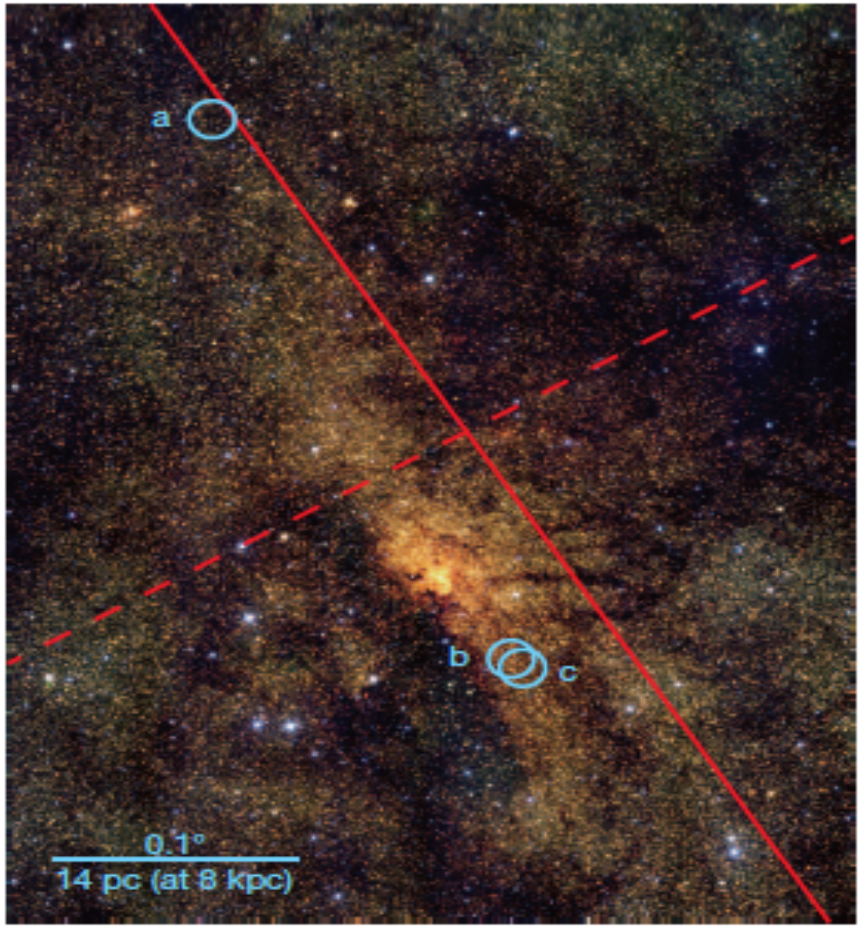
NIR High resolution spectroscopy with WINRED@NTT

G. Bono, (Univ. of Rome TOV), + L. Inno, R. O. da Silva, V. Braga, B. Lemasle, K. Fukue, D. Magurno, S. Rastello, B. Proxauf + Japanese + Romans + ESO + Neapoletans + …… Ennio + Enrico …..



Padua, March 3, 2017

NIR high resolution spectroscopy with WINRED@NTT

OUTLINE OF THE TALK

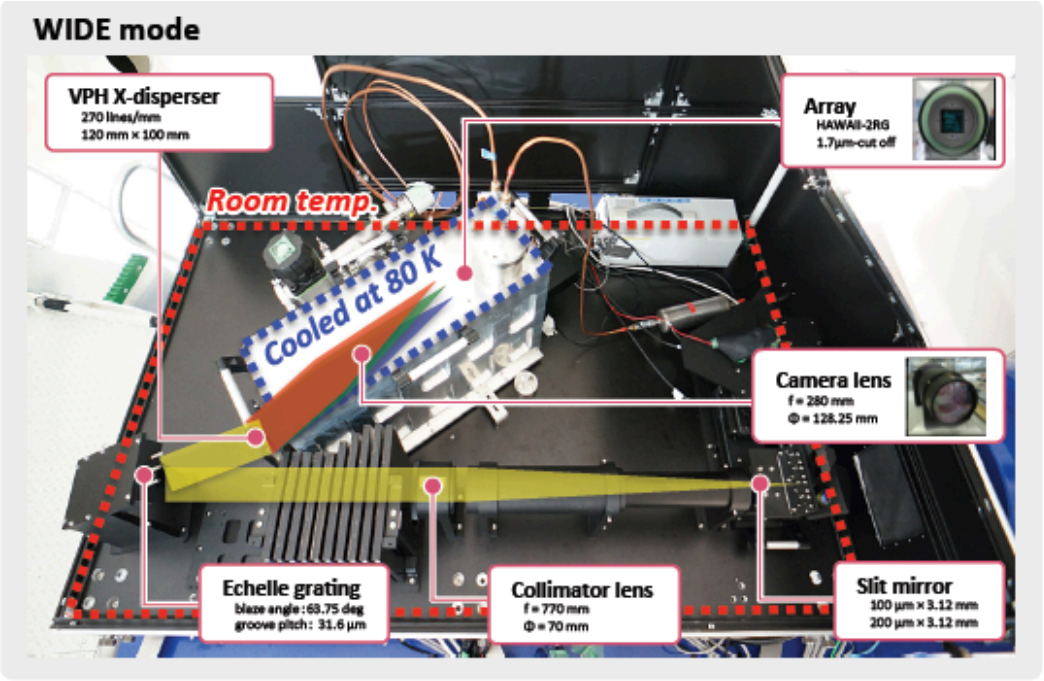
→ Science drivers for WINERED@NTT

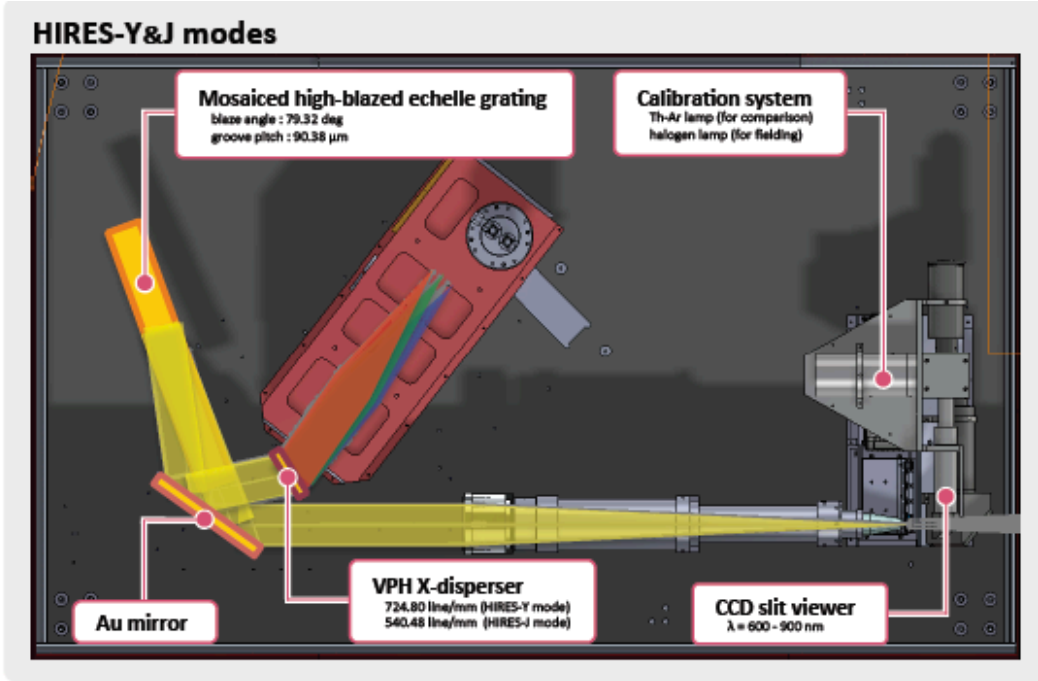
→ Why NIR HR spectroscopy?

→ Current status

→ Future perspectives

WINERED





WINERED@NTT → as a visitor instrument

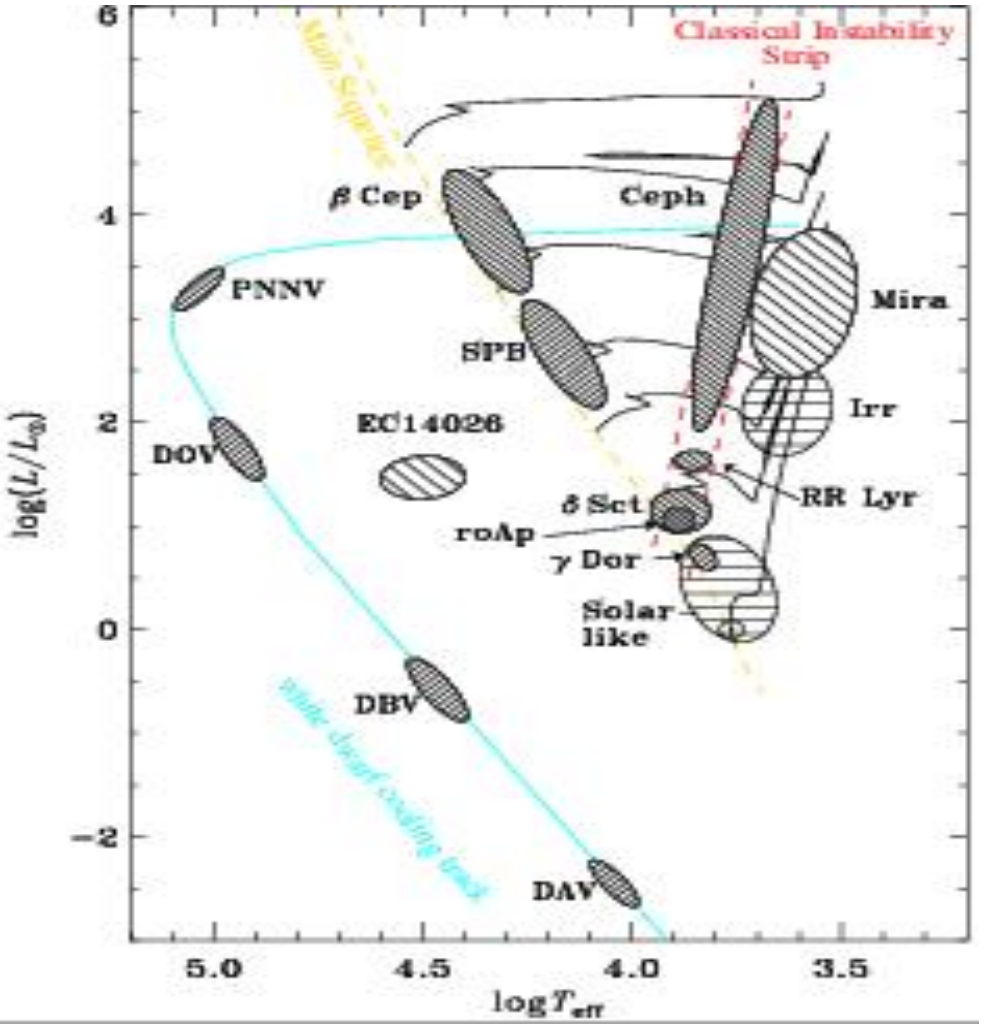
Oscillating Stars with wIneRed near-Infrared Spectroscopy [OSIRIS]

