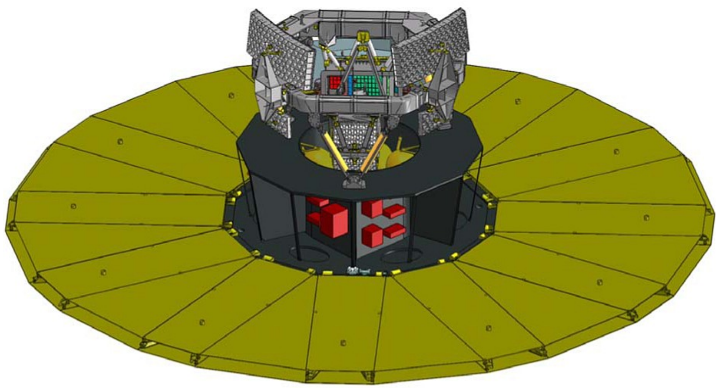
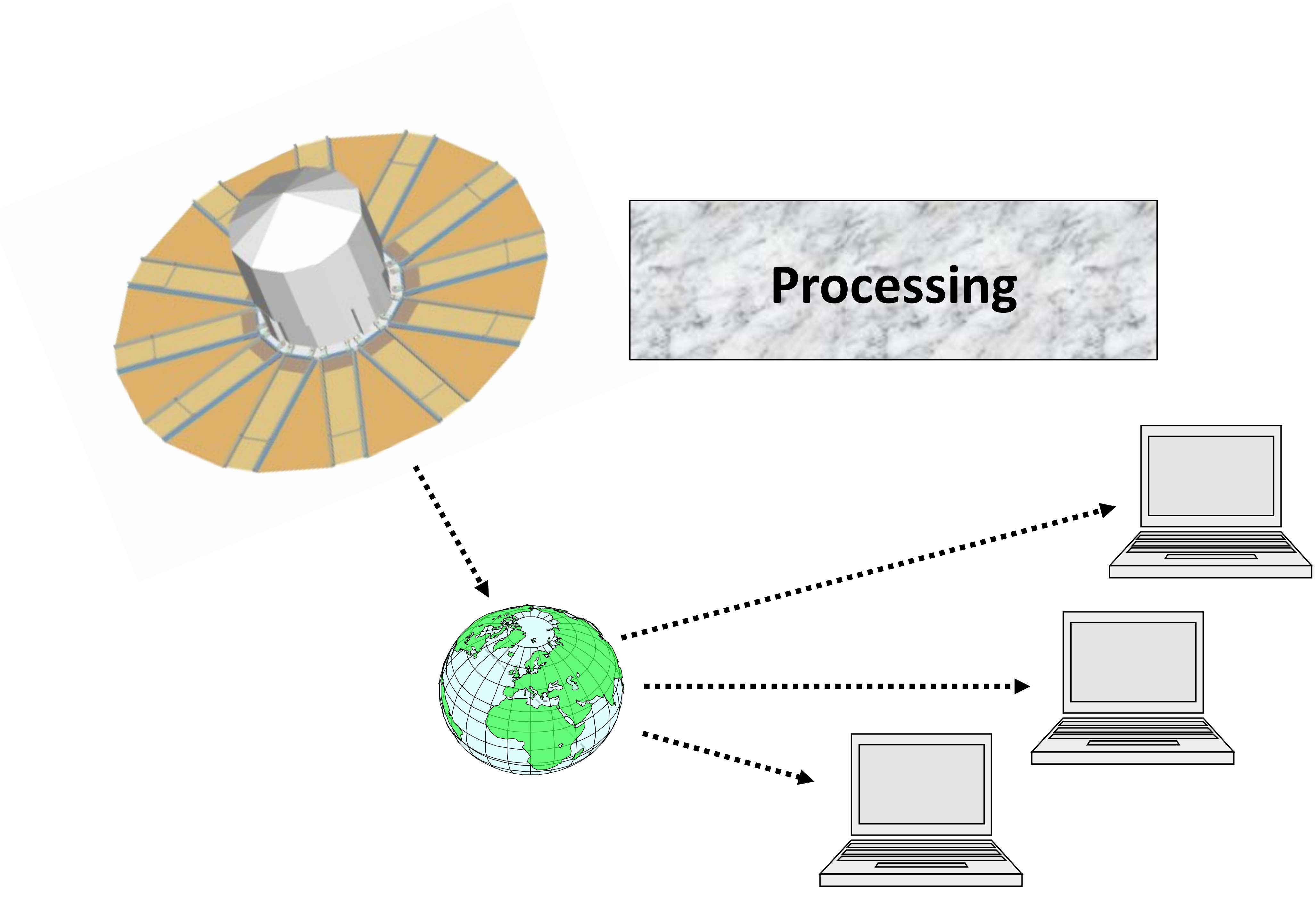
