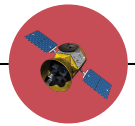
@hubble86_

A PSF-based Approach to TESS High quality data Of Stellar clusters

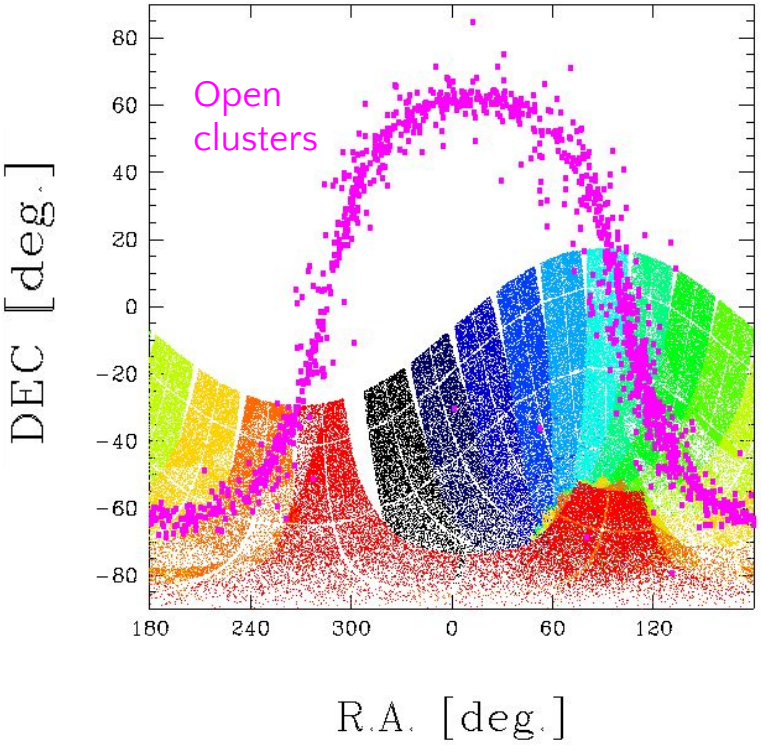
TESS Science Conference I
Cambridge, July 31st, 2019



Nardiello Domenico
Università degli Studi di Padova
Dipartimento di Fisica e Astronomia “Galileo Galilei”

Stellar clusters with TESS

- **Stellar properties** of cluster members are more reliably measured than for field stars
- Stellar clusters have **well measured ages** that go from ~10 Myr up to ~10 Gyr (Bossini+2019)
- **>1500** open and globular clusters and young associations populate the Milky Way and **almost all of them will be observed by TESS**



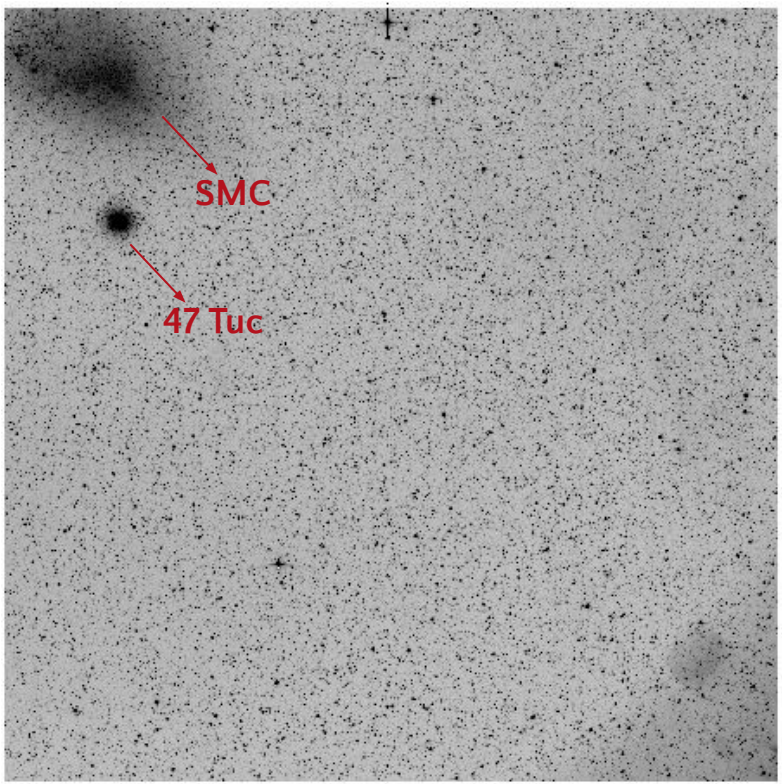
Photometry of stars in crowded environments

