Studies of circumstellar and interstellar matter with spectroscopic surveys

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+ RAVE, Hermes-GALAH, Gaia-ESO collaborations

Talk outline:
- peculiar vs. normal spectra,
- their discovery (and cleaning),
- connection to interstellar medium,
- its mapping,
- connection to ages and evolution of Galactic components,
- for Apogee see talk from Jo Bovy, for LAMOST Tim may know.
Example of a Hermes-GALAH spectrum

Galahic_3580176, V=13.55. Exposure: 60 min (R=28800), 240 min (R=48000)

blue: R=28800, red: R=48000, green: T=5000 K, logg=2.5 [M/H]=-0.5, R=20000
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Hermes-GALAH: S/N ratio achieved

R = 28800, 3 pixels per resolution element

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V magnitude

S/N per resolution element & 1 hour exposure

ccd 1

ccd 2

ccd 3

ccd 4

blue
green
red
infrared

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All spectra are not »normal«:
emission spectra of Hermes-GALAH

- »Peculiar« spectra are from stars in brief phases of stellar evolution,
- not considered in grids of stellar atmosphere models (Kurucz, Marcs, etc),
- not in focus of even 3-D stellar models (see talk of Karin Lind),
- examples are extensive optically thin envelopes, disks, in/outflows,
- include binaries and multiple systems.
All spectra not »normal«: emission spectra of Gaia-ESO
Morphology of Gaia-ESO emissions

2 components; ≥3 components; moderate (•) and strong (×) emission, dominating absorption (⊙).
Simbad classification of emission spectra in Gaia-ESO
Emission spectra in Gaia-ESO

GES cluster membership

$J_{abs}$ vs $J_{abs} - K_{abs}$
Time variability of Gaia-ESO emissions

2011-12-04

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.

2011-12-20
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.

2012-01-13
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.

2012-01-19
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.

2012-01-20
Time variability of Gaia-ESO emissions

Total timespan of about 50 days.
Time variability of Gaia-ESO emissions

2012-01-24

Total timespan of about 50 days.
Time variability in spectra – contribution of Gaia

- Gaia-ESO, Hermes-GALAH, RAVE are mostly single shot surveys.
- Gaia is multi-epoch, so real variability of spectra with time.
- But variations non-periodic, except for binaries and pulsators.
Spectroscopic binaries (SB2) in Hermes-GALAH
Automated* morphology classification via locally linear embedding (LLE)

LLE (Roweis & Saul 2000, Vanderplas & Connolly 2009, Daniel et al. 2011) makes a projection of data to a low-dimensional space which optimally preserves the local similarity of observed spectra: pinpoints special objects, systematic problems, wrong RV determinations.

- Find neighbors for each spectrum
- Compute weights $W_{ij}$ that best reconstruct each spectrum from its neighbors, minimizing the cost function $E(W) = \sum |X_i - \sum W_{ij} X_j|^2$
- Determine a lower-dimensional analog of the dataset which best preserves these local reconstruction weights.
- So similar spectra will be close in the lower-dimensional space.
- Compute the vectors in the lower dimensional space that are best reconstructed by the weights $W_{ij}$, minimizing the quadratic form $\Phi(Y) = \sum |Y_i - \sum W_{ij} Y_j|^2$.

* Not enough PhD students (or hard workers like Tim Beers) around.
Automated morphological classification: locally linear embedding in RAVE

Matijevič et al. (2012)

Normal: 90-95%
Binary: 1%
Ca II em.: 3%
TiO band: 1%
Pec. giant: 0.03%
Carbon: 0.03%
Obs. problem <1%
Physical classification of CaII emissions in RAVE

Mostly chromospheric emission
Fig. 5.— Distribution of $\text{EW}_{\text{IRT}}$ for active stars (grey area), normal stars (which are assumed to be inactive; solid line) and pre-main sequence stars (selection is based on Simbad classification of RAVE stars; dashed line). The scale is logarithmic. $p_{\log}$ is a measure for the probability that a star with given $\text{EW}_{\text{IRT}}$ differs from an inactive spectrum. $p_{\log}$ values correspond to 5 and 2 $\sigma$ below zero and 2, 5 and 10 $\sigma$ above zero. 0.3 marks zero.
From circumstellar to interstellar: K I line in Hermes

Resonant interstellar doublets of Na I (5890 Å) and K I (7699 Å) are correlated with E(B-V). The method takes care of saturation and multiple-component effects. It is used to determine IS reddening towards supernovae etc.

Munari & Zwitter 1997
Potential of diffuse interstellar bands in all stellar surveys

DIBs are absorption features in VIS and NIR of yet unidentified molecules with the following properties:

- **wide** (compared to other ISM species) - between 40 Å and 0.5 Å,

- the **strength correlates with** $E_{B-V}$, H I abundance, also with the abundances of many other atoms and molecules in the ISM,

- show **fine structure**,

- **weak** ($W_e \leq 1$ Å / 1 mag of $E_{B-V}$),

- **numerous** (∼ 500 known).

Not knowing what DIBs are is **not an objection** against using them in variety of studies!
DIBs in cool stars: RAVE

Kos et al. 2013
DIBs in cool stars: check of cluster membership in Gaia-ESO

Cluster membership: “We are looking for suspect ones.”

There are outliers on histograms for the DIB strength and DIB radial velocity!

- Peculiar circumstellar medium envelope cannot explain it, as DIBs only exist in diffuse ISM.

- So possibly they are not cluster members.

Kos et al., to be submitted
Conclusions

- Emissions, binaries, DIBs nuisance to many, but jewels to us.
- 6-D mapping of potentially young field stars.
- 4-D mapping of gas, dust, DIB carriers in Galaxy.
Things to come

Fig. 19. Projections of the target stars onto the face on map of the Galaxy (image from Churchwell et al. 2009). Units are parsecs, counted from the Sun, with $d$(Sun)=8kpc. The color coding corresponds to the equivalent of the 6284 Å DIB, either directly measured, or, when not measured, estimated from the other DIB measurements using the average EW(6284)/EW(8620) or EW(6284)/EW(6614) ratios computed from the whole dataset. The asterisk marks the Bulge field 5 (Baade Window direction) for which the X coordinate has been multiplied by 4 to avoid confusion with the other directions. The galactic latitude of each field is indicated at the extremity of the sightline.

Things to come

**Figure 2:** Evolution of gas column density (a), dust column density (b) and magnetic field structure (c) at $t = 2; 7; 11; 15$ Myr. Panel (d) is the distribution of gas (left) and dust grains of different sizes ($a = 10^{-4}; 10^{-5}; 10^{-6}$ cm — from left to right) at $t = 15$ Myr.