Department of Astronomy University of Tokyo & Kyoto

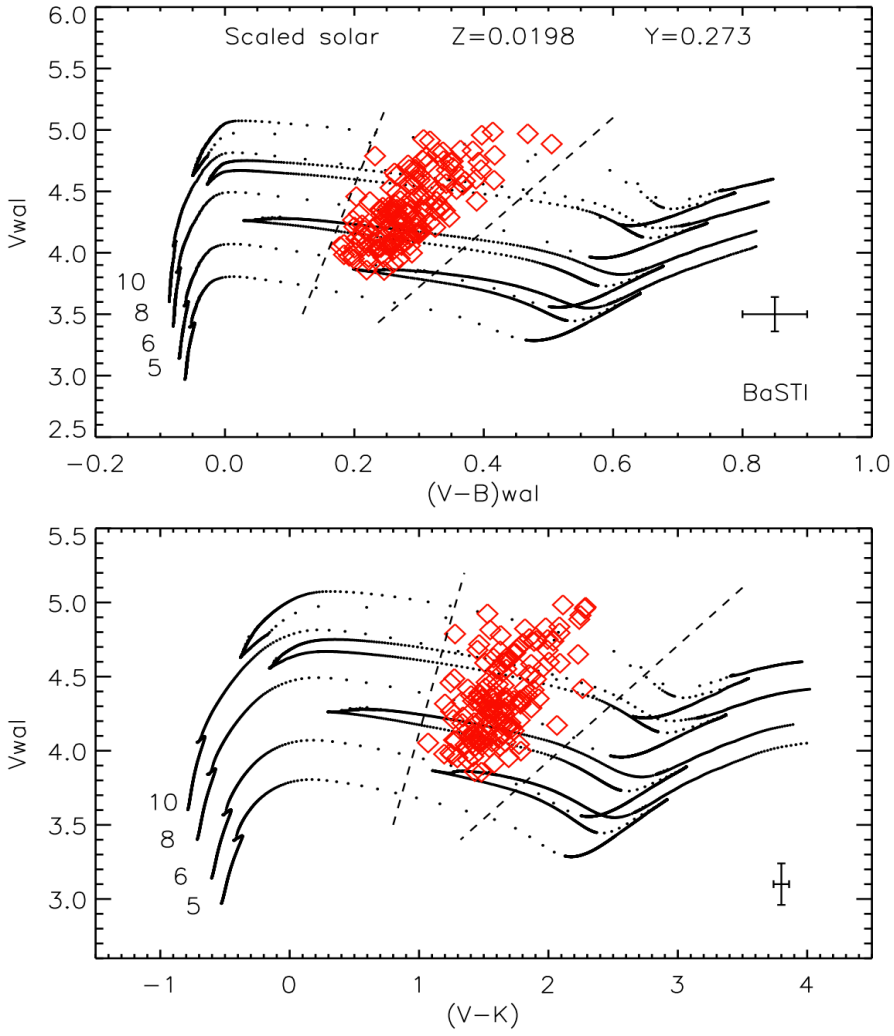
P.I. Naoto Kobayashi -- Germanium patent

http://merlot.kyoto-su.ac.jp/LIH/top_winered.html

Pulsation & Evolutionary Properties



Instability Strips



Low & Intermediate-mass stars H & He-burning phase

Cepheids & Miras & RR Lyrae+TIICs

MW disk/halo/bulge
Magellanic Clouds

→ They can be easily identified
→ Distance better than ~3%
→ stellar tracers → Age constraints
Cepheids → young [5-300 Myr]
Miras → Intermediate-age
RR Lyrae TIICs → old [> 10 Gyr]

→ Demanding targets!

Cepheids & Miras & RR Lyrae+TIICs

MW disk/halo/bulge Magellanic Clouds

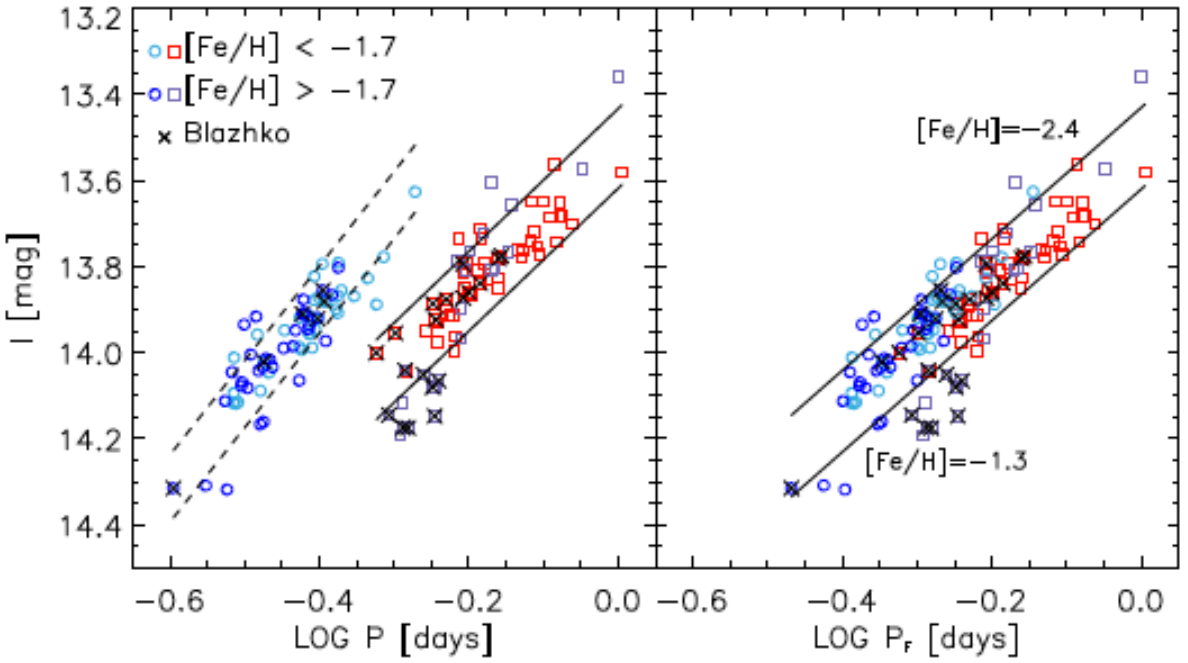
→ Near Infrared vs optical spectroscopy

Optical spectra of variable stars driven by temperature variations → strong non-linearities for shock formation and propagation

NIR spectra driven by radius variations

The HR spectroscopy of RR Lyrae stars is lagging in total less than ~70 objects

Next Gaia data release in one year or so



RR Lyrae in Omega Cen

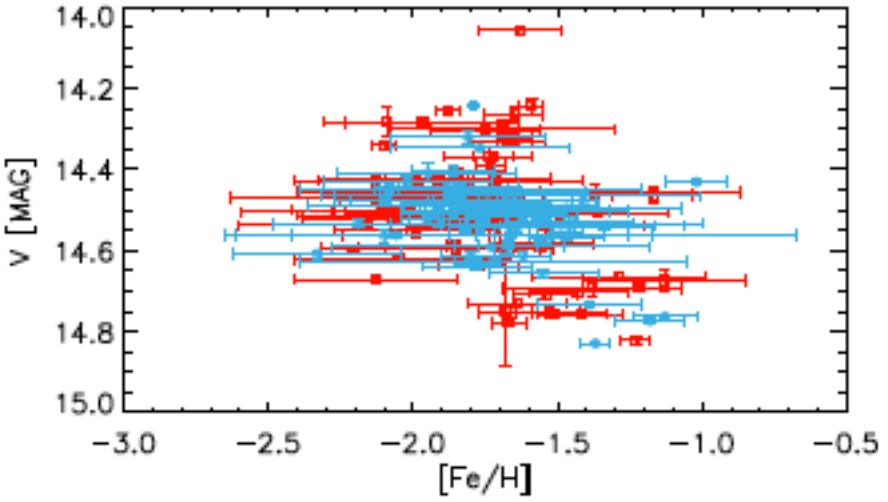
Sollima +
Rey +

Long Term project:

Thousands of optical images

Hundreds of NIR images
+ spectroscopic follow up

Magellan (FourStars + M2FS)



Braga + 2016

The largest NIR+MIR data set ever collected for MC Cepheids

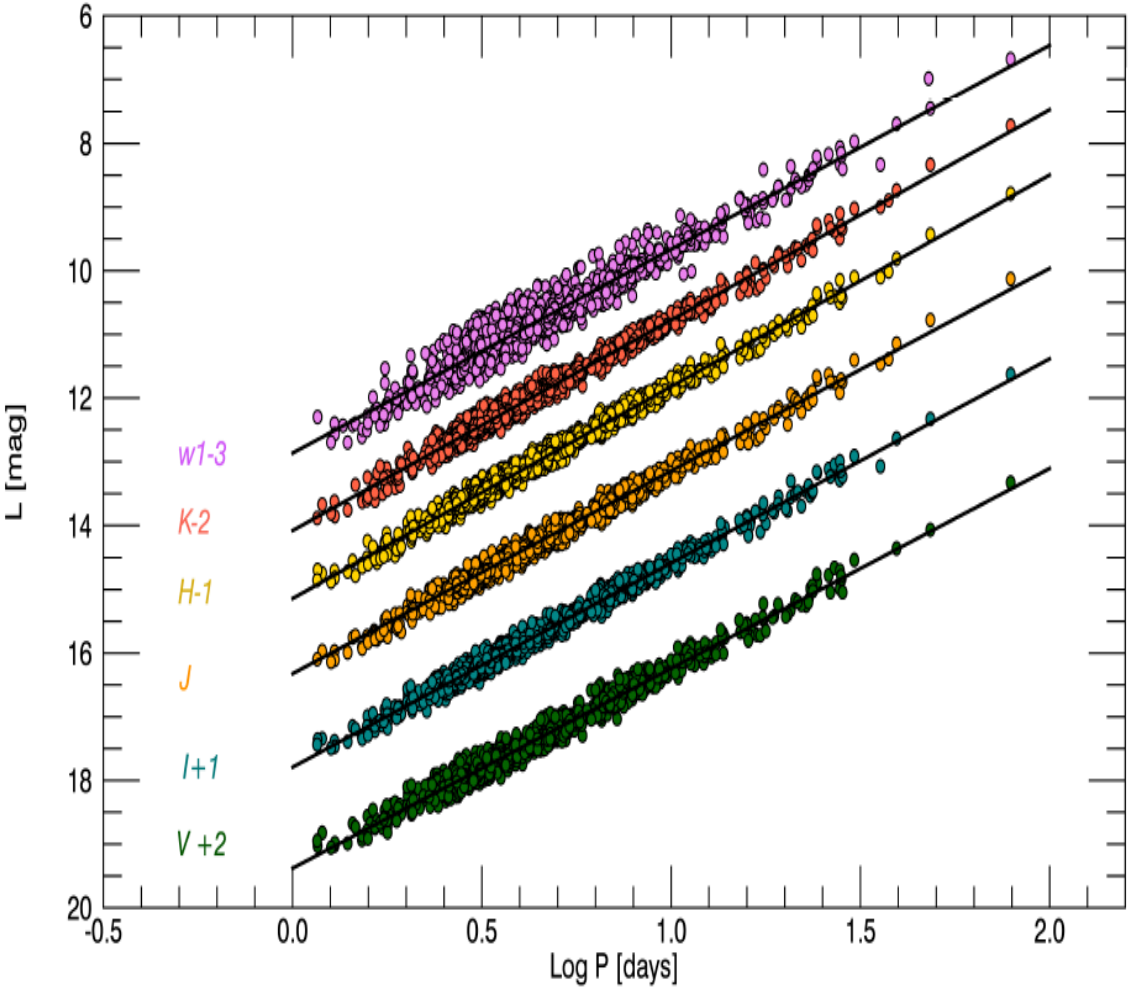
Inno + (2013,2016 + IRSF survey) → LMC → SMC pending