The PATHOS pipeline

From FFIs to Light curves

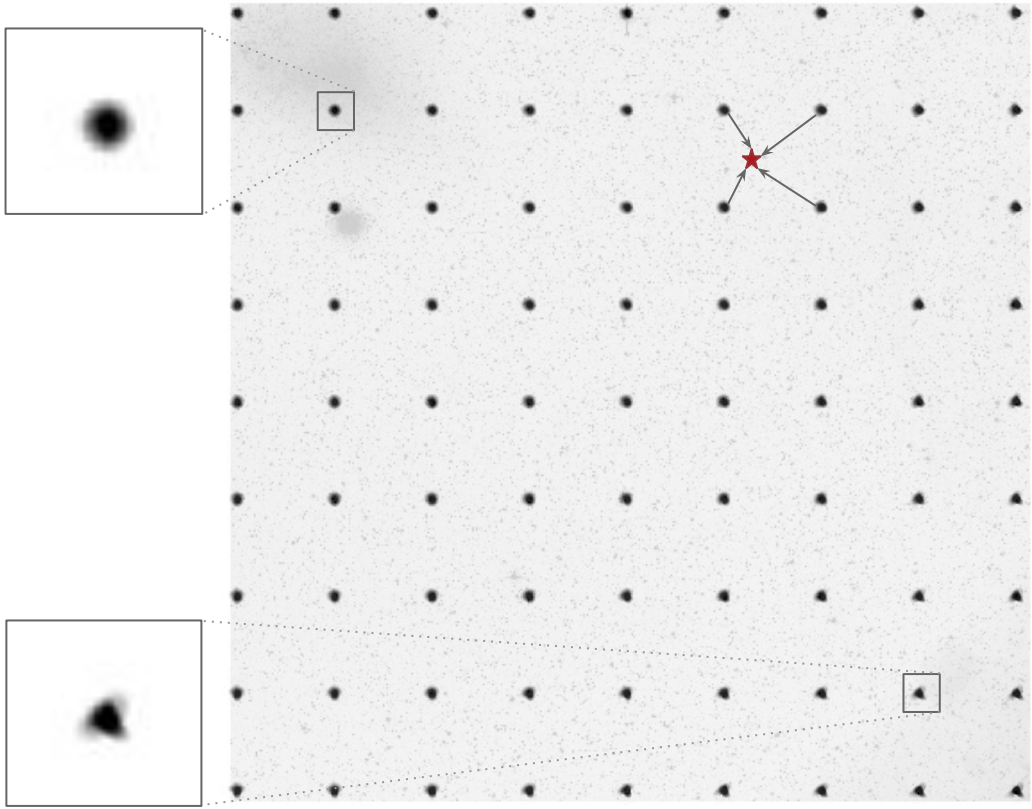
- FFIs download
- Empirical PSFs extraction for a CCD of a Camera
- Light curves extraction

Sector 1 – Camera 3.2



Empirical PSFs

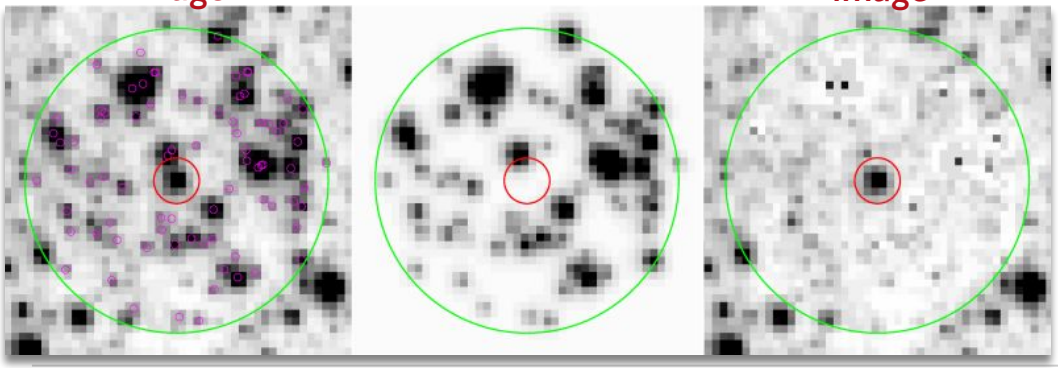
- Modelling the best PSF is important for:
  - the subtraction of neighbour stars
  - the extraction of high precision photometry for faint stars
- 9x9 array of **empirical PSFs** for each CCD
- Each PSF model in the array is associated to a region of the image
- **High variation** of the PSF model among the FoV of the single image
- For each point `(x,y)` on the CCD, extraction of a local empirical PSF given by the the bi-linear interpolation of the 4 closest PSFs



