COLIBRI scientific performances

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CENTRE NATIONAL D'ÉTUDES SPATIALES

Région Provence Alpes Côte d'Azur

Outline

OVERVIEW

- Observatory availability: 90%
- Median seeing: about 0.8"
- Primary mirror: 1.3m
- Delay for pointing: $\lesssim$ 30 seconds (goal: 20s)
- Dedicated follow-up telescope for SVOM
- 2 (goal 3) simultaneous arms:
  - FoV: 26' in VIS, 21.7' in NIR
  - spectral coverage: 400-1700 nm

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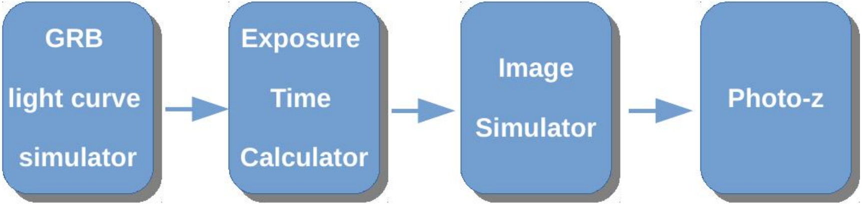
Main requirements

- Precision of localisation: $< 0.5''$
- Limiting magnitude:
  - 30s: R=19.2, J=18 (AB mag)
  - 5min: R=22, J=20 (AB mag)
- Delivering redshift estimation 5 minutes after start of observations

END-TO-END SOFTWARE



- GRB light curve modelling: Empirical and synchrotron model
- Exposure Time Calculator: T_{exp}, SNR, limiting magnitude
- Image Simulator: insert GRB in realistic FoV
- Photometric redshift code
- open source

Exposure Time Calculator

- Compute T_{EXP}, SNR, limiting magnitude
- Transmission of each optical element
- Detector characteristics
- Easily adaptable to other telescopes
- Developed to
  - compare different instrument designs
  - observation preparation tool

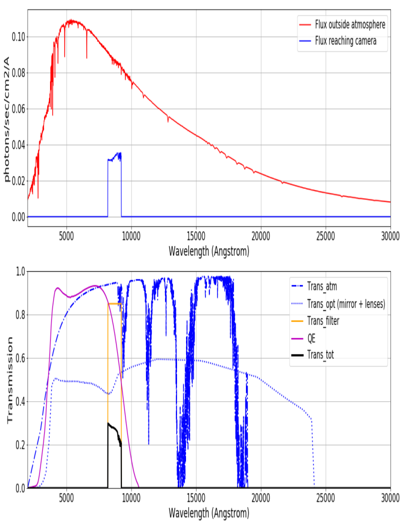


IMAGE SIMULATOR

- Realistic Point Spread Functions
- Querying astronomical sources catalogues
- Position a GRB in realistic FoV
- Easily adaptable to other telescopes
- Developed to feed and test the reduction pipeline

ILLUSTRATION FOR GRB 170817A

Outline

COLIBRI: a ground follow-up telescope for SVOM

COLIBRI's sensitivity

Estimation of photo-z accuracy

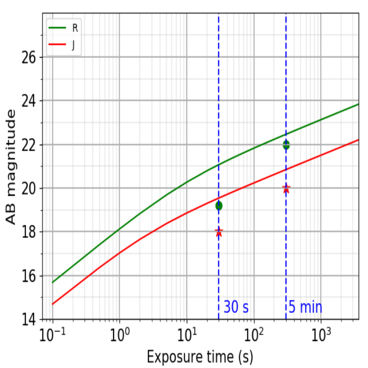
SCIENTIFIC PERFORMANCES: 1/3

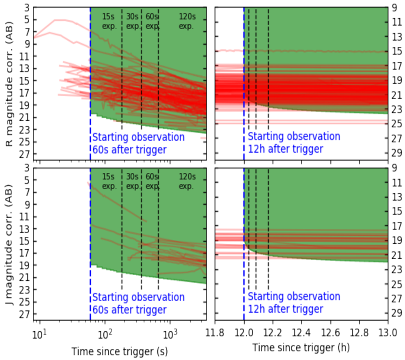
Estimated 5 σ limiting magnitudes

- 30s: r=19.2, J=18 (AB mag)
- 5min: R=22, J=20 (AB mag)

