GRENOBLE | MODANE

IDENTIFICATION OF ORPHAN GAMMA-RAY BURST AFTERGLOWS IN RUBIN/LSST DATA WITH THE ALERT BROKER FINK

FINK COLLABORATION MEETING

19-20 MAY 2022

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With:
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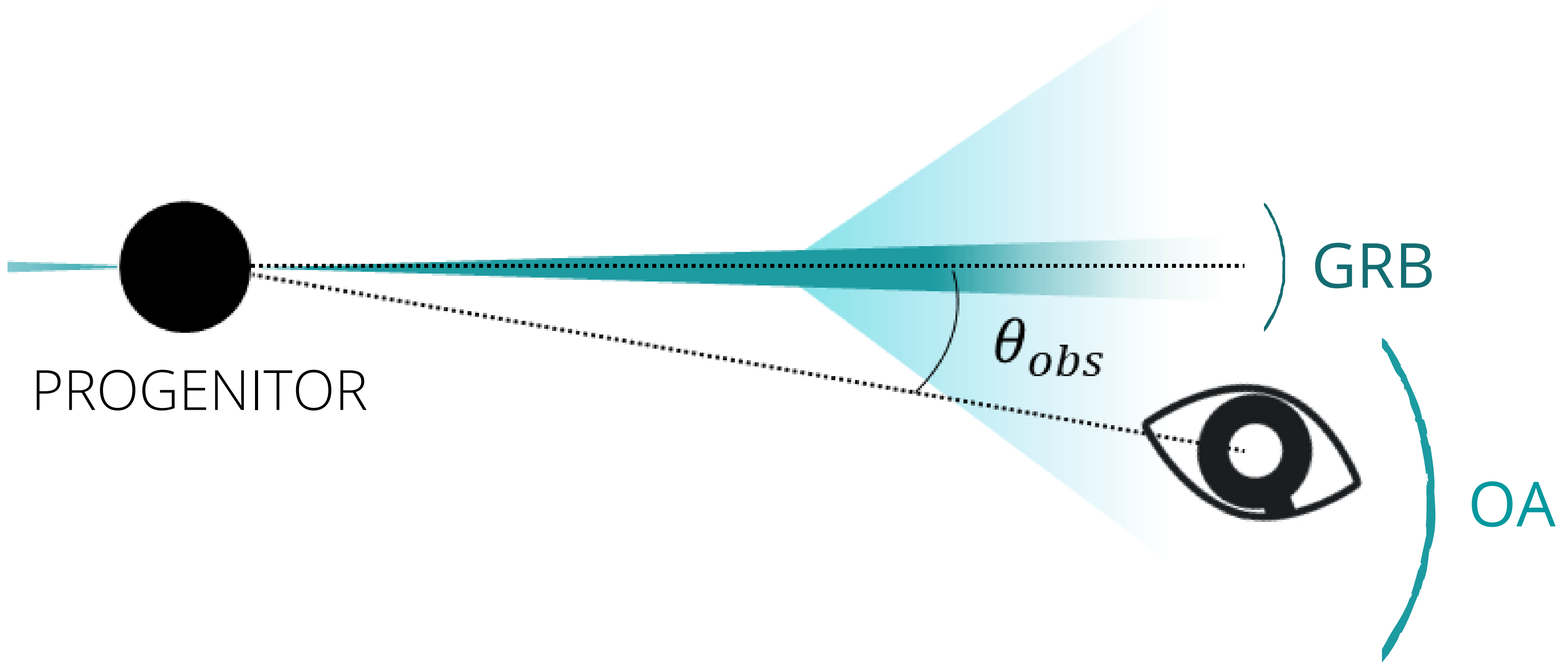
MASTER 2 INTERNSHIP

CONTENTS OF THE PRESENTATION

WHAT IS AN ORPHAN GAMMA-RAY BURST AFTERGLOW?



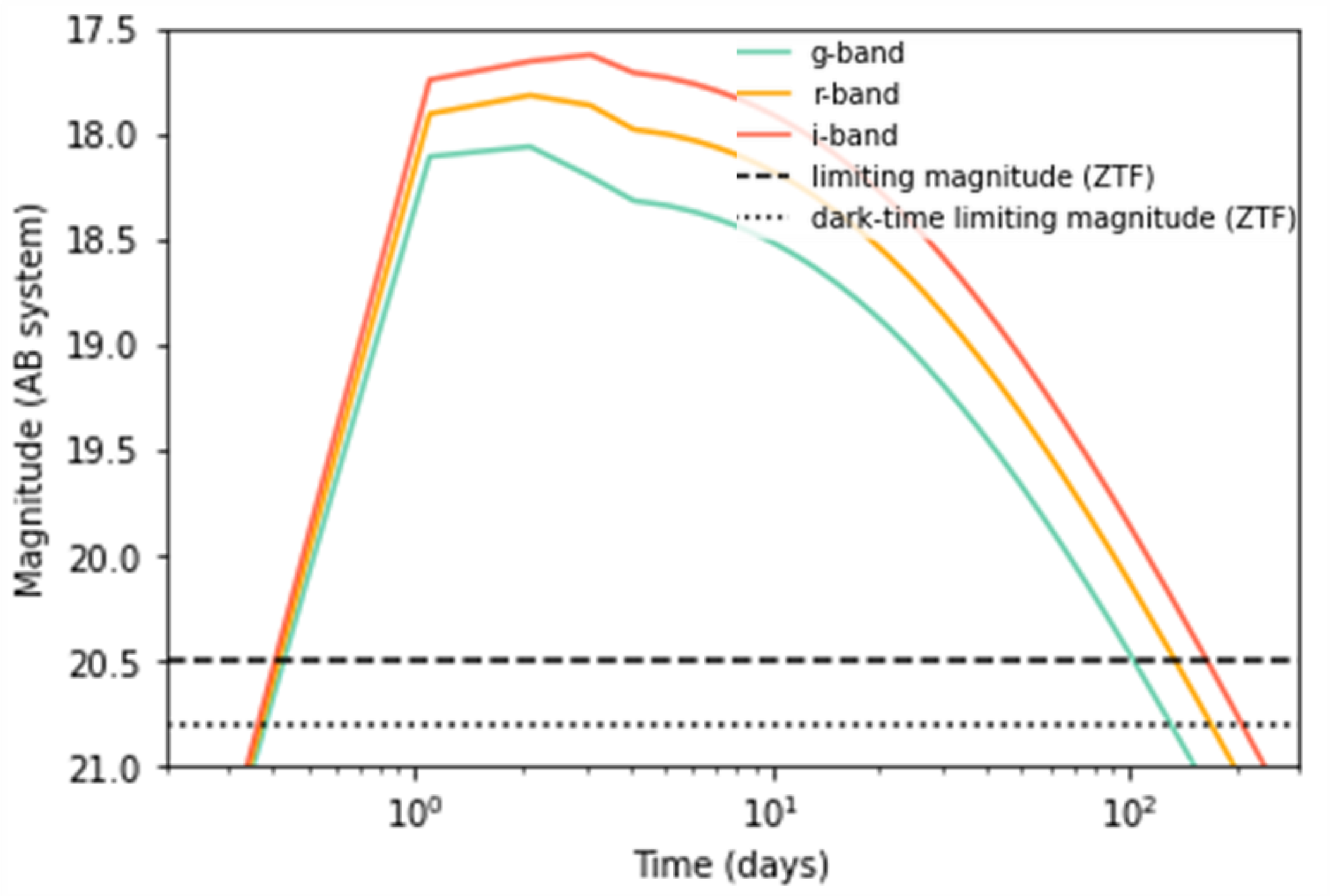
Objective of my internship > To identify potential orphan gamma-ray burst afterglows in Rubin/LSST data by implementing a filter in the alert broker FINK