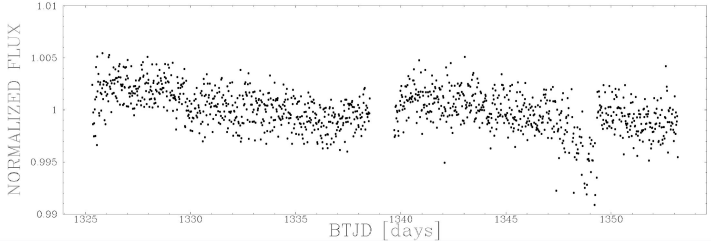
Light Curve Extraction

- **Software** developed by me: `img2lc`
- **Input**:
  - ✓ Full Frame Images
  - ✓ Empirical PSF arrays
  - ✓ Input catalog: Gaia DR2
- **How it works**: Given a target star in the input catalog, the software **subtracts all its neighbor sources** and measures the target flux:
  - ✓ Aperture photometry
  - ✓ PSF-fitting photometry
- **Output**: light curves of the stars in the input catalog

Full Frame Image – Model = Neighbor-subtracted image



Raw Light curve

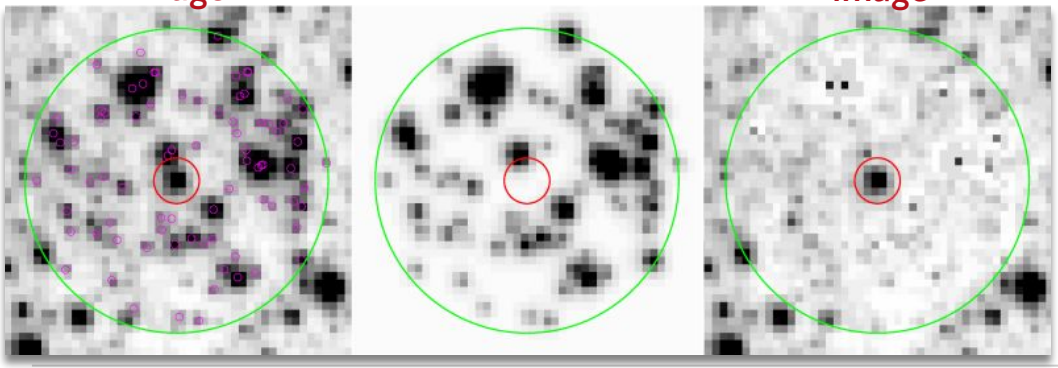


$T \sim 12.8$

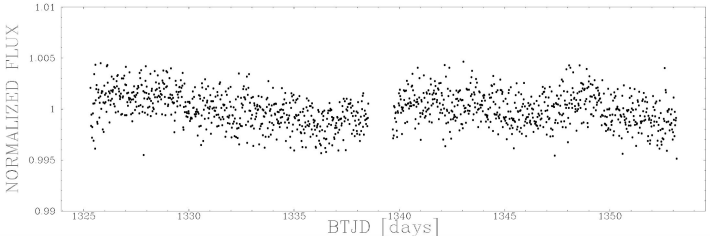
Light Curve Extraction

- **Software** developed by me: `img2lc`
- **Input**:
  - ✓ Full Frame Images
  - ✓ Empirical PSF arrays
  - ✓ Input catalog: Gaia DR2
- **How it works**: Given a target star in the input catalog, the software **subtracts all its neighbor sources** and measures the target flux:
  - ✓ Aperture photometry
  - ✓ PSF-fitting photometry
- **Output**: light curves of the stars in the input catalog

