



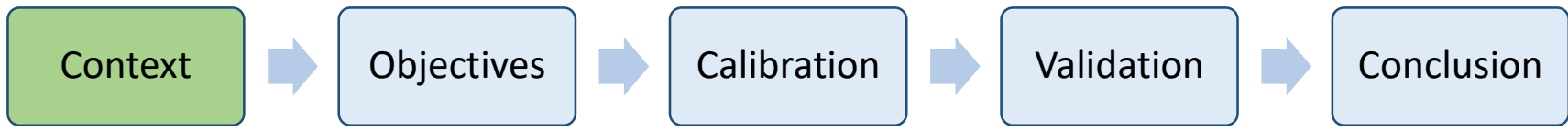
# Prediction of milk mid-infrared spectrum using mixed test-day models

P. Delhez<sup>1,2</sup>, S. Vanderick<sup>2</sup>, F. Colinet<sup>2</sup>, N. Gengler<sup>2</sup> and H. Soyeurt<sup>2</sup>

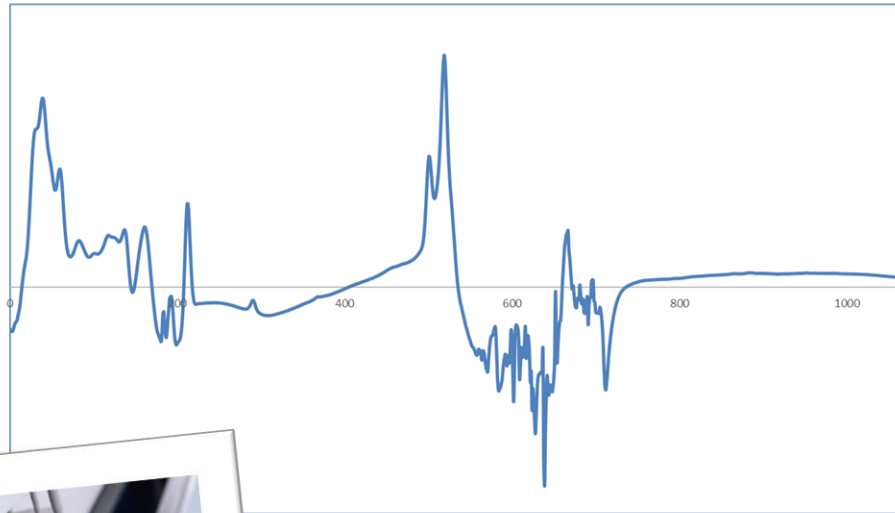
*<sup>1</sup>F.R.S-FNRS, 1000 Brussels, Belgium*

*<sup>2</sup>ULiege-GxABT, 5030 Gembloux, Belgium*

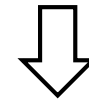




## Mid-infrared (MIR) spectroscopy



- ✓ Fine milk composition
- ✓ Fast and cost-effective



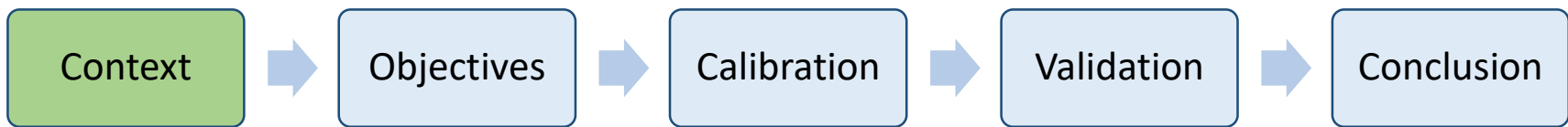
Milk recording



**FOSS**  
spectrometer

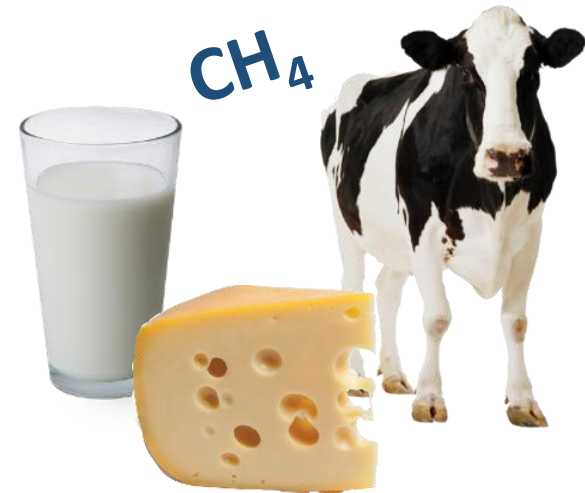


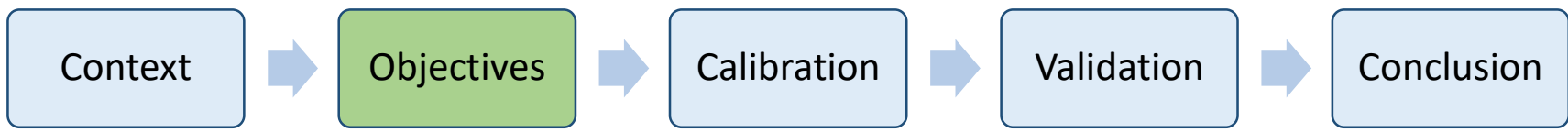
- 1060 spectral points
- Wavelengths 900-5000  $\text{cm}^{-1}$



## MIR spectroscopy

- ✓ More than 150 traits predicted or still studied:
  - milk quality
  - milk technological properties
  - environmental impact
  - status of cow
  - ...



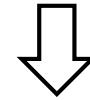


## Predicting milk MIR spectra using test-day mixed models

↪ Predicting **new/expected/future** spectra



Predicting traits using calibration equations

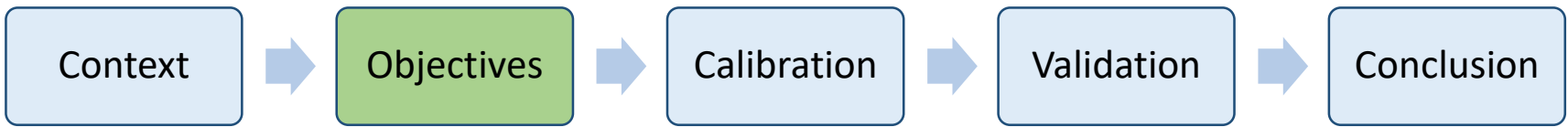


- ✓ Herd management (e.g. detecting problems, potential of heifers)
- ✓ Simulation (e.g. modifying data, predicting future)

