A consistent spectro-polarimetry focused reduction of all archival HARPSpol data (~490 stars, 3000+ datasets)

a fun side-project

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← *Kleine Welten V*, Wassily Kandinsky, 1922

Spectropolarimeters

Designed as spectropolarimeter from the start

(Neo-)Narval
Télescope Bernard Lyot

ESPaDOnS
Canada-France-Hawaii Telescope

SPIRou
Canada-France-Hawaii Telescope

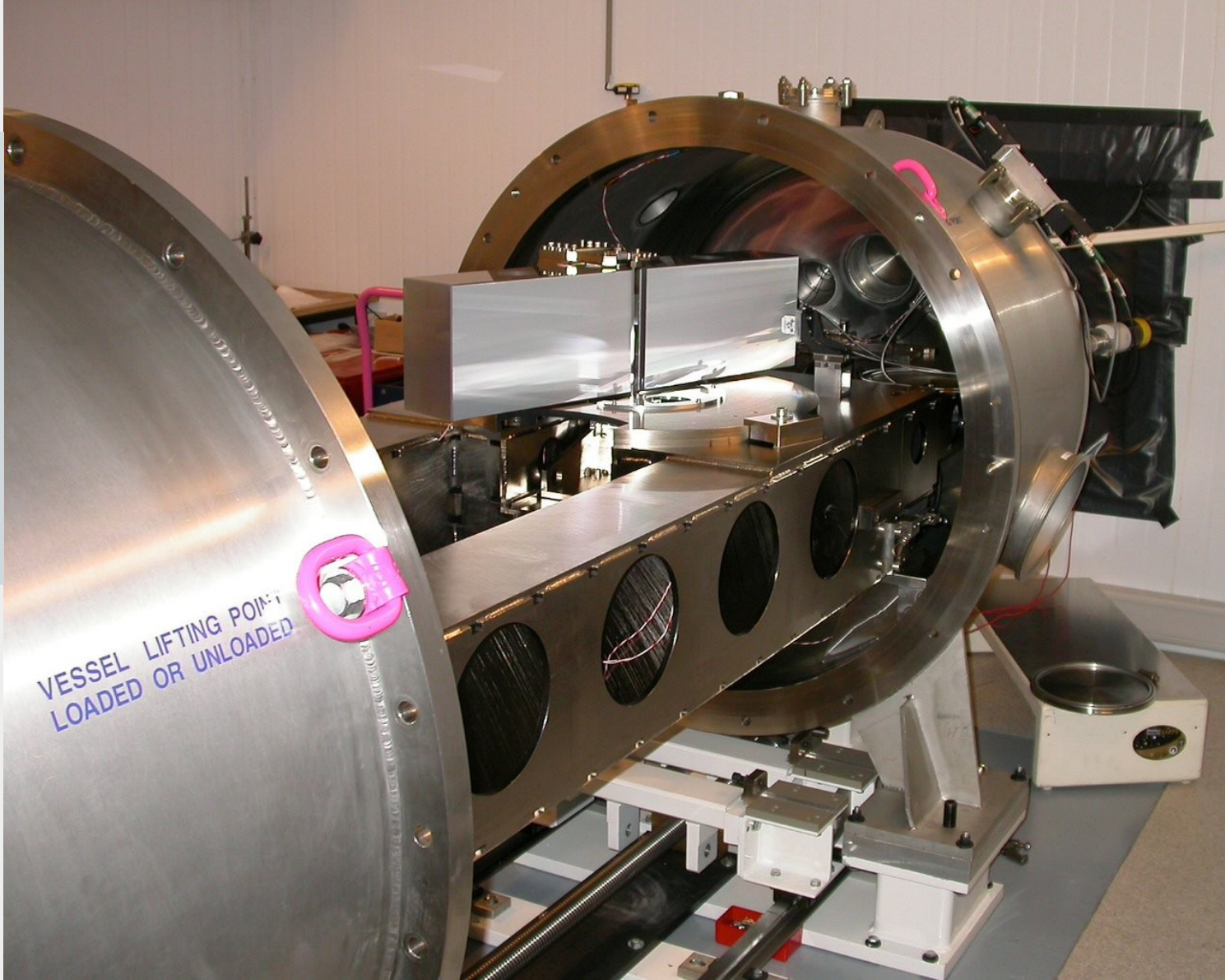
Designed as spectrograph with polarimetry as add-on

HARPSpol
ESO/La Silla 3.6m telescope

CRIRES+
ESO Very Large Telescope

HARPSpol

HARPS
Mounted at ESO 3.6m telescope, La Silla since 2003
R~115000
λ: 378 – 691 nm
HARPSpol – polarimetric mode for HARPS from 2009
Stokes QUV



Why though?