Full Frame Image – Model = Neighbor-subtracted image



Cotrended Light curve



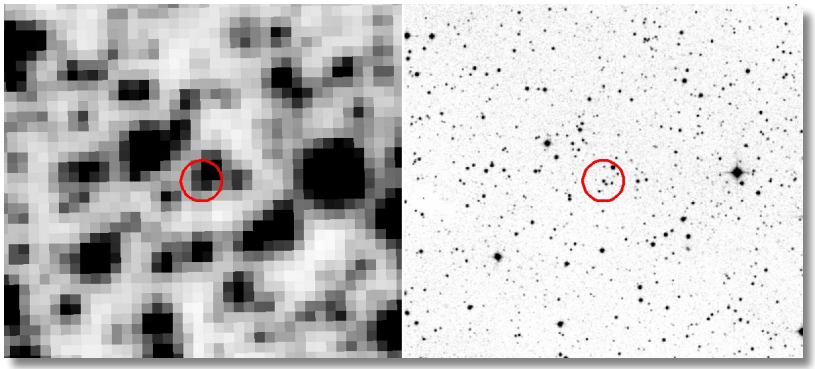
T ~ 12.8 *rms* ~ 1.5 mmag

The PSF-based approach and the neighbor subtraction

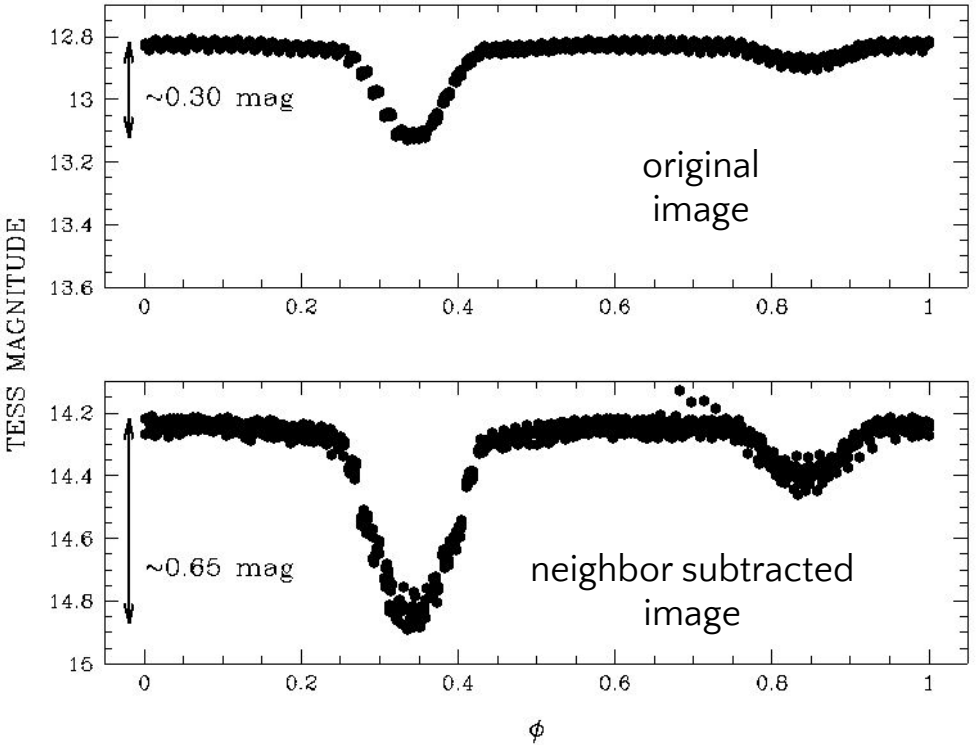
Our technique allows us to:

- **minimise the dilution effects in crowded environments**
- extract high-precision photometry (and the real flux) for faint stars (T>13)

TESS **DSS**



Raw Light curve of Gaia DR2 3336159419614147584



The PSF-based approach and the neighbor subtraction

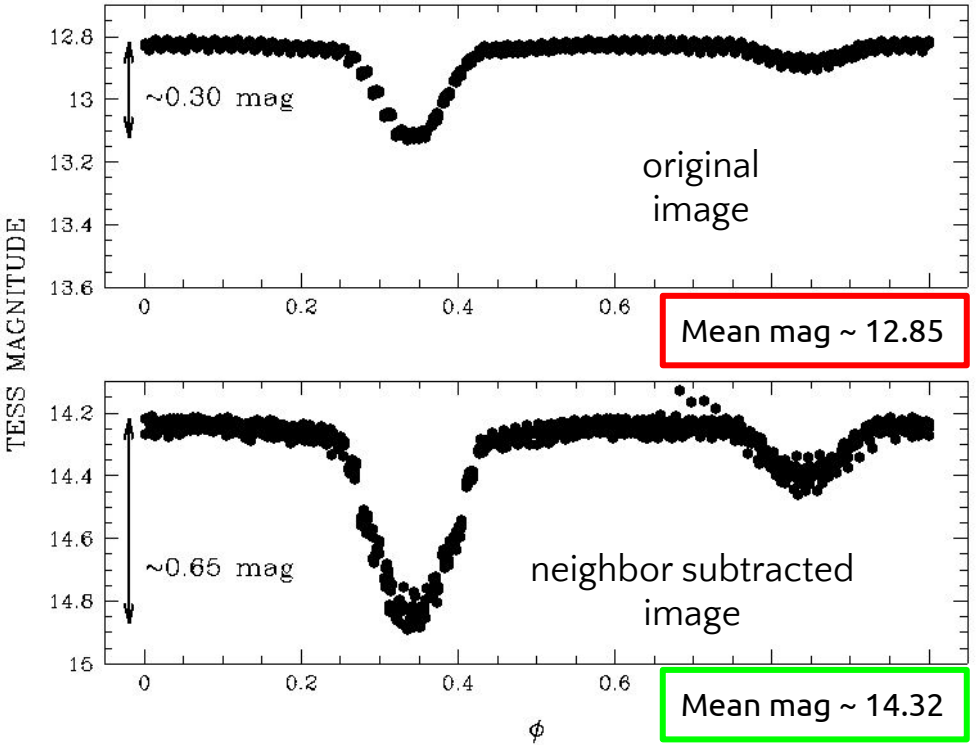
Our technique allows us to:

- minimise the dilution effects in crowded environments
- **extract high-precision photometry (and the real flux) for faint stars (T>13)**

G ~ 15.75 G_{BP}-G_{RP} ~ 2.97

Expected T ~ 14.45 (Stassun+2019)

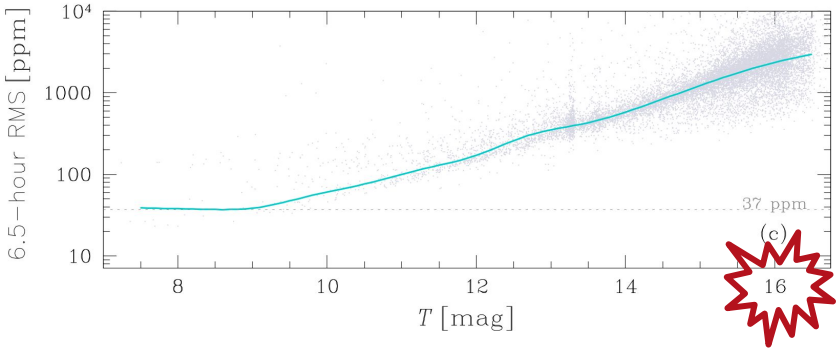
Raw Light curve of Gaia DR2 3336159419614147584



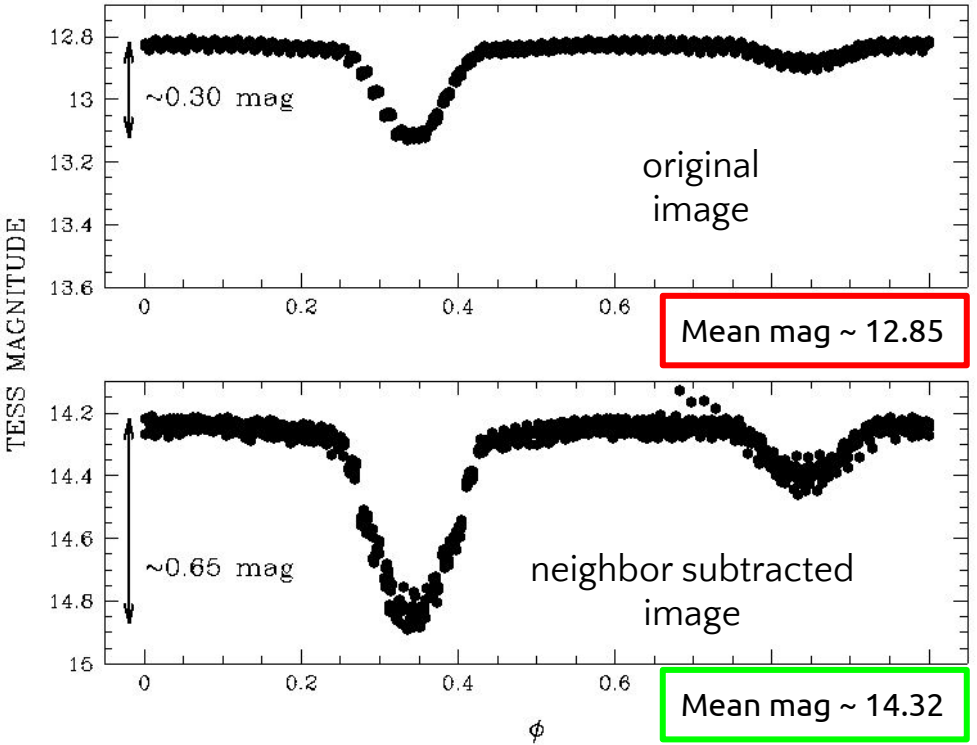
The PSF-based approach and the neighbor subtraction

Our technique allows us to:

- minimise the dilution effects in crowded environments
- **extract high-precision photometry (and the real flux) for faint stars (T>>13)**



Raw Light curve of Gaia DR2 3336159419614147584



The Pathos project

A PSF-based Approach to TESS High quality data Of Stellar clusters (PATHOS) - I. Search for exoplanets and variable stars in the field of 47 Tuc.

