PLATO Complementary Science

website: fys.kuleuven.be/ster/Projects/plato-cs/home

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More than 250 registered scientists

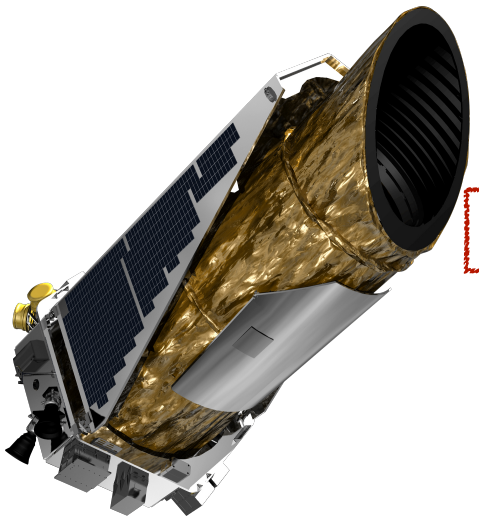
On behalf of the PLATO-CS team

Andrew Tkachenko
Institute of Astronomy, KU Leuven (BE)

Space missions and their legacy

Stellar Astrophysics Revolution triggered by space missions

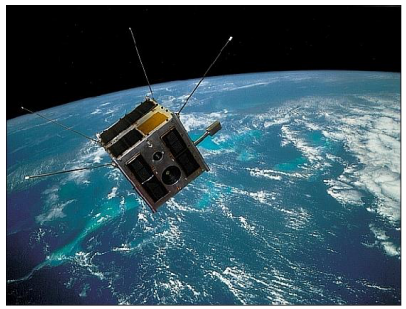
“Yesterday”



Kepler

Legacy

“Today”

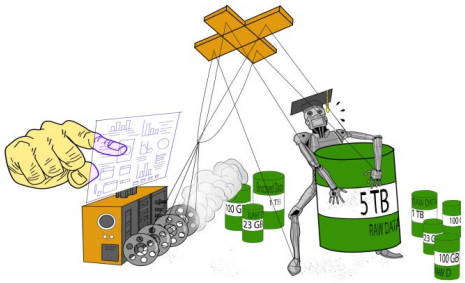


TESS (+), BRITE

Legacy

“Tomorrow”

PLATO



Millions of objects and light curves, Terabytes of data → **Stellar (Astro)physics**

PLATO Complementary Science

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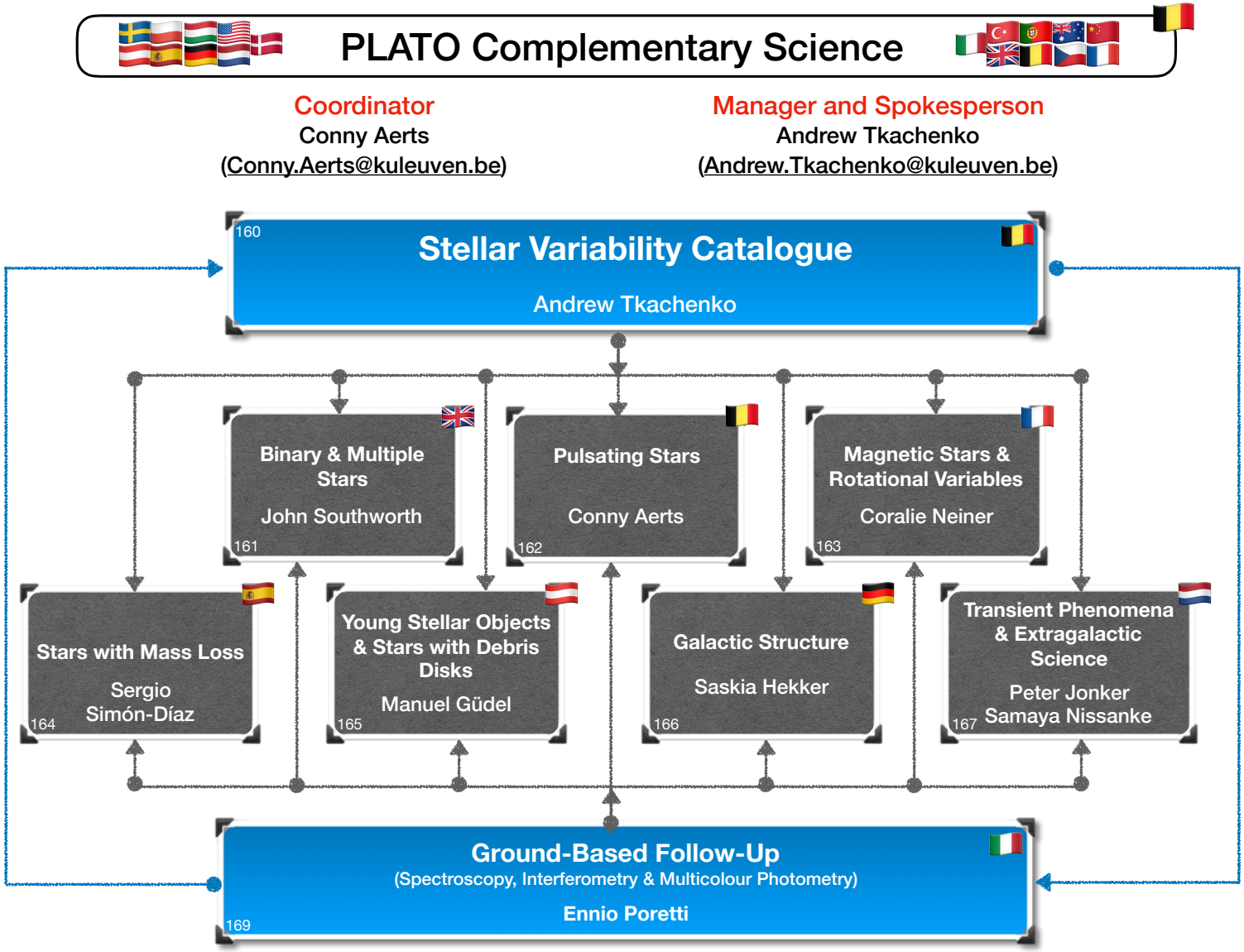


Objectives

- Scientific programmes distinct from the Core Science
- Unique database of variable phenomena

