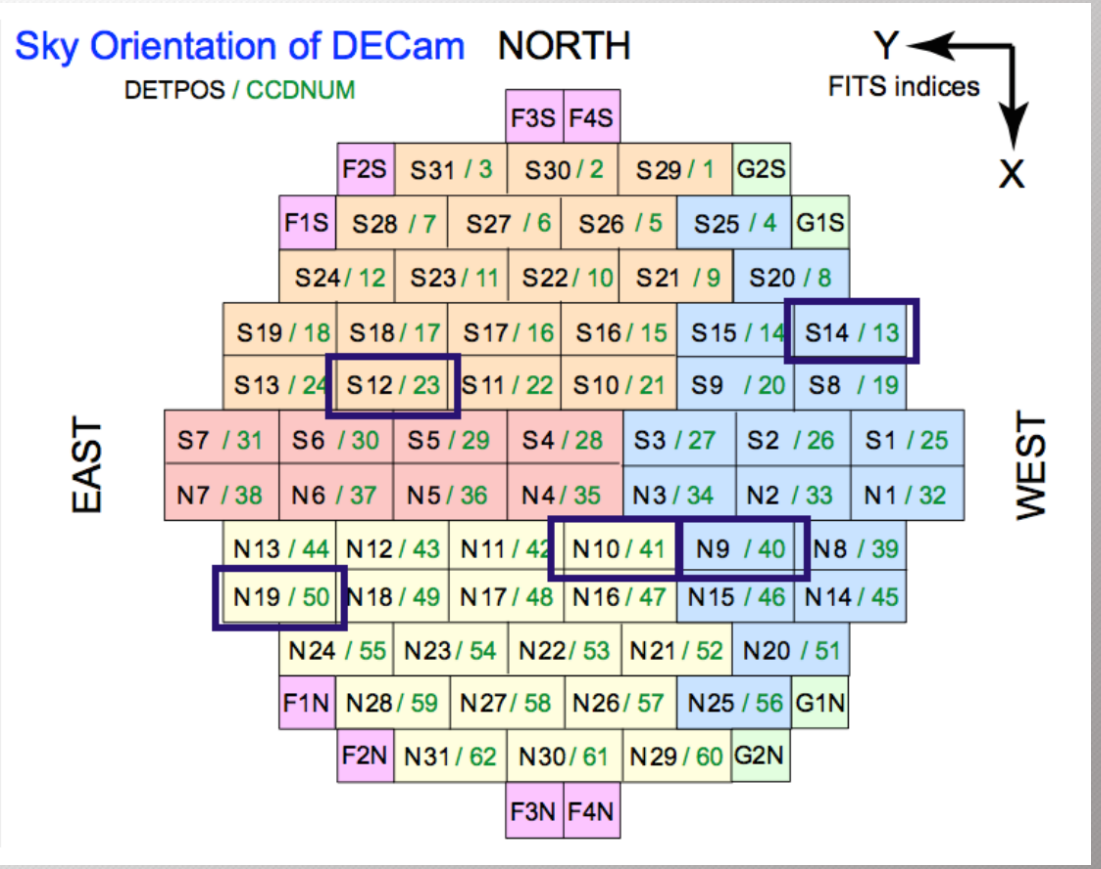
- At a first stage, we discarded other available DECam data (too away from the center of the Bulge, poor overlap with OGLE IV, too few epochs)

- 2014A-0429: bands *griz*, 1328 images (PI: Finkbeiner)
- 2016A-0327: bands *grizY*, 2319 images (PI: Finkbeiner)
- 2016B-0279: bands *grizY*, 6150 images (PI: Finkbeiner)
- 2017A-0936: bands *grizY*, 190 images (PI: A. Calamida



# Test Dataset: the Galactic bulge

- We identified a subset of “only” 150 mosaics (*resampled*, not *stacked*)
- We focused (to date) on *r*- and *i*-bands
- In a first step, only a few CCDs selected, typically with a higher number of known RR Lyrae
- Then, at this preliminary stage we decided to fully focus on a single CCD, to perform a deeper analysis
- Unfortunately, the LSST pipeline is still at a too crude stage, and it was not available at the time of the beginning of our experiment

