Gaia spectroscopy overview and synergy with ground-based surveys

Meeting SF2A - AS GAIA
29 June Besançon

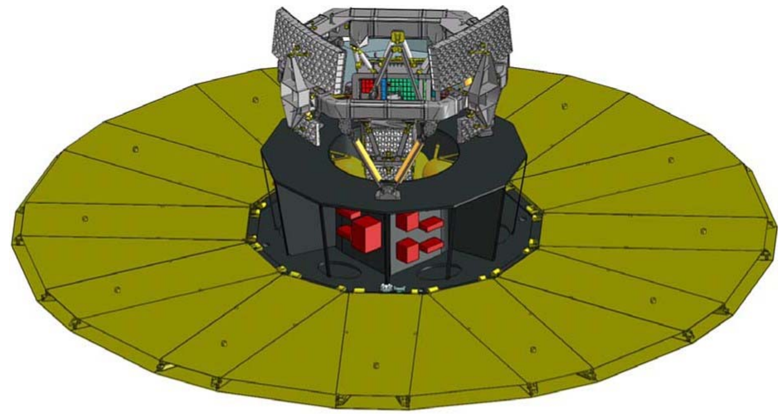
D. Katz

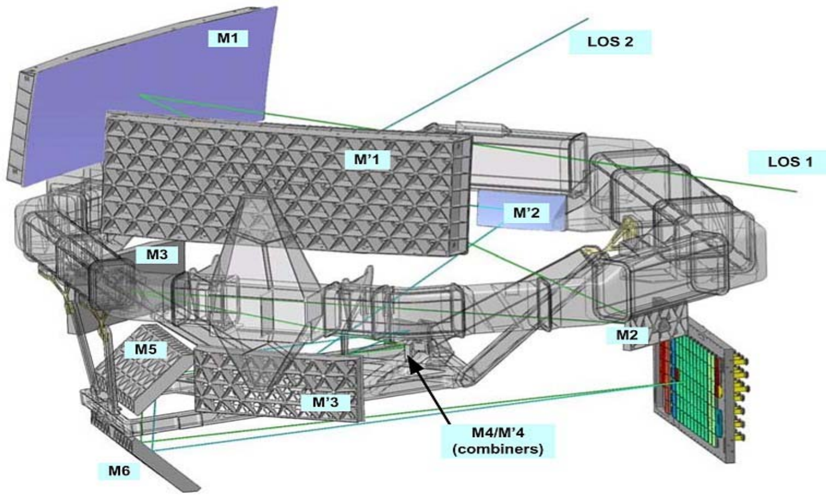
on behalf of the RVS community

(with many inputs, in particular: C. Babusiaux, P. Bonifacio, A. Gomez, M. Haywood, V. Hill, A. Recio-Blanco, A. Robin, A. Siebert, C. Soubiran, F. Thévenin, C. Turon)