How

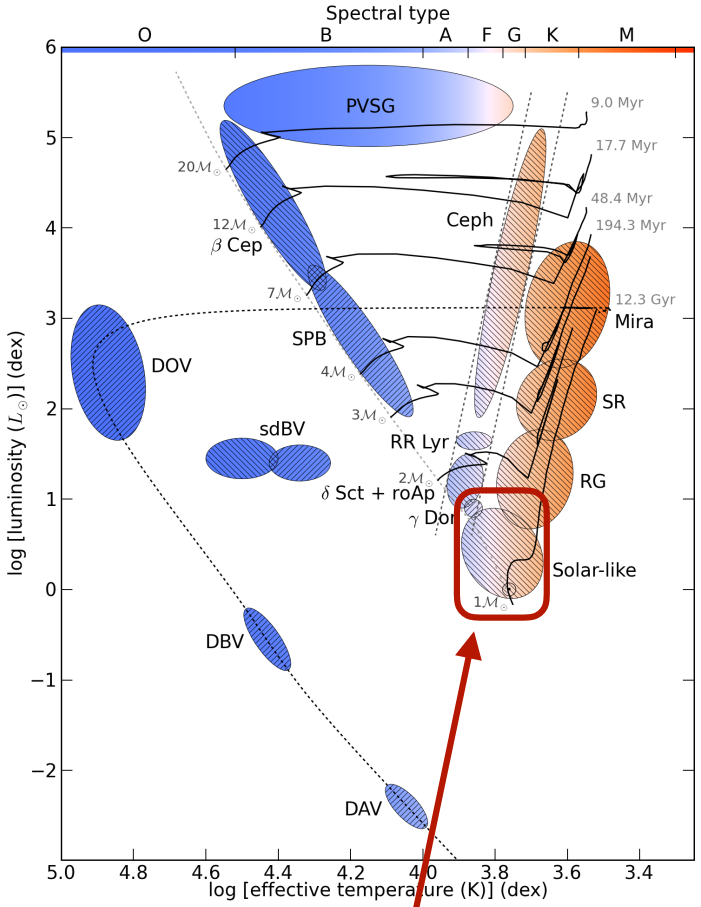
- **Guest Observer** (GO) programme (call and selection by ESA)
- GO is assigned **8% of the science data** (10^{th} of thousands objects)

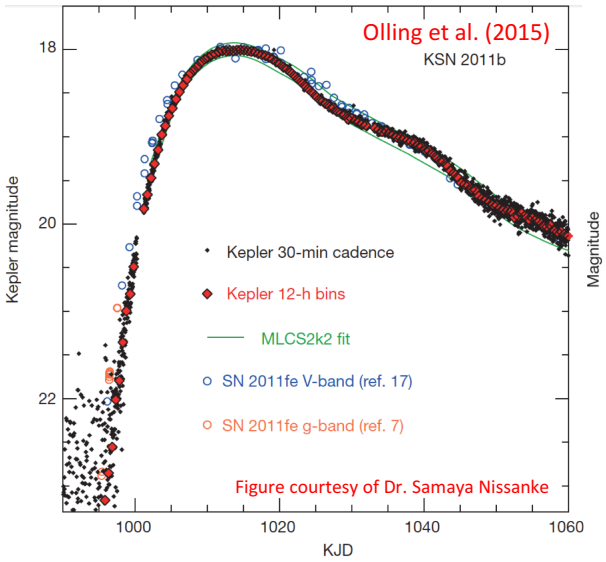
Task

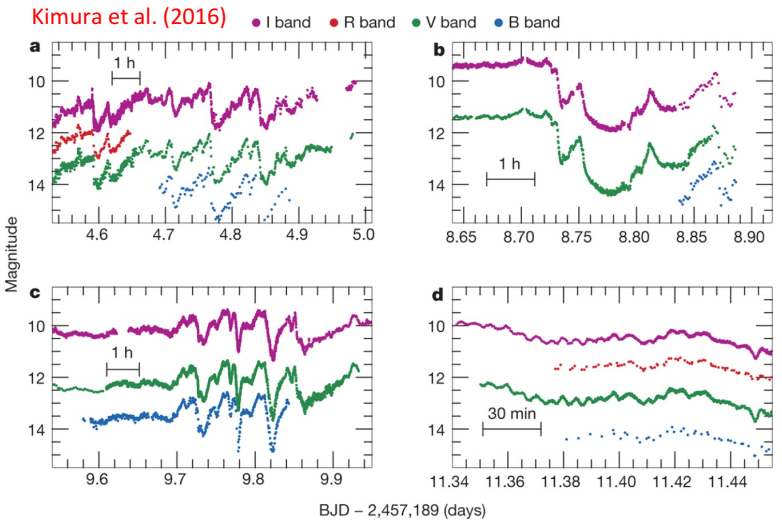
Make sure community is ready for optimal GO proposal submission

PLATO-CS: Science component

Stellar Science → **Extragalactic Science** → **Transient phenomena**







Core Science

Asteroseismology of solar-like pulsators

Extragalactic Science

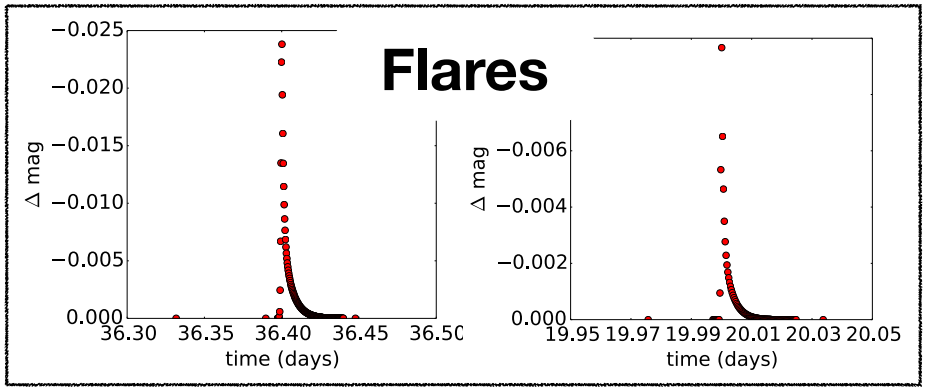
- **SNe explosions** in distant galaxies: progenitor shock-breakout physics
- **Monitoring cores of 1000s AGNs** to understand SMBH accretion & variability