band	5s	30s	5min	1h
gri	20.42	21.57	22.83	24.19
zy	18.76	19.94	21.21	22.57
B	19.35	20.80	22.08	23.43
g	19.74	21.12	22.40	23.76
r	19.65	21.02	22.30	23.66
i	19.26	20.54	21.81	23.17
z	18.60	19.87	21.14	22.49
y	17.65	18.99	20.27	21.63
J	18.16	19.32	20.58	21.93
H	17.68	18.69	19.95	21.30

SCIENTIFIC PERFORMANCES: 2/3

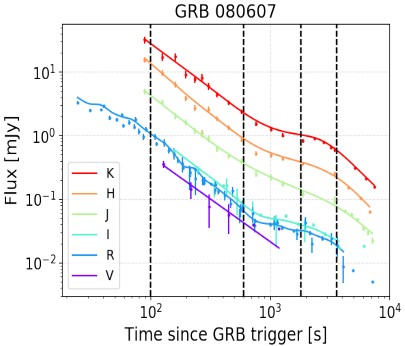




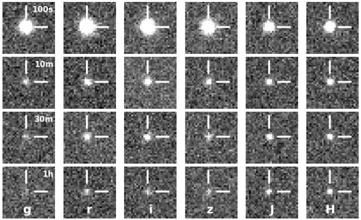
- Limiting magnitudes requirement satisfied
- at least 2.5 mag deeper at early times compared to previously detected GRBs

Scientific performances: 3/3

- Ability to detect high-z, dusty GRB: GRB 080607 with $A_V \sim 2.33$ mag at z=3.03



Stack of 30s exposures



Outline

COLIBRI: a ground follow-up telescope for SVOM

COLIBRI's sensitivity

Estimation of photo-z accuracy

Photo-z: Method

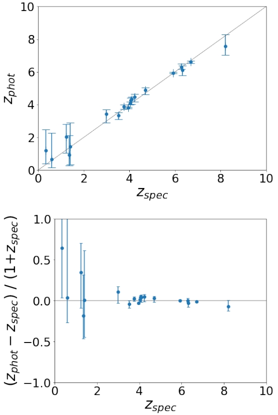
Method

MCMC algorithm based on detection of spectral signatures: Ly-α transition and Lyman break at 1216$\times$(1+z) and 912$\times$(1+z) Å

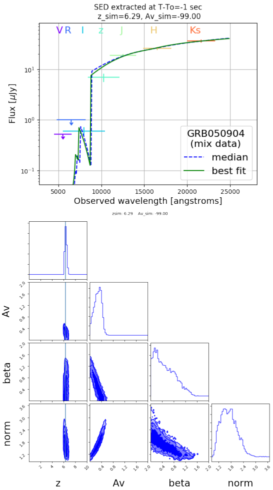
Illustration

- $F_{mod} = F_0 \times (\frac{\lambda}{\lambda_0})^{\beta} \times exp\left[-\tau_{dust}(z, A_V^{host}) - \tau_{IGM}(z)\right]$
- F_0= 1 mJy , β=0.66, MW extinction curve with A_V=0.5 mag, only redshift varies

PHOTO-Z: VALIDATION USING 19 GRBS SED



$$z > 3: \frac{z_{phot} - z_{true}}{1 + z_{true}} = -0.003 \pm 0.034$$



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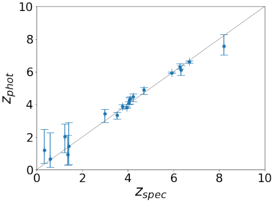
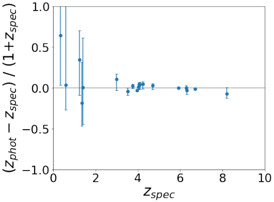
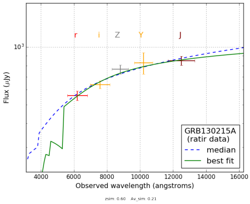
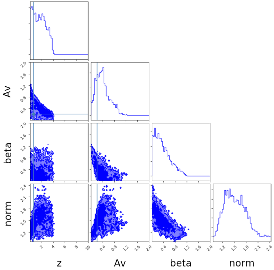