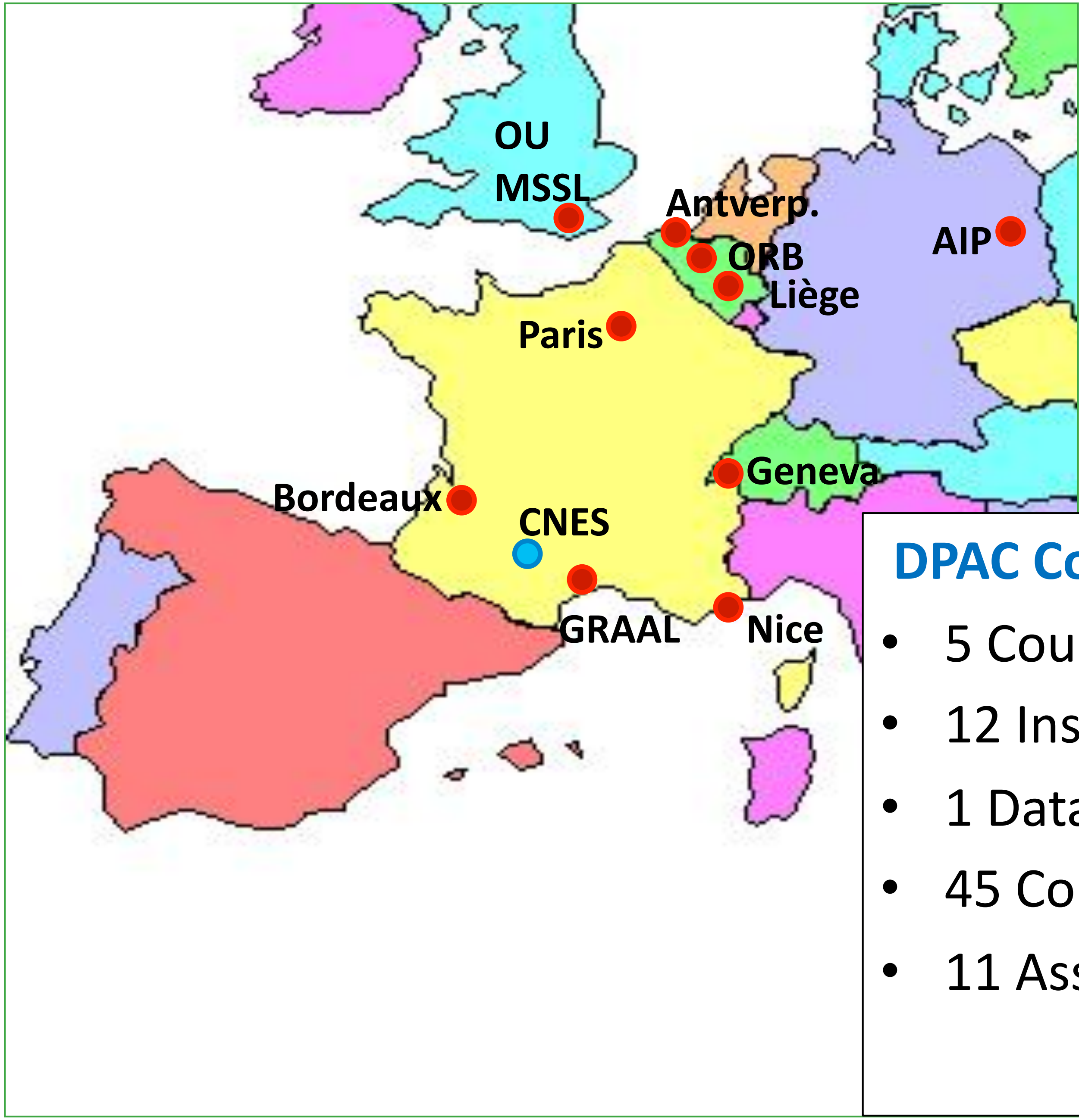
Gaia spectroscopy
processing
performances
scientific returns



