THE SPA LARGE PROGRAMME AT TNG

Livia Origlia – INAF OAS Bologna

SPA - Stellar Population Astrophysics

The detailed, age-resolved chemistry of the Milky Way disk

THE ASTROPHYSICAL CONTEXT

a golden era for stellar pops astrophysics

Gaia, VVV, PTF, OGLE, LSST + MOS surveys as Gaia-ESO, GALAH, APOGEE, WEAVE, MOONS-GAL and 4MOST are setting the **observational framework** for an exhaustive description of the **MW** structure, kinematics and global chemical properties with high statistical significance

still sparse/missed

complementary truly high resolution (>40k) spectroscopy of representative sub-samples of stars for an exhaustive description of the **detailed chemistry** and **nucleosynthesis** of the various MW stellar pops

only **echelle spectroscopy** with **simultaneous high resolution + wide spectral coverage** potentially allow the measurements of the **full set of chemical elements** of interest and with the necessary **high precision** to constrain scenario and timescales of stellar structure formation, evolution and chemical enrichment

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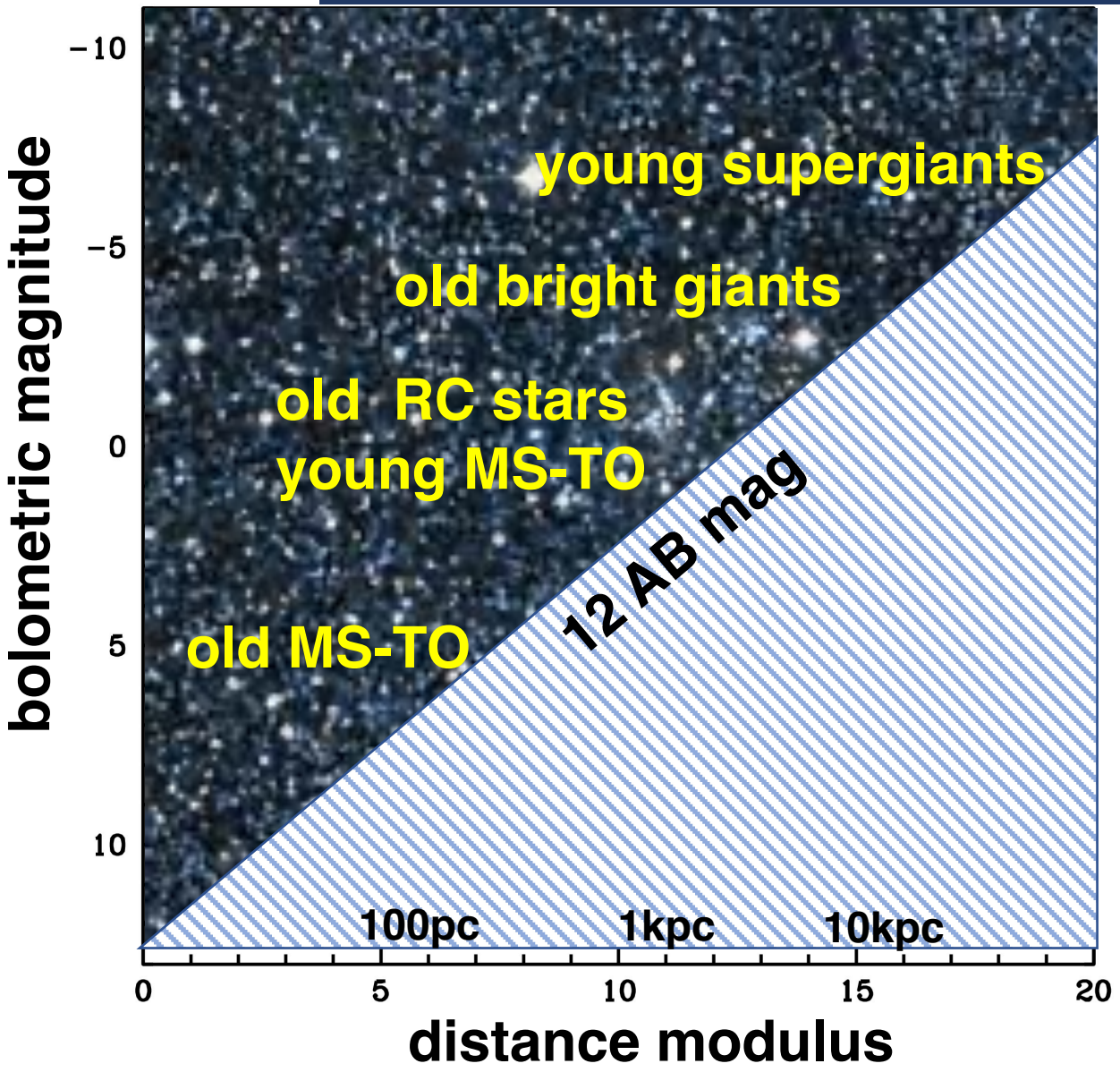

quantitative stellar spectroscopy down to ~12 AB mag

Galactic disc stars in a wide range of ages & evolutionary stages

detailed chemistry, kinematics (RV, rotation), m.f., chromospheric activity, winds, mass loss *etc.*

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simultaneous optical+NIR high resolution spectroscopy at 4m-class telescopes

widest spectral coverage in a single obs ➔ **maximizing the astrophysical information**

Southern emisphere

- ESO La Silla 3.6m – HARPS-S + NIRPS (no K-band)

Northern emisphere

- CalarAlto – Carmenes (NIR with gaps and no K band)
- **TNG – HARPS-N + GIANO-B (YJHK)**

http://nisp.oabo.inaf.it/SPA_TNG_LP/

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first, comprehensive **high resolution, age-resolved, multi-element chemical maps** of the field and cluster/association stellar pops in the

- **Solar neighborhood**
- **inner & outer disk**
- **young Scutum & Perseus complexes**

thus tracing

- radial /Azimuthal **gradients**
- **age-chemistry-kinematics** relations
- **cosmic scatter** and other **inhomogeneities** of abundances and abundance ratios
- **modes and timescales for cluster formation & evolution**
- **gas inflows, interactions** with the host sub-structures

enabling critical tests of **stellar evolution** & **stellar physics**

SPA - Stellar Population Astrophysics

The detailed, age-resolved chemistry of the Milky Way disk

THE SPA TEAM is composed of **42+ researchers** from INAF and other national and international institutes

PI: L.Origlia

WP Responsibles: G.Bono (Variable stars)
A.Bragaglia (Open clusters)
E.Dalessandro (Massive stars, young clusters)

Co-Is : J.Alonso-Santiago, G.Andreuzzi, E.Carretta, *G.Casali*, S.Cassisi, R.Carrera, G.Catanzaro, G.Cescutti, V.D'Orazi, *C.Fanelli*, G.Fiorentino, A.Frasca, L.Inno, A.Lanzafame, S.Lucatello, L.Magrini, M.Marconi, A.Mucciarelli, E.Oliva, *M.Rainer*, D.Romano, *N.Sanna*, *L.Spina*, O.Straniero, M.Tosi, A.Vallenari, *R.Zhang*

Co-Is from foreign Institutes: V.Braga, T.Cantat-Gaudin, X.Fu, K.Fukue, H.Hartman, N.Kobayashi, O.Kochuckov, B.Lemasle, N.Matsunaga, M.Monelli, N.Ryde, B.Thorsbro

