La missione e le prospettive scientifiche di TNG nell'astrofisica del 2020

Telescopio Nazionale Galileo

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

1-3 March 2017, Museo Diocesano di Padova

GIANO science

Livia Origlia

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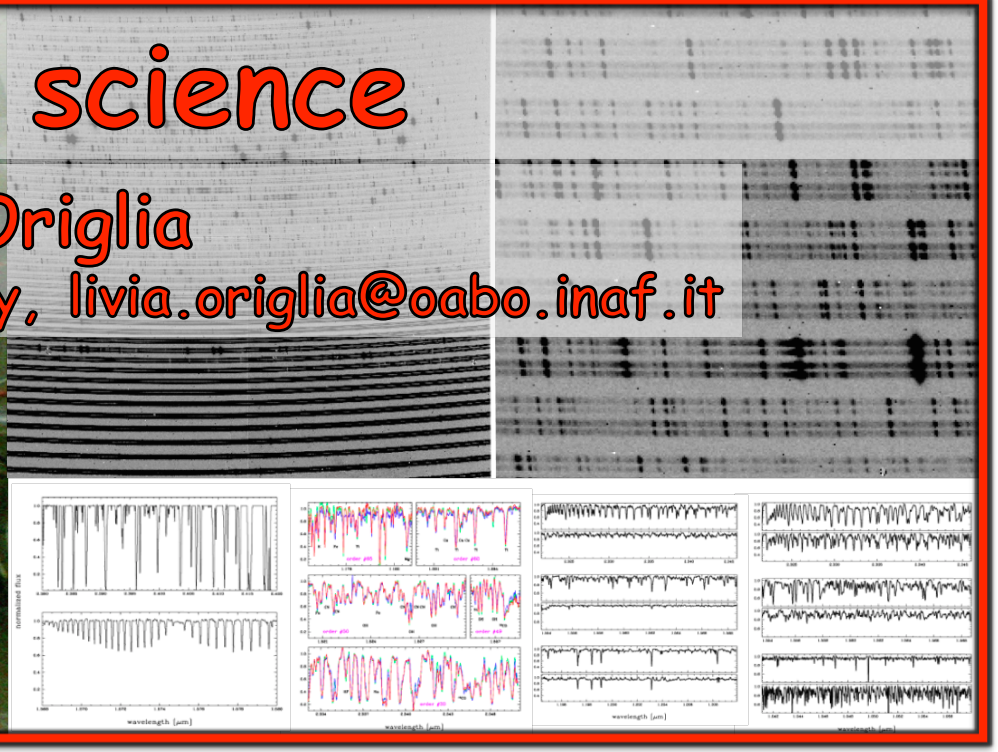

GIANO science

GIANO is the near infrared **echelle spectrograph** of the **TNG**, which can yield, in a single exposure, 0.95-2.45 micron (i.e **YJHK** simultaneously) spectra at **R~50,000**

cross-dispersed echelle spectrographs in the near IR

spectrograph	telescope	spectral range	M,ax res
NIRSPEC	Keck	Y,J,H,K	37,000
GIANO	TNG3.6m	YJHK single exp	50,000
IGRINS	McDonald2.7m	HK single exp	40,000
Carmenes	CalarAlto3.5m	YJH(<50%) single exp	82,000
IRCS	Subaru	zY,J,H,K	20,000
XShooter	VLT	JHK single exp	8,000
CRIRES+	VLT	YJ,H,K	100,000
SPIRou	CFHT	YJHK	70,000
HPF	HET	ZYJ	50,000
I-Locater	2 LBT	YJ	170,000
NIRPS	ESO 3.6m	YJH	100,000
WINERED	visitor	Y,J	80,000

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Commissioning 2013

some sky tests during 1 night in July, 2 nights in October

Science Verification 2014

7-16 September, allocated 9 nights, 2 lost for bad weather

AOT since 2015

AOT	schedule – assigned nights	nights GAPS	nights stars comets YSOs	nights CAT OPT NOT
31	5 + 8x0.5 + 3 + 2 + 2x0.5 + 1x0.5 + 3	8.5	5.0	5.0
32	2x0.5 + 4x0.5 + 2x0.5 + 2 + 5 + 3x0.5	-	4.5	8.0
33	4x0.5 + 8x0.5 + 3 + 1 + 1x0.5	2.0	3.25	5.0

GIANO science

GIANO cookbook for proposers

prepared by L. Origlia & E. Oliva

September 2014

Table 3: Spectral accuracy and sensitivities

Wavelength calibration[1] accuracy with U-Ne lamp	300 m/s (r.m.s)
Radial velocity[2] accuracy with telluric lines	7 m/s (r.m.s)
Maximum S/N[3] on flatfield (about photon-noise limited)	~1000 (Y,J), ~300 (H,K)
Maximum S/N[3] on stars (limited by fiber modal noise)	~70 (Y,J), ~50 (H,K)
Zero point (J-band, Vega mag for 1 ADU/s)	10.1
Zero point (H-band, Vega mag for 1 ADU/s)	10.3
Zero point (K-band, Vega mag for 1 ADU/s)	10.2
Limiting magnitude (z-band, Vega mag) of the guiding camera[4]	15

Table 4: Recommended on-source integration times

Target Vega magnitudes	**On source integration times (seeing <1 arcsec)**
JHK < 3	200 sec = 1AB cycle with 100sec on A and 100sec on B
3 <= JHK < 6	600 sec = 1AB cycle with 300sec on A and 300sec on B
6 =< JHK < 7	1200 sec = 2AB cycles with 300sec on A and 300sec on B
7 =< JHK < 8	1800 sec = 3AB cycles with 300sec on A and 300sec on B
8 =< JHK < 9	2400 sec = 4AB cycles with 300sec on A and 300sec on B
9 =< JHK < 10	3600 sec = 6AB cycles with 300sec on A and 300sec on B

GIANO science

high resolution near-IR spectroscopy at 4m-class telescopes

powerful/unique capability to study the IR-bright Universe

[exo]-planetary science

- to search for exo-planets around late type M-dwarfs
- to characterize hot Jupiter's atmospheres
- to characterize the chemistry of comets

stellar evolution and stellar populations

- to measure velocities, chemical abundances, magnetic fields etc. of a large variety of cool stars and stellar populations, which are bright in the IR and do not require a larger collective area to be observed with sufficiently high signal to noise
- to measure the chemical composition and dynamical mass of extra-galactic star clusters in integrated light (dominated by cool giants/supergiants), and trace the properties of their host galaxies