> **How do people use HARPSpol data for their publications?**

I checked ADS for publication containing keywords like HARPSpol.
Found 42 publications, can be sorted into 3 groups:

"Uppsala connection"

REDUCE IDL

Kochukhov, Piskunov, Wade or Alecian in author list

28

"Toulouse connection"

LIBRE-ESPRIT

Donati or Blazère in author list

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"Potsdam connection"

HARPS DRS

Järvinen/Hubrig/Schöller in author list

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(# papers)

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pyReduce

(1)

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There is already a “HARPS-Polarimetry pipeline processed data” archive!
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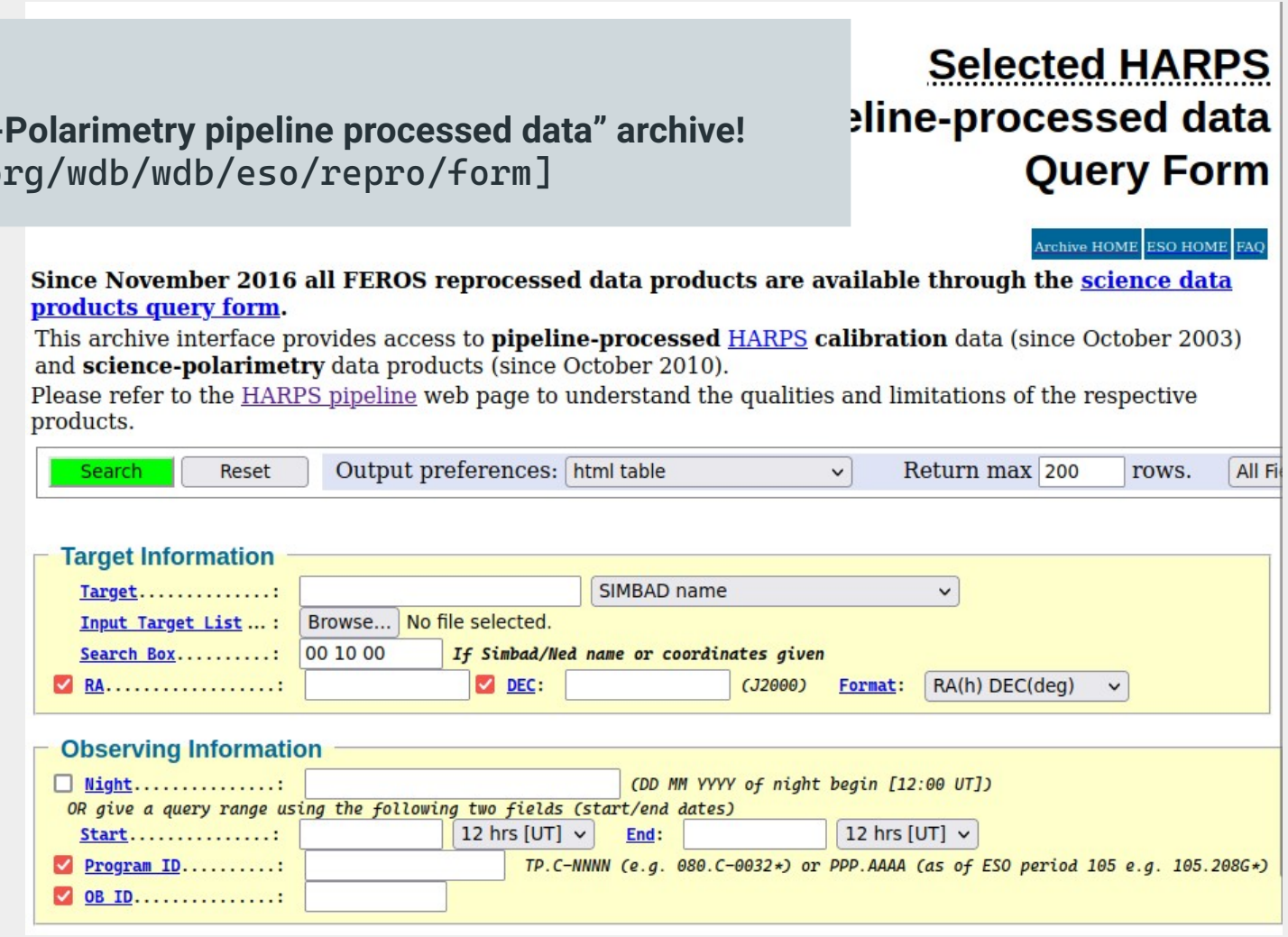

Selected HARPS
eline-processed data
Query Form

Archive HOME | ESO HOME | FAQ

Since November 2016 all FEROS reprocessed data products are available through the science data products query form.