SPA - Stellar Population Astrophysics

The detailed, age-resolved chemistry of the Milky Way disk

THE LARGE PROGRAM - Timeline

- ✓ request of 80 nights in 6 semesters
- ✓ 15% cut applied by the TAC to fulfill the 85% ceiling of the TNG time assigned to LPs
- ✓ **granted 68 nights** of observing time in 6 semesters (**AOT37-42, 2018-2020**)
- ✓ 66 nights of open shutter: **56 nights of good data**, 10 nights of poor data (focus problems, very bad seeing (>2”), clouds *etc.)*
- ✓ 6 nights of compensatory time in 2021 (4 already executed in July, 2 scheduled for next November)

in 2018 and 2019 most of the SPA observations were executed in visitor mode

the SPA Team acknowledges the TNG staff for executing the SPA observations in service during 2020 and 2021 due to COVID-19

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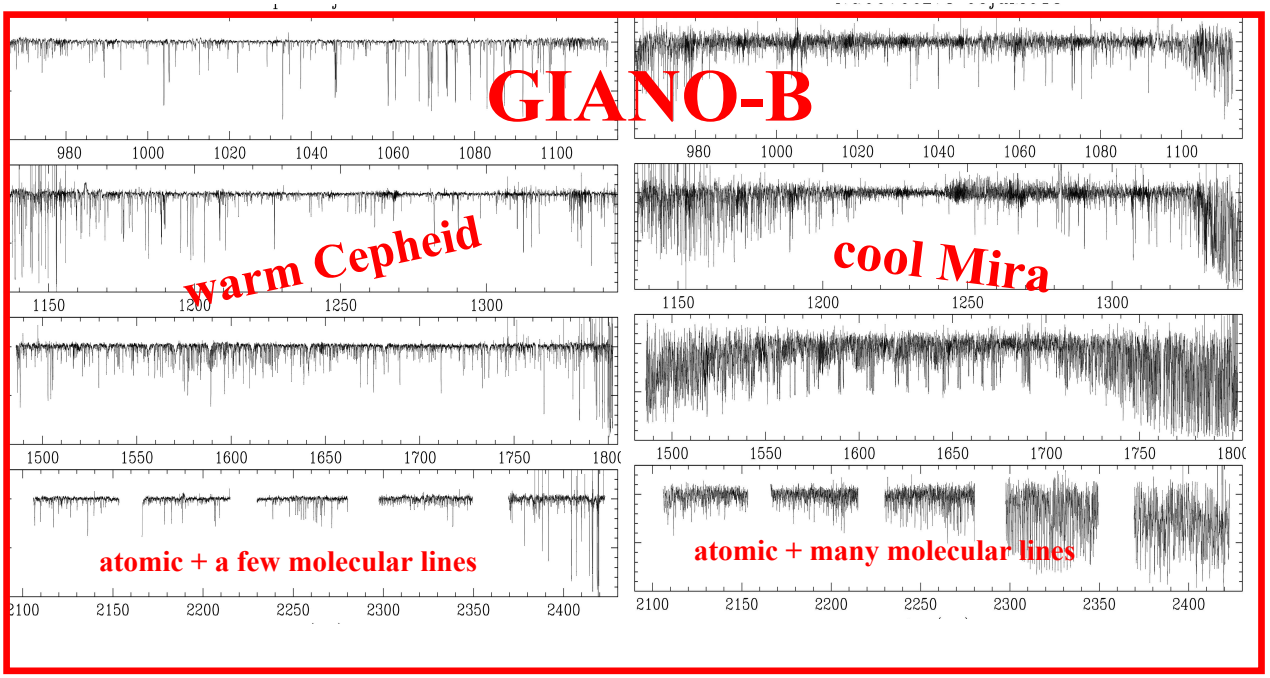
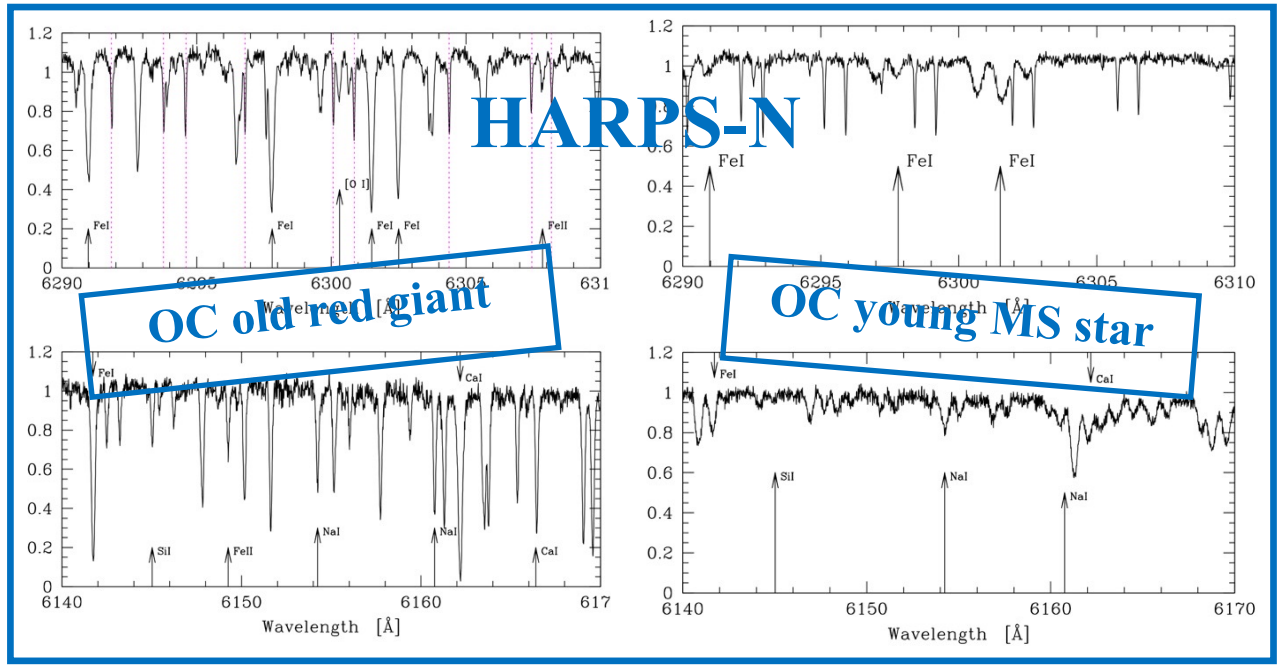
THE LARGE PROGRAM – Observations: Targets

- red/reddened stars: **Mira & type 2 Cepheid variables, RSGs in the Scutum complex** too faint in the visual to be observed with HARPS-N ➔ only near IR **GIANO-B** spectra
- stars in **open clusters,** in the ***Perseus* complex, Classical Cepheids, RSGs** with low reddening ➔ bright enough both in the visual and in the NIR to be observed with **GIARPS**