Gaia mission & payload

- ESA Cornerstone
- Launch **Spring 2012**
- Mission duration: 5 + 1 years

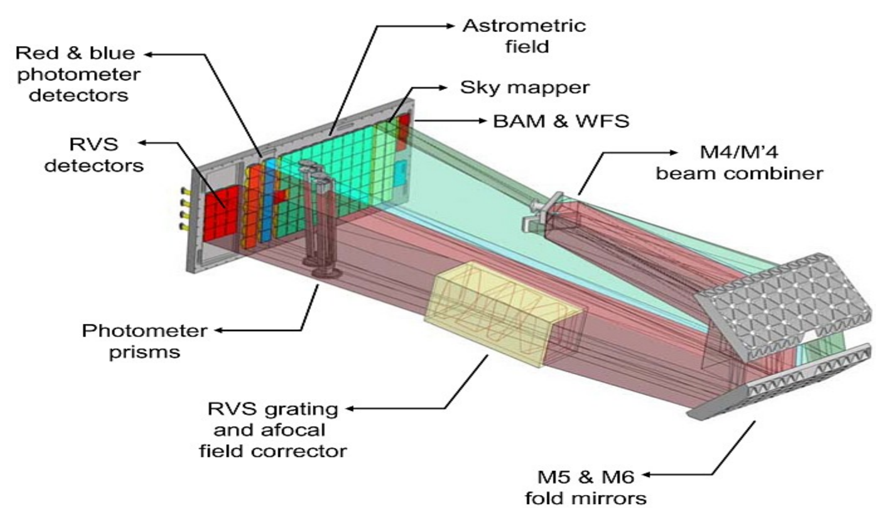




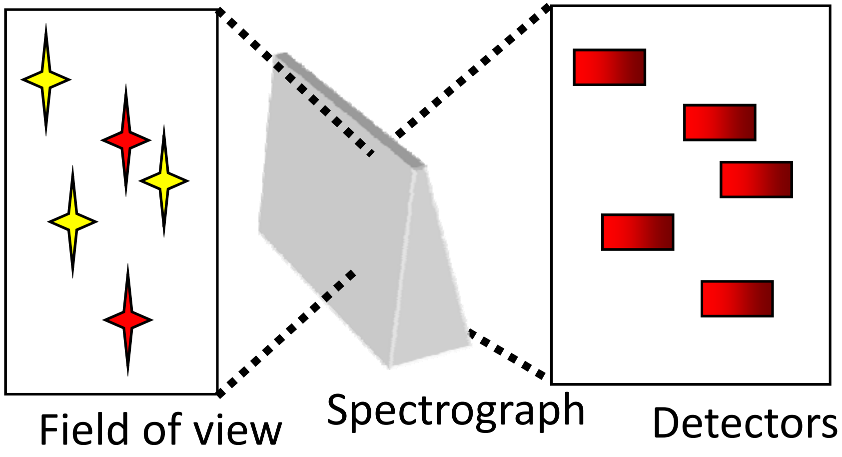
- 2 lines of sight
- 1 focal plane

Conceived with 3 instruments:

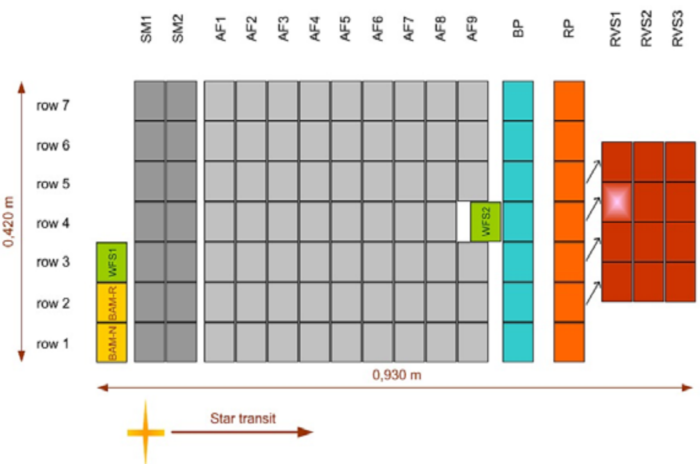
- Astrometric instrument
- Spectro-photometer
- Spectrograph: RVS



