SVOM and COLIBRI synergy to characterize dust content of GRB host galaxies

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SVOM meeting, OHP, nov. 2021j

outline

- Introduction
- Astrophysical background: extinction curves and dust properties
- Extinction curves along the l.o.s of GRBs
- What can we do with photometric measurements? COLIBRI data
- Combination of UV-optical and X-ray data
- Further step: Extinction and attenuation curves of GRB hosts

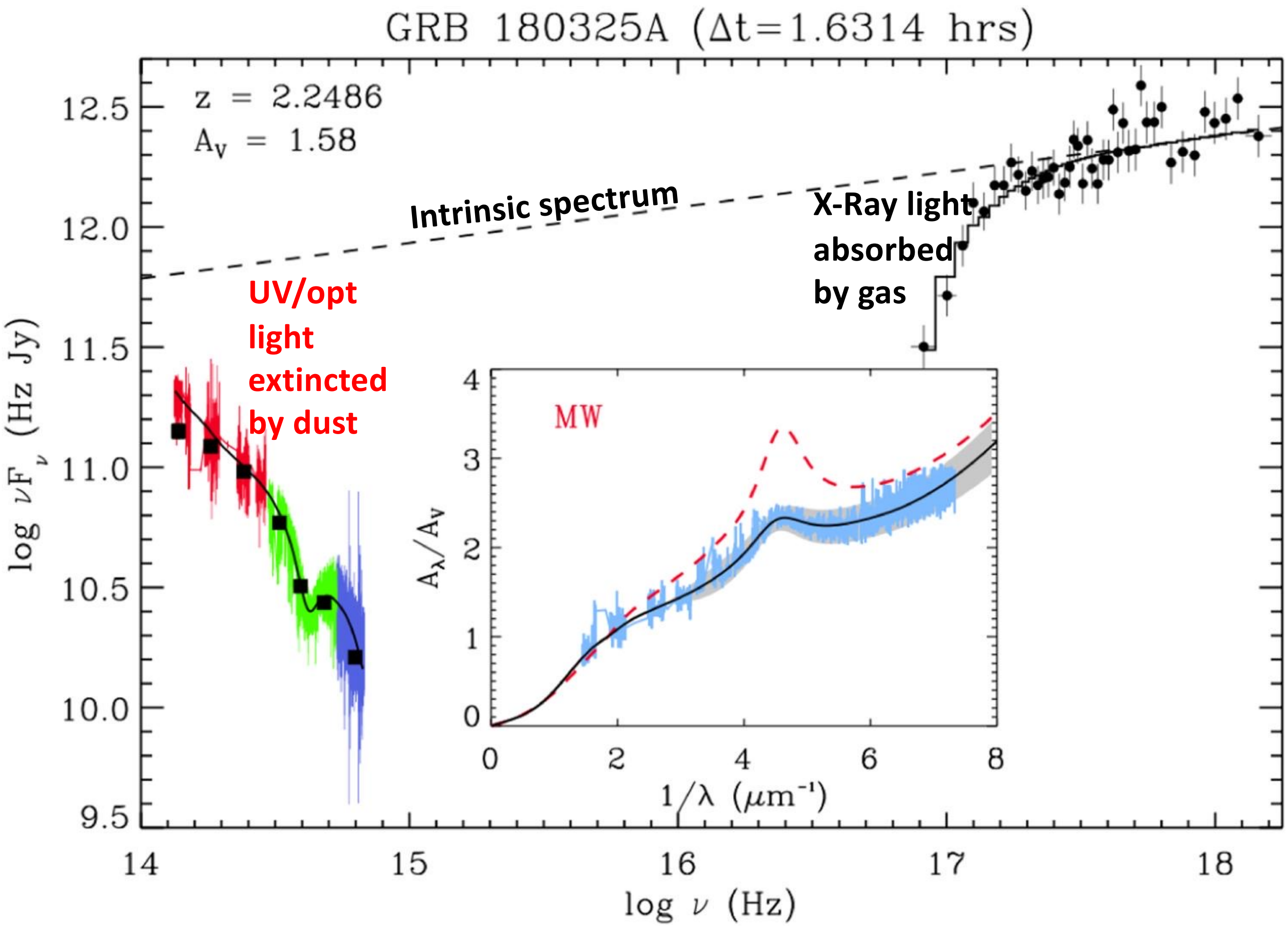
GRB as probes of galaxies interiors

Many advantages:

- Bright enough to reach very high redshifts
- Occur in dense media, and with sightlines representative of star forming regions
- Very simple and featureless intrinsic spectrum

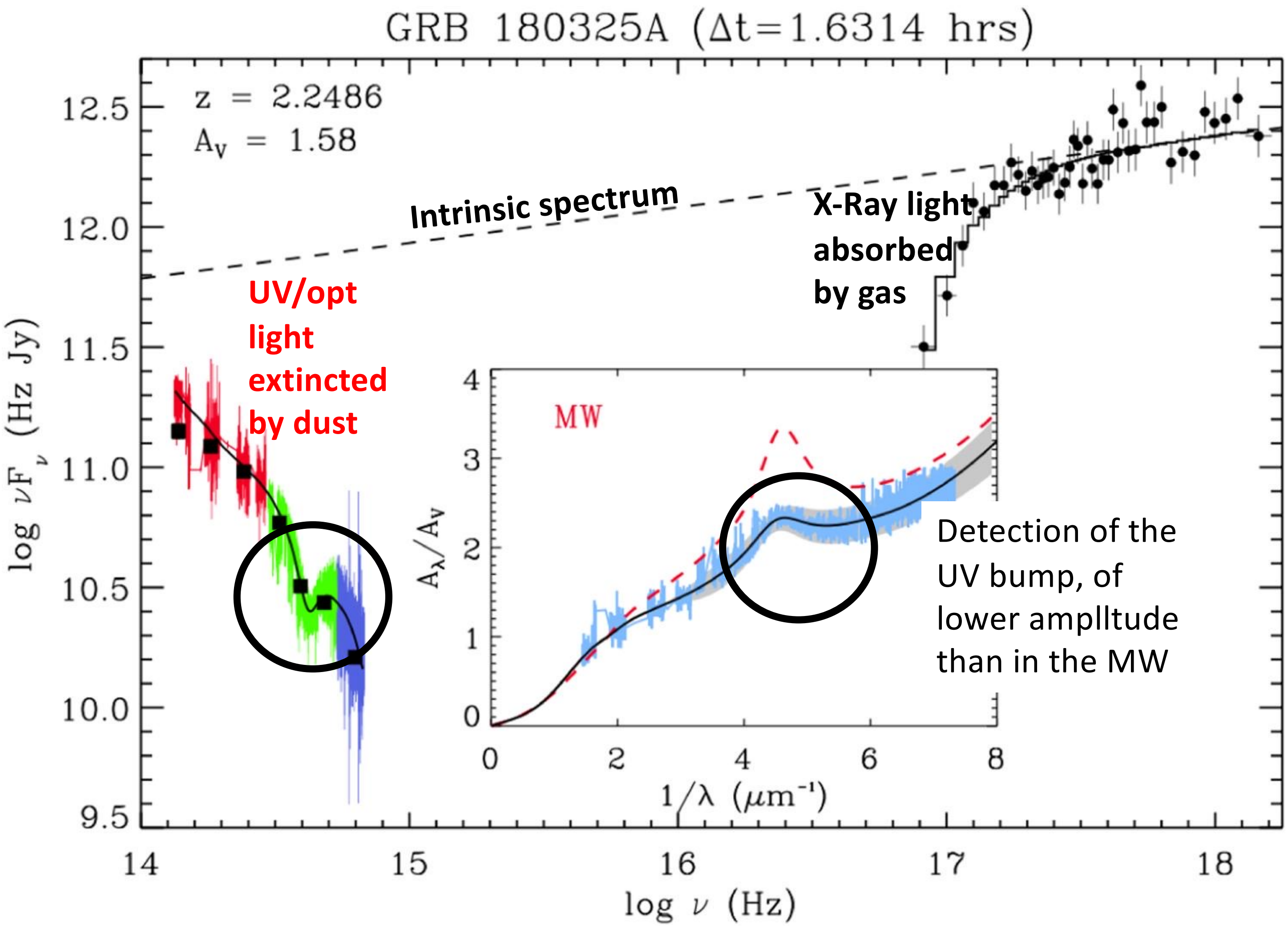
Some issues:

- Bright but fades rapidly
- Probes typical regions but the GRB can influence their (dust) content



GRB 180325A (Δt=1.6314 hrs)
z = 2.2486
A_V = 1.58
Intrinsic spectrum
X-Ray light absorbed by gas
UV/opt light extincted by dust
MW
A_λ/A_V
1/λ (μm⁻¹)
log νF_ν (Hz Jy)
log ν (Hz)

Zafar+18


GRB 180325A (Δt=1.6314 hrs)
z = 2.2486
A_V = 1.58
Intrinsic spectrum
X-Ray light absorbed by gas
UV/opt light extincted by dust
MW
Detection of the UV bump, of lower amplltude than in the MW
log νF_ν (Hz Jy)
log ν (Hz)
A_λ/A_V
1/λ (μm⁻¹)
12.5
12.0
11.5
11.0
10.5
10.0
9.5
14
15
16
17
18
0
1
2
3
4
6
8