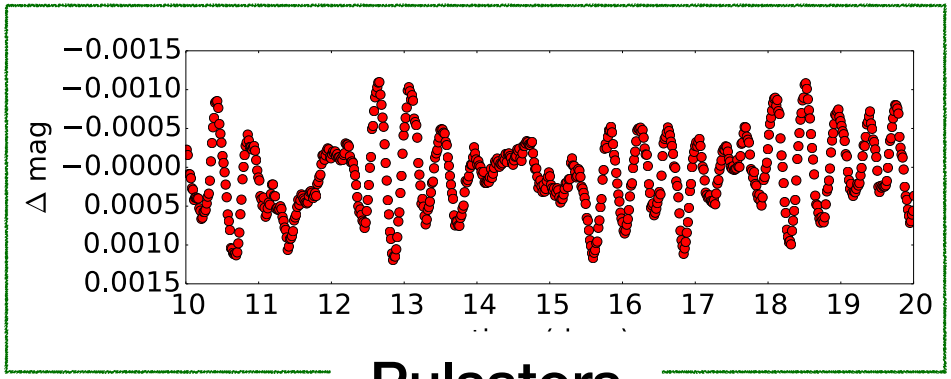
Transient Universe

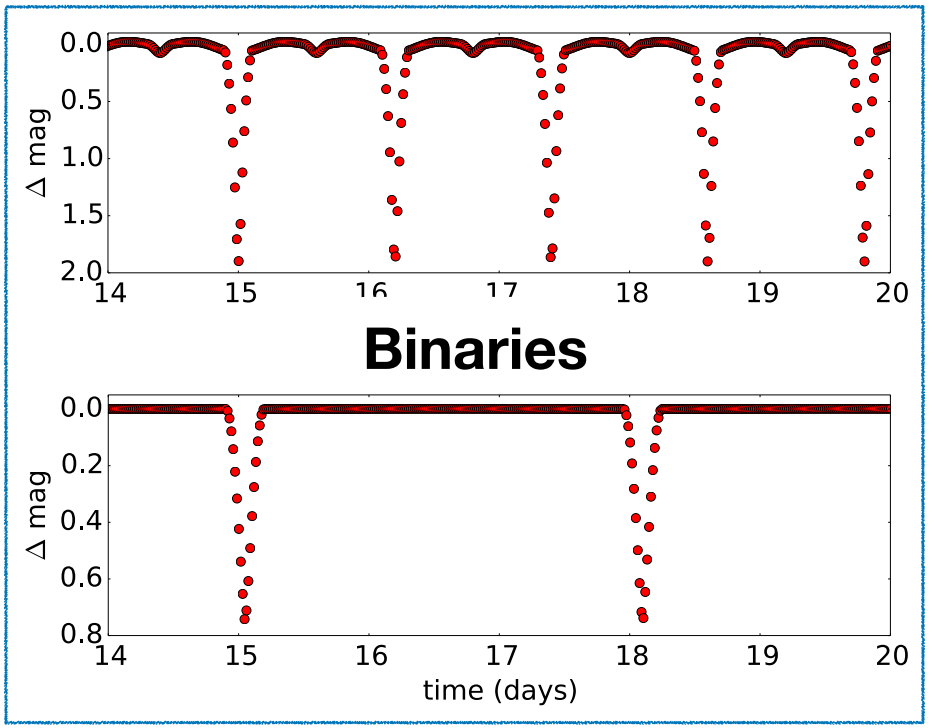
- **Mapping and understanding of accretion physics near YSOs**
- **White dwarfs, black holes, and neutron stars:** monitoring in fast cadence asap after transient

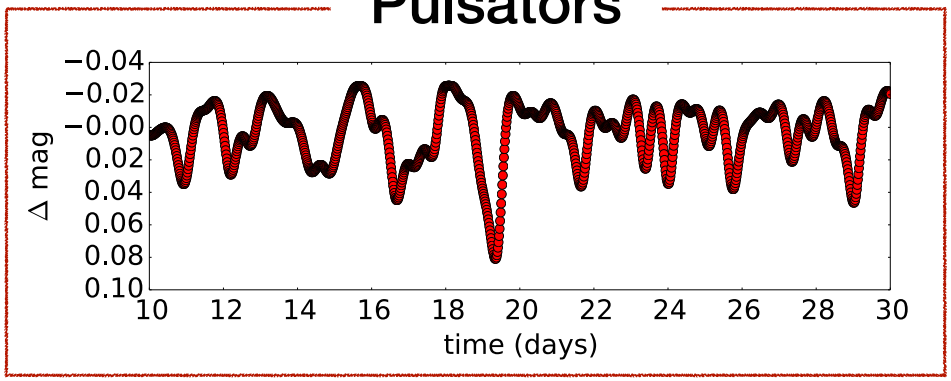
PLATO-CS: on-board & L1 data simulations

PlatoSim (http://ivs-kuleuven.github.io/PlatoSim3/) + Stellar Variability = Instrument/pipeline capabilities + Variable phenomena (PLATO-CS)









Soon

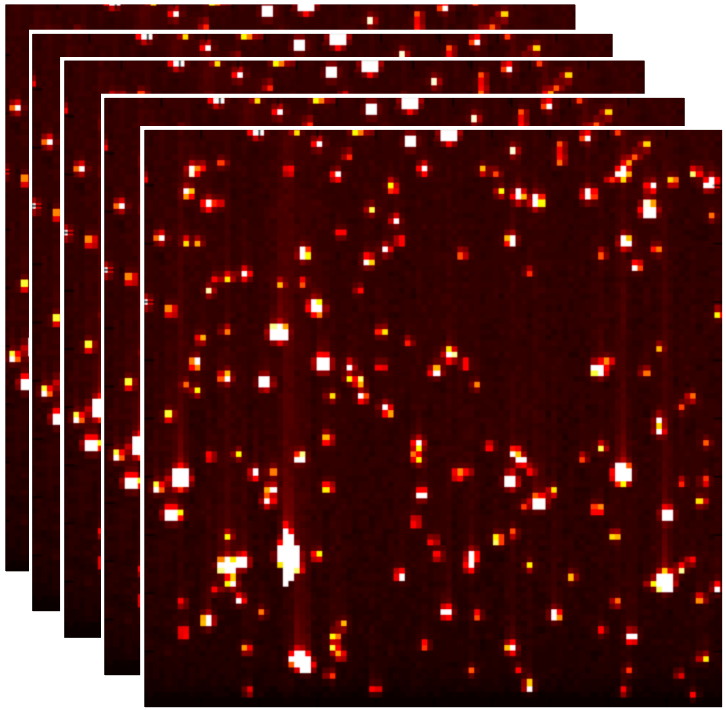
More variable phenomena will be included

Release of reference simulation data set

PlatoSim: PLATO CCD Image Simulator

- Generates time-series of CCD images
- Including realistic instrumental noise
- More and more effects are included - hard to put them on one slide in a decent font

