Pontificia Universidad Católica

Departamento de Astronomía y Astrofísica

THE VVV TEMPLATES PROJECT

Towards an Automatic Classification of VVV Light Curves

Rodolfo Angeloni

on behalf of the *VVV Templates Project* Team

MWM
The Milky Way Millennium Nucleus

CONICYT
COMISIÓN NACIONAL DE INVESTIGACIÓN CIENTÍFICA Y TECNOLÓGICA

INICIATIVA CIENTIFICA MILENIO
ICM

The *VVV Templates Project* team

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The main goal of the *VVV Templates Project* is to derive well-defined light curve templates in the near-infrared for the automated classification of VVV light curves.

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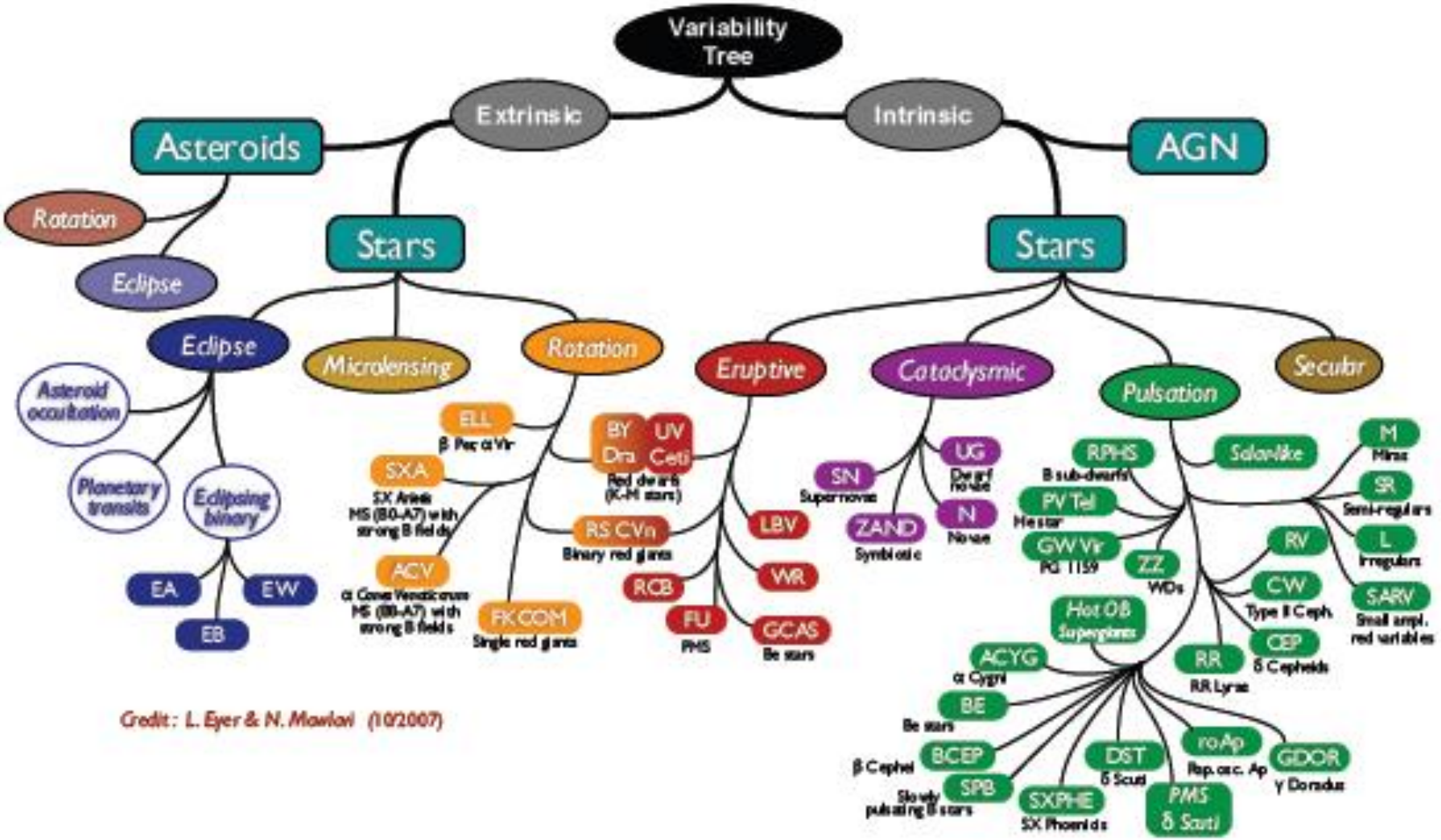
These light curves also offer a unique opportunity to expand our knowledge of the stellar variability phenomenon *per se*.



Variability tree

A tentative organization of variable objects

OUTLINE

1. Why the need of an automated classification of VVV light curves?
2. Why the need of building variability class templates?
3. Why the need of additional telescope time (i.e. why not literature data)?

Why the need of an automated classification of VVV light curves?

VVV highlights in numbers

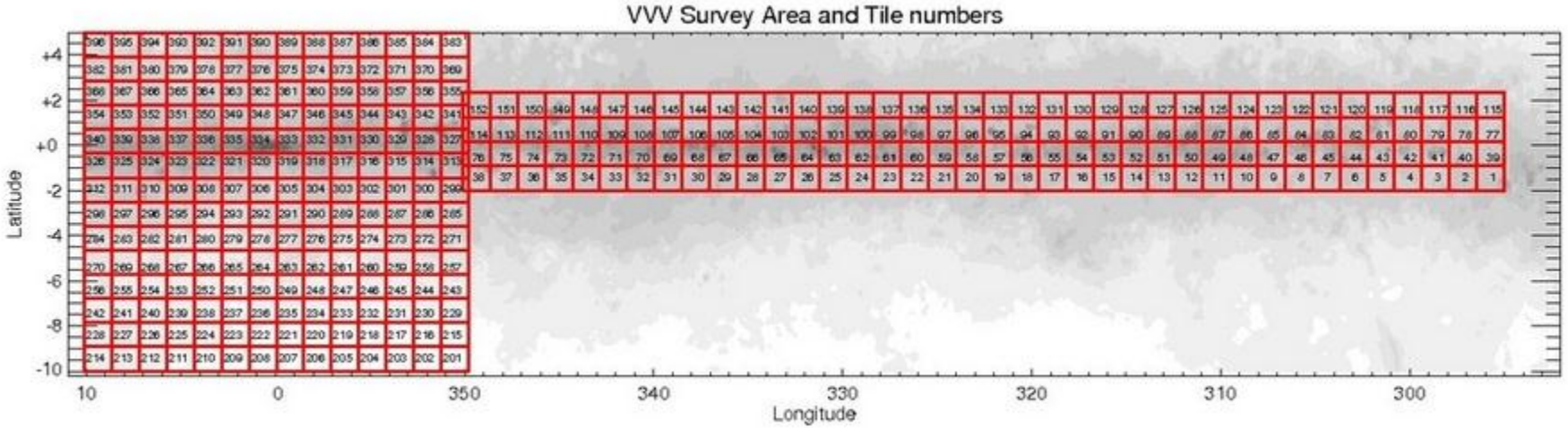
survey area ~ 520 sq. deg.

> 33 globular clusters

> 350 open clusters

~ 10^9 points sources

~ 10^6 variable stars



Why the need of an automated classification of VVV light curves?

It has become a Hobson's choice for large astronomical surveys

- ✓ *On machine-learned classification of variable stars with sparse and noisy time-series data*
  Richards J. W. et al. - arXiv:1101.1959
- ✓ *Random forest automated supervised classification of Hipparcos periodic variable stars*
  P. Dubath et al. – 2011 MNRAS – 414, 2602
- ✓ *Automated Classification of Variable Stars in the Asteroseismology Program of the Kepler Space Mission*
  J. Blomme et al. – 2010 ApJ – 713, 204
- ✓ *Automated supervised classification of variable stars in the CoRoT programme. Method and application to the first four exoplanet fields*
  J. Debosscher et al. - 2009 A&A - 506, 519
- ✓ *Automated supervised classification of variable stars. II. Application to the OGLE database*
  L. M. Sarro et al. – 2009 A&A - 494, 739
- ✓ *Automated classification of variable stars for All-Sky Automated Survey 1–2 data*
  L. Eyer & C. Blake – 2005 MNRAS - 358,30

Why the need of variability class templates?