Zafar+18

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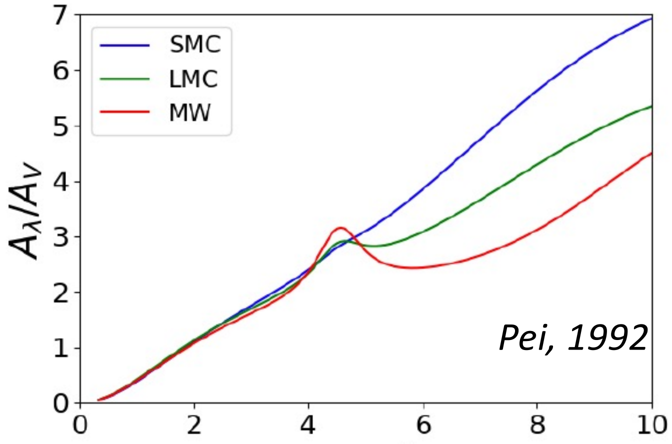
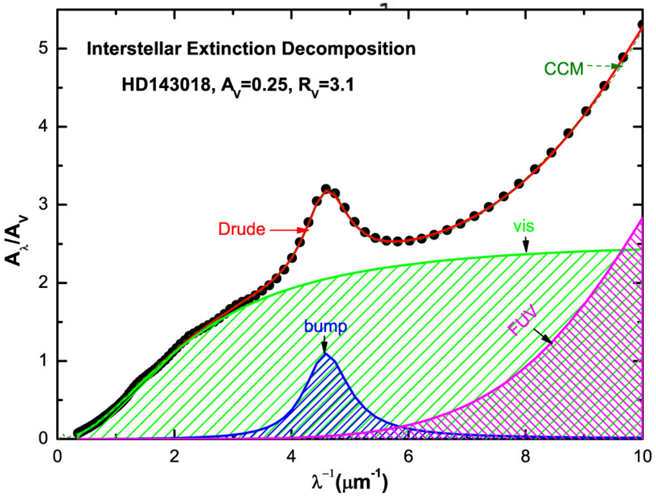
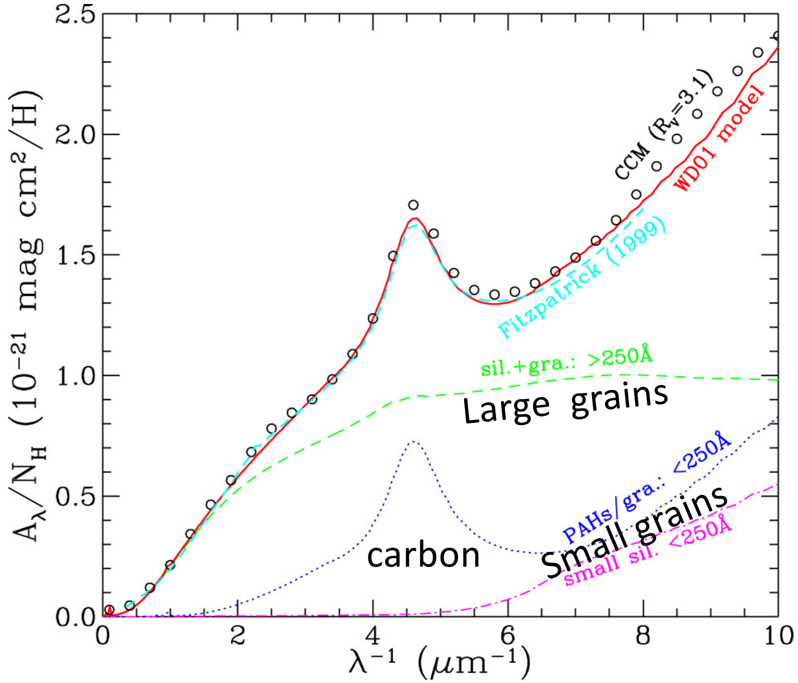
Extinction curves in the local group: taken as a reference, the only ones well measured along the l.o.s of individual stars