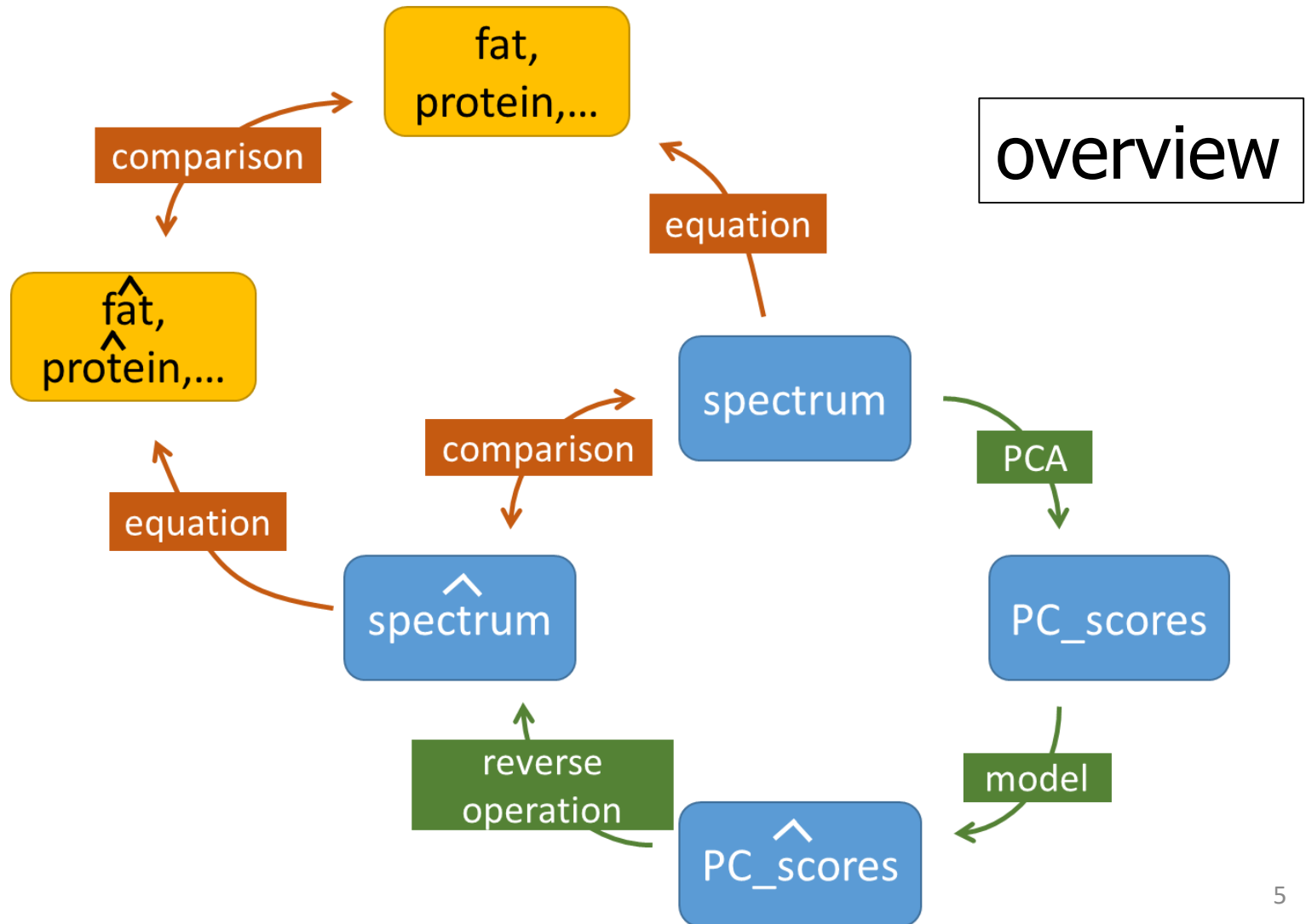


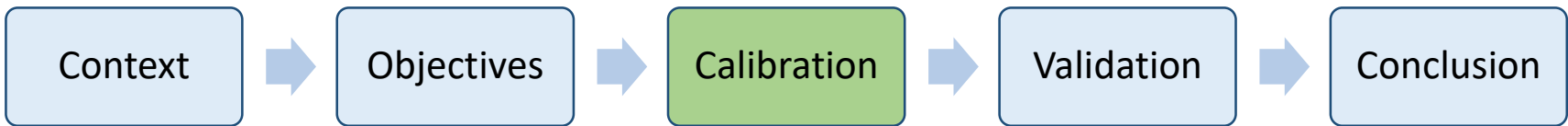
No need to do one model for each trait

**innovation**



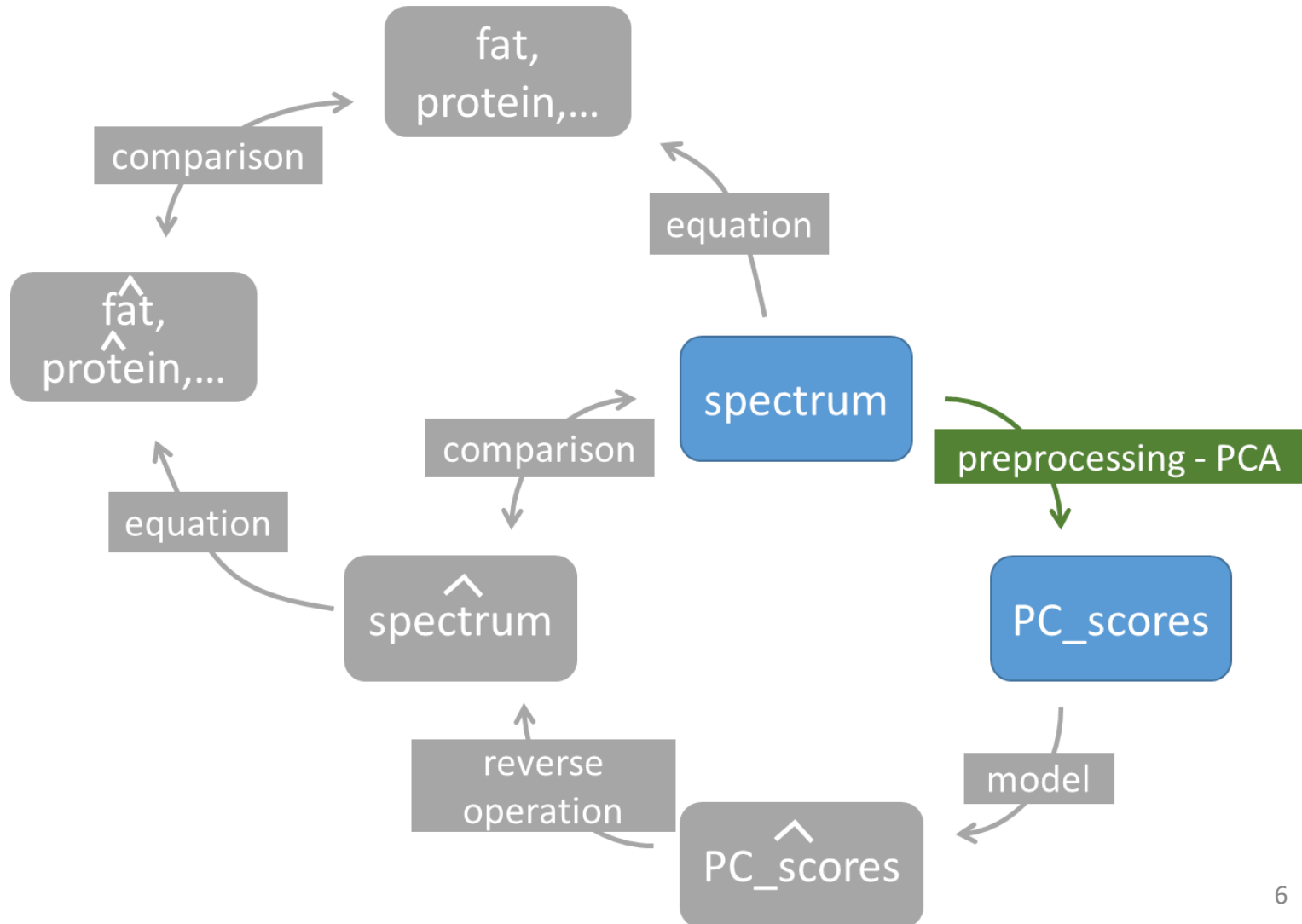
## Predicting milk MIR spectra using test-day mixed models