GIANO: publications

first high resolution NIR spectrograph with full spectral coverage

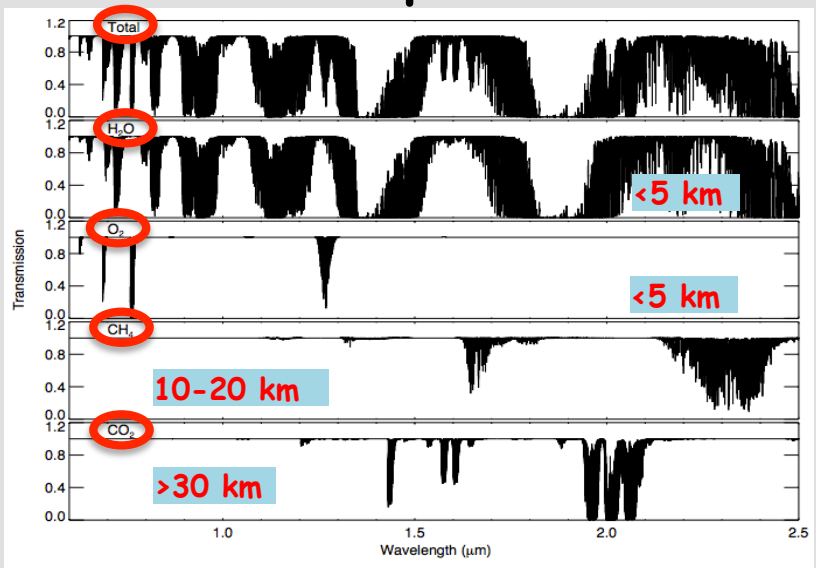
- a new, wide space of parameters & diagnostics to explore & calibrate for scientific use
- a lot of pioneering work

Referred papers: calibration

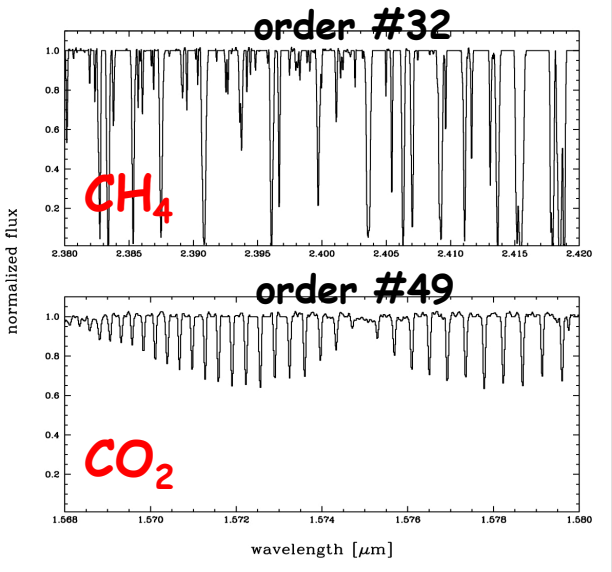
- ✓**Oliva+** *A GIANO-TNG high-resolution IR spectrum of the airglow emission*, **2013**,A&A,555,78 **Com.**
- ✓**Oliva+** *Lines and continuum sky emission in the near IR: observational constraints from deep high spectral resolution spectra with GIANO-TNG*, **2015**,A&A,581,47 **SV**
- ✓**Carleo+** *High precision radial velocities with GIANO spectra*, **2016**,ExA,42,99 **SV**