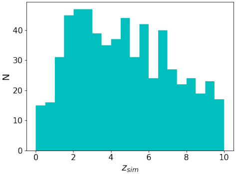
$$z > 3: \; \frac{z_{phot} - z_{true}}{1 + z_{true}} = -0.003 \pm 0.034$$

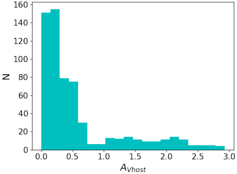
Mock sample

Goal

Estimate photometric redshift accuracy on a GRB mock sample

- 625 GRBs spanning $0 < z < 10$
- 25% GRBs with $A_V > 1$ mag
- Other parameters randomly drawn from distributions based on real observations





GRB light curve modelling

GRB intrinsic emission

Empirical Model

- $F_{em}(\lambda, t, \beta, \alpha) = F_0 \times (\frac{\lambda}{\lambda_0})^{\beta} \times (\frac{t}{t_0})^{\alpha}$

Theoretical Model

- Synchrotron model (Granot & Sari 2002)
- Governed by 7 parameters:
  - t: time
  - z: GRB redshift
  - E_{52}: total energy in the shell
  - p: index e- power-law distribution
  - ϵ_B: fraction shock energy $\Rightarrow$ B
  - ϵ_e: fraction shock energy $\Rightarrow$ e-
  - n_0: particle density

Flux attenuation along GRB l.o.s

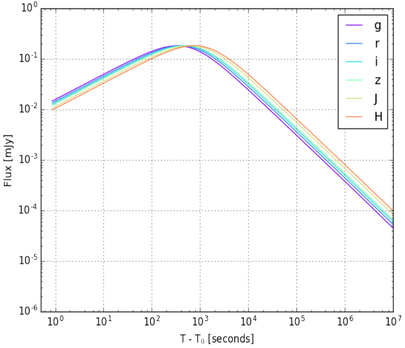
- Dust in Host galaxy + Inter Galactic Medium
- $F_{obs}(\lambda, t, \beta, \alpha, A_V, z) = F_{em}(\lambda, t, \beta, \alpha) \times exp\left[-\tau_{dust}(z, A_V^{host}) - \tau_{IGM}(z)\right]$

END-TO-END SIMULATION EXAMPLE

GRB intrinsic emission simulated with synchrotron model at z = 5

ATTENUATED BY:

- dust in Host galaxy (A_V=0.2 mag)
- IGM (z=5)
- Galactic extinction (A_V=0.1 mag)
- Earth atmosphere
- Telescope



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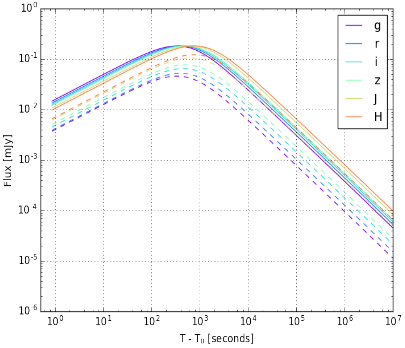

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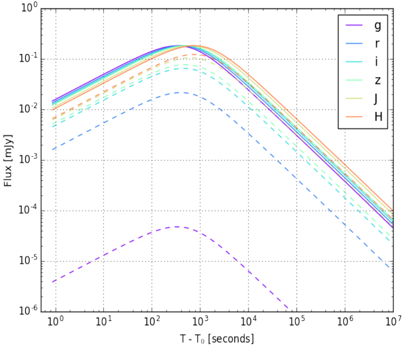