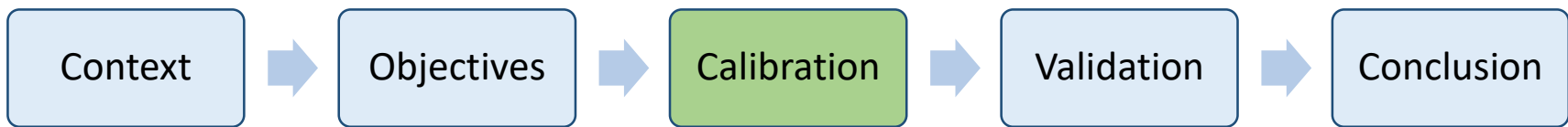




## MIR spectra preprocessing

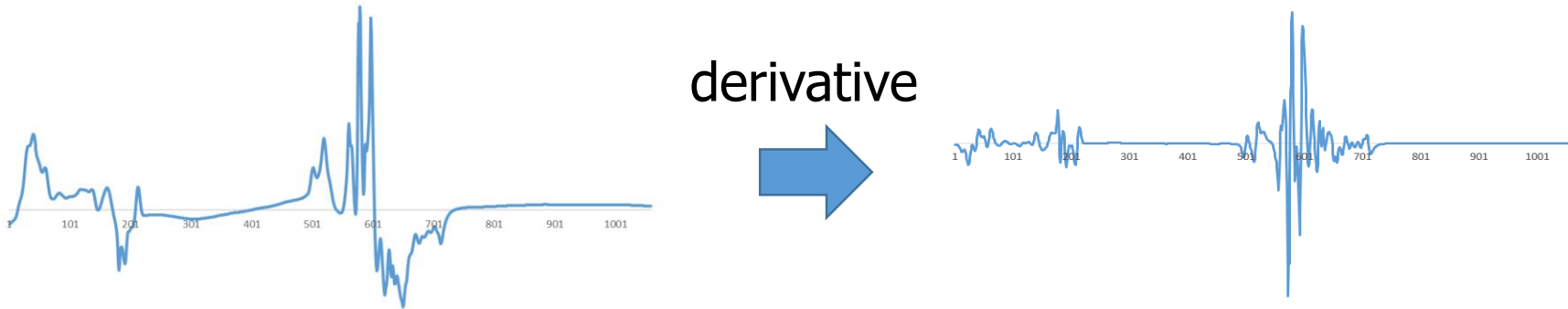
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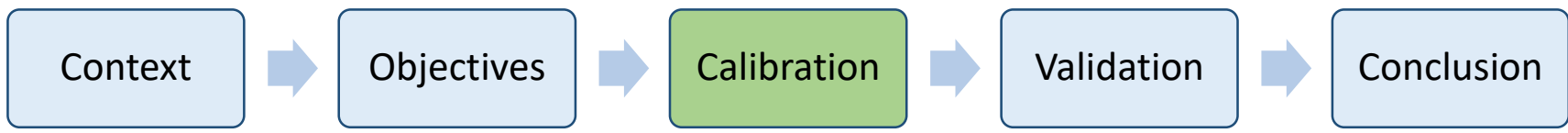


## MIR spectra preprocessing

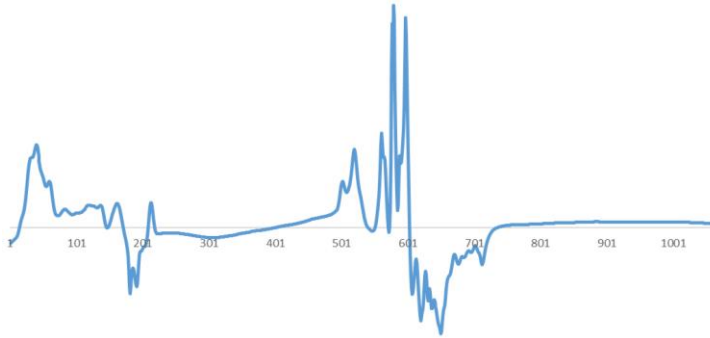
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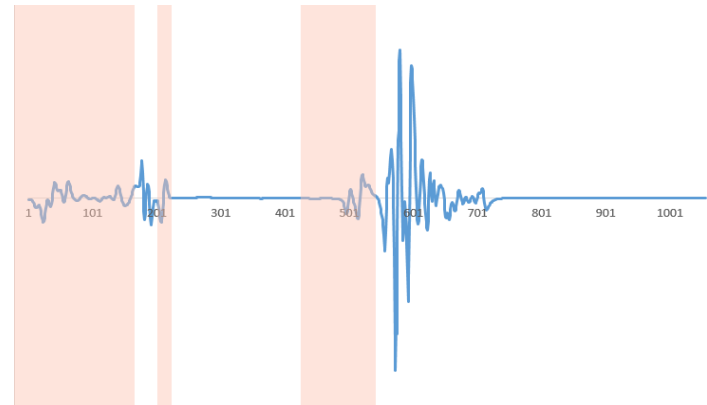
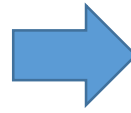
1060 spectral points  
Wavelengths  $900-5000\text{ cm}^{-1}$



## MIR spectra preprocessing



derivative

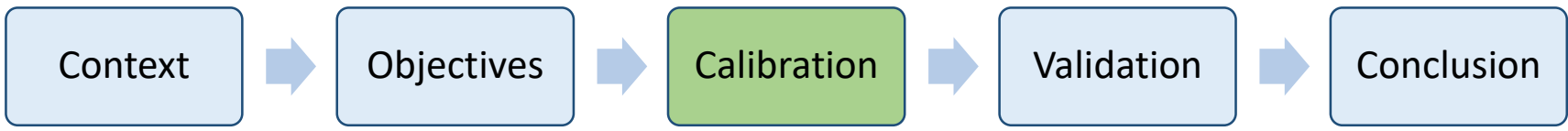


selection of 311 spectral points

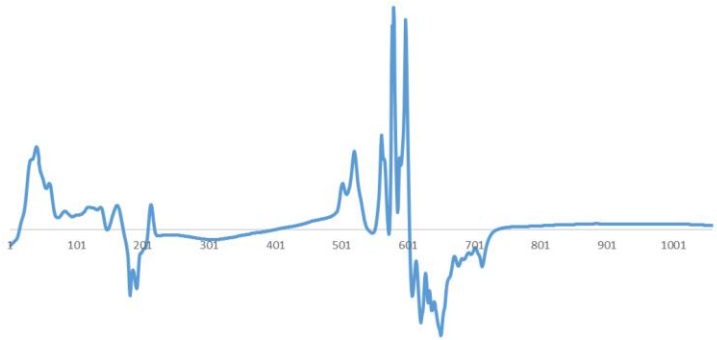
1060 spectral points  
Wavelengths  $900-5000 \text{ cm}^{-1}$



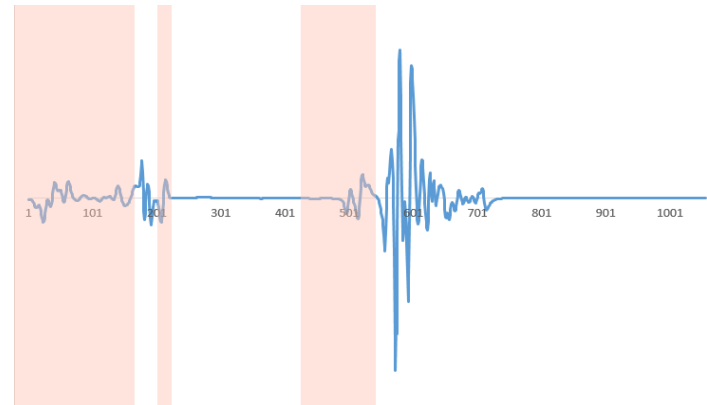
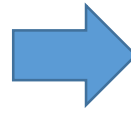