RVS concept

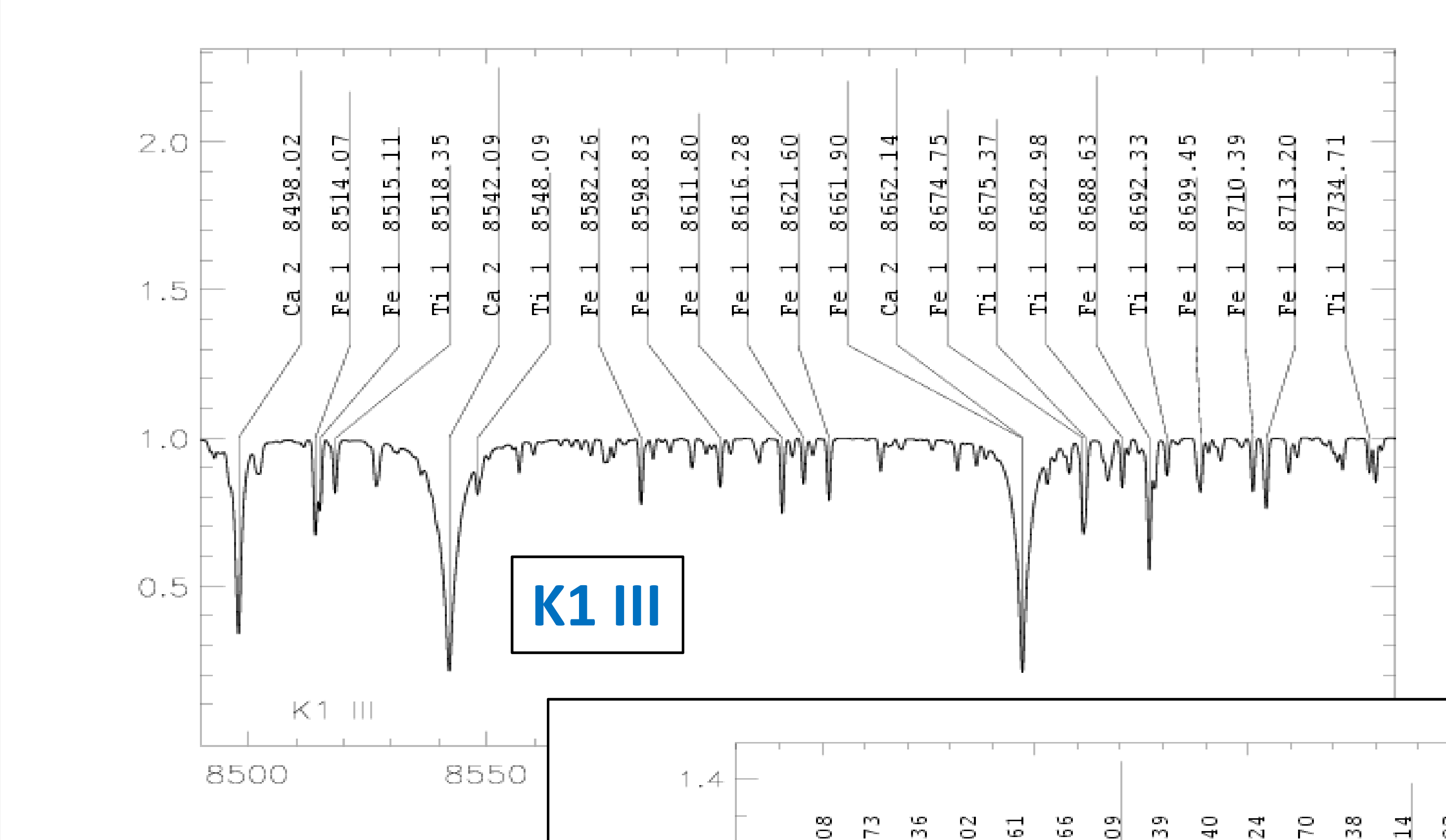


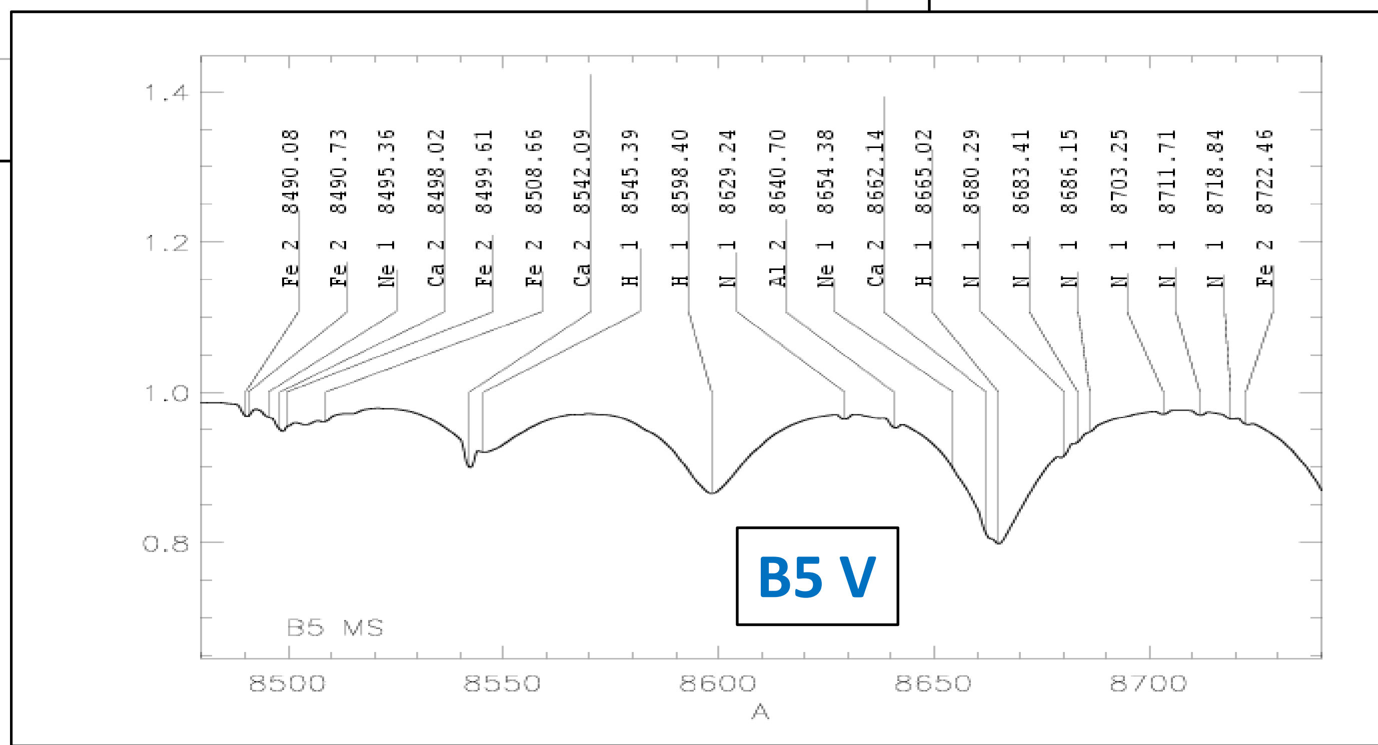
- Integral field spectrograph
  - ⟹ spectra overlap
- Wavelength range : **[8470 – 8740] A**
- Operated in **T**ime **D**elay **I**ntegration mode
- Dispersive power : **R = λ / Δλ = 11 500**
- Multi-epoch scan : **~40 observations** (on average)



- 12 CCDs : 4500 (AL) × 1966 (AC) pix / CCD
- FoV : 0.22×0.39 deg^2
- Exposure : 4.42 s per CCD