http://ivs-kuleuven.github.io/PlatoSim3/



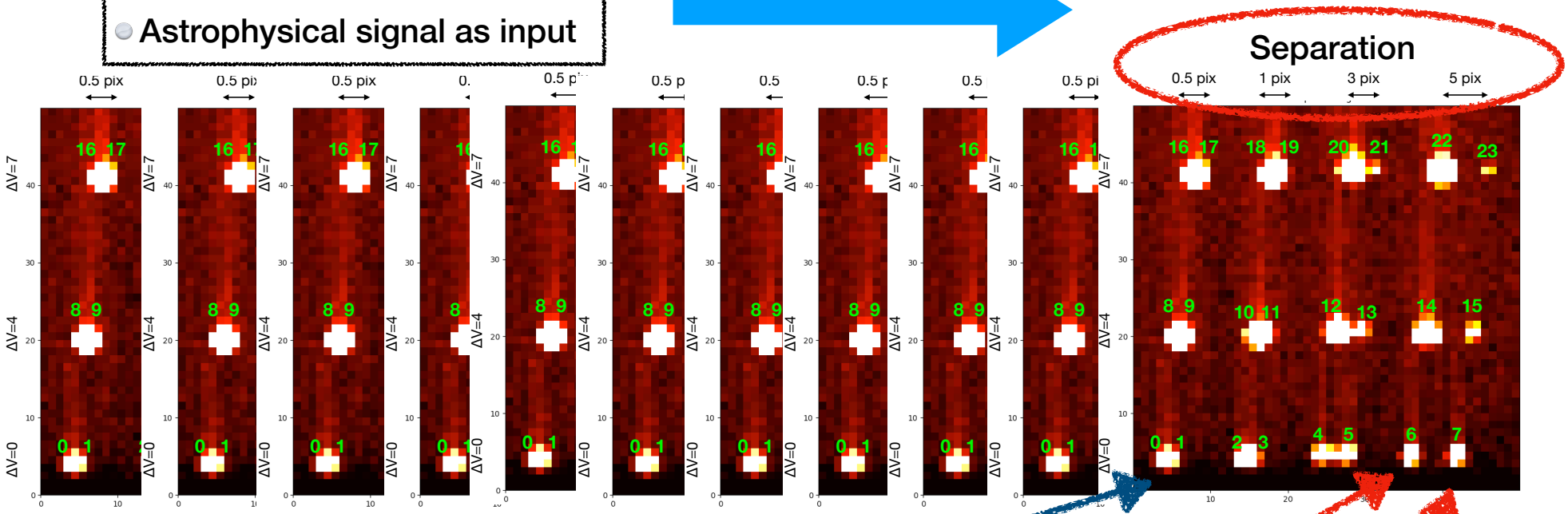
35000 exposures - Normal Cam

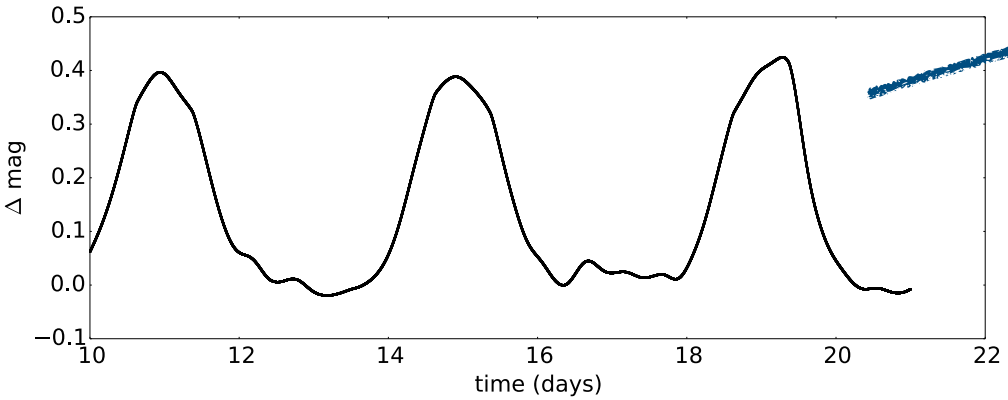
- Realistic star field
- Jitter
- Thermo-elastic drift
- Position dependent PSF
- Cosmics
- Sky background
- Variable sources
- Transmission degradation
- Kinematic aberration
- Optical distortion
- Photon noise
- Blooming
- Charge diffusion
- CTI
- CCD half dependent gain
- Geometrical vignetting
- Spatial PRNU noise
- Angle dependent QE
- Polarization
- Particle contamination
- Brighter-Fatter effect
- Dark signal
- Readout noise
- Open shutter smearing

Stellar Variability in PlatoSim

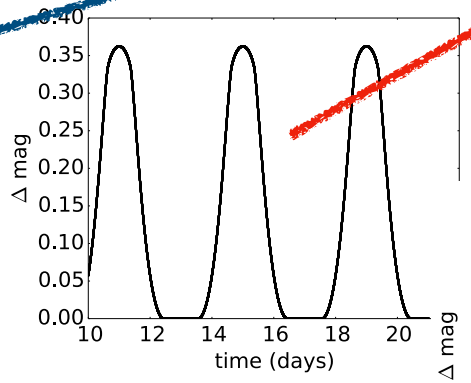
- Realistic instrumental noise
- Astrophysical signal as input

Time series



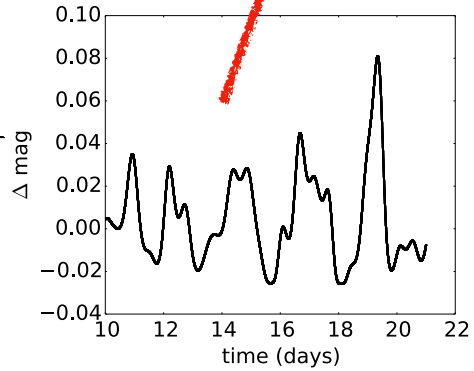


Contamination seen as a pulsator in a binary



Binary

Pulsator



TESSting the PLATO-CS model

Transiting Exoplanet Survey Satellite

- **2-year nominal mission**, nearly full sk
- 27 - 360 days long time-series
- 4 cameras covering insta ector
- 26 sectors (13 per h min (long-) and 1 min (short-) cadenc
- Pixel size ar to PLATO

- **extension** (including ecliptic!!!)
- dence: 10 min (long-) and 2 min (short-) cadence
- Ob ng strategy is being discussed

Nicely introduced yesterday, e.g., cf talk by K. Stassun

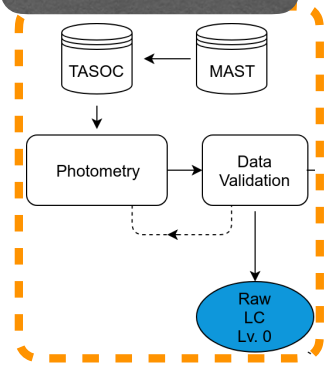
TESS Legacy for PLATO-CS

TESS Asteroseismology Science Consortium (TASC) Coordinated Activities

- Data Reduction/ Processing
- Guest Investigator Proposals
- Stellar Variability Classification
- Ground-Based Follow-Up

TESS Photometry Pipeline

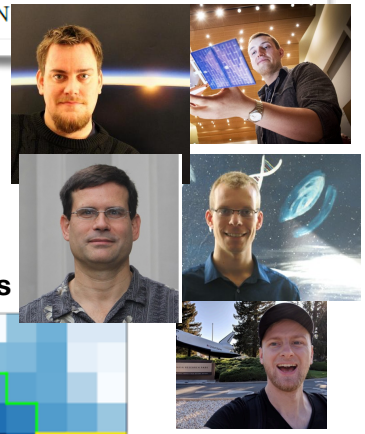
Data Reduction/ Processing



To be submitted: 2019

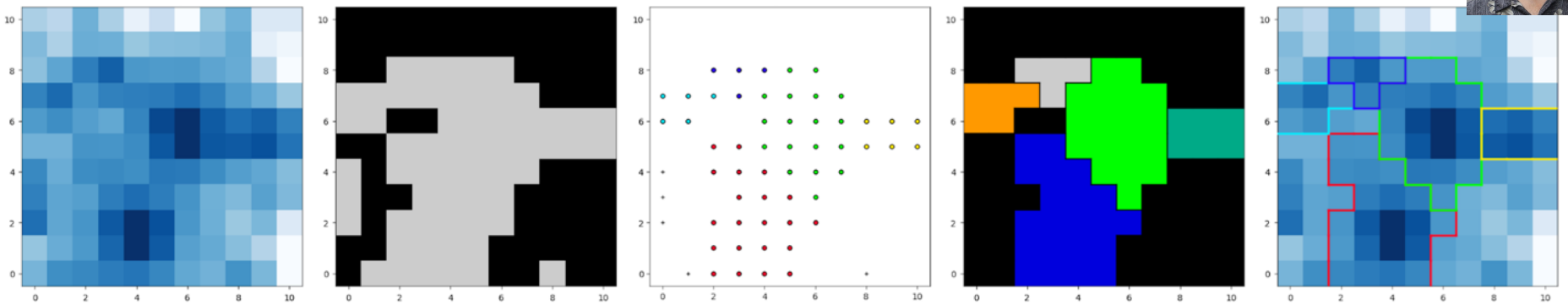
TESS Data for Asteroseismology: Photometry

