First look at StarDICE spectrophotometry and photometry

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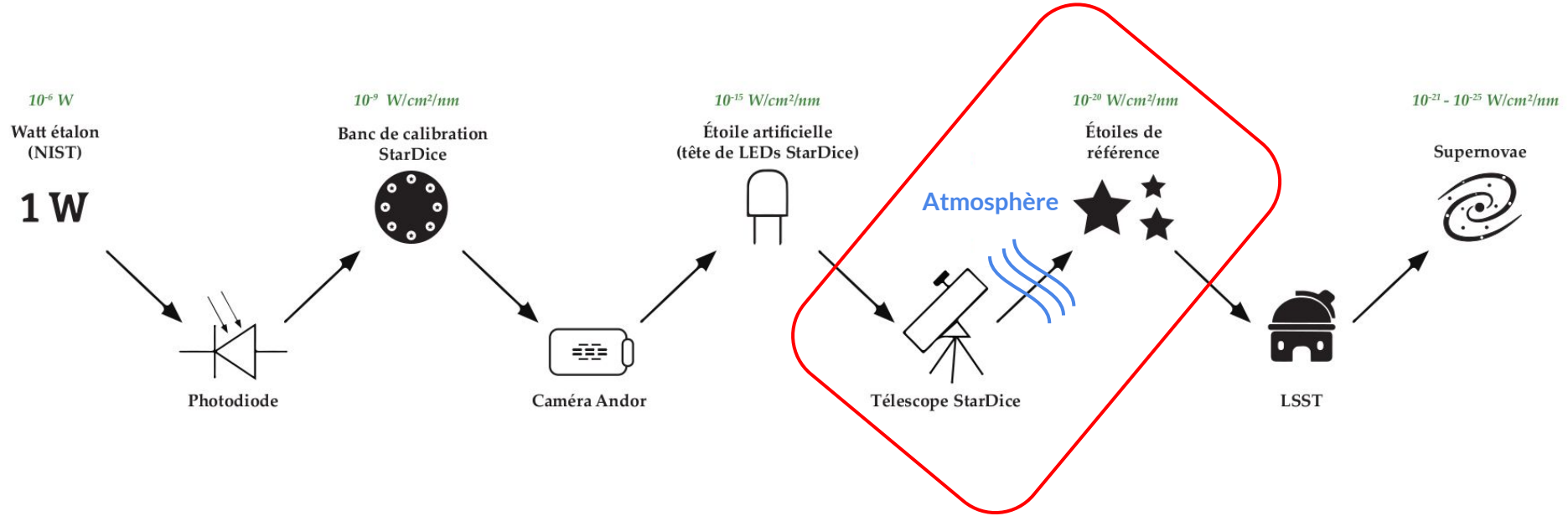
StarDICE

LSST Legacy Survey of Space and Time

Vera C. Rubin Observatory

I. StarDICE experiment

Photometric calibration transfer

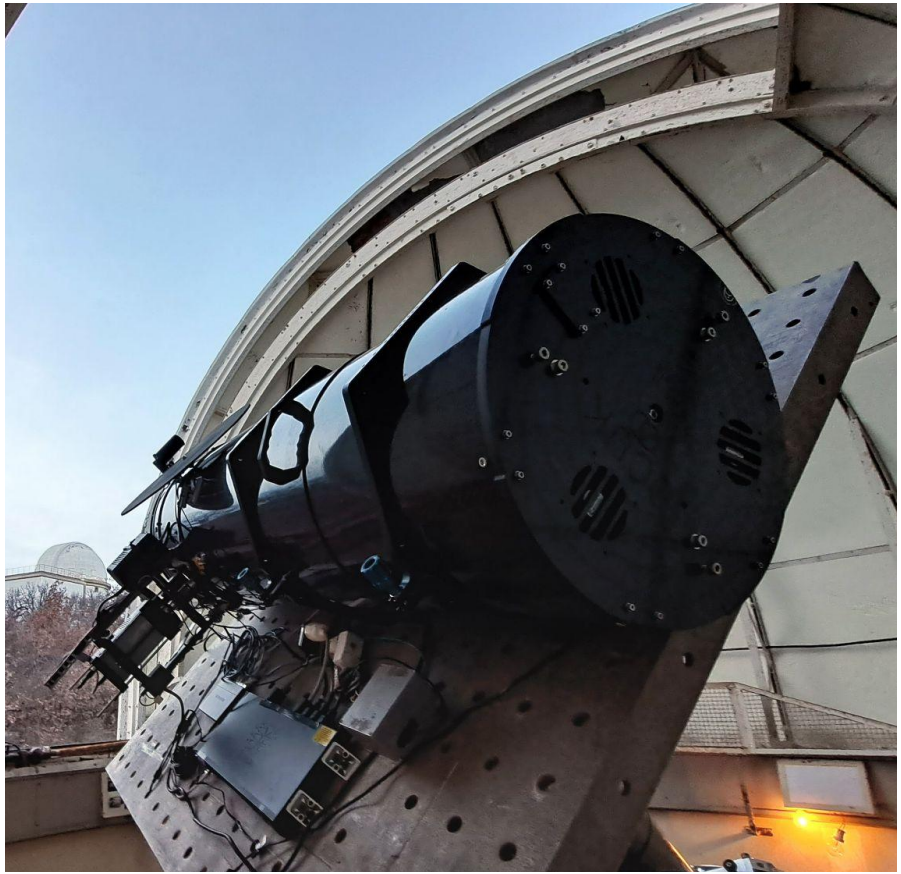


Measurement of the spectra of standard stars

Observatory site : Observatoire de Haute-Provence

StarDICE telescope

Newton telescope ; D=40cm ; f=1.6m ; camera 1 Mpixel



Response of the telescope calibrated :

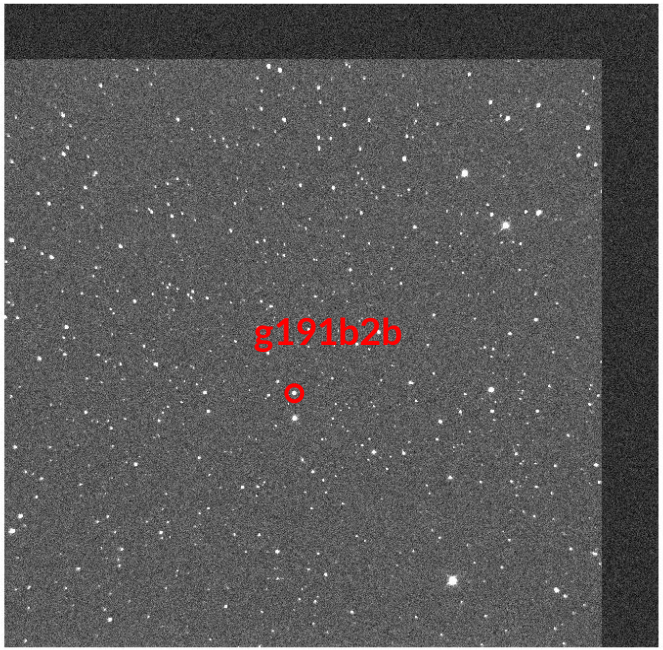
- $\mathbf{R_{tel,CBP}}$ high resolution with the CBP (talk J. Neveu)
- $\mathbf{R_{tel,DICE}}$ low resolution monitoring with the StarDice artificial star (talk M. Betoule)