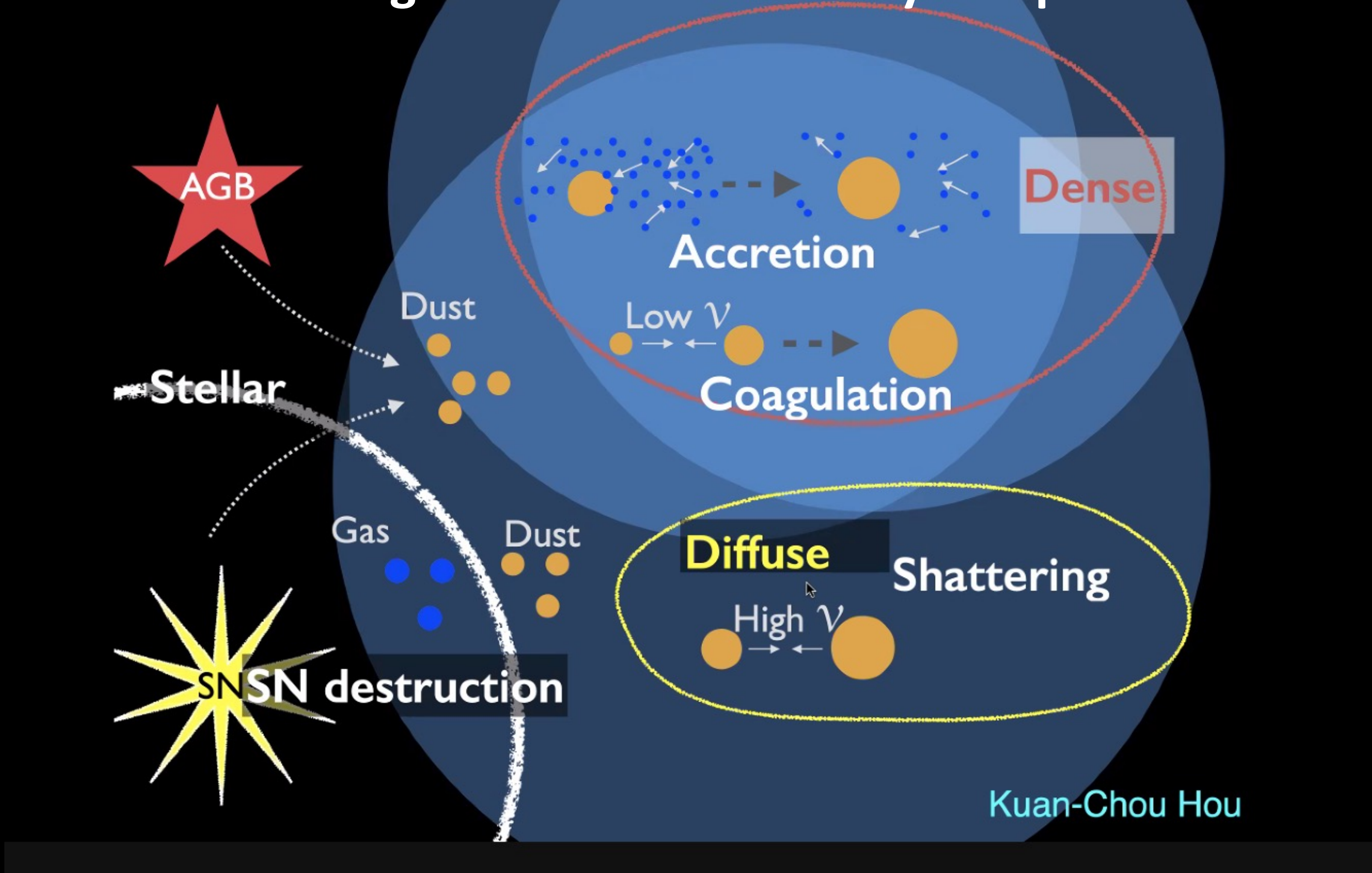




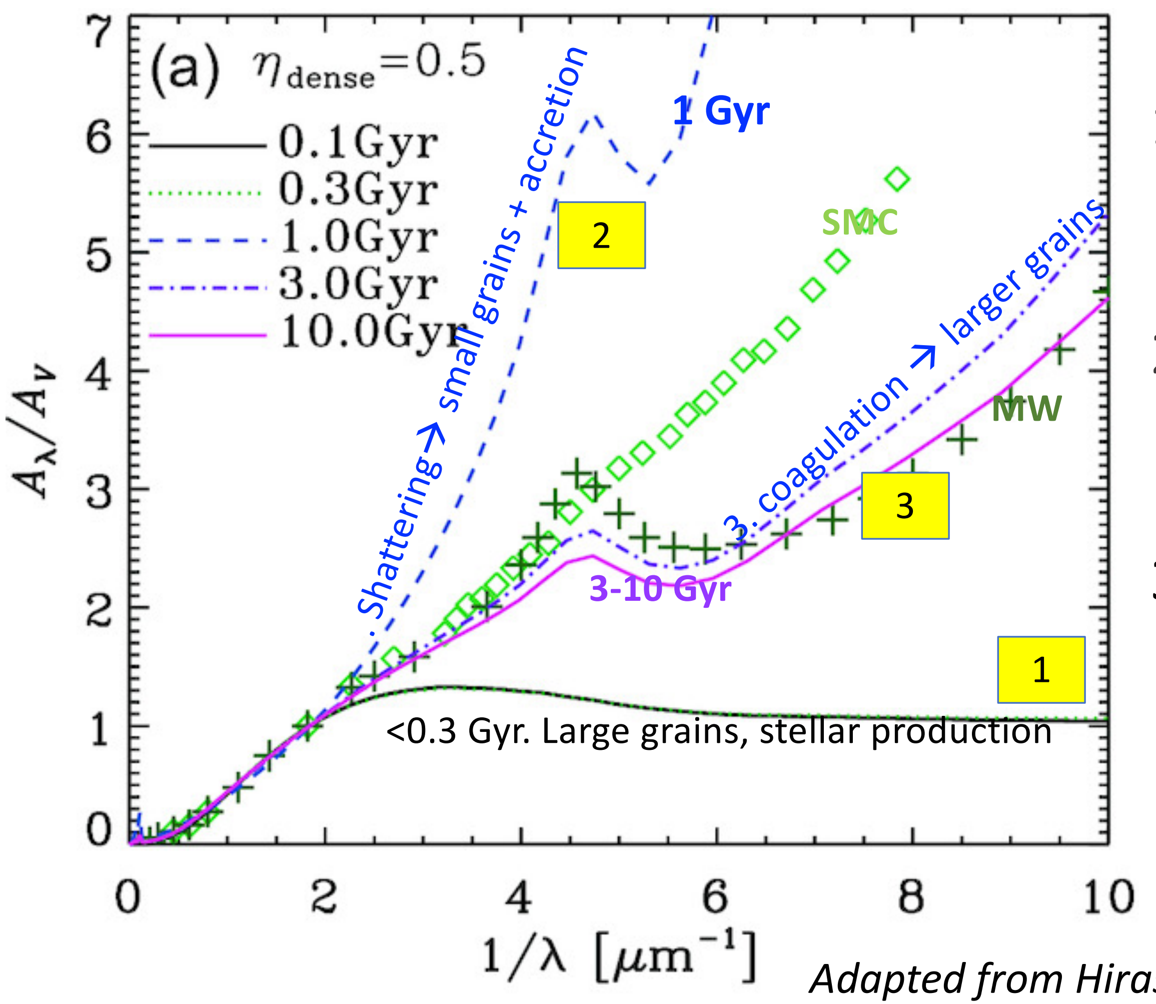


Xiang+14

Modelling dust evolution is very complexx



Evolutive sequence of the extinction curve



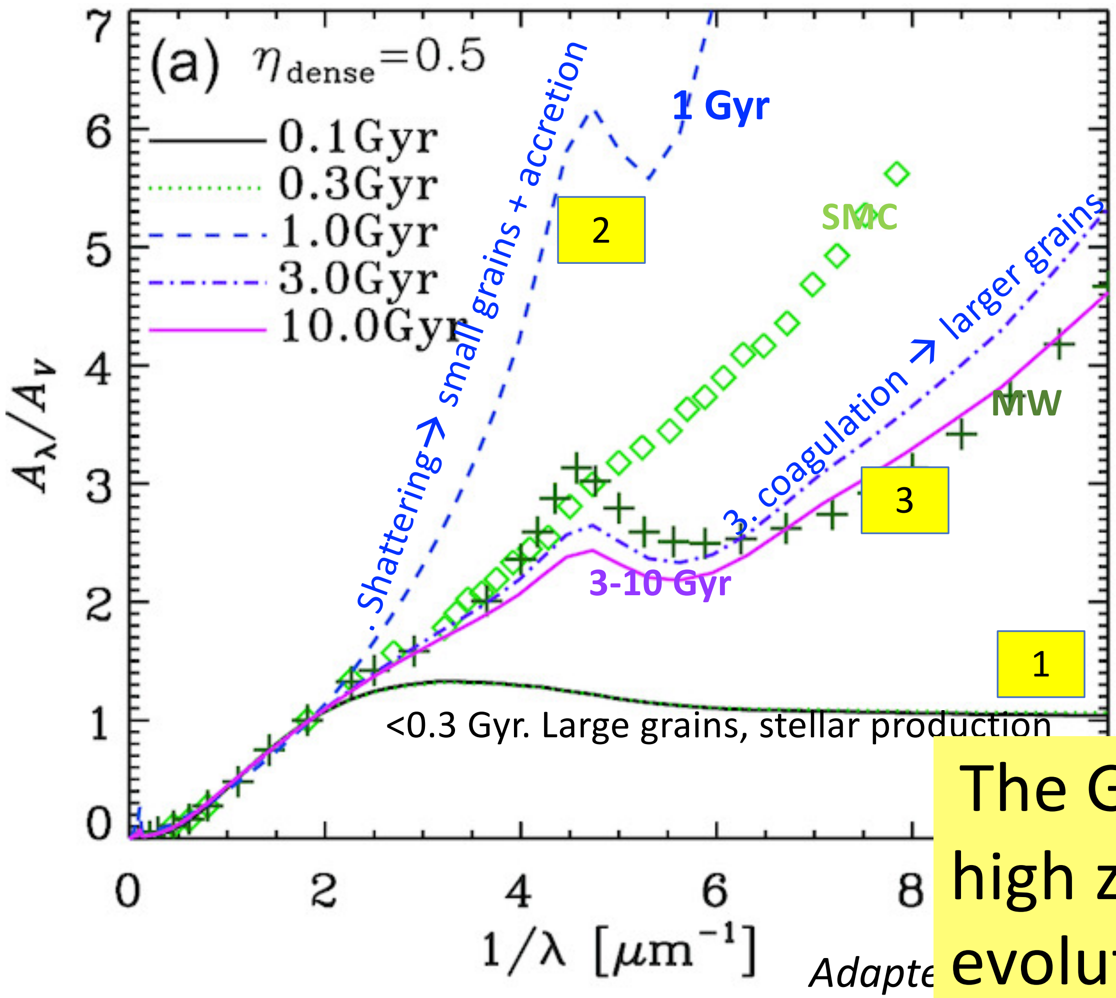
Adapted from Hirashita & Murga 2020

v. 2021j

3 main steps

1. Stellar dust production → large grains → **flat UV extinction curve**
2. Shattering and accretion → small grains→ **steep UV extinction curve**
3. Coagulation→ large grains → **flatter UV extinction curve**

Evolutive sequence of the extinction curve



Adapte

3 main steps

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The GRBs are observed up to very high z, can be used to study this evolution of the extinction curve

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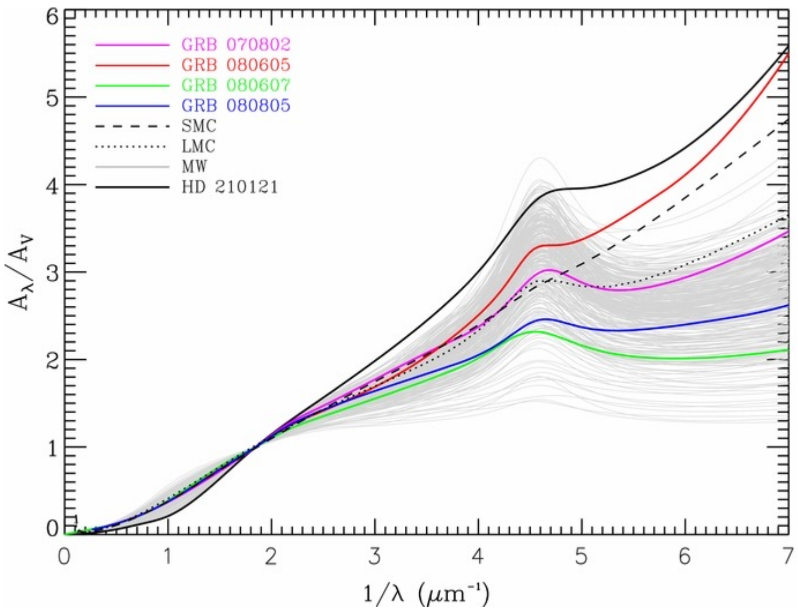
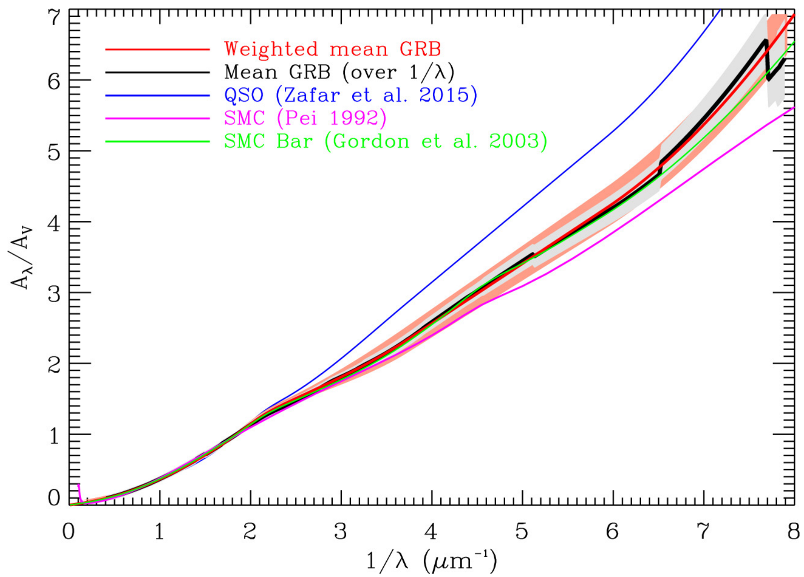
Extinction curves already measured along the line of sight of GRBs afterglows:

Mostly steep (SMC like or steeper), a few curves with UV bumps

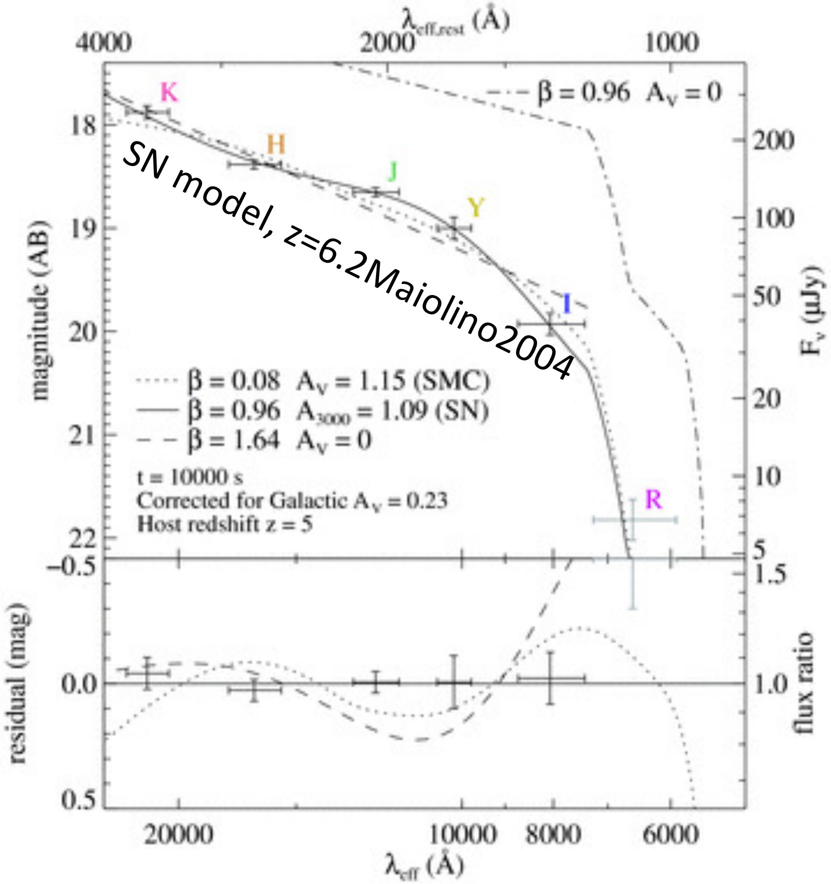


Zafar+12

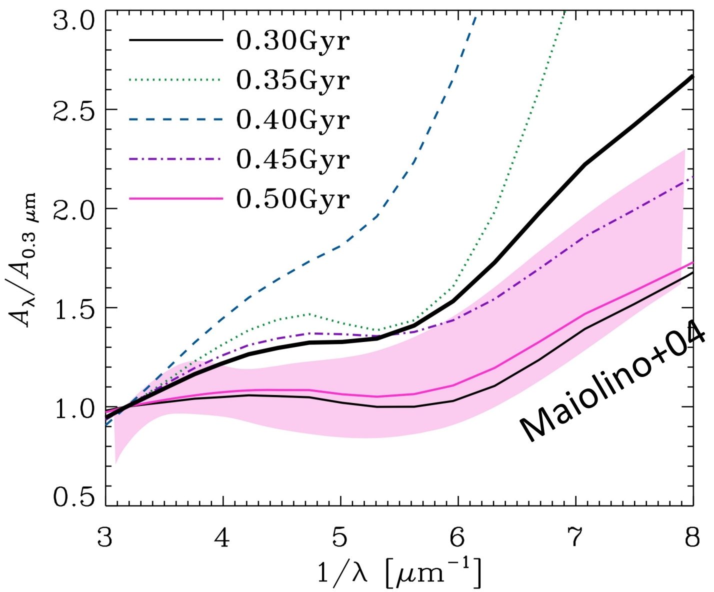


Average extinction curve for GRBs steeper than SMC, Zafar+18, 0.34<z<7.8

One GRB l.o.s best fitted with a flat (SNe like) extinction curve
GRB071025 z=5



Perley+10, see also Jang et al. 2011,
but see Bolmer+18

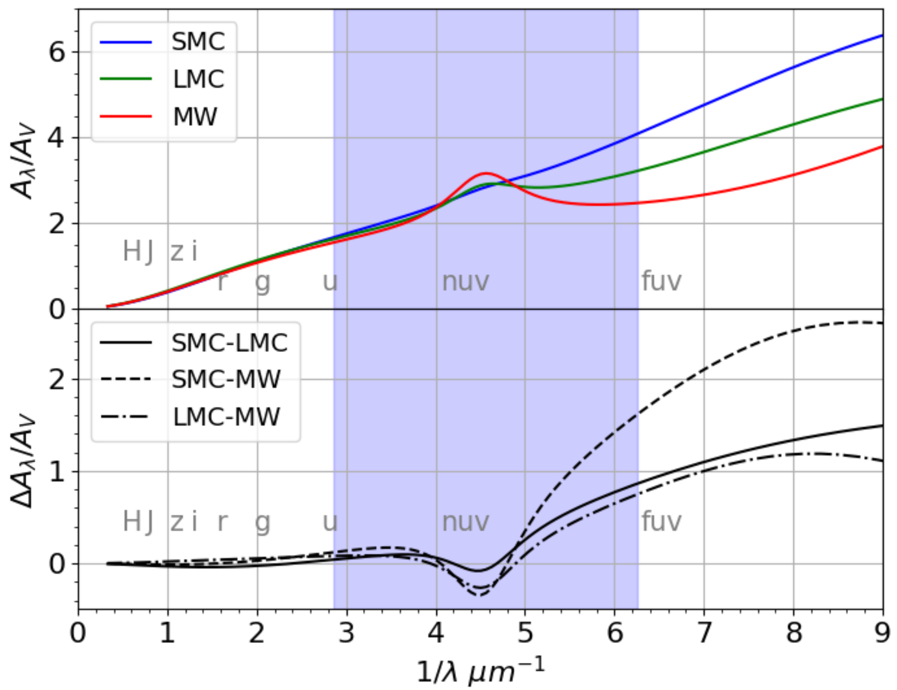


Hirashita & Murga 2020 :
young age SNe+small grains production, dense medium & short burst

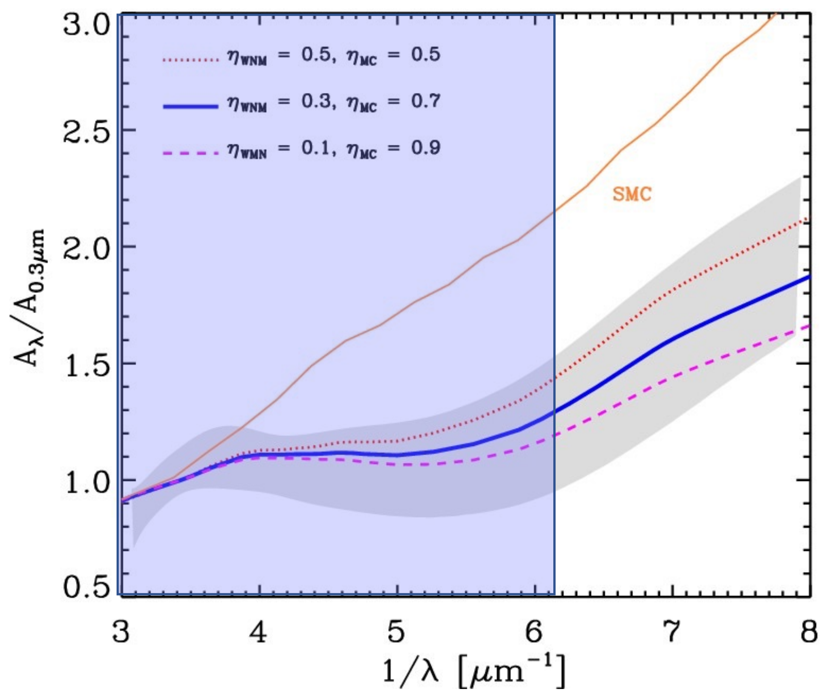
But Nozawa+15: old ages and coagulation

The UV rest-frame range is crucial to discriminate between different extinction curves

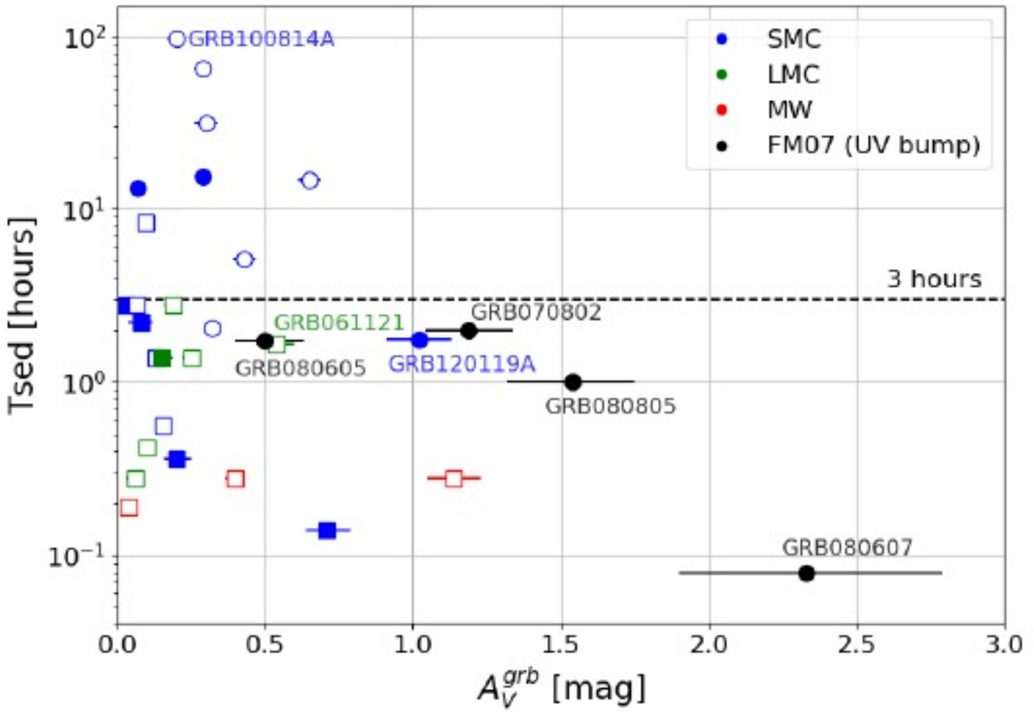
Local extinction curves



SNe versus SMC



The afterglow has to be observed less than 3 hours after the burst to get a large variety of extinction curves



Corre+18

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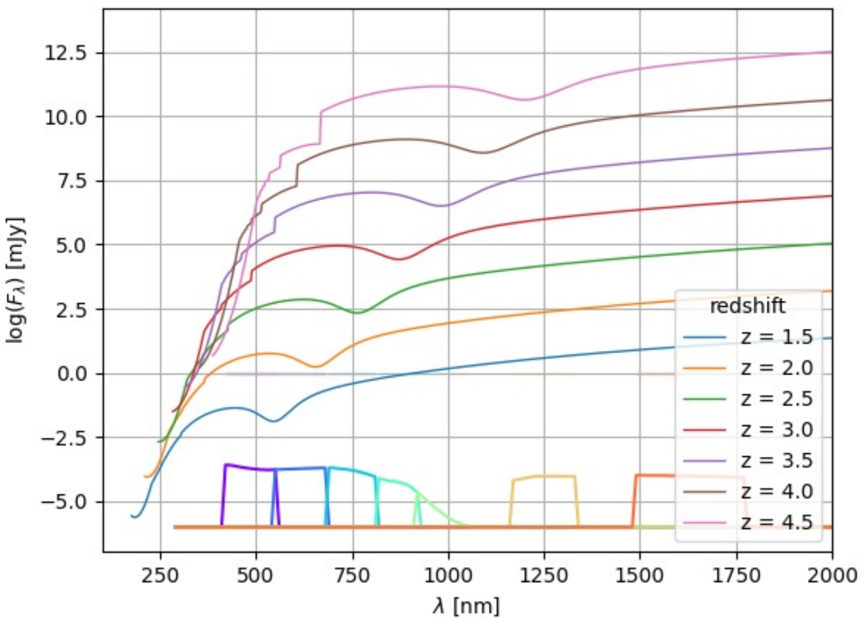
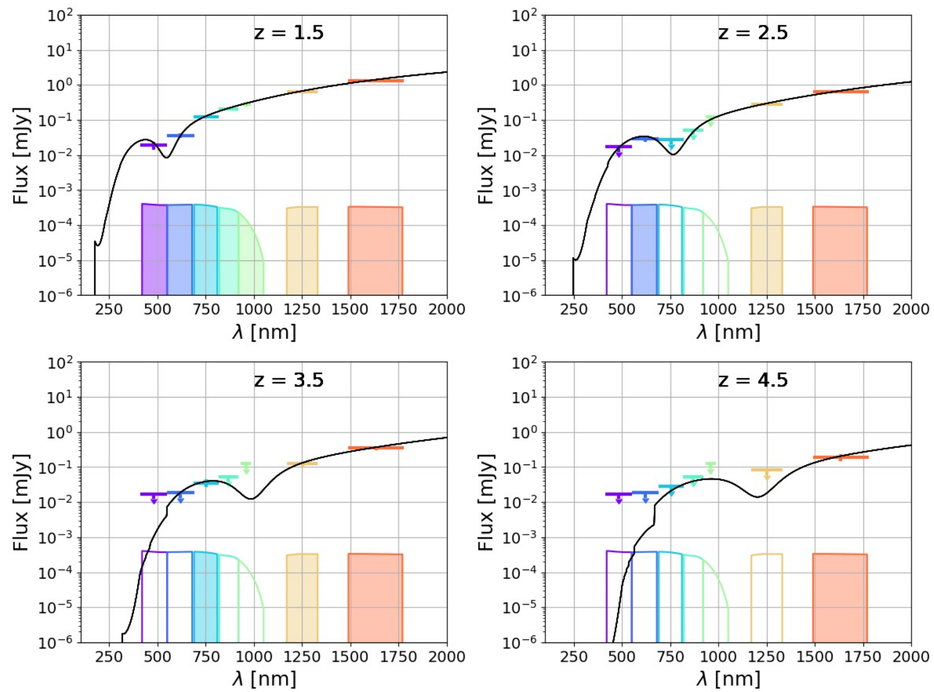
- **What can we do with photometric measurements? COLIBRI data**
  Nathanael Ghesquiers internship (may-sept. 2021)
- Combination of UV-optical and X-ray data
- Further step: Extinction and attenuation curves of GRB hosts