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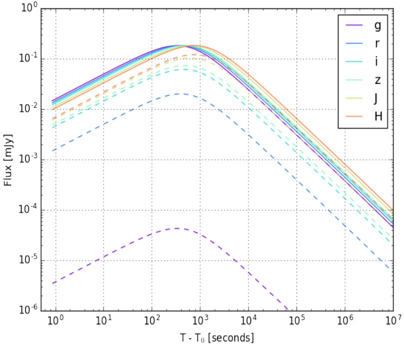

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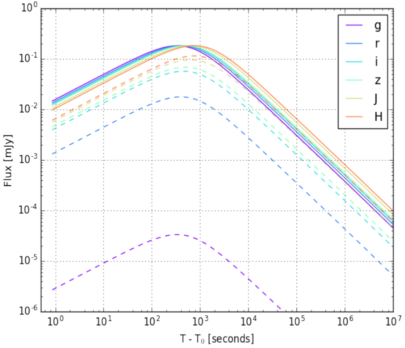

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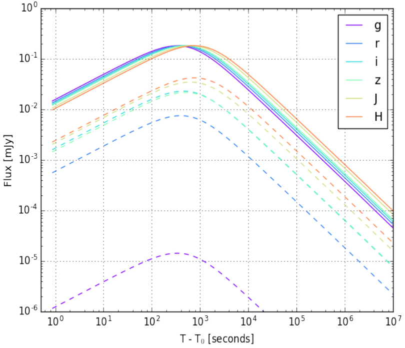
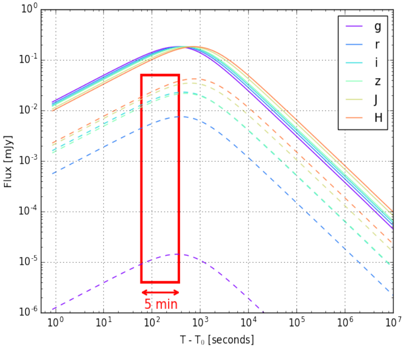


End-to-end simulation example

GRB intrinsic emission simulated with synchrotron model at z = 5

Focus on first 5min:

- Observation strategy
- COLIBRI response
- Fit light curve each band
- Extract SED
- Run MCMC
- Bayesian estimation of z, A_V, β



End-to-end simulation example

GRB intrinsic emission simulated with synchrotron model at $z = 5$

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Sequence	Time since burst s	Exposure time s	band
1	60	30	gri
1	60	30	zy
1	60	30	J
2	90	30	r
2	90	30	z
2	90	30	H
3	120	30	i
3	120	30	y
3	120	30	J
4	150	30	z
4	150	30	g
4	150	30	H
5	180	30	y
5	180	30	r
5	180	30	J
6	210	30	g
6	210	30	i

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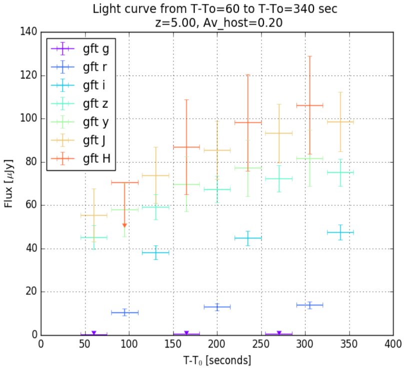

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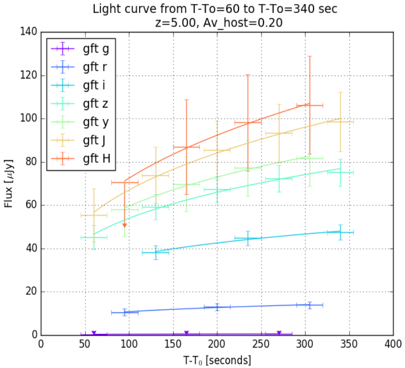

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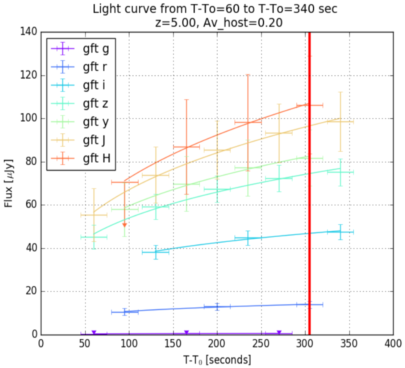