## MIR spectra preprocessing



derivative

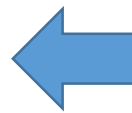


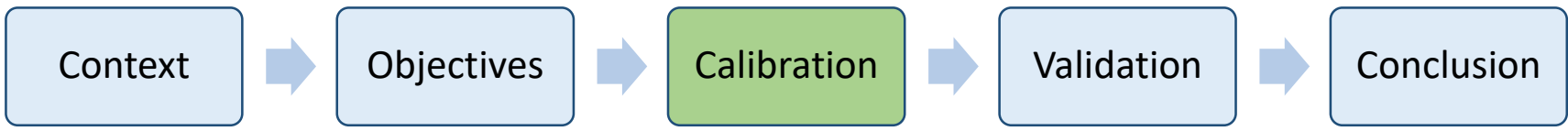
selection of 311 spectral points



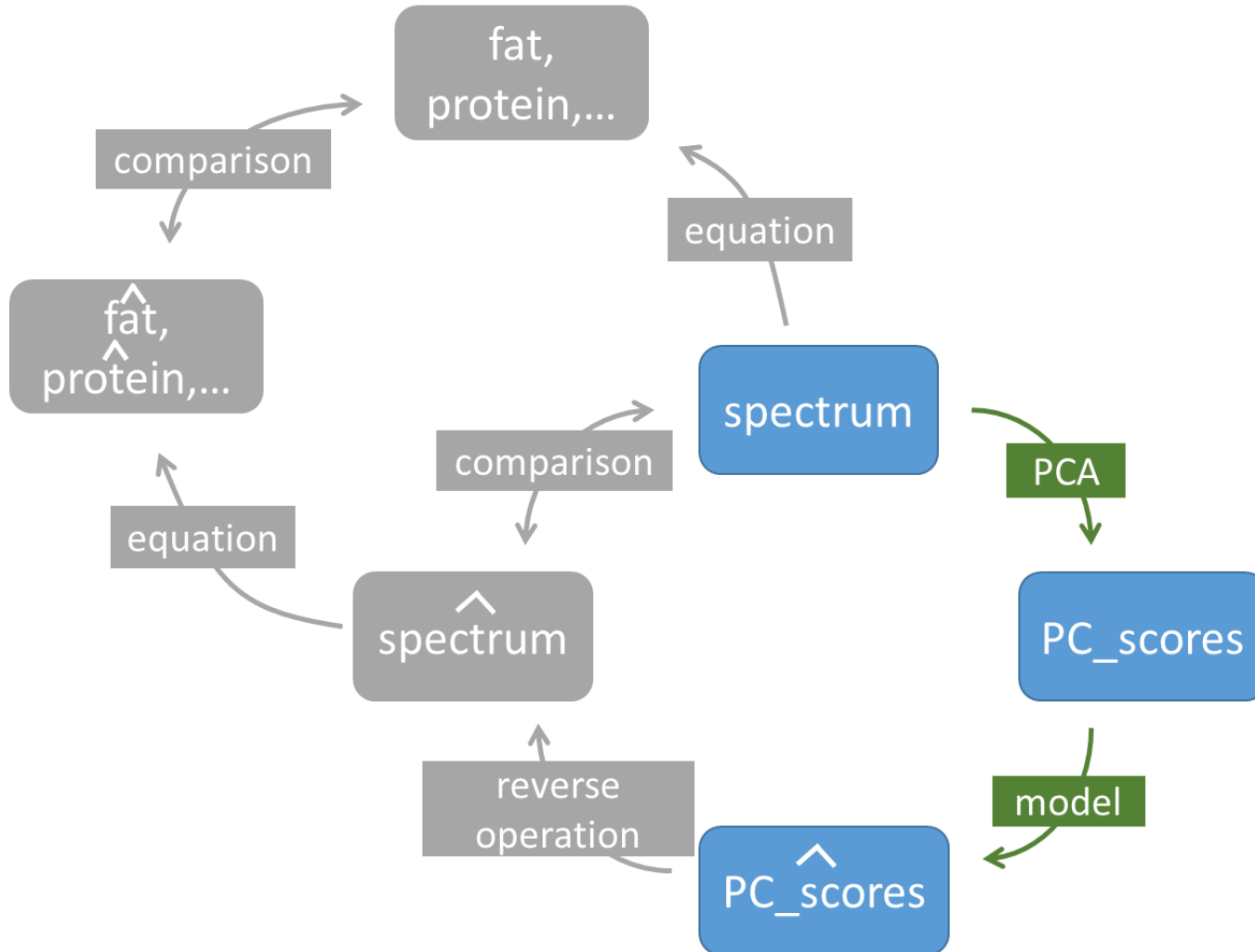
12 PC – 96% of total spectral information

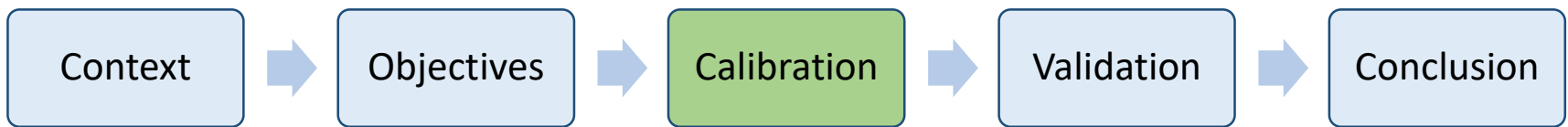
PCA





## Test-day mixed model





## Test-day mixed model



- 467,496 records from 53,781 Holstein cows in 1<sup>st</sup> lactation within 541 herds
- $\geq 5$  records/cow

12 PC  $\Rightarrow$  12 models

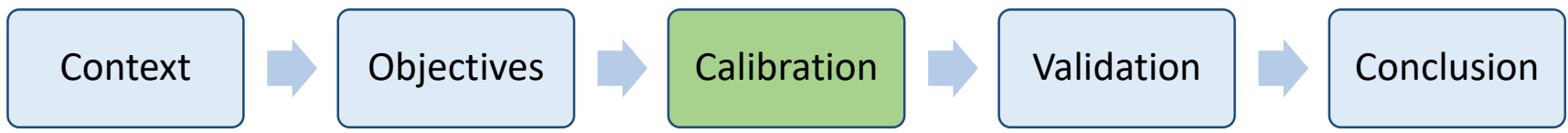
$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$



Fixed effects



Random effects



## Test-day mixed model

- 467,496 records from 53,781 Holstein cows in 1<sup>st</sup> lactation within 541 herds
- $\geq 5$  records/cow

herd-year 

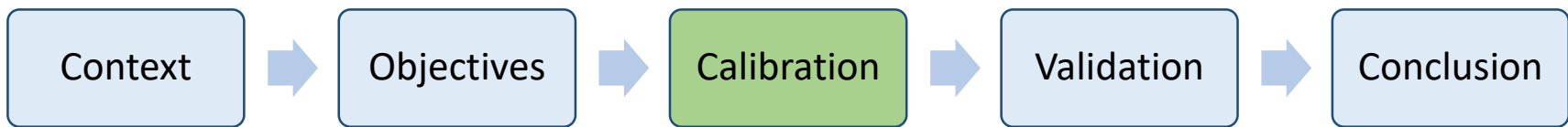
$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$



Fixed effects



Random effects



## Test-day mixed model

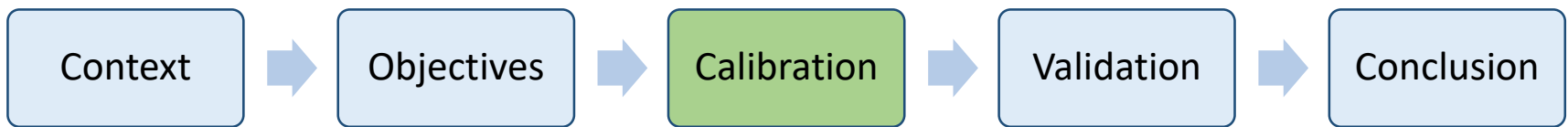
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herd-year  $\nearrow$

herd-month  $\swarrow$

$\underbrace{\hspace{15em}}_{\text{Fixed effects}}$        $\underbrace{\hspace{25em}}_{\text{Random effects}}$