D. Nardiello[1,2]★, L. Borsato[1,2], G. Piotto[1,2], L. S. Colombo[1], E. E. Manthopoulou[1], L. R. Bedin[2], V. Granata[1], G. Lacedelli[1], M. Libralato[3], L. Malavolta[4], M. Montalto[1,2], V. Nascimbeni[2,1]

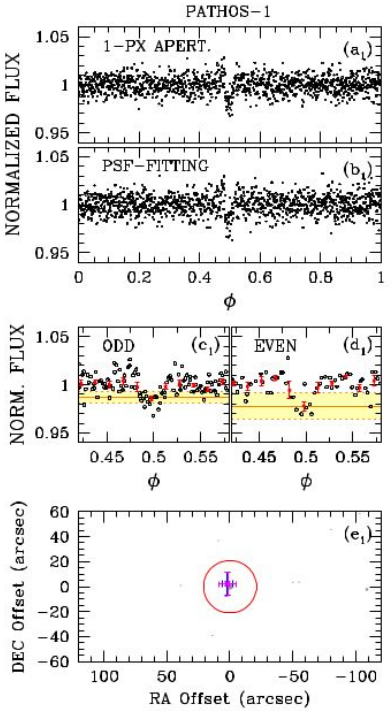
[1]*Dipartimento di Fisica e Astronomia "Galileo Galilei", Università di Padova, Vicolo dell'Osservatorio 3, IT-35122, Pado*
[2]*Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, IT-35122,*
[3]*Space Telescope Science Institute, 3800 San Martin Drive, Baltimore, MD 21218, USA*
[4]*Istituto Nazionale di Astrofisica - Osservatorio Astronomico di Catania, Via S. Sofia 78, IT-95*

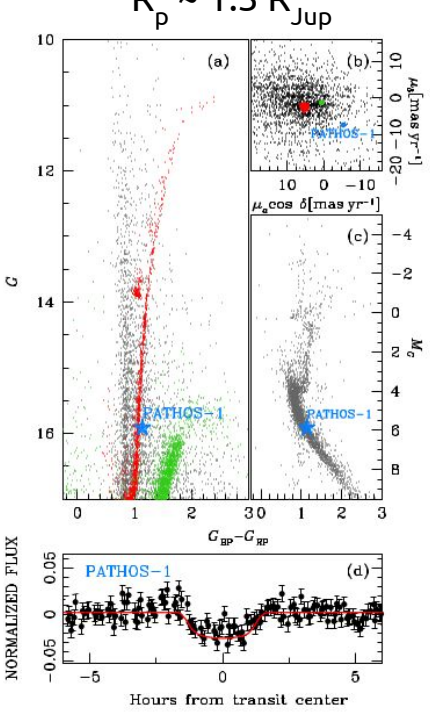
PATHOS

MNRAS submitted

Light curves used during the PATHOS project and for other works will be publically available on the MAST archive as HLSP