The fast classification of new variable stars is an important step in making them available for further research. Selection of science targets from large databases is much more efficient if they have been classified first. Defining the classes in terms of physical parameters is also important to get an unbiased statistical view on the variability mechanisms and the borders of instability strips.

from Automated supervised classification of variable stars. I. Methodology

J. Debosscher et al. – *2007 A&A – 475, 1159*

Why the need of variability class templates?

In the last few years, there has been an increasing interest towards the application of artificial intelligence algorithms in astronomical research

supervised machine learning

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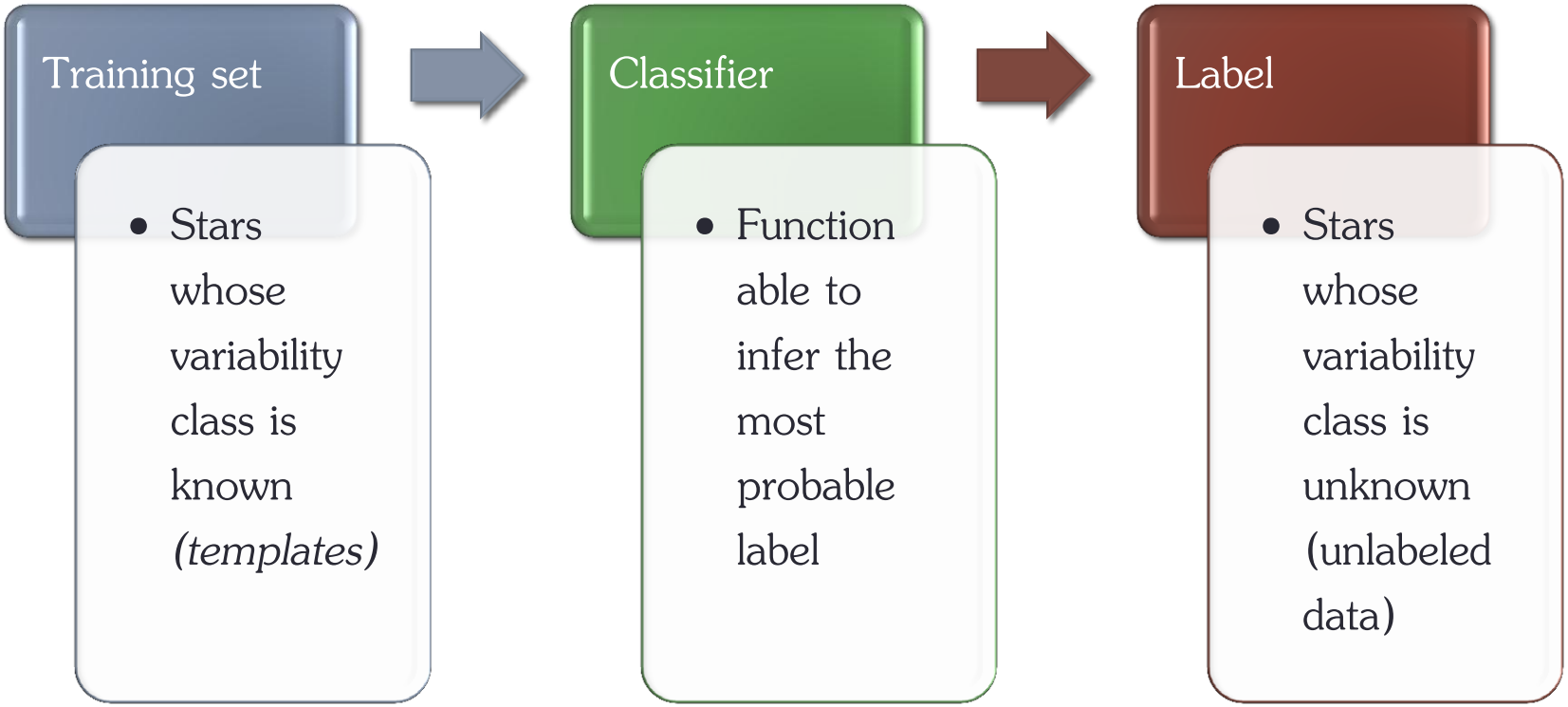
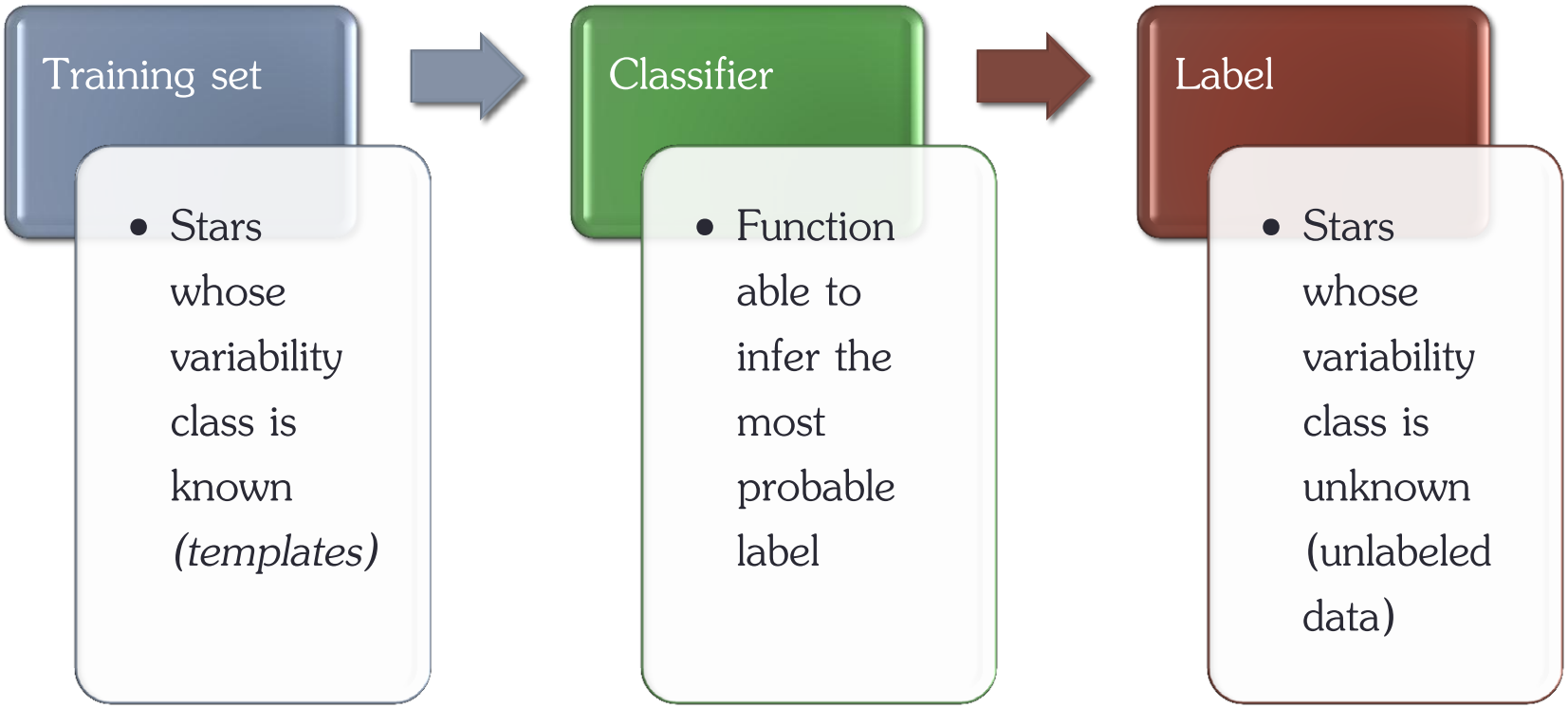
supervised machine learning



Why the need of variability class templates?