## Test-day mixed model

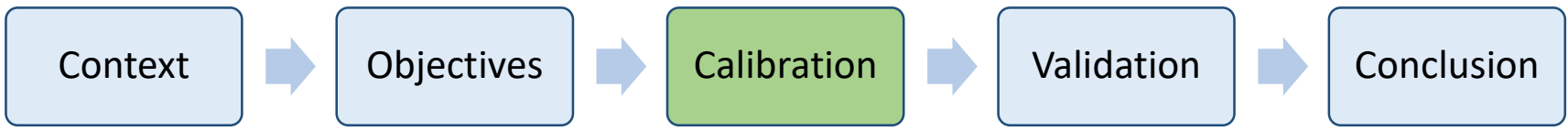
- 467,496 records from 53,781 Holstein cows in 1<sup>st</sup> lactation within 541 herds
- $\geq 5$  records/cow

$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$

herd-year  $\swarrow$       day in milk  $\swarrow$

herd-month  $\swarrow$

$\underbrace{\hspace{15em}}_{\text{Fixed effects}} \quad \underbrace{\hspace{15em}}_{\text{Random effects}}$



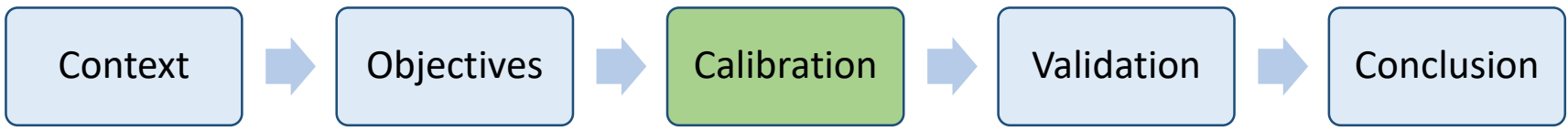
## Test-day mixed model

- 467,496 records from 53,781 Holstein cows in 1<sup>st</sup> lactation within 541 herds
- $\geq 5$  records/cow

$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$

herds-year  $\swarrow$   $\nearrow$  day in milk  
 herds-month  $\swarrow$   $\searrow$  herds-test-day

Fixed effects Random effects



## Test-day mixed model

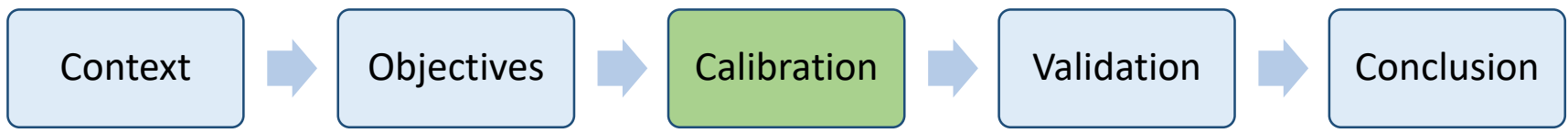
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- $\geq 5$  records/cow

$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$

herd-year  $\swarrow$   $\nearrow$  day in milk  $\swarrow$  permanent environment  $\nearrow$   
 herd-month  $\swarrow$  herd-test-day  $\swarrow$

Fixed effects Random effects





## Test-day mixed model

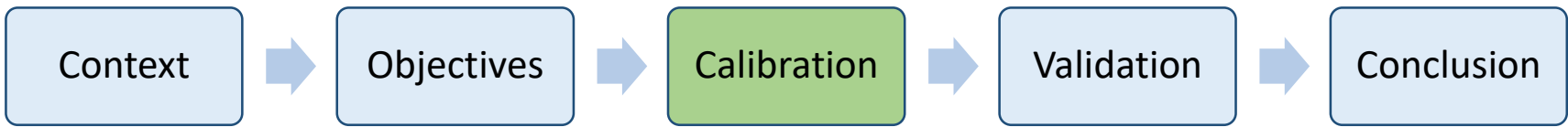
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$$\text{PC\_score} = \text{HY} + \text{HM} + \text{DIM} + \text{HTD} + \text{genetics} + \text{PE} + e$$

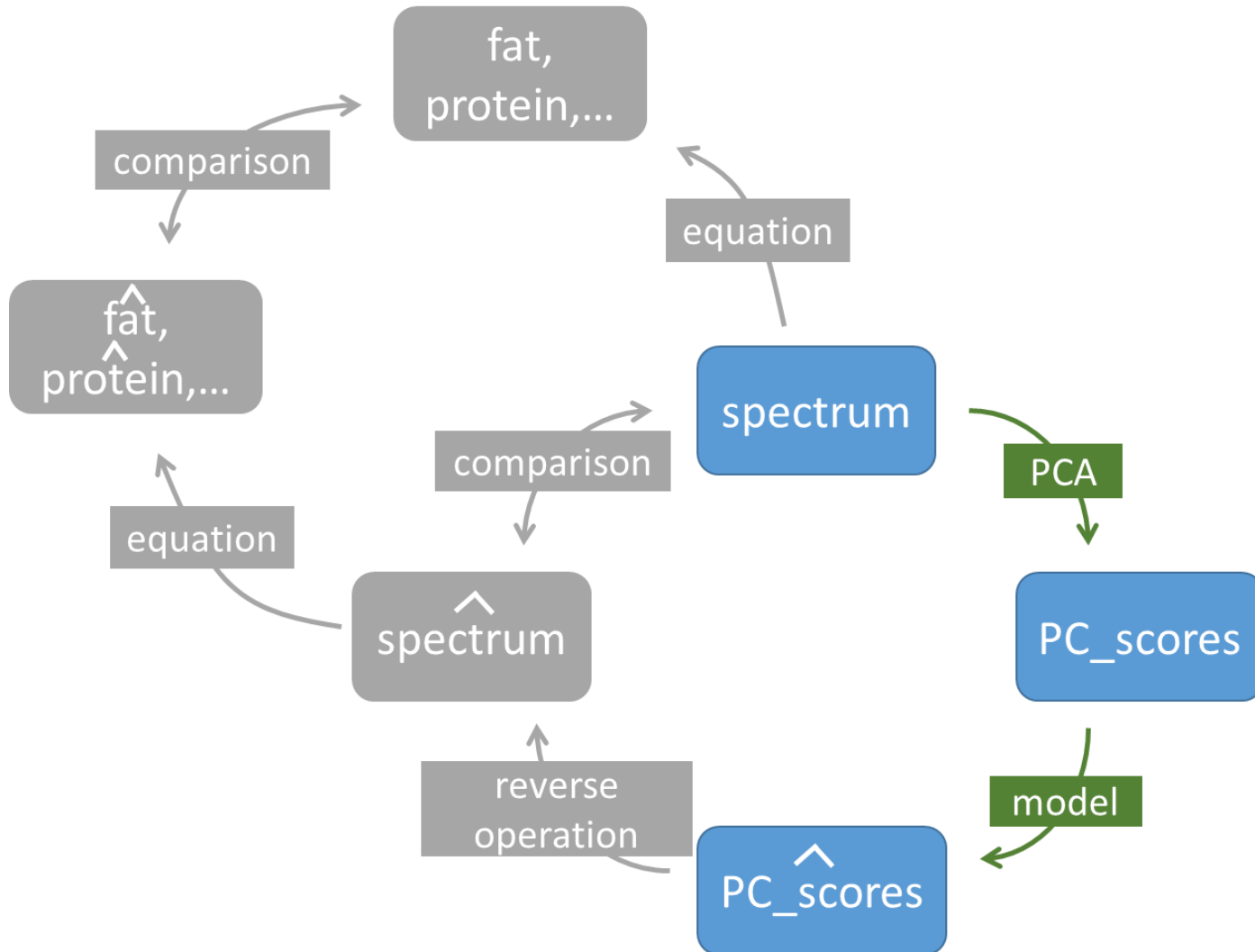
herds-year  $\swarrow$   $\searrow$  day in milk  $\swarrow$  permanent environment  $\swarrow$   
 $\swarrow$   $\searrow$   $\swarrow$   $\searrow$   $\swarrow$   
 herd-month  $\searrow$  herd-test-day  $\swarrow$  residual effect  $\searrow$   
 Fixed effects Random effects

