The Gaia-ESO Survey

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Survey Co-PIs: Gerry Gilmore & Sofia Randich
300++ Co-Is (mostly from Europe, but not only)
90++ institutes

1 The Gaia-ESO Survey

Credits and thanks!

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OUTLINE

- Scientific drivers
- Survey history, overview, and data products
- Observing strategy
- Project organization, data flow and analysis
- First observing runs
- Towards science verification and first releases

SCIENTIFIC DRIVERS (1/3)

Key open issues in the **formation and evolution of the MW** and its component stars and stellar pops.
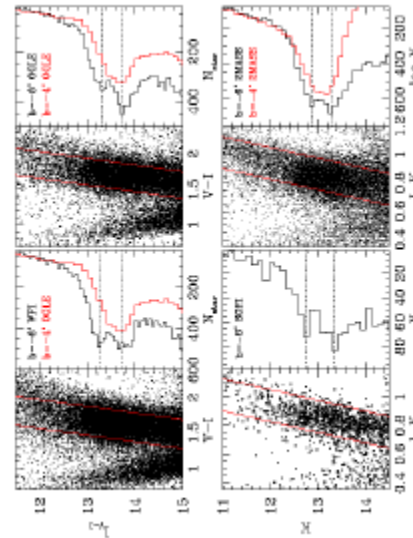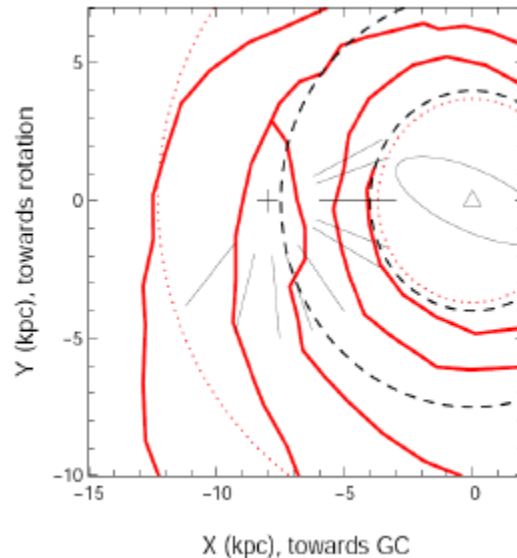
● The (dynamical)evolution of clusters: from birth to disruption into the field

● Stellar evolution (ages, masses)
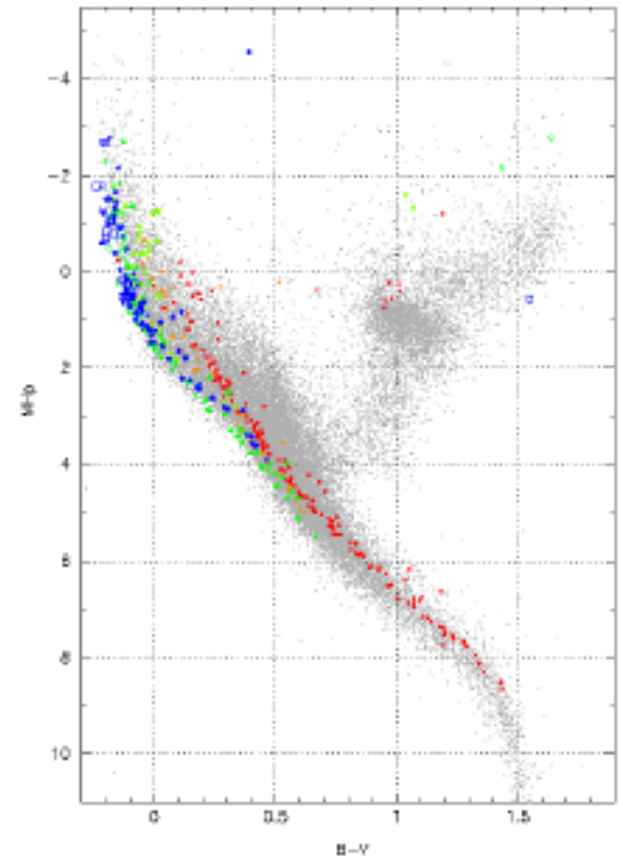
SCIENTIFIC DRIVERS (2/3)

- Galaxy phase-space substructure
- Formation and evolution of the thin and thick discs
- Halo substructure, Dark Matter
- Formation and nature of the Galactic bulge

Dynamics of spiral arms

Complexity of inner bulge

SCIENTIFIC DRIVERS (3/3)

To comprehensively
address all those questions
and make a significant step forward
we need the **full 6-D phase space,
plus stellar parameters, plus
ages, plus chemistry**
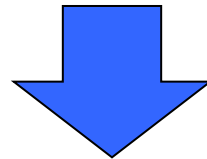
GAIA **+ GB SPECTROSCOPY
(now, before Gaia!)**

HISTORY

Aug. 2010: Eso Call for Letters of Intents for Large Public Spectroscopic surveys

Oct. 2010: Two Gaia-related LoIs submitted

→ Focus on MW field –PI: G. Gilmore

→ Focus on open clusters –PI: S. Randich

Jan. 2011: both LoIs approved and invited to submit a merged proposal → **Added Value**

June 2011: Proposal approved by PSSP and OPC

New year eve 2011/2012: observations started

2 papers: 1 from the Consortium (ESO Messenger)
1 from outside

Gaia-ESO survey in a nutshell

- **Public** large spectroscopic survey with FLAMES@VLT
- **300 (240+60) nights** (30n/semester) over **5 (4+1) years**; start 12/2011 (P88), end 9/2016 (P97)++; visitor mode
- **All populations of the MW:** Halo; Bulge; Thick & Thin discs; open clusters and associations
- **Uniform analysis:** First homogeneous overview of the distributions of kinematics and element abundances in the Galaxy