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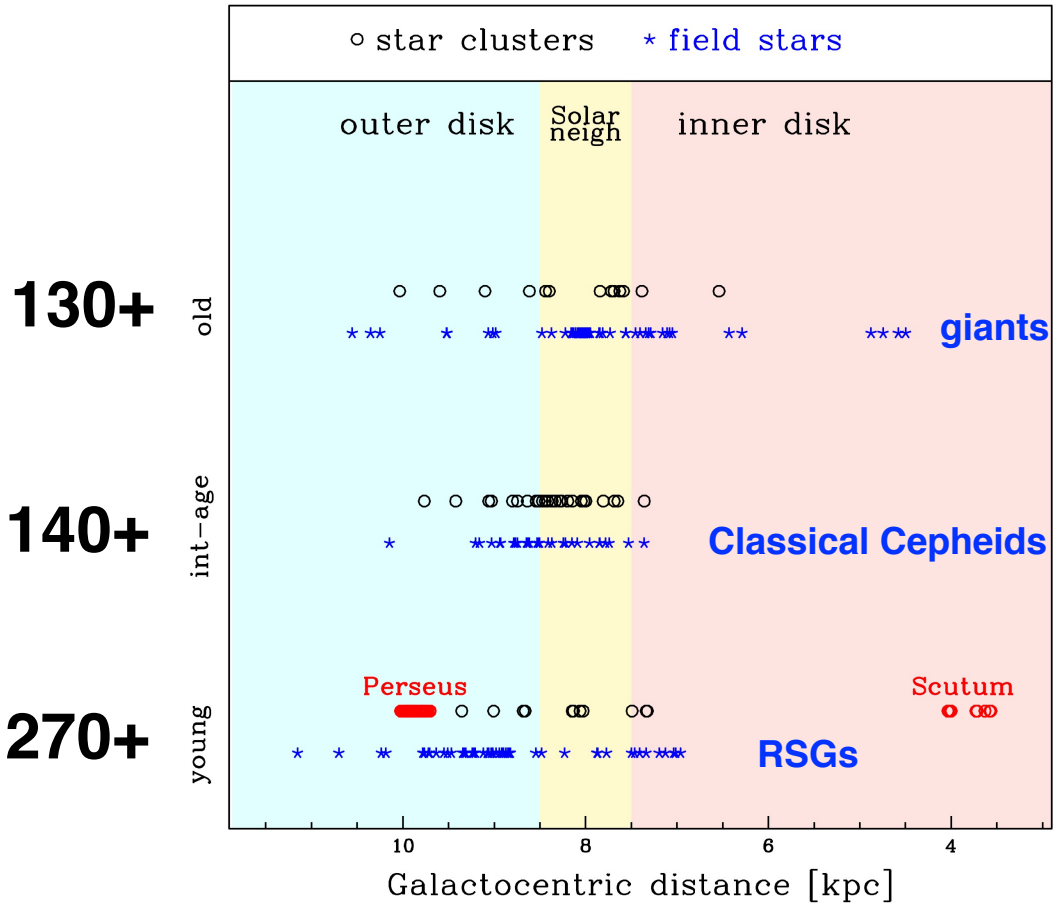
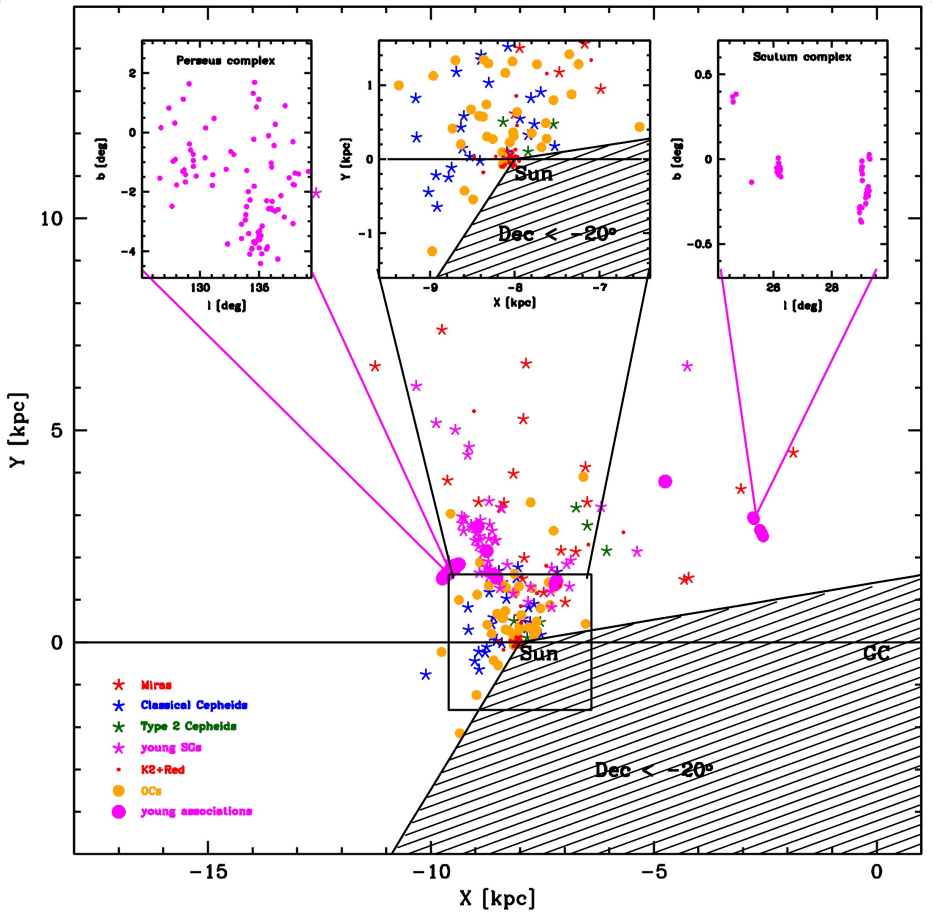
THE LARGE PROGRAM – Summary

540+ stars in the disc field and clusters/associations well spread in age **[10Myr-10Gyr], in Galactocentric distances [3-12 kpc]** and in the **X,Y plane**





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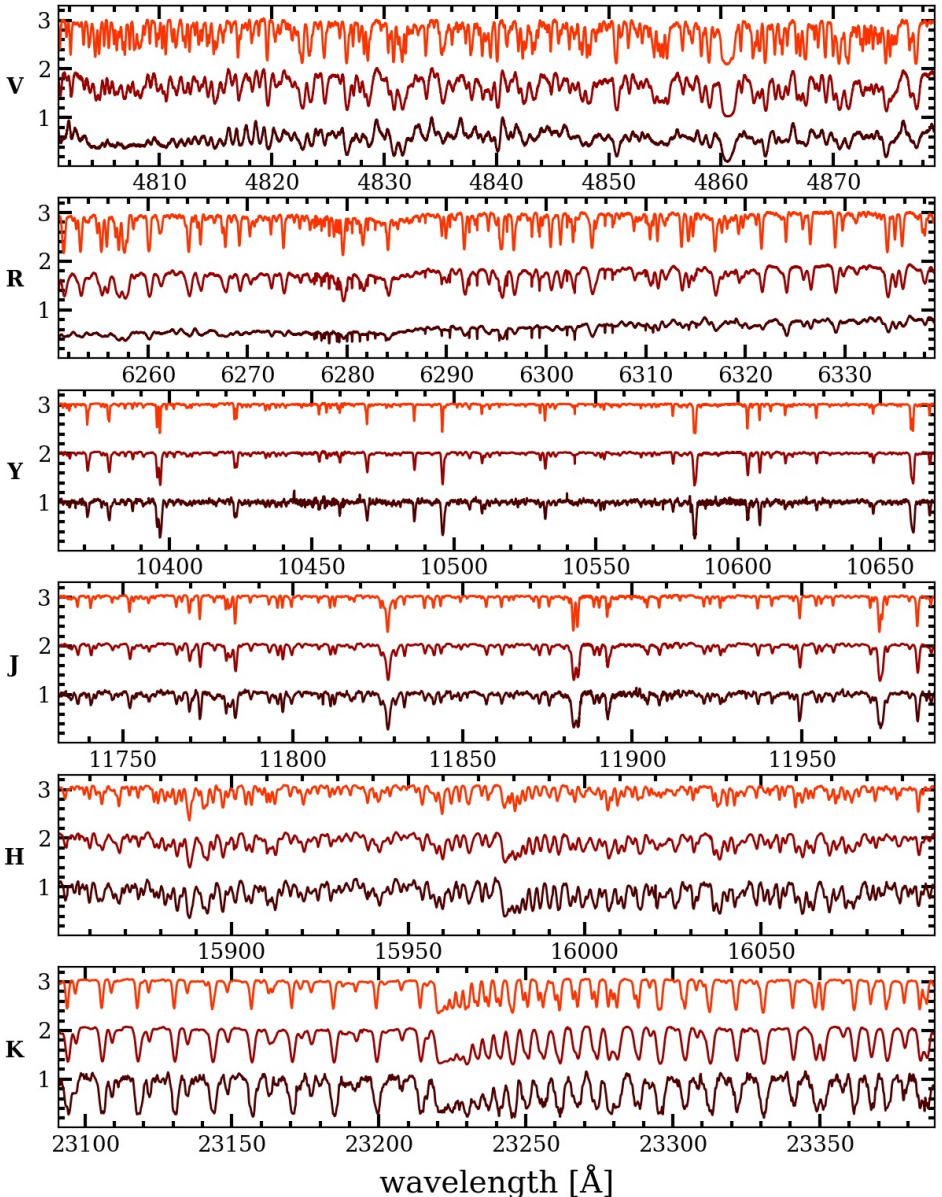