Filterwheel :

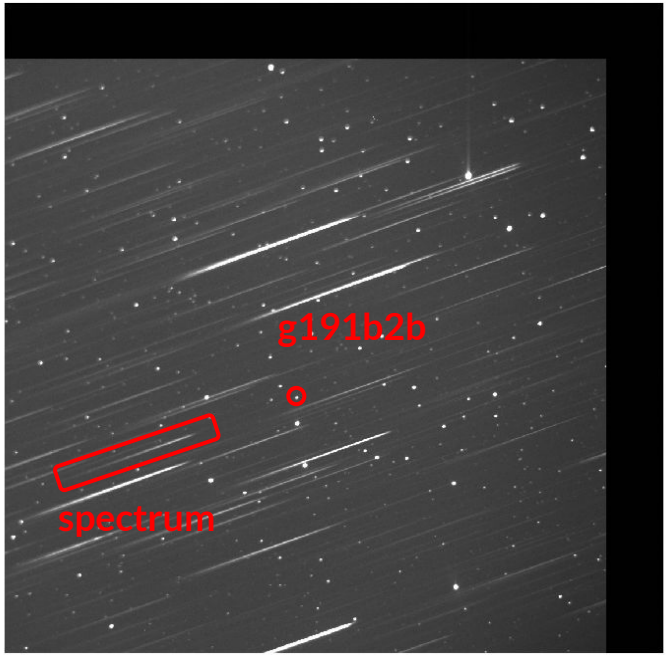
- **Grating** → low resolution (R~150) spectrophotometry to fit $T_{atm}(\lambda)$
- **ugrizy filters** → broadband photometry calibration

State of the experience

g filter



grating



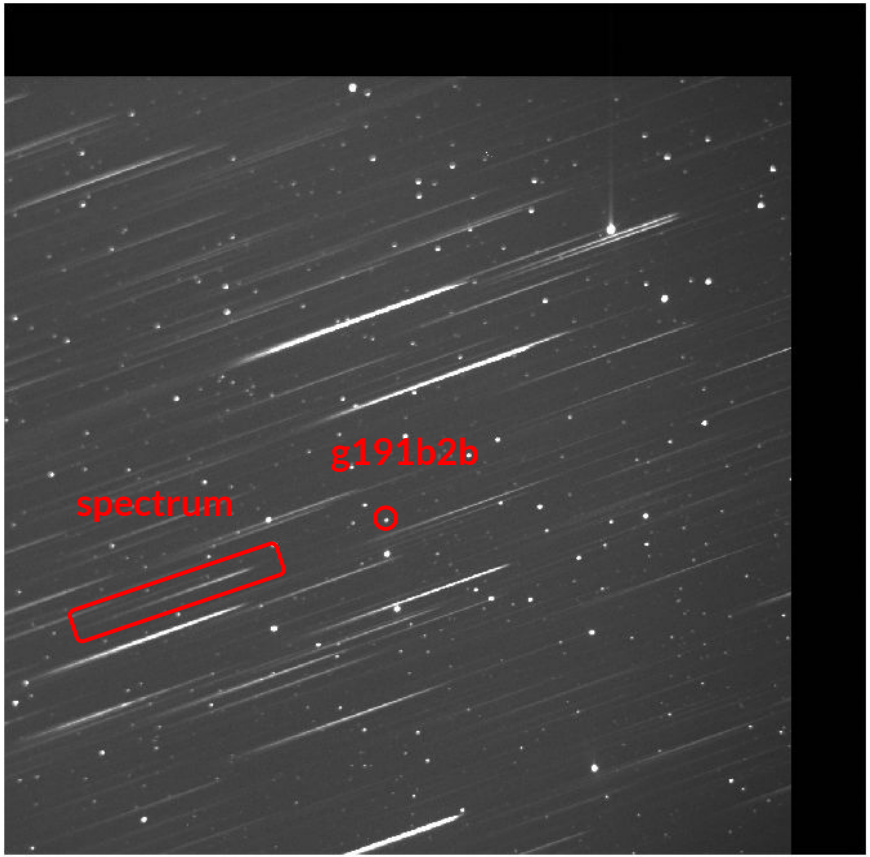
6 observation nights with StarDICE telescope : **~300 images per filter + grating** every night

⇒ **Preliminary results from photometric and spectrophotometric analysis**

II. Spectrum extraction

Spectrum of “g191b2b”