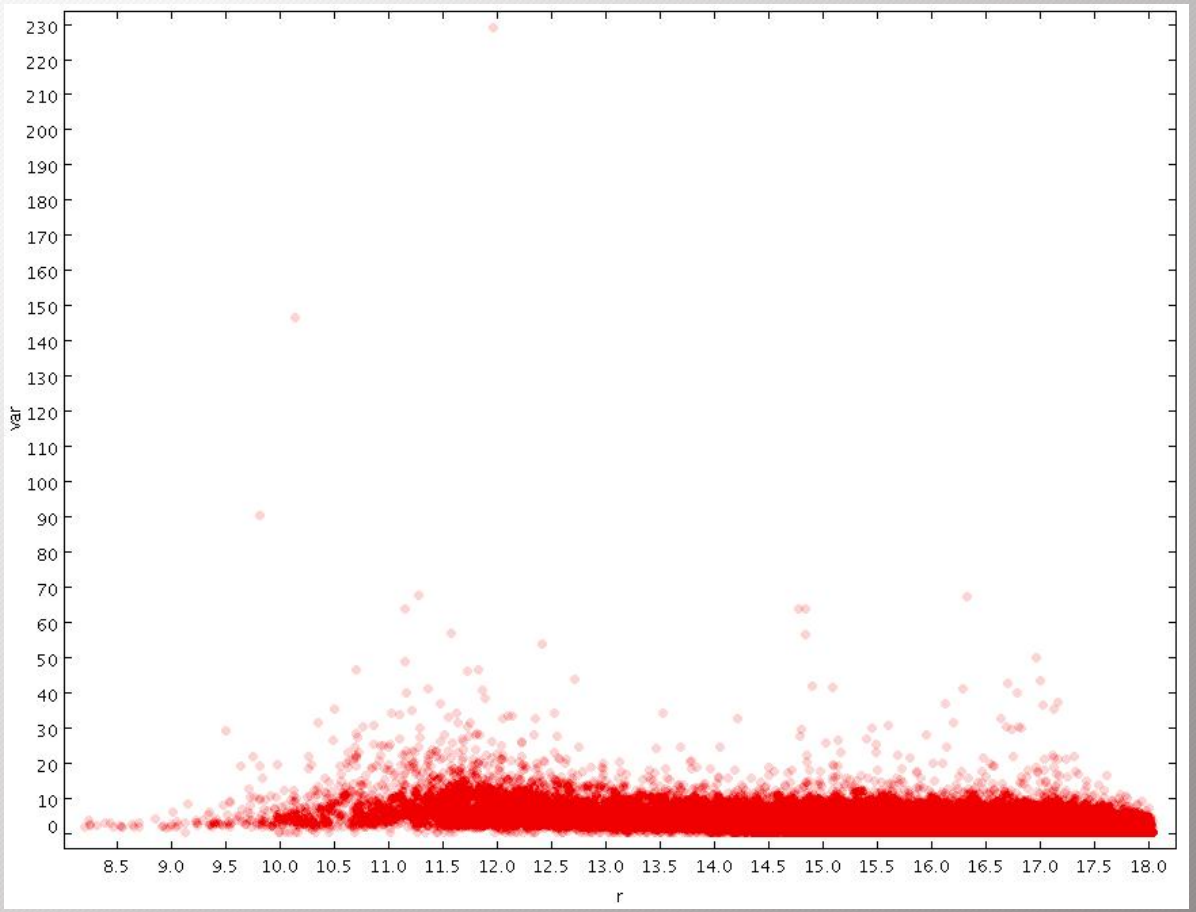


# Blind analysis approach

- DAOPHOT/ALLSTAR reduction
- Fully automated PSF photometry: no visual check of the PSF stars, automatic discarding the outliers
- To test our procedures, we focus only on the *r*-band images
- TBD: photometric calibration based on DECaps
- Search for variability: spread of the photometry and FFT power spectrum
- FFT and Phase Dispersion Minimization analysis → periods search
- Cross-match with the OGLE IV catalogue
- Manual check of the light curves?