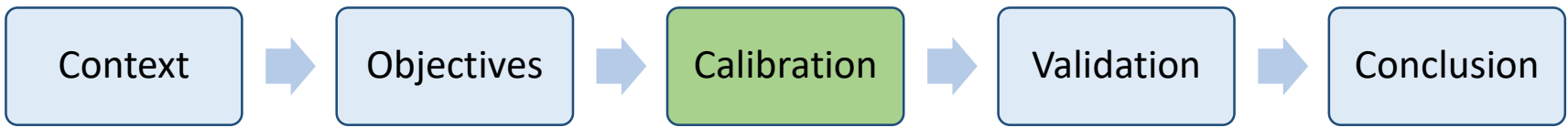
Variance components: REML

$\Rightarrow$  Best Linear Unbiased Prediction (BLUP)

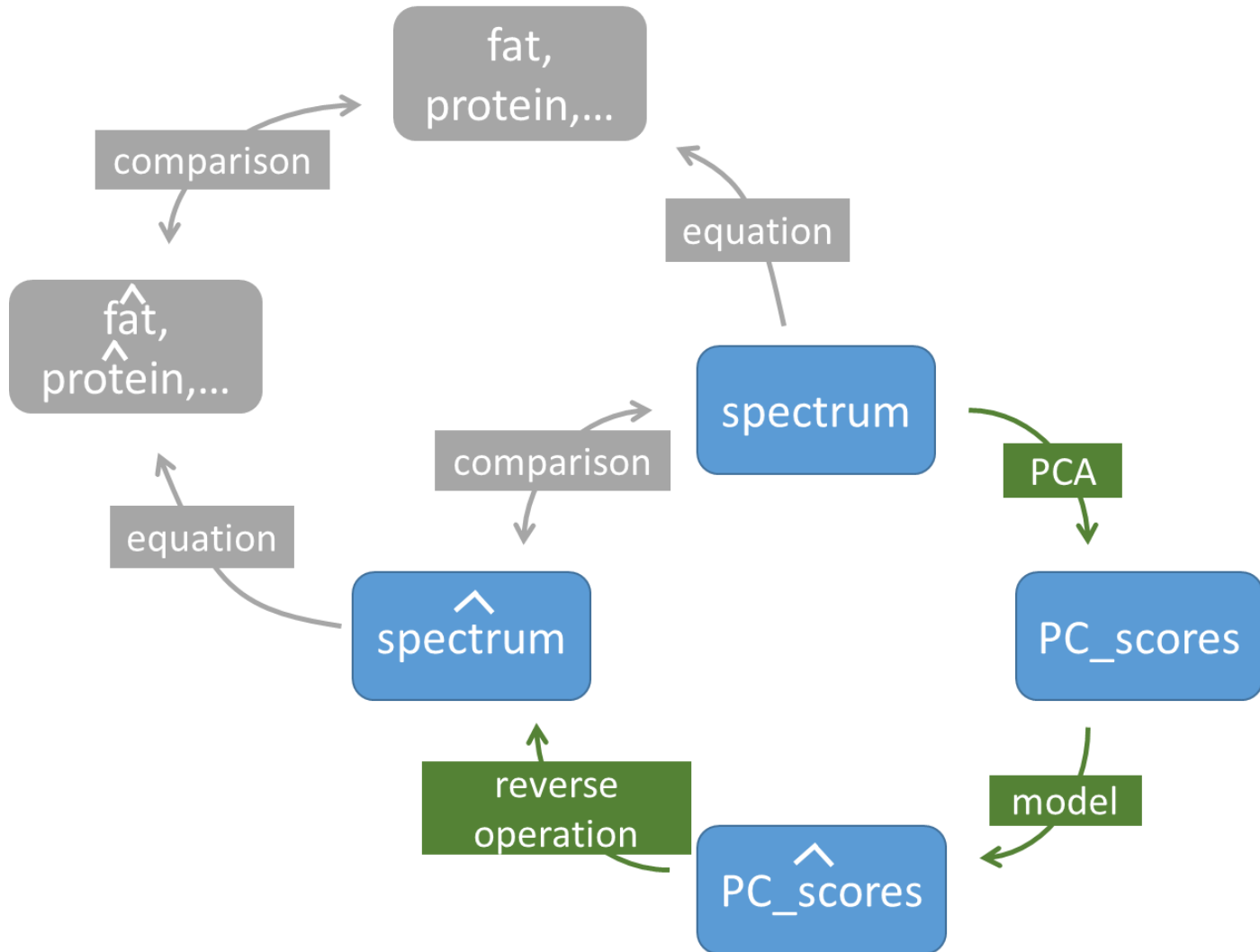


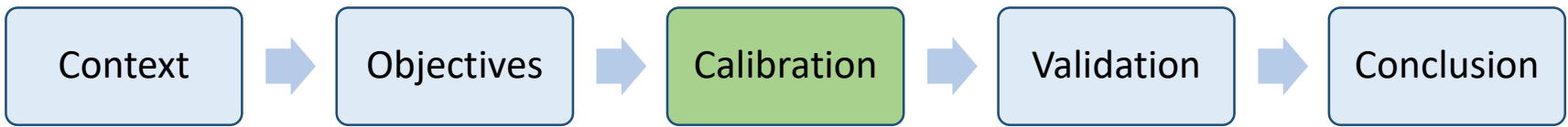
## Computation of spectral points predictions