calibration - in preparation

telluric spectrum



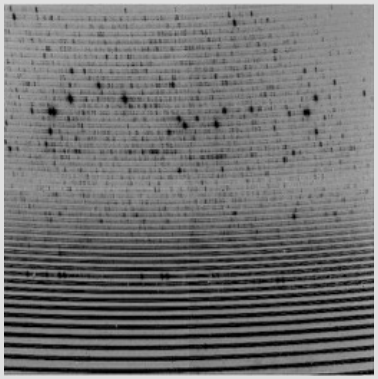
O star - GIANO

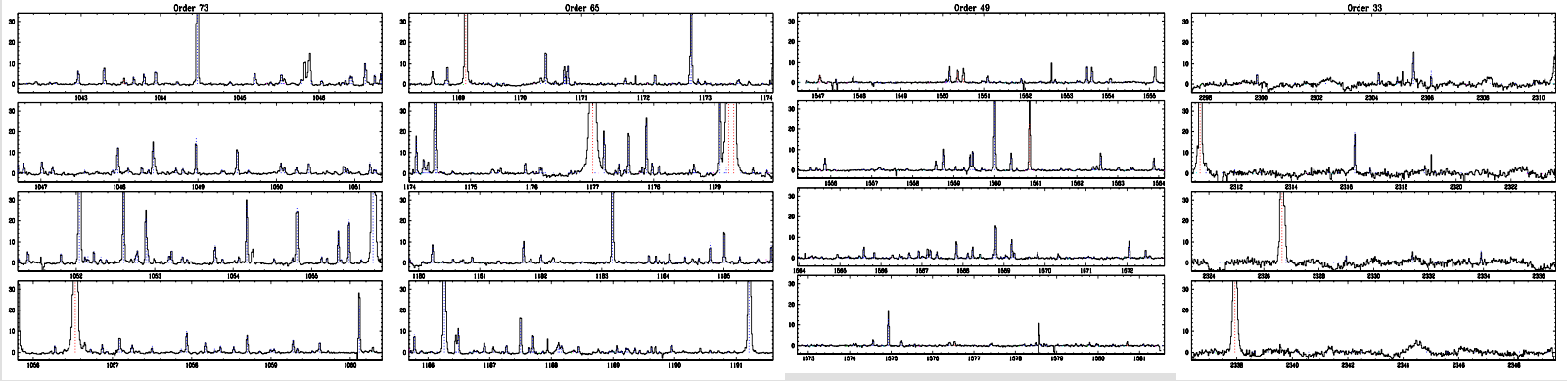


GIANO: publications

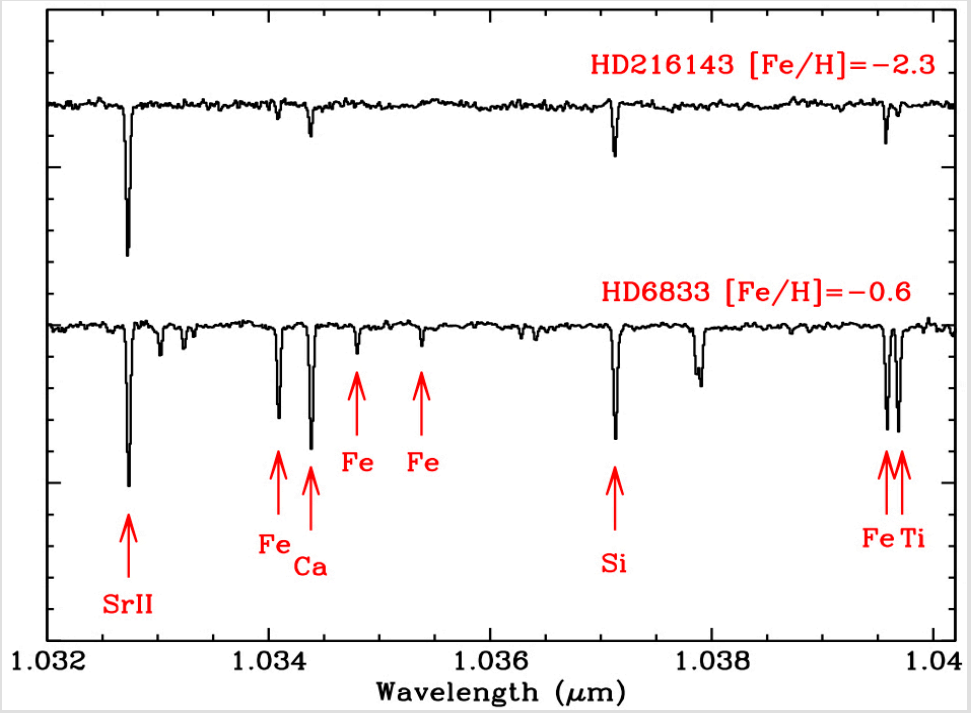
calibration - in preparation

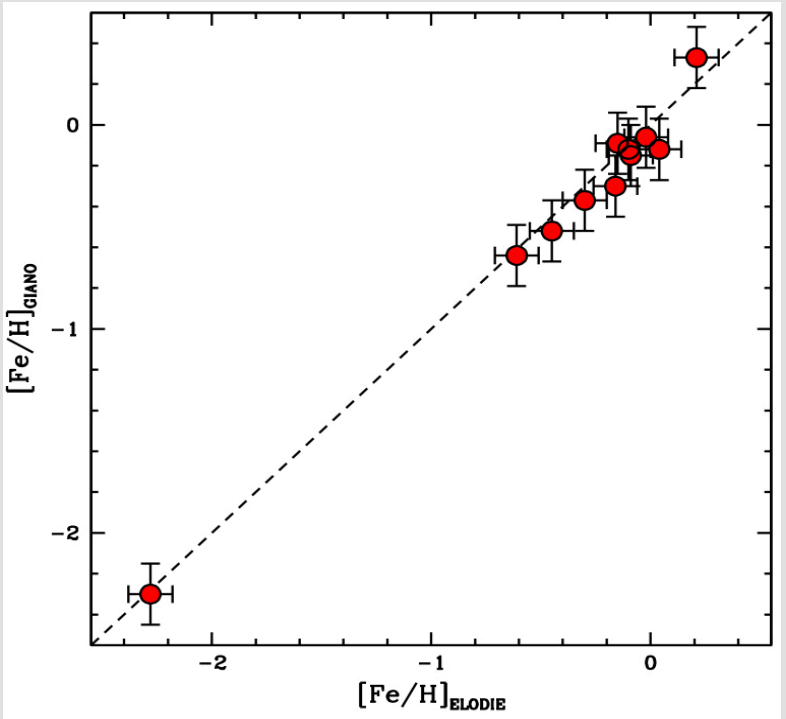
U-Ne spectrum courtesy of E. Oliva





suitable line lists for chemical analysis of giants and dwarfs





courtesy of A. Mucciarelli

GIANO: publications

Referred papers: science

✓**Origlia+** *GIANO-TNG spectroscopy of red supergiants in the young star cluster RSGC2,* **2013**,A&A,560,46 **Com.**

✓**Origlia+** *GIANO-TNG spectroscopy of red supergiants in the young star cluster RSGC3,* **2016**,A&A,585,14 **SV**

✓**Caffau+** *GIANO Y-band spectroscopy of dwarf stars: P, S, and Sr Abundances,* **2016**,A&A,585,16 **SV**

✓**Pecchioli+** *Deriving the Extinction to Young Stellar Objects using [Fe II] Near-infrared Emission Lines: Prescriptions from GIANO High-resolution Spectra,* **2016**,PASP,128,073001 **Com./SV**

✓**Faggi+** *Detailed Analysis of Near-IR Water (H_2O) Emission in Comet C/2014 Q2 (Lovejoy) with the GIANO/TNG Spectrograph,* **2016**,ApJ,830,157 **A31**

✓**Antoniucci+** *High-resolution TNG spectra of T Tauri stars: near-IR GIANO observations of the EXor variables XZ Tau and DR Tau,* **2017**,A&A,submitted **SV**

a few more from SV + those from AOT31-33 runs ….

Other publications

✓ **21** SPIE papers 2004 ➔ 2016

✓ **1** ESO Proc. (2005), **2** MnSAI (2015), **2** DPS (2015, 2016)

a special thanks to F. Massi for the provisional pipeline and to N. Sanna, who has reduced most of the data

stellar pops with GIANO/GIARPS in the surveys era

MOS spectroscopy for surveys

- medium spectral resolution → R ~ 20-30,000
- limited spectral coverage in a single exposure → ~λ/5-10
- high multiplexing → 100-1000
- astrophysical information → RVs and some chemistry

ongoing/near future Galactic surveys

optical: Gaia-ESO survey, Hermes, WEAVE, 4MOST
main targets: warm, red clump giants and young pre-MS in the low reddening MW

near IR: APOGEE N+S, MOONS
main targets: giants in the reddened bulge/disk and in the MCs

echelle spectroscopy of selected/representative targets

- high spectral resolution → R > 30,000
- wide spectral coverage in a single exposure → ~λ_{min}
- single object
- astrophysical information → detailed chemistry & kinematics