N. Ghesquiers internship (May-sept 21)

1) Creation of a GRB catalogue & afterglow emission
   - MW, SMC (LMC) extinction curves parameters:
   - $2.0 \leq z \leq 7.0$
   - $0.25 \leq A_V \leq 2.0$
   - Single intrinsic power-law spectrum
2) Simulated observations with COLIBRI (observation strategy as in Corre 18)
3) Estimation of parameters
   - A_V ,redshift (as in Corre 18)
   - **Identification of a MW Extinction curve**

The UV bump will be covered by COLIBRI (DDRAGO_B & R and CAGIRE)





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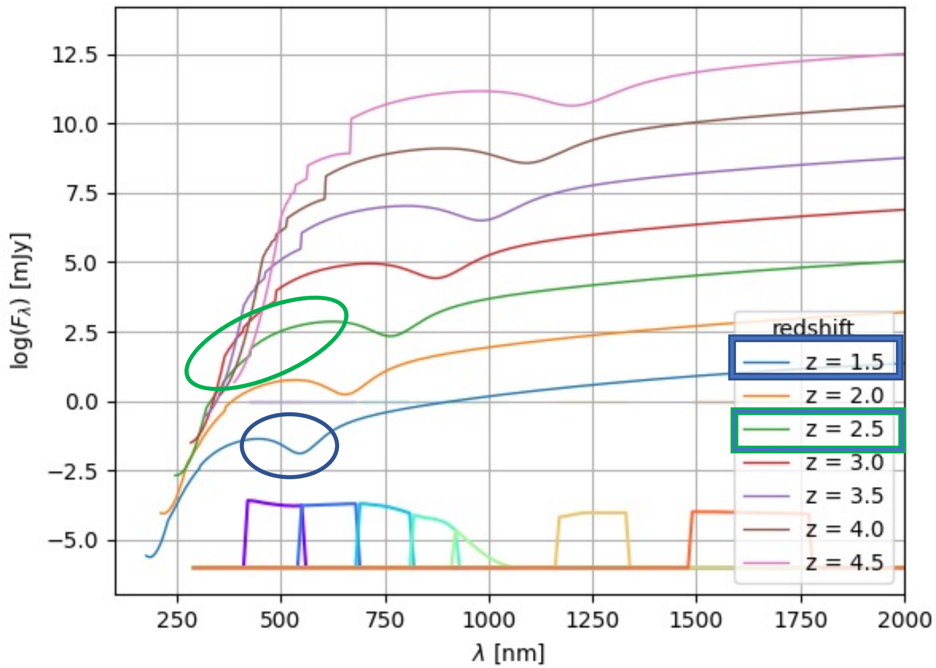

- **UV bump for z>~1.5**
- **Far-UV continuum z> ~2.5**

With a simulated MW extinction curve: redshift, Av, and the extinction curve (MW or SMC) well recovered up to high z for moderate extinctions

MW law associated results	Av 0,25		Av 0,50		Av 0,75		Av 1,0		Av 1,25		Av 1,50		Av 1,75		Av 2,0	
redshift z	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy
2,0	1,967 +/- 0,003	0,217 +/- 0,004	1,979 +/- 0,002	0,463 +/- 0,002	1,982 +/- 0,001	0,707 +/- 0,006	1,985 +/- 0,003	0,947 +/- 0,003	1,986 +/- 0,002	1,143 +/- 0,009	2,026 +/- 0,007	1,342 +/- 0,007	2,043 +/- 0,007	1,427 +/- 0,007	5,741 +/- 0,035	0,450 +/- 0,073
2,25	2,266 +/- 0,006	0,216 +/- 0,003	2,252 +/- 0,004	0,460 +/- 0,003	2,251 +/- 0,002	0,702 +/- 0,005	2,258 +/- 0,003	0,916 +/- 0,008	2,267 +/- 0,002	1,382 +/- 0,012	2,185 +/- 0,008	1,296 +/- 0,004	2,059 +/- 0,013	1,021 +/- 0,008	7,452 +/- 0,551	0,020 +/- 0,021
2,5	2,522 +/- 0,003	0,237 +/- 0,003	2,515 +/- 0,002	0,489 +/- 0,003	2,514 +/- 0,002	0,732 +/- 0,003	2,518 +/- 0,003	0,972 +/- 0,010	2,387 +/- 0,004	1,258 +/- 0,017	2,417 +/- 0,010	0,876 +/- 0,007	7,680 +/- 0,434	0,004 +/- 0,003	7,301 +/- 0,386	0,039 +/- 0,032
2,75	2,766 +/- 0,004	0,246 +/- 0,004	2,760 +/- 0,002	0,502 +/- 0,003	2,767 +/- 0,003	0,760 +/- 0,006	2,694 +/- 0,004	0,775 +/- 0,007	2,563 +/- 0,007	0,771 +/- 0,001	7,369 +/- 0,349	0,005 +/- 0,003	7,659 +/- 0,481	0,012 +/- 0,010		
3,0	3,009 +/- 0,002	0,253 +/- 0,004	3,040 +/- 0,003	0,533 +/- 0,003	3,028 +/- 0,005	0,774 +/- 0,007	3,012 +/- 0,004	0,624 +/- 0,007	2,580 +/- 0,026	0,956 +/- 0,008	7,357 +/- 0,457	0,011 +/- 0,012				
3,25	3,264 +/- 0,004	0,255 +/- 0,002	3,281 +/- 0,004	0,562 +/- 0,005	3,280 +/- 0,004	0,813 +/- 0,011	3,273 +/- 0,011	0,371 +/- 0,012	7,410 +/- 0,552	0,003 +/- 0,002	7,119 +/- 0,386	0,020 +/- 0,014				
3,5	3,515 +/- 0,003	0,273 +/- 0,002	3,498 +/- 0,001	0,627 +/- 0,008	3,447 +/- 0,006	0,552 +/- 0,016	1,007 +/- 0,006	1,751 +/- 0,017	7,267 +/- 0,424	0,007 +/- 0,007						
3,75	3,744 +/- 0,001	0,288 +/- 0,006	3,724 +/- 0,004	0,623 +/- 0,007	3,751 +/- 0,006	0,598 +/- 0,024	5,881 +/- 0,002	0,534 +/- 0,012								
4,0	3,989 +/- 0,002	0,315 +/- 0,002	4,003 +/- 0,002	0,407 +/- 0,014	1,273 +/- 0,013	1,474 +/- 0,009	5,794 +/- 0,005	0,421 +/- 0,020								
4,25	4,233 +/- 0,003	0,324 +/- 0,010	4,161 +/- 0,004	0,644 +/- 0,015	1,388 +/- 0,011	1,497 +/- 0,007	5,589 +/- 0,060	0,085 +/- 0,054								
4,5	4,404 +/- 0,001	0,332 +/- 0,005	4,813 +/- 0,037	0,000 +/- 0,000	5,140 +/- 0,002	0,016 +/- 0,009	5,673 +/- 0,064	0,069 +/- 0,041								
4,75	4,657 +/- 0,006	0,278 +/- 0,005	4,975 +/- 0,004	0,001 +/- 0,000	5,631 +/- 0,062	0,016 +/- 0,007	5,602 +/- 0,041	0,183 +/- 0,137								
5,0	5,058 +/- 0,002	0,201 +/- 0,010	5,219 +/- 0,005	0,001 +/- 0,001	5,790 +/- 0,009	0,264 +/- 0,011										
5,25	5,307 +/- 0,000	0,130 +/- 0,026	5,964 +/- 0,001	0,176 +/- 0,004	5,877 +/- 0,002	0,243 +/- 0,011										
5,5	5,693 +/- 0,011	0,034 +/- 0,006	5,963 +/- 0,002	0,195 +/- 0,006	5,955 +/- 0,009	0,271 +/- 0,009										
5,75	5,798 +/- 0,002	0,043 +/- 0,005	6,045 +/- 0,002	0,187 +/- 0,006	6,098 +/- 0,027	0,261 +/- 0,024										
6,0	6,043 +/- 0,005	0,086 +/- 0,004	6,126 +/- 0,002	0,194 +/- 0,005	7,226 +/- 0,462	0,010 +/- 0,007										
6,25	6,118 +/- 0,007	0,142 +/- 0,005	7,320 +/- 0,499	0,001 +/- 0,002	6,908 +/- 0,219	0,030 +/- 0,024										
6,5	6,934 +/- 0,257	0,050 +/- 0,050	7,528 +/- 0,552	0,001 +/- 0,001	7,197 +/- 0,564	0,052 +/- 0,052										
6,75	7,421 +/- 0,524	0,023 +/- 0,018	7,288 +/- 0,428	0,001 +/- 0,002												
7,0	7,459 +/- 0,508	0,030 +/- 0,034	7,335 +/- 0,567	0,001 +/- 0,001												