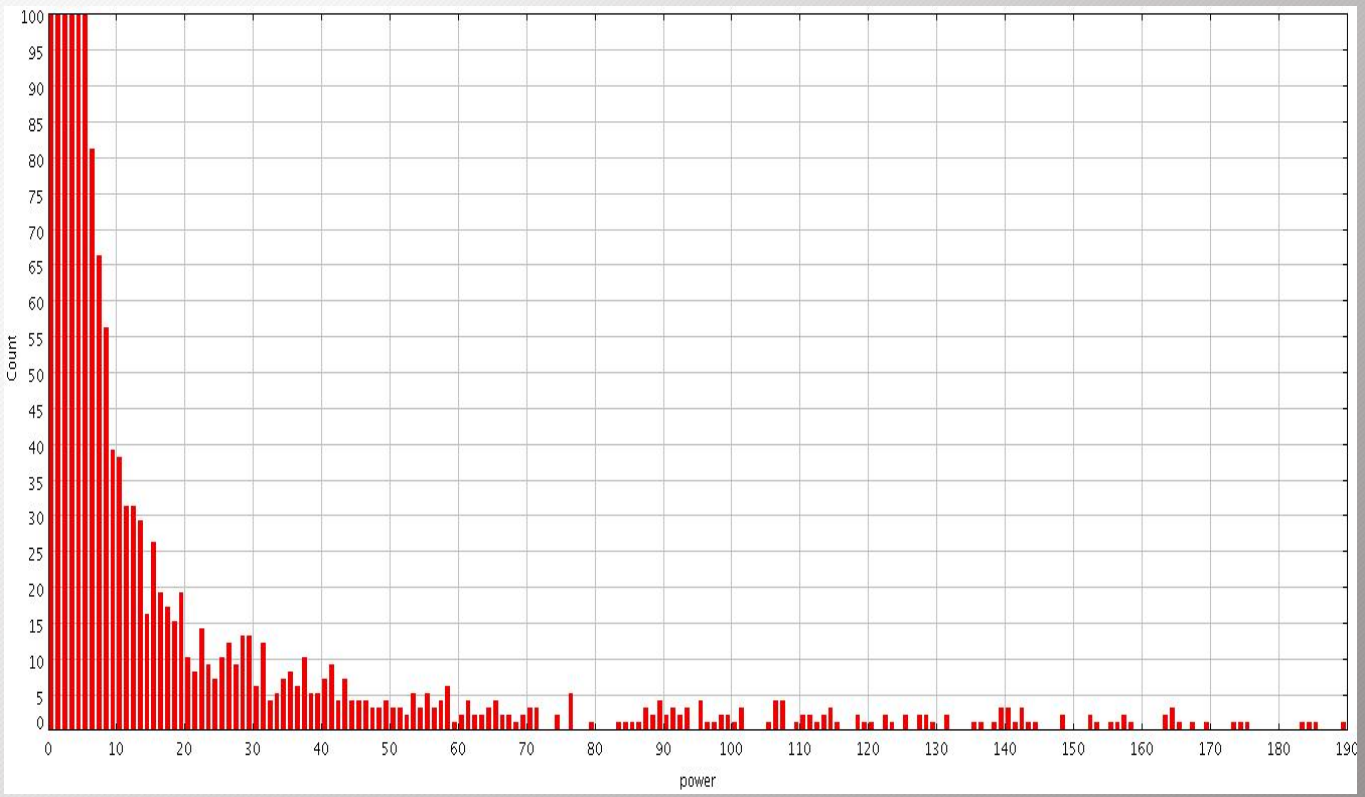
# Blind analysis approach: individual steps