- **Gamma-Ray Burst (GRB) =** highly energetic explosions (~ 10^51 erg) involving compact objects
- **Orphan GRB afterglow (OA) =** optical afterglow without gamma-ray emission
  ⟹ **No orphan afterglow detected so far!** (some candidates but none confirmed)
- **OAs important for**
  - GRB physics and progenitors
  - Multi-messengers analyses (gravitational waves)

(Work done in 2021)

MODEL OF LIGHT CURVE

GRB afterglow physics described by the **Synchrotron Radiation** $\Longrightarrow$ distinctive shape of the light curve.



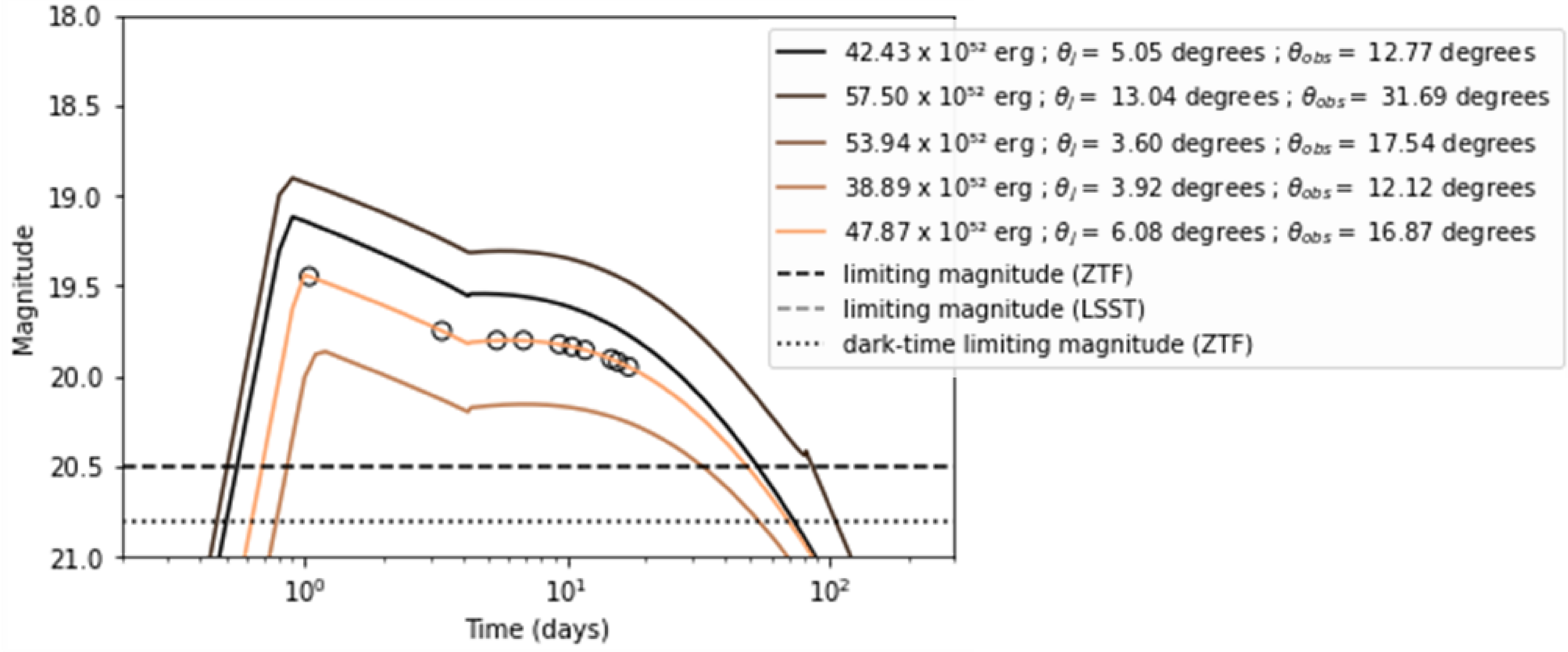
Model from **Sari, Piran and Narayan 1997**

$$F_\nu = \begin{cases} (\nu/\nu_m)^{1/3} F_{\nu,max} & \nu_m > \nu \\ (\nu/\nu_m)^{-(p-1)/2} F_{\nu,max} & \nu_c > \nu > \nu_m \\ (\nu_c/\nu_m)^{-(p-1)/2} (\nu/\nu_c)^{-p/2} F_{\nu,max} & \nu > \nu_c \end{cases}$$

And from **Zou, Wu et Dai 2006**

$$F_\nu(\theta_{obs}, t) = a^3 F_{\nu/a}(0, at) \quad \text{where} \quad a = \frac{1-\beta}{1-\beta cos\theta_{obs}}$$

SIMULATED LIGHT CURVES



Studied parameters:

- E between 10^51 and 10^54 erg
- θj between 5 and 15 degrees
- θobs between 2 and 5 times θj

Common features between the simulated light curves:

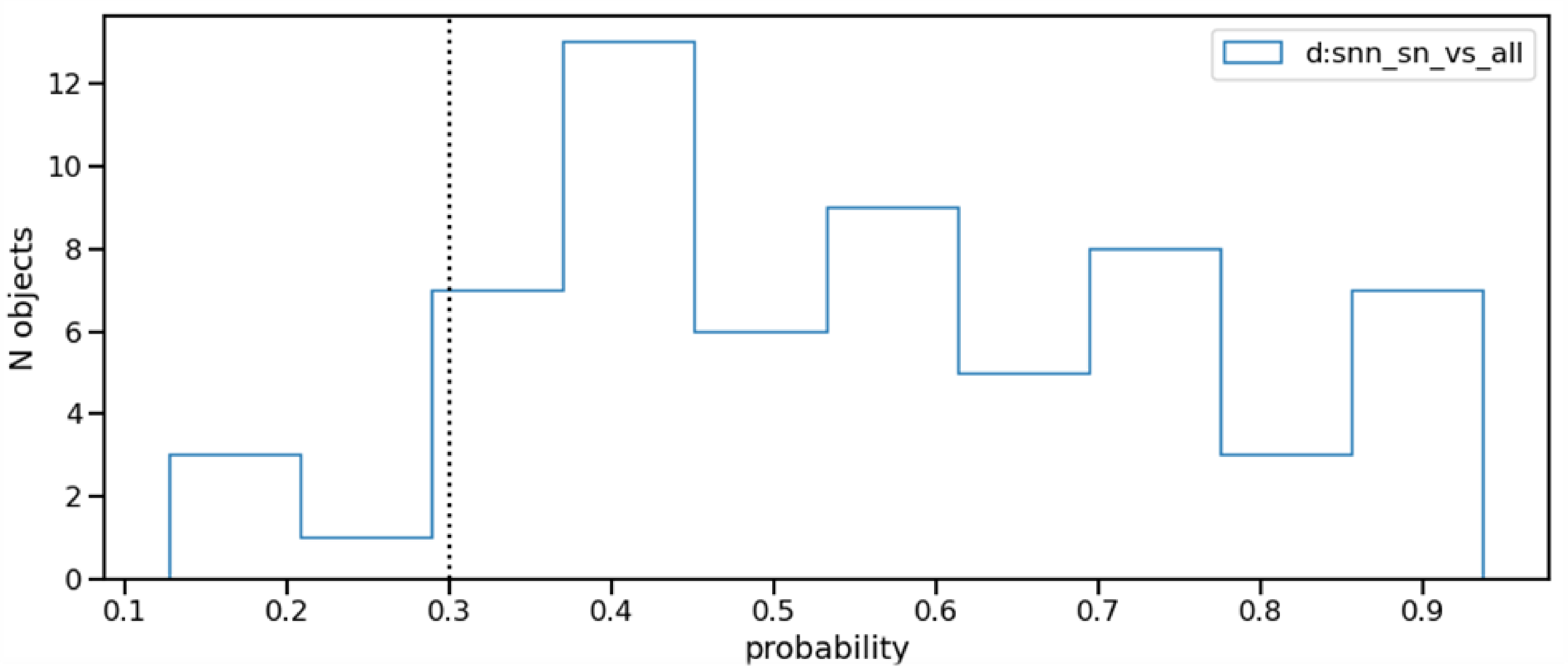
- Magnitude higher than 18 (faint transient)
- At least 3 detections in 10 days (slow transients) + 3rd point lower than the previous one
- « Colour » **g-r** constant and positive
- Less than a month between the first and the last detection

PRE-SELECTION OF THE CANDIDATES

« Real » pre-selection: magnitude > 18 and > 3 detections in 10 days
80 millions of alerts ⟹ 100 objects per month

Thanks to Julien Peloton (IJCLab) for the pre-selection!

ANALYSIS OF THE CANDIDATES:



ZTF data from January 2020 to June 2021

Additional criteria:
- Duration < 30 days to remove variable stars
- Probability of being a supernova < 30%.

(Work done in 2021)

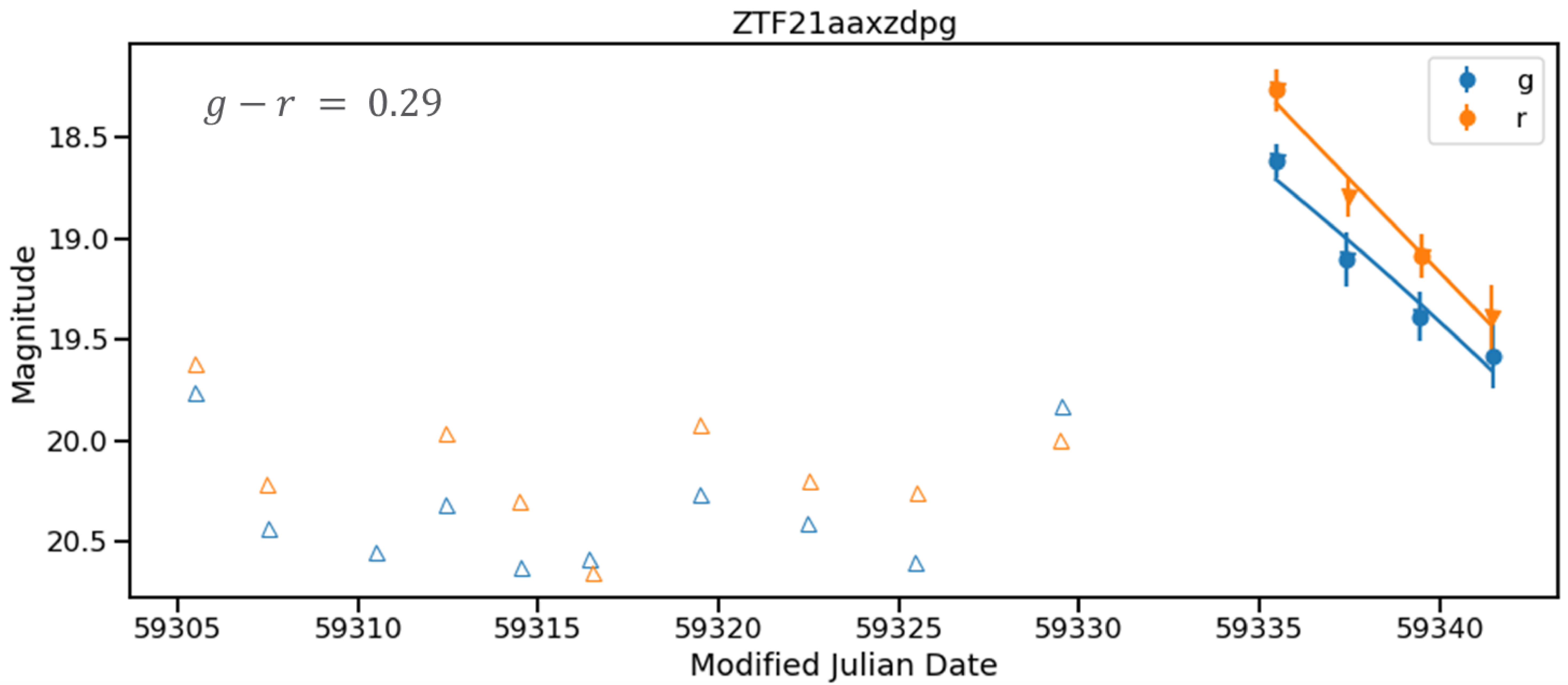
EXAMPLE OF ZTF21aaxzdpg

This object is located in the Milky Way ☹

Galactic coordinates:
79.40180125°, 6.52736581°

Cross-match with SIMBAD →

NGC 6866:
Open cluster located in the Milky Way



CONTENTS OF THE PRESENTATION

WHAT IS AN ORPHAN GAMMA-RAY BURST AFTERGLOW?