1. **Raw data immediately public**

2. **Semester Advanced Data Product Releases**

- 1D, λ calibrated, sky-subtracted spectra
- Radial and rotational velocities (+ var. analysis)
- Object classification
- Photometry used to select the targets

All with quantitative uncertainties

First release January 2013

Data products and releases (2/2)

3. **Annual Advanced Data Product Releases**

- APs: T_{eff}, log g
- Equivalent Widths
- [Fe/H], [X/Fe] (Li, C, O, Na, Mg, ..Ni, ..Ba, Y,..)
- Stellar properties: accretion rates, mass loss
- (Final release) Average values for the clusters

All with quantitative uncertainties

First release June 2013

Observing strategy
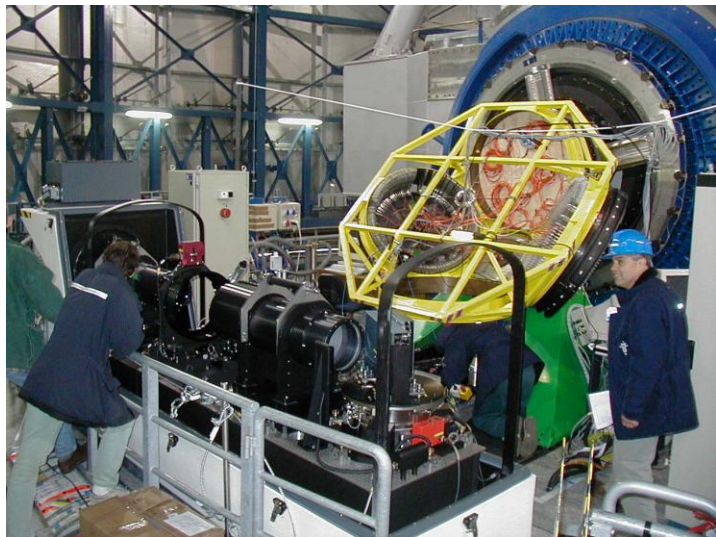
Giraffe for faint targets (V<19)
HR03/5A/6/9B/10/14 (O/B/A)
HR15N/21 (cool) – SNR > 10

UVES for 'bright' stars (V<16.5)
520 /580 nm (warm/cool) SNR > 20

- **>10^5 Giraffe** spectra (R~16,000-25,000)
  → RVs, APs, [Fe/H], [X/Fe], stellar properties
- **>10^4 UVES** spectra (R~47,000)
  → precise multi element abundances
- + **ESO archive** exploitation/re-analysis

Breaking by population – 1. Field stars

GIRAFFE

- **Bulge:** mostly giant stars (clump and RGB), I=15
- **Halo /thick disc:** FG TO stars (17 < r < 18); giants in known streams, predominantly NGC and SGC
- **Thin disc** –only RVs for dynamics; I<19

UVES parallel

- **Solar neighborhood:** complete unbiased 5000-star sample. Look at Mv~5.5, ➜ unbiased survey to 1kpc at V=15. Kinematic-Abundance Local DF At V=15, survey 2000 thin disk, 2000 thick disk, 1000+ halo

Braking by population – 1. Field stars

Selection based on CMDs using **VISTA** and SDSS

Fix a box in the
CMD with thick
disc and halo
turnoff

Select thick
disk/halo locus

SDSS $(\alpha, \delta) = (350, 0)$

VISTA

Implement in **VHS**
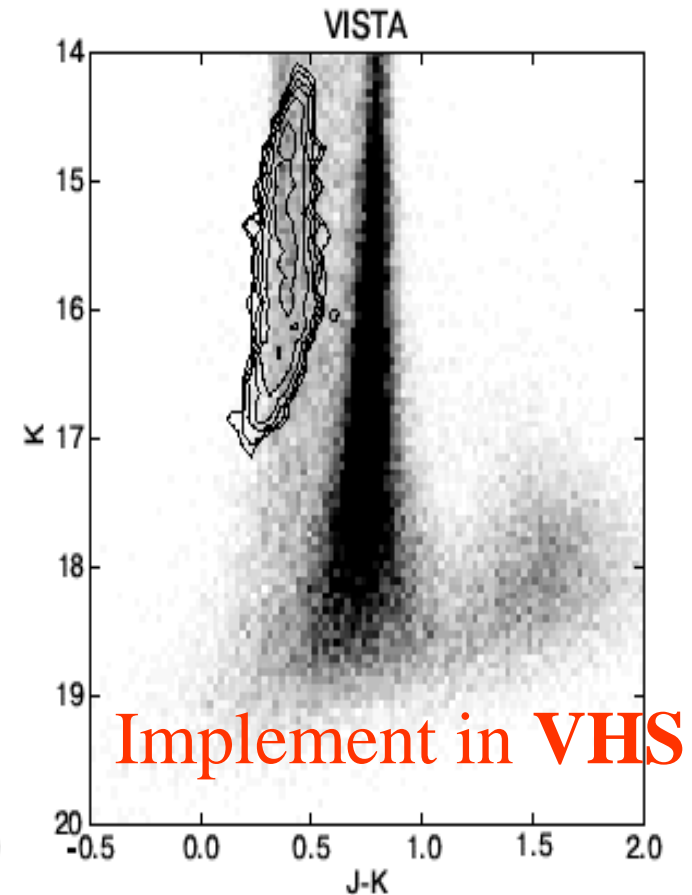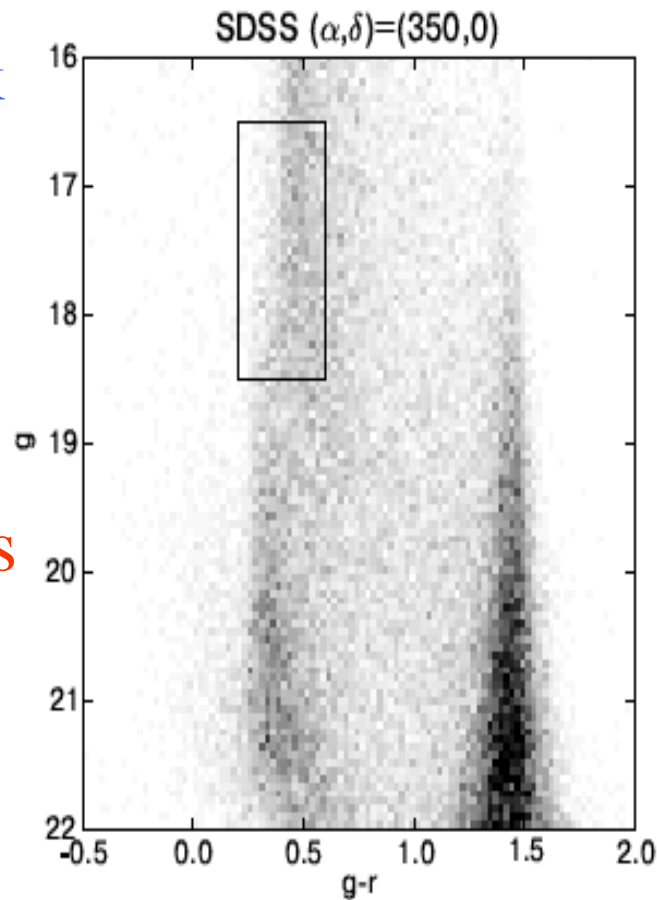
Braking by population – 2. Open Clusters