There are concrete cases in which it is convenient to keep the training set as small as possible, while still retaining its maximum information content

supervised machine learning



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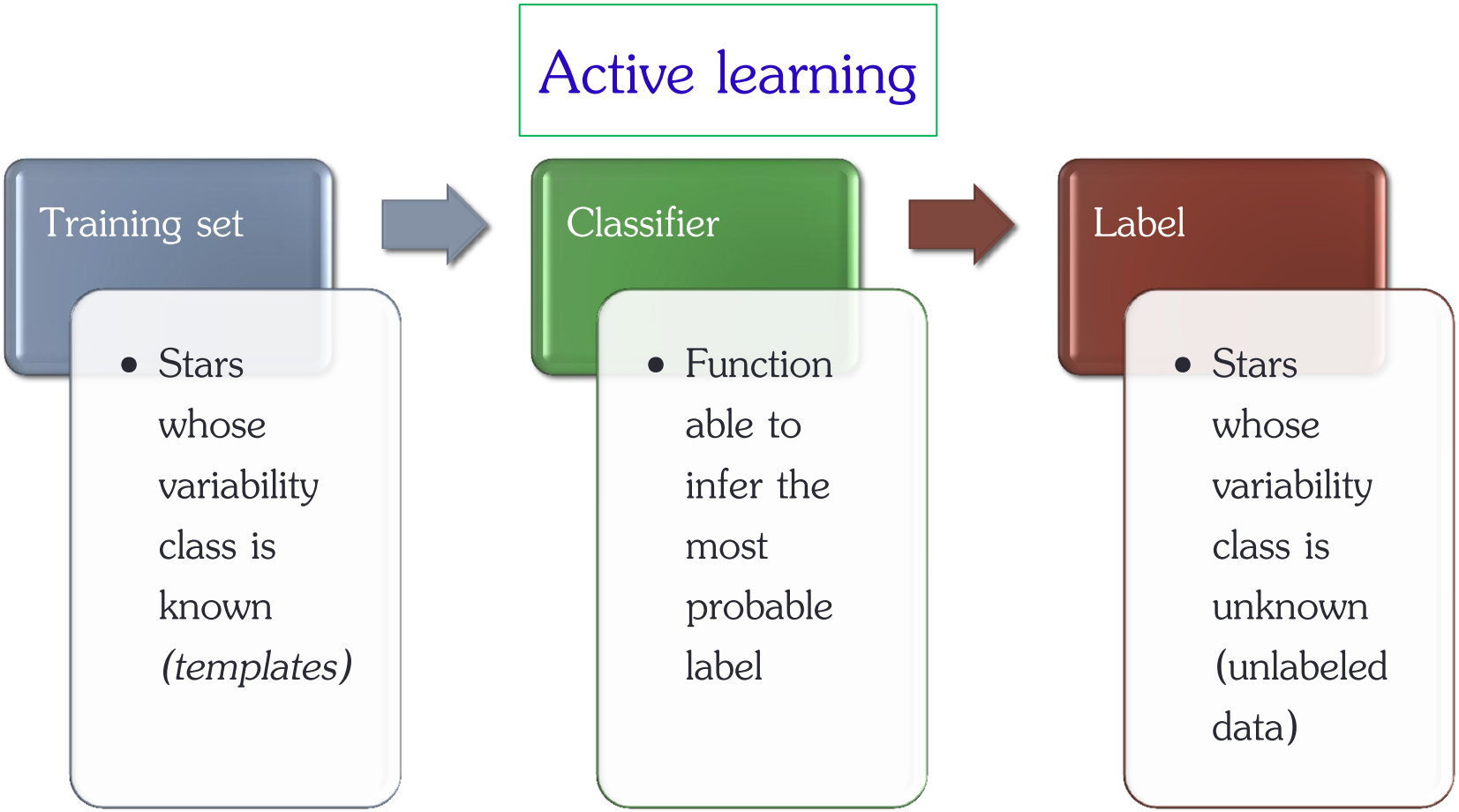

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Active learning

Active learning is a form of supervised machine learning in which the learning algorithm is able to interactively query the user (or some other information source)

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Active learning

Active learning is a form of supervised machine learning in which the learning algorithm is able to interactively query the user (or some other information source)

In other words, the active learner aims to achieve high accuracy using as few template light curves as possible, thereby minimizing the cost of obtaining observational data.

Why the need of telescope time?

The necessary high-quality templates that are needed for automated variable star classification algorithms are not available in the near-IR

Type	**N (CoRoT)**	**N (VVV)**
RRab Lyrae	129	15
EA-type	169	8
Classical Cepheids	195	32

For many classes there are **no data** at all

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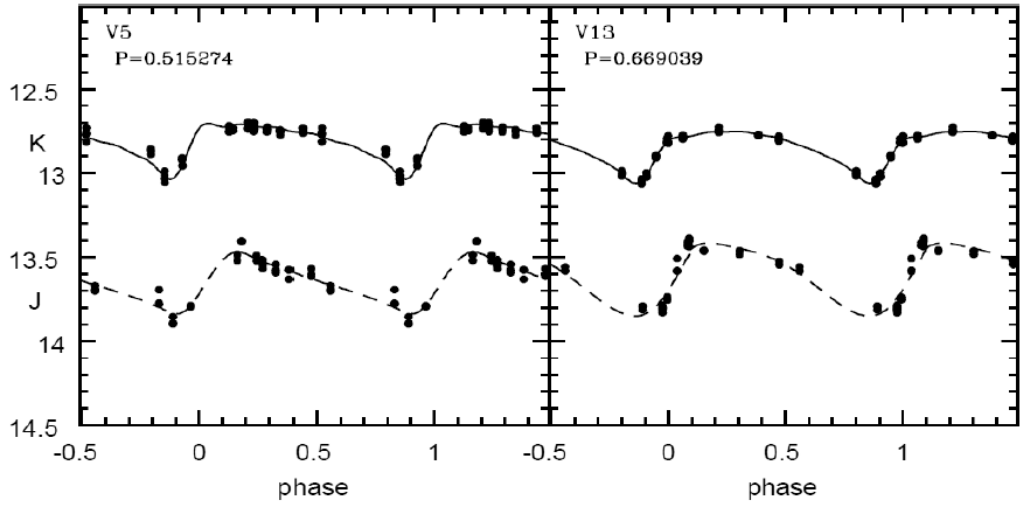
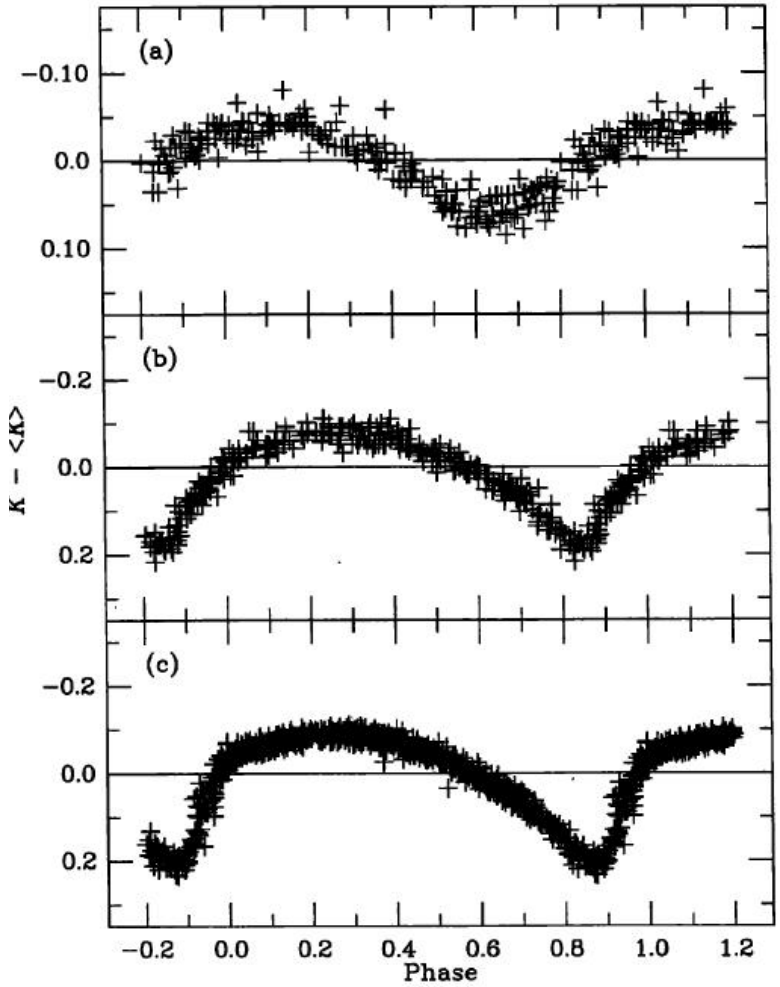
We have to build our own templates

Why the need of telescope time?