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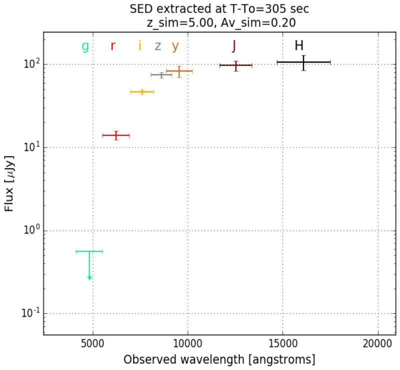

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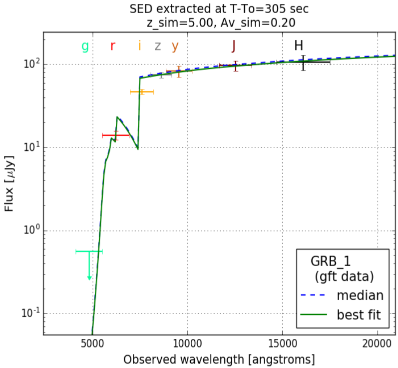

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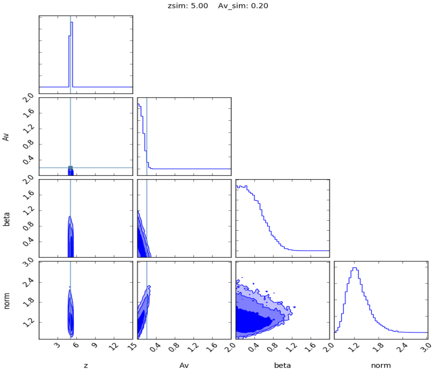
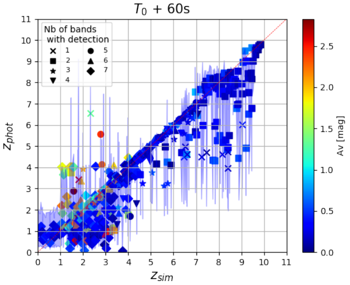
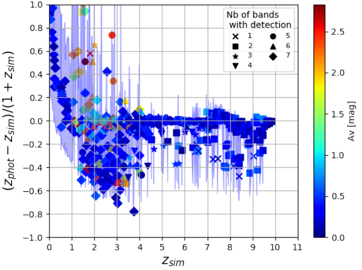


Mock sample results

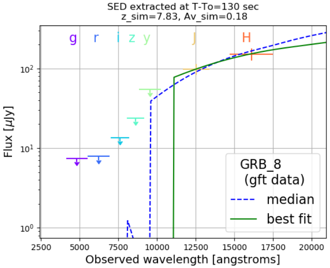
GRB light curve simulated for 5min starting at T_0+1min for a given observation strategy

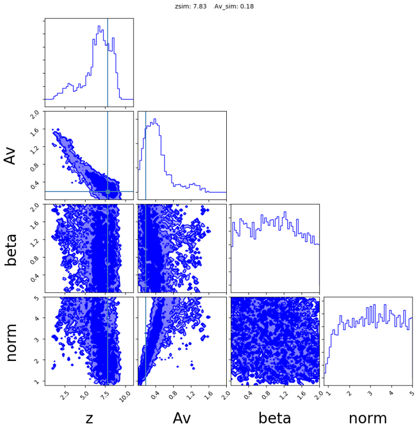




	nb of detections	$z_{phot} - z_{true}$	$\left(z_{phot} - z_{true}\right) / (1 + z_{true})$
z < 3.5	207 / 238 (87%)	-0.21 ± 1.11	0.0 ± 0.42
3.5 ≤ z ≤ 8	243 / 304 (80%)	-0.14 ± 0.49	-0.03 ± 0.10
z > 8	61 / 83 (73%)	-1.21 ± 1.32	-0.13 ± 0.14
A_V > 1 mag	94 / 125 (75%)	-	-