echelle *vs* MOS → <u>complementary information</u>

stellar pops with GIANO/GIARPS

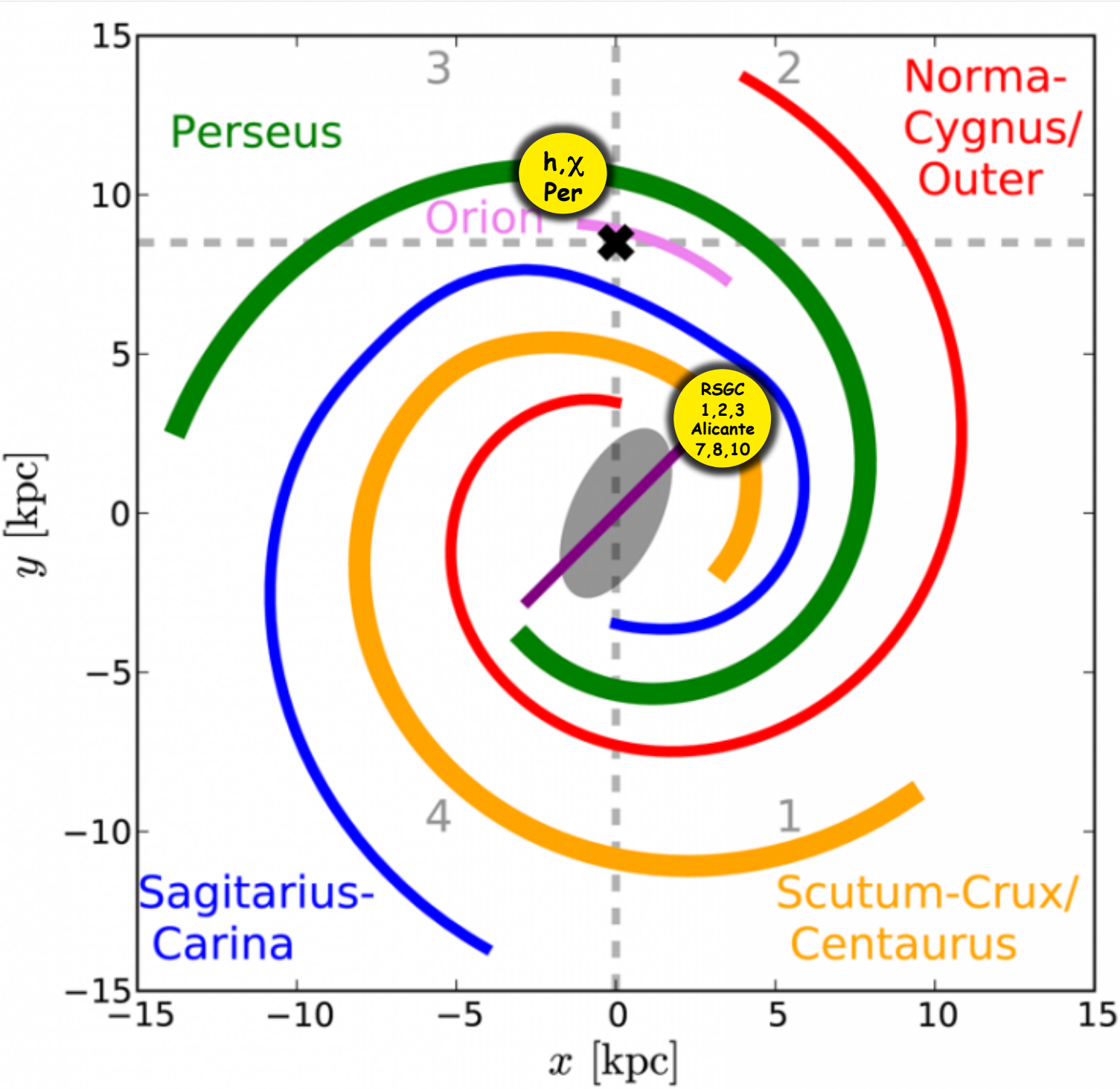
- **young red supergiants, Cepheids, old cool giants in the Galaxy**
- warm giants and young MS stars within ~1 kpc (Bragaglia talk)
- star forming regions: T-Tauri stars, YSOs (Antoniucci, Massi talks)

chemistry of cool giants and supergiants ➔ a recent field of investigation

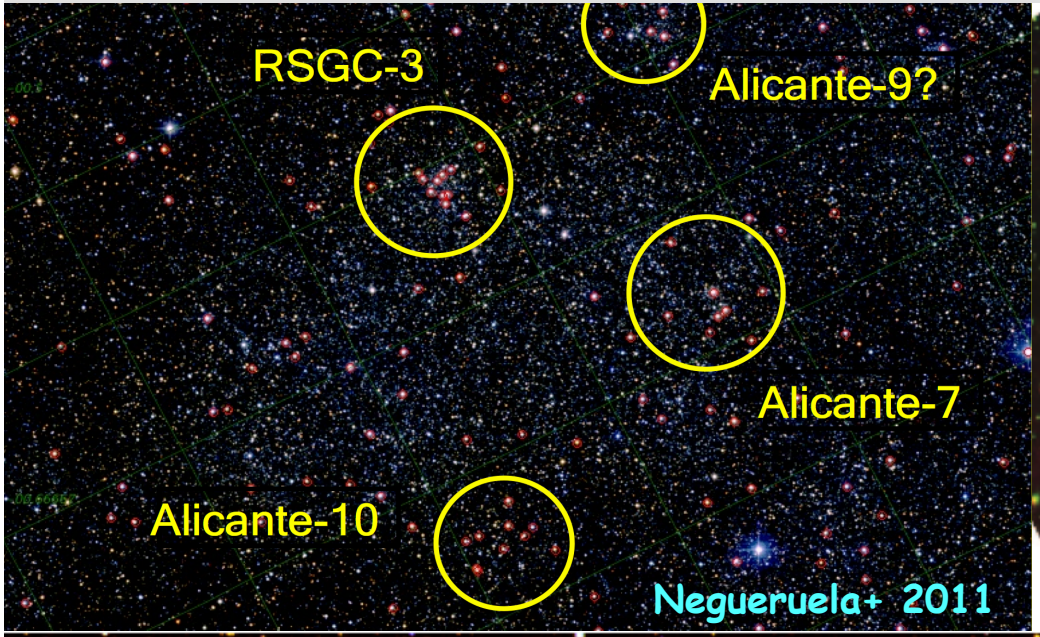
IR spectroscopy often needed because of the low temperatures & high reddening