Image of g191b2b observed by StarDICE with the grating in the filterwheel

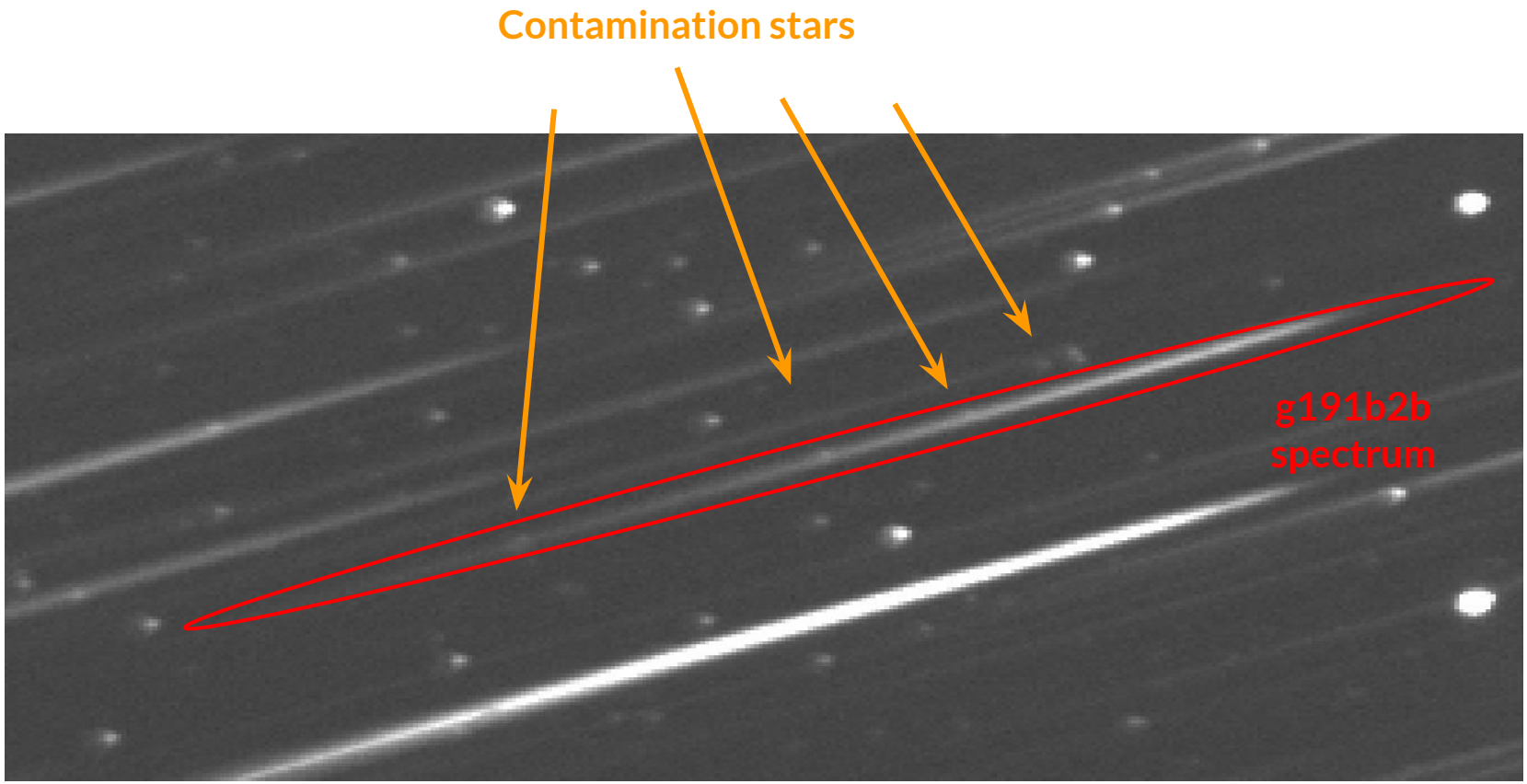


<u>Goal</u> : Extract spectra of the 3 prime standards of the CALSPEC calibration such as **g191b2b** :

- $m_{g191b2b} = 11.69$
- Light is dispersed by the grating (blazed ⇒ maximum flux in 1st order)
- Very crowded field

⇒ Extract the spectrum with **Spectractor package**

Spectrum of “g191b2b”



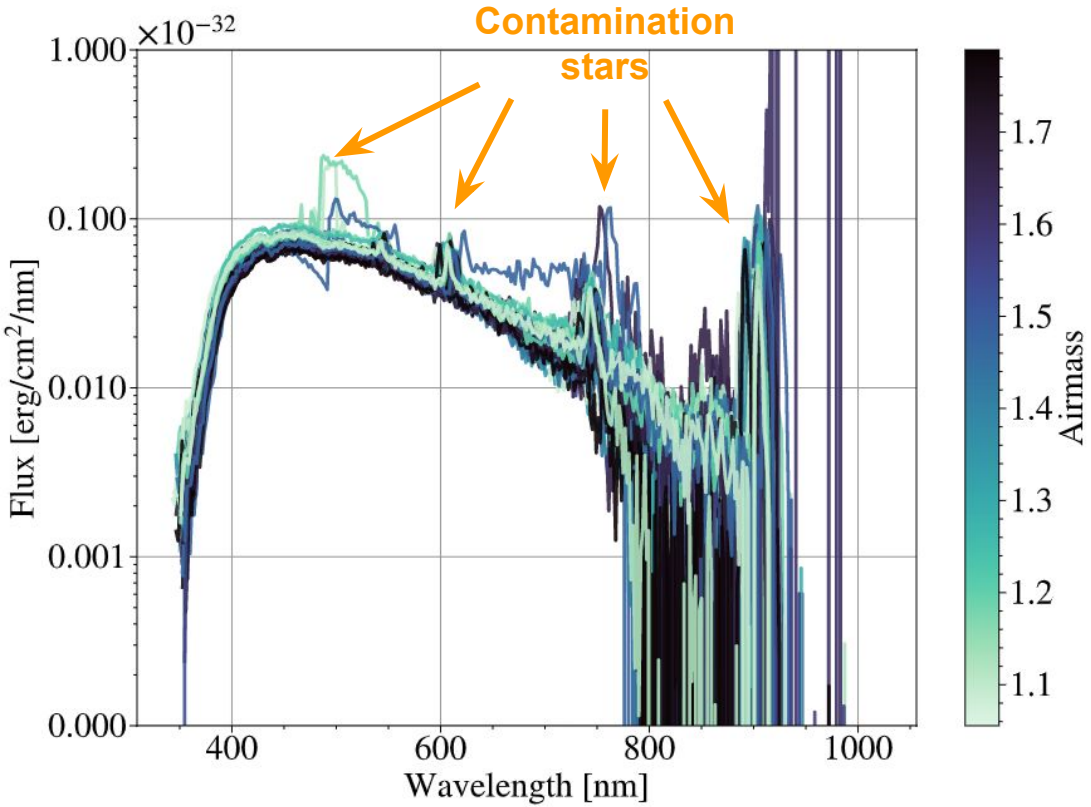
Spectrum of “g191b2b”