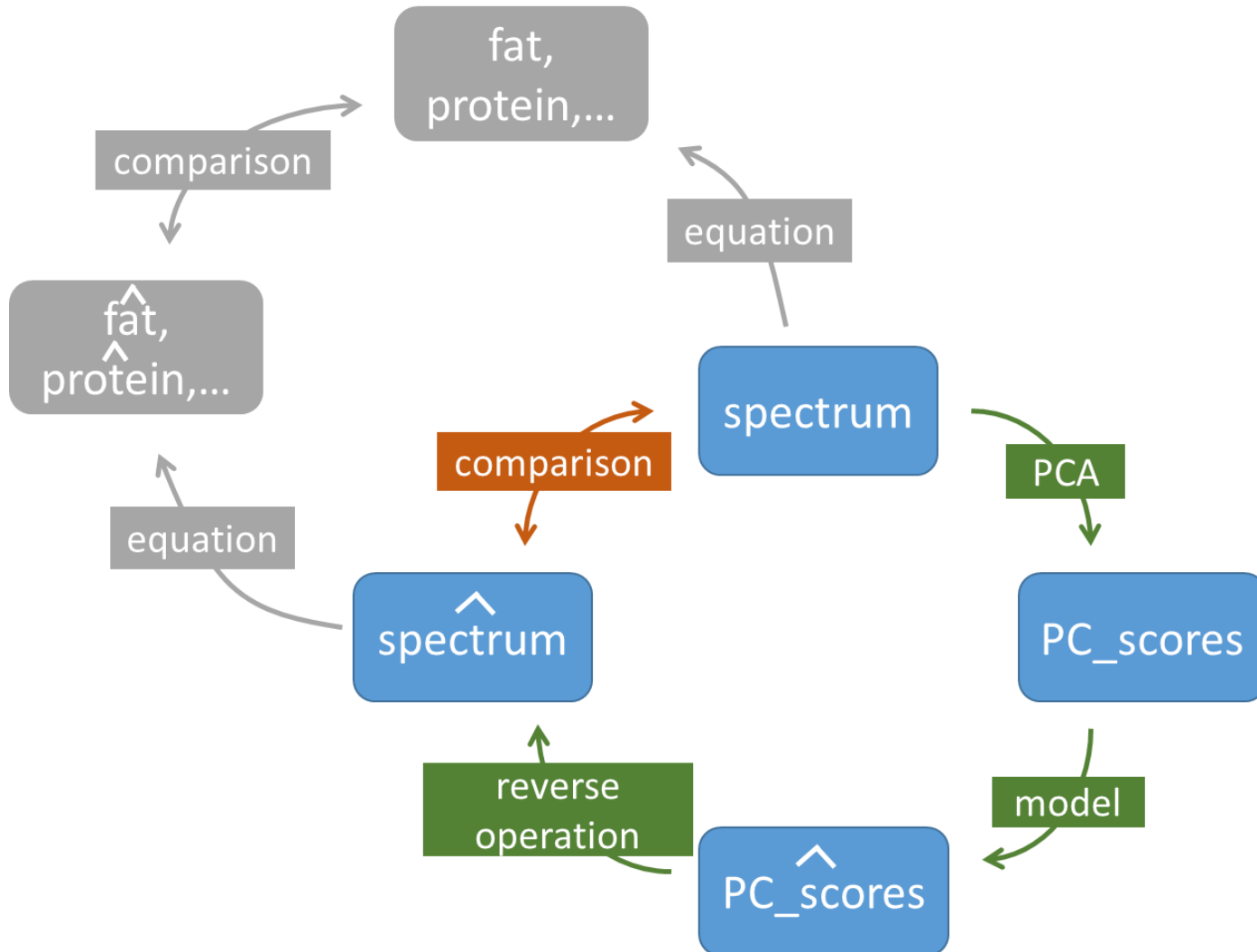


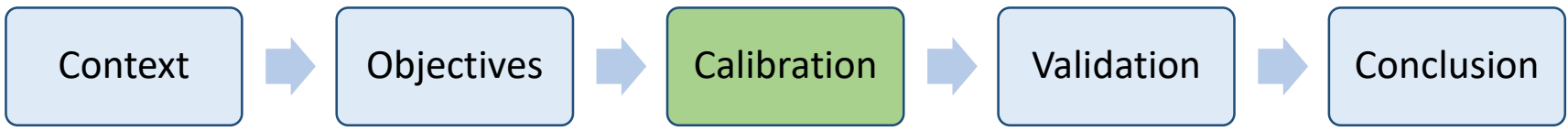
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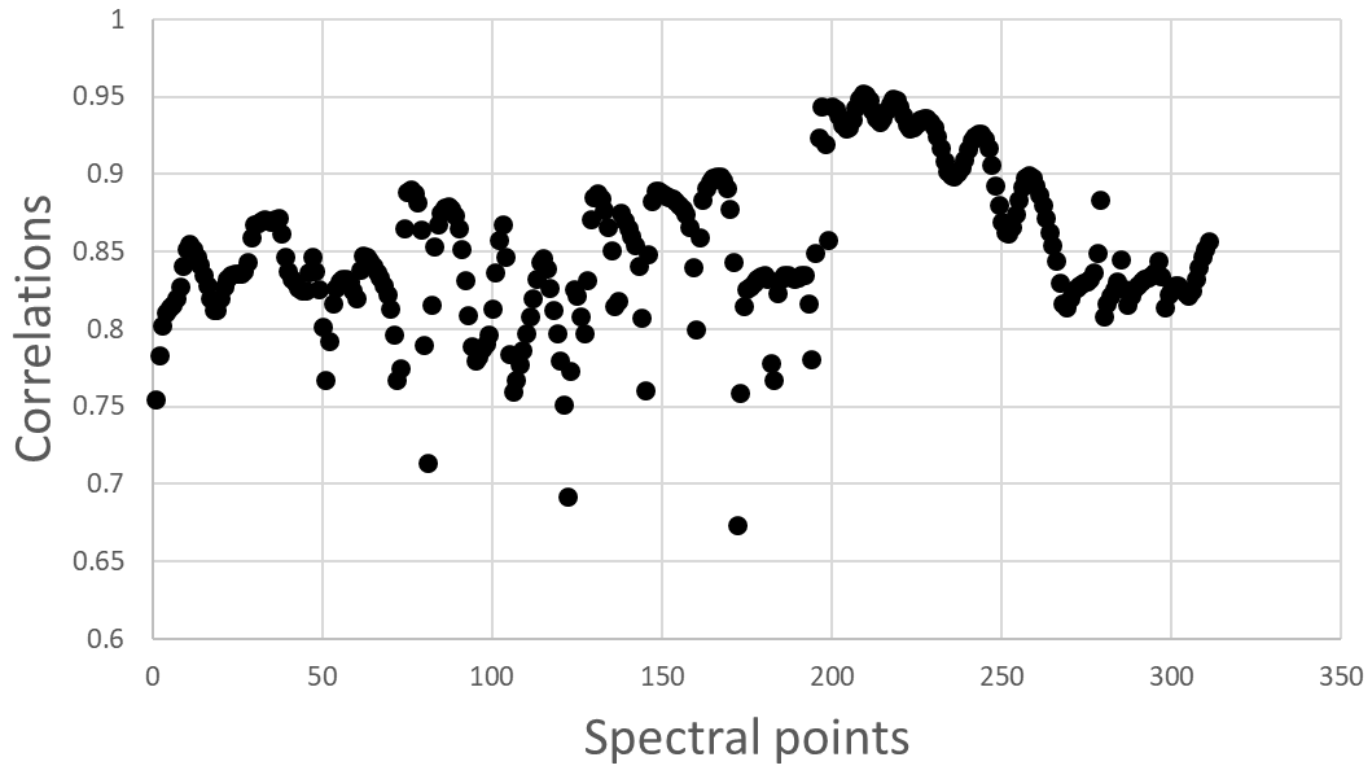


