Numerically inverting the fundamental stellar parameters of A/F stars

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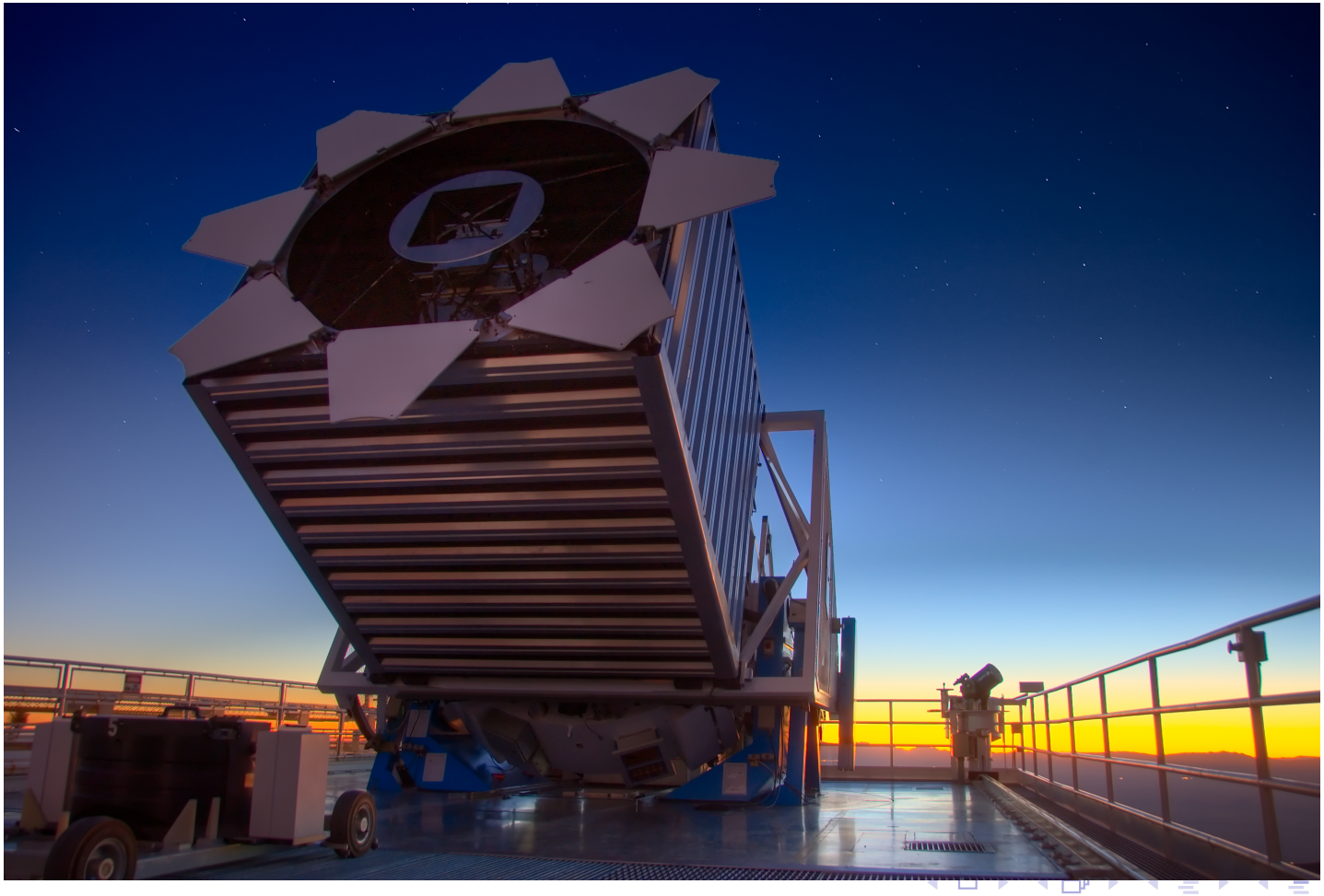
Sky Surveys

