ERASMUS MUNDUS JOINT MASTER DEGREE
MASTER IN ASTROPHYSICS AND SPACE SCIENCE

Introduction to Active Galactic Nuclei

Tutorial 5

Photometric reverberation mapping with Astro Data Lab

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Lecture outline

- What is Astro Data Lab?
- Introduction to Astro Data Lab tools and datasets
- Introduction to photometric reverberation mapping
- Astro Data Lab tutorial: Photometric Reverberation Mapping of AGNs
- Homework 5 overview

What is Astro Data Lab?

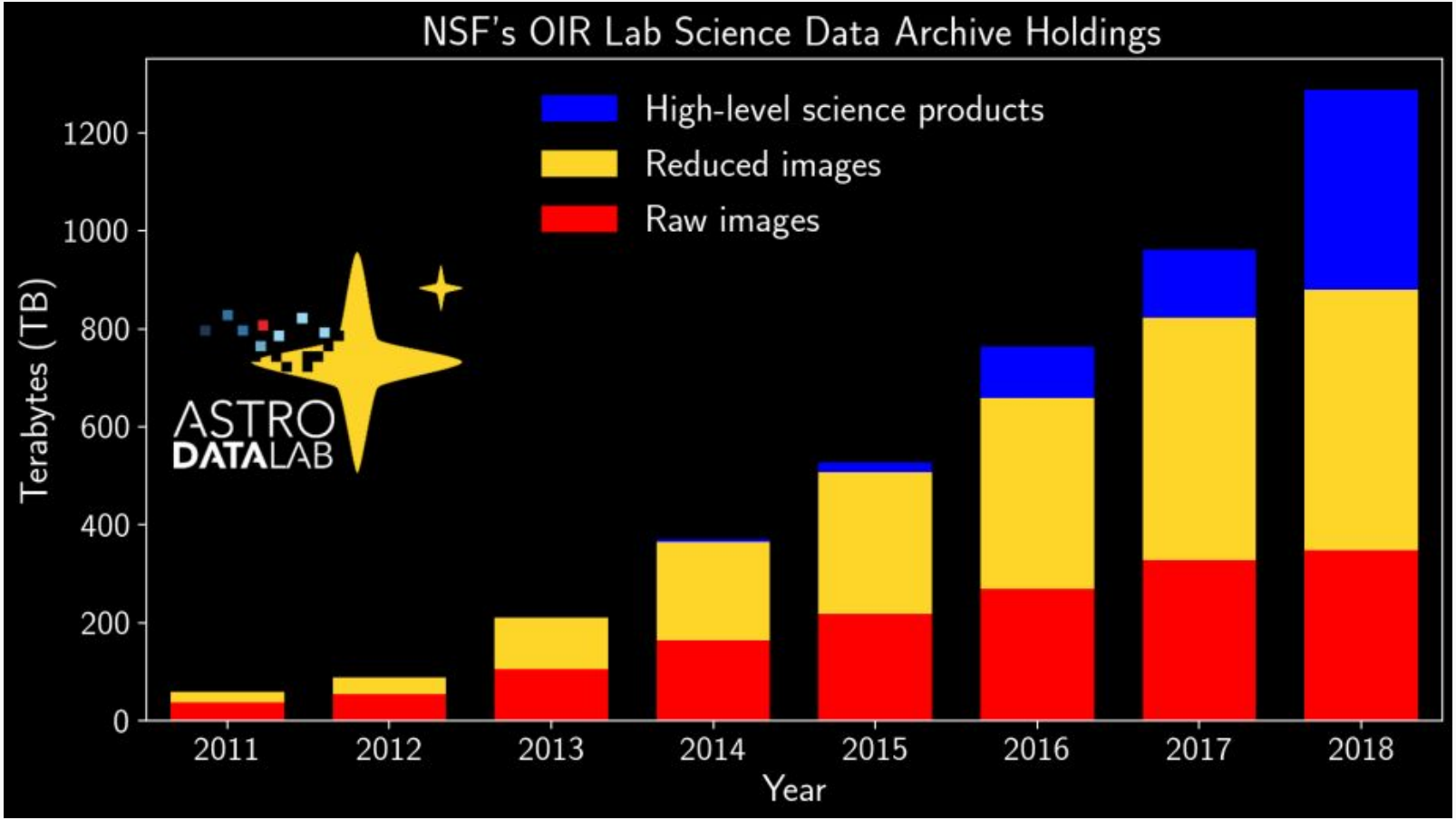
Astro Data Lab - Open-Data, Open-Access Science Platform