THE LARGE PROGRAM

exploring a new space of parameters in high resolution stellar spectroscopy

stellar parameters & full set of iron-peak, CNO, alpha, light & neutron-capture element abundances for

RSGs

K-M spectral types [*i.e.* T_{eff}~3400-4200 K, log(g)~0.0]

- GIANO-B (300+ atomic+molecular lines) and HARPS-N (100+ atomic lines) spectra

Miras and other massive AGBs

giants with late-M spectral types [*i.e.* T_{eff}<3500 K]

- GIANO-B spectra

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THE LARGE PROGRAM – Progress Report

- ✓ **data reduction** completed for all the stars observed so far (Periods 37-43)
- ✓ **science analysis** in progress, completed for about 40% of the observed targets
- ✓ **advertisement** of SPA at several conferences/workshops
- ✓ **publication strategy**
  - results for suitable group of stars and/or clusters in a serie of papers on A&A and other Main Journals
  - a few papers deal with calibrations and/or methodologies
  - a few papers will discuss the global picture of the disc chemistry and formation scenarios

- ✓ **milestones**
  - **January 21, 2018:** notified that *SPA LP* was approved ➔ kickoff of the project
  - **June 29, 2018:** observations started
  - **August 2019:** first SPA refereed paper published on A&A
  - **November 25, 2020:** observations ended
  - **February 2, 2021:** notified that *SPA LP* was granted 6 nights of compensatory time

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THE LARGE PROGRAM – Progress Report

✓ **publication record**

from the first 40% science analysis

- **9 papers already published, 1 submitted, other 5 currently drafted**
- first 5 papers published between end of 2019 and 2020 already count 34+ citation

from the remaining 60% science analysis

- **20+ papers** in the next 2-3 years

expectations for highly innovative scientific content and overall legacy value for astrophysics are going to be well accomplished

SPA - Stellar Population Astrophysics

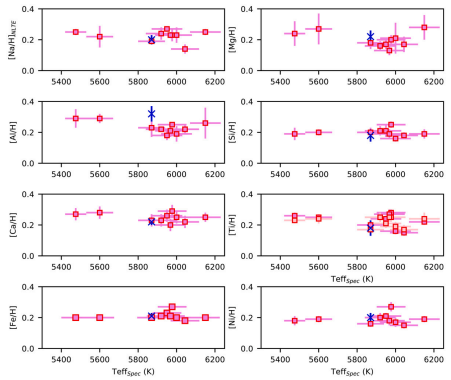
The detailed, age-resolved chemistry of the Milky Way disk

intermediate-age open clusters: individual

M4 (Praesepe):
int age, d~185pc

abundances for 8 chem elements in **10 MS stars**

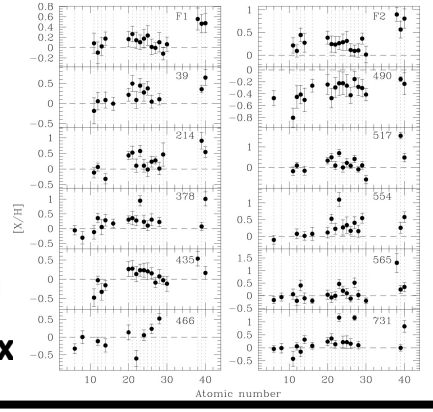
[Fe/H]=+0.21±0.01dex



ASCC123:
young, d~240pc

abundances for 21 chem elements in **12 MS stars** + Li

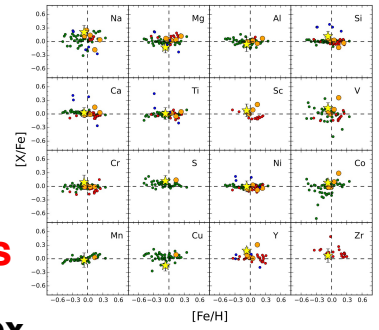
[Fe/H]=+0.14±0.04dex



Stock 2:
int age, d~300pc

abundances for 22 chem elements in **29 MS+giant stars**

[Fe/H]=+0.14±0.04dex



A&A 633, A38 (2020)
https://doi.org/10.1051/0004-6361/201936651

Astronomy & Astrophysics

Stellar population astrophysics (SPA) with the TNG

Revisiting the metallicity of Praesepe (M 44)★,★★

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Received 7 September 2019 / Accepted 13 November 2019

ABSTRACT

Context. Open clusters exquisitely track the Galactic disc chemical properties and its time evolution; a substantial number of studies and large spectroscopic surveys focus mostly on the chemical content of relatively old clusters (age ≥ 1 Gyr). Interestingly, the less studied young counterpart populating the solar surrounding has been found to be solar (at most), with a notable surprising lack of young metal-rich objects. While there is wide consensus about the moderately above-solar composition of the Hyades cluster, the metallicity of Praesepe is still controversial. Recent studies suggest that these two clusters share identical chemical composition and age, but this conclusion is disputed.
Aims. With the aim of reassessing the metallicity of Praesepe, and its difference (if any) with the Hyades cluster, we present in this paper a spectroscopic investigation of ten solar-type dwarf members.
Methods. We exploited GIARPS at the TNG to acquire high-resolution, high-quality optical and near-IR spectra and derived stellar parameters, metallicity ([Fe/H]), light elements, α- and iron-peak elements, by using a strictly differential (line-by-line) approach. We also analysed in the very same way the solar spectrum and the Hyades solar analogue HD 28099.
Results. Our findings suggest that Praesepe is more metal-rich than the Hyades, at the level of Δ[Fe/H] = +0.05 ± 0.01 dex, with a mean value of [Fe/H] = +0.21 ± 0.01 dex. All the other elements scale with iron, as expected. This result seems to reject the hypothesis of a common origin for these two open clusters. Most importantly, Praesepe is currently the most metal-rich, young open cluster living in the solar neighbourhood.