Katz, Cropper, Meynadier, Jean-Antoine, Allende-Prieto, Baker, Benson, Berthier, Bigot, Blomme, Boudreault, Chemin, Crifo, Damerdji, David, David, Delle Luche, Dolding, Frémat, Gersen, Gomez, Gosset, Guerrier, Guy, Hall, Hestroffer, Huckle, Jasniewicz, Ludwig, Martayan, Morel, Nguyen, Ocvirk, Parr, Royer, Sartoretti, Seabroke, Simon, Smith, Soubiran, Steinmetz, Thévenin, Turon, Udry, Viala


Processing

Gaia spectroscopic processing



DPAC Coordination Unit 6

- 5 Countries
- 12 Institutes
- 1 Data processing centre: CNES
- 45 Core members
- 11 Associate members

CU6 tasks

1. **Extract the spectra**: transform the telemetry stream into calibrated spectra that can be analysed.
2. **Calibrate the spectrograph**: calibrate the characteristics of the Radial Velocity Spectrometer
3. **Perform a single-epoch analysis of the spectra**: derive the radial and rotational velocities
4. **Perform a multi-epoch analysis of the spectra**: derive the radial and rotational velocities
5. **Define the zero points**: transform the relative radial velocities into absolute radial velocities **(see G. Jasniewicz presentation)**

CU4
Study of multiple systems

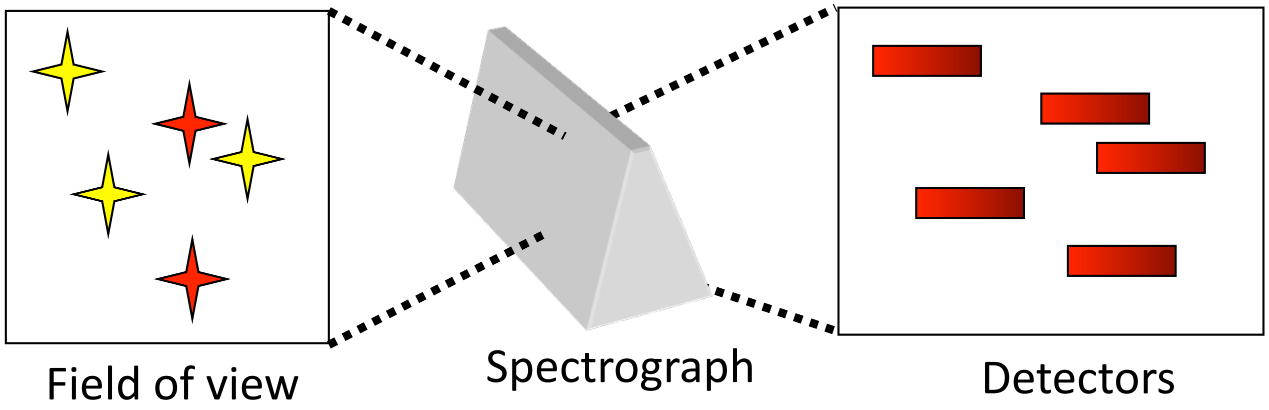
CU7
Study of variable stars

CU8
Derivation of atmospheric parameters and abundances

Spectra extraction (1)