Spectra extracted from 105 images with the grating at different airmasses

There are stars in the axis of dispersion
⇒ The fit crash

1) Work in progress on full-forward model of the field

2) Alternative scenario : visit of a bright and isolated star

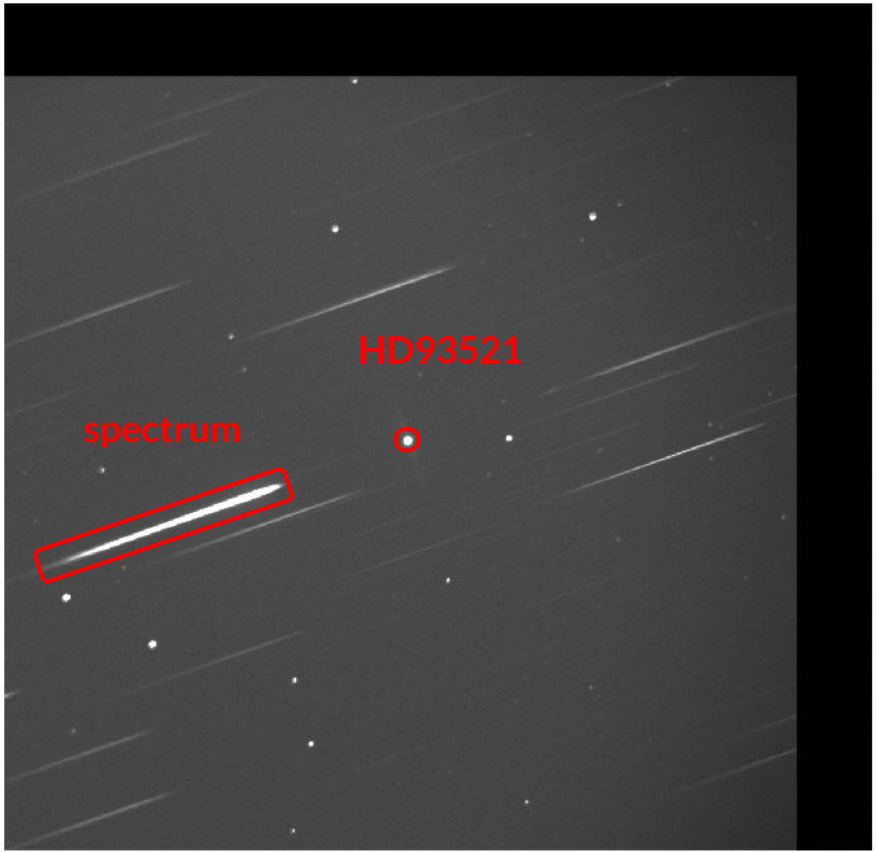


Spectrum for “HD93521”

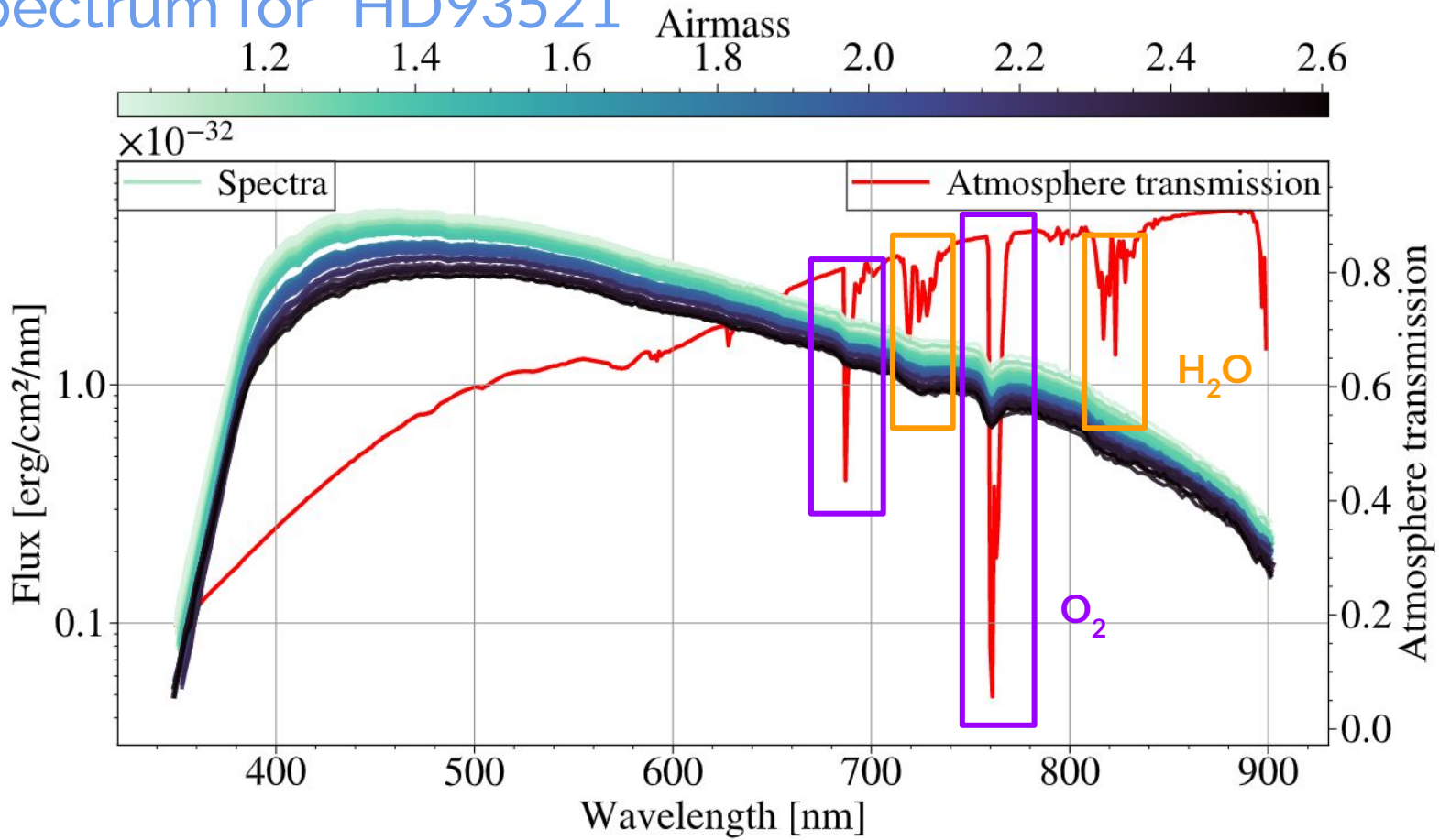
StarDICE image of HD93521 :

- $m_{HD93521} = 6.99$
- Part of CALSPEC calibration
- Isolated field
- Light is dispersed by the grating (blazed ⇒ dispersed at 1st order)

Image of HD93521 observed by StarDICE with the grating in the filterwheel



Spectrum for “HD93521”



⇒ **Fit the atmosphere transmission thanks to airmass regression**

III. Preliminary photometry analysis

Theoretical flux formula

$$F_{\mathrm{SD}} = \int_{\lambda} S_{\star}(\lambda) \times R_{\mathrm{SD}}(\lambda) \times T_{\mathrm{atm}}(\lambda) \times t_{\mathrm{exp,SD}} \times A_{\mathrm{mirror,SD}} \times \frac{\lambda d\lambda}{hc}$$