With a simulated MW extinction curve: redshift, Av, and the extinction curve (MW or SMC) recovered up to high z for moderate extinctions

MW law associated results		Av 0,25		Av 0,50		Av 0,75		Av 1,0		Av 1,25		Av 1,50		Av 1,75		Av 2,0	
		Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy	Zmoy	Av moy
redshift z	2,0	1,967 +/- 0,003	0,217 +/- 0,004	1,979 +/- 0,002	0,463 +/- 0,002	1,982 +/- 0,001	0,707 +/- 0,006	1,985 +/- 0,003	0,947 +/- 0,003	1,986 +/- 0,002	1,143 +/- 0,009	2,026 +/- 0,007	1,342 +/- 0,007	2,043 +/- 0,007	1,427 +/- 0,007	5,741 +/- 0,035	0,450 +/- 0,073
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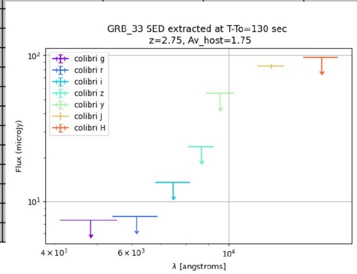
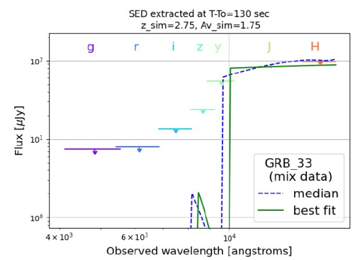
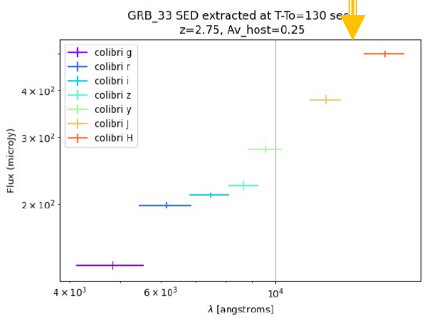


(a) Observational data from the filters.



(b) Best fit of MW law spectrum according to the algorithm.



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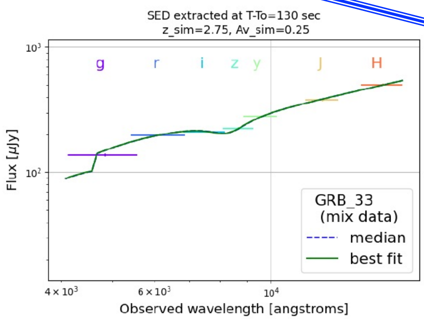

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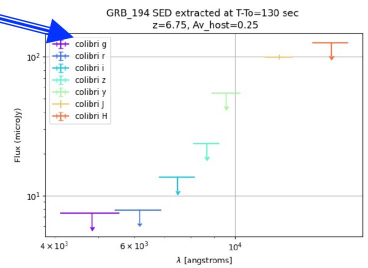

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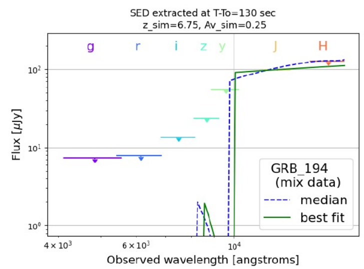

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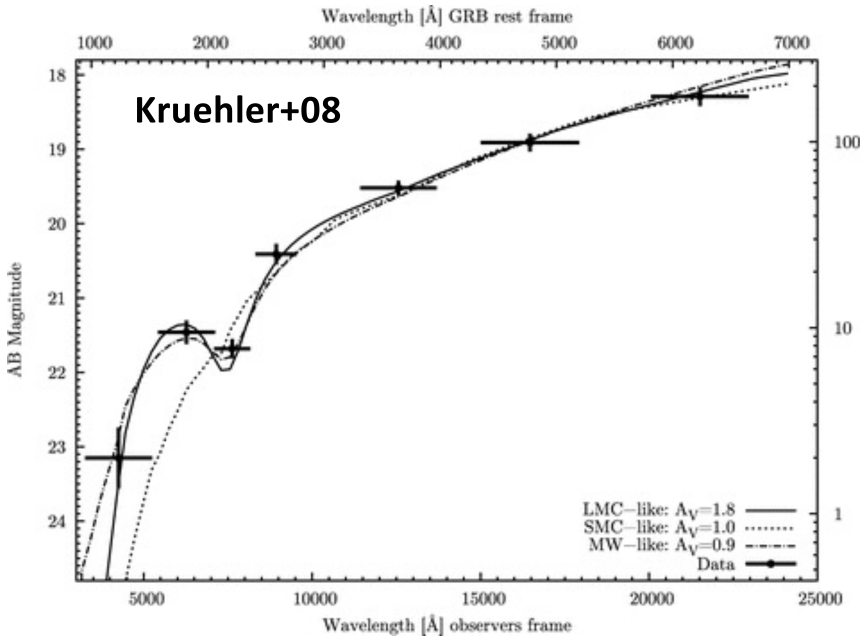


Photometric data only: it is difficult to measure the slope of the extinction law

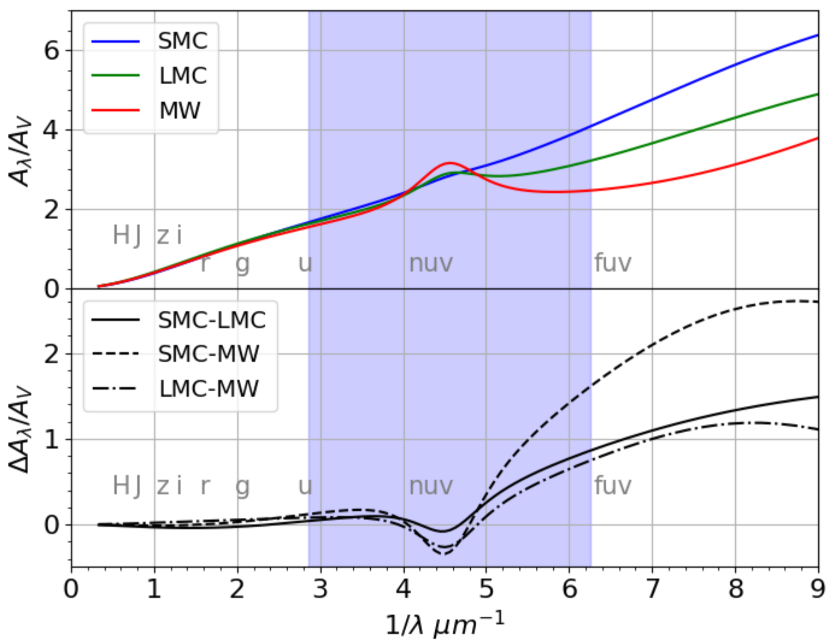
- **The bump can be detected in a photometric band (Kruehler+08, Nathanael 's results)**
- **More difficult for the slope of the extinction law (LMC, SMC, MW) (Japelj+15, Nathanael's results)**

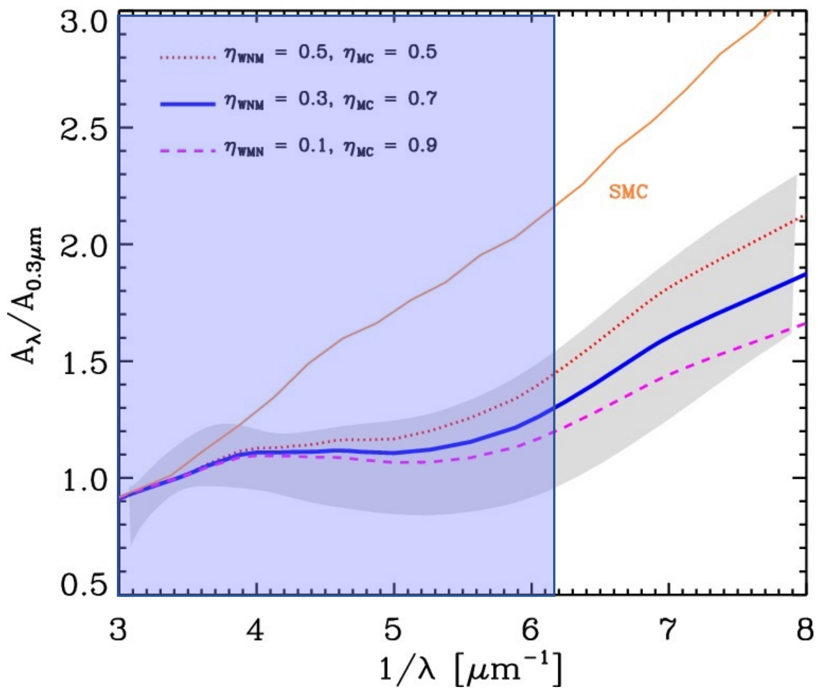
GRB	SMC		LMC		MW		Best model	
	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{phot}}$	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{spec}}$	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{phot}}$	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{spec}}$	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{phot}}$	$(\chi^2/\mathrm{d.o.f.})_{\mathrm{spec}}$	Phot	Spec
100219A	3.8/10	41.7/30	4.3/10	34.8/30	6.9/10	44.2/30	MW	LMC
100418A	11.2/12	20.8/23	10.7/12	20.2/23	11.1/12	20.0/23	Any	SMC†
100814A	48.1/33	70.8/66	47.8/33	71.0/66	47.9/33	257/67	Any	SMC†
100901A	15.4/26	44.2/41	14.8/26	160/47	14.6/26	355/47	Any	SMC
120119A	59.7/47	194.1/81	57.5/47	106.0/81	79.5/47	1023/81	SMC/LMC	LMC
120815A	21.3/21	26.0/47	22.2/21	122.9/47	20.0/22	353.1/27	Any	SMC
130427A	62.6/64	129.3/147	62.5/64	130.0/147	62.5/64	123.9/147	Any	SMC†
130603B	11.5/9	21.3/23	11.1/9	20.9/23	10.6/9	21.2/23	Any	SMC†
130606A[a]	15.9/18	48.8/31	16.0/18	48.8/31	16.0/18	48.8/31	Any	Any