PMS clusters
(10-100 Myr)

Very young clusters,
star forming regions,
associations

Intermediate-age
and old clusters
(100 Myr – 8 Gyr)

**Nearby (< 1.5 kpc) and distant
Relevant populations covered**

~ 100 OCs **in all phases of evolution** (~1 Myr → several Gyr), sampling the a**ge-distance-R_{GC}-density-mass-metallicity parameter space**

OB type stars → M dwarfs

plus evolved stars (mostly clump giants)

use of literature and **VPHAS+** photometry to select target stars within clusters

Braking by population. 3 –calibration fields

Crucial to control match parameters/abundances within GES and across surveys

- (Gaia) RV standards
- (Gaia) Benchmark stars
- COROT fields
- Targets observed by other surveys (e.g. Apogee)
- Well studied open & globular clusters

Project organization
data flow and analysis

Data flow & survey management (1/2)

Gaia-ESO data flow – conceptual, WGs identified

Target selection OB preparation	Clusters WG 1,2,4,6	Field stars WG 3,6	Calibrations WG 5

OB transfer to ESO; Observing (WG 0); data from archive to PIs

Reduction pipelines WG7
Radial velocities WG8
Classification WG9
First quality control

Spectrum Analyses

FGK Giraffe (10)	FGK UVES (11)	PMS (12)	OBA (13)	(14) Non standard
Quality Control		QC	QC	QC

(Iterative)   Parameter Homogenization, WG 15 & WG5

Data storage and archive, WG17,18

Survey Progress Monitoring WG16

Value added products, science quality control   (consortium)

Value added products, metadata to ESO WG16,17

SC

GG&SR
M. Asplund (A)
J. Binney (UK)
P. Bonifacio (F)
J. Drew (UK)
S. Feltzing (S)
A. Ferguson (UK)
R. Jeffries (UK)
G. Micela (I)
I. Negueruela (Sp)
T. Prusti (ESA)
H.-W. Rix (D)
A. Vallenari (I)

Data flow & survey management (2/2)

- Reductions with ESO pipeline + in-house software at CASU and Keele

- Spectrum analysis: multiple analyses. But common linelists, model atmospheres, etc

- Internal and external homogeneization (lots of calibrators)

Our approach is to retain strengths of all proven methods, delivering both a recommended result and a range. Our challenge is to keep everything working together.

FIRST
50 NIGHTS

Observations

- ✓ First light: Dec. 31 2011-Jan 5 2012
- ✓ 10 runs completed
- ✓ 9 clusters observed/started covering different characteristics – young & old, massive & low mass stars, evolved & MS stars,…
- ✓ Several MW fields –thick disc, halo, bulge
- ✓ Several calibration fields & benchmark stars

Milky Way fields targeted
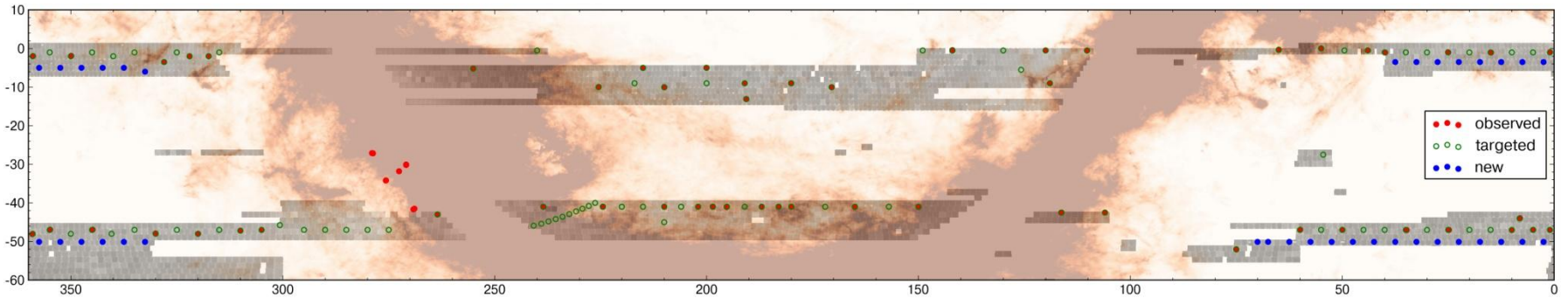
red = observed, green/blue = prepared