- 120 spectra/star in 5 years (on average).

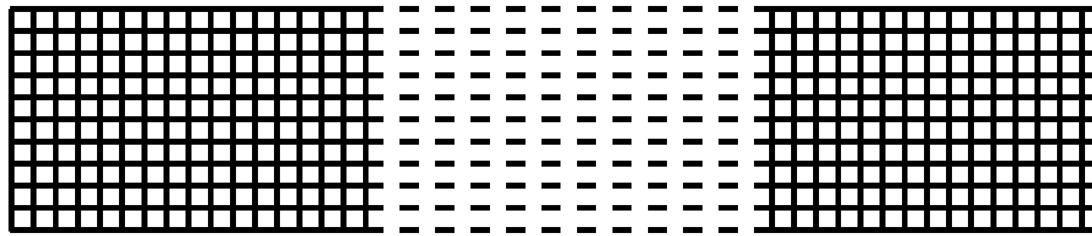
The faintests need to be combined for analysis.


Ca 2 8498.02
Fe 1 8514.07
Fe 1 8515.11
Ti 1 8518.35
Ca 2 8542.09
Ti 1 8548.09
Fe 1 8582.26
Fe 1 8598.83
Fe 1 8611.80
Fe 1 8616.28
Fe 1 8621.60
Fe 1 8661.90
Ca 2 8662.14
Fe 1 8674.75
Ti 1 8675.37
Ti 1 8682.98
Fe 1 8688.63
Ti 1 8692.33
Fe 1 8699.45
Fe 1 8710.39
Fe 1 8713.20
Ti 1 8734.71
2.0
1.5
1.0
0.5
K1 III
8500
8550
K1 III