Multi-band approach
Pioneered by
Freedman & Madore

OGLE+IRSF+
WISE+SPITZER

Distances &
Extinctions

LMC geometry &
reddening map



Far from being a fishing expedition

Optical & NIR time series

Optical: OGLEIV +
IAC (IAC80,TCS; PI: Monelli)

NIR: IRSF@SAAO (Matsunaga) +
VVV+VVVX (Minniti/Zoccali)
IAC (IAC80,TCS; PI: Monelli)

→Opt/NIR Spectroscopic follow up

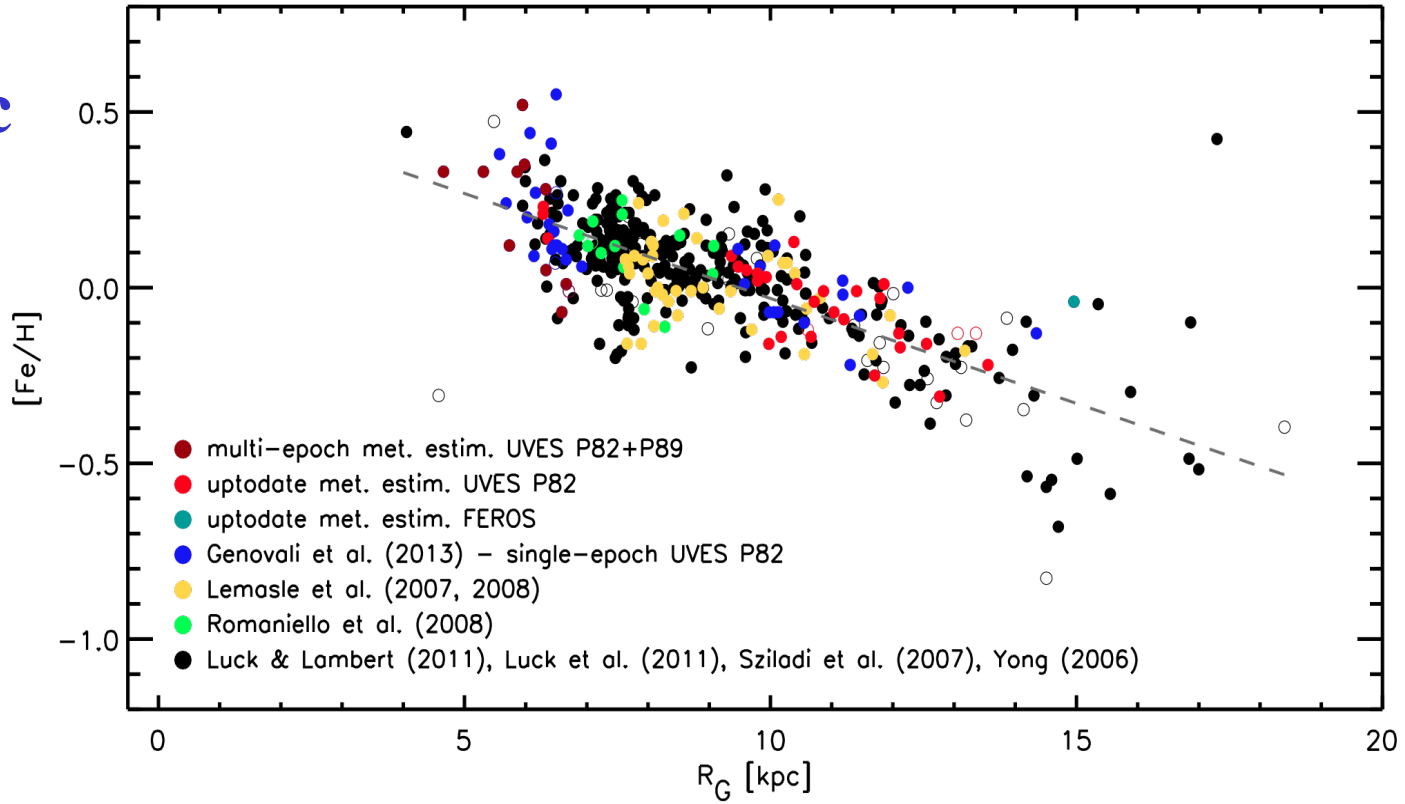
UVES/X-SHOOTER@VLT + IRCS@SUBARU
FEROS@2.2m MPG + GIANO@TNG + …

Homogeneous iron scale for 440 Galactic Cepheids

High spectral-resolution, a few tens of Cepheids in common.

~1/3 proprietary

~2/3 Luck + Andriewski +

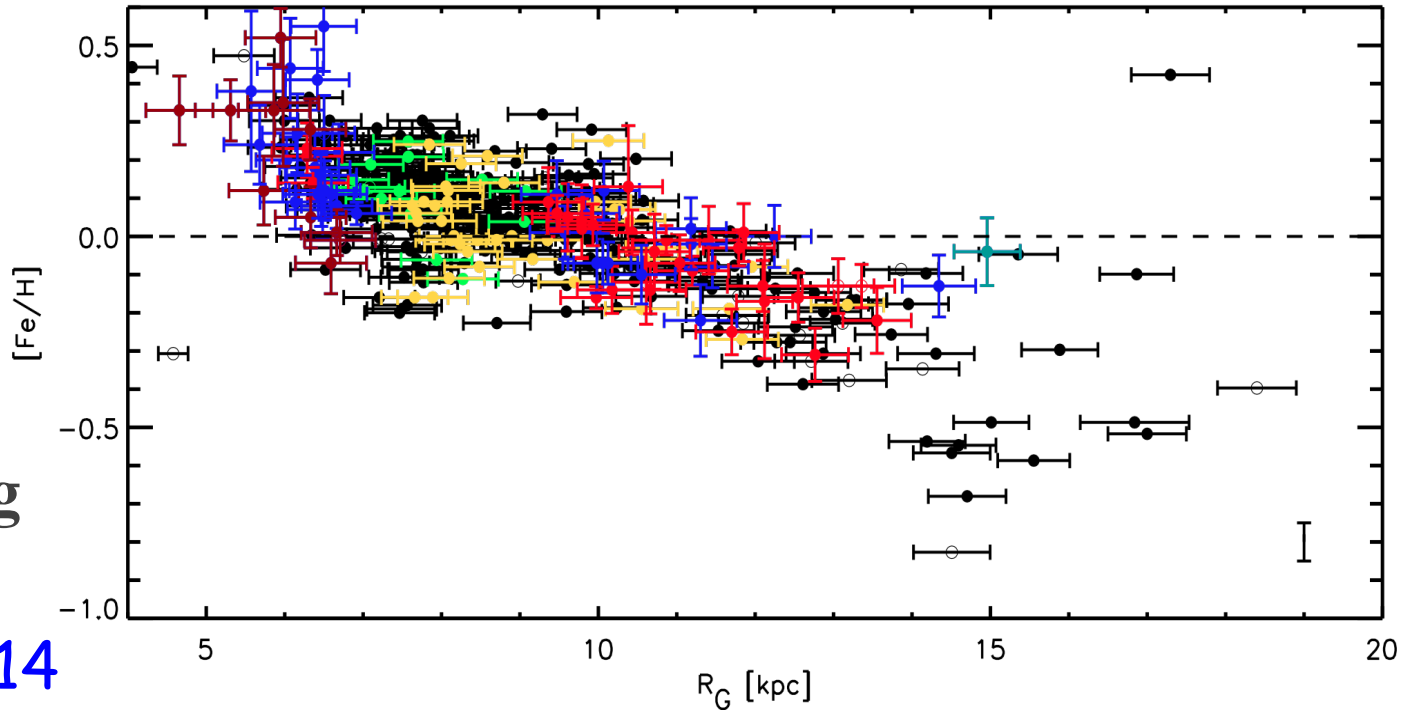


Linear trend
-0.060±0.002 dex/kpc

Steepening in the inner disk (Rg ≤ 6/7 kpc)

Increase in spread in the outer disk (Rg> 13 kpc)

Large spread at fixed Rg



Genovali et al. 2013,2014

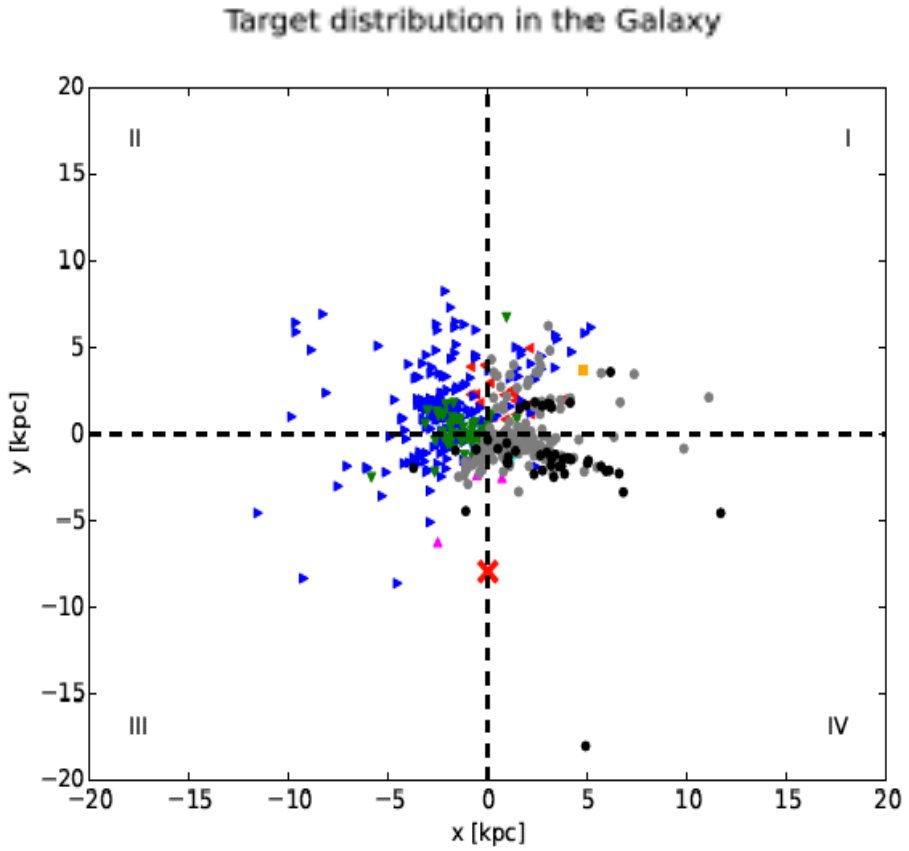
Spectrograph	FEROS	HARPS	UVES	All
No. of objects	169	9	76	205
Nometal cepheids	8	1	0	8
Cluster cepheids	11	10	8	14
Calibrators (>2 spectra)	77	9	17	108
No. of spectra	486	199	152	837