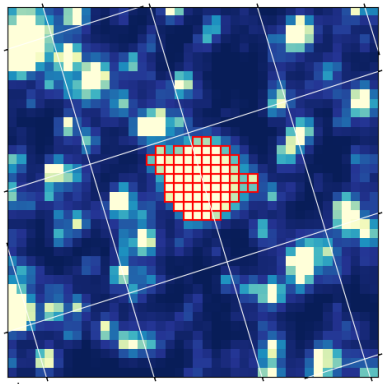
Rasmus Handberg [1], Mikkel N. Lund [1], Jonas S. Hansen, [1] Timothy R. White [2, 3, 1] Benjamin J. S. Pope [4] Oliver J. Hall [5, 1] Carolina von Essen, [1] and the T'DA Collaboration

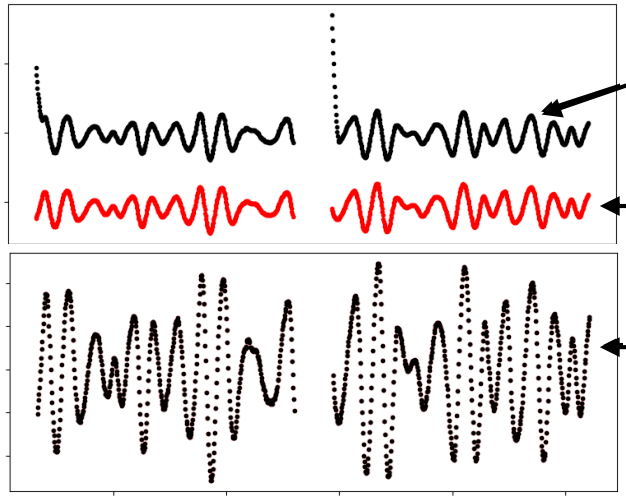


Aperture Photometry (based on Lund+ 2015, Handberg & Lund 2017)

Sum image | **Significant flux** | **Clustering + Watershed** | **Extracted Clusters** | **Final masks**



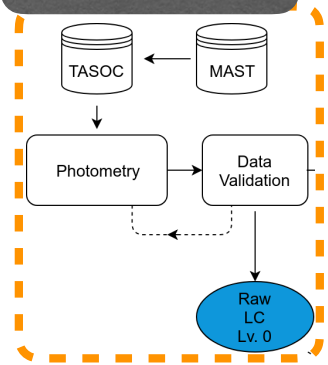




- Clustering and watershed using info of the known targets in the image
- PSF & Difference Imaging photometry also implemented but are currently not used

T'DA Photometry Pipeline: Bright Stars

Data Reduction/ Processing



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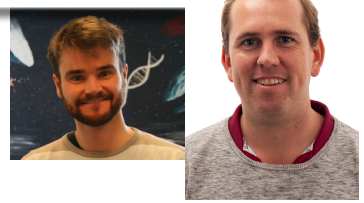


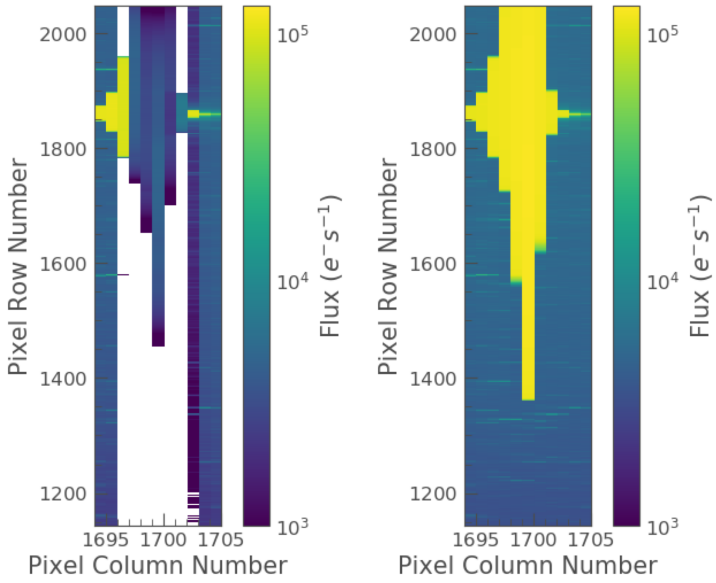
Bloody Bright Stars

Smear calibration problems

For the brightest stars (Tmag < 2), the bleed-columns can cause serious problems with the pixel-level calibrations.

But do not fear! We are able to reconstruct the flux!
- And yes, Procyon is oscillating!

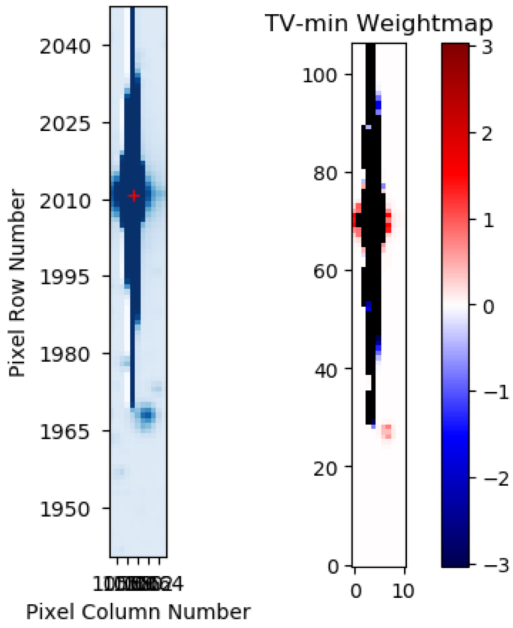
alpha Cen



Halo Photometry

Halo photometry is able to reconstruct the light curve, even in cases where all the flux has not been captured.