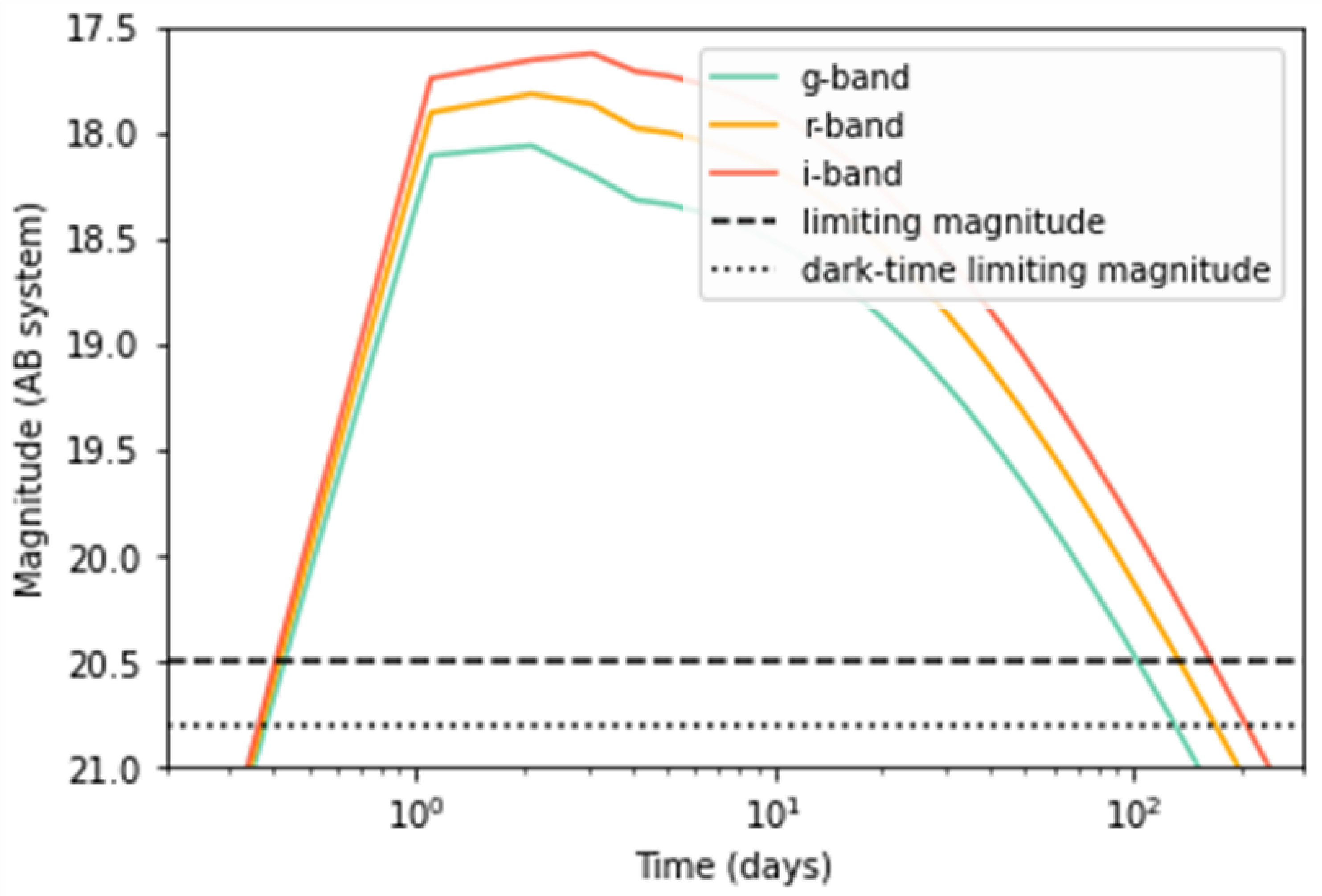
WORK DONE IN 2021

- Used model
- Simulated light curves
- Pre-selection
- The most promising candidate