Courtesy S. Koposov (Cambridge)

First spectra - UVES

Bulge giant

γ Vel member
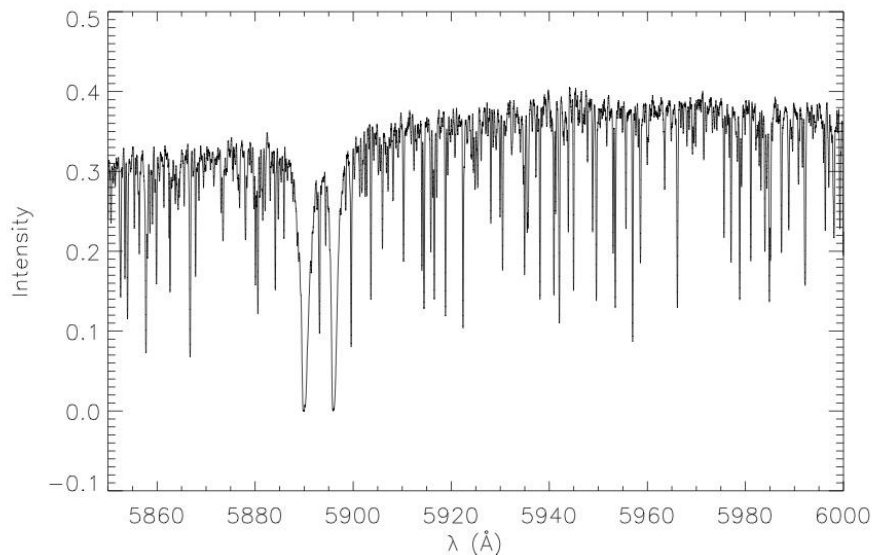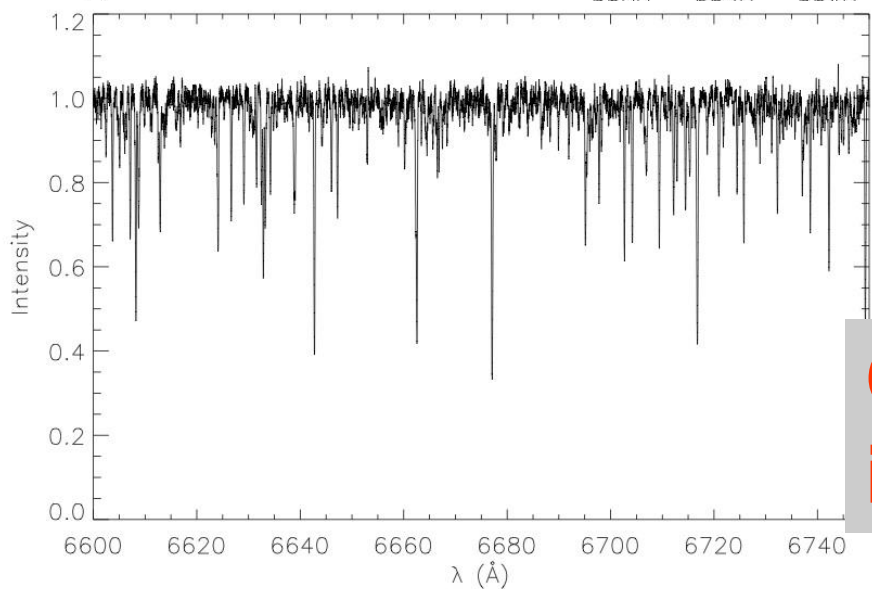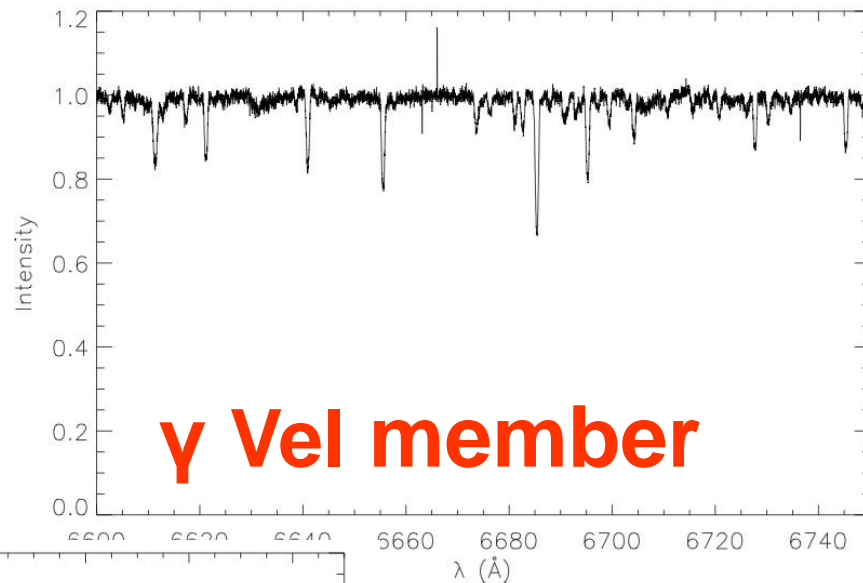
Clump giant in Trumpler 20