Weight each pixel to minimize scatter in light curve (White et al. 2017)



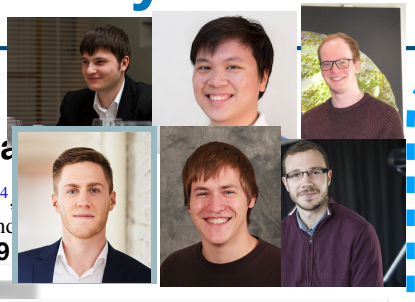
T'DA Pipeline: Variability Classification

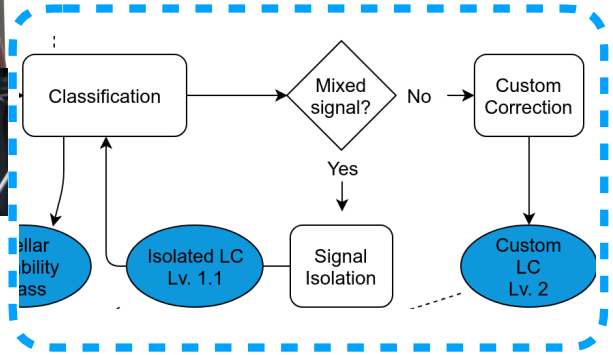
Stellar Variability Classification

TESS Data for Asteroseismology (T'DA) Stellar Variability Classification Pipeline: Set-Up and Application to Kepler Q9 data

A. Tkachenko[1], J. S. Kuszlewicz[2,3], K. J. Bell[2,4], D. Armstrong[5,6], M. Hon[7], R. Kgoadi[8], R. Handberg[4], M. Lund[4], L. Bugnet[9,10], D. M. Bowman[1], C. Johnston[1], R. A. García[9,10], T. R. Bedding[11,4], N. Barbara[11], D. Stello[7,11,4], and T'DA collaboration

To be submitted: 2019





Stellar Variability Classification

Unsupervised Methods

- FOPTICS (Clustering; all classes)

Supervised Methods

- SLOSH (Neural Network; solar-like pulsators)
- GBGC (Gradient Boosting; all classes)
- RFGC (Random Forest; all classes)

Meta Classifier ("stacking")

Top Level Classification (I)

Solar-like pulsators | Transiting/ Eclipsing | RR Lyrs/ Cepheids | γ Dors/ SPBs | δ Scts/ β Ceps | SC only: Rapid pulsators | Transients | Contact binaries/ rotation | Aperiodic variability | Constant/ white noise

Second-level Classification (II)

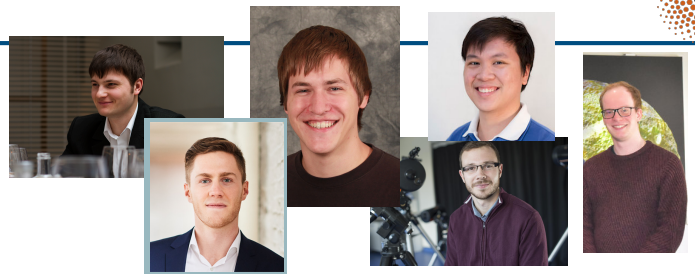
- $\nu_{max}/\Delta\nu$ RG vs. RC
- RR Lyraes | Cepheids
- δ Scts | β Ceps
- Contact binaries | Rotation
- Period/ morphology | Second-order variability
- γ Dors | SPBs
- LPVs | Instrumental | Irregular variables | New classes
- roAp | White dwarfs | sdB stars | New classes

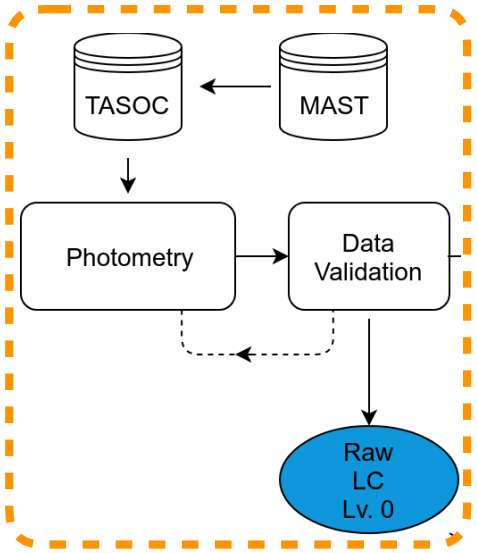
Machine Learning Techniques

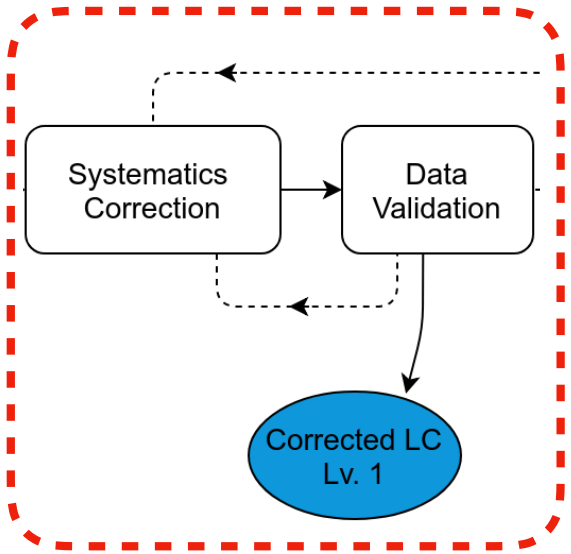
Sorting out stars into broad classes (light-curves only)

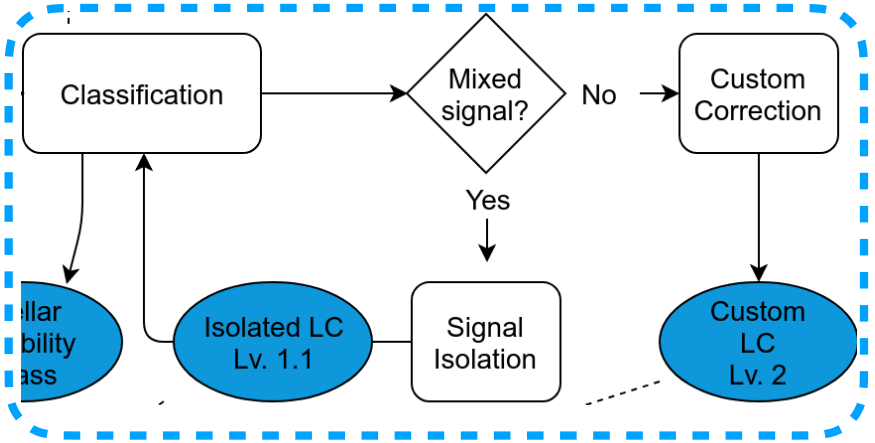
Detailed classification (using extra information)