~200

A new spin 50% of known Cepheids 10% new

~1000

Small numbers when compared with AMBER/GES



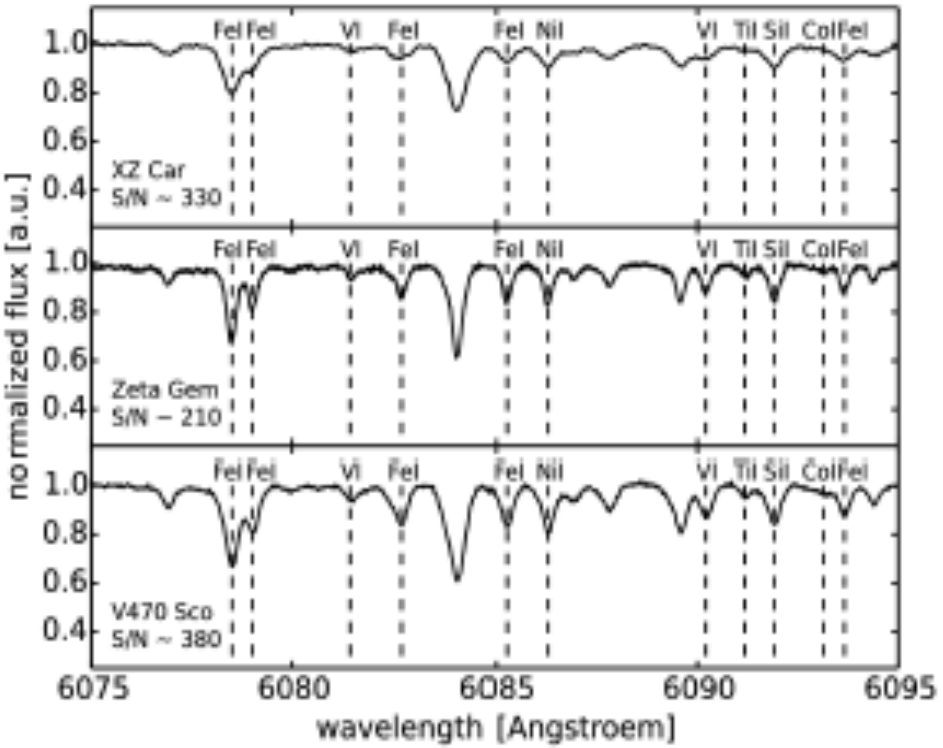
Homogenous temperature & metallicity scale based on EWs → LTE

R≥35,000 – SNR ≥ 100

→ Dozen calibrators
→ Dozen cluster Cepheids

Master Thesis by B. Proxauf

A new spin

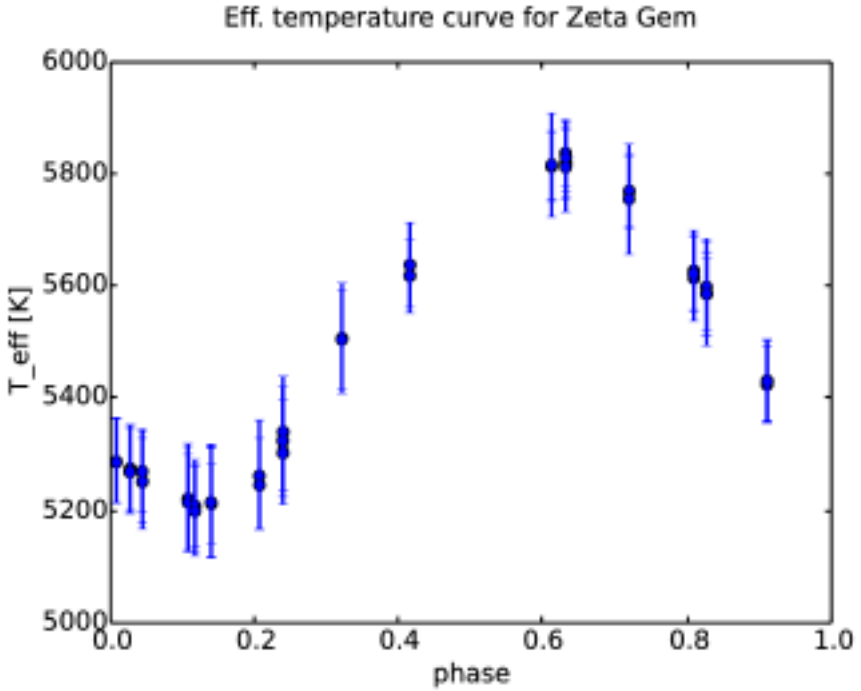


Line depth ratios for 260 pairs
by Kovtyukh & Gorlova old + new

Extended spectral coverage
from ~4000 to 8000 AA

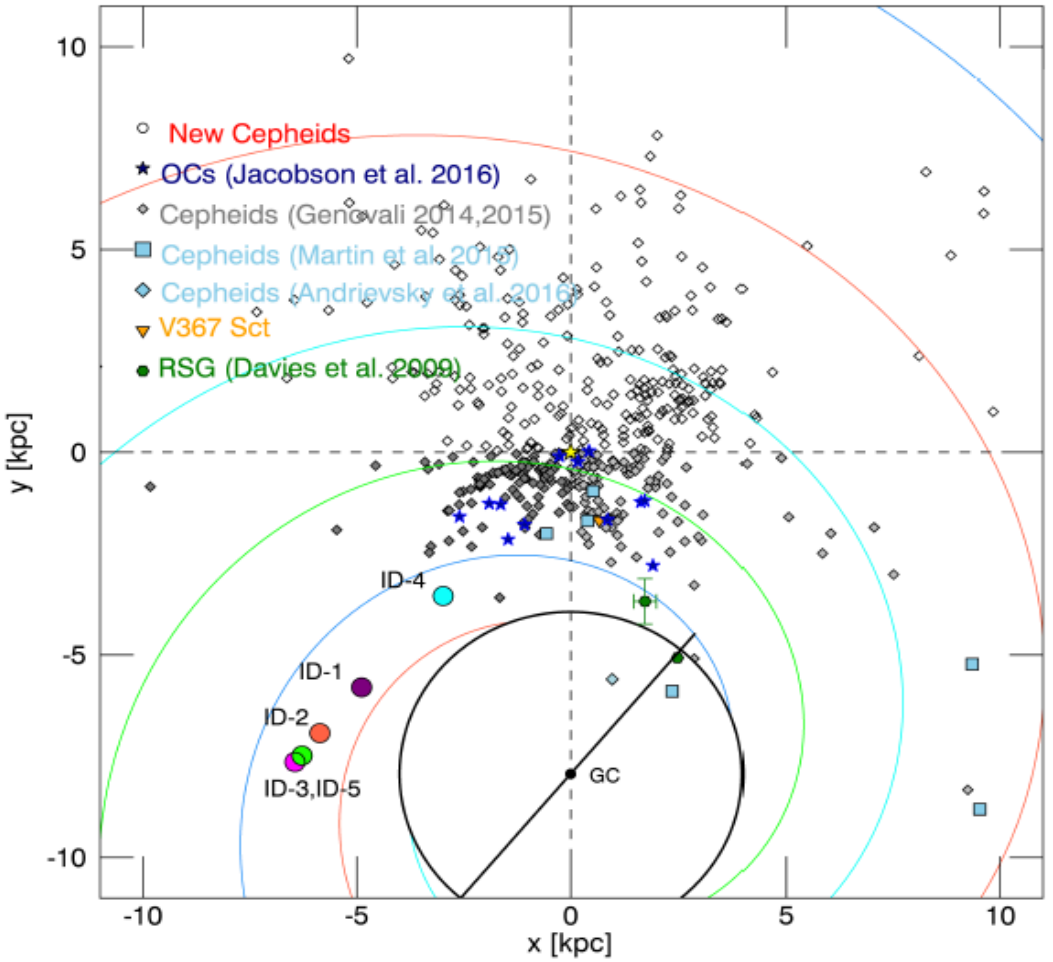
Extended temperature coverage
from ~3500 to 7500 K

Smooth temperature estimates
along the rising branch



← Based on HARPS spectra

…. more on the inner disk



Five new Cepheids in the inner disk (IV quadrant)

NIR Photometry IRSF at SAAO

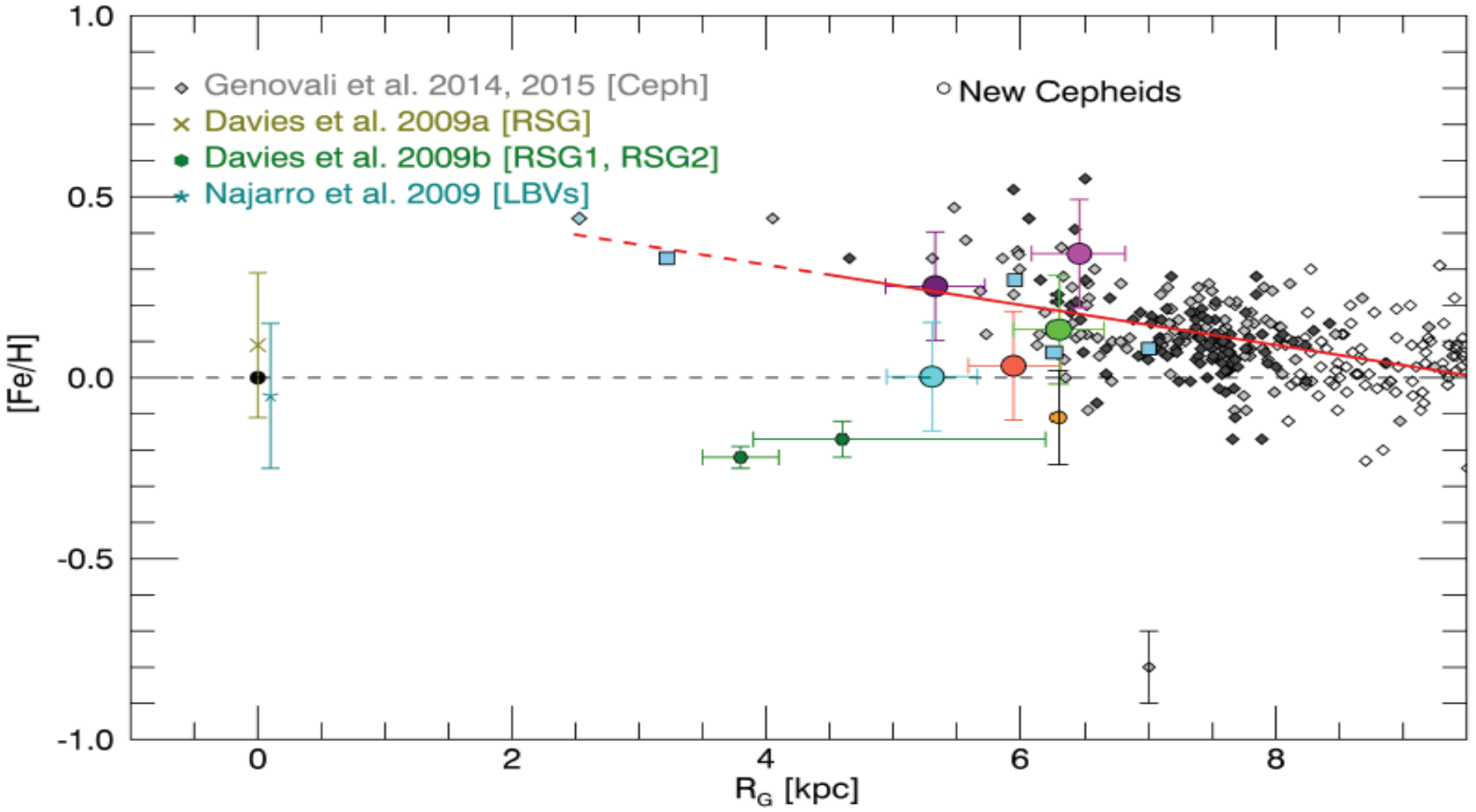
MIR Photometry SPITZER + WISE (time series)

Reddening laws by Cardelli + 1989 Nyshiama + 2006

Inno + (2017, tbs)