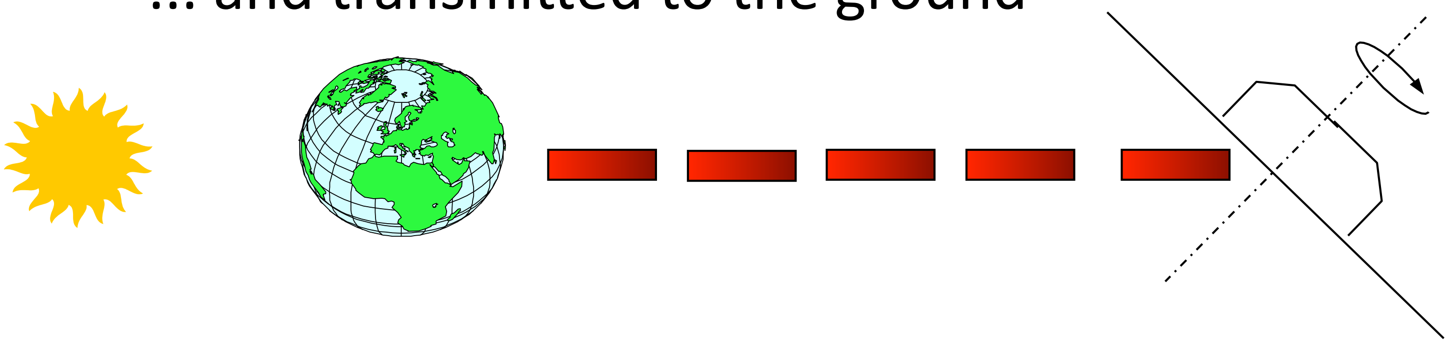
The RVS is an integral field spectrograph:

→ all the light entering the field of view is dispersed



The pixels containing the spectra of stars V < 18 are selected ...

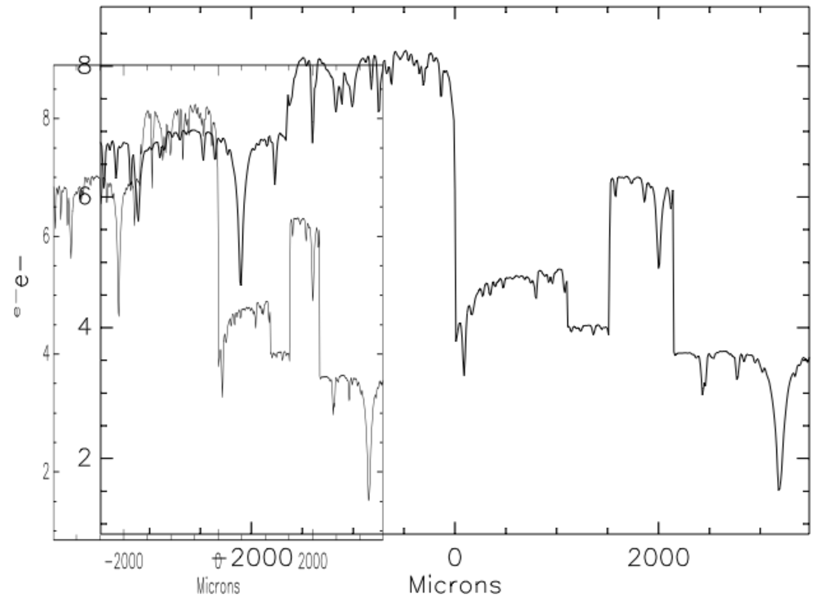
... and transmitted to the ground



Spectra extraction (2)