First spectra – Giraffe (1/2)
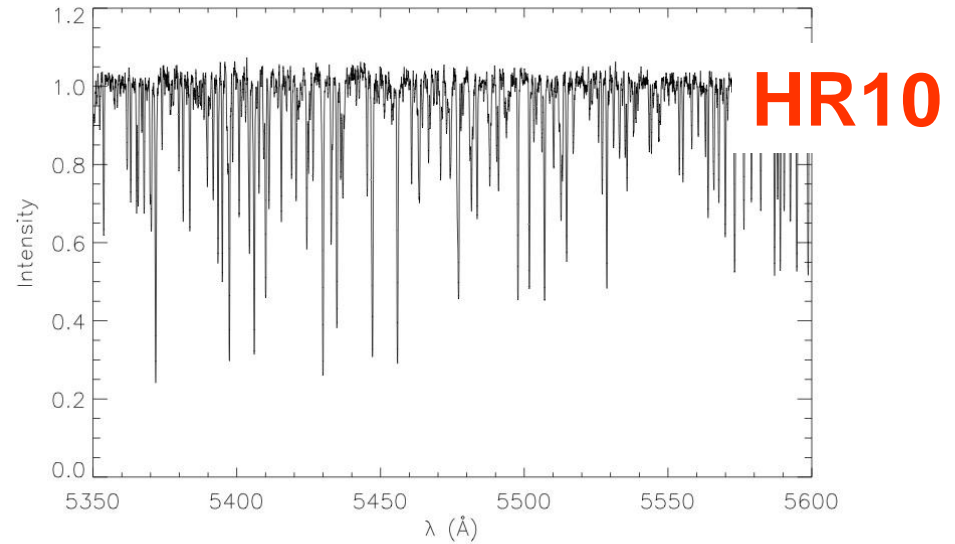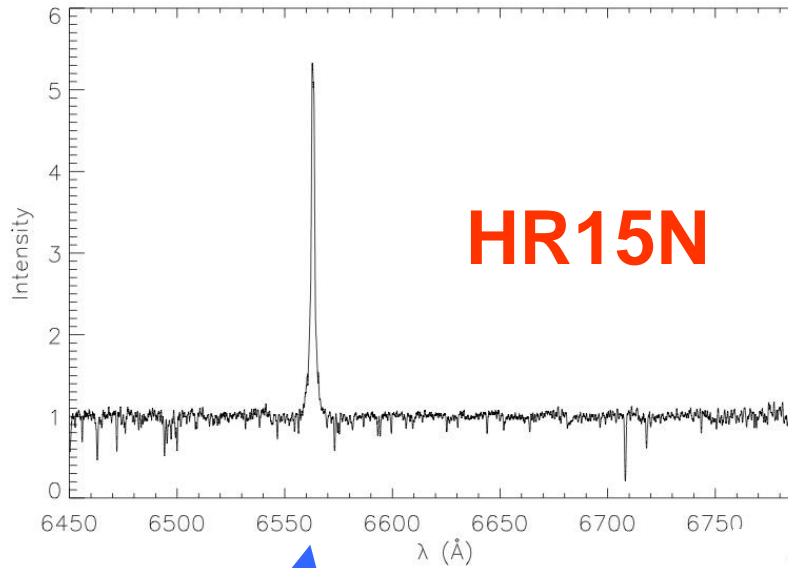
HR15N
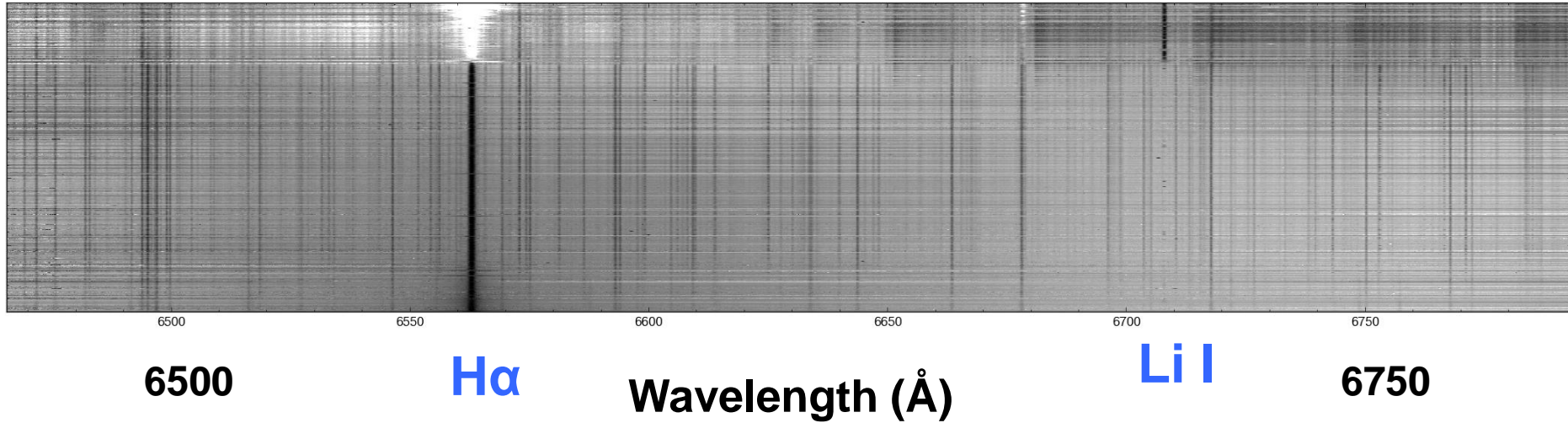
HR10

Cha I member
(2-3 Myr)