R_p ~ 1.3 R_{Jup}





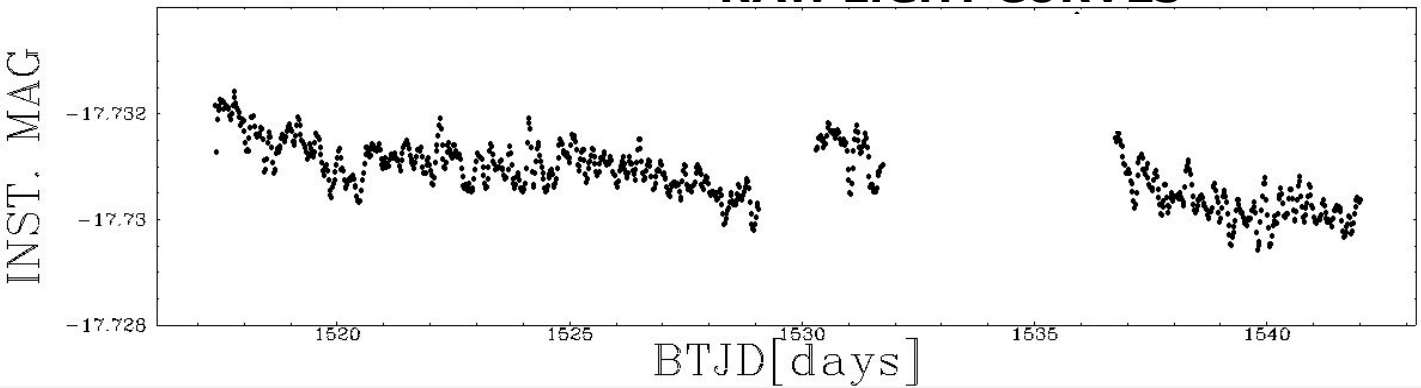
Bonus …

Bright and faint stars

Tmag ~ 2.8

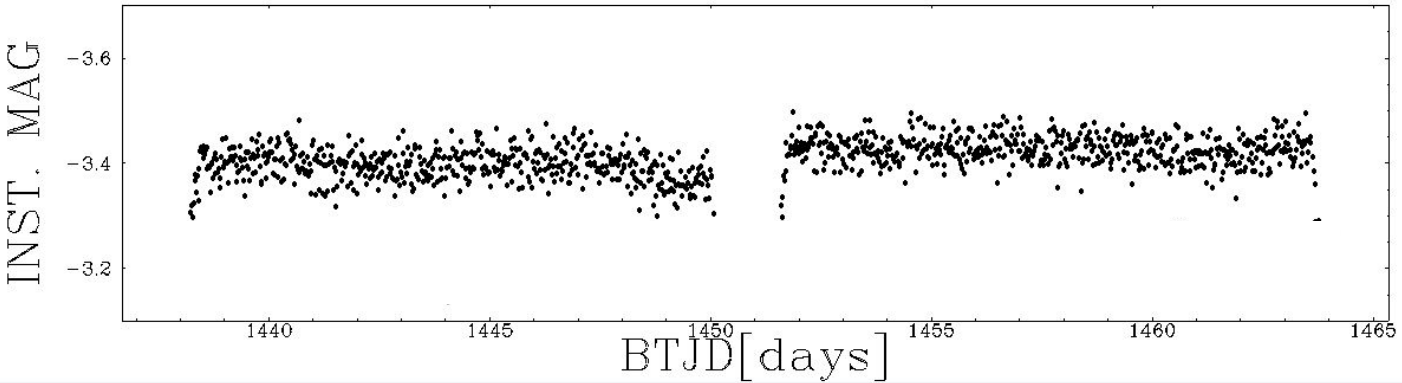
Saturated stars are recovered using the charges in the bleeding column as we already do with HST