Key words. stars: abundances – stars: solar-type – open clusters and associations: individual: M 44

A&A 632, A16 (2019)
https://doi.org/10.1051/0004-6361/201936687

Astronomy & Astrophysics

Stellar population astrophysics (SPA) with the TNG

Characterization of the young open cluster ASCC 123★

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Received 13 September 2019 / Accepted 3 October 2019

ABSTRACT

Star clusters are crucial to understanding stellar and Galactic evolution. ASCC 123 is a little-studied, nearby, and very sparse open cluster. We performed the first high-resolution spectroscopic study of this cluster in the framework of the Stellar Population Astrophysics (SPA) project with GIARPS at the TNG. We observed 17 stars, 5 of which turned out to be double-lined binaries. Three of the investigated sources were rejected as members on the basis of astrometry and lithium content. For the remaining single stars we derived the stellar parameters, extinction, radial, and projected rotational velocities, and chemical abundances for 21 species with atomic numbers up to 40. From the analysis of single main-sequence stars we found an average extinction $A_V \simeq 0.13$ mag and a median radial velocity of about −5.6 km s^{-1}. The average metallicity we found for ASCC 123 is [Fe/H] ≃ +0.14 ± 0.04, which is in line with that expected for its Galactocentric distance. The chemical composition is compatible with the Galactic trends in the solar neighborhood within the errors. From the lithium abundance and chromospheric Hα emission we found an age similar to that of the Pleiades, which agrees with that inferred from the Hertzsprung-Russell and color-magnitude diagrams.

Key words. stars: fundamental parameters – open clusters and associations: individual: ASCC 123 – stars: activity – stars: abundances – binaries: spectroscopic

Astronomy & Astrophysics manuscript no. Stock2_aa_final
September 30, 2021

Stellar Population Astrophysics (SPA) with the TNG

Stock 2, a little-studied open cluster with an eMSTO★

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ABSTRACT

Stock 2 is a little-studied open cluster that shows an extended main-sequence turnoff (eMSTO). In order to investigate this phenomenon and characterise the cluster itself we performed high-resolution spectroscopy in the framework of the Stellar Population Astrophysics (SPA) project. We employed the High Accuracy Radial velocity Planet Searcher in North hemisphere spectrograph (HARPS-N) at the Telescopio Nazionale Galileo (TNG). We completed our observations with additional spectra taken with the Catania Astrophysical Observatory Spectrograph (CAOS). In total we observed 46 stars (dwarfs and giants), which represent, by far, the largest sample collected for this cluster to date. We provide the stellar parameters, extinction, radial and projected rotational velocities for most of the stars. Chemical abundances for 21 species with atomic numbers up to 56 have also been derived. We notice a differential reddening in the cluster field whose average value is 0.27 mag. It seems to be the main responsible for the observed eMSTO, since it cannot be explained as the result of different rotational velocities, as found in other clusters. We estimate an age for Stock 2 of 450±150 Ma which corresponds to a MSTO stellar mass of ≈2.8 $M_\odot$. The cluster mean radial velocity is around 8.0 km s^{-1}. We find a solar-like metallicity for the cluster, [Fe/H]=−0.07±0.06, compatible with its Galactocentric distance. MS stars and giants show chemical abundances compatible within the errors, with the exceptions of Barium and Strontium, which are clearly overabundant in giants, and Cobalt, which is only marginally overabundant. Finally, Stock 2 presents a chemical composition fully compatible with that observed in other open clusters of the Galactic thin disc.

Key words. open clusters and associations: individual: Stock 2 – Hertzsprung-Russell and C-M diagrams – stars: abundances – stars: fundamental parameters

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A&A 643, A12 (2020)
https://doi.org/10.1051/0004-6361/202039176
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Astronomy & Astrophysics

Stellar Population Astrophysics (SPA) with TNG

The old open clusters Collinder 350, Gulliver 51, NGC 7044, and Ruprecht 171★,★★

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Received 13 August 2020 / Accepted 4 September 2020

ABSTRACT

Context. Open clusters are excellent tracers of the chemical evolution of the Galactic disc. The spatial distribution of their elemental abundances, through the analysis of high-quality and high-resolution spectra, provides insight into the chemical evolution and mechanisms of element nucleosynthesis in regions characterised by different conditions (e.g. star formation efficiency and metallicity).
Aims. In the framework of the Stellar Population Astrophysics (SPA) project, we present new observations and spectral analysis of four sparsely studied open clusters located in the solar neighbourhood, namely Collinder 350, Gulliver 51, NGC 7044, and Ruprecht 171.
Methods. We exploit the HARPS-N spectrograph at the TNG telescope to acquire high-resolution optical spectra for 15 member stars of four clusters. We derive stellar parameters ($T_{\rm eff}$, log g, [Fe/H] and ξ) using both the equivalent width (EW) analysis and the spectral fitting technique. We compute elemental abundances for light, α-, iron-peak, and n-capture elements using the EW measurement approach. We investigate the origin of the correlation between metallicity and stellar parameters derived with the EW method for the coolest stars of the sample ($T_{\rm eff}$ < 4300 K). The correlation is likely due to the challenging continuum setting and to a general inaccuracy of model atmospheres used to reproduce the conditions of very cool giant stars.
Results. We locate the properties of our clusters in the radial distributions of metallicity and abundance ratios, comparing our results with clusters from the *Gaia*-ESO and APOGEE surveys. We present the [X/Fe]−[Fe/H] and [X/Fe]−R_{GC} trends for elements in common between the two surveys. Finally, we derive the C and Li abundances as a function of the evolutionary phase and compare them with theoretical models.
Conclusions. The SPA survey, with its high-resolution spectra, allows us to fully characterise the chemistry of nearby clusters. With a single set of spectra, we provide chemical abundances for a variety of chemical elements, which are comparable to those obtained in two of the largest surveys combined. The metallicities and abundance ratios of our clusters fit very well in the radial distributions defined by the recent literature, reinforcing the importance of star clusters to outline the spatial distribution of abundances in our Galaxy. Moreover, the abundances of C and Li, modified by stellar evolution during the giant phase, agree with evolutionary prescriptions (rotation-induced mixing) for their masses and metallicities.

Key words. stars: abundances – open clusters and associations: general – Galaxy: evolution – Galaxy: disk

Astronomy & Astrophysics manuscript no. aanda
June 16, 2021

Stellar Population Astrophysics (SPA) with TNG*

Atmospheric parameters of members of 16 unstudied open clusters

R. Zhang[1,2], S. Lucatello[2], A. Bragaglia[3], R. Carrera[2], L. Spina[2], J. Alonso-Santiago[4], G. Andreuzzi[5,6], G. Casali[7,8], E. Carretta[3], A. Frasca[4], X. Fu[8,3], L. Magrini[9], L. Origlia[3], V. D'Orazi[2], and A. Vallenari[2]