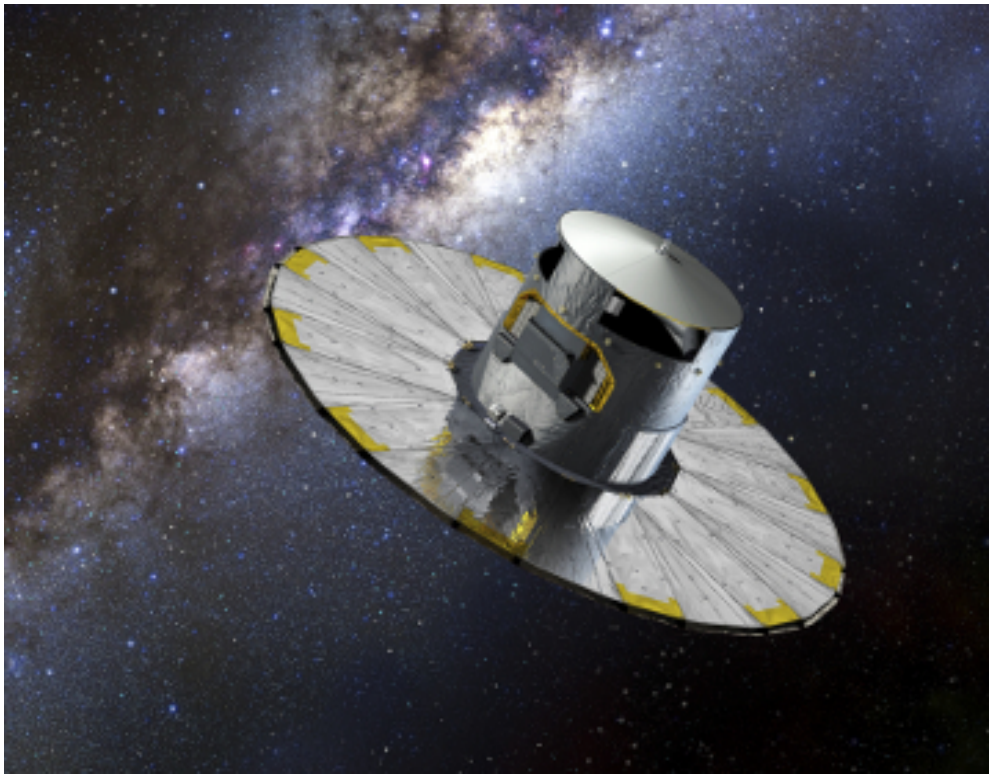
SDSS

Sloan Digital Sky Survey



Sky Surveys

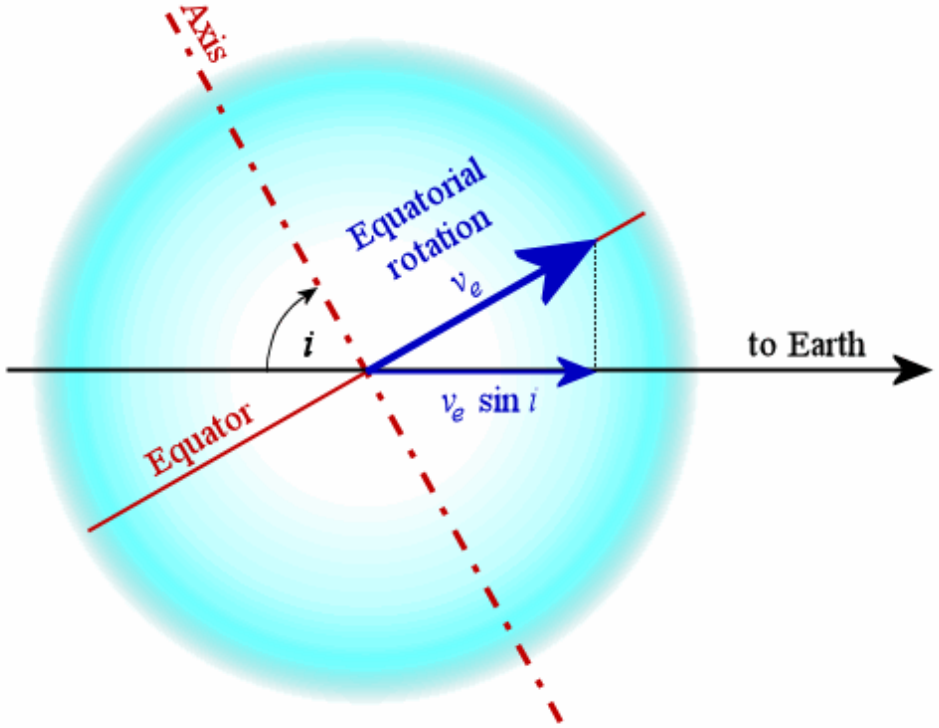
Gaia space telescope
Complemented Gaia-ESO survey