…. more on the inner disk

Martin + 2015 – Andrievsky + 2016 → distances based on optical photometry

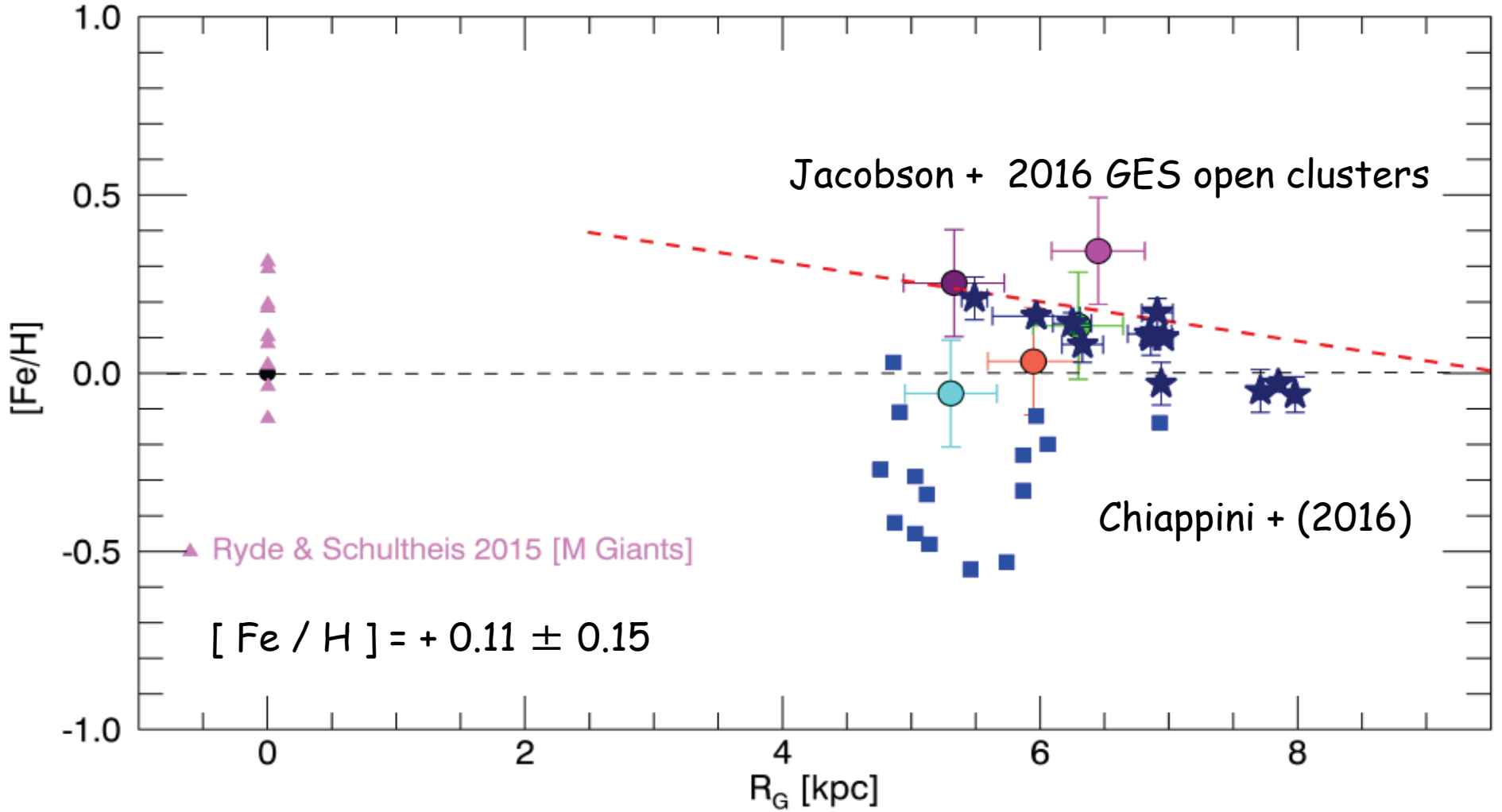


Flattening vs Slope [?]

Laura Fecit

Livia's talk

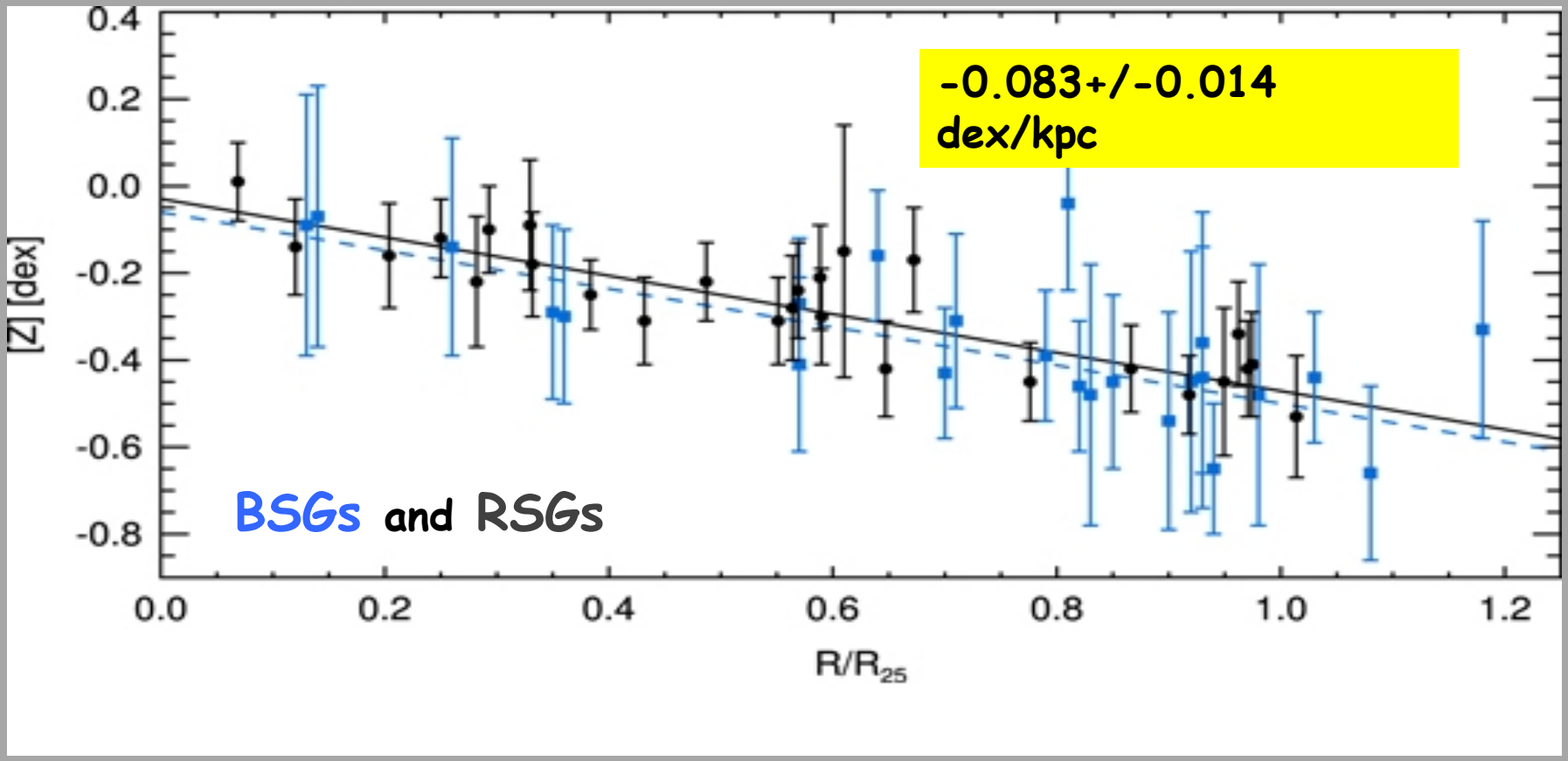
…. more on the inner disk



Open Clusters in the inner disk are telling Us the same story ….
Marginal evidence of a large spread

RSGs as cosmic abundance probes

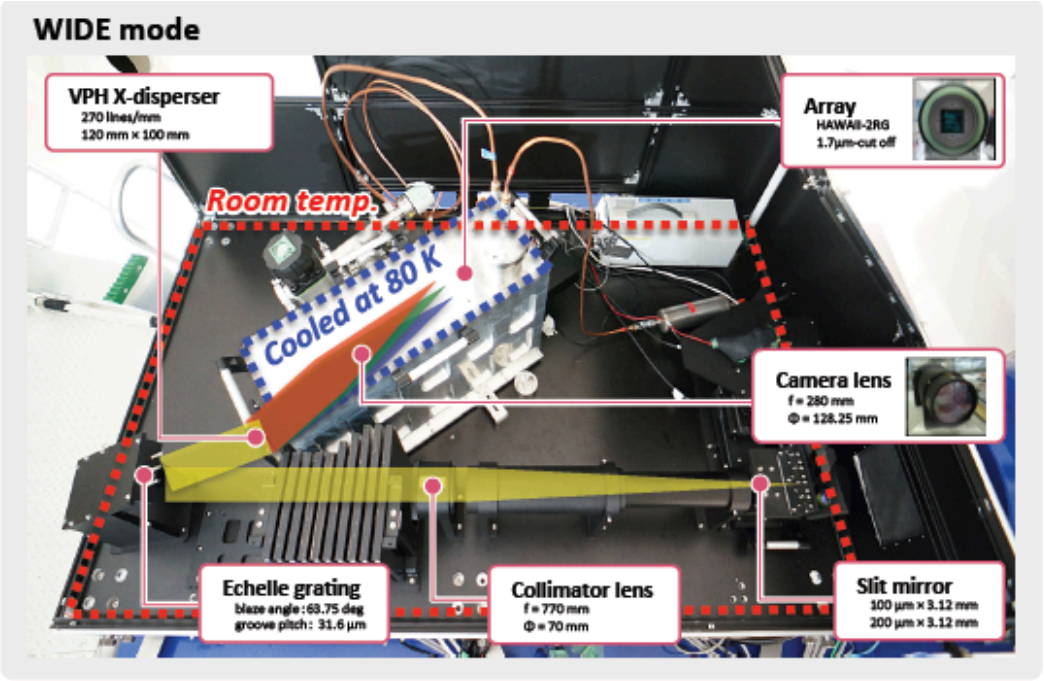
low resolution J-band spectroscopy of individual metal-rich RSGs

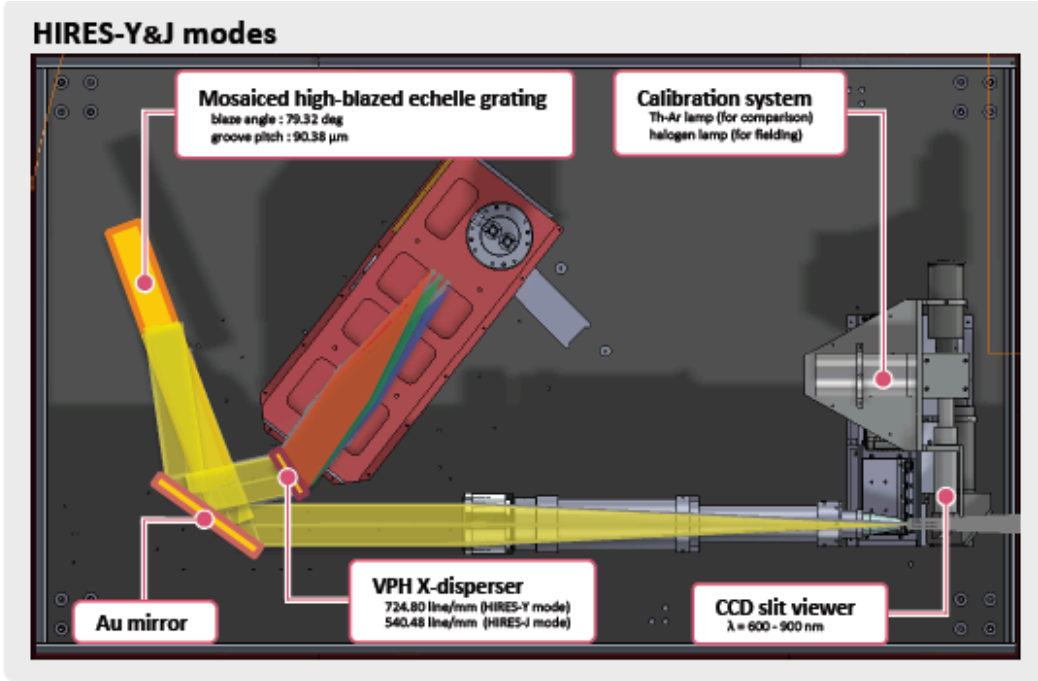


Gazak+ 2015: RSGs in Sculptor galaxy NGC300 (1.9 Mpc) KMOS@VLT

Evidence of an inversion in the metallicity gradient
CALIFA (Sanchez-Menguiano + 2016)

Paving the way: WINERED





WINERED@NTT → as a visitor instrument (sabbatical leave!!!)