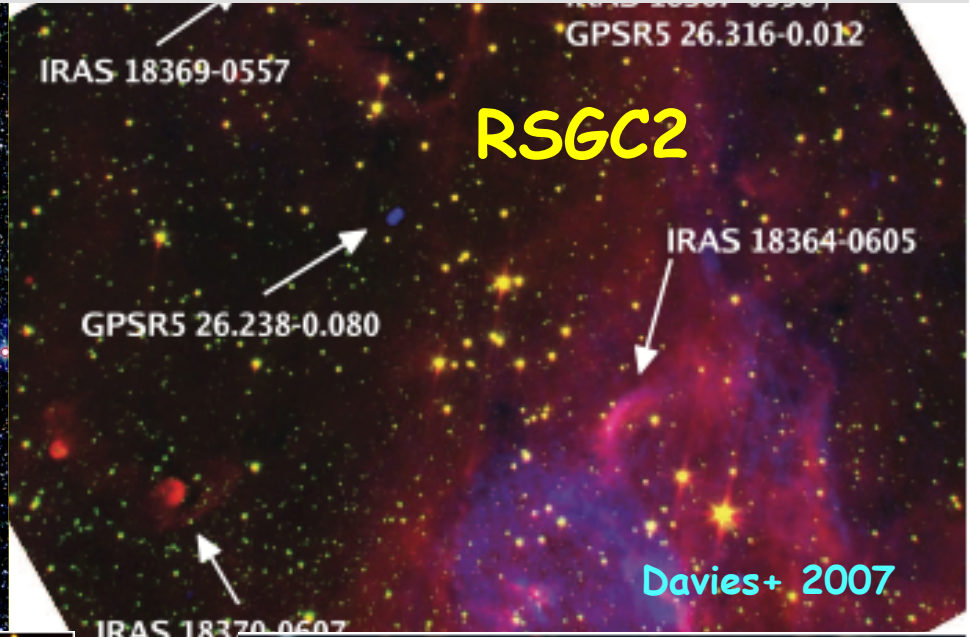
state-of-the-art chemical analysis

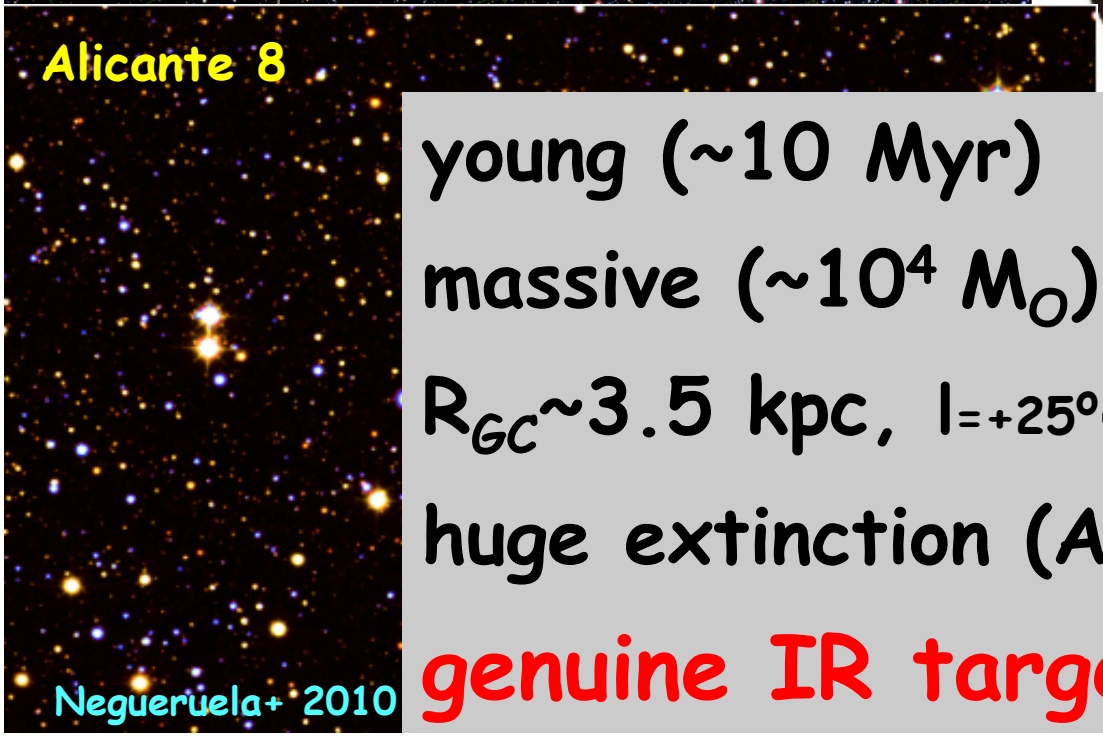
- CNO and F abundances from molecular (CO, CN, OH, HF) lines,
  all the other metal abundances from atomic (mostly neutral) lines
- mostly based on 1D or spherical model atmospheres
- abundances with <u>random</u> errors of <0.1 dex , <u>systematic</u> errors ~0.2 dex
  (stellar parameters & degeneracy, log(gf), model atmospheres etc.)


Perseus
Norma-
Cygnus/
Outer
Orion
h,χ
Per
RSGC
1,2,3
Alicante
7,8,10
Sagitarius-
Carina
Scutum-Crux/
Centaurus
3
2
4
1
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10
15
y [kpc]
x [kpc]

RSGs in the Scutum arm young clusters







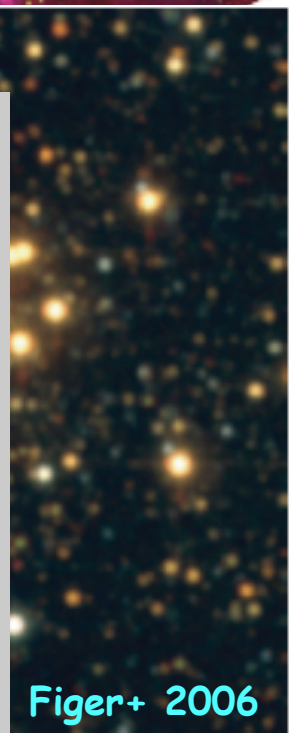
young (~10 Myr)

massive (~10^4 M_O)

R_{GC}~3.5 kpc, l=+25º→29º b=-0.2→0.0º

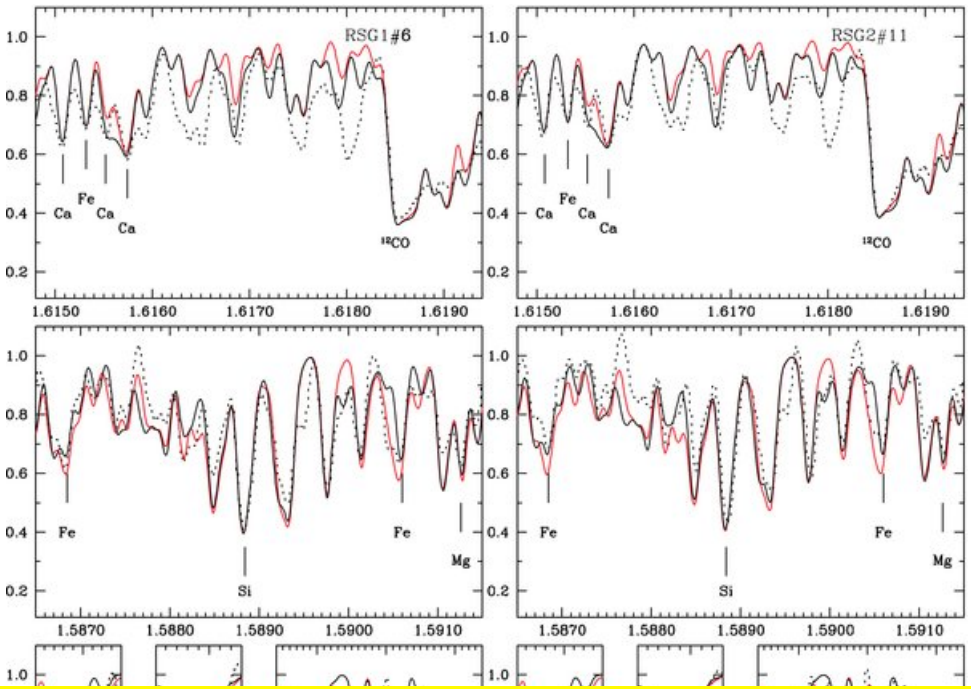
huge extinction (A_V>10 mag!)