Star Parameters

Fundamental stellar parameters:

- T_{eff}
- $log(g)$
- $[\frac{Fe}{H}]$
- ξ_t



In addition to these parameters we can find the $v_e sin(i)$ which is the projected equatorial velocity

The benefit of the parameters

They form constrains for:

- Cosmology
- Galactic chemical evolution and dynamics
- Extra-solar habitability
- .... And many more....

Spectra from surveys

- Spectroscopic data from many stars
- We need to find **its** fundamental parameters

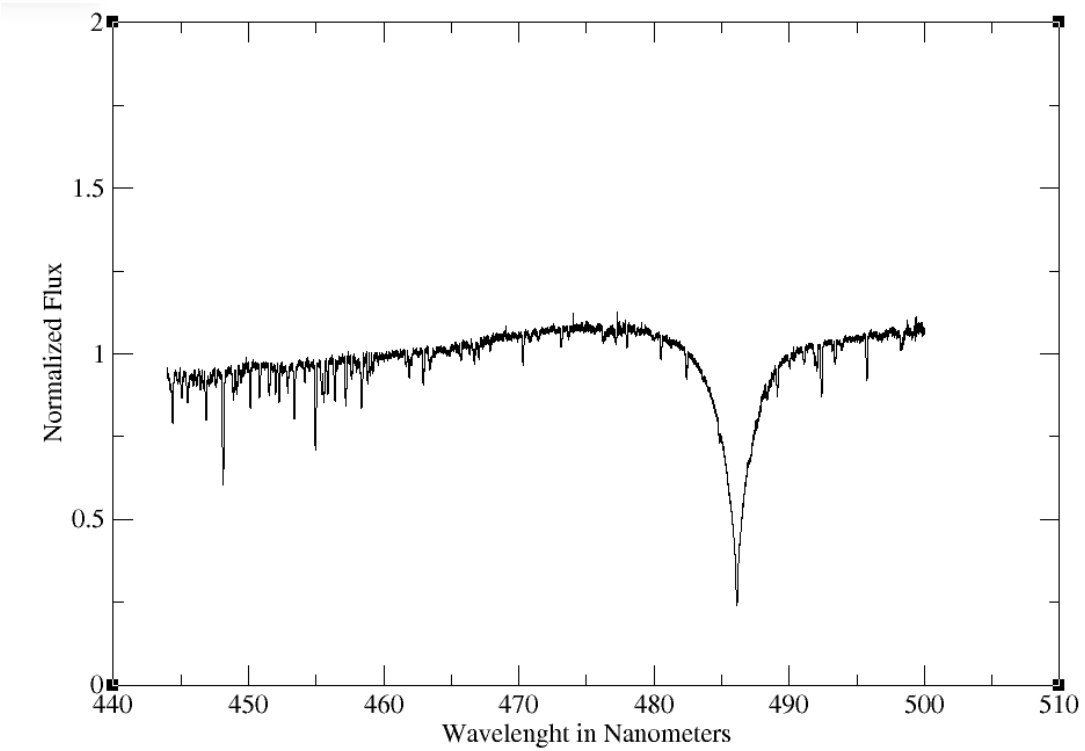
HD98377

$RA : 11^h 19^{min} 06^{sec}$

$DEC : +09^o 45^{arcm} 03^{arcsec}$

$mag_B : 8.17 \pm 0.02$

$mag_V : 8.05 \pm 0.01$



Finding the parameters numerically

LUT: Look up table

Radiative transfer model of stellar atmospheres $\longrightarrow$ database(synthetic spectra)