Top panels. Example of "well-sampled" light curves from the literature (ab-type RR Lyrae stars in the globular cluster ω Centauri – Del Principe et al. 2006). The solid lines indicate fits based on templates from Jones et al. (1996; see Fig. 2), whereas the dashed lines show spline fits. This kind of data are suitable for distance determinations, but completely inadequate for the reliable determination of Fourier decomposition parameters, therefore cannot be used as templates for automated light curve classification.



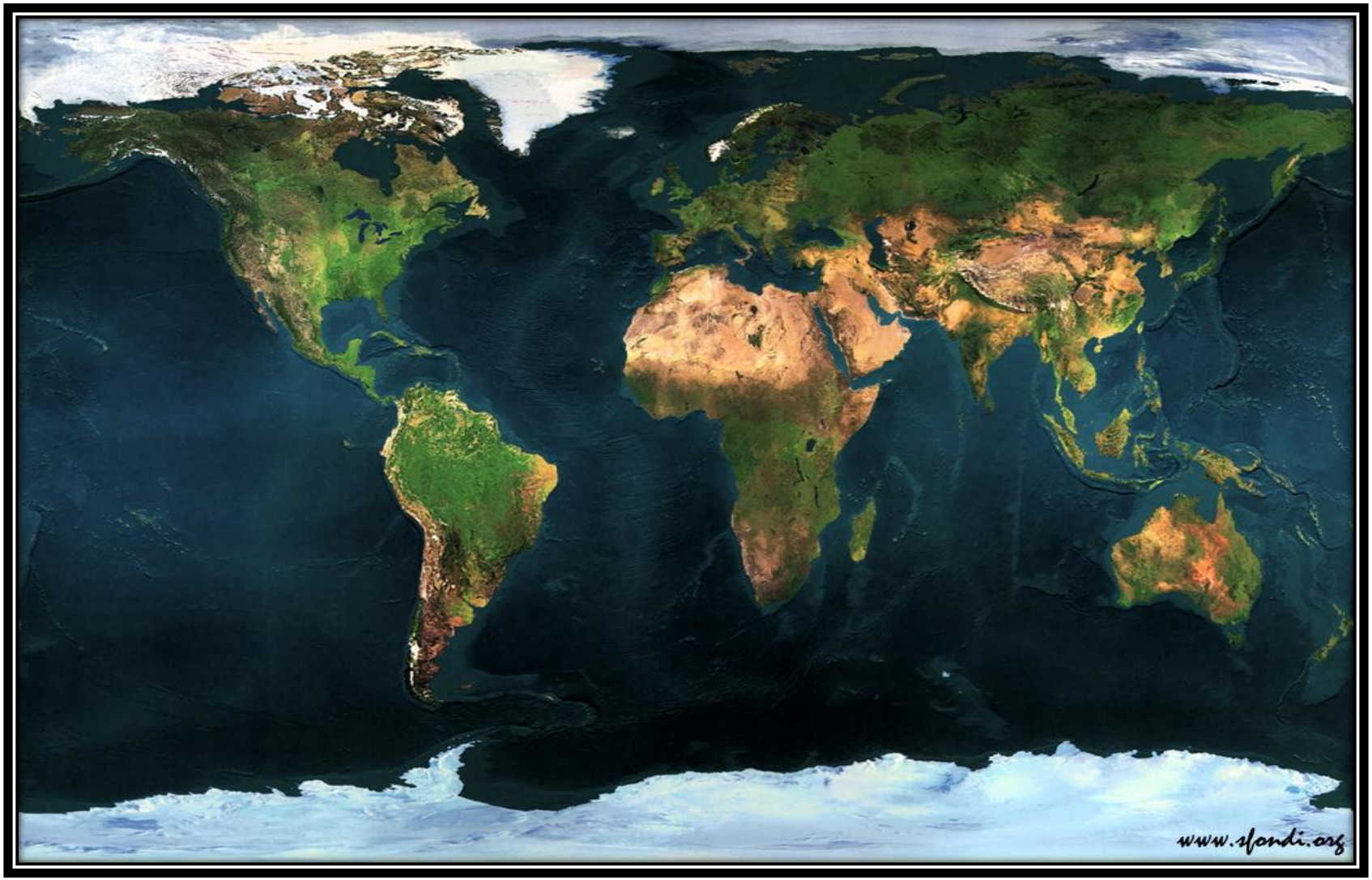
Right panel: Light curves templates by Jones et al. (1996). Templates data of this quality are seldom found in the literature.

Why the need of telescope time?

By monitoring hundreds of (optically well-studied) variable stars in the JHKs bands, the primary goal of the *VVV Templates Project* is thus to provide a statistically significant training set for the automated classification of VVV light curves.

Facilities around the world

We have secured time for this project using several IR facilities across the world



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In order to ensure a homogeneous observational strategy and to optimize the use of the awarded time, each telescope/instrument combination is used to build template light curves for at most a very few specific variability classes.

Facilities around the world

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VVV Templates Project: Observing Time at Different Observatories

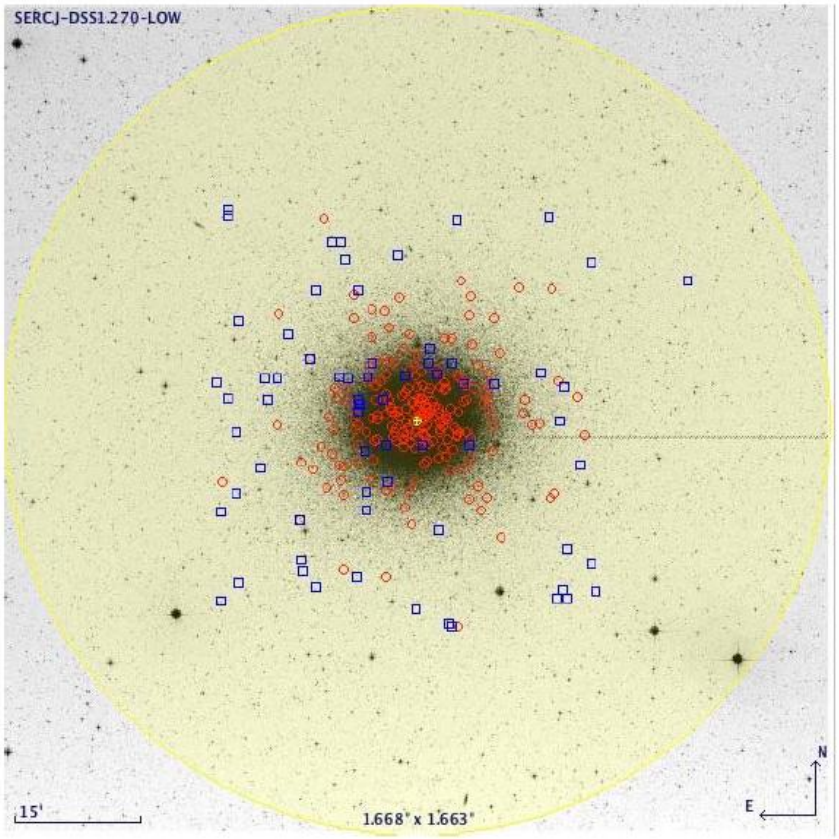
Observatory	Telescope	IR Camera	FoV	Awarded Time	Target
ESO Paranal	VISTA 4m	VIRCAM	$60' \times 90'$	34 hours	ω Centauri
CTIO	Blanco 4m	NEWFIRM	$28' \times 28'$	3 nights	NGC 3293/4755/6231
KASI	BOAO 1.8m	KASINICS	$3.6' \times 3.6'$	6 weeks	CVs, δ Scutis
IAC	TCS 1.4m	CAIN-III	$4.2' \times 4.2$	36 nigths	NGC 1817/7062
SAAO	IRSF 1.4m	SIRIUS	$7.7' \times 7.7'$	3 weeks	M62, NGC 1851/6134
CTIO	SMARTS 1.3m	ANDICAM	$2.4' \times 2.4'$	90h/sem	field RR Lyrae
SAAO	0.75m	MkII phot	–	3 weeks	SX Phe, Ellipsoidal, ...
ESO La Silla	REM	REMIR	$10' \times 10'$	225h/sem	EBs, δ Scutis
Asiago[a]	Schmidt	Opt. CCD	$52' \times 36'$	36 nights	NGC 1817/7062
Kazakshtan[b]	1m	Opt. CCD	$30' \times 30'$	6 weeks	CVs
OMM	1.6m	CAPAPIR	$30' \times 30'$	8 hours	NGC 7062
OAGH	2.1m	CANANEA	$4' \times 4'$	10 nights	NGC 1817