This archive interface provides access to **pipeline-processed** HARPS **calibration** data (since October 2003) and **science-polarimetry** data products (since October 2010).

Please refer to the HARPS pipeline web page to understand the qualities and limitations of the respective products.

Search | Reset | Output preferences: html table | Return max 200 rows. | All Fi

Target Information

Target.....: SIMBAD name

Input Target List ... : Browse... No file selected.

Search Box.....: 00 10 00 *If Simbad/Ned name or coordinates given*

RA.....: DEC: (J2000) Format: RA(h) DEC(deg)

Observing Information

Night.....: *(DD MM YYYY of night begin [12:00 UT])*

OR give a query range using the following two fields (start/end dates)

Start.....: 12 hrs [UT] End: 12 hrs [UT]

Program ID.....: *TP.C-NNNN (e.g. 080.C-0032*) or PPP.AAAA (as of ESO period 105 e.g. 105.208G*)*

OB ID.....:

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Why reinventing the wheel?

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HARPS pipeline manual 3.0.0, 2023-01-31

> *The HARPS instrument produces raw data in 3 different configurations or modes (**HARPS**, **EGGS**, and **POLARIMETRY**). Currently, **only the reduction of data taken in HARPS mode is supported by the HARPS pipeline***

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> Reduced **data format is complicated** (have not found wavelength solution yet)

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> Put all reduced data on PolarBase

So ... what's the plan?

1> Download all the science data from the ESO archive.

2> Download all the raw calibration files

3> Reduce calibrations for each night.

4> Reduce science for each dataset

5> Package data with metadata and make it available

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6> Enjoy

1> **Download all the science data from the ESO archive.**

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Quite simple using `astroquery.eso`

```
from astroquery.eso import Eso   # import astroquery Eso package
table = eso.query_main(column_filters=  {    # query ESO main archive
    'instrument': 'HARPS',       # select HARPS instrument
    'dp_cat' : 'SCIENCE',        # select SCIENCE data
    'dp_tech' : 'ECHELLE,CIRPOL'})   # select Stokes V data
datafiles = eso.retrieve_data(table['Dataset ID'][:]) # download everything
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End up with 16284 raw science files at ca. 34MB each after quick QC:

- spectropolarimetric sequences should contain multiple of 4 exposures
- removed some very early commissioning data

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2> **Download all the raw calibration files** (should be as easy as science data right?)

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For each night of HARPSpol observation, run :