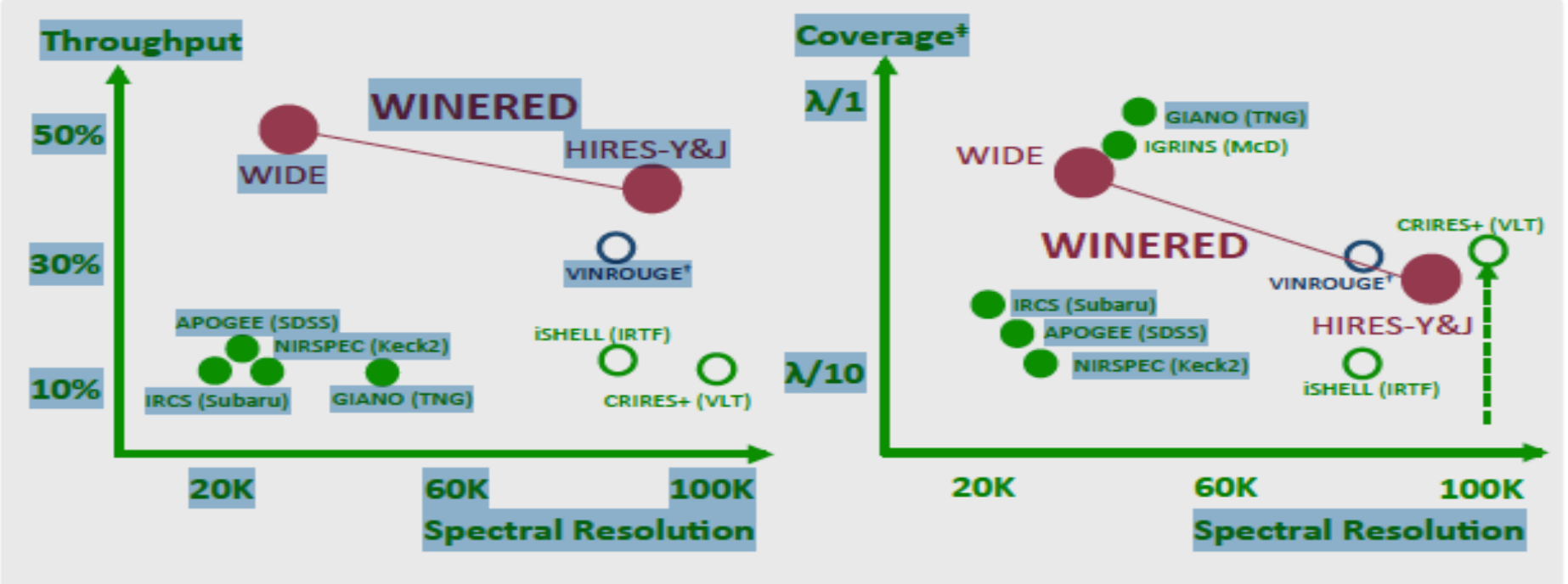
Feb. 9-17/2017 → Pilot project (nine nights)

Large Programme → core science primary distance indicators
old → RR Lyrae + type II Cepheids
intermediate-age → MIRAS
young → classical Cepheids

+

Offered to ESO users P100 .. waiting for CRIRES+ & SOX

Paving the way: WINERED



WINERED@NTT

Two different observing modes:

WIDE → zYJ in a single shot with R~14,000 & 28,000

HIRES → either Y or J with R~80,000

NUTRITION FACTS

■Limiting magnitude (Vega mag) sensitivity per resolution element ($\Delta\lambda/2$)
-S/N=30 1 hour (900 sec x 4)

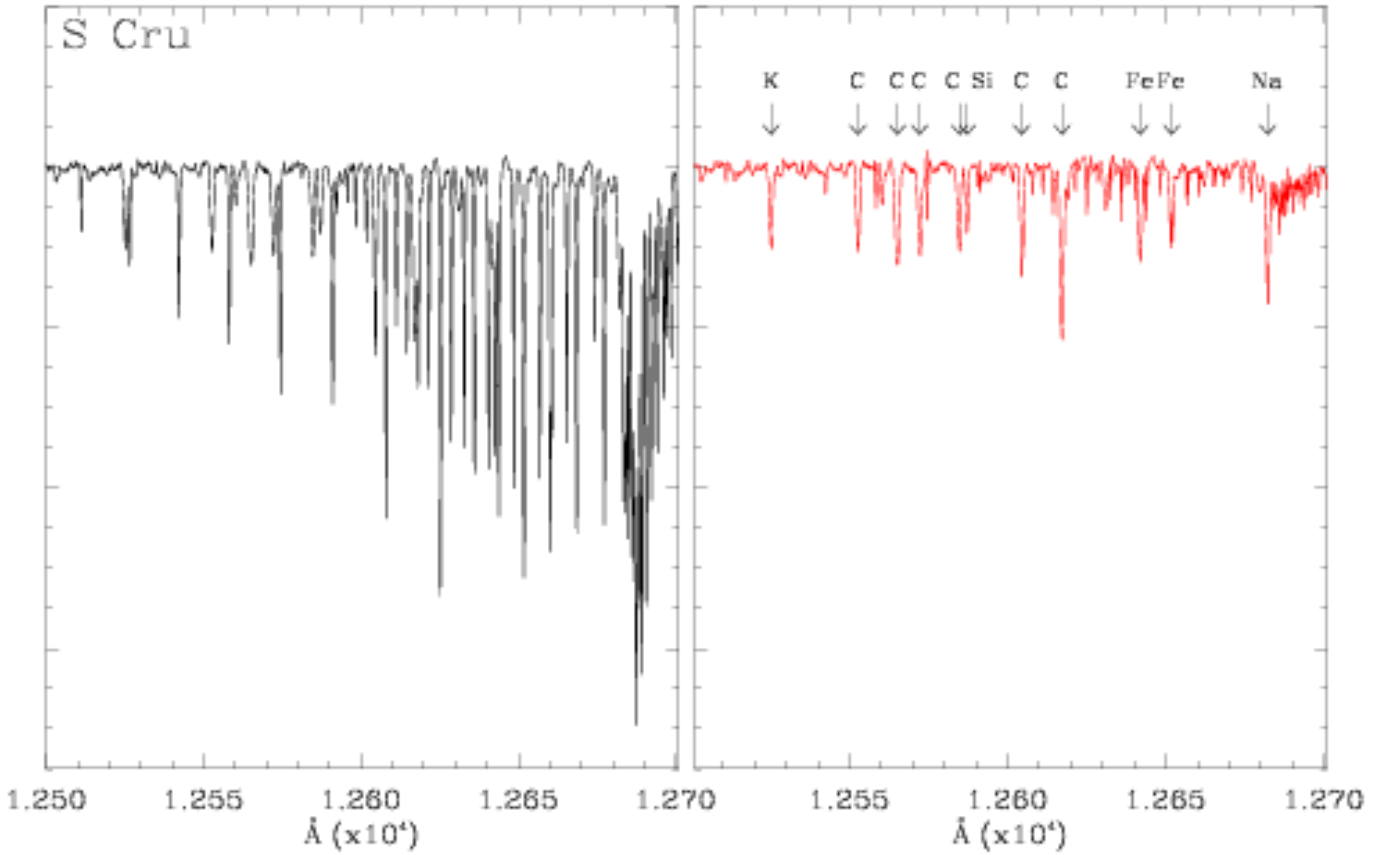
Mode	WIDE (zYJ simultaneous)			HIRES		
Slit	0".54	0".81	1".08	0".54	0".81	1".08
pixel	2	3	4	2	3	4
Resolution	28,000	18,700	14,000	80,000	53,000	40,000
z	14.9	15.6	16.1	—	—	—
Y	15.1	15.8	16.3	13.7	14.3	14.6
J	15.2	15.9	16.4	13.8	14.4	14.7

LARGE PROGRAMME (P100+4yrs):
BULGE + halo RRLs + TIICs
MW & MC Cepheids
MW & MC Miras
A,B K type gints/supergiants