Star SED

Atmosphere transmission

StarDICE collection surface

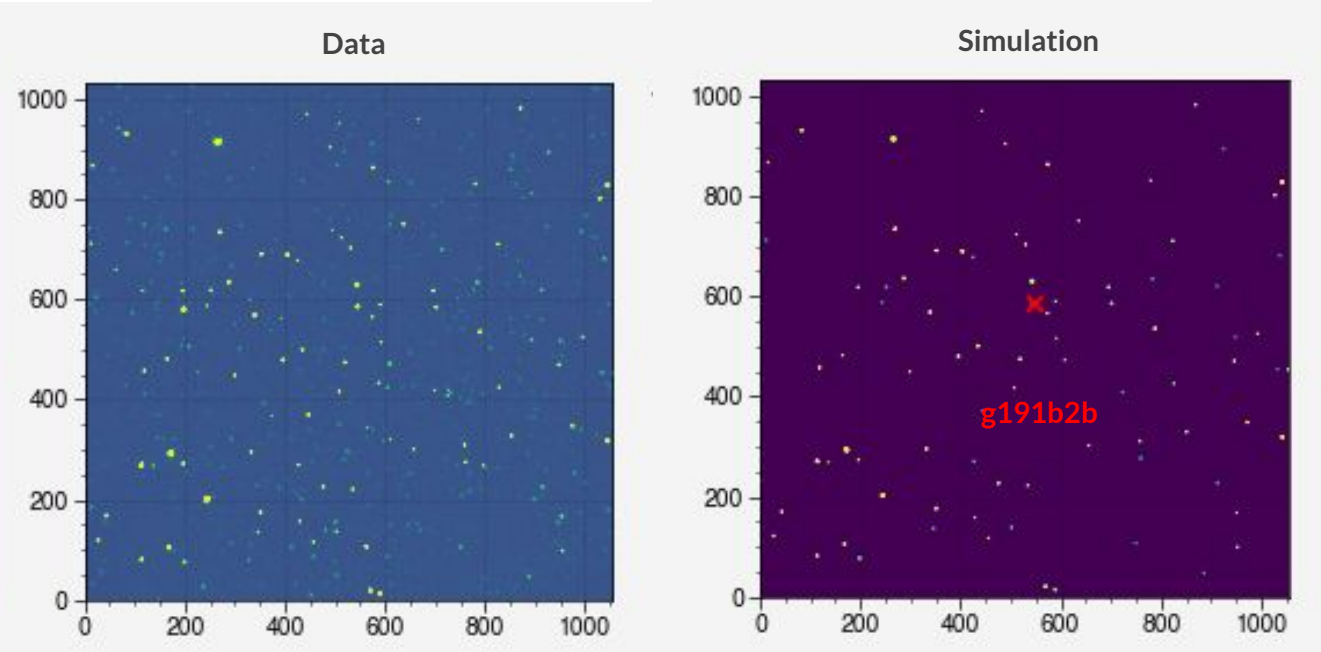
StarDICE flux

StarDICE telescope response

Exposition time

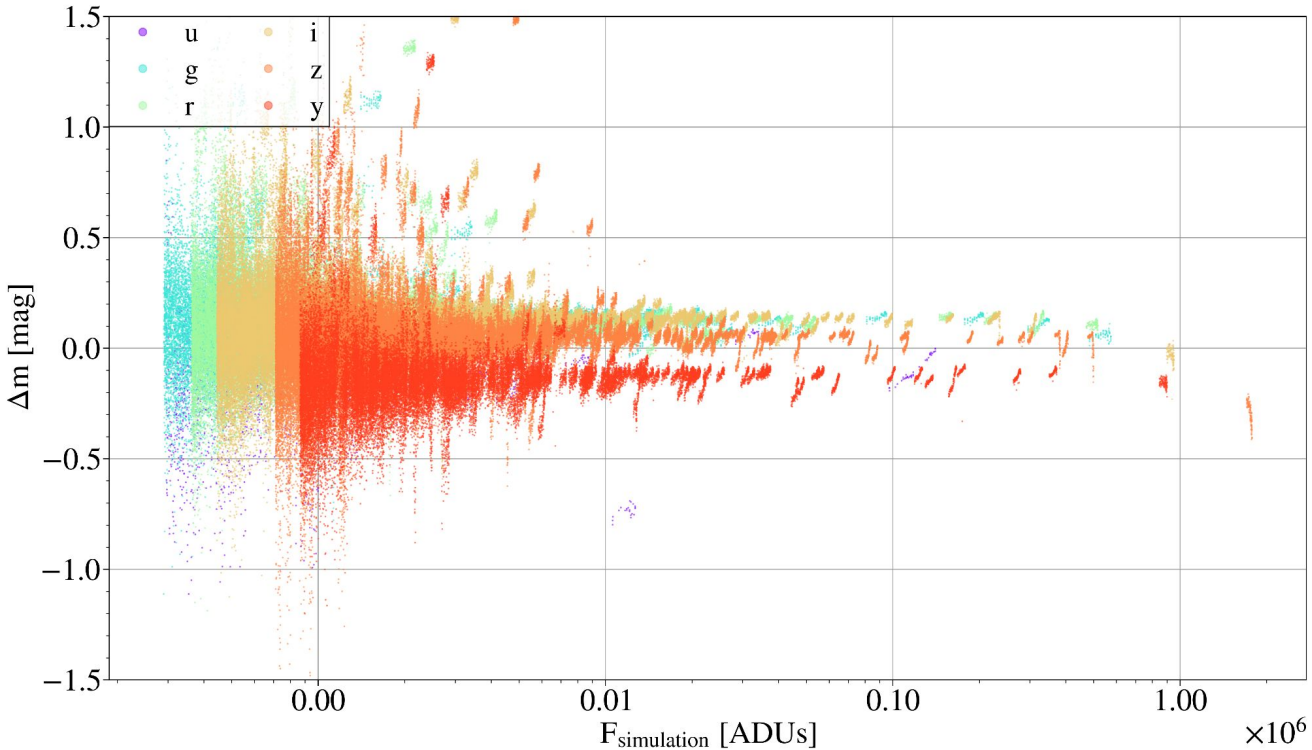
Field simulation for “g191b2b”

Simulate the flux and positions of stars in the StarDICE field with GAIA catalog



$$\Delta m = m_{\text{photometry}} - m_{\text{simulation}} = -2.5 \times \log_{10}\left(\frac{F_{\text{photometry}}}{F_{\text{simulation}}}\right)$$