RAW LIGHT CURVES

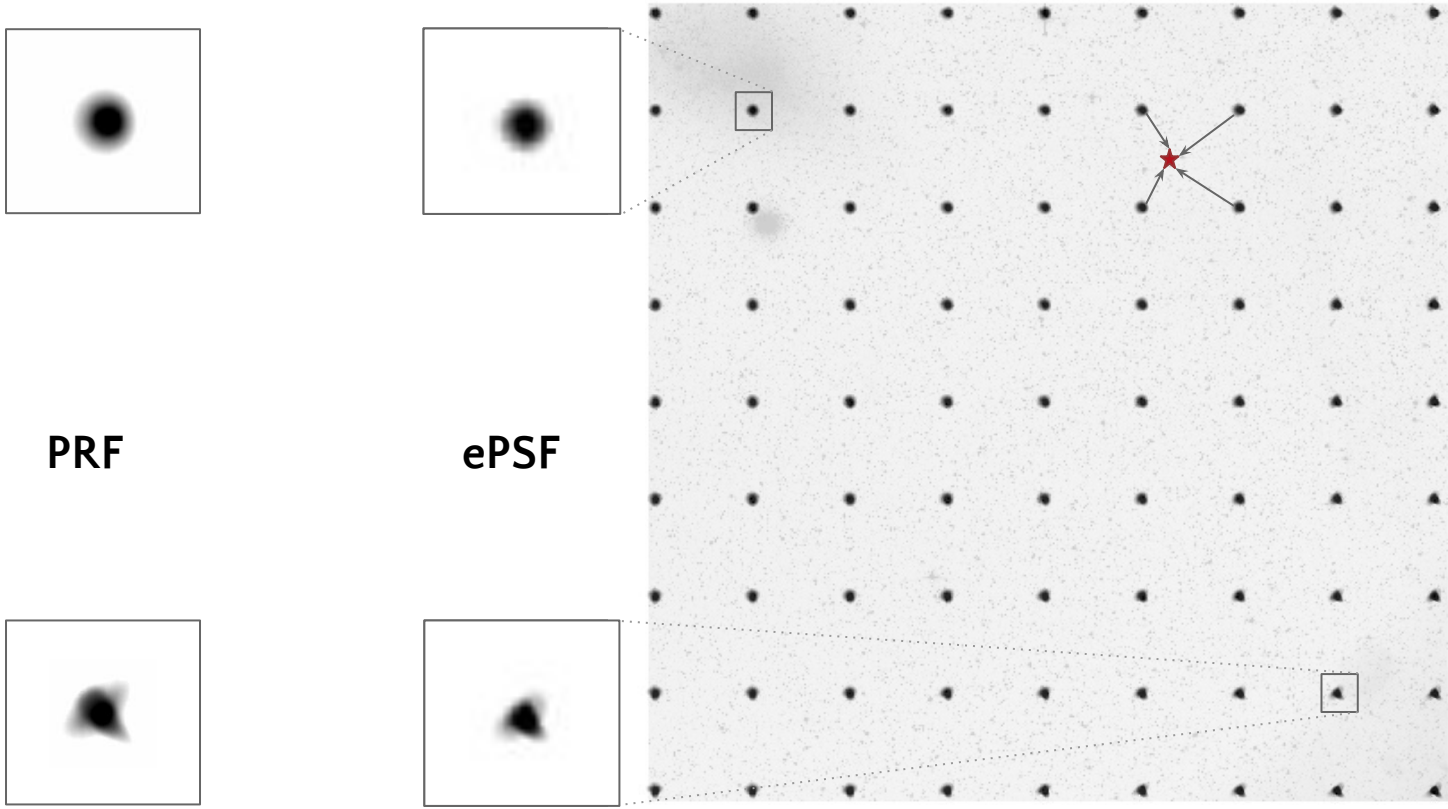


Tmag ~ 17.55

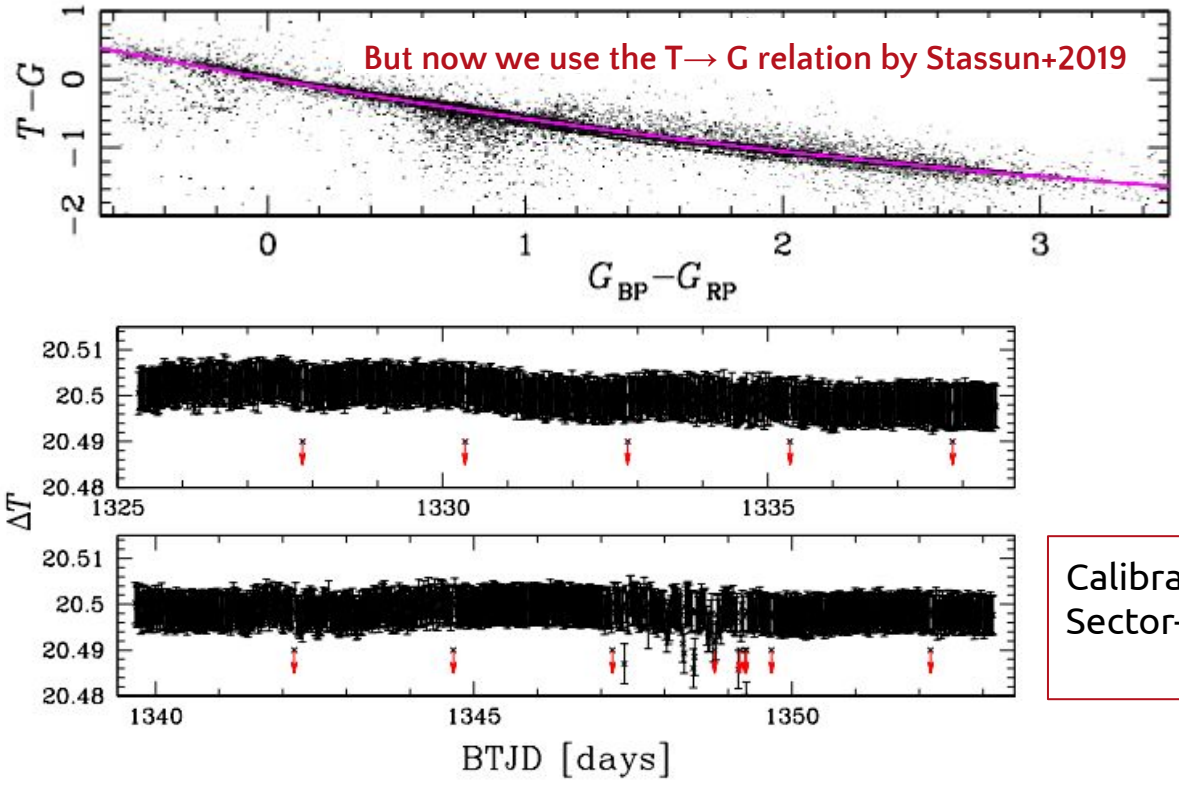
Best photometry for faint stars is the PSF-fitting photometry



ePSFs vs TESS PRFs



From Gaia DR2 to FFIs



From WCS to pixel

Astrometric transformation from Gaia DR2 (RA, DEC) to TESS FFI (pixel) is obtained thanks to the transformation coefficients and the distortion solutions in the header of the images

Calibrated -> instrumental TESS mag in Sector-1