Benchmark star

HR21

Chamaeleon I field

6500   **Hα**   **Wavelength (Å)**   **Li I**   **6750**
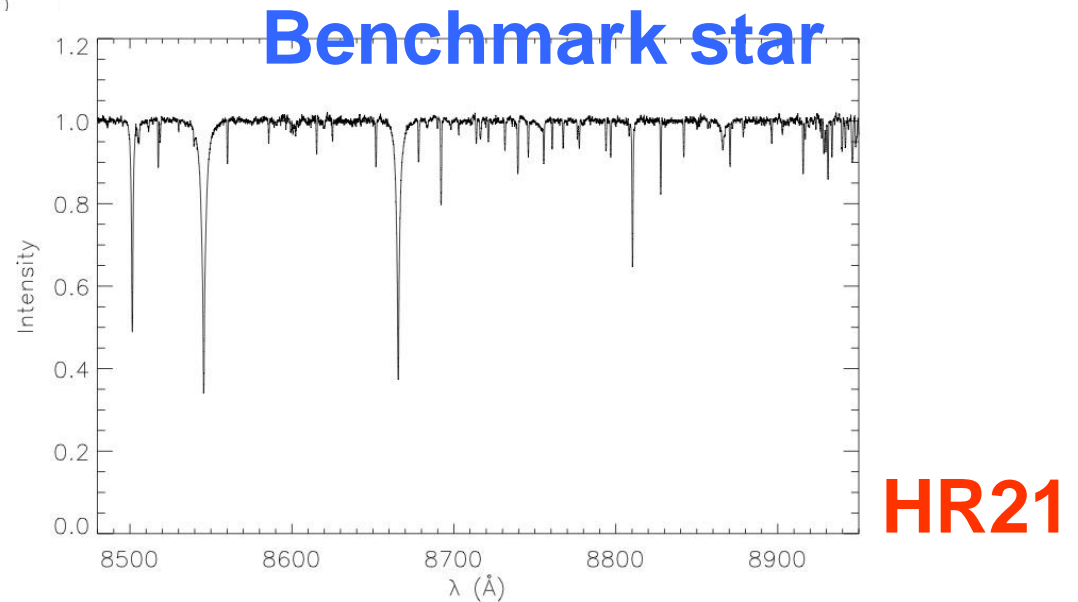
TOWARDS SCIENCE VERIFICATION
1. Radial Velocities

Radial Velocity Precisions

$$\sigma = 0.26 + 1.5/\text{SNR}$$

22% lognormal β=1.4

From repeat observations
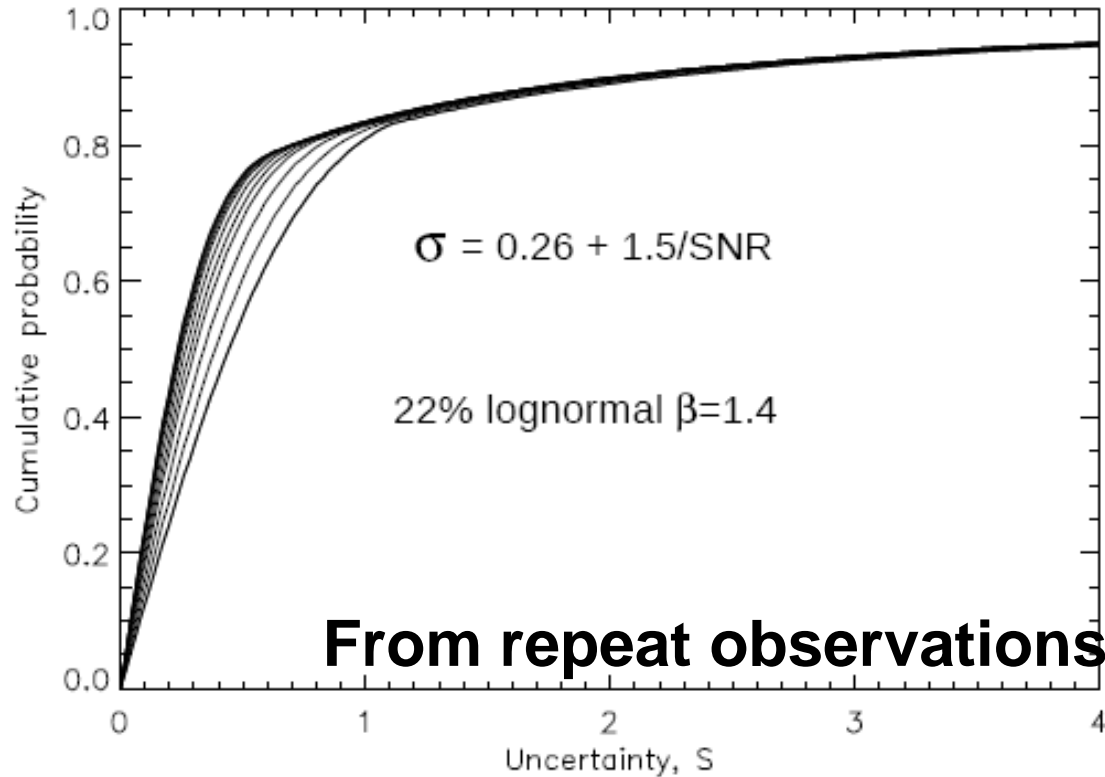
Courtesy Rob Jeffries (Keele)