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Received

ABSTRACT

Context. Thanks to modern understanding of stellar evolution, we can accurately measure the age of Open Clusters (OCs). Given their position, they are ideal tracers of the Galactic disc. Gaia data release 2, besides providing precise parallaxes, led to the detection of many new clusters, opening a new era for the study of the Galactic disc. However, detailed information on the chemical abundance for OCs is necessary to accurately date them and to efficiently use them to probe the evolution of the disc.
Aims. Mapping and exploring the Milky Way structure is the main aim of the Stellar Population Astrophysics (SPA) project. Part of this work involves the use of OCs and the derivation of their precise and accurate chemical composition. We analyze here a sample of OCs located within about 2 kpc from the Sun, with ages from about 50 Myr to a few Gyr.
Methods. We used HARPS-N at the Telescopio Nazionale Galileo and collected very high-resolution spectra (R = 115 000) of 40 red giant/red clump stars in 18 OCs (16 never or scarcely studied plus two comparison clusters). We measured their radial velocities and derived the stellar parameters ($T_{\rm eff}$, log g, v_{micro}, and [Fe/H]) based on equivalent width measurement combined with 1D - LTE atmospherical model.
Results. We discussed the relationship between metallicity and Galactocentric distance, adding literature data to our results to enlarge the sample and taking also age into account. We compared the result of observational data with that from chemo-dynamical models. These models generally reproduce the metallicity gradient well. However, at young ages we found a large dispersion in metallicity, not reproduced by models. Several possible explanations are explored, including uncertainties in the derived metallicity. We confirm the difficulties in determining parameters for young stars (age < 200 Myr), due to a combination of intrinsic factors (activity, fast rotation, magnetic fields, etc) which atmospheric models can not easily reproduce and which affect the parameters uncertainty.

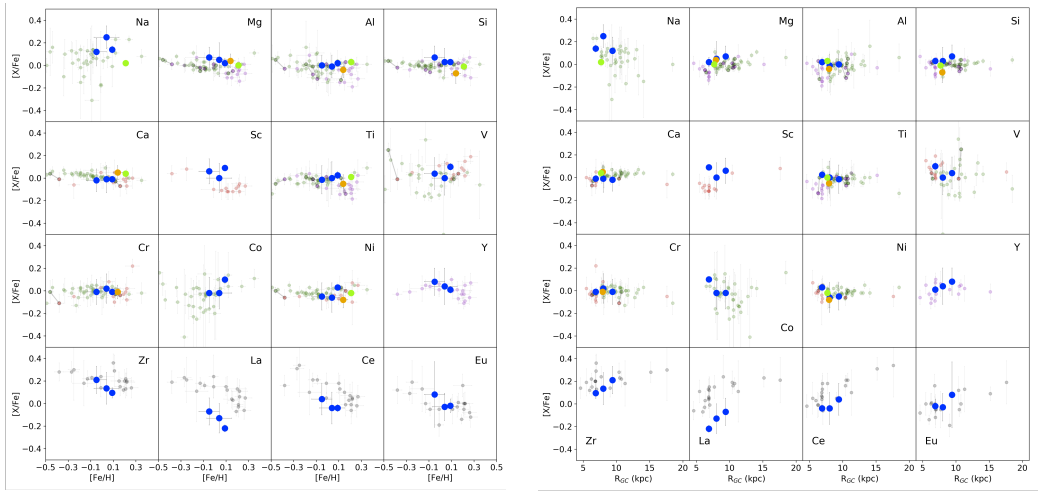
Key words. Stars: abundances – stars: evolution – open clusters and association: general – open clusters and associations: individual (ASCC 11, Alessi 1, Alessi-Teutsch 11, Basel 11b, COIN-Gaia 30, Collinder 463, Gulliver 18, Gulliver 24, Gulliver 27, NGC 2437, NGC 2509, NGC 2548, NGC 7082, NGC 7209, Tombaugh 5, UPK 219, Collinder 350, NGC 2682)

open clusters: survey

15 giant stars in **4 OCs**

d ~ 370pc – 3.2kpc
age ~ 360Myr – 2.8Gyr

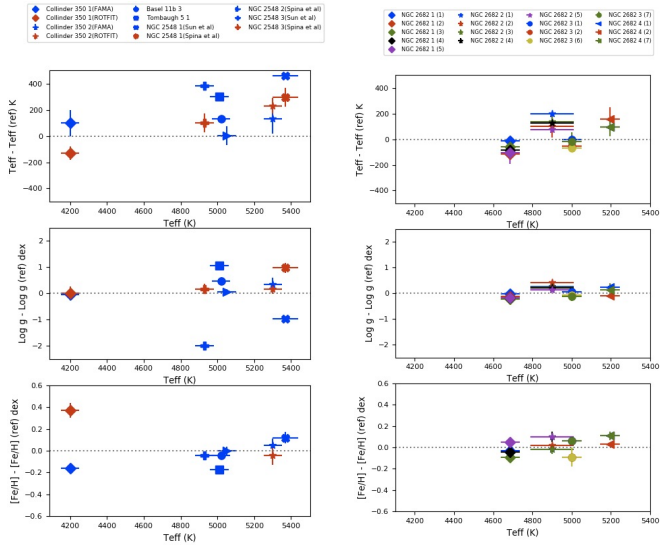
RVs, stellar parameters and abundances for 16 chem elements + C and Li in a few stars



40 giant/RC stars in **18 OCs**

d ~ 500pc - 3kpc, 50
age ~ 50 Myr - a few Gyr

RVs, $T_{\rm eff}$, log(g), $v_{\rm micro}$, and [Fe/H]



SPA - Stellar Population Astrophysics

The detailed, age-resolved chemistry of the Milky Way disk

A&A 629, A117 (2019)
https://doi.org/10.1051/0004-6361/201936283

Astronomy & Astrophysics

Stellar population astrophysics (SPA) with the TNG

GIANO-B spectroscopy of red supergiants in Alicante 7 and Alicante 10*

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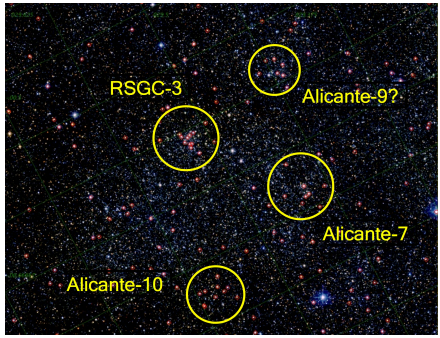
Received 10 July 2019 / Accepted 12 August 2019

ABSTRACT

Aims. The Scutum complex in the inner disk of the Galaxy hosts a number of young clusters and associations of red supergiant stars that are heavily obscured by dust extinction. These stars are important tracers of the recent star formation and chemical enrichment history in the inner Galaxy.
Methods. Within the SPA Large Programme at the TNG, we secured GIANO-B high-resolution ($R \simeq 50000$) *YJHK* spectra of 11 red supergiants toward the Alicante 7 and Alicante 10 associations near the RSGC3 cluster. Taking advantage of the full *YJHK* spectral coverage of GIANO in a single exposure, we were able to measure several hundreds of atomic and molecular lines that are suitable for chemical abundance determinations. We also measured a prominent diffuse interstellar band at λ1317.8 nm (vacuum). This provides an independent reddening estimate.
Results. The radial velocities, *Gaia* proper motions, and extinction of seven red supergiants in Alicante 7 and three in Alicante 10 are consistent with them being members of the associations. One star toward Alicante 10 has kinematics and low extinction that are inconsistent with a membership. By means of spectral synthesis and line equivalent width measurements, we obtained chemical abundances for iron-peak, CNO, alpha, other light, and a few neutron-capture elements. We found average slightly subsolar iron abundances and solar-scaled [X/Fe] abundance patterns for most of the elements, consistent with a thin-disk chemistry. We found depletion of [C/Fe], enhancement of [N/Fe], and relatively low $^{12}C/^{13}C < 15$, which is consistent with CN cycled material and possibly some additional mixing in their atmospheres.