## Computation of spectral points predictions

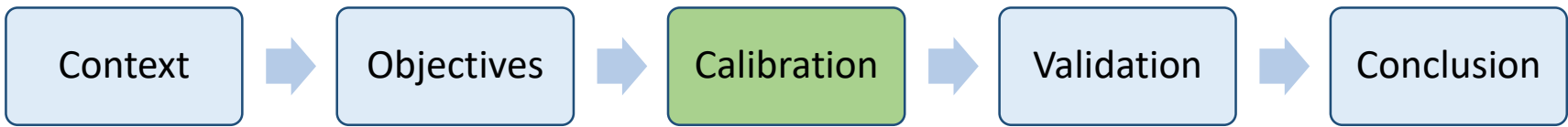




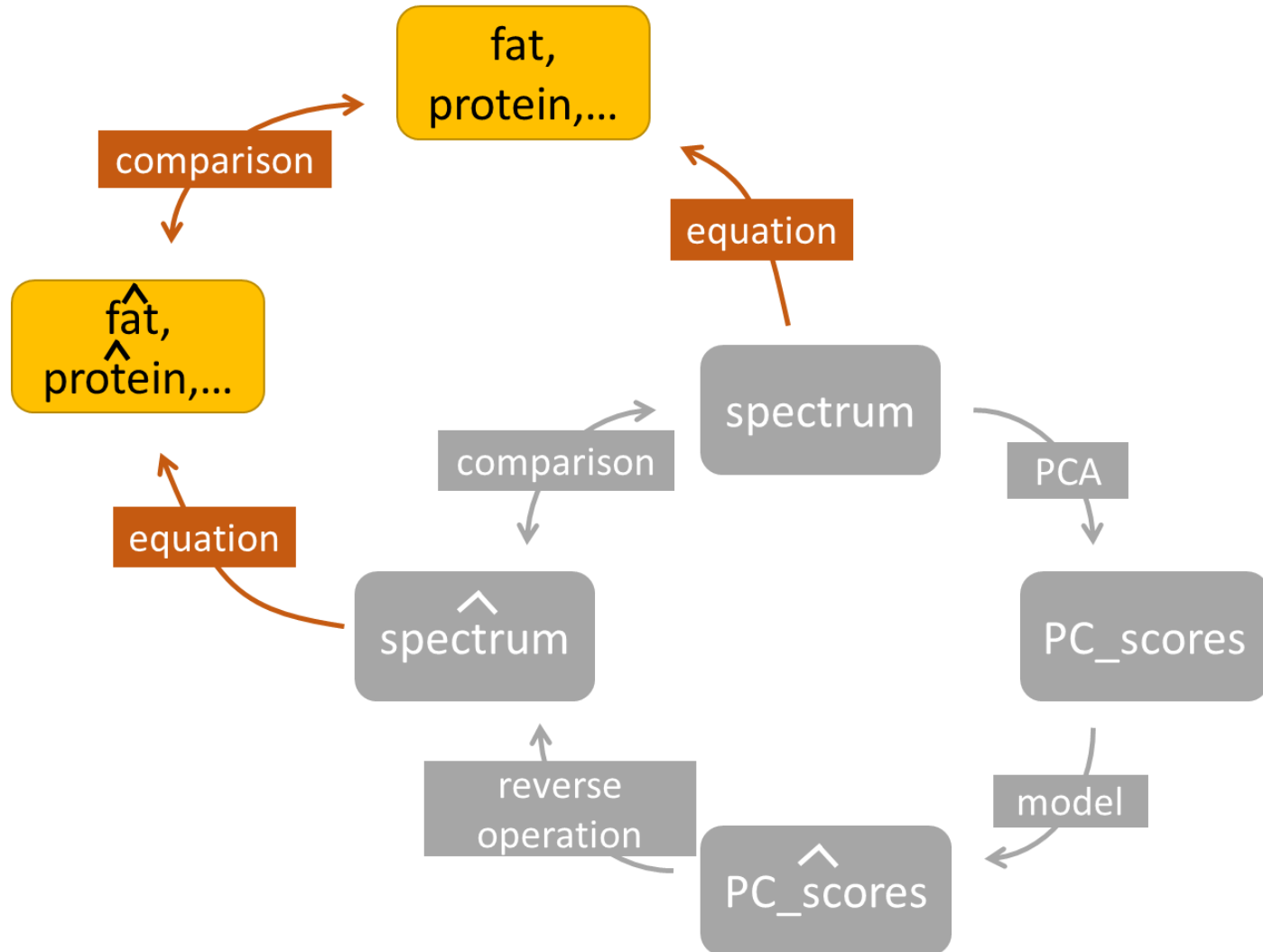
## Correlations between observed and predicted spectral points

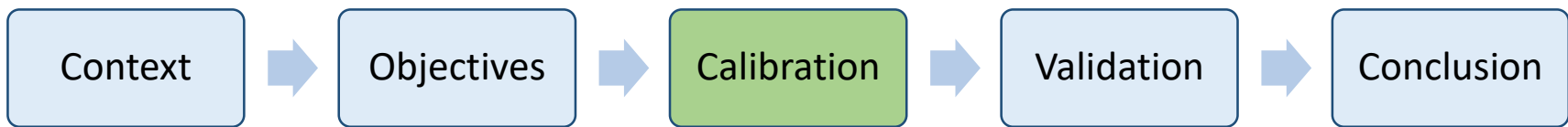


mean	min	max
0.85	0.67	0.95



## Prediction of milk composition traits

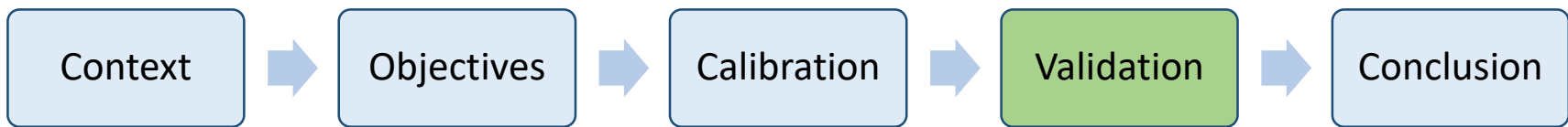




## Correlations between traits predicted on observed spectra vs. on predicted spectra

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	r
Fat % ( $r^2=0.99$ )	0.83
Protein % ( $r^2=0.99$ )	0.89
Lactose % ( $r^2=0.92$ )	0.83

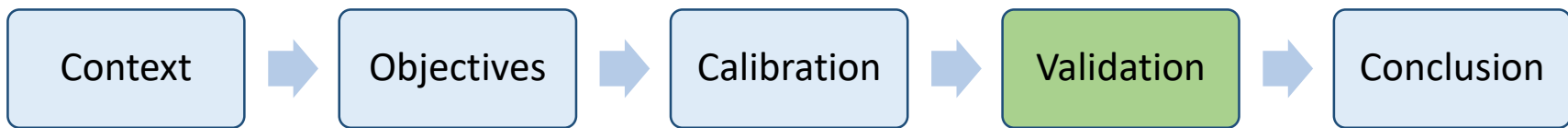


## Correlations between observed and predicted spectral points

122,032 records - 4 groups of cows

		mean	min	max
Future record	$y = HY + HM + DIM + \cancel{HTD} + \text{gen} + PE + e$	0.56	0.06	0.72
New cow in known herd and known test date	$y = HY + HM + DIM + HTD + \text{gen} + \cancel{PE} + e$	0.62	0.30	0.89
New cow in known herd	$y = HY + HM + DIM + \cancel{HTD} + \text{gen} + \cancel{PE} + e$	0.37	0.00	0.62
New cow in new herd	$y = \cancel{HY} + \cancel{HM} + DIM + \cancel{HTD} + \text{gen} + \cancel{PE} + e$	0.36	0.05	0.63

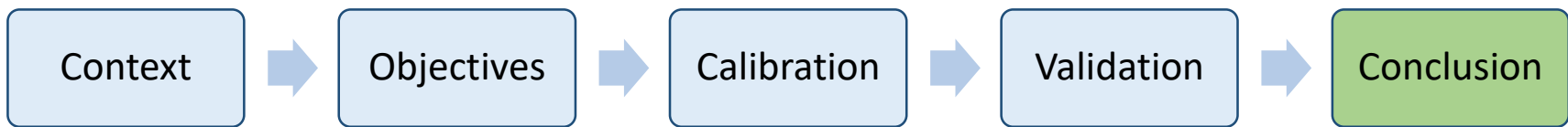




## Correlations between traits predicted on observed spectra vs. on predicted spectra

122,032 records - 4 groups of cows

		Fat % ( $r^2=0.99$ )	Prot % ( $r^2=0.99$ )	Lact. % ( $r^2=0.92$ )
Future record	$y = HY + HM + DIM + \cancel{HTD} + gen + PE + e$	0.63	0.68	0.62
New cow in known herd and known test date	$y = HY + HM + DIM + HTD + gen + \cancel{PE} + e$	0.53	0.73	0.47
New cow in known herd	$y = HY + HM + DIM + \cancel{HTD} + gen + \cancel{PE} + e$	0.36	0.62	0.46
New cow in new herd	$y = \cancel{HY} + \cancel{HM} + DIM + \cancel{HTD} + gen + \cancel{PE} + e$	0.41	0.64	0.32



## Conclusion

Moderate ability to predict milk MIR spectra and related traits with the current model

↪ Some spectral regions are better predicted than others

↪ Improvements are possible, such as:

- New effects in the model
- Legendre polynomials

# Thank you for your attention

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## Acknowledgments



Contact: [pauline.delhez@uliege.be](mailto:pauline.delhez@uliege.be)