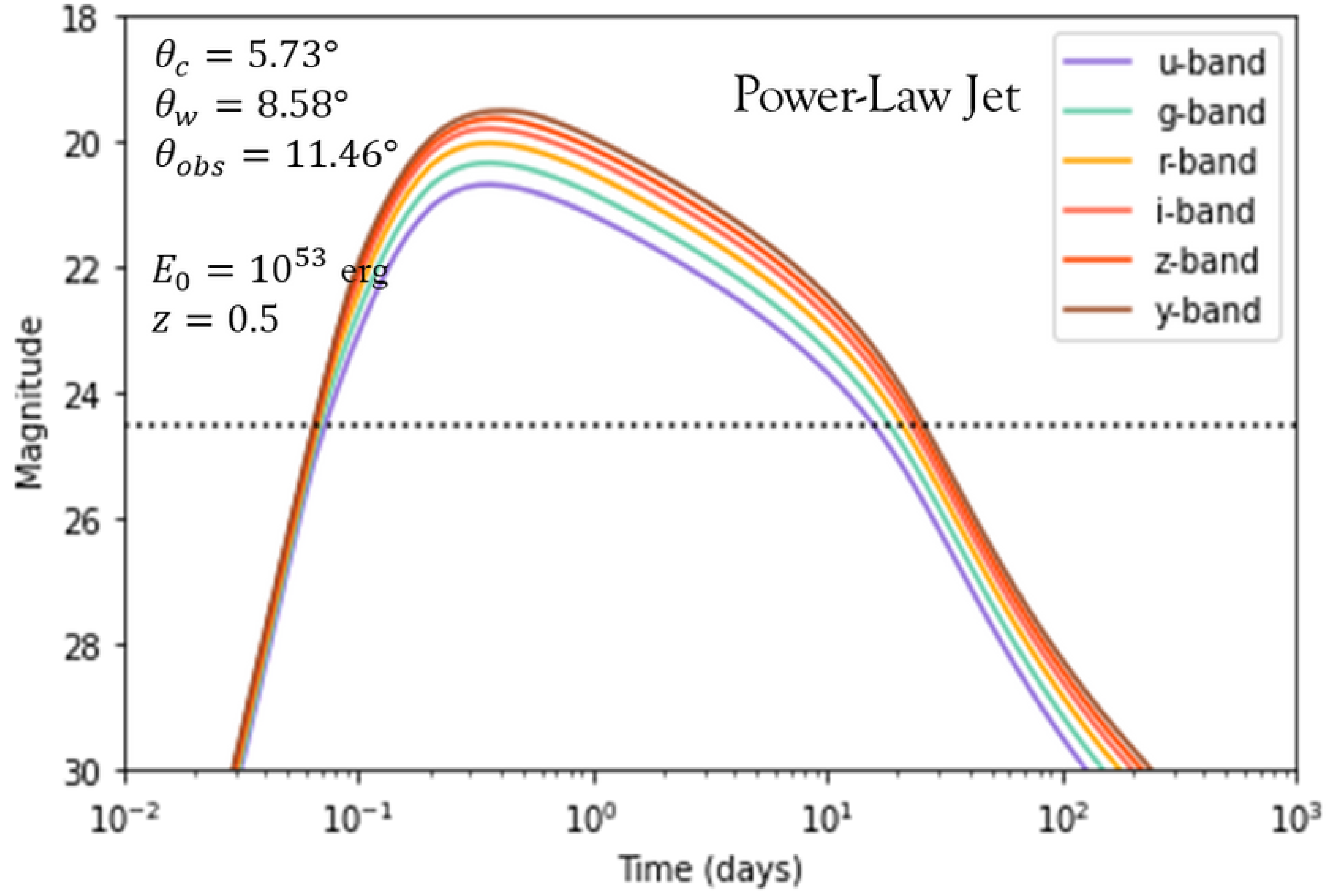
HOW TO IMPROVE THIS WORK?

- Comparison of the light curves
- Impact of each parameter
- Pseudo-observations with rubin_sim

COMPARISON OF THE LIGHT CURVES



Sari, Piran and Narayan 1997
for ZTF photometric filters



afterglowpy package for
Rubin/LSST photometric filters

afterglowpy package → more complex model with more parameters:

- Jet type (Top-Hat, Gaussian, Power-Law and others...)
- Core angle θc
- Truncature angle θw