Key words. supergiants – stars: abundances – infrared: stars

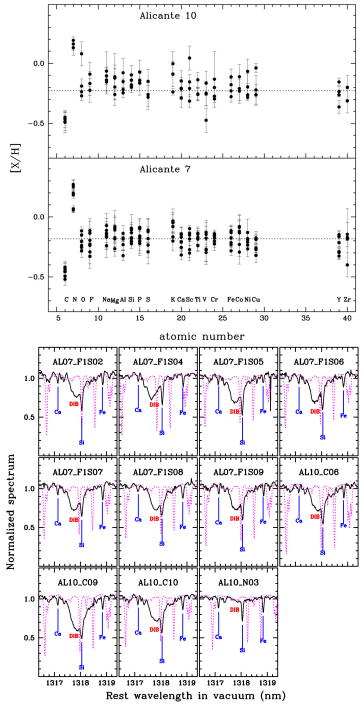
The Scutum complex



R_{GC}~3-4 kpc, A_V >10 mag

GIANO-B spectra of **11 RSGs** in Alicante 7 and Alicante 10 associations near RSGC3

- sub-solar [Fe/H] ➔ dilution by metal-poor halo gas driven there by dynamical interactions
- about solar-scaled alpha, iron, neutron-capture elements
- [C/Fe] depletion, [N/Fe] enhancement, low $^{12}C/^{13}C$ ➔ CN cycled material and extra mixing
- DIB at 1317.8 nm ➔ powerful reddening indicator for A_V >5



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The detailed, age-resolved chemistry of the Milky Way disk

The Astrophysical Journal, 909:90 (10pp), 2021 March 1 https://doi.org/10.3847/1538-4357/abda43

First Phase Space Portrait of a Hierarchical Stellar Structure in the Milky Way

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Received 2020 October 27; revised 2021 January 5; accepted 2021 January 7; published 2021 March 9

Abstract

We present the first detailed observational picture of a possible ongoing massive cluster hierarchical assembly in the Galactic disk as revealed by the analysis of the stellar full phase space (3D positions and kinematics and spectro-photometric properties) of an extended area (6° diameter) surrounding the well-known *h* and χ Persei double stellar cluster in the Perseus Arm. Gaia-EDR3 shows that the area is populated by seven comoving clusters, three of which were previously unknown, and by an extended and quite massive ($M \sim 10^5 M_\odot$) halo. All stars and clusters define a complex structure with evidence of possible mutual interactions in the form of intra-cluster overdensities and/or bridges. They share the same chemical abundances (half-solar metallicity) and age ($\tau \sim 20$ Myr) within a small confidence interval and the stellar density distribution of the surrounding diffuse stellar halo resembles that of a cluster-like stellar system. The combination of these pieces of evidence suggests that stars distributed within a few degrees from *h* and χ Persei are part of a common, substructured stellar complex that we named LISCA I. Comparison with results obtained through direct *N*-body simulations suggest that LISCA I may be at an intermediate stage of an ongoing cluster assembly that can eventually evolve in a relatively massive (a few times $10^5 M_\odot$) stellar system. We argue that such a cluster formation mechanism may be quite efficient in the Milky Way and disk-like galaxies and, as a consequence, it has a relevant impact on our understanding of cluster formation efficiency as a function of the environment and redshift.

Unified Astronomy Thesaurus concepts: Star clusters (1567); Dynamical evolution (421); Photometry (1234); Astrometry (80)

Astronomy & Astrophysics manuscript no. output ©ESO 2021
October 14, 2021

Stellar population astrophysics (SPA) with the TNG⋆

The chemical content of the young stellar population in the Perseus complex.

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ABSTRACT

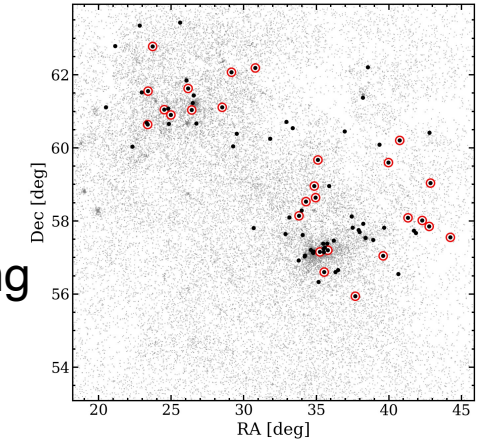
Context. The Perseus complex in the outer disk of the Galaxy hosts a number of clusters and associations of young stars. Gaia is providing a detailed characterization of their kinematic structure and evolutionary properties.
Aims. Within the SPA Large Programme at the TNG, we secured HARPS-N and GIANO-B high-resolution optical and near-infrared (NIR) spectra of the young stars in the Perseus complex, in order to obtain accurate radial velocities, stellar parameters and detailed chemical abundances.
Methods. We used spectral synthesis to best-fit hundreds of atomic and molecular lines in the observed spectra of 27 red supergiants (RSGs). We obtained accurate estimates of the stellar temperature, gravity, micro and macro turbulence velocities and chemical abundances for 25 different elements. We also measured the $^{12}C/^{13}C$ abundance ratio.
Results. We found half-solar iron with a small dispersion, about solar-scaled abundance ratios for the iron-peak, alpha and other light elements and a small enhancement of Na, K and neutron-capture elements, consistent with the thin disk chemistry traced by older stellar populations at a similar Galactocentric distance of about 10 kpc. We inferred enhancement of N, depletion of C and of the $^{12}C/^{13}C$ isotopic abundance ratio, consistent with mixing processes in the stellar interiors during the RSG evolution.

Key words. Techniques: spectroscopic - stars: abundances - stars: late-type - stars : supergiants

The Perseus complex

R_{GC}~10 kpc, $A_V < 2$ mag

GIARPS spectra of **27 RSGs** of K-M spectral type within a projected area of ~10 deg on sky, hosting a number of young star clusters and associations, the densest being h,chi Per, NGC457, NGC654, NGC633

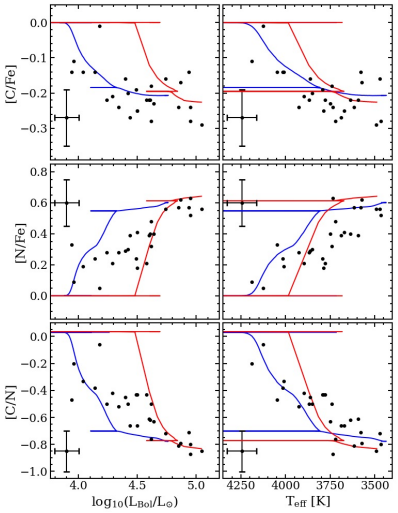


- Gaia EDR3+SPA obs ➔ 7 co-moving clusters + an extended halo around h,chi Per kinematics and structural properties consistent with an ongoing formation of a massive cluster through hierarchical assembly

- homogeneous chemical abundances of Fe (half-solar), iron-peak, alpha and several other light and heavy elements over the entire 10deg area

- depleted [F/Fe] and [C/Fe], enhanced [N/Fe] and low $^{12}C/^{13}C$

- warmer (likely less massive) K-type RSGs less luminous and less mixed than cooler M-type RSGs



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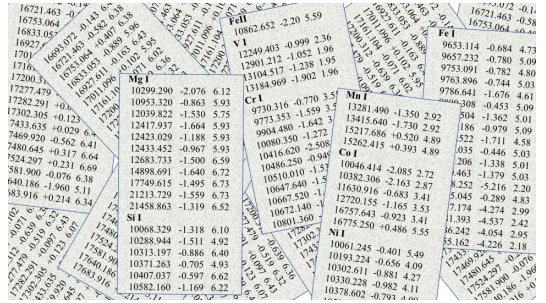
NIR diagnostics