Difference data - model in magnitude

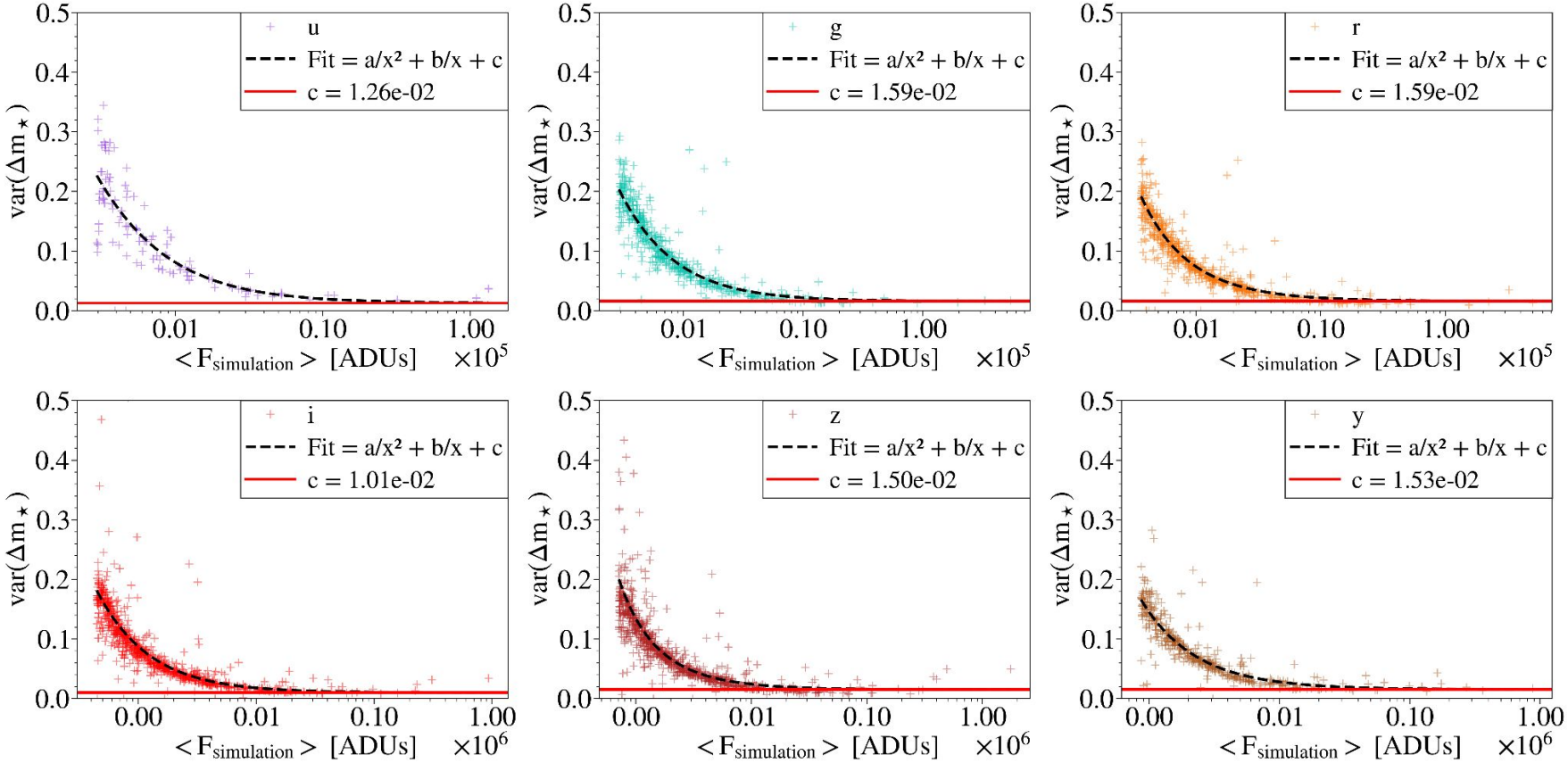


- 1 point ⇔ 1 star observation
- 115 images per band
- 6 bands (ugrizy)
- 1000 - 1500 stars detected for each filters

⇒ We expect the curves to be horizontal and around 0

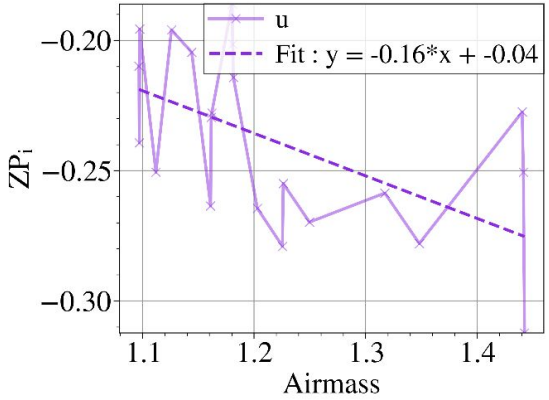
Modelisation of $var(\Delta m_\star)$

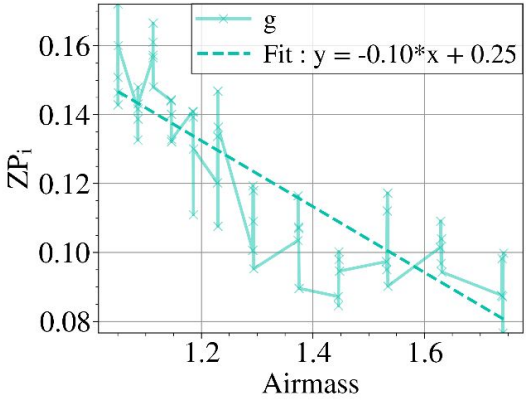
$$var(\Delta m_\star) = var(< \Delta m >_\star)$$

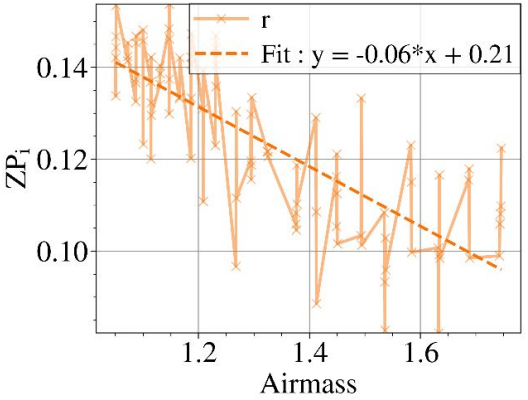


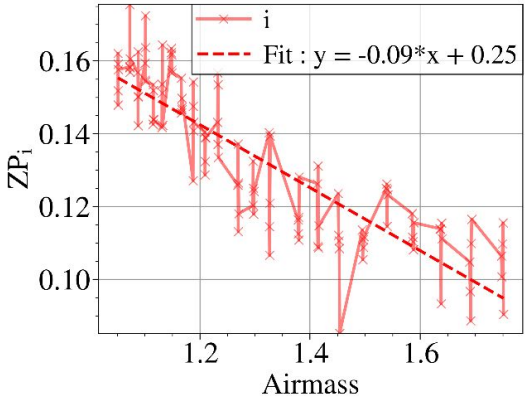
Zero point for each filter

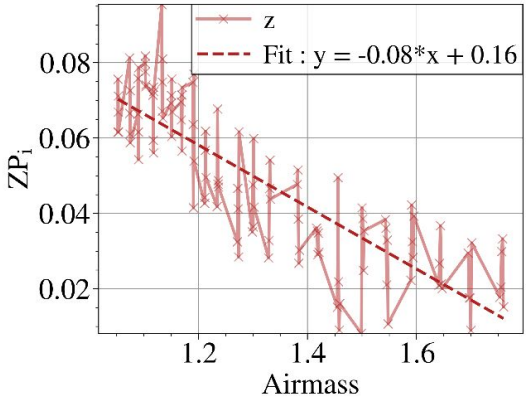
$$ZP_i = < \Delta m >_{image} = K \times airmass + ZP_{\text{filter}}$$