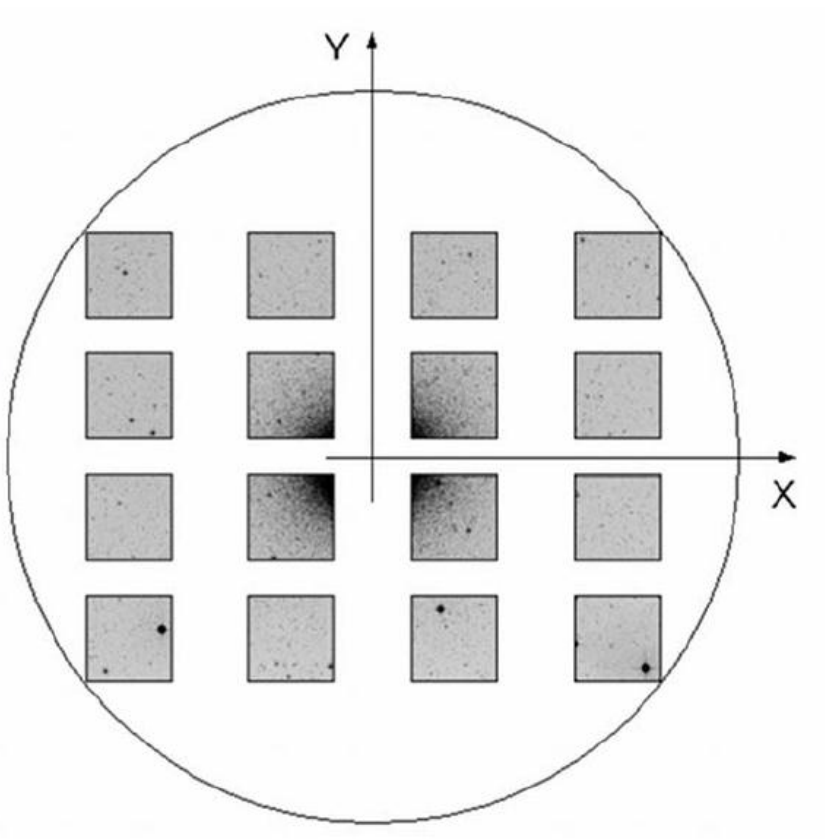
[a] Simultaneous optical monitoring of TCS targets.
[b] Simultaneous optical monitoring of BOAO targets.

from Catelan et al. 2011arXiv1105.1119C

Facilities around the world

ESO/VISTA 4m Telescope + VIRCAM

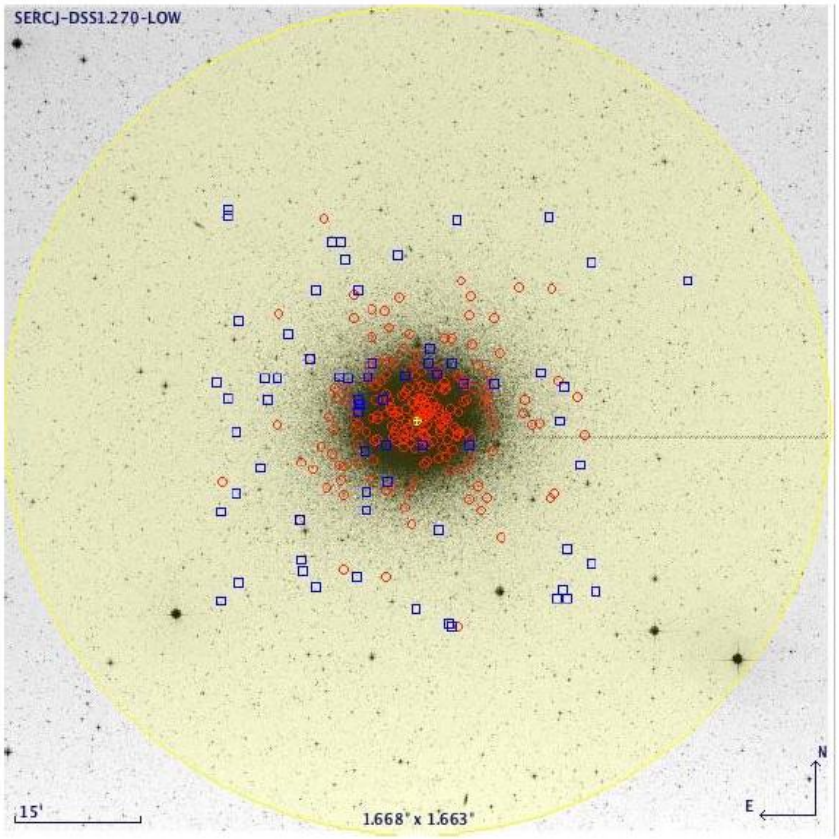


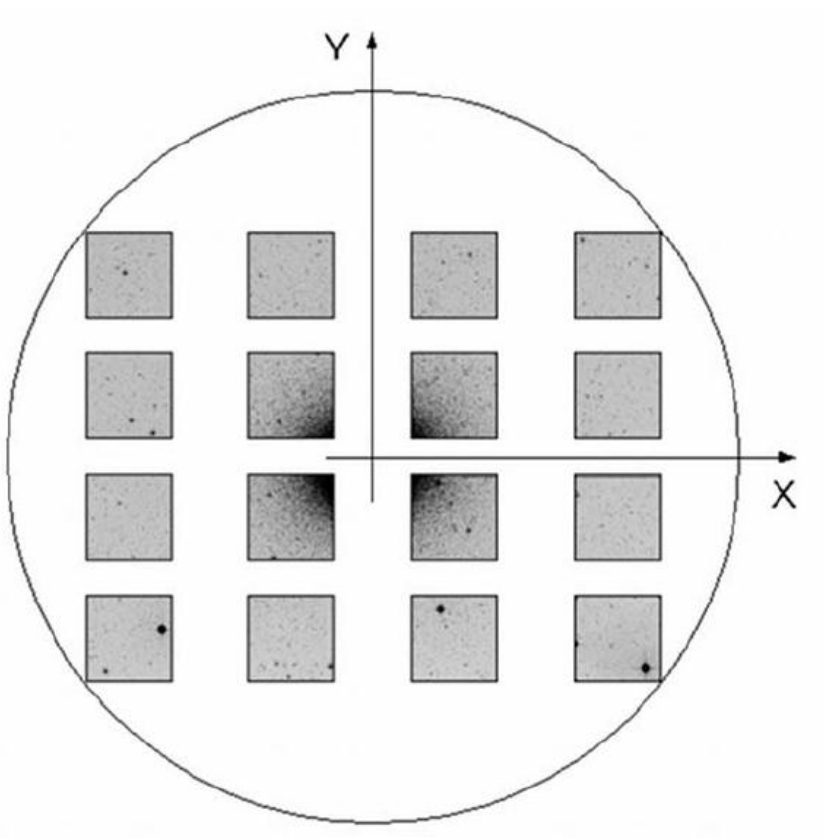


Upcoming VISTA observations of the globular cluster ω Cen. Left panel: an example of variable star distribution across the cluster field: red circles mark the positions of known RR Lyrae stars, while blue squares mark the positions of known eclipsing binaries. Right panel: VIRCAM@VISTA's 16 detectors, with ω Cen at the center of the focal plane.