Main tasks

- Remove the background signals
- De-blend overlapped spectra
- Apply calibrations
- Model CCD defects



2 originalities

- The background is made of the sum of the spectra of the neighbouring sources (discrete or extended). It is modelled and subtracted
- Several CCD specificities **(see M. Cropper presentation)**:
  - Charge trapping
  - Charge trailing

➡ consequences, e.g. PSF profile is function of signal intensity

CCD effects are applied on the template (not corrected on the observed spectrum)

RVS calibration (1)

Originality

No calibration device (no flat field lamp, no wavelength calibration lamp)

Self calibrated instrument

Most properties of the RVS are calibrated using its own observations

- Wavelength
- Photometric response
- Point Spread Function
- Scattered light

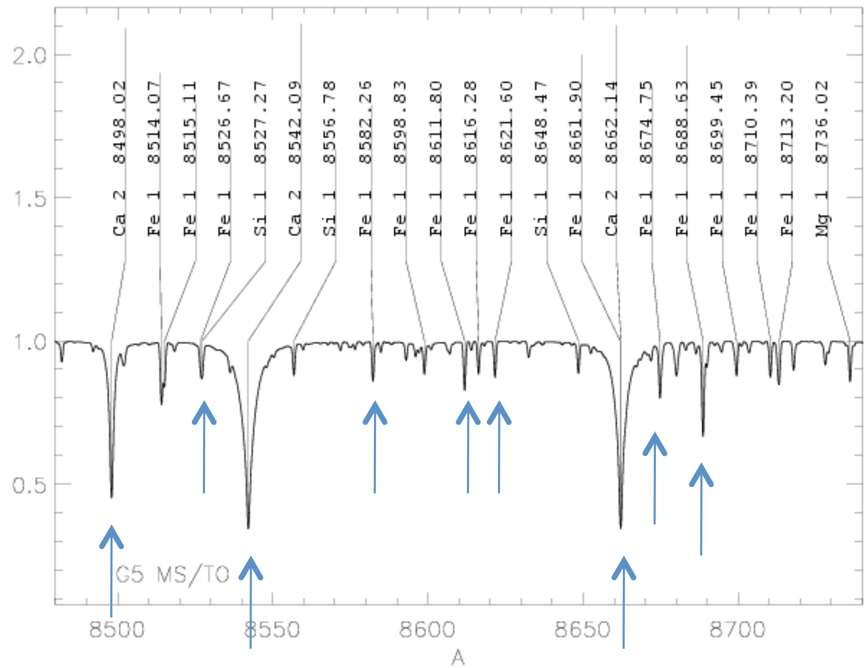
Relative to absolute reference frame

using ground-based references

RVS calibration (2)

Example: wavelength calibration

- Select suitable reference stars with “narrow” lines, i.e. F, G, K stars
- Select reference lines (e.g. non-blended) with well known rest-frame wavelengths, in each reference star
- Solve simultaneously for the wavelength dispersion law and for the radial velocities → solution still partly undefined: free translation parameters
- Degeneracy is solved using ground-based Vr standard **(see G. Jasniewicz presentation)**



Single transit analysis
derivation of the Vr per transit

Originality

Very different S/N ratios: 1000 to 1 (per pixel)

All stellar types and stellar evolution phase

Single and multiple stars

↓

5 different modules

Cross-correlation in direct space

Cross-correlation/analysis in Fourier space (2 methods)

Minimum distance method

TODCOR (optimised for binaries – simultaneous cross-correlation with 2 templates)

↓ Combined Vr

↓ Binarity diagnostic

Multiple transit analysis

40 epochs of observation on average over the 5 years of the mission

Vr time series

Cross-correlation time series

Spectra time series

Variability analysis

Time series modelling (e.g. binary models)