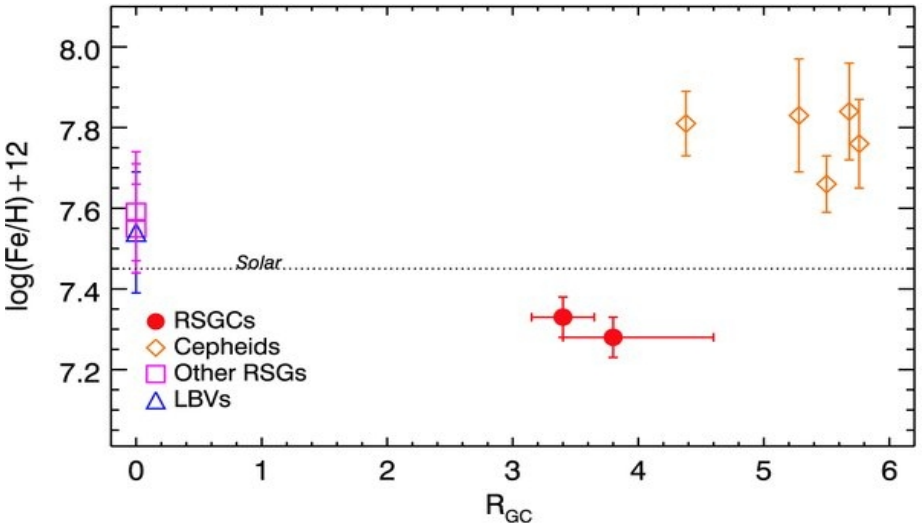
genuine IR targets

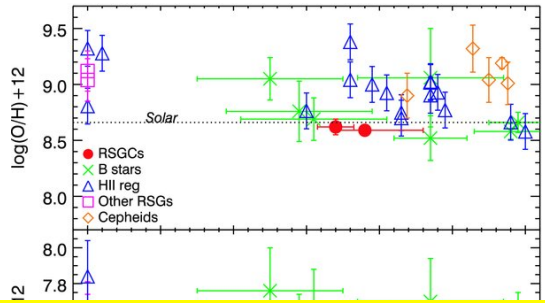


chemical abundances of RSGs in the Scutum young clusters

14 RSGs in RSGC1 and 13 RSGs in RSGC2
NIRSPEC-Keck, H-band, R~17,000
Davies+ 2009







Fe, C, O, Ca, Si, Mg, Ti

half-solar metallicity, solar-scaled alpha
lower envelope of the metallicity distribution in the inner disk

C-depletion consistent with extra-mixing (rotational)

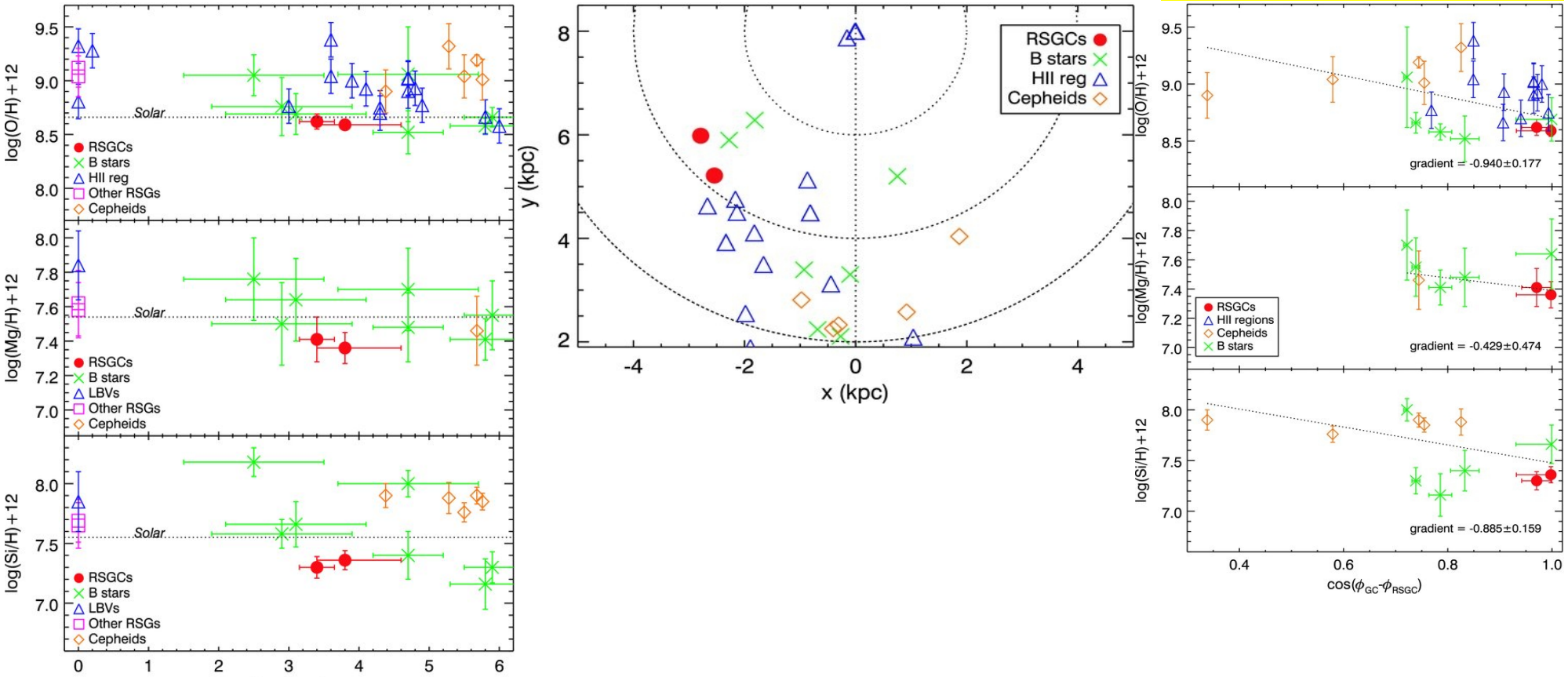
chemical abundances of RSGs in the Scutum young clusters