Parallel Programmes:
ESO users + winered
PIONIER docet

WINERED@NTT vs APOGEES@du Pont

Spectra collected during technical nights 1 month ago



Galactic Cepheid

S Cru
[Fe/H]=0.1
J~5.5 mag
T_exp=30 s
Seeing=0.75

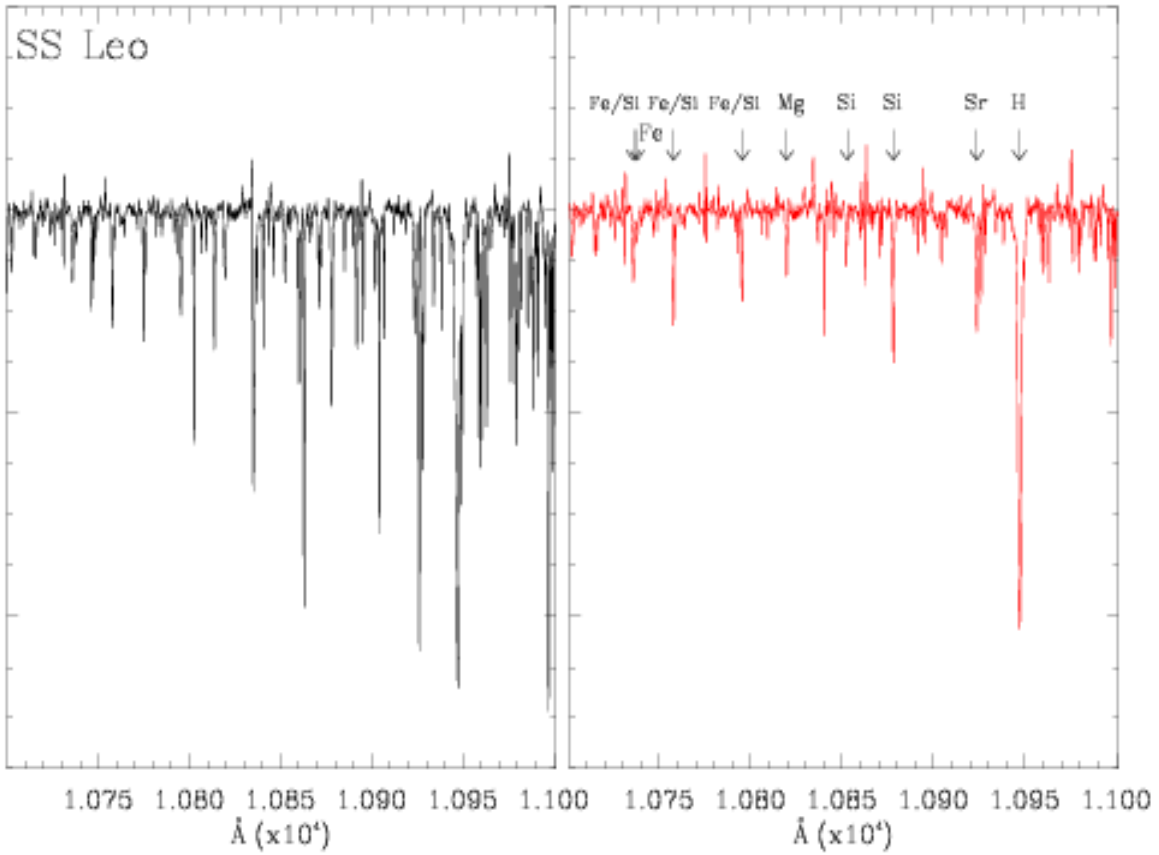
SNR~200

BEFORE & AFTER telluric subtraction

with TELFIT → Huge savings of telescope time

Davide Fecit

Spectra collected during technical nights 1 month ago



Galactic RR Lyrae

ACID TEST

SS Leo

[Fe/H]=-1.8

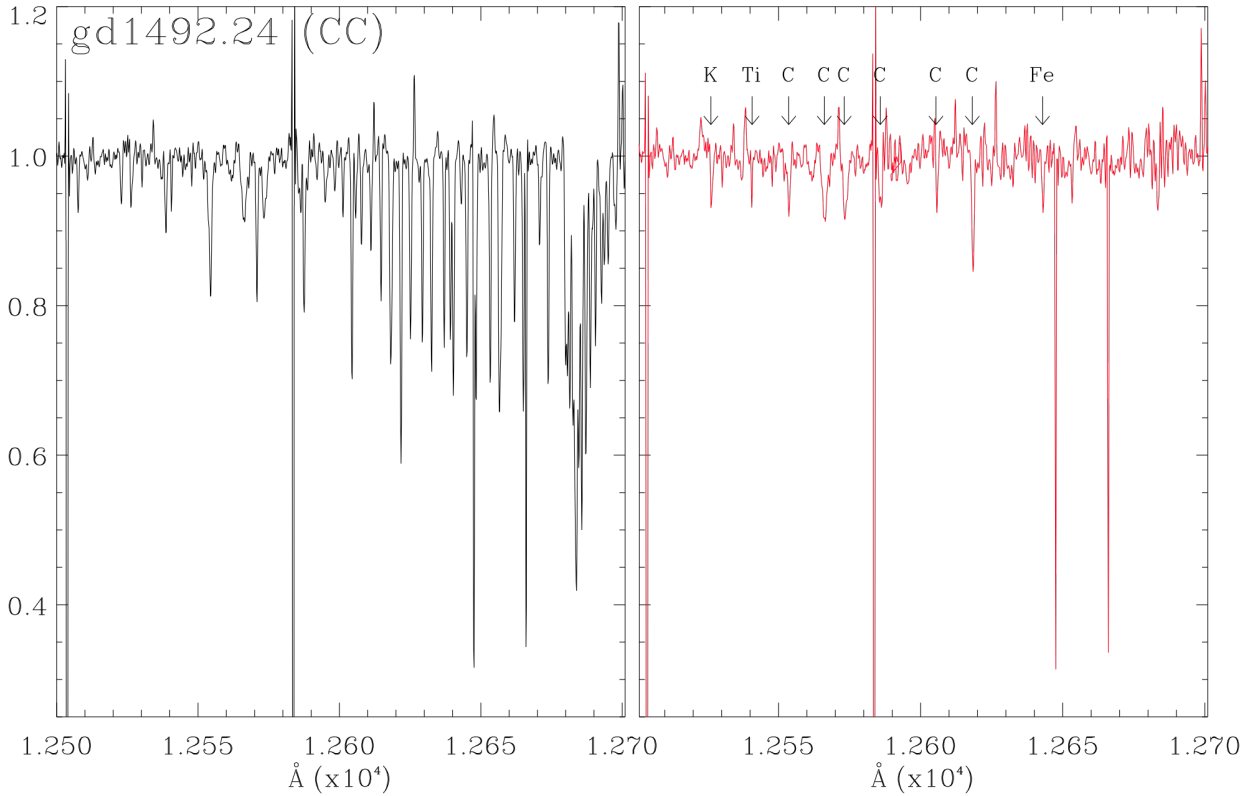
J~10.5 mag
T_exp= 900 s
Seeing=0.70
SNR~200

BEFORE & AFTER telluric subtraction

with TELFIT → Huge savings of telescope time

Davide Fecit

Spectra collected during february run



New Cl. Cepheid discovered by OGLEIV

J~12.5 mag

t_exp= 600 s

Seeing=0.90

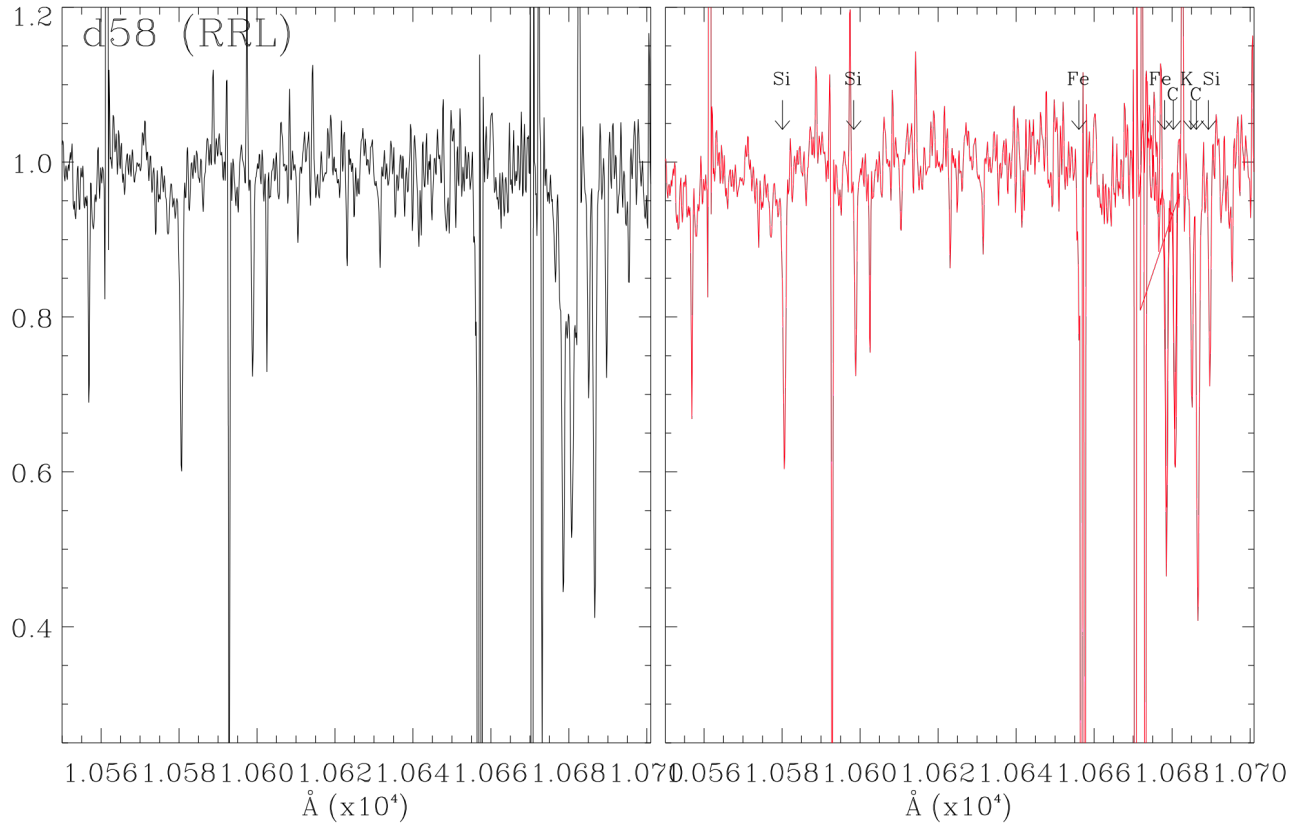
SNR~60

BEFORE & AFTER telluric subtraction

with TELFIT → Huge savings of telescope time

Davide Fecit

Spectra collected during february run



New RR Lyrae discovered by VVV transition Bulge/thick disk

J~13.0 mag

t_exp= 500 s

Seeing=0.8

SNR~45

BEFORE & AFTER telluric subtraction

with TELFIT → Huge savings of telescope time

Davide Fecit

CONCLUSIONS

→ Marriage of convenience!!!

WINERED@NTT better sensitivity than SUBARU!!!

New results for supporting the large programme

Collaborations are very very welcome!!!

No restrictions on targets and you can submit your own ESO proposal!!!

E-ELT: FLI → MICADO/HARMONI/METIS

Future developments

→ Galaxy: Outer disk – KISOGP survery
Inner disk + NB → IRFS survey
OGLE IV

→ Magellanic Clouds: field & cluster Cepheids

LACES → Abundances (PI: M. Romaniello)
UVES + KMOS
VIMOS → radial velocity (PI: L. Inno)

→ Transition from HR optical to NIR spectra
GIANO, WINERED, CRIRES

→ Kinematics & chemo-dynamical models

Where we go with GIANO@TNG?