We must search for clear features:

UV bump, flat/steep extinction curves in the UV

SMC and MW extinction laws too similar

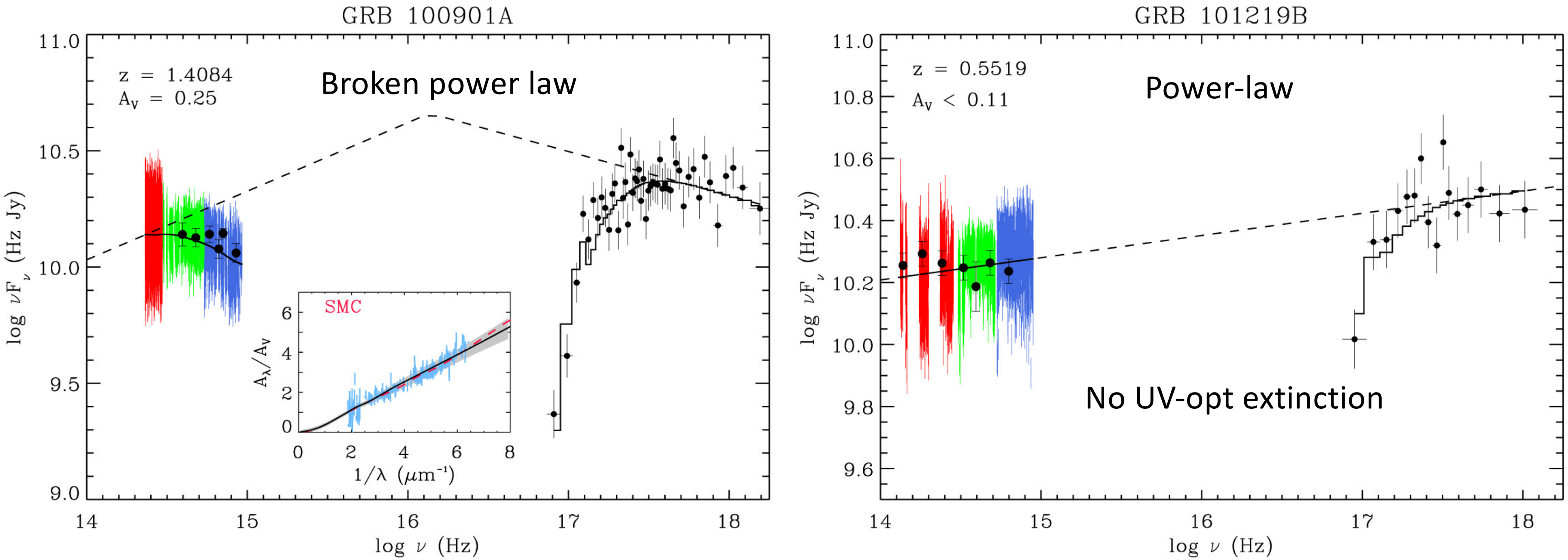




outline

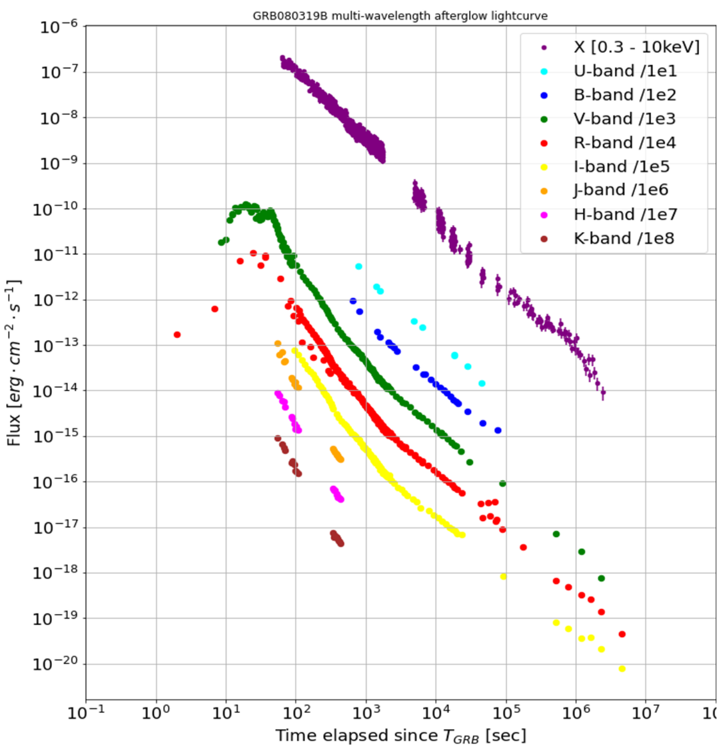
- Introduction
- Astrophysical background: extinction curves and dust properties
- Extinction curves along the l.o.s of GRBs
- What can we do with photometric measurements? COLIBRI data
  Nathanael Ghesquiers internship (may-sept. 2021)
- **Combination of UV-optical and X-ray data**
- Further step: Extinction and attenuation curves of GRB hosts

Combination of UV-optical and X-ray data



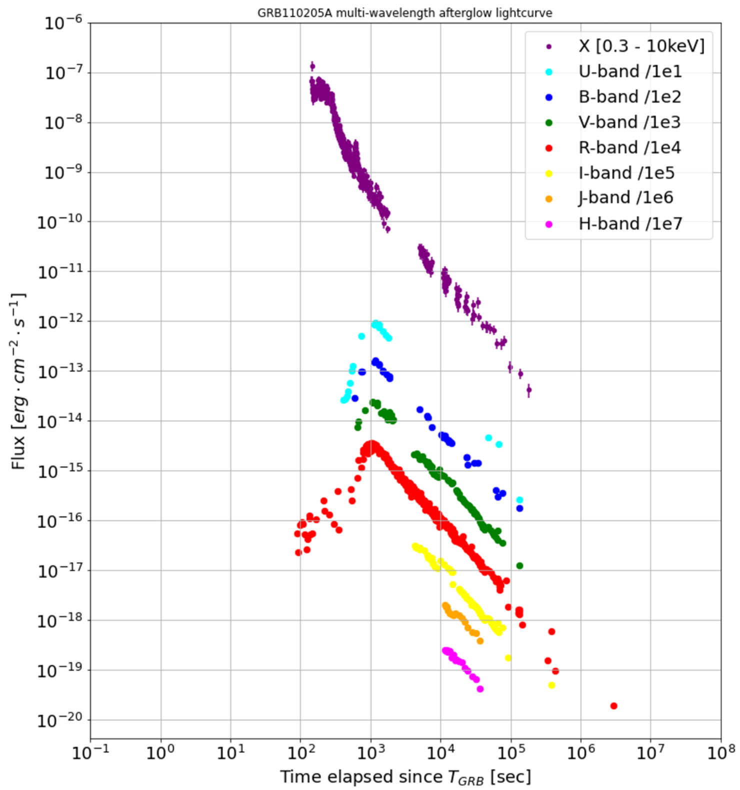
Zafar+18

Broadband Afterglow emission



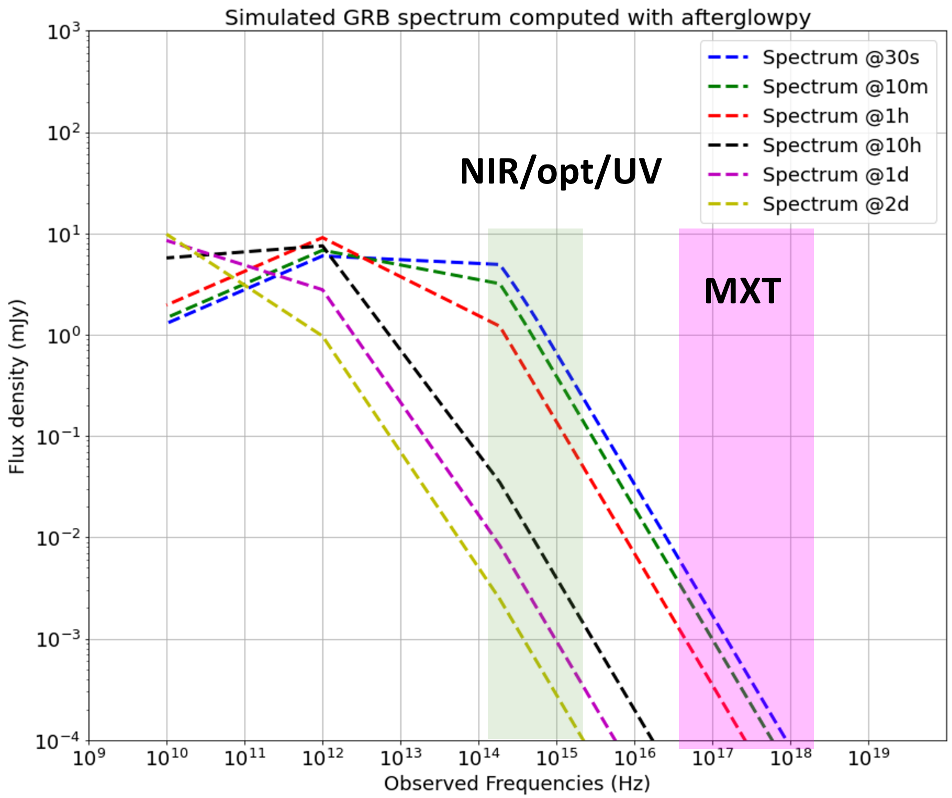
Different structures in the x-ray/opt afterglow light curves:

- internal (flares) vs external shock emissions
- different external shock emission region (forward or reverse shock)
- cooling break frequencies
- energy injection
- etc..