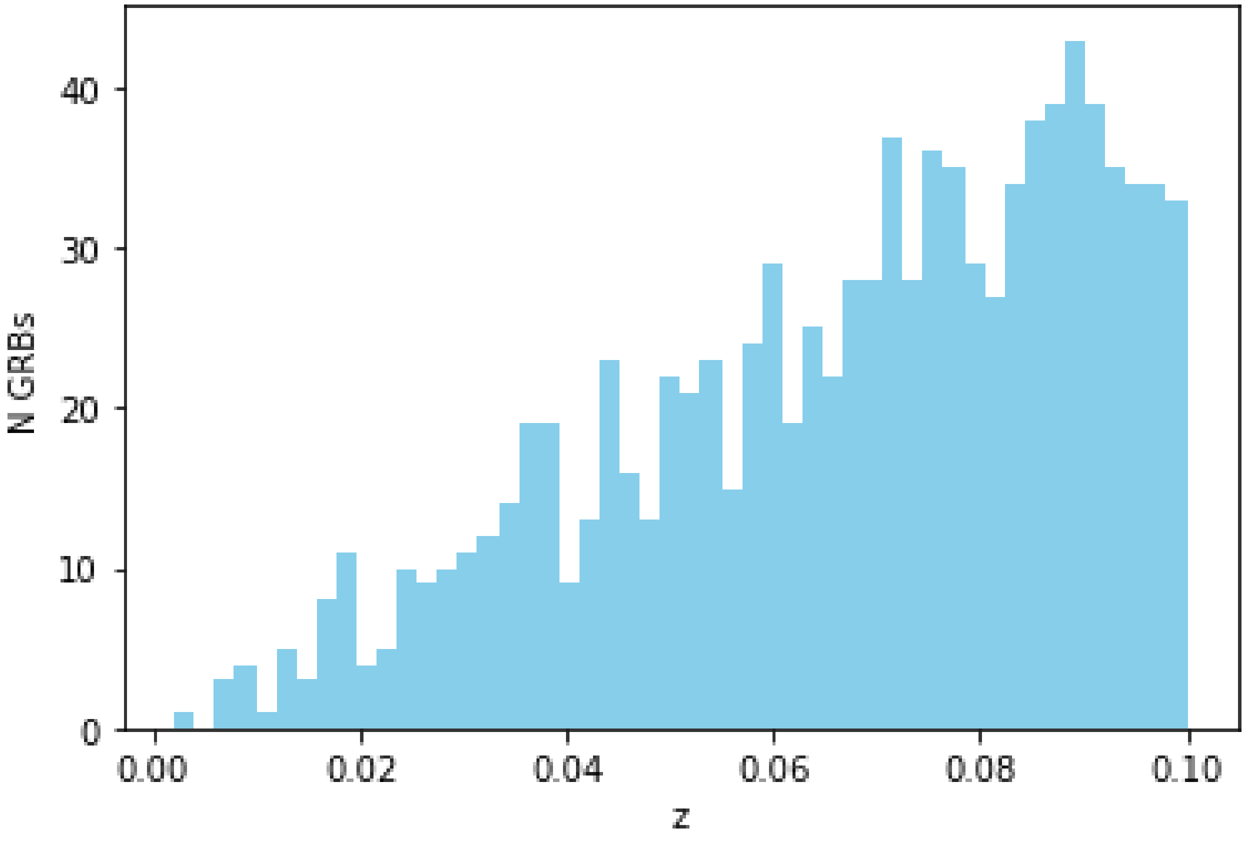
SOME SIMULATIONS FOR SHORT GRBS

Goal: To simulate somewhat realistic distributions for short GRBs

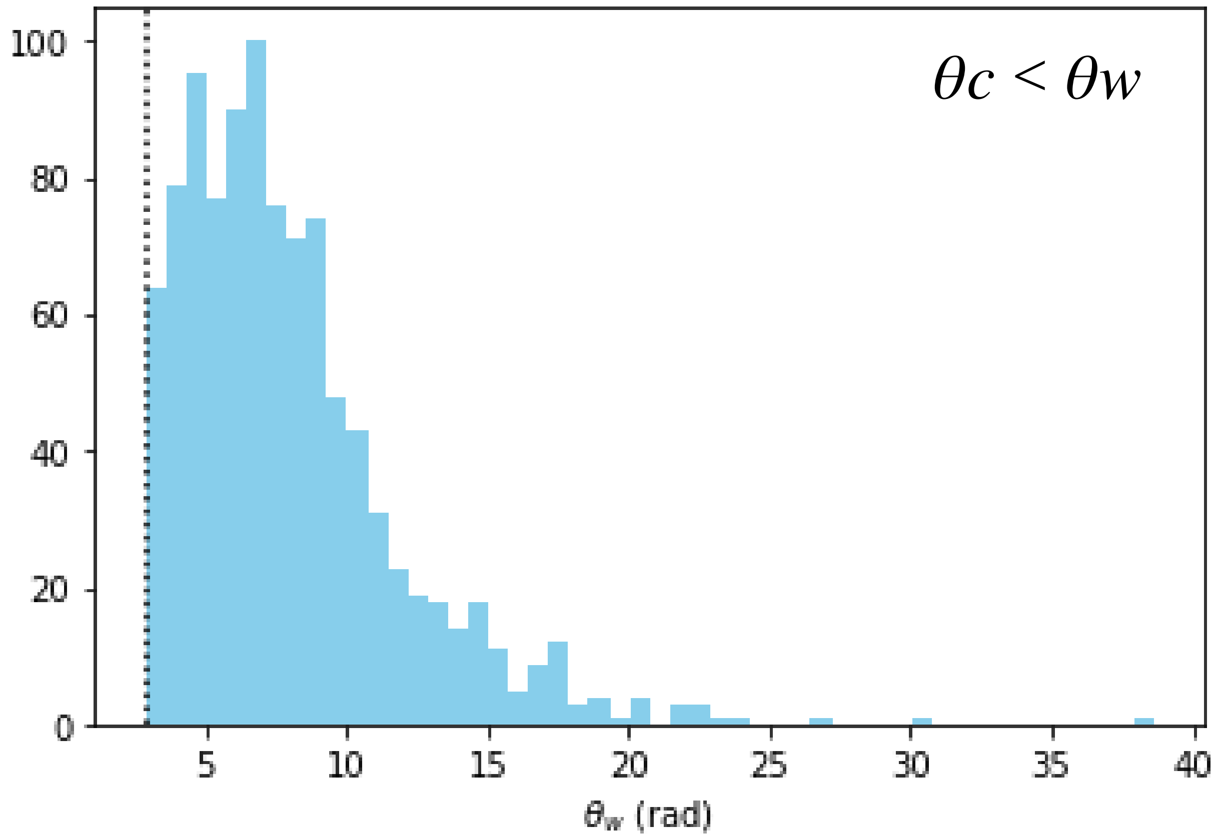
Studied parameters:

- **Core angle θc:** 2.86 and 8.60 degrees
- **Circumburst density n0:** uniform distribution [0.001 ; 1.0] cm^-3
- **Observer angle θobs:** uniform distribution [0 ; π/2] radians