Facilities around the world

ESO/VISTA 4m Telescope + VIRCAM

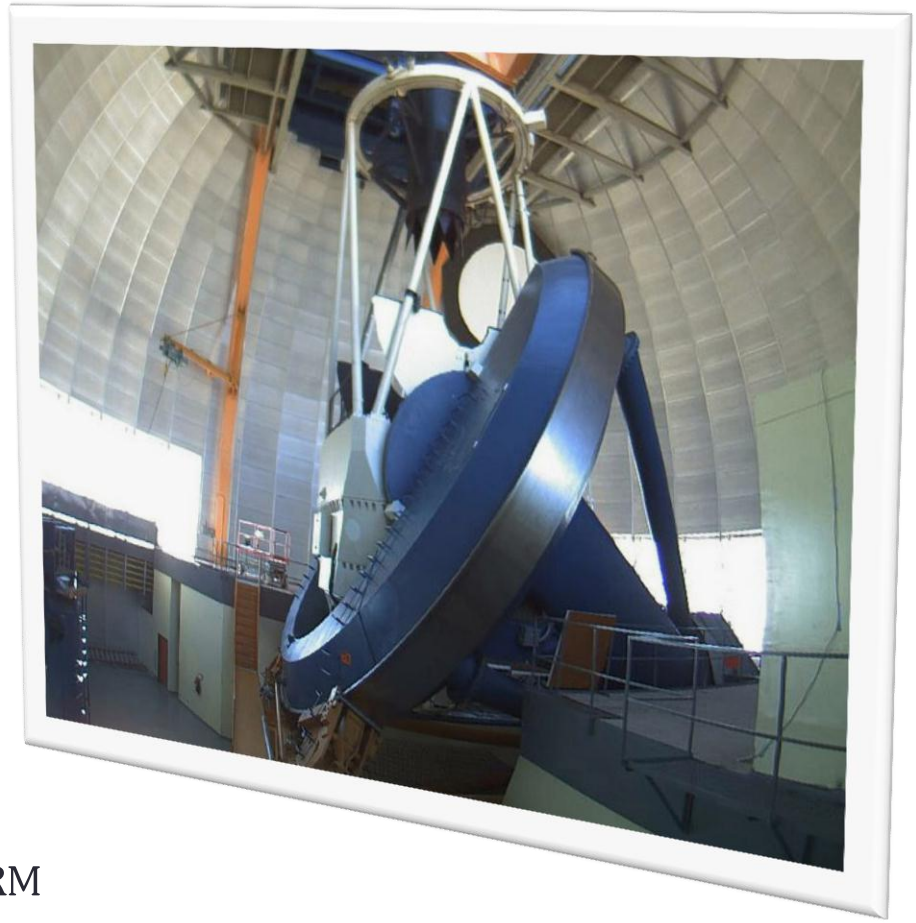




Such a project will lead to high-quality light curves for more than 250 variables, greatly exceeding, both in quantity and in completeness of each individual light curve, what was achieved in previous near-IR studies of the cluster.