Fe 2 8490.08
Fe 2 8490.73
Ne 1 8495.36
Ca 2 8498.02
Fe 2 8499.61
Fe 2 8508.66
Ca 2 8542.09
H 1 8545.39
H 1 8598.40
N 1 8629.24
Al 2 8640.70
Ne 1 8654.38
Ca 2 8662.14
H 1 8665.02
N 1 8680.29
N 1 8683.41
N 1 8686.15
N 1 8703.25
N 1 8711.71
N 1 8718.84
Fe 2 8722.46
1.4
1.2
1.0
0.8
B5 MS
8500
8550
8600
8650
8700
A
B5 V

Windowing and Sampling

- **3 Sampling schemes**
  - ✓ $5 \leq G\_RVS \leq 7$
  - ✓ Calibration faint stars
  - ✓ 1260 × 10 samples (1 × 1)
  - ✓ 0.26 A/sample



  - ✓ $7 \leq G\_RVS \leq 10$
  - ✓ 1260 × 1 samples (1 × 10)
  - ✓ 0.26 A/sample

  - ✓ $10 \leq G\_RVS \leq 17$
  - ✓ 420 × 1 samples (3 × 10)
  - ✓ 0.78 A/sample

  - ✓ Number of available windows allows to observe a maximum of 36 000 stars per square degree (i.e. 36 000 brightest stars per square degree)
  - ✓ Baade's window Vlim ~ 13-14

Radiation damages

- High energy particles will create traps in the CCD
  - ✓ Different types of traps with different time release constant
  - ✓ Impact on spectra stronger for fainter stars

- "Fast" release traps
  - ✓ Distort the lines
  - ✓ Fill the lines

- "Slow" release traps
  - ✓ Fill the lines
  - ✓ Net charge loss over the spectrum

- Modelling of the radiation damages included in the RVS system

- Radiation tests campaign #3 (analysed by **C. Allende-Prieto & Astrium**)
  - ✓ **Vr "proven" to magnitude Grvs ~ 15.75 (with bias to be "calibrated")**
  - ✓ **At V=12 Δ EW/EW ~ 15-20%**

Bias non-uniformity

- The RVS spectra are "divided" in 12 parts (called macro-samples).

- Because of a CCD-Proximity electronic (PEM) effect, the bias level vary from 1 macro-sample to the next:
  - ✓ Main impact: equivalent width determination and therefore Teff, logg, [Fe/H], chemical abundances.
  - ✓ Impact on the performance larger at fainter magnitude.

- Several actions on-going under ESA-Astrium responsibility (conclusion mid-July):
  - ✓ Assessment of possible hardware improvement.
  - ✓ Modification of the read-out strategy.
  - ✓ Calibration of the effect as a function of the read-out history.

- Correction of any "residual" effect to be included in the RVS processing system.

Vr specifications & S/N performance

End of mission specifications

	V	Vr km/s
B1V	7	1
B1V	12	15
G2V	13	1
G2V	16.5	15
K1 III MP	13.5	1
K1 III MP	17	15

G2 V

V	S/N / transit	S/N / mission
6	150	1000
10	20	150
12	8	50
14	2	10
16		2

Spectroscopic survey

- **Stellar and interstellar parameters**
  - Radial velocities **$V \leq 17$** **$\sim 150\ 10^6$**
  - Rotational velocities **$V \leq 13$** **$\sim 5\ 10^6$**
  - Atmospheric param. **$V \leq 13$** **$\sim 5\ 10^6$**

    much fainter with spectro-photometer
  - Abundances **$V \leq 12$** **$\sim 2\ 10^6$**
  - Interstellar reddening **$V \leq 13$** **from 862 nm DIB**
- **Diagnostics**
  - Binarity/multiplicity, variability, …

Scientific harvest

- **Halo streams and merger relics:** $\sigma V_r \leq 10$ km/s K2 III ~ 20 kpc
- **MW mass/gravitational potential:** RGB tip ~50 kpc AGB/CH stars ~60 kpc
- **Spiral arms:** $\sigma V_r \leq 5$ km/s B stars ~ 2.5 kpc Cepheid ~ 6-10 kpc
- **Chemical history:** [α/Fe] $V \leq 12$ G2V ~250 pc K0III ~1.5 kpc
- **"Extreme" pop. II stars:** K III: discriminate [Ca/H] = -4.0/-3.0 ~ 5-7 kpc
- **Binaries:** ~10^6 spectroscopic ~10^5 eclipsing (~25% SB 2 → masses)
- **Variable stars:** "Long" period classical Cepheids: $\sigma V_r \leq 7$ km/s ~20-40 kpc