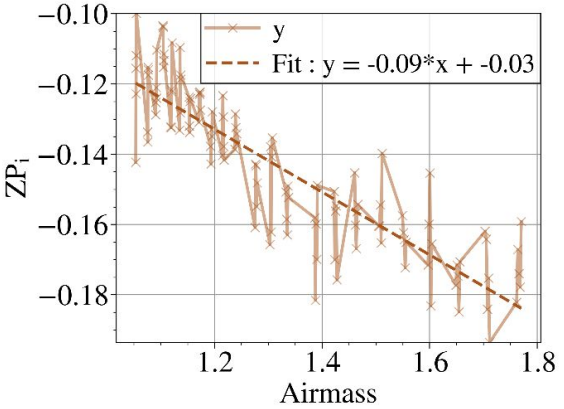






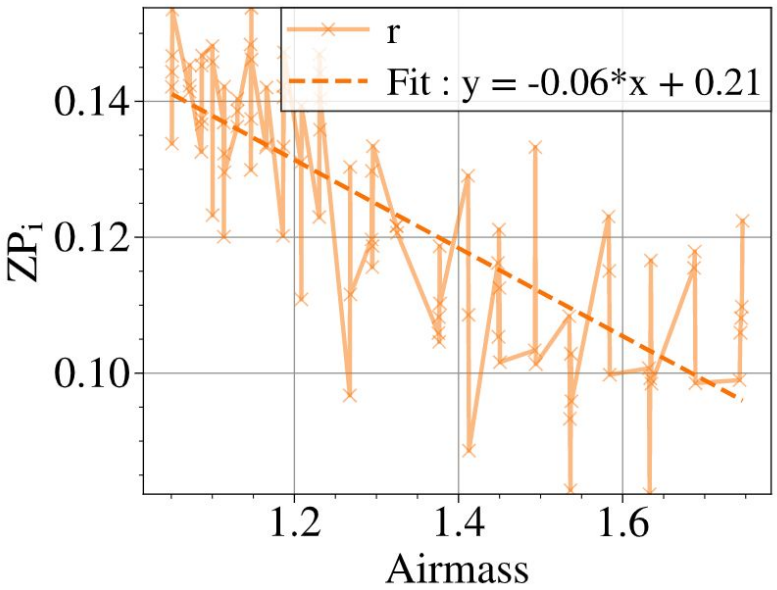






Zero point for each filter

$$ZP_i = K \times airmass + ZP_{\text{filter}}$$



- K corresponds to extinction during the night
- ZP_{filter} corresponds to the zero point for a given filter

⇒ For each filter we want **$\sigma(ZP_{filter}) = 0.1\%$**, we measure **$\sigma(ZP_{filter})_{night}$** for one night and infer the number of nights **N_{night}** needed to reach this goal with :

$$\sigma(ZP) = \frac{\sigma(ZP)_{\text{night}}}{\sqrt{N_{\text{night}}}} \leq 0.001$$

Zero point for each filter

$$\sigma(ZP) = \frac{\sigma(ZP)_{\mathrm{night}}}{\sqrt{N_{\mathrm{night}}}} \leq 0.001$$

Filter	u	g	r	i	z	y
$\sigma(ZP)_{\mathrm{night}}$	0.0687	0.0106	0.0075	0.0064	0.0067	0.0063
N_{night}	4724	114	57	41	46	40

Conclusion

Spectrophotometry

- Difficulties to extract spectrums of low intensity stars in crowded field such as **g191b2b**

⇒ Simulate a full-forward model of the field to deal with the contamination stars

⇒ Observe bright stars to fit the **atmosphere transmission**

Photometry

- The goal is to reach an uncertainty of **0.1%** over the **zero point** for each **filter**

⇒ First analysis on one night observation estimate the needed number of night around $\mathbf{N_{night}}$**=100** for filters **"grizy"**

⇒ **"u"** filter lacks of data because of stars undetected, we plan to force the photometry at expected positions to increase the statistics

Thank you
for your attention

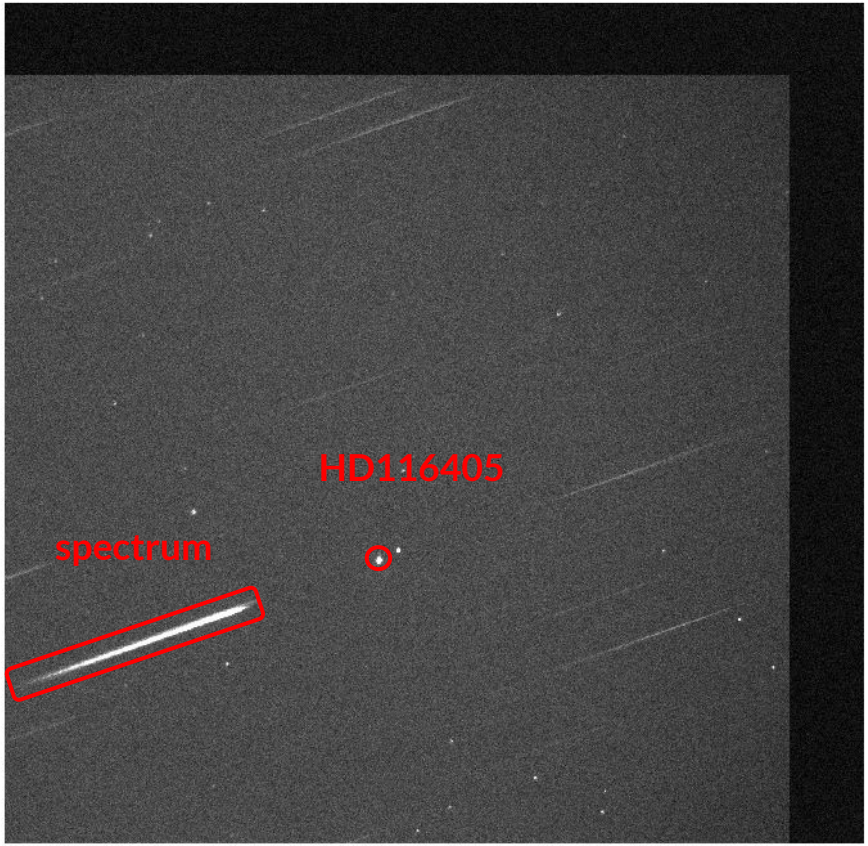
Spectrum of “HD116405”

StarDICE image of HD116405 :

- Part of CALSPEC calibration
- $m_{HD116405}$ = 8.34
- Light is dispersed by the grating (blazed ⇒ focus at 1st order)

⇒ Extract the spectrum with Spectractor

Image of HD116405 observed by StarDICE with the grating in the filterwheel



Variance modelization

Gain

$$\frac{var(\phi)}{F^2} = \frac{1}{F^2}\left[\frac{B}{G^2} + var(b_{RO})\right] + \frac{1}{FG^2} + var(\alpha)$$

Readout noise and background

Inhomogeneities of the focal plane

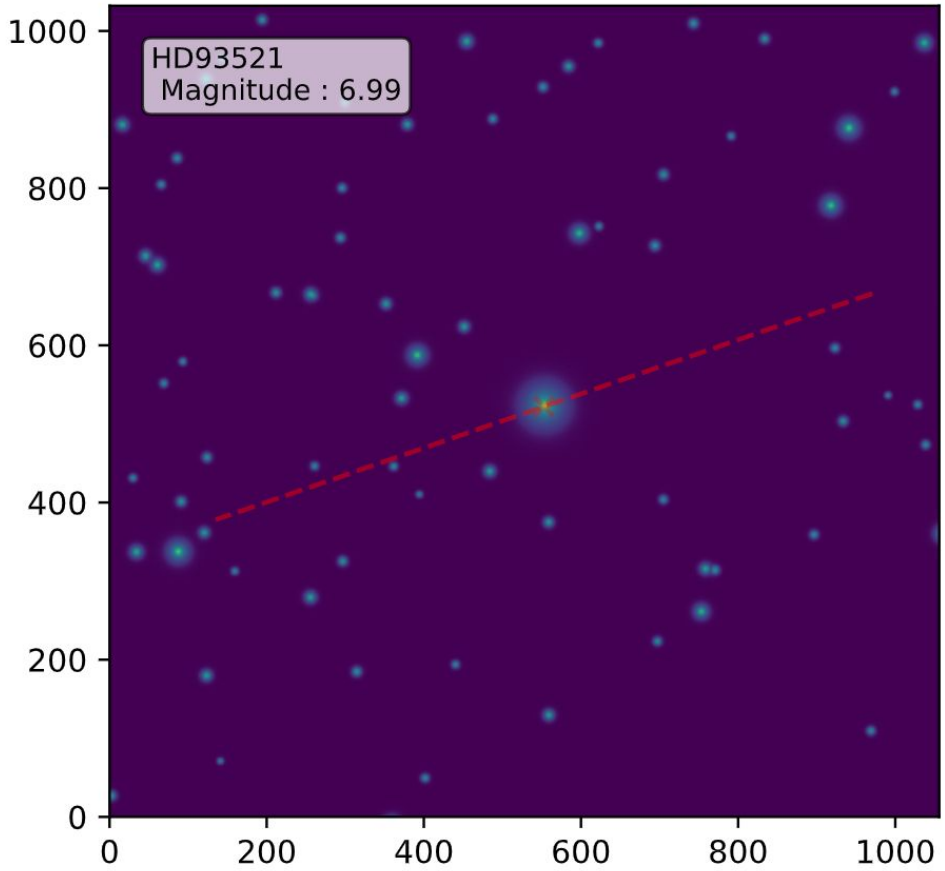
Find a good candidate

Simulate field for different stars :

- Part of CALSPEC calibration
- Magnitude < 10 to have a good signal
- Not crowded field with no stars on the axis of dispersion

⇒ HD93521

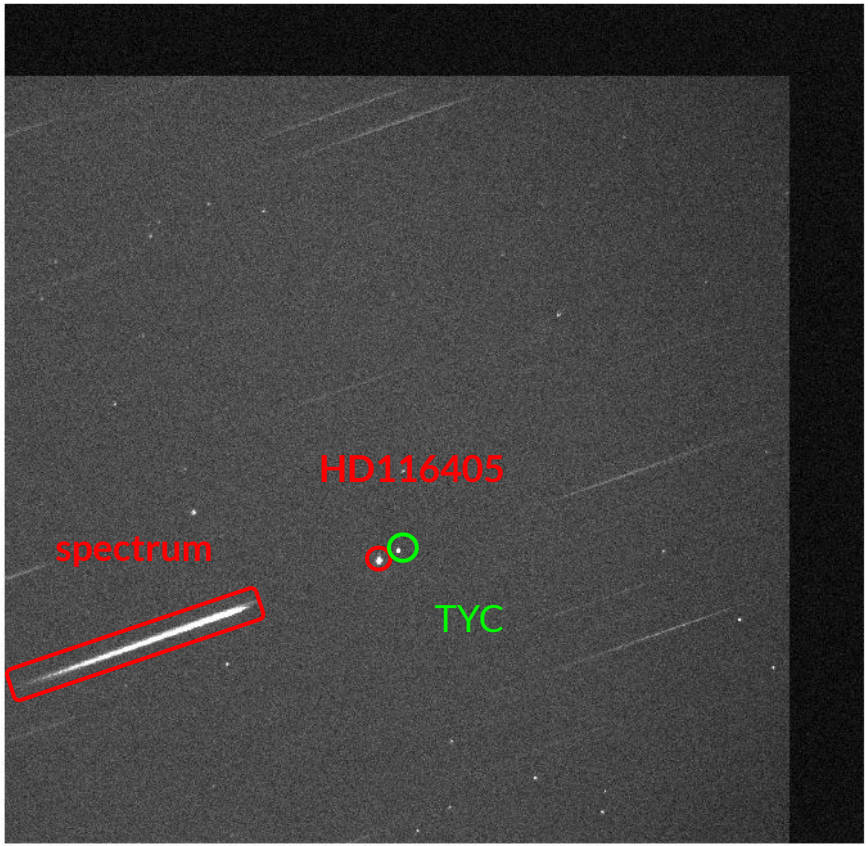
Simulation of HD93521 field observed by StarDICE



Little friend of “HD116405”

TYC 3031-988-1 → little friend

mag = 11.1



Spectrum of “HD116405”

Spectra extracted from 77 images with the grating at different airmasses