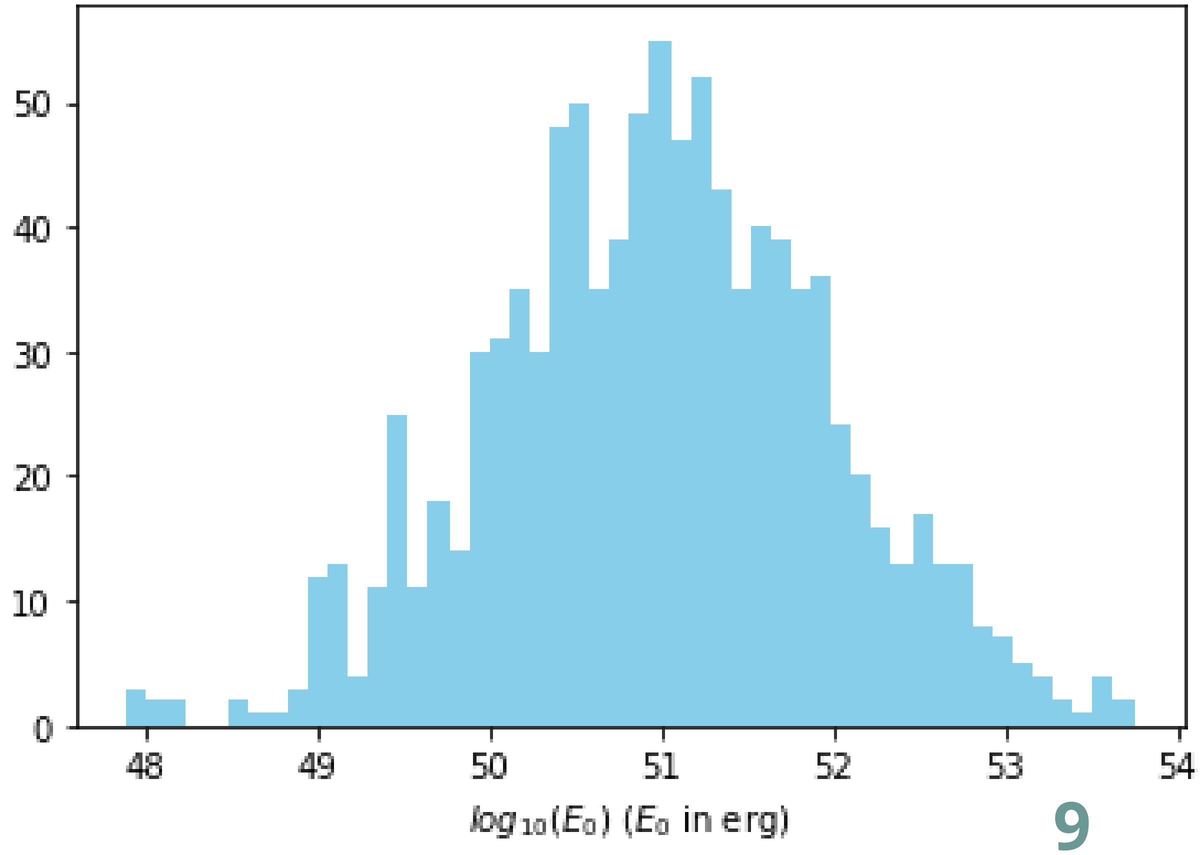
Redshift z



Truncature angle θw



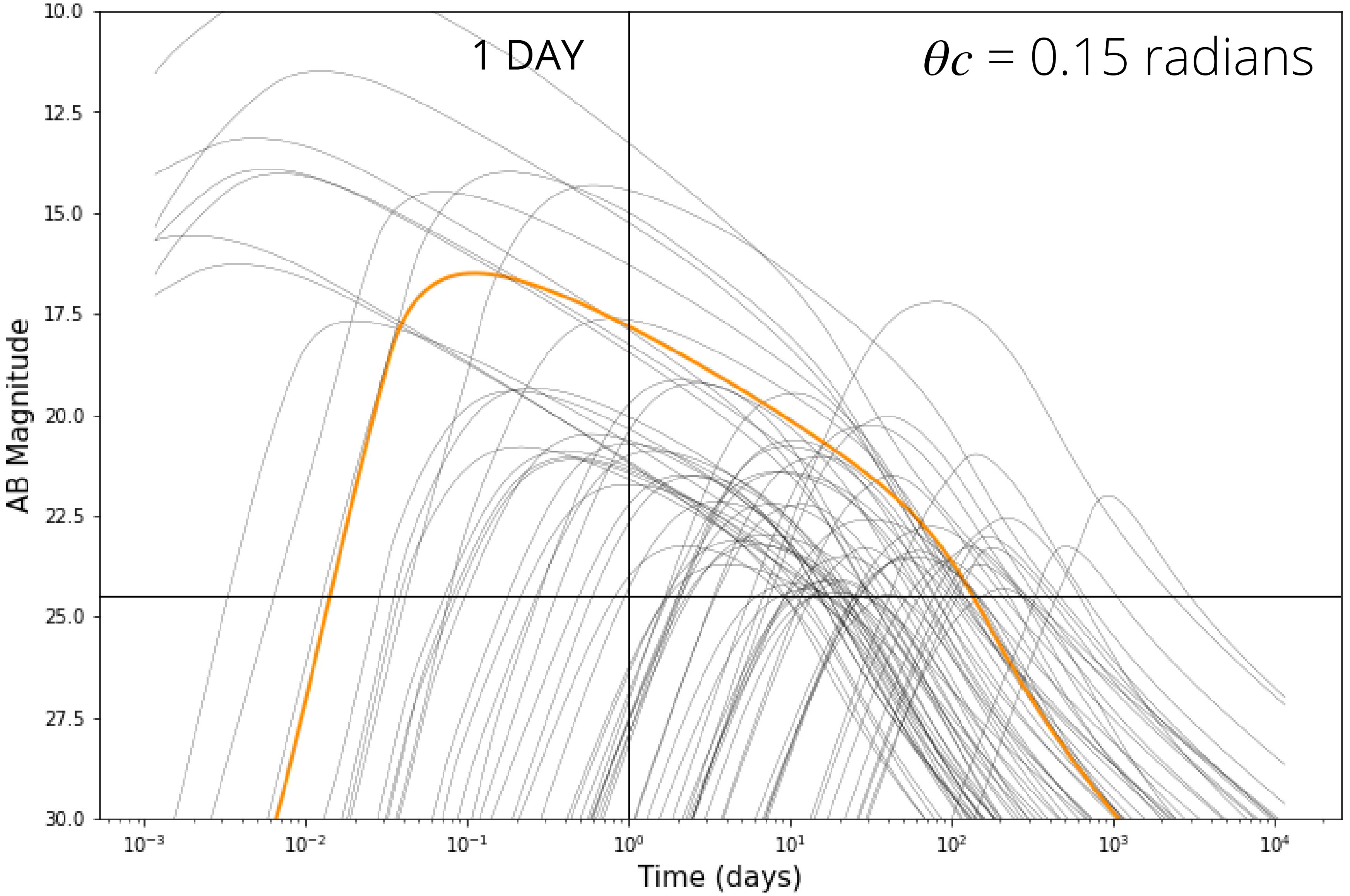
Isotropic equivalent energy E0



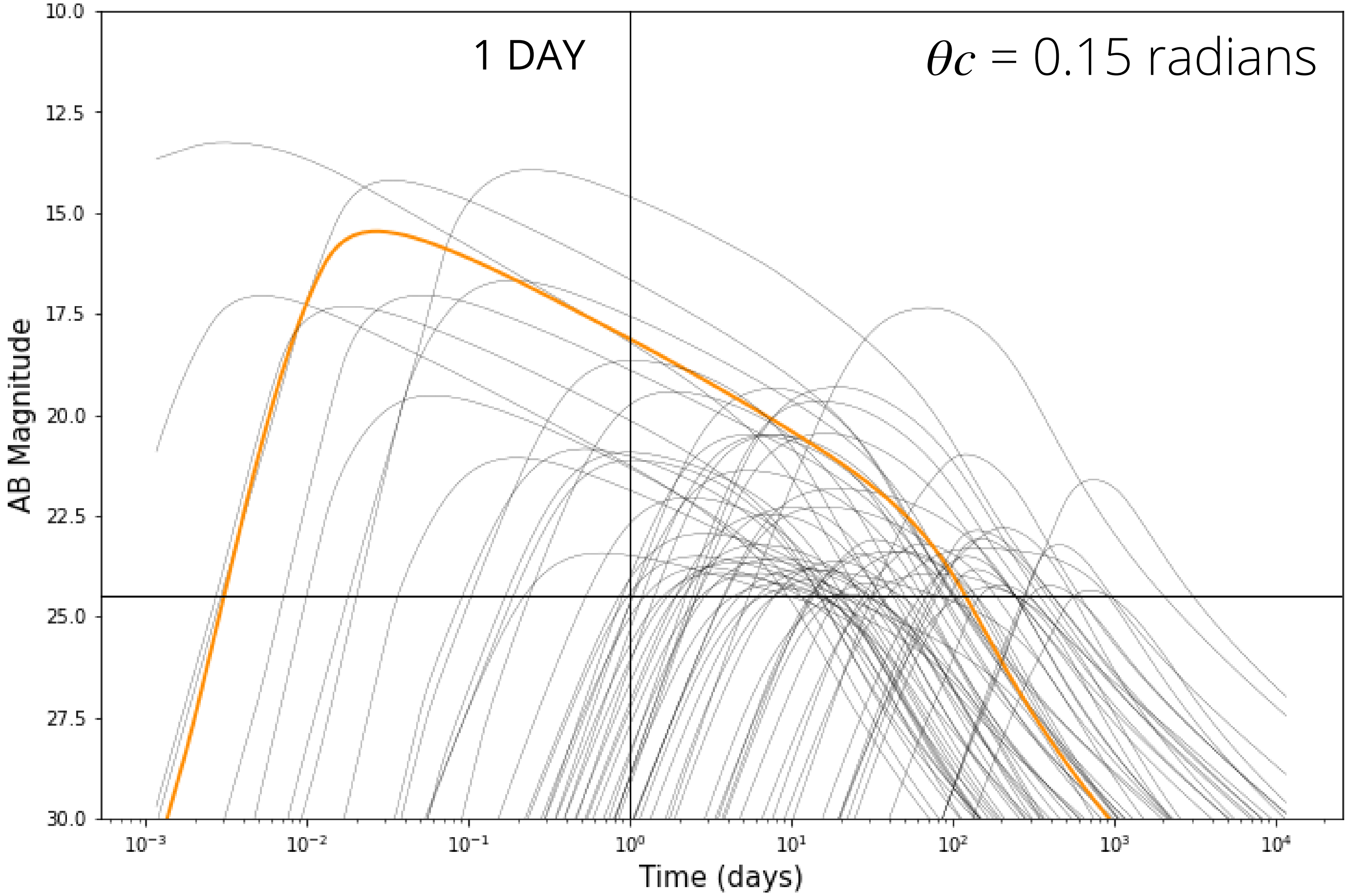
SIMULATED LIGHT CURVES FOR OFF-AXIS AFTERGLOWS