- Automatic PSF photometry
- Astrometric solution
- photometric catalogue of 211,989 sources (in a 5’ x 10’ arcmin^2 area)
  - Cleaning from unwanted sources → unresolved blends, galaxies, spikes → daophot *chi* and *sharpness* parameters → 40k sources
- Variability criteria → Stetson’s variability index and minimum number (15) of measures→ 4,434 sources



# Analysis approach: individual steps

- FFT analysis, to check (periodic) variability and find preliminary periods
- Only sources above a given power spectrum value have been considered → 487 sources
- PDM period search
- Light curves

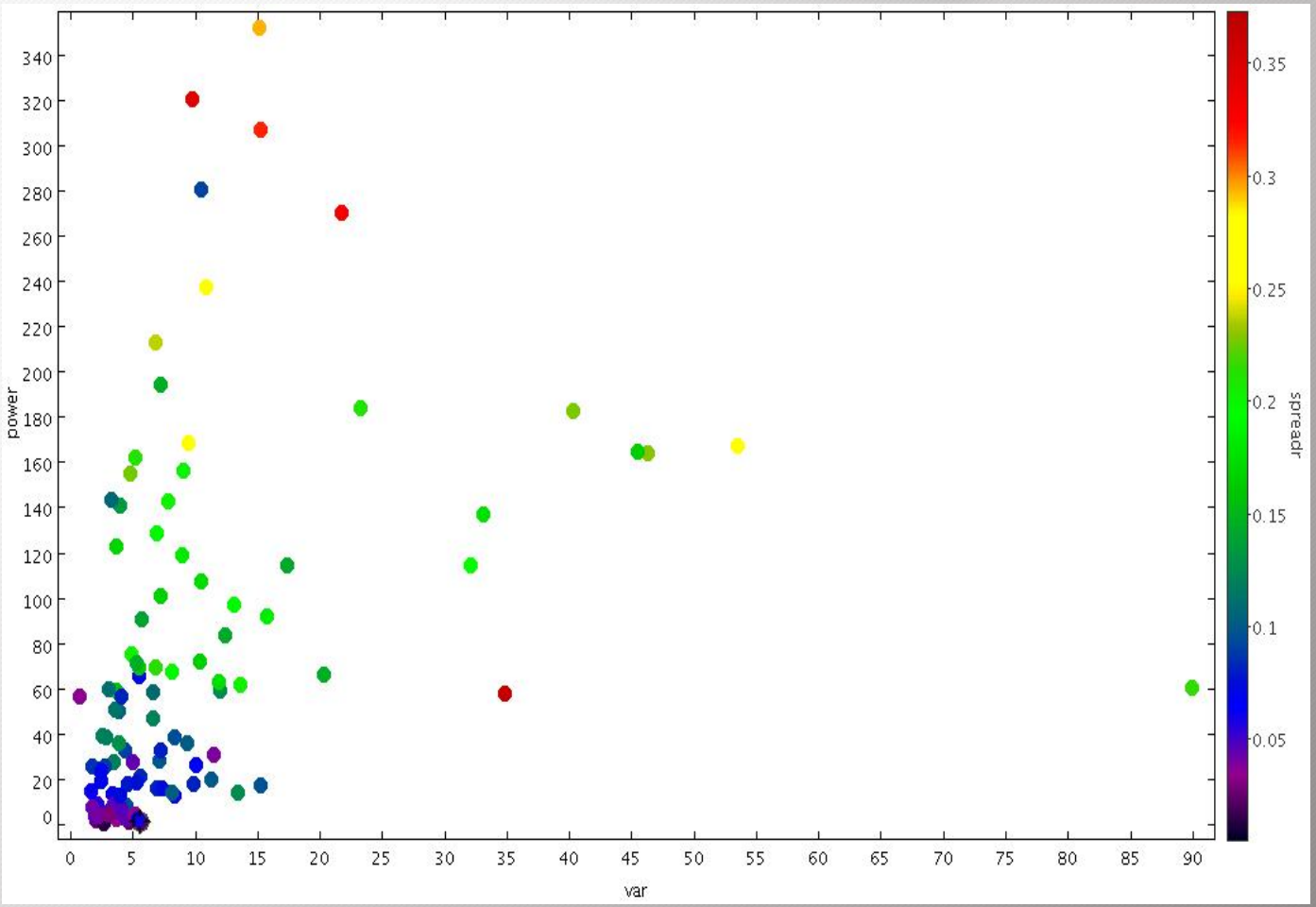


# Validation: OGLE IV comparison

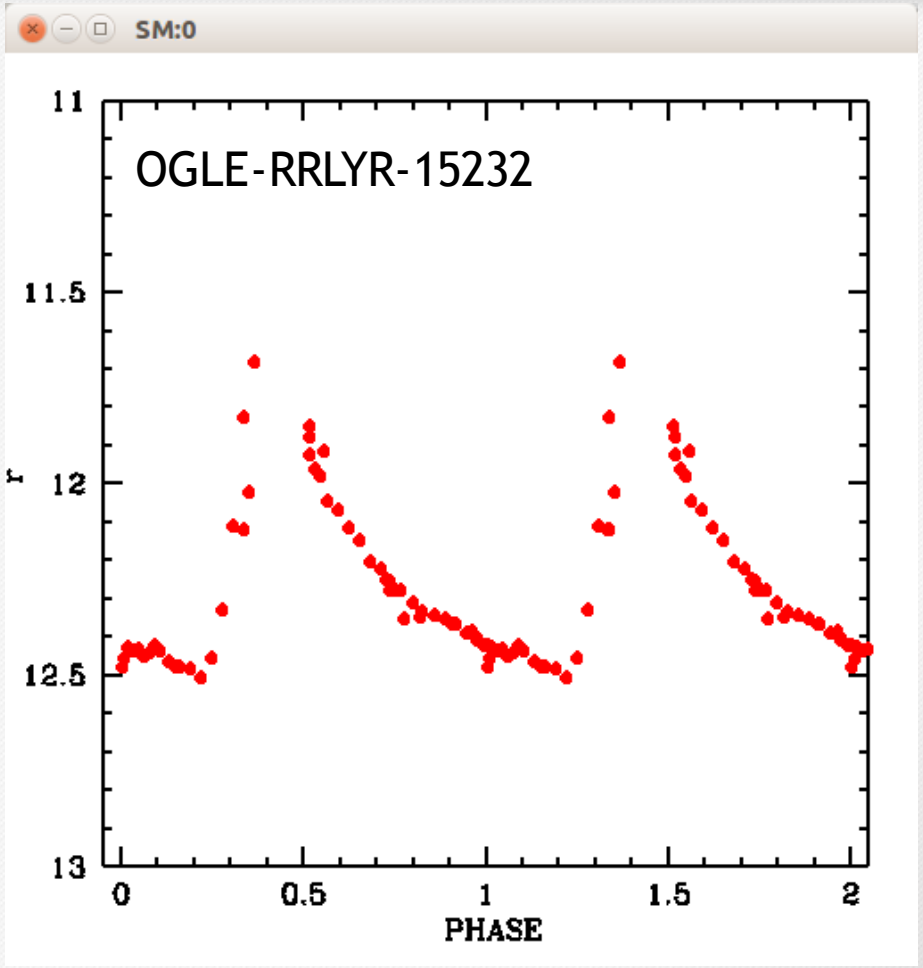
- OGLE IV
  - 9 RR Lyrae stars
  - 123 eclipsing binaries
- Us
  - 8 RR Lyrae stars (one with only 10 measures, and then cut by our selections)
  - 30 eclipsing binaries fully detected
  - 23 with < 15 measures, or undetected
  - The others cut by the adopted criteria