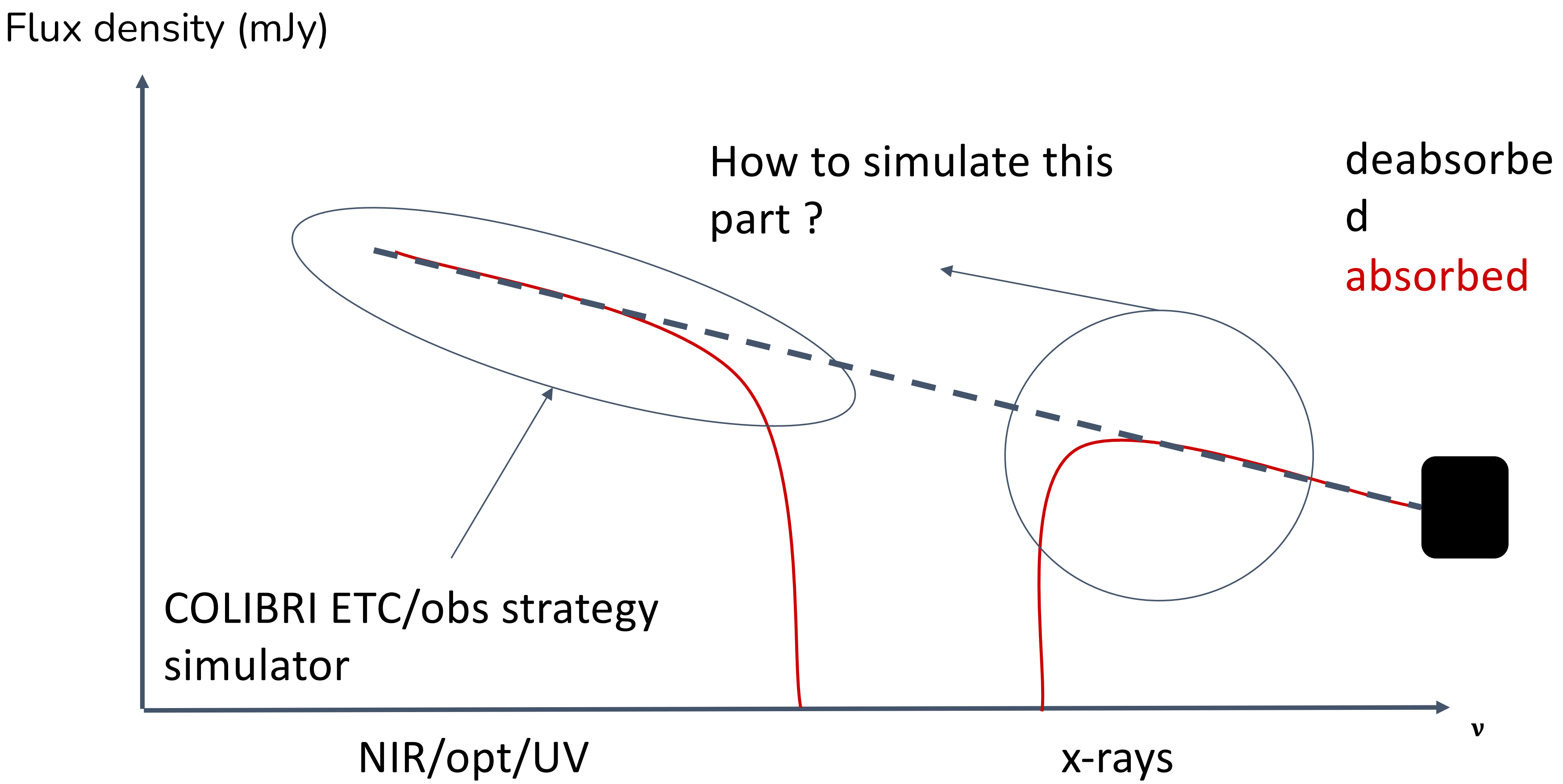


Broadband Afterglow synchrotron spectrum

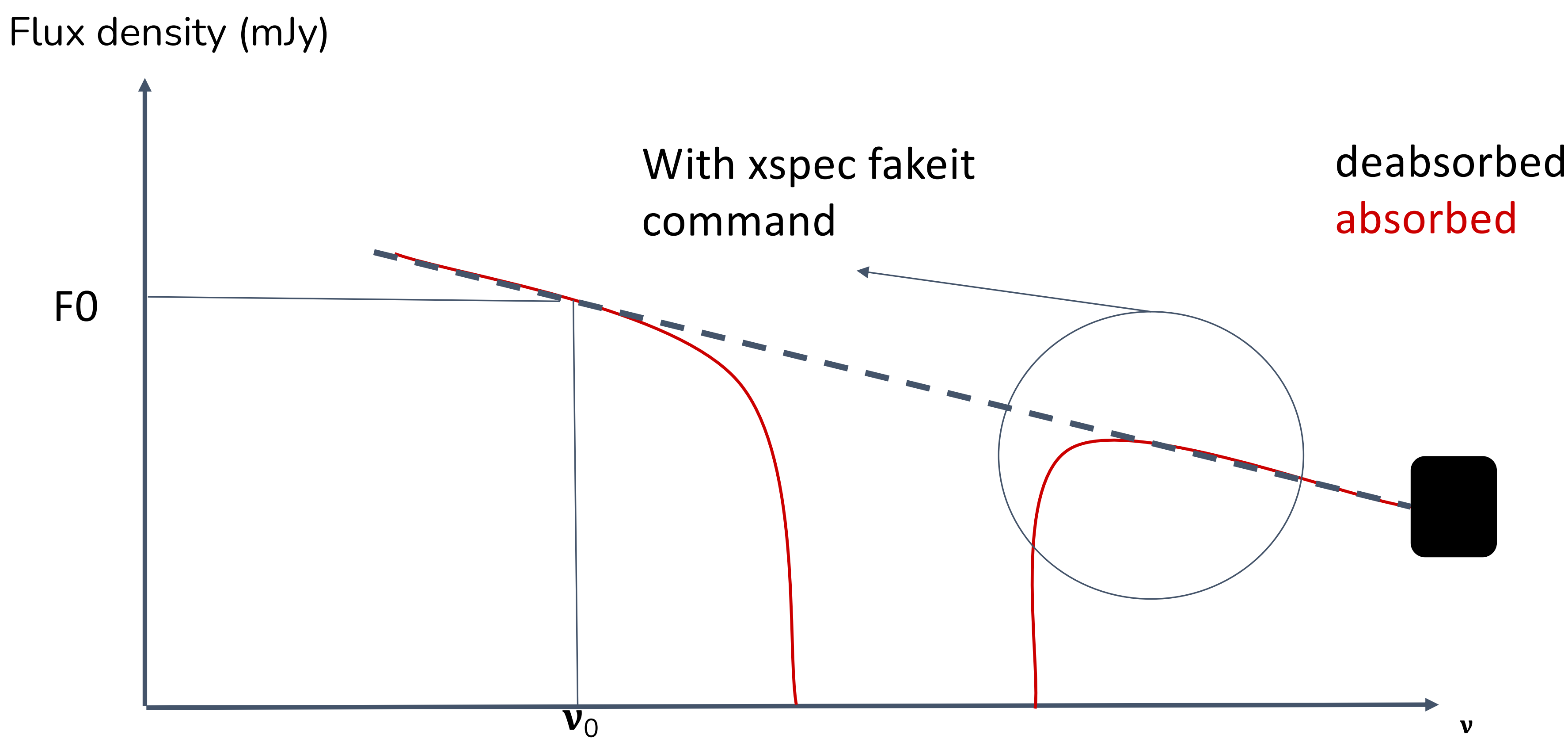
Depending on the microphysical parameters of the external shocks and the time at which we observe, the position of the typical synchrotron frequency, ν_m, can introduce a break between the NIR and X-ray emissions



X-ray afterglow simulations with SVOM/MXT: philosophy for a NIR/X PL SED



X-ray afterglow simulations with SVOM/MXT: philosophy for a NIR/X PL SED



X-ray afterglow simulations with SVOM/MXT: philosophy for a NIR/X PL SED

Xspec fakeit inputs:

- a model -> ztbabs x tbabs x pegpwrlw
- a mxt rmf file
- a mxt arf file
- a mct background file (taken as an average estimate for extragal. background)

Kindly provided by D. Götz

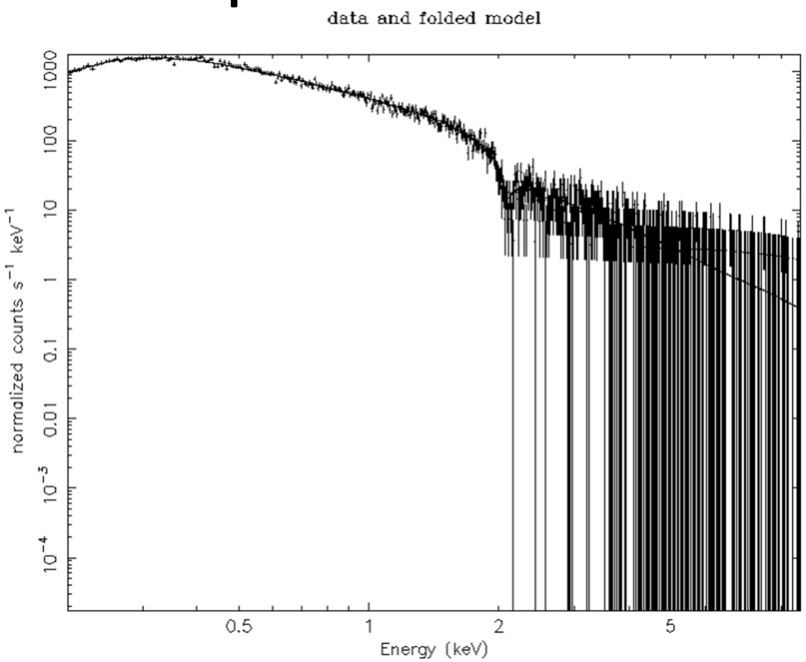
pegpwrlw ***(power law, pegged normalization)***

$$A(E) = F_0 \times (E/E_0)^{-\alpha}$$

- F_0 = flux in micro-Jy at E_0
- E_0 = Reference Energy in keV
- α = photon index of power law

X-ray afterglow simulations with SVOM/MXT: philosophy for a NIR/X PL SED