Mock sample results

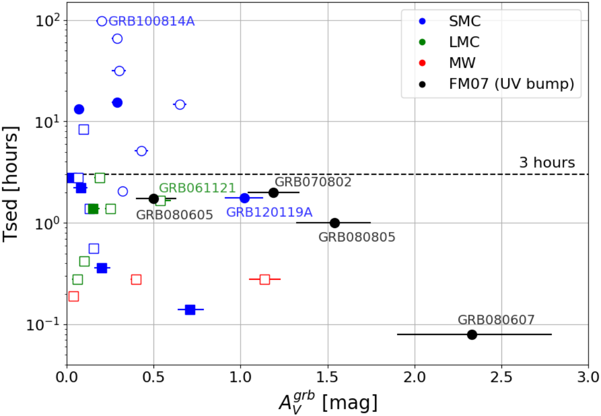




SUMMARY

- Development of an end-to-end software to assess COLIBRI's sensitivity. (Adaptable to other optical/NIR telescopes)
- Development of a Bayesian photometric redshift code validated on real GRB SEDs
- COLIBRI's design fulfils requirements on sensitivity
- Relative accuracy on z_{phot}:
  - $3.5 < z < 8$: about 10%
  - $z > 8$: about 14%
- Due to its sensitivity and very rapid follow-up, COLIBRI will routinely detect GRBs suffering a high amount of visual extinction.

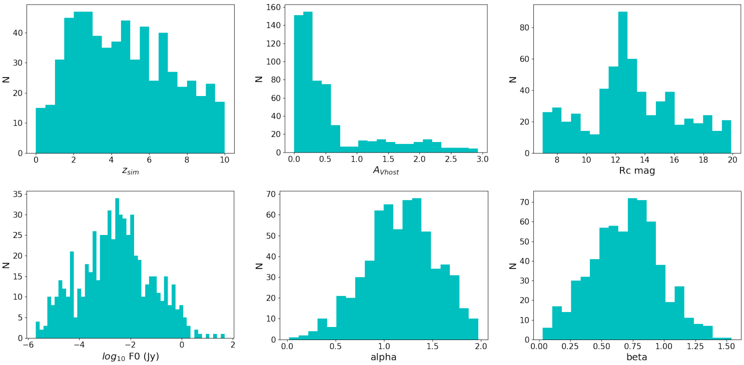
One interesting Perspective with COLIBRI:



Corre+18

Thank you!

Mock samples: Empirical model



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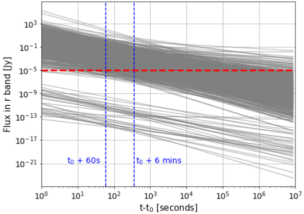
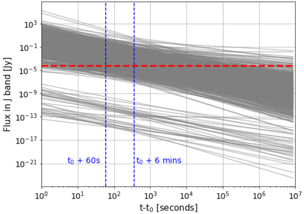
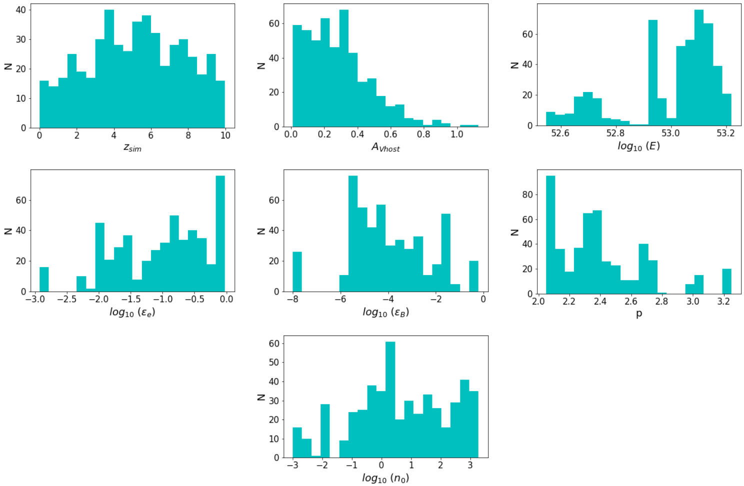