The RV uncertainty attained for objects in γ Vel cluster, is **0.25 km/s –our goal** ➔ detailed kinematical studies of clusters and/or selection of cluster members kinematically .
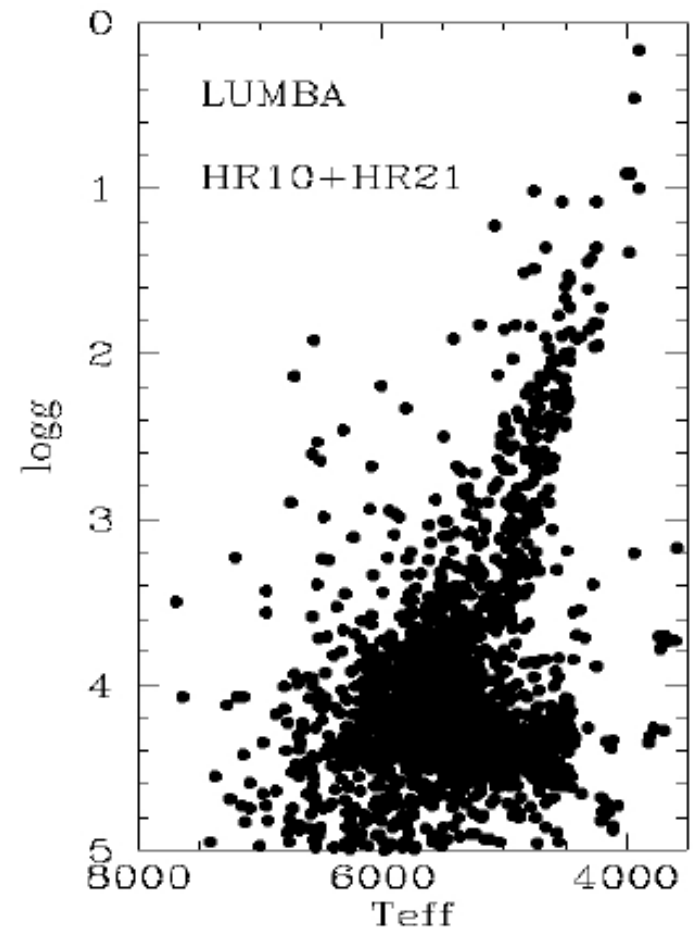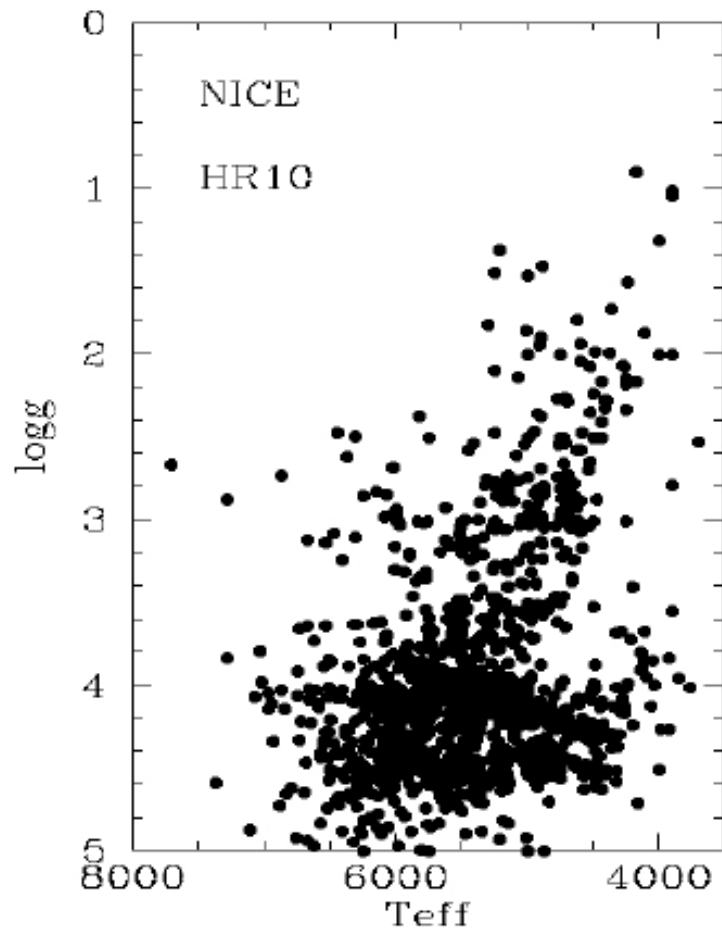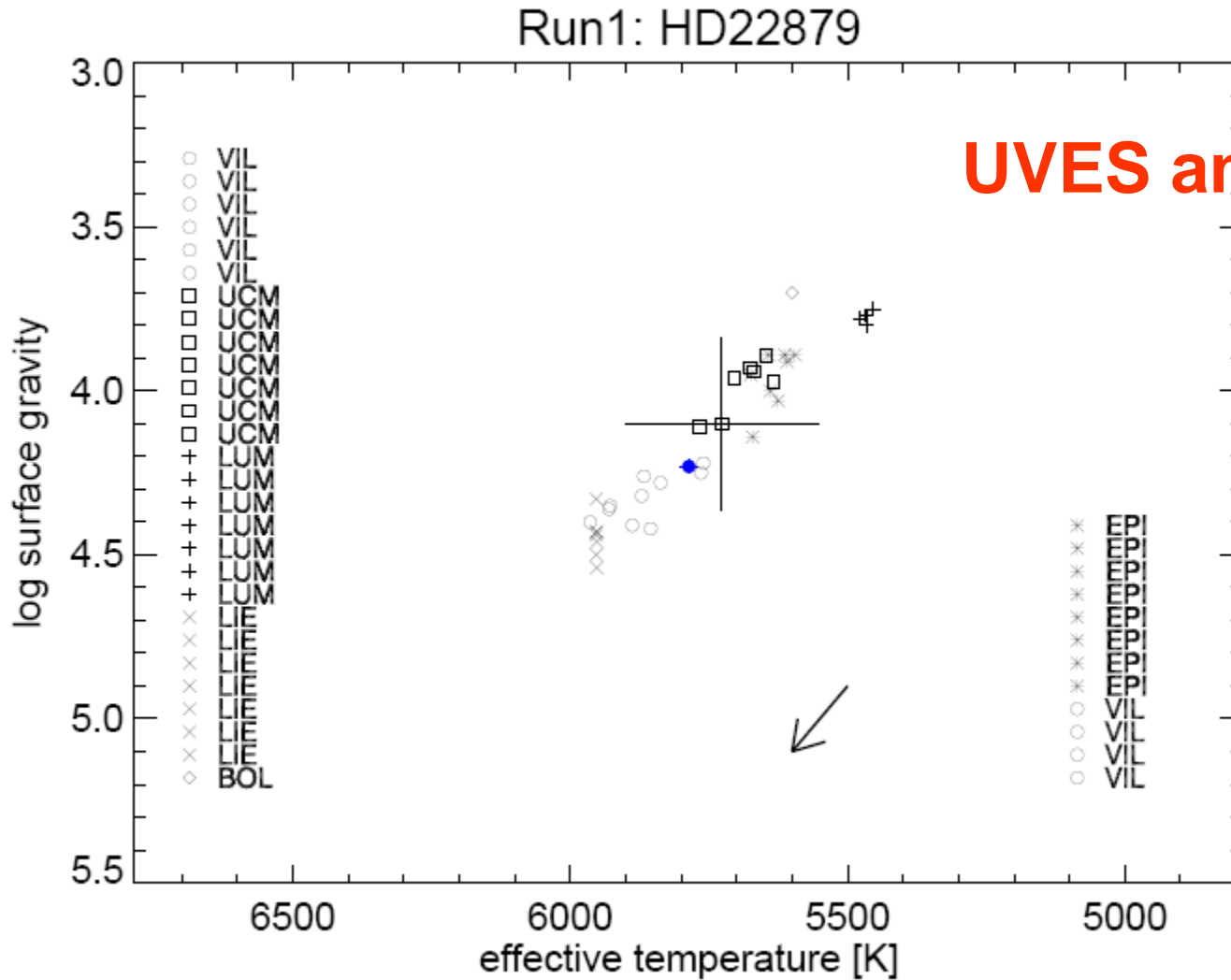
RV distribution in γ Velorum
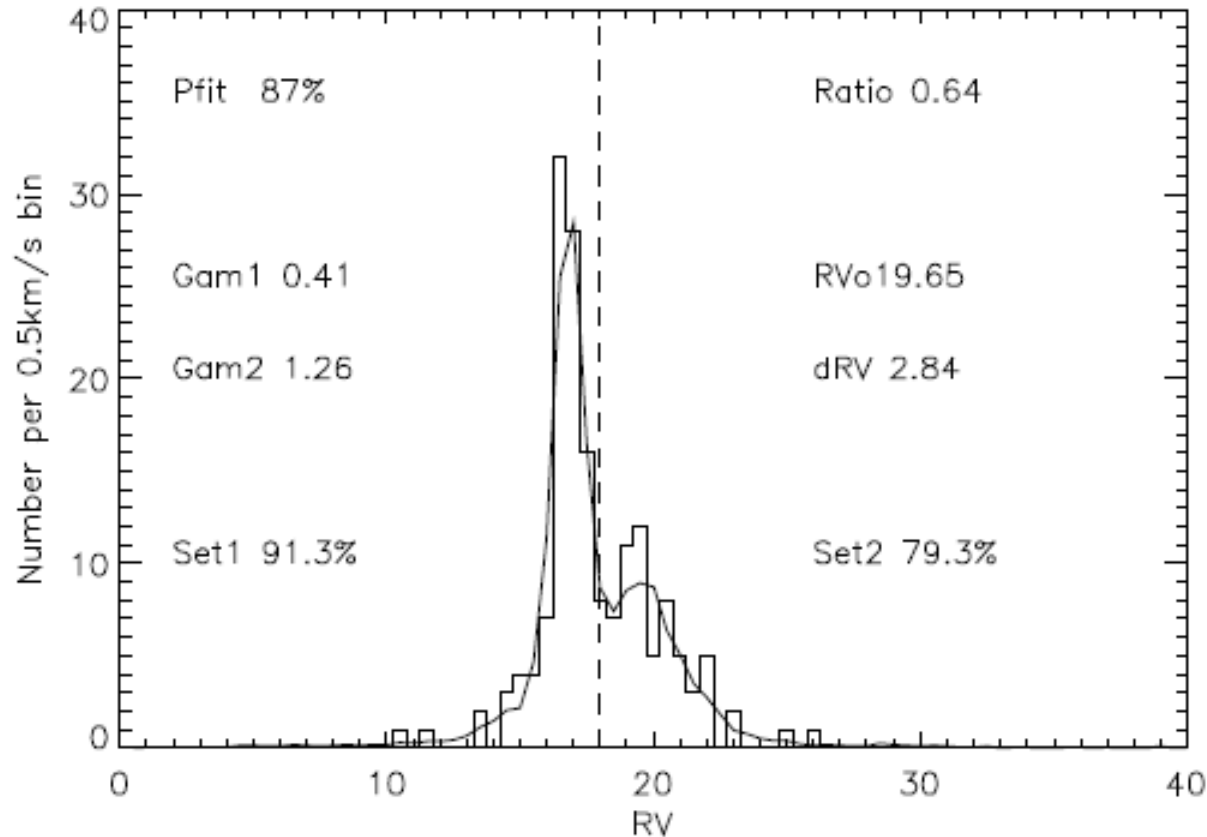
evidence for kinematic substructure that might be indicative of multiple star forming events and a spread of stellar ages

TOWARDS SCIENCE VERIFICATION
2. APs and abundances

Spectrum analysis: consistency checks

Spectrum analysis: benchmark stars

Run1: HD22879

UVES analysis

Conclusions and perspectives (1/2)

- Big Themes in European astronomy require *space and ground based observations*

- MW studies key words: Gaia & Spectroscopy

- Gaia-ESO Survey among the largest and most ambitious ground based spectroscopic surveys ever attempted by European astronomy. The largest on a 8-m telescope

Conclusions and perspectives (2/2)

- Gaia-ESO Survey **end data taking >2016++?** gives **overlap with first Gaia** data **release**. Combined → full 6D phase space $f(x,y,z,v_x,v_y,v_z)$, plus stellar parameters, and chemistry for a very large number and variety of stars: **core science plus legacy science**

- Future dedicated survey spectroscopic facilities are under study (WEAVE, 4MOST, MOONS), to allow Europe to carry the torch forward, **learning from the first effort**

THANK YOU!