Facilities around the world

CTIO/Blanco 4m Telescope + NEWFIRM

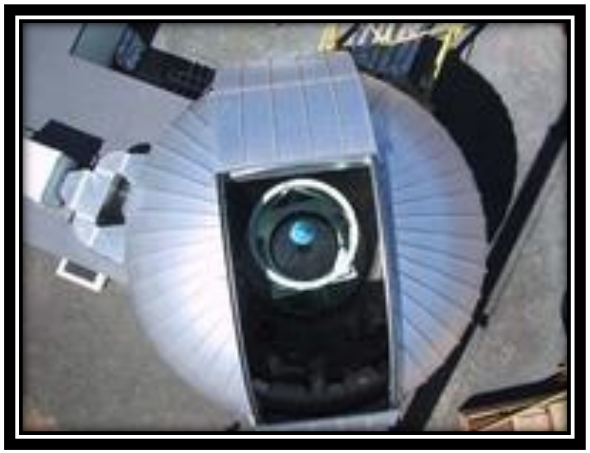


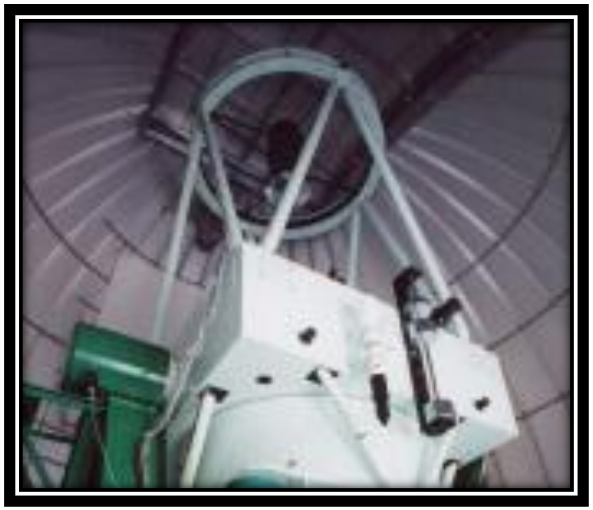
NEWFIRM

FoV: 27.6'x27.6' – pixel scale: 0.40 arcsec/pix

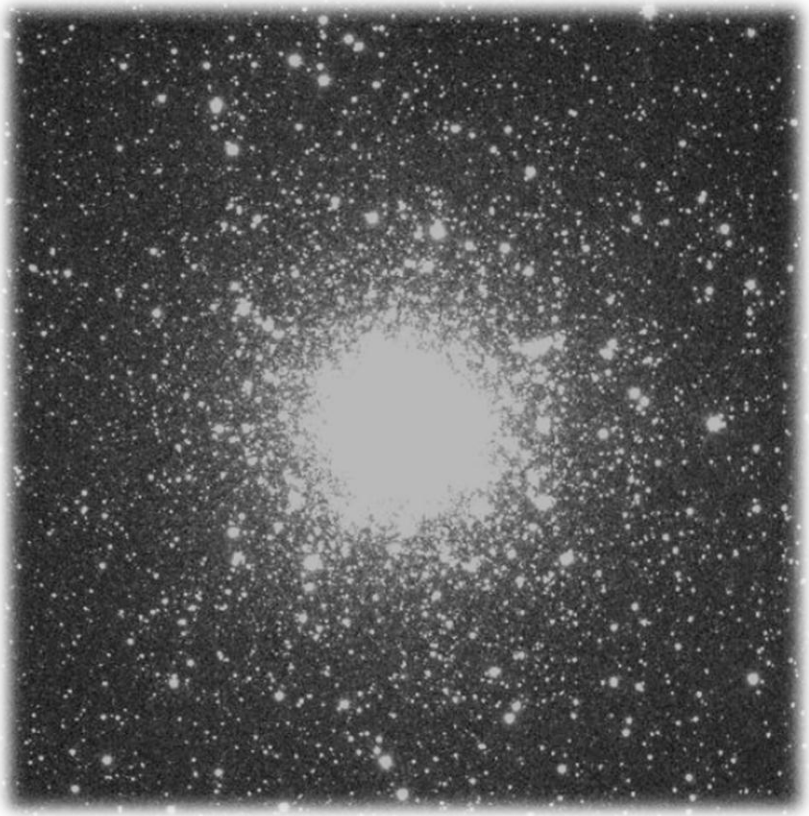
Facilities around the world

SAAO/IRSF 1.4m Telescope + SIRPOL





SIRPOL



M62

FoV: 7.7'x7.7' – pixel scale: 0.45 arcsec/pix

Facilities around the world

SAAO/IRSF 1.4m Telescope + SIRPOL

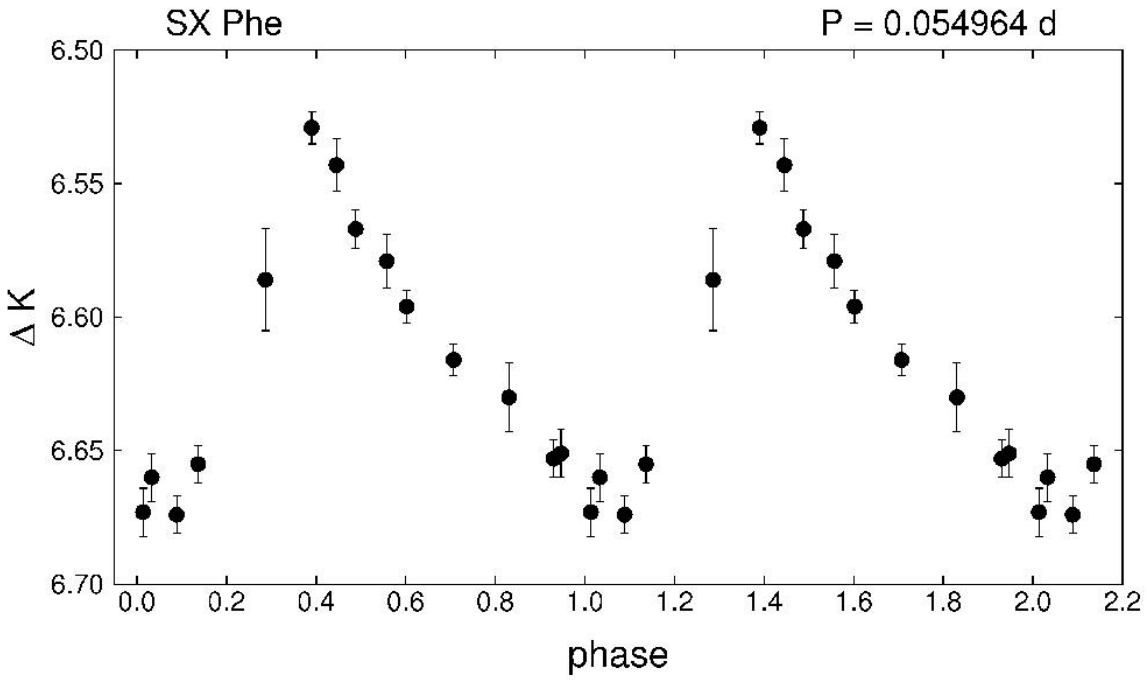
We have recently started to monitor a series of open clusters known to host sizeable populations of δ Scuti stars. In addition to high-quality near-IR templates, this will also allow us to verify the period-luminosity relation in the near-IR that has been suggested for this important class of variables (King 1990).

SIRPOL

FoV: 7.7'x7.7' – pixel scale: 0.45 arcsec/pix

Facilities around the world

SAAO/0.75m Telescope + MkII photometer



K-band light curve of SX Phe, taken at the SAAO 0.75 mt Telescope in Sept. 2010. Note the overall amplitude of 0.15 mag!