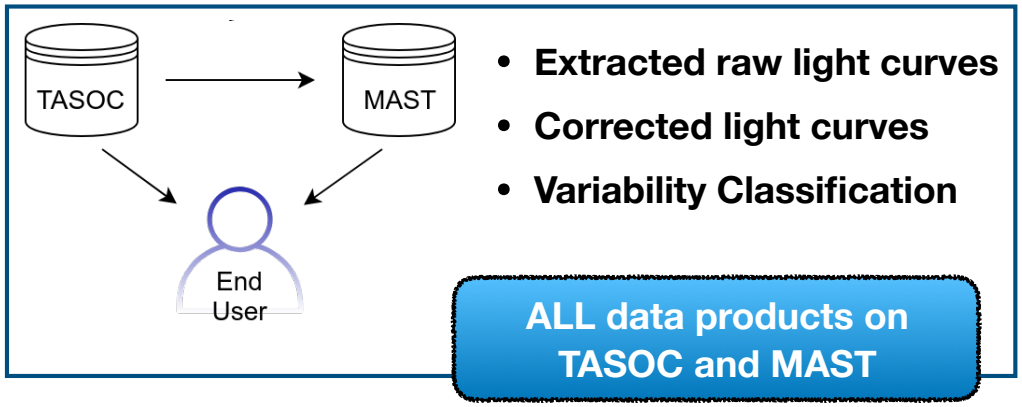
T'DA Pipeline: in summary





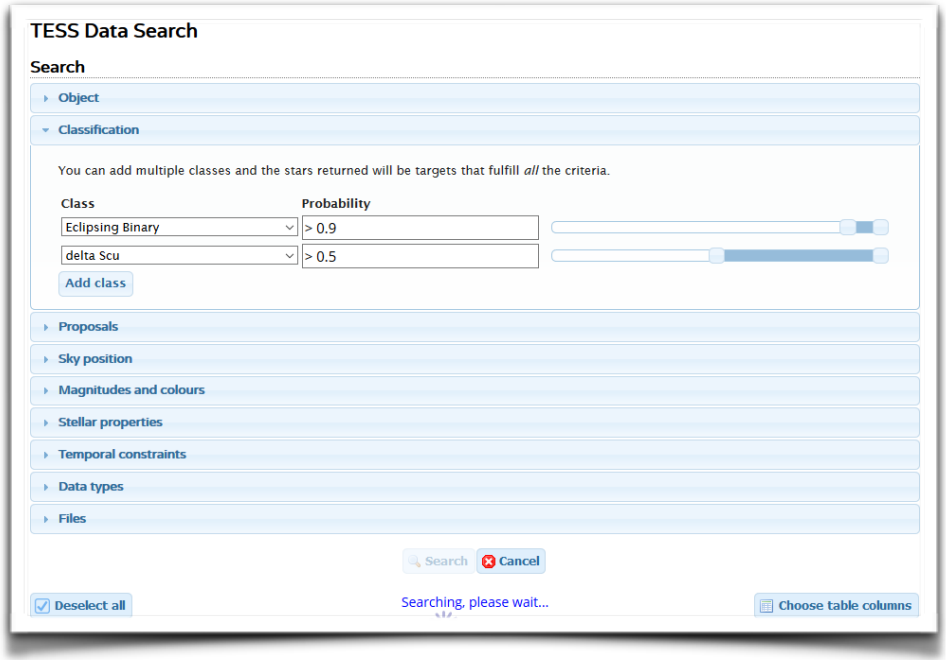






- **Extracted raw light curves**
- **Corrected light curves**
- **Variability Classification**

ALL data products on TASOC and MAST



Ground-based follow-up activities

Ground-based follow-up

The Catalogue

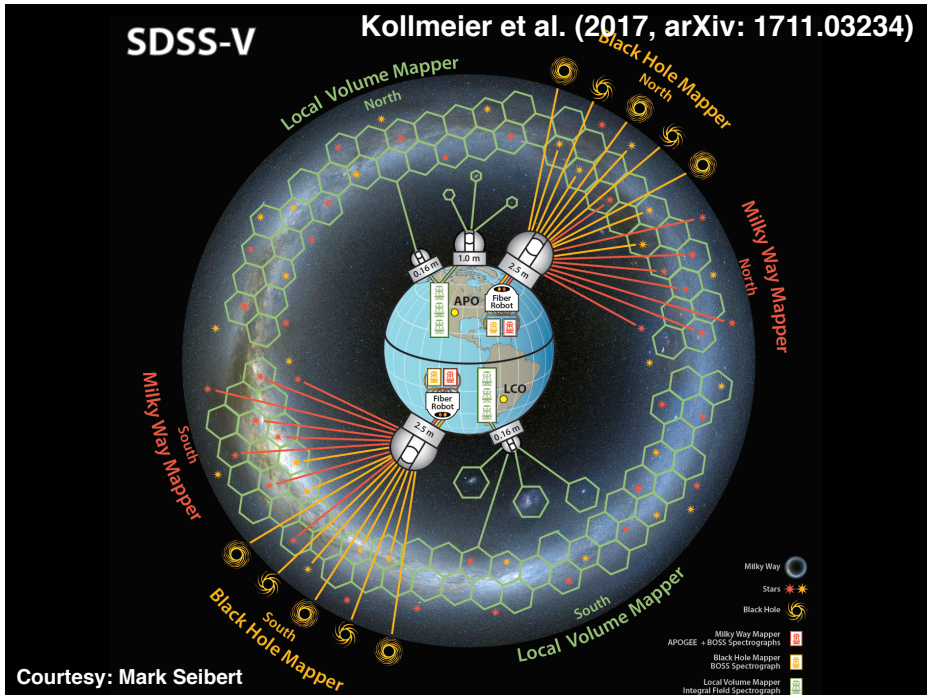
- all **data** that are **publicly available** + literature parameters
- information: **existing** but **not immediately accessible** data
- link to the entry in the TESS Input Catalogue (TIC)

Coordinated Activities

- WGs and consortium-wide **coordination of observing programmes**
- **small-class telescopes:** time-resolved observations of bright stars
- **large facilities:** faint stars and big samples in large programmes