```
from astroquery.eso import Eso   # import astroquery Eso package
table = eso.query_main(column_filters=  {    # query ESO main archive
    'instrument': 'HARPS',       # select HARPS instrument
    'dp_cat' : 'CALIB',      # select CALIB data
datafiles = eso.retrieve_data(table['Dataset ID'][:]) # download everything
```

End up with raw calibration files for 671 nights

But

- calibration procedures and FITS keywords of files change every now and then ...

1> Download all the science data from the ESO archive. Quite simple using `astroquery.eso`

2> Download all the raw calibration files (should be as easy as science data right?)

3> **Reduce calibrations for each night**

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Using `pyReduce` : an easy-to-use and flexible Data Reduction System for echelle spectrographs

`https://github.com/AWehrhahn/PyReduce`

Works for many instruments : different config files for each instrument, core routines stay the same

`PyReduce` (*Piskunov, Wehrhahn & Marquart 2021*) is an update and port to python of the `IDL REDUCE` package (*Piskunov & Valenti 2002*).

Runs a serie of standard steps e.g :

`bias, flat, orders, scatter, norm_flat, wavecal`

Config files already exist for HARPS !

4> **Reduce science for each dataset**

Using `pyReduce` : an easy-to-use and flexible Data Reduction System for echelle spectrographs

Runs a serie of standard steps e.g :

`science`

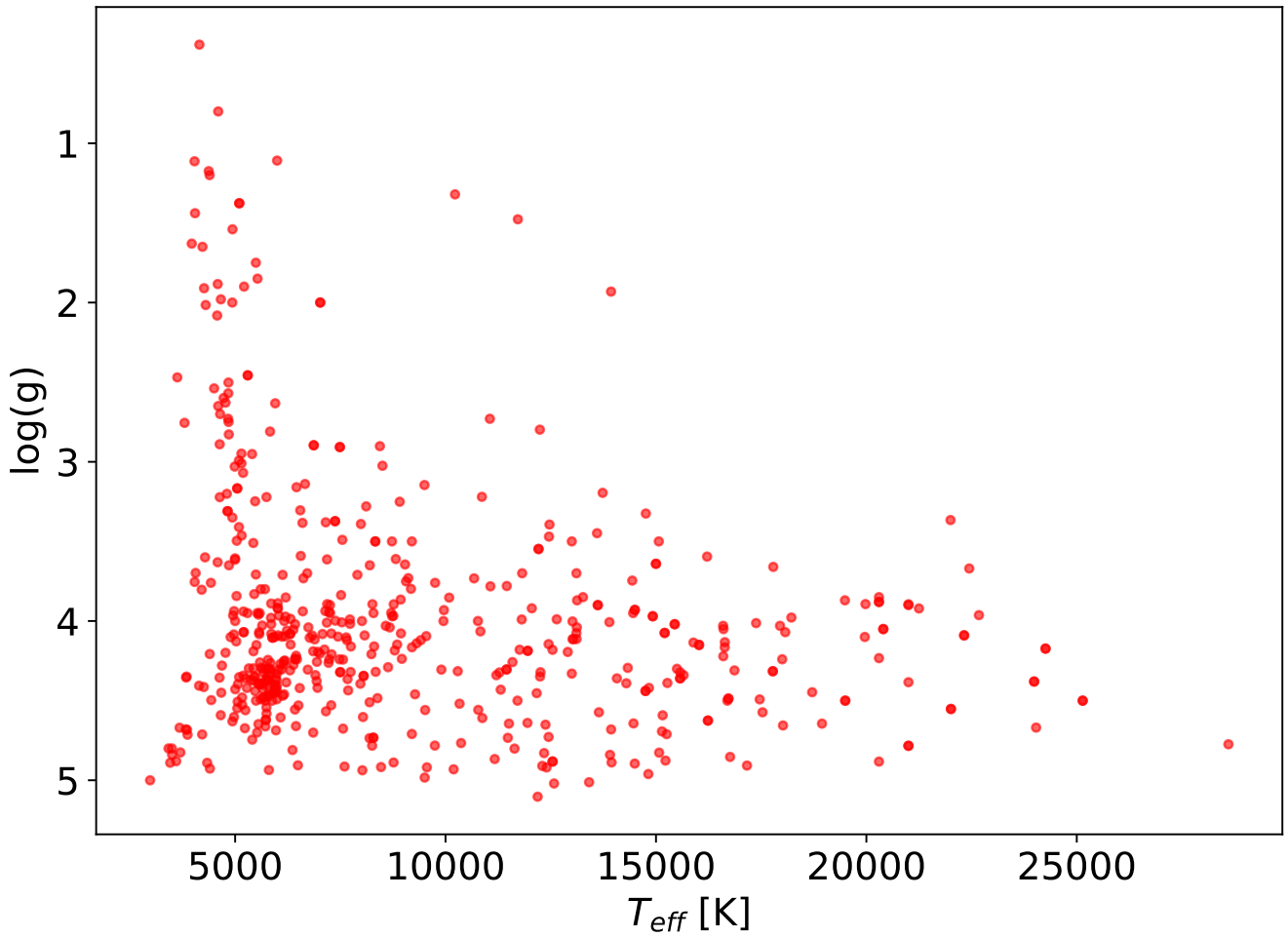
Outputs extracted science spectra.

HARPSpol star sample

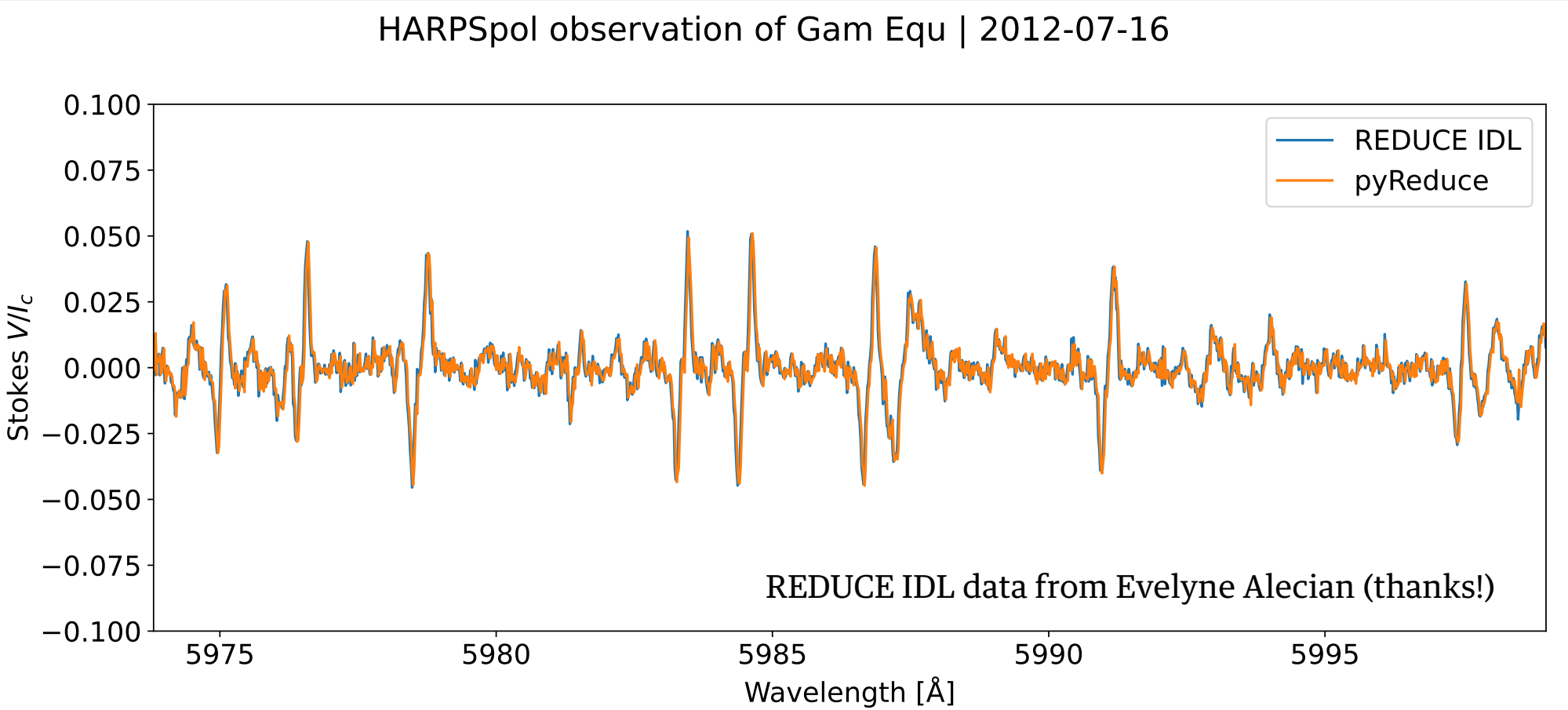
> Many solar-like and massive stars (reflects the large programmes *e.g* MiMeS ?)

> T_{eff} and logg are estimated automatically *via* Simbad and Vizier (median value of all catalogue matches).

Thanks to Frédéric Paletou and Pascal Petit for the python script.



IDL REDUCE vs pyReduce



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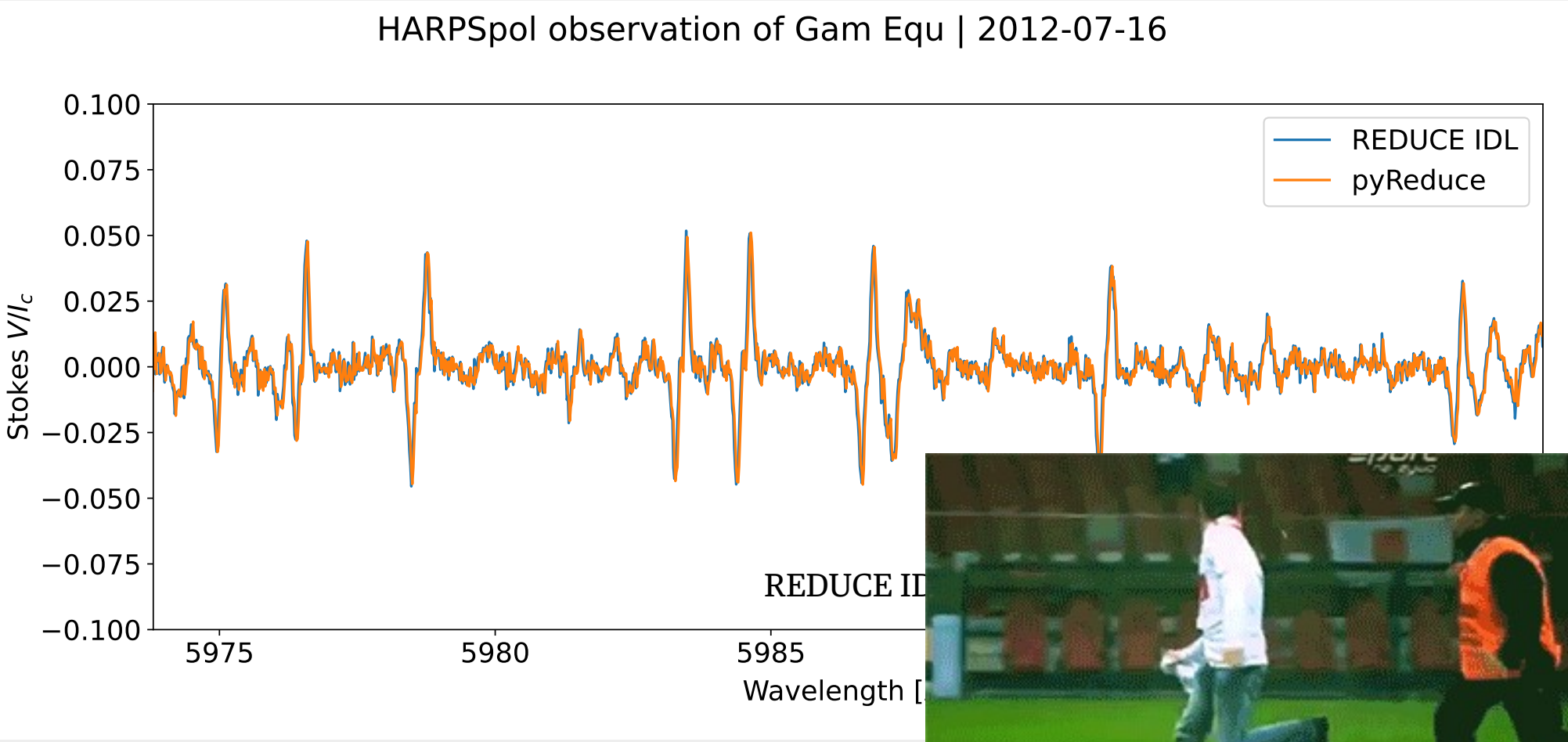
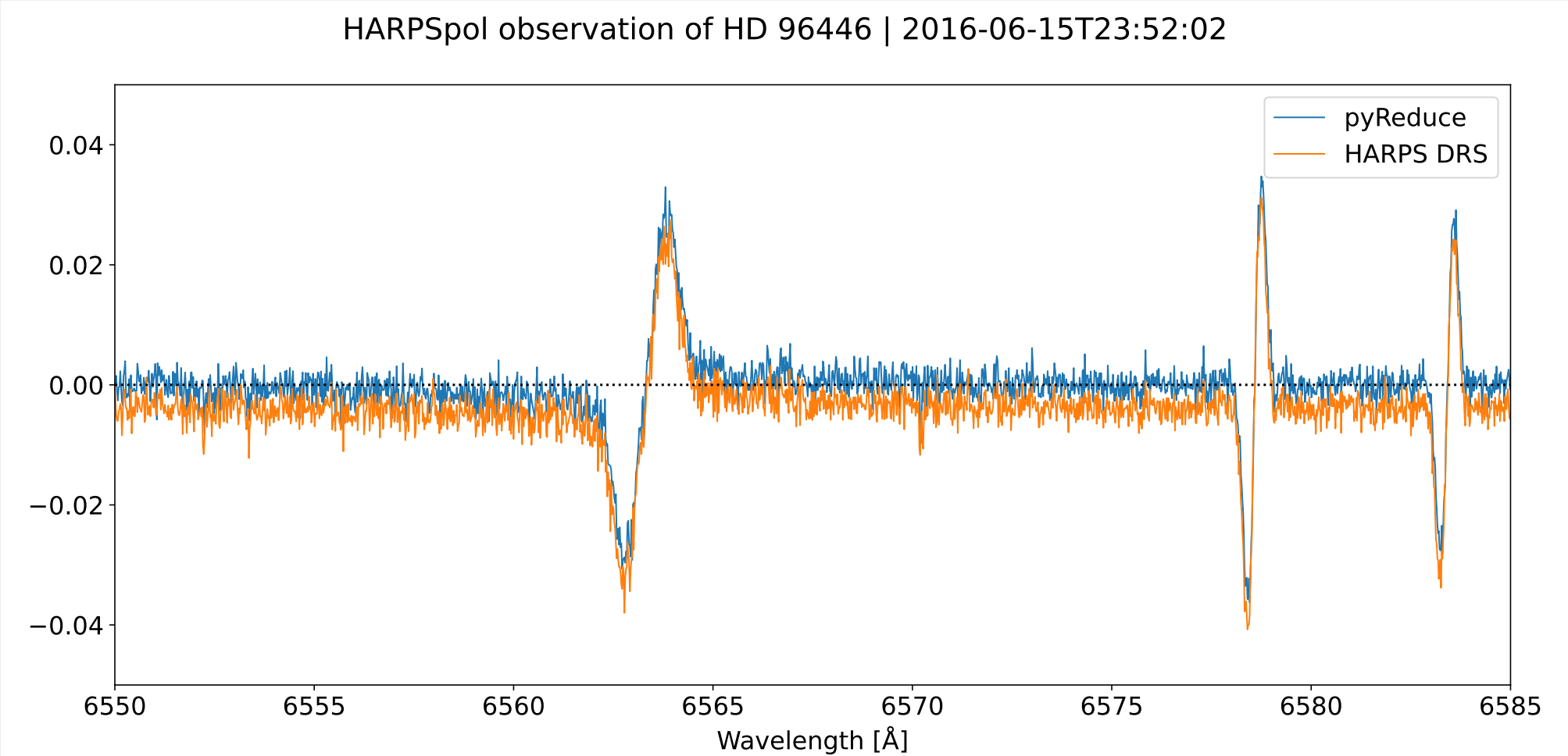


HARPS DRS vs pyReduce



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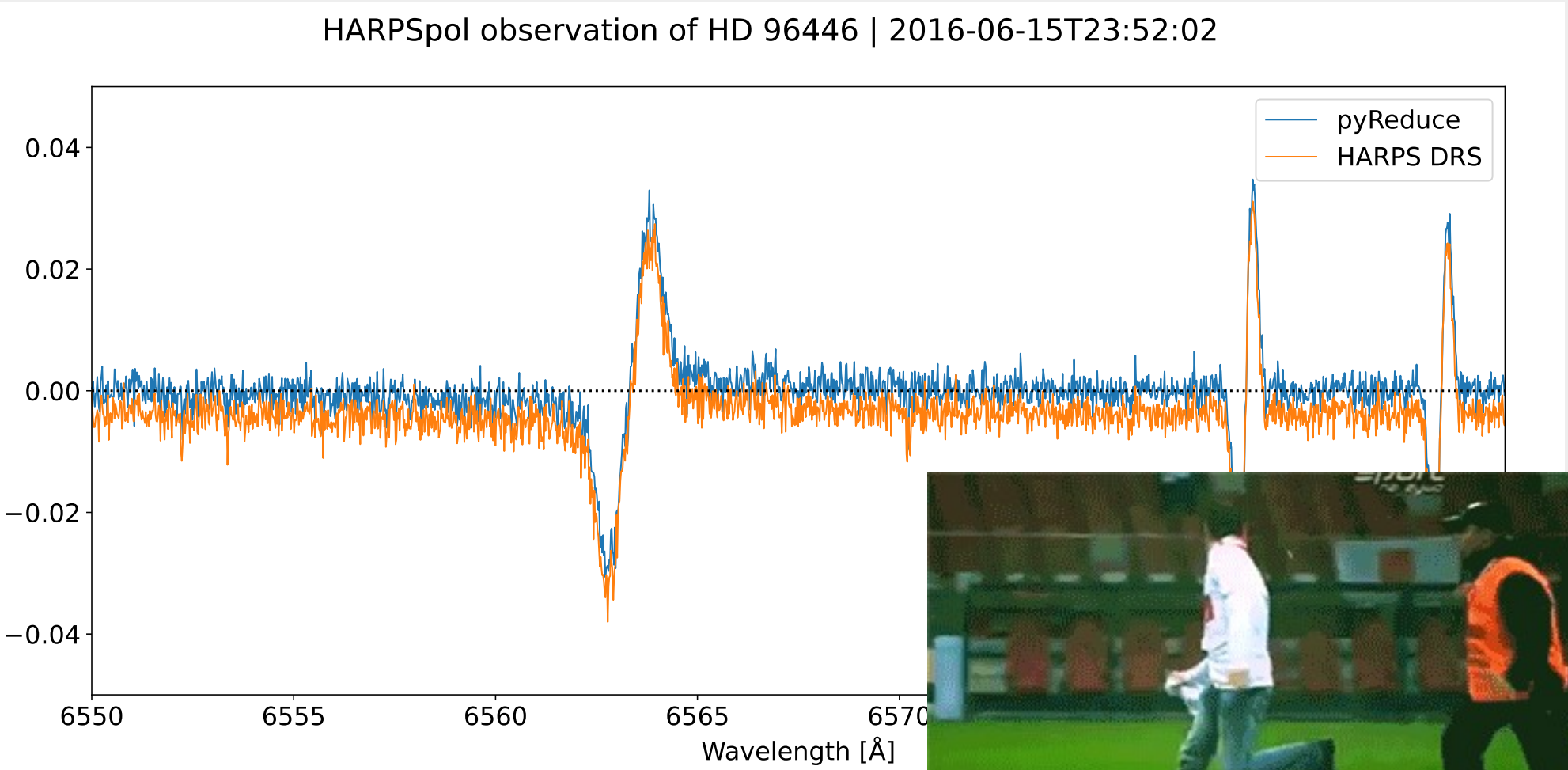

Takeaway points

> I downloaded **all** public HARPSpol science data in the ESO archive (with calibrations)

> After a quick QC, **reduced all** data using pyReduce : **3000+** polarimetric **datasets** of ~< **490 stars**

> Will make it available online quickly, eventually on PolarBase

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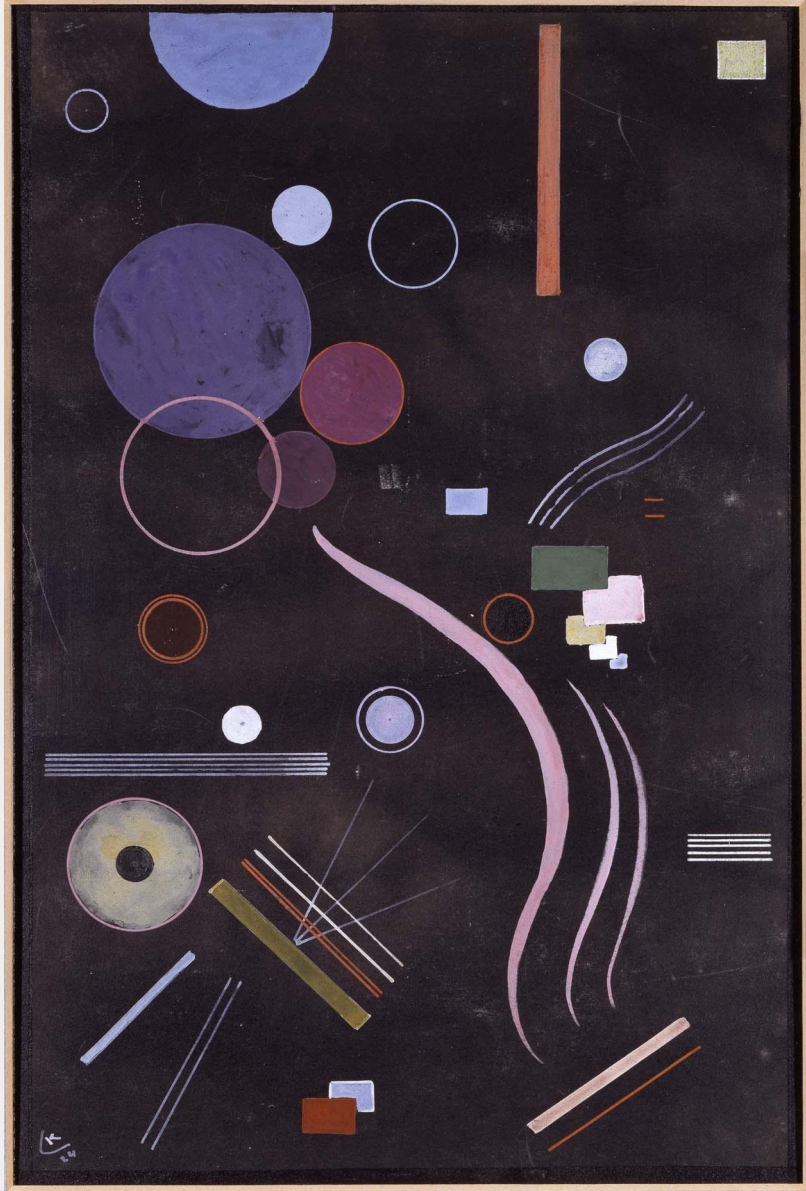

Acentric, Wassily Kandinsky, 1924 ⟶