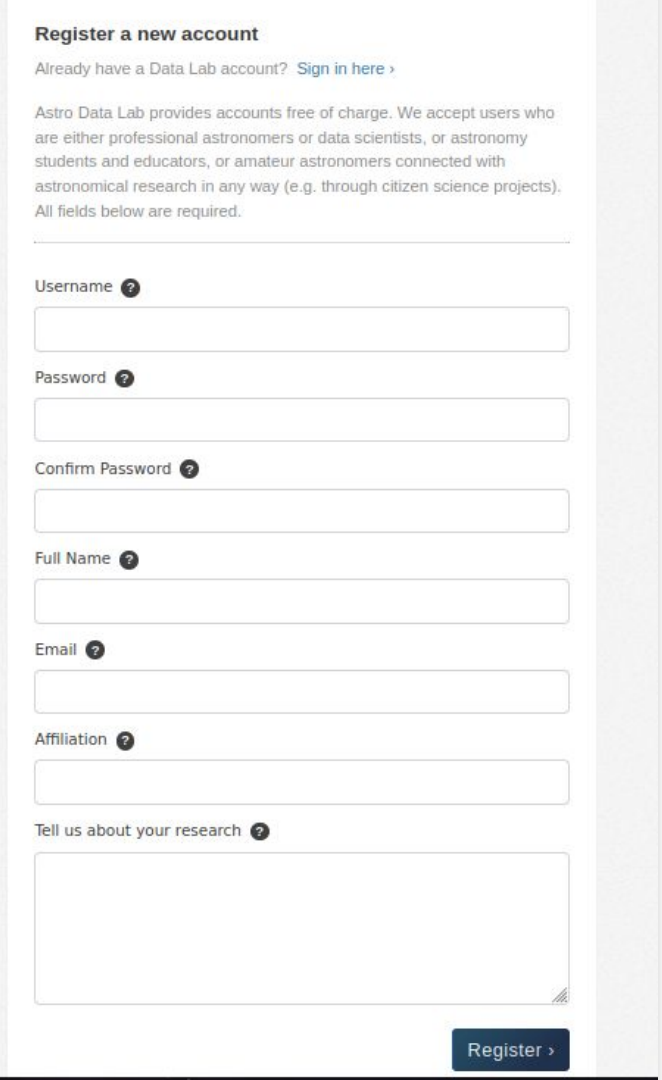
- Repository for large (mainly photometric) datasets (catalogs & images)
- Spectroscopy - SDSS DR16, more surveys in future plans (DESI)
- Services to access data (VO, SQL/ADQL, TAP, SIA, ...)
- Exploratory tools (survey coverage, catalog overlay, ...)
- Cross-matching service
- Visualization
- Analysis facilities (Jupyter notebook server)
- Remote storage (vospace, mydb, notebook space)
- You are now part of a community of ~1500 users!

Why Astro Data Lab?

- **Originally:** exploit NOIRLab (formerly NOAO and Gemini) public data (4-m telescopes), surveys, time-domain; specifically: DES
- Bring user's analyses to the data
- Joint analysis with other datasets (ingested by ADL, or uploaded by user)
- Preparation of users for PB-scale data, readiness for LSST
- Today: DES just one of 21 surveys hosted at Data Lab

More than 80 TB of catalog data, 150+ billion rows





You…

- Get 1TB of storage on vospace
- 250 GB of MyDB storage
- Can upload datasets for joint analysis
- Can edit/create/delete notebooks
- Can upload own Python source code
- Can share data with others
- Access the tutorials
- Can contribute with your own science cases

Tutorials: Intros, How-Tos, Data Access, complete Science Cases

astro-datalab / **notebooks-latest** Public

Edit Pins

Code | Issues 10 | Pull requests 5 | Actions | Projects | Security | Insights

master | **18** branches | **1** tag | Go to file | Add file | Code

rnikutta Merge pull request #163 from astro-datalab/gmos-iraf ··· 3009712 last week **590** commits