Mock samples: Theoretical model



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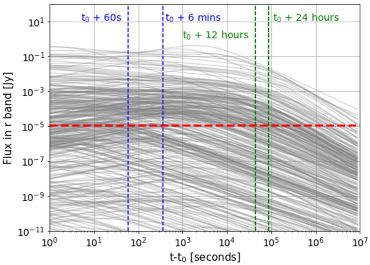
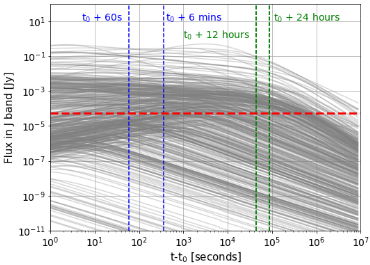
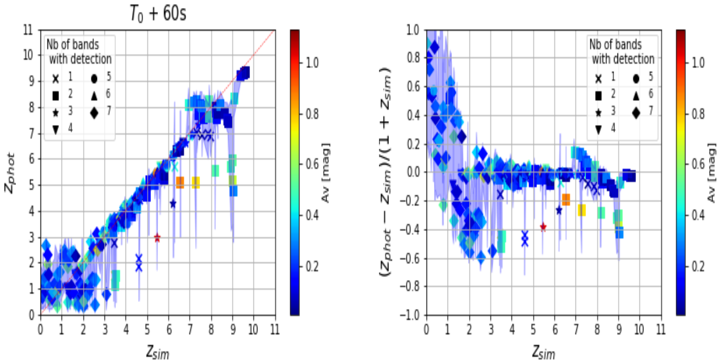




MOCK SAMPLES: THEORETICAL MODEL RESULTS



Mock samples: Empirical model

		nb of detections	$z_{phot} - z_{true}$	$\left(z_{phot} - z_{true}\right) / (1 + z_{true})$
without CAGIRE	$z < 3.5$	190 / 238 (80%)	-0.15 $\pm$ 1.29	0.03 $\pm$ 0.51
	$3.5 \leq z \leq 8$	199 / 304 (65%)	-0.14 $\pm$ 0.61	-0.03 $\pm$ 0.12
	$z > 8$	1 / 83 (1%)	-	-
	A_V > 1 mag	75 / 125 (60%)	-	-
with CAGIRE	$z < 3.5$	207 / 238 (87%)	-0.21 $\pm$ 1.11	0.0 $\pm$ 0.42
	$3 \leq z \leq 8$	243 / 304 (80%)	-0.14 $\pm$ 0.49	-0.03 $\pm$ 0.10
	$z > 8$	61 / 83 (73%)	-1.21 $\pm$ 1.32	-0.13 $\pm$ 0.14
	A_V > 1 mag	94 / 125 (75%)	-	-

Mock samples: Theoretical model

		nb of detections	$z_{phot} - z_{true}$	$\left(z_{phot} - z_{true}\right) / (1 + z_{true})$
	$z < 3.5$	97 / 138 (70%)	0.01 ± 0.89	0.11 ± 0.46
t_0+60s	$3.5 \leq z \leq 8$	137 / 279 (49%)	-0.07 ± 0.33	-0.01 ± 0.05
	$z > 8$	37 / 83 (23%)	-1.29 ± 1.31	-0.13 ± 0.13
	$z < 3.5$	63 / 138 (46%)	-0.11 ± 0.74	0.06 ± 0.48
t_0+12h	$3.5 \leq z \leq 8$	99 / 279 (35%)	-0.14 ± 0.45	-0.03 ± 0.09
	$z > 8$	11 / 83 (13%)	-1.10 ± 1.11	-0.11 ± 0.11
	$z < 3.5$	57 / 138 (41%)	-0.27 ± 0.79	-0.02 ± 0.34
t_0+24h	$3.5 \leq z \leq 8$	90 / 279 (32%)	-0.16 ± 0.36	-0.03 ± 0.07
	$z > 8$	10 / 83 (12%)	-1.21 ± 1.24	-0.12 ± 0.12