Wilkinson, Vallenari, Turon, Munari, Katz et al., 2005, MNRAS, 359, 1306

Synergy with ground-based surveys: Galactic kinematic & dynamic

- **Improved Vr precision/accuracy**
  - ✓ Vr = 1 (a few) km/s for 12-13 < V < 16-17 Disk studies
    - **Hermes: V < 14-15 (1.2 millions stars)**
    - **SEGUE (240 000) – LAMOST (2.5 millions)**

- **Expand sample**
  - ✓ Toward faint magnitudes: Vr < 10-15 km/s for V > 16
    Halo, streams, mass, potential
    - **LAMOST: 17 < g < 20 (2.5 millions stars)**
  - ✓ Observations in high stellar density areas
    - **Winered: bulge (1 million stars)**
    - **Apogee: disk/bulge (100 000 stars)**
    - **RAVE (several fields in the Galactic plane)**

Future survey:
Galactic kinematic & dynamic

- Objective:
  - ✓ $\sigma Vr < 5$ km/s   e.g. streams, Galactic populations
  - ✓ $16 < V < 20$ Gaia astro/photo limiting magnitude
  - ✓ Dense & absorbed areas   Bulge, bar, globular clusters

- Instrument
  - "Low" resolution R~5000   By-product metallicity
  - Large field-of-view (>1 deg2)
  - High multiplexing (>1000 fibers)
  - "Near"-infrared   For absorbed areas
  - Synergies with LAMOST (only survey $17 < g < 20$):
    - Southern hemisphere
    - Target more the disk (and bulge/bar if visible)

Synergy with ground-based surveys: Galactic chemistry

Improved precision/accuracy

- ✓ Higher resolving power R > 30 000 - 40 000
  - **Winered (R=100 000) – Hermes (R=30 000) – Apogee (R=20 000)**
- ✓ Larger/different wavelength range (and R > 10 000)
  - **See below**

Additional chemical species

- ✓ Larger/different wavelength range (and R > 10 000)
  - **Winered 0.9 – 1.35 μm – Apogee 1.52 – 1.69 μm – Hermes 370 - 950 nm**

Expend sample

- ✓ Abundances V > 12
  - **Hermes (V<14-15) – Apogee (H<13.5) – Winered (?)**
- ✓ Observations in high stellar densities areas
  - **Winered (bulge) – Apogee (disk/bulge)**

Synergy with ground-based surveys: Galactic chemistry

- Objective:
  - ✓ Detailed chemical abundances
  - ✓ $10 < V < 16$

- Instrument
  - High resolution $R > 30\,000$
  - Large field-of-view ("minimum" >0.25 deg2; desirable >1 deg2)
  - Multiplexing > 250 Fibers
  - Large wavelength-range
    - ✓ Self-consistent determination of the atmospheric parameters
    - ✓ Large number of chemical species
  - Northern hemisphere: synergy with HERMES in the southern hemisphere.

European preparation of Gaia in 08/09

- ESO/ESA working group report on "Galactic Populations, Chemistry and Dynamics" (Turon et al, June 2008)

- "The Astronet infrastructure roadmap" 2008: Implement a wide-field, multiplexed spectrograph on a 8-10 m class telescope for 2015-2020.

- Nice workshop 19-20 Feb (Hill – Recio-Blanco – see O. Bienaymé talk)
  - ✓ Science cases
  - ✓ Concept/specifications for future instrument/survey

- ESO workshop 9-10 March
  - ✓ Review of existing/near surveys
  - ✓ Presentation of projects for the next generation VLT instrument (e.g. OKAPI)
  - ✓ Possible ESO call to replace Giraffe

- GREAT plenary session - Cambridge 26-27 March (Walton)
  - ✓ Review science interests in Gaia community (at large)
  - ✓ Structure scientific interests in working groups

- GREAT: High resolution spectroscopy meeting – Cambridge 8-9 July (Feltzing – Walton)
  - ✓ Science cases for high-resolution spectroscopy
  - ✓ Concept/specifications for future instrument/survey