Facilities around the world

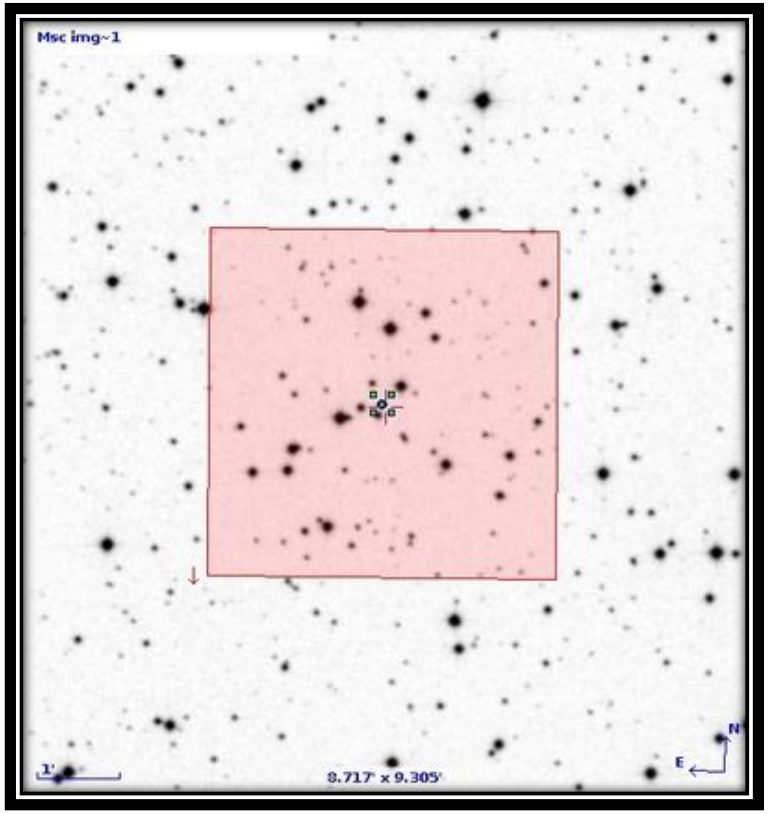
IAC/TCS 1.5m Telescope + CAIN III

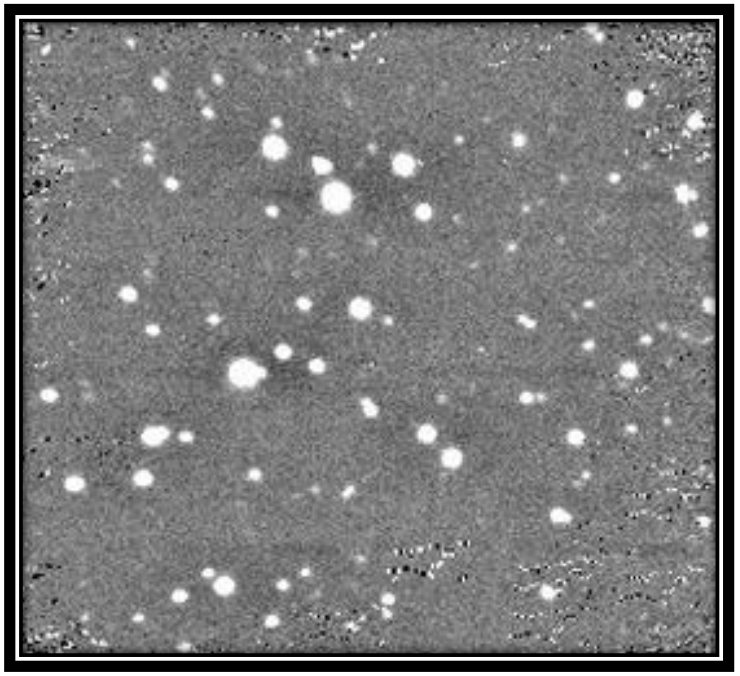
CAIN III

FoV: 4.2'x4.2' – pixel scale: 1 arcsec/pix

Facilities around the world

IAC/TCS 1.5m Telescope + CAIN III

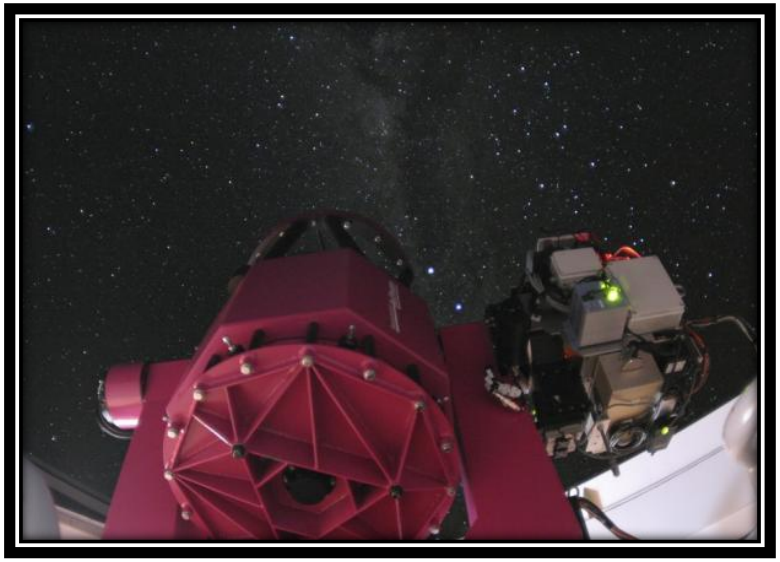


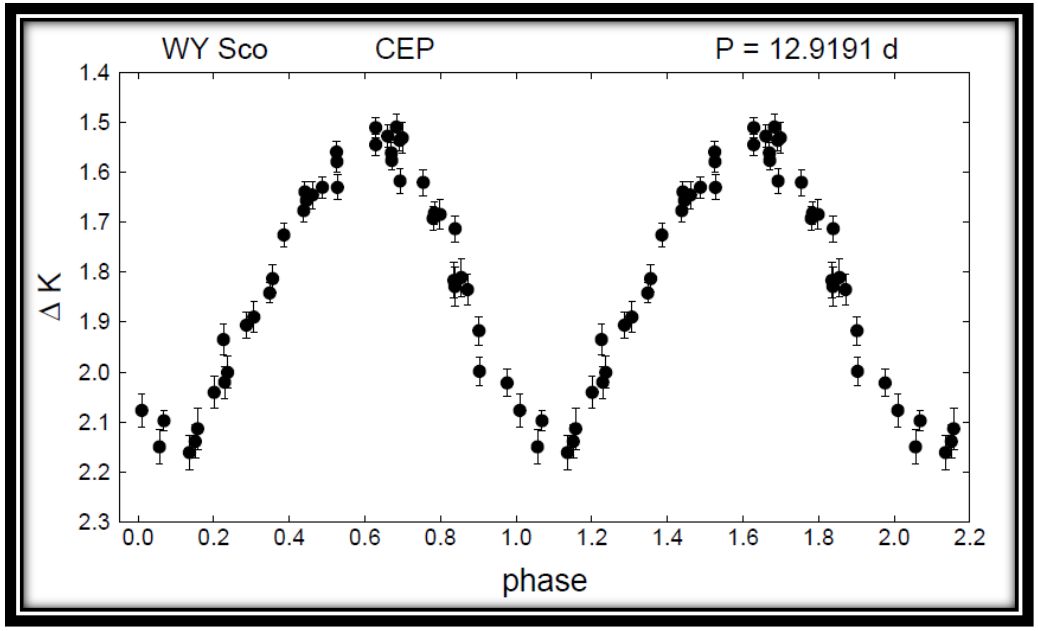


Left panel: the central part of the open cluster NGC1817. The shaded box is the 4.2′x4.2′ field of view of CAIN III. Right panel: Ks-band image of the same field.

Facilities around the world

INAF/REM 0.6m Telescope + REMIR





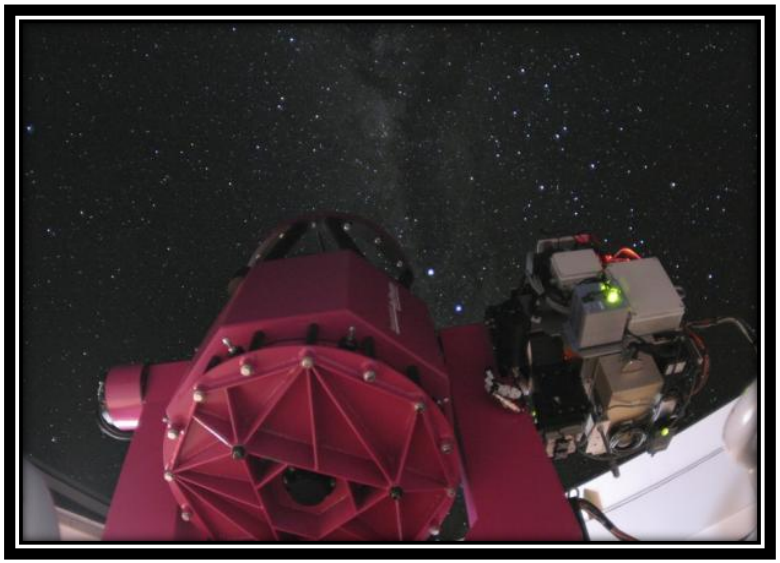
K-band light curve of the (suspected type II) Cepheid WY Sco, currently being observed with the REM 0.6m Telescope.

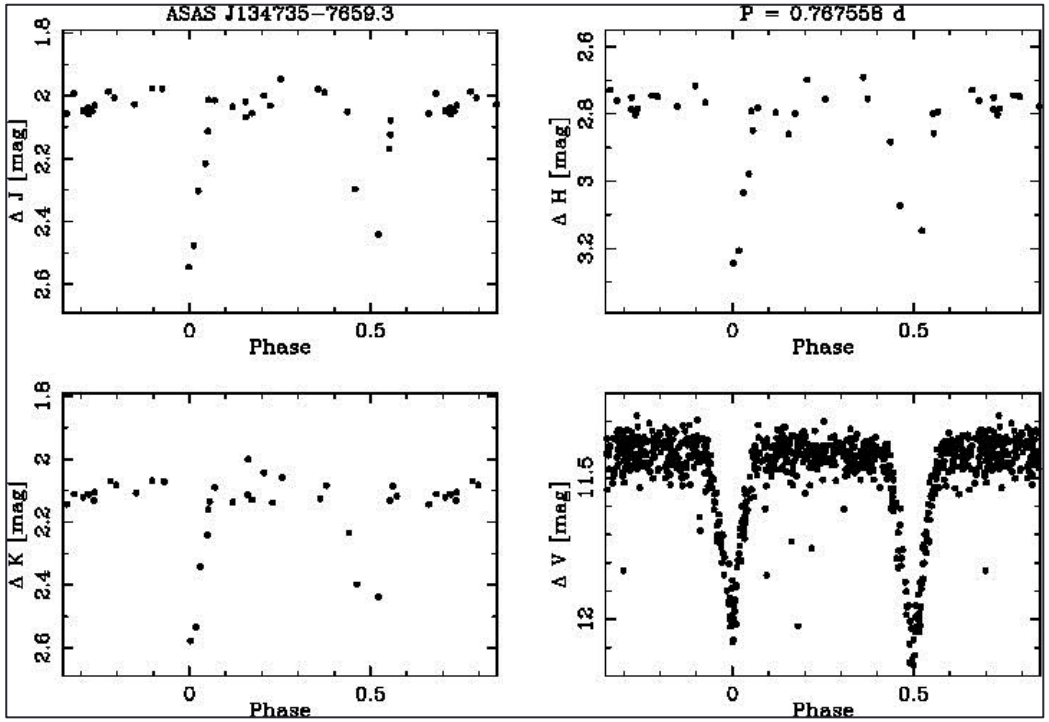
REMIR

FoV: 10'x10' – pixel scale: 1.2 arcsec/pix

Facilities around the world

INAF/REM 0.6m Telescope + REMIR





REMIR

FoV: 10'x10' – pixel scale: 1.2 arcsec/pix

Local collaborators

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Kusakin, A.

To stay tuned...

http://www.vvvtemplates.org