SDSS-V: Pioneering Panoptic Spectroscopy

website: https://www.sdss.org/future/

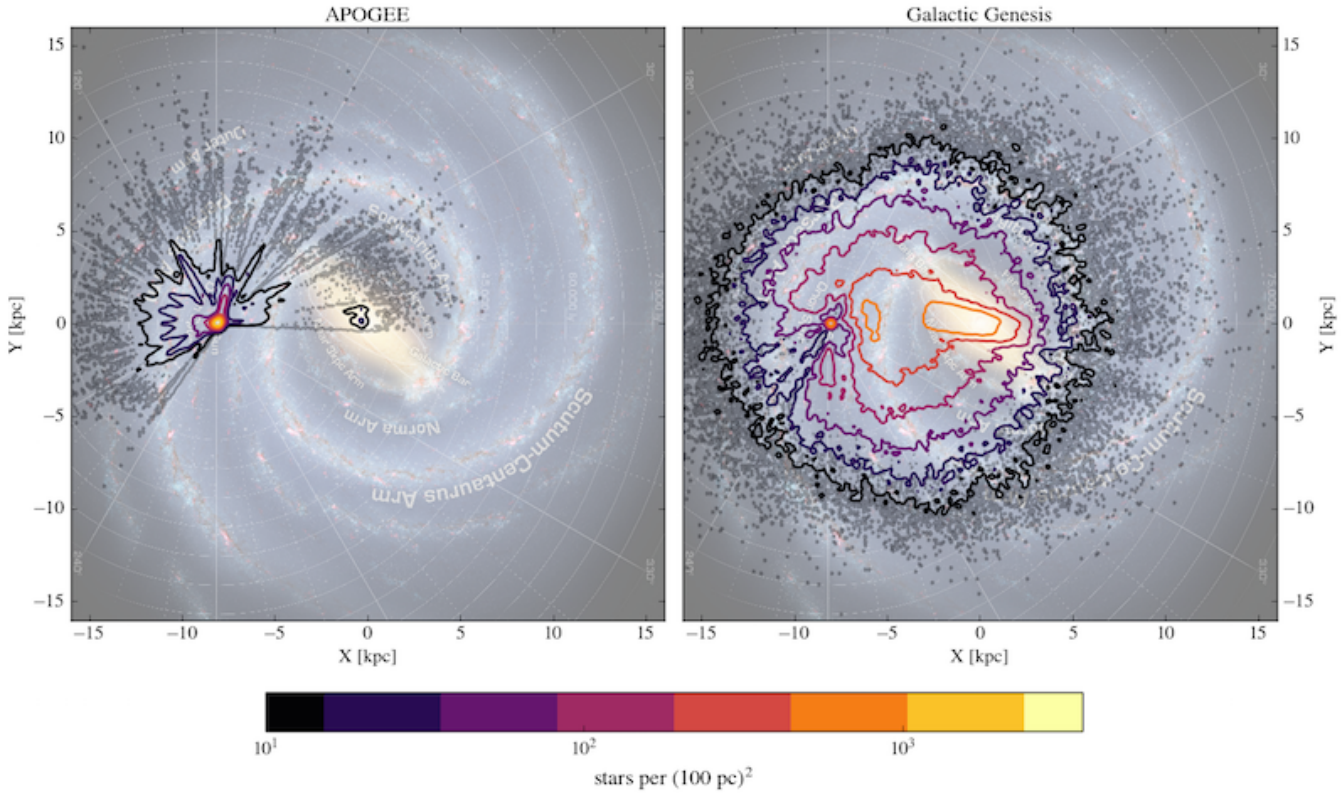


- Time frame 2020 - 2025
- Full sky survey of ~7x10^6 stars
- Twin (2.5m) telescopes and (optical + NIR) instruments in the South and North
- Multi-epoch observations: N^{epochs} between 1 and 180

- **Milky Way Mapper** (MWM): Stellar Astrophysics
- **Black Hole Mapper** (BHM): Quasars and X-ray sources
- **Local Volume Mapper** (LVM): Integral-field spectroscopy of MW and its galactic neighbours

SDSS-V: Milky Way Mapper

Program	Science Targets	$N_{Objects}$ and/or Sky Area	Primary Spectral Range and Hardware	Primary Science Goals
Milky Way Mapper (MWM)	Stars across the Milky Way	>6M stars; all-sky	IR; APOGEE ($R \sim 22,000$) with fiber-positioning system	Understanding the formation of the Milky Way and the physics of its stars



For discussion: is there way for us to join SDSS-V as PLATO Consortium?

- We seem to be in need of spectroscopy **now** in addition to follow-up
- We **can still** influence target selection
- We will have access to **all the data** —> helps PIC, calibration stars sample?

APOGEE DR14/DR15 **MWM SDSS-V**

PLATO Complementary Science

website: fys.kuleuven.be/ster/Projects/plat

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Jonker (Ned
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ce), Manuel Güdel (Austria), Peter
um), Sergio Simón-Díaz (Spain), Saskia
anke (Nederlands), Ennio Poretti (Italy)

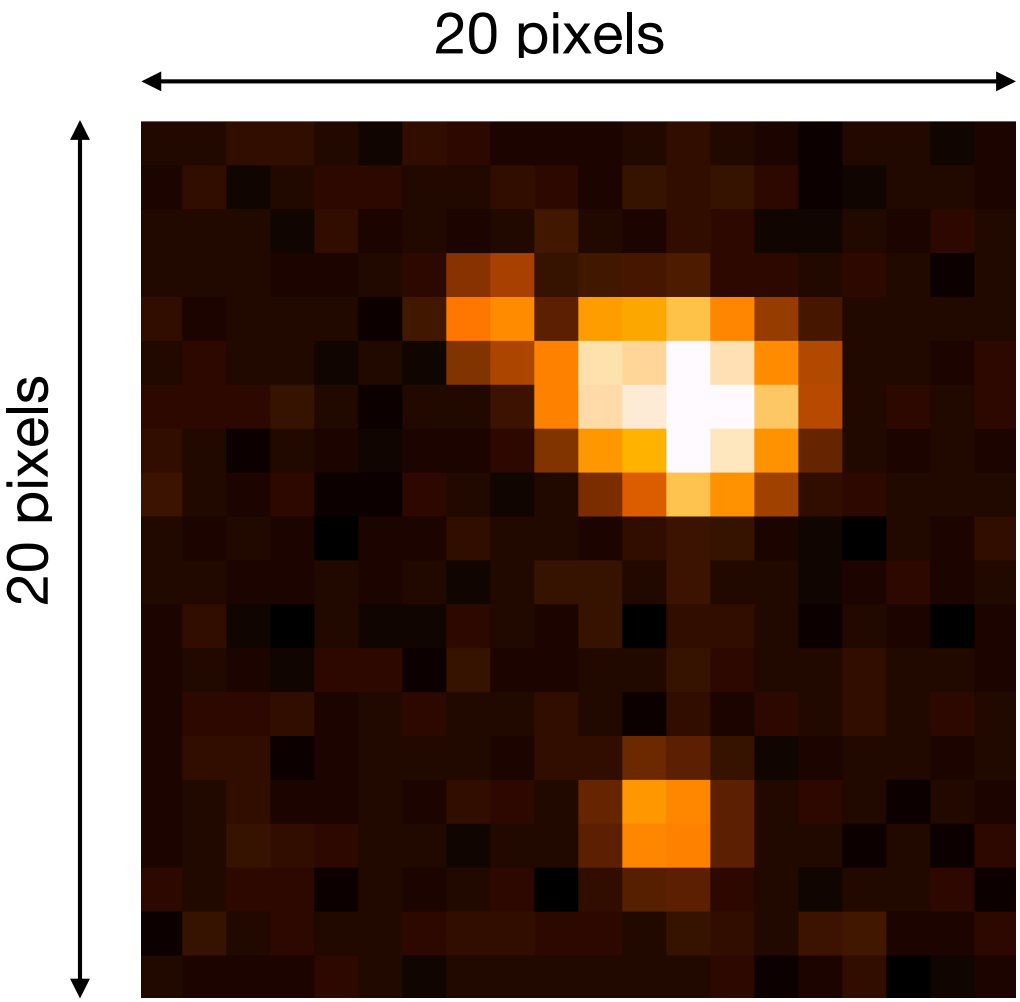
nan 250 registered scientists

Advertise within your institution and join us!!!

On behalf of the PLATO-CS team

Andrew Tkachenko
Institute of Astronomy, KU Leuven (BE)

PlatoSim: Performance example



- Simple configuration:
  - 5 nearby stars, overlapping PSFs
- For 1 telescope and 1 quarter:
  - 315’241 exposures, long cadence
  - Computing time: 40 min
  - Output file size: 3.6 GB
- For all telescopes:
  - Simultaneously launch all simulations on computer cluster