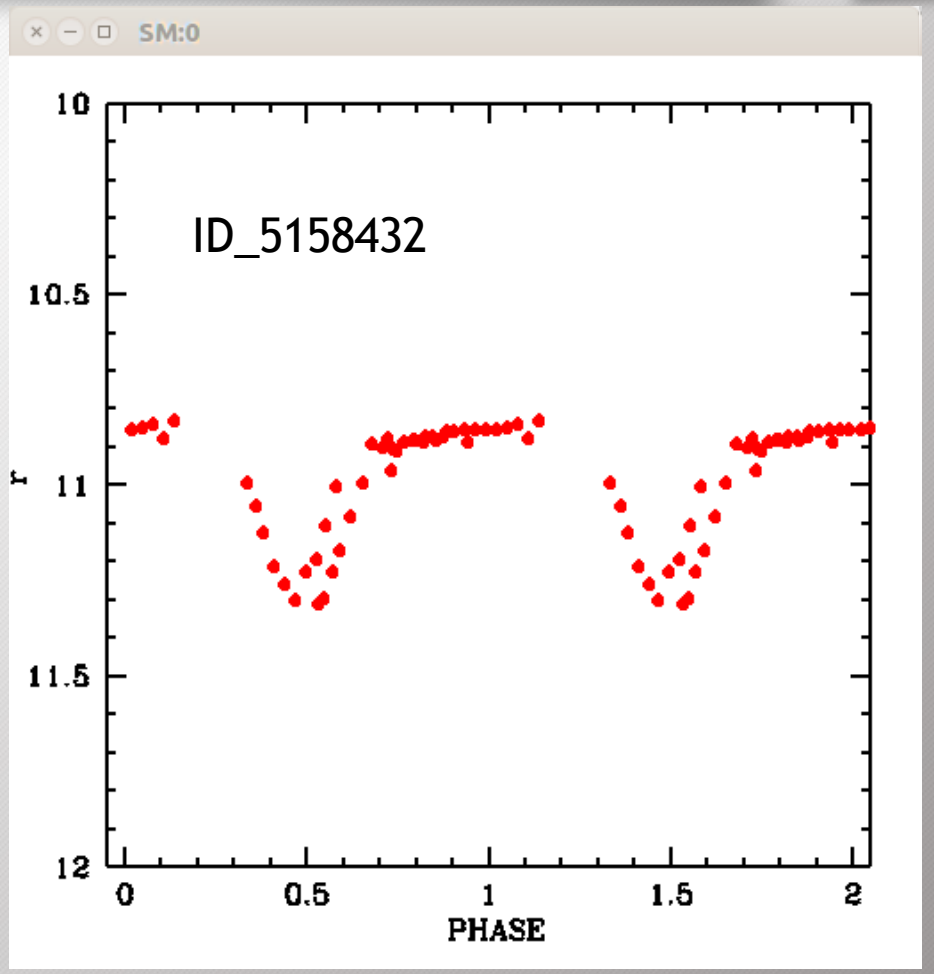
# Which stars are we missing?

- Our technique, with the current photometric accuracy, isn't efficient with variables with amplitudes lower than 0.05 mag
- Waiting for ALLFRAME



# Some examples



# Next Steps

Ok, we found the variables with PSF photometry, not a surprise, but…

- what is the lesson learned for the LSST pipeline? DIA is ok, but… is the only possible technique?
- In the LSST era, which will be the best reduction/analysis strategy?
- What is the “best” (i.e. more effective) cadence for the various variables? → Deep Drilling Fields?

# Next steps

- Full ALLFRAME reduction of the images → better determinations of the centroids and deeper reference catalog → better photometry
- RR Lyrae stars: light curves, comparison of the pulsation parameters with OGLE
- Experiments on the cadence (by adding the other available datasets?)
- Search for new and faint variables: experiments with several techniques (var. index, FFT, other)

# An independent long term project?

- Mining the DECam archive, we can put all the stuff together and get
- A deep view of the Bulge
- A wide view of the Bulge → what about calibration?
- A long-term view of the Bulge → 4 years baseline
- But…
- We are talking about of 13,763 images → 880k individual CCD images
- This means fully automated procedures (and a lot of disk space)