1) Optical → KISO Survey

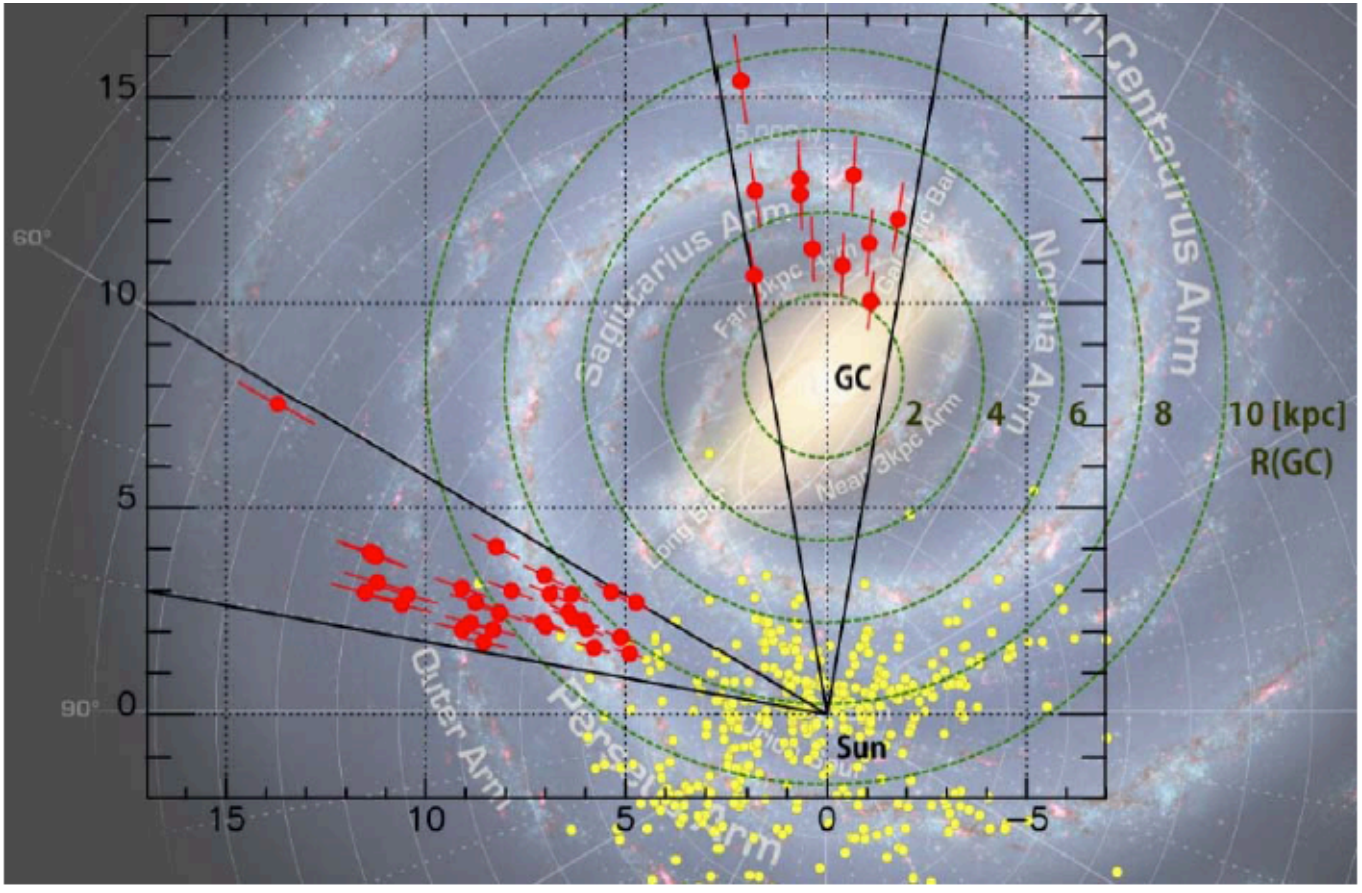
2) NIR → IRSF Survey

GIANO HK-band

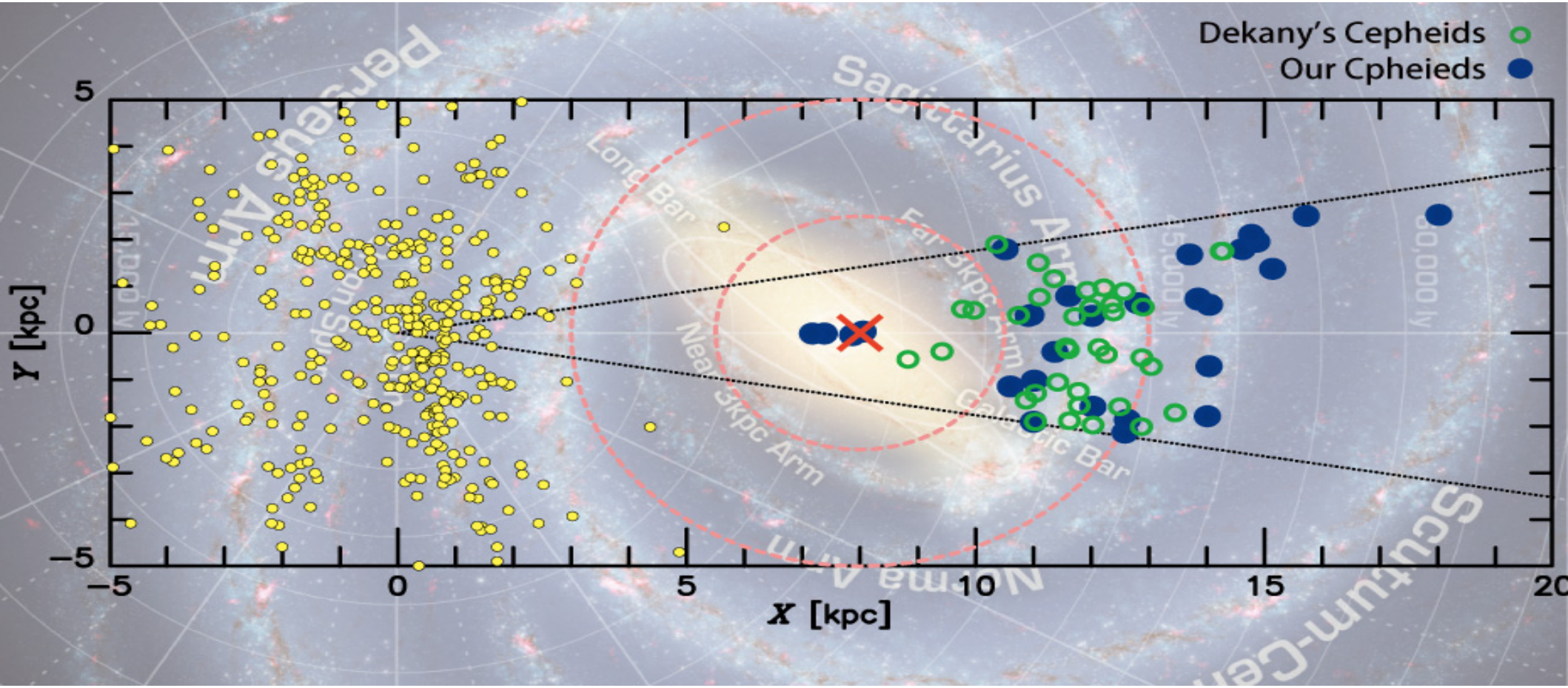
Is crucial in

highly reddened

regions



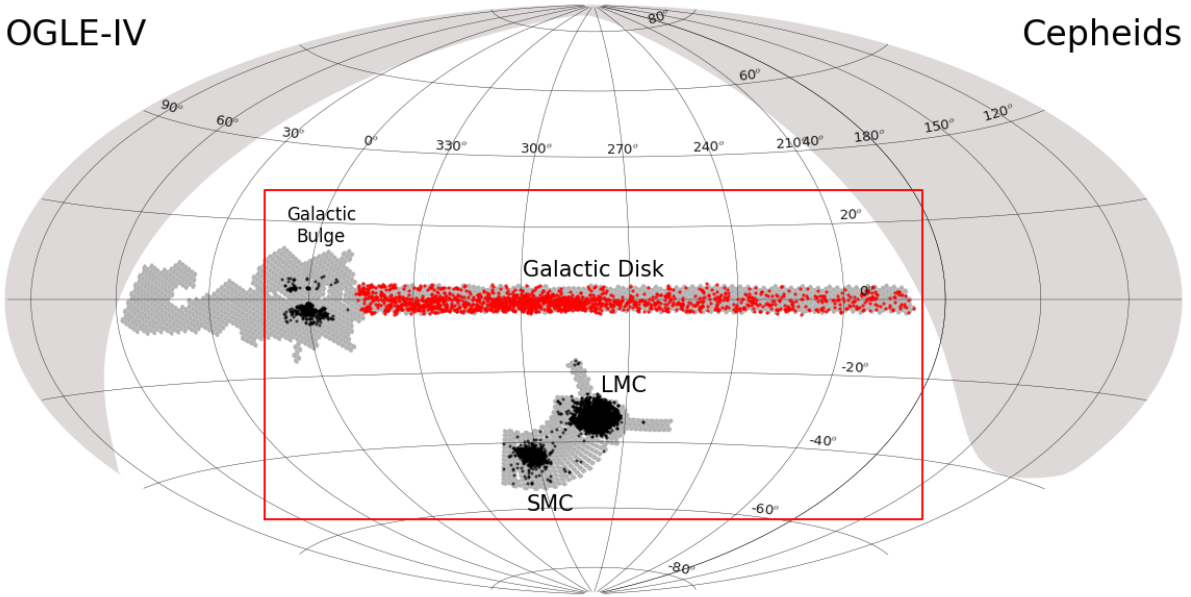
Beyond The Galactic Centre: classical Cepheids

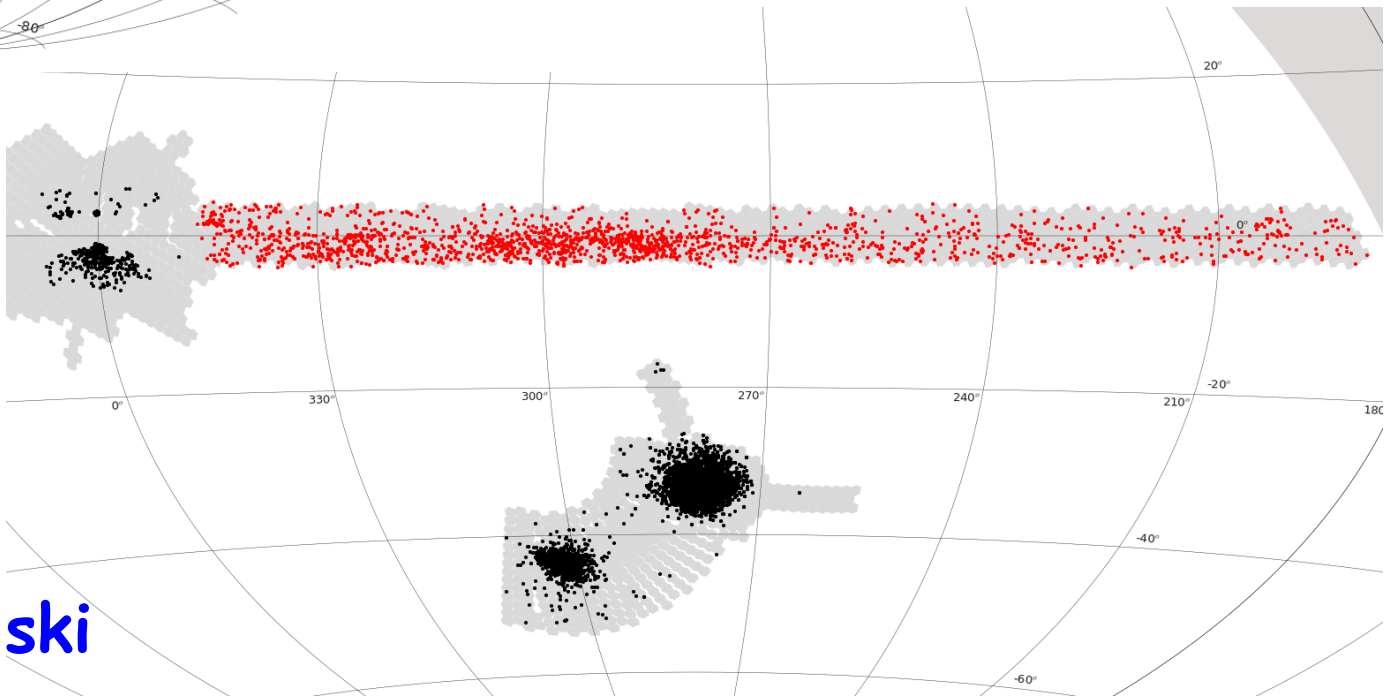


New constraints on stellar populations & Kinematics beyond the Nuclear bulge

Matsunaga + (2016) → Press Release RAS + TSR!!

More than 1000 new Cepheids discovered by OGLEIV along the Galactic plane





Courtesy by A. Udalski

Credits

To young, differently young & senior colleagues with whom I have the pleasure to share this wonderful adventure

D. Magurno (Rome), M. Fabrizio[ASDC], L. Inno[heid], S. Marinoni, P. Marrese, B. Lemasle[heid], R. O. da Silva (asdc), K. Fukue (Tokyo)

THANKS!