(OFF-AXIS OBSERVABLE MORE THAN 7 DAYS)

TOP-HAT JET



POWER-LAW JET



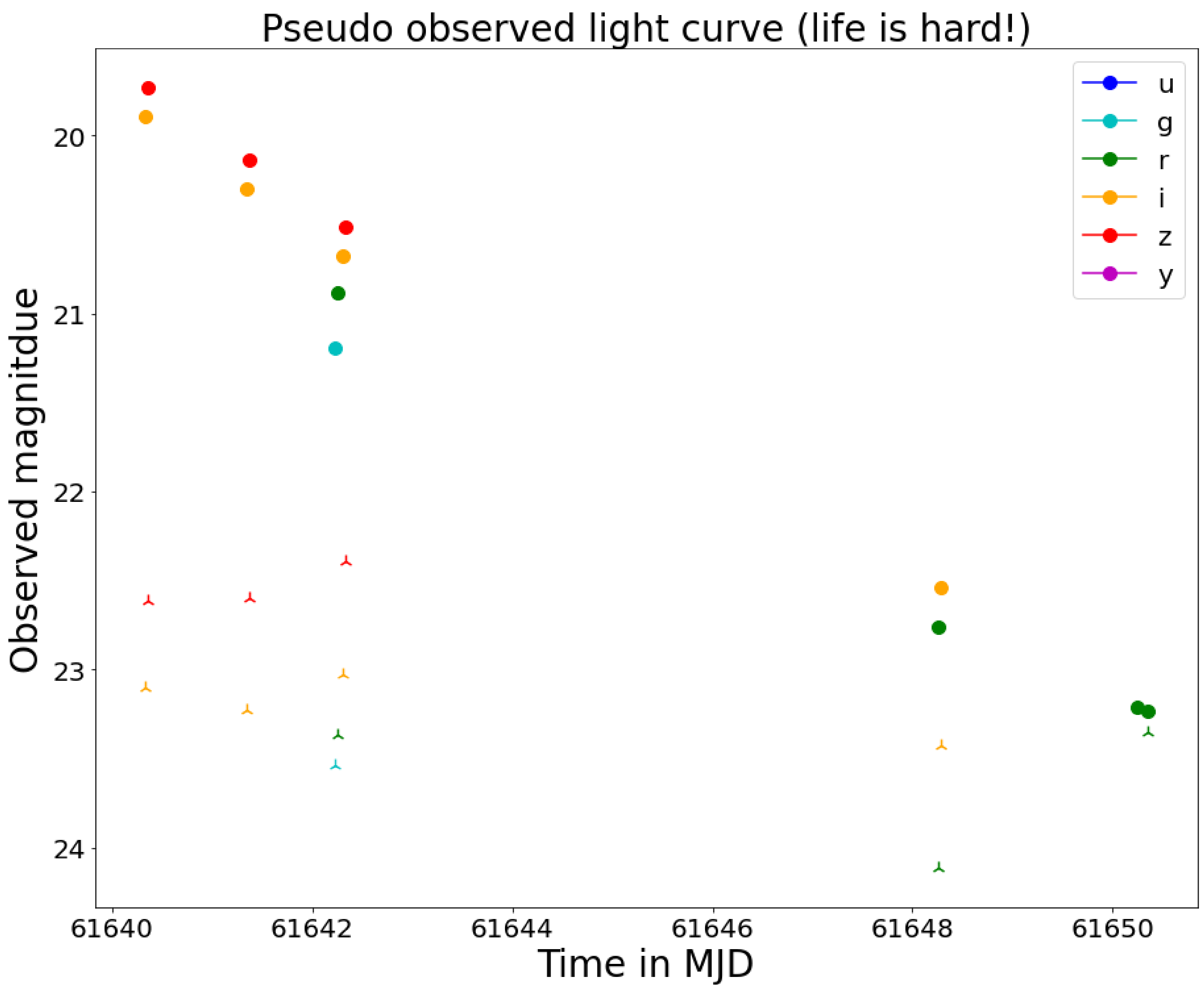
$\Longrightarrow$ **Large diversity of light curves:** faint and long OAs + bright and short OAs

$\Longrightarrow$ **Not obvious impact of the jet structure on observability**

PSEUDO OBSERVATIONS WITH THE RUBIN_SIM PACKAGE

With rubin_sim:

1- Take time and ra/dec of GRB270817 ("future" GW170817)
2- Keep only observations inside the Rubin/LSST field of view (angular separation < 1.7 degree)
3- Compute observation time in the GRB time frame
4- Compute spectra at observation time bins in magnitude
5- Keep only "real" observation for the right filter
6- Plot pseudo observed light curve



CONCLUSION AND PERSPECTIVES

afterglowpy package easily calculates light curves and spectra of OAs:

⟹ Large parameters space (E0, n0, θc, θw, θobs, z)

⟹ Observability of an OA not trivial!

"Rough" simulations of a "rough" population of GRBs:

⟹ Need of a complex filter

Perspectives

- To simulate “true” pseudo-observations with the rubin_sim package: scheduler, filters, air mass, night sky conditions...
- To generate pseudo-alerts for the alert broker **FINK**
- To develop a filter for FINK to identify OAs

All the codes can be accessible at:

https://gitlab.in2p3.fr/johan-bregeon/orphans

THANK YOU FOR YOUR ATTENTION !