14 RSGs in RSGC1 and 13 RSGs in RSGC2

NIRSPEC-Keck, H-band, R~17,000

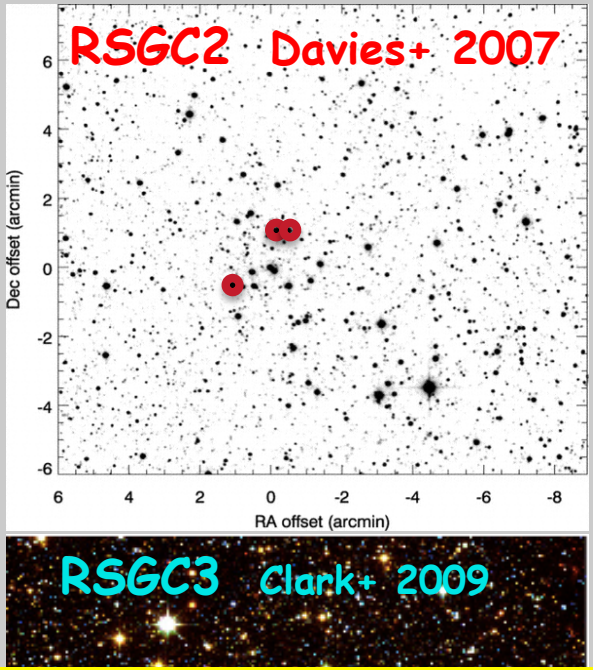
Davies+ 2009

Azimuthal gradient



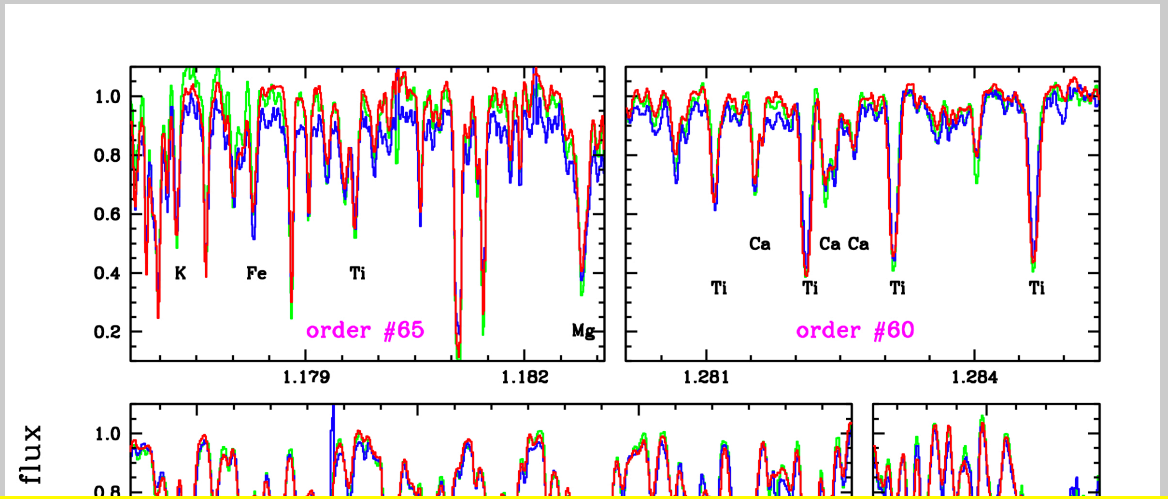
large-scale (~kpc) azimuthal variations in abundances at Galactocentric distances of 3–5 kpc from the intense but patchy SF driven by the potential of the central bar

chemical abundances of RSGs in the Scutum young clusters



GIANO pilot project

Origlia+ 2013;2016 SV

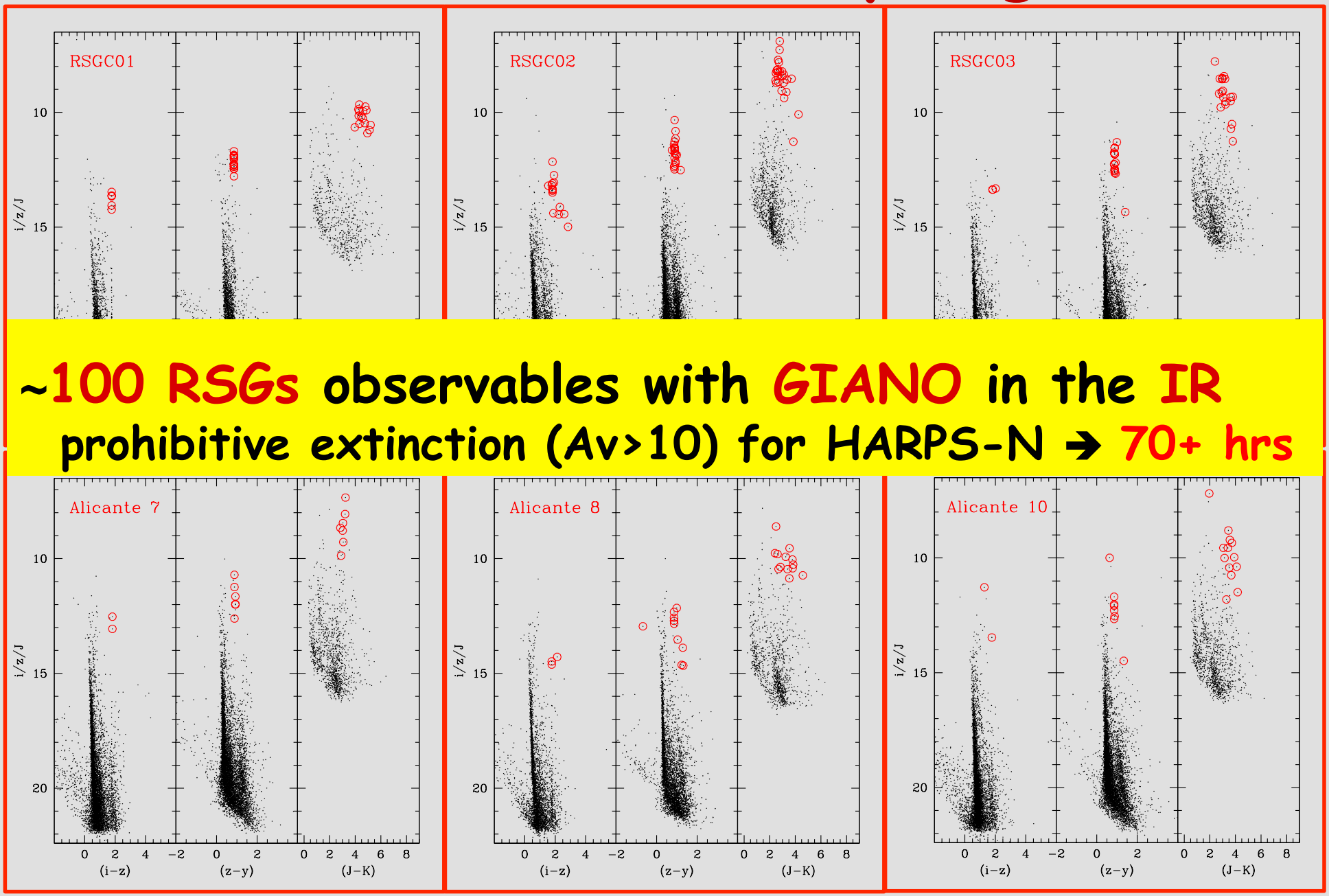


from several to a few tens lines per species

~20 different species: CNO, alpha, some other light, iron-peak, neutron-capture elements

- **[Fe/H] and other iron-peak elements (Cr,Ni,V,Cu) ~ half solar**
- **about solar-scaled α, K, Na, Al, s-process elements (Sr,Y)**
- **some (if any) enhancement of F, Sc**
- **depleted (2-3x) C enhanced (2-3x) N $^{12}C/^{13}C$ ~ 10±1**