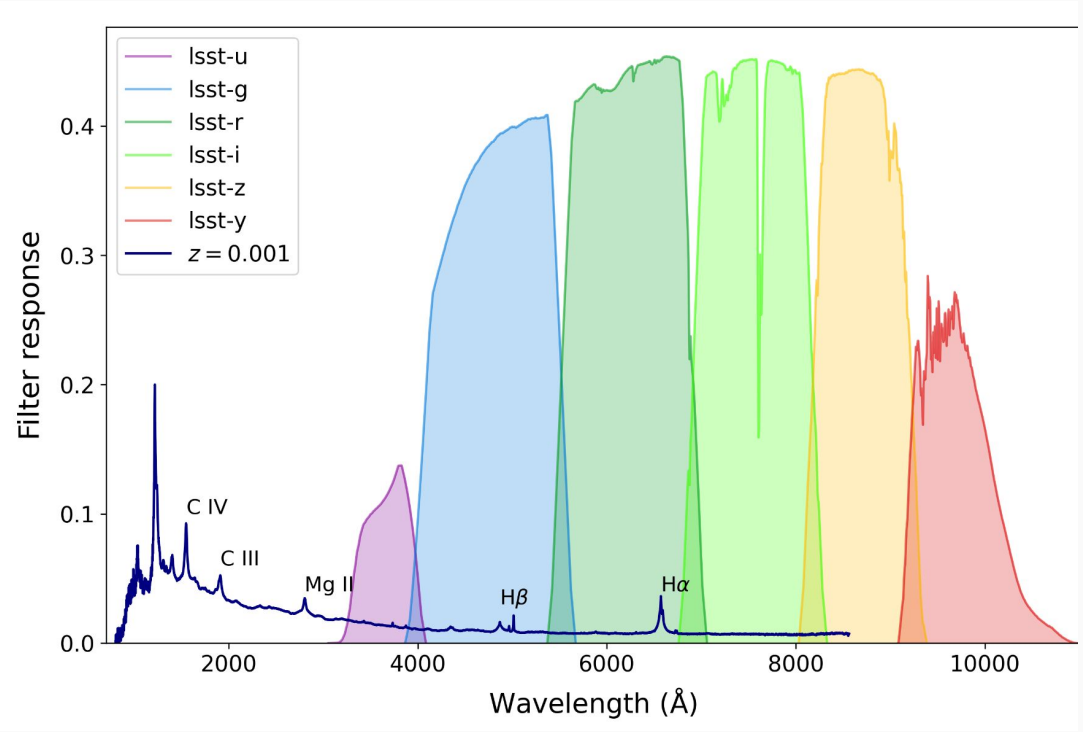
01_GettingStartedWithDataLab	Replace gaia dr2 with gaia dr3 in JupyterPythonSQL101	3 months ago
02_DataAccessOverview	- noao to noirlab NB update batch 1 (both ipynb and html files)	2 years ago
03_ScienceExamples	Set half_sky=False in healpy.orthview() lest plotting fails.	2 weeks ago
04_HowTos	Clear cell outputs.	last week
05_Contrib	Fix plt.savefig() by removing overwrite=True in HIPASS contributed NB.	last week
06_EPO	Added missing image and corrected filename issue	3 months ago
tests	- Exclude e-TeenAstronomyCafe NBs from default testing.	2 years ago
.gitignore	Set lineWidth parameter to 3,on lightcurve_slider.py in order to solv…	2 years ago
CONTRIBUTING	Update README.txt and CONTRIBUTING with new 'astro-datalab' GH …	last year
DataLabNotebookTemplate.ipynb	Replace broken link, update authentication section	3 weeks ago
LICENSE	- noao to noirlab NB update batch 1 (both ipynb and html files)	2 years ago

Let’s briefly explore the actual platform…

→ https://datalab.noirlab.edu/

Intro to photometric reverberation mapping science case

Photometric reverberation mapping of BLR in AGN



LSST passbands + composite quasar spectrum (Vanden Berk+2001)