- Check Gebran et al.(2016): A new method for the inversion of atmospheric parameters of A/Am stars
- Dr. Mounib Eid's (AUB) Lecture

Inversion

- Observed spectra are compared to synthetic spectra
- The parameters of synthetic spectra with the best fit with the observed are used.

The big data era

- Large quantity of data from surveys
- High resolution spectra $\Rightarrow$ many flux values(up to 20000)
- Many parameter permutations
- Reaching up to Petabytes $= 10^6$ Gigabytes

YOU WILL NOT LIVE TO SEE YOUR RESULTS!!!!

Dimension Reduction

I will share with you my secret numerical recipes!

- PCA: Principle Component Analysis
- SIR: Sliced Inverse Regression

These 2 techniques are used to reduce the dimension of the spectra

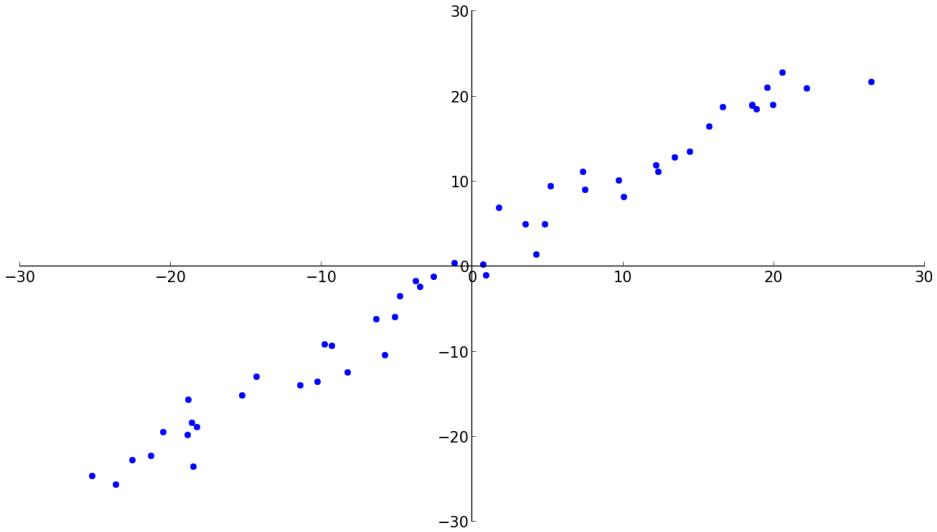
PCA

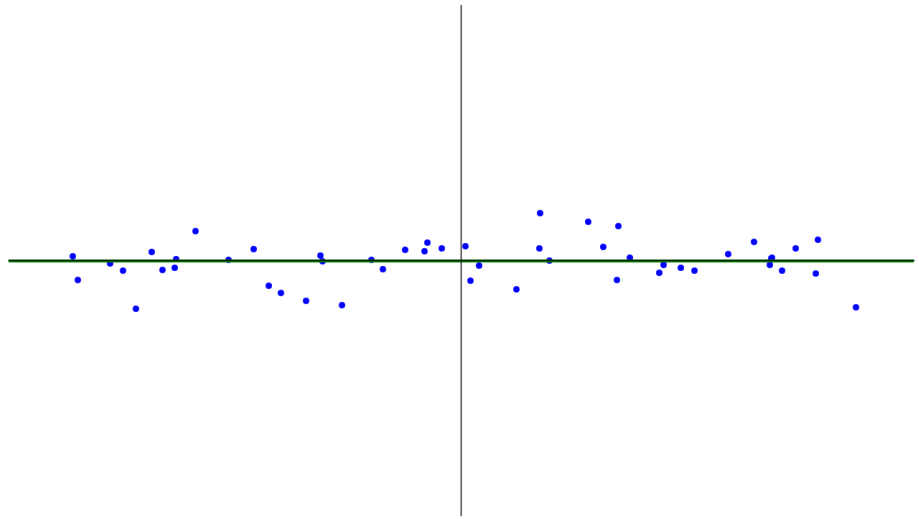
- PCA was invented in 1901 by Karl Pearson
- Finds a lower dimensional space and projects all the data on this new subspace using the covariance matrix.