Combination of the epoch spectra

Multiplicity diagnostic

Variability diagnostic

Combined spectra

CU4
multiple systems

CU7
variable stars

CU8
Atmospheric param. and abundances

CU6 operations

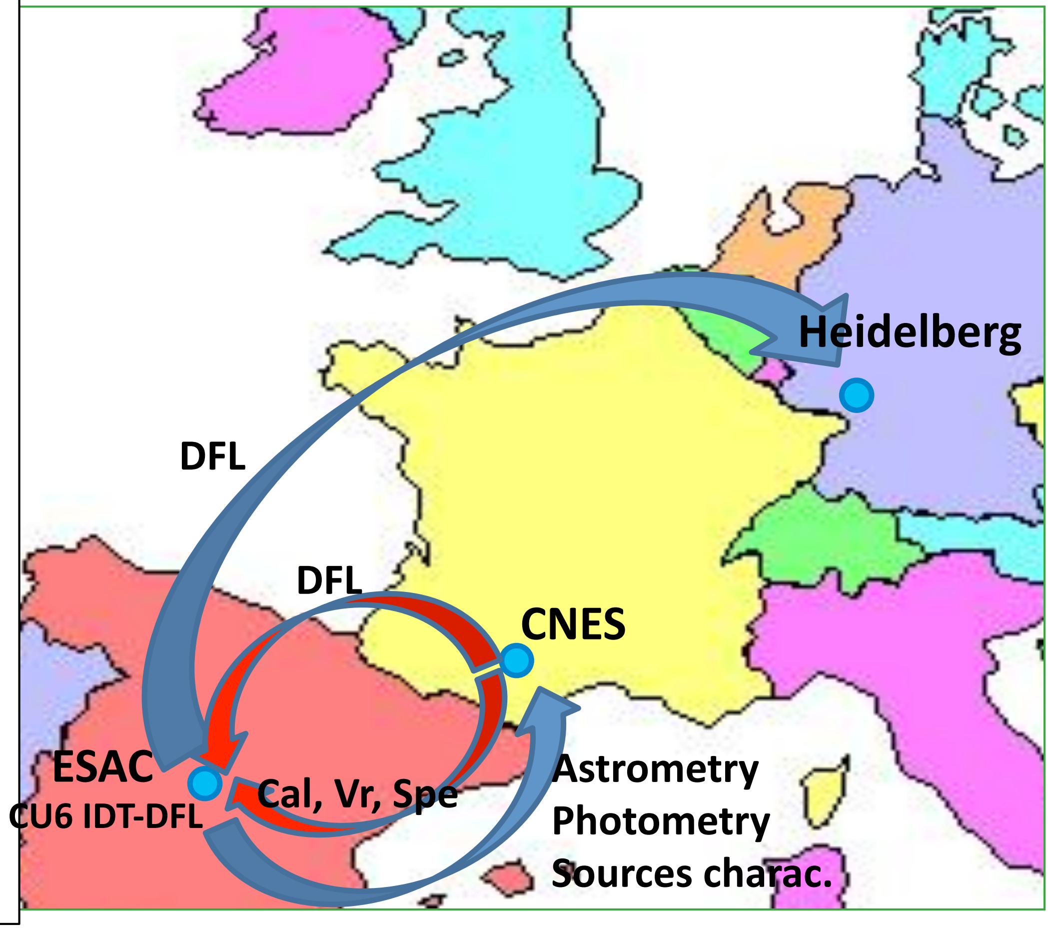
2 time scales:

Daily processing

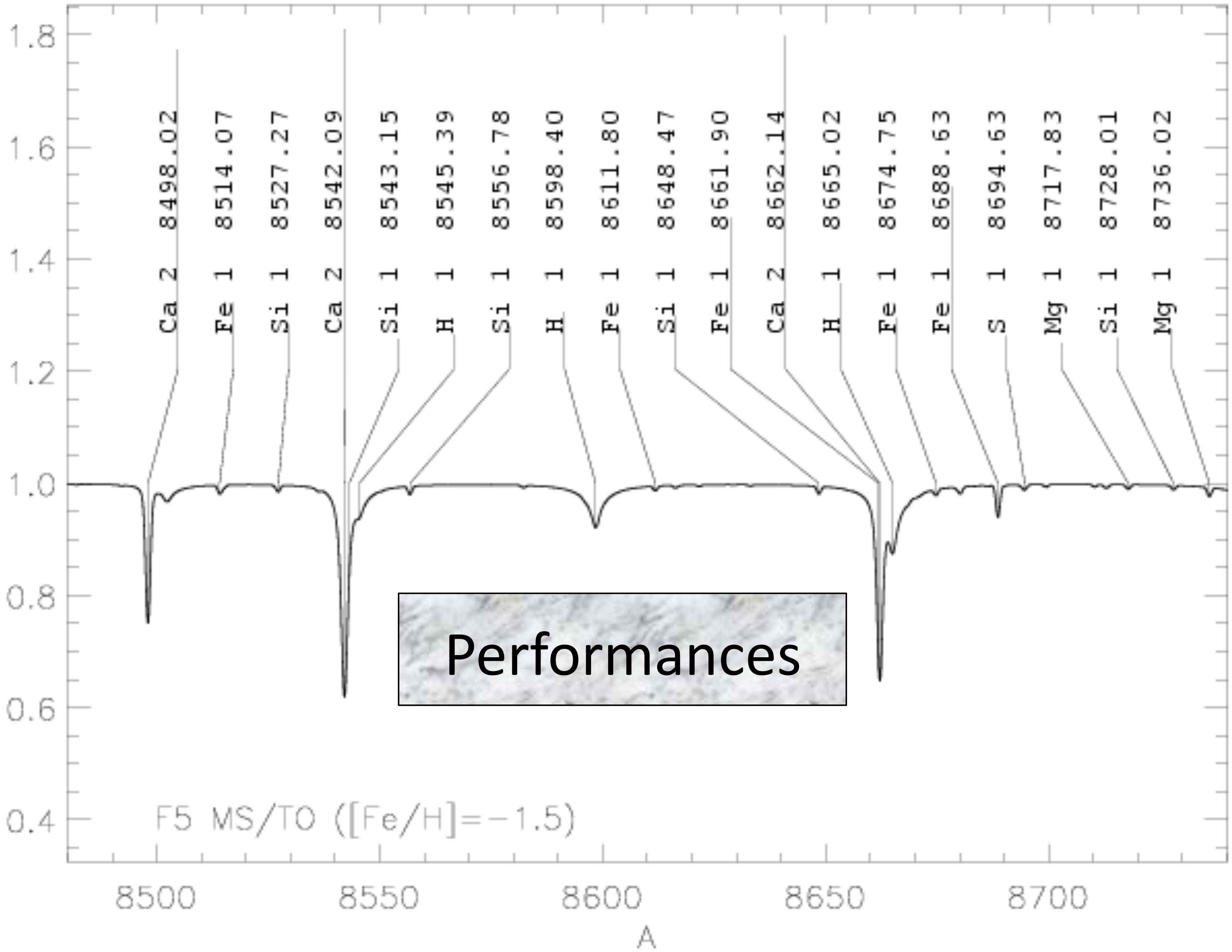
- Process 24h of data
- Check the good health of the instrument
- Provide a first solution for the calibrations and the Vr

Cycle processing

- Process all data since the beginning of the mission
- Iteratively improve the calibrations and Vr, with more epochs, i.e. more information on the sources (and refined information from the other CUs)