RSGs in the Scutum arm young clusters

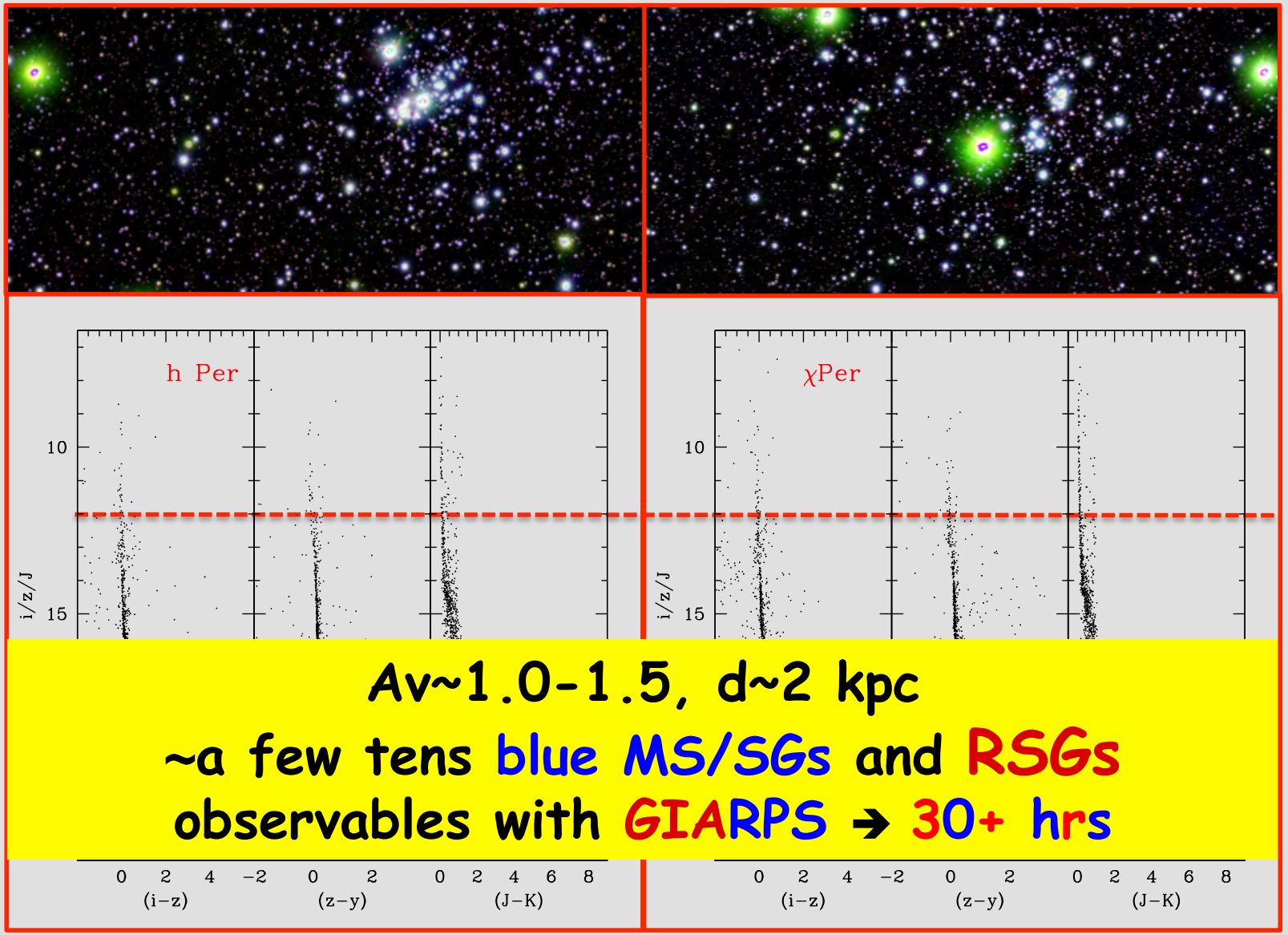


~100 RSGs observables with GIANO in the IR

prohibitive extinction (Av>10) for HARPS-N → 70+ hrs

courtesy of E. Dalessandro

RSGs in the h,χ Persei young clusters



Av~1.0-1.5, d~2 kpc

~a few tens blue MS/SGs and RSGs observables with GIARPS ➔ 30+ hrs

courtesy of E. Dalessandro

CNO in globular cluster cool giants

GIANO pilot project

Lapenna+ AOT33

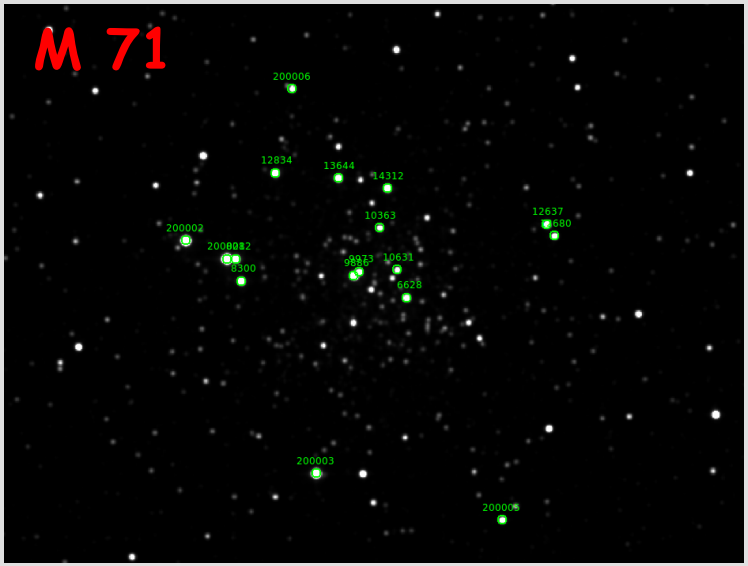
work in progress…

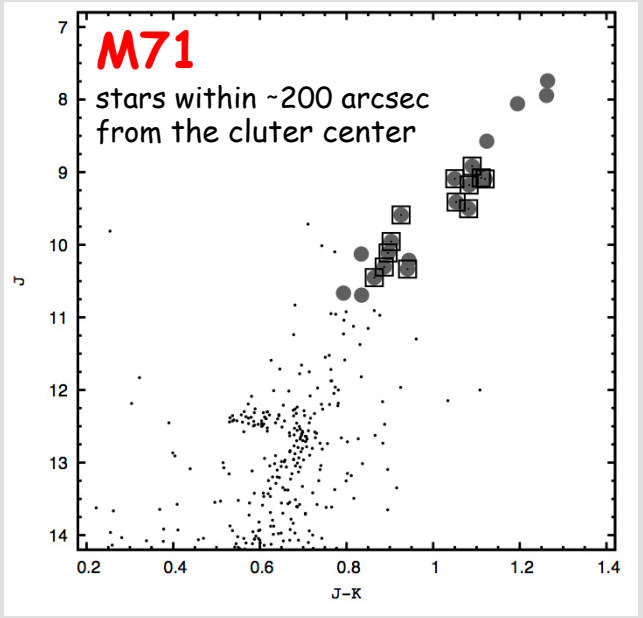
some literature

chemistry:
Ramirez&Cohen'02, Alves-Brito+'08, Melendez&Cohen'09, Carretta+'09a,b

X-ray sources:
Elsner+'08, Huang+'10

PMs and structural parameters:
Cadelano+'17





detailed abundances of ^{12}C, ^{13}C, **N & O** + iron-peak, alpha, Na, Al, other light, some neutron-capture elements

- abundance spreads and anti-correlations for the full set of CNO, Na, Mg, Al and other light elements, for a detailed chemical characterization of the multiple SPs
- reliable [C+N] and [C+N+O] total abundances to constrain the nature of the polluters
- accurate trends of [C/Fe], [N/Fe] and $^{12}C/^{13}C$ with luminosity/temperature, thus quantifying C depletion and N enhancement due to extra-mixing processes along the RGB/AGB
- cross-checking chemical abundances in the optical and near IR ranges

other ~10 GCs observable with GIARPS ➔ 100+ hrs