$$C = (S - \bar{S})^T (S - \bar{S}) \tag{1}$$

- S is the row matrix of spectra
- $\bar{S}$ is the matrix of average of spectra **(identical rows)**
- N eigenvectors with largest eigenvectors of C form the new eigenbasis
- In Gebran et al.(2016) N=12 (Dimension lowered from 20000 to 12)

2D to 1D example





SIR

- SIR was elaborated by Ker-Chau Li(1991)
- We adopted reducing the dimension of spectra into 1

Estimation of Mars surface physical properties from hyperspectral images using Sliced Inverse Regression

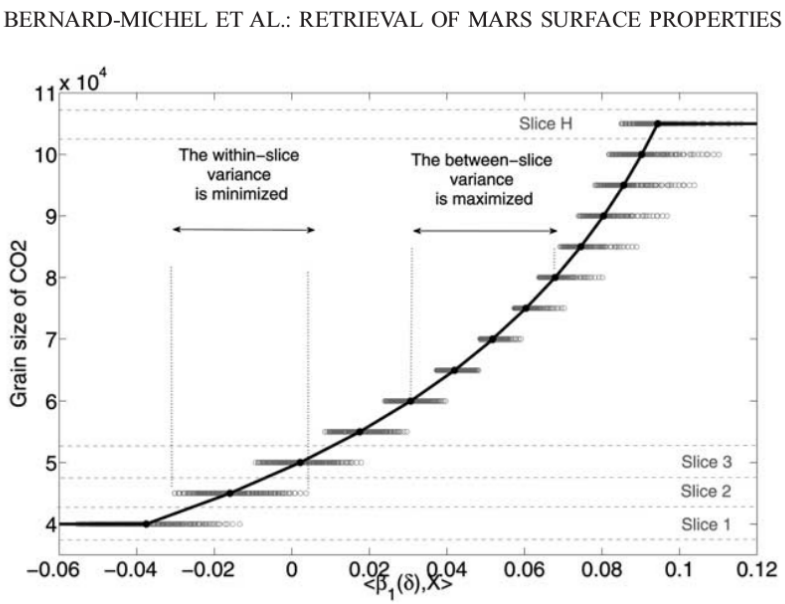
Caroline Bernard-Michel, Sylvain Douté, Laurent Gardes, Stephane Girard

SIR

- Doing regression vs parameters
- Calculate a **sorted** covariance matrix of all spectra: Σ
- Find covariance matrix of averages of slices: Γ
- Finally the eigenvector of the largest eigenvector

$$\Sigma^{-1}\Gamma \tag{2}$$

Serves as an eigenbasis



Latest work on the topic

- $\Sigma^{-1}\Gamma$ is ill-posed(ill-conditioned)
- At **NDU Louaize - Lebanon** in collaboration with **Paul Sabatier University-Toulouse-France** as a part of my masters thesis , we are working to regularize this covariance matrix and make it well-conditioned (well-posed)

Latest work on the topic

PCA has been applied on stars with high accuracy of parameter value in the works of:

- Gebran et al.(2016) $\longrightarrow$ For A and F stars
- Paletou, Gebran et al.(2015) $\longrightarrow$ For M dwarfs
- New tests of SIR will be done on A and F stars aiming to achieve higher accuracy of parameters.

Grazie per il tuo tempo!!

Thank you for your time!!