GIANO-B Arcturus spectrum ➔ lab to verify linelists

- new diagnostics tools to derive stellar parameters and chem abundances in cool stars
- variability of the He I line at 1083 nm tracing chromospheric activity



A&A 645, A19 (2021)
https://doi.org/10.1051/0004-6361/202039397
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Astronomy & Astrophysics

Stellar population astrophysics (SPA) with the TNG[⋆,⋆⋆]

The Arcturus Lab

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Received 11 September 2020 / Accepted 30 October 2020

ABSTRACT

Context. High-resolution spectroscopy in the near-infrared (NIR) is a powerful tool for characterising the physical and chemical properties of cool-star atmospheres. The current generation of NIR echelle spectrographs enables the sampling of many spectral features over the full 0.9–2.4 μm range for a detailed chemical tagging.
Aims. Within the Stellar Population Astrophysics Large Program at the TNG, we used a high-resolution ($R = 50\,000$) NIR spectrum of Arcturus acquired with the GIANO-B echelle spectrograph as a laboratory to define and calibrate an optimal line list and new diagnostic tools to derive accurate stellar parameters and chemical abundances.
Methods. We inspected several hundred NIR atomic and molecular lines to derive abundances of 26 different chemical species, including CNO, iron-group, alpha, Z-odd, and neutron-capture elements. We then performed a similar analysis in the optical using Arcturus VLT-UVES spectra.
Results. Through the combined NIR and optical analysis we defined a new thermometer and a new gravitometer for giant stars, based on the comparison of carbon (for the thermometer) and oxygen (for the gravitometer) abundances, as derived from atomic and molecular lines. We then derived self-consistent stellar parameters and chemical abundances of Arcturus over the full 4800–24 500 Å spectral range and compared them with previous studies in the literature. We finally discuss a number of problematic lines that may be affected by deviations from thermal equilibrium and/or chromospheric activity, as traced by the observed variability of He I at 10 830 Å.

Key words. techniques: spectroscopic – stars: abundances – stars: individual: Arcturus – stars: late-type

A&A 631, L3 (2019)
https://doi.org/10.1051/0004-6361/201936594
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Astronomy & Astrophysics

LETTER TO THE EDITOR

Stellar population astrophysics (SPA) with the TNG

Identification of a sulphur line at λ_{air} = 1063.6 nm in GIANO-B stellar spectra[⋆]

N. Ryde[1], H. Hartman[2,1], E. Oliva[3], L. Origlia[4], N. Sanna[3], M. Rainer[3], B. Thorsbro[1], E. Dalessandro[4], and G. Bono[5,6]

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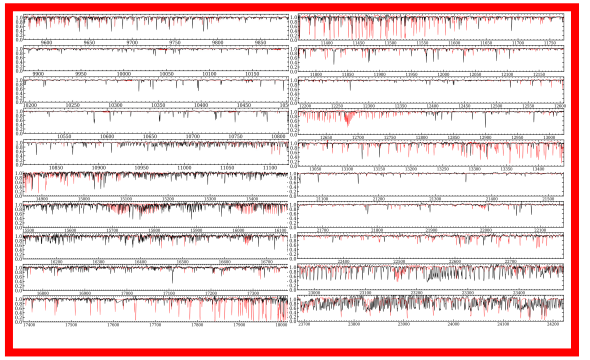
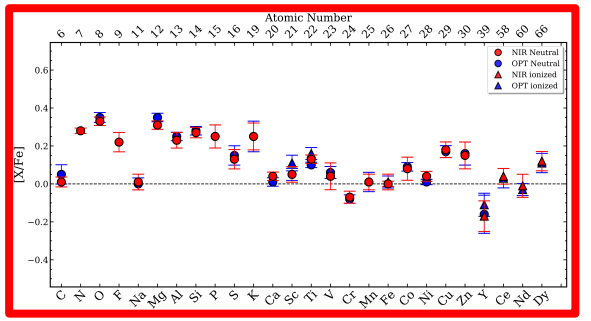
Received 27 August 2019 / Accepted 8 October 2019

ABSTRACT

Context. In the advent of new infrared high-resolution spectrometers, accurate and precise atomic data in the infrared are urgently needed. Identifications, wavelengths, strengths, broadening, and hyper-fine splitting parameters of stellar lines in the near-infrared are in many cases not accurate enough to model observed spectra, and in other cases, these parameters do not even exist. Some stellar features are unidentified.
Aims. The aim with this work is to identify a spectral feature at λ_{vac} = 1063.891 nm or λ_{air} = 1063.600 nm that is visible in spectra of stars of different spectral types that are observed with the GIANO-B spectrometer.
Methods. The search for spectral lines to match the unidentified feature in line lists from standard atomic databases was not successful. However, by investigating the original published laboratory data, we were able to identify the feature and solve the problem. To confirm its identification, we modelled the presumed stellar line in the solar intensity spectrum and found an excellent match.
Results. We find that the observed spectral feature is a stellar line originating from the 4s′–4p′ transition in S I, and that the reason for its absence in atomic line databases is a neglected air-to-vacuum correction in the original laboratory measurements from 1967 for this line only. From interpolation we determine the laboratory wavelength of the S I line to be λ_{vac} = 1063.8908 nm or λ_{air} = 1063.5993 nm, and the excitation energy of the upper level to be 9.74978 eV.

Key words. atomic data – infrared: stars – line: identification – instrumentation: spectrographs – methods: laboratory: atomic – techniques: spectroscopic





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THE LARGE PROGRAM – Lessons learned

Observing time cap

- design of a *LP* ➔ trade-off among several parameters & strategies to optimize observational procedures, to mitigate non-optimal observing conditions, to maximize scientific output
- more effective if the observing time cap (in total and for each semester) for a *LP* is mentioned **in the *Call for Proposals***, thus enabling the design of a LP tuned to it since the beginning, rather than adjusting it a-posteriori (with unavoidable scientific drawbacks)

Observing in non-optimal weather conditions

- variable and occasionally non-optimal weather conditions, especially during winter time ➔ strategical to select targets bright enough to be observed also when seeing is >1" and sky is not fully transparent
- SPA achieved **97% of open shutter** and **>80% of usable data** <u>also since</u>
  ~**50%** of the **targets not seeing/sky critical**
  ~**15% especially bright** to be observed in **prohibitive conditions** when most of the other telescopes were closed

Compensatory time

- some **r**ecovering of the time lost either for technical issues or bad weather **is scientifically critical**

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THE LARGE PROGRAM – Lessons learned

Visitor mode: second observer

for relatively long runs with GIARPS, a second observer paid by the TNG has been very valuable

- more efficient real-time control of the observations and the scheduler
- off-line quick-look reduction and science analysis to check the quality of the acquired spectra
- an opportunity for young students and other beginner observers to be properly introduced to high resolution spectroscopic observations

Service observing

a direct interaction with the TNG observer before starting the observations has been very valuable

- to clarify some aspects of the program and the observational strategy
- to update the schedulers if needed

Science training

SPA LP with GIARPS at TNG ➔
a formidable astrophysical gym in view of HIRES at ELT

happy 25th birthday TNG! and … wish you many more …


un abrazo sentido a la población de La Palma afectada por el volcan
LP2/LP3 18 October 20