Performances



Vr specifications & S/N performance

End of mission specifications

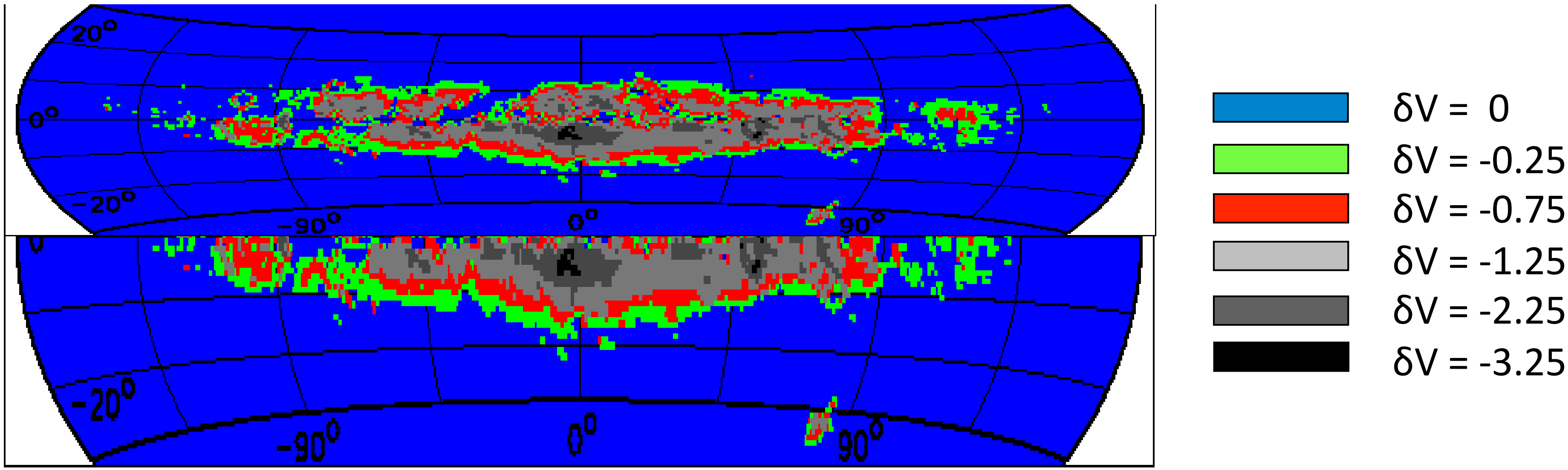
	V	Vr km/s
B1V	7	1
B1V	12	15
G2V	13	1
G2V	16.5	15
K1 III MP	13.5	1
K1 III MP	17	15

G2 V

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

Vr performances versus crowding

In dense areas the neighbouring spectra will overlap
→ impact on Vr performances



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

Spectroscopic survey

- **Stellar and interstellar parameters**
  - Radial velocities **V ≤ 17** **~ 150 10^6**
  - Rotational velocities **V ≤ 13** **~ 5 10^6**
  - Atmospheric param. **V ≤ 13** **~ 5 10^6**
    and much fainter with spectro-photometer
  - Abundances **V ≤ 12** **~ 2 10^6**
  - Interstellar reddening **V ≤ 13** **from 862 nm DIB**
- **Diagnostics**
  - Binarity/multiplicity, variability, …

Scientific returns

Scientific harvest (1)

Kinematics and dynamics

- **Halo streams and merger relics**

→ $\sigma Vr \leq 10$ km/s K2 III ~ 20 kpc

- **MW mass/gravitational potential**

→ RGB tip ~50 kpc AGB/CH stars ~60 kpc

- **Spiral arms**

→ $\sigma Vr \leq 5$ km/s B stars ~ 2.5 kpc Cepheid ~ 6-10 kpc

Chemical composition

- **Chemical tagging**

→ [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

Scientific harvest (2)

- **Binaries**

→ ~10^6 spectroscopic ~10^5 eclipsing (~25% SB 2 → masses)

- **Variable stars**

→ "Long" period classical Cepheids: $\sigma Vr \leq 7$ km/s ~20-40 kpc

... And much more in

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