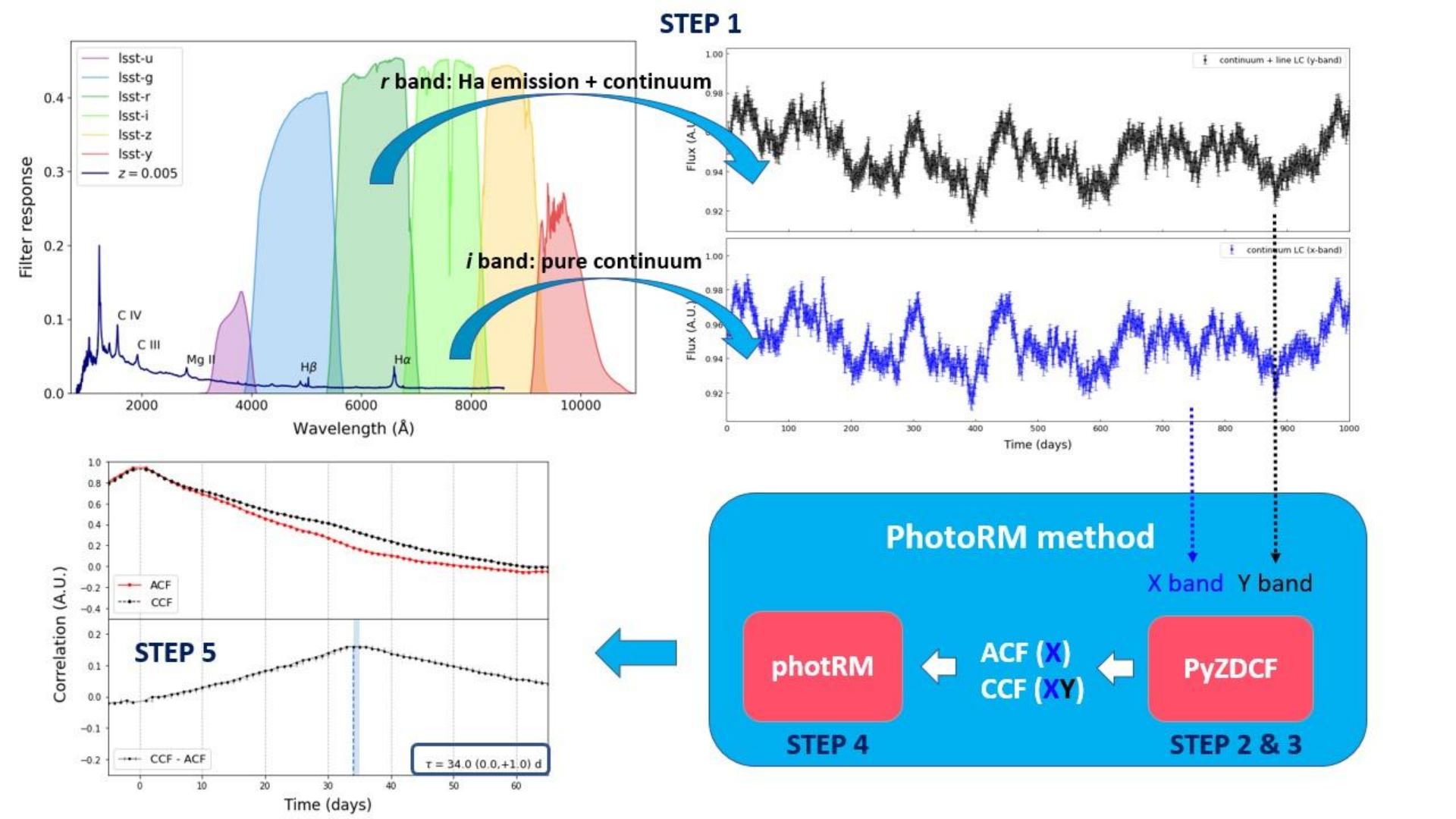
- **PhotoRM:** method for BLR radius estimation using broadband photometric filters.
- **Relevance:** Utilization of LSST data for BLR radius evaluation may allow black hole mass estimation of unprecedented number of AGNs.
- **Difficulty:** Photometric light curves track both continuum and emission line variability together.
- **Example (z = 0.001):**
  - Continuum: *i-band*
  - Hα + continuum: *r-band*
  - Hβ + continuum: *g-band*

Time-lags obtained using a **formalism** by **Chelouche & Daniel (2012)**

1. Identify suitable filters: one covering the continuum emission (X-band) and the other covering continuum + line emission (Y-band)
2. Calculate auto-correlation function (ACF) of the continuum light curve (X-band)
3. Calculate cross-correlation function (CCF) of the continuum (X-band) + line light curve (Y-band)
4. Subtract ACF from CCF:

$$CCF(\tau) = CCF_{YX}(\tau) - ACF_X(\tau)$$

5. Find the peak in their difference, it will correspond to the time-lag (τ)


STEP 1
lsst-u
lsst-g
lsst-r
lsst-i
lsst-z
lsst-y
z = 0.005
r band: Ha emission + continuum
i band: pure continuum
C IV
C III
Mg II
Hβ
Hα
Filter response
Wavelength (Å)
continuum + line LC (y-band)
continuum LC (x-band)
Flux (A.U.)
Time (days)
PhotoRM method
X band Y band
PyZDCF
ACF (X)
CCF (XY)
photRM
STEP 2 & 3
STEP 4
STEP 5
ACF
CCF
CCF - ACF
τ = 34.0 (0.0,+1.0) d
Correlation (A.U.)
Time (days)

Let’s open this notebook in Astro Data Lab…

Hands-on session (begin now, finish at home)

Upload the HW5 notebook and lc_proc.py to Astro Data Lab

→ notebooks/05_Contrib/TimeDomain/PhotoReverberationMappingAGN

Goals:

Task 1:

- Understand the photometric reverberation mapping method and its limitations.
- Introduction to the tools for simulating AGN light curves and performing photoRM.

Task 2:

- Apply photometric reverberation mapping to real-world data.

Homework 5 deadline: **Monday 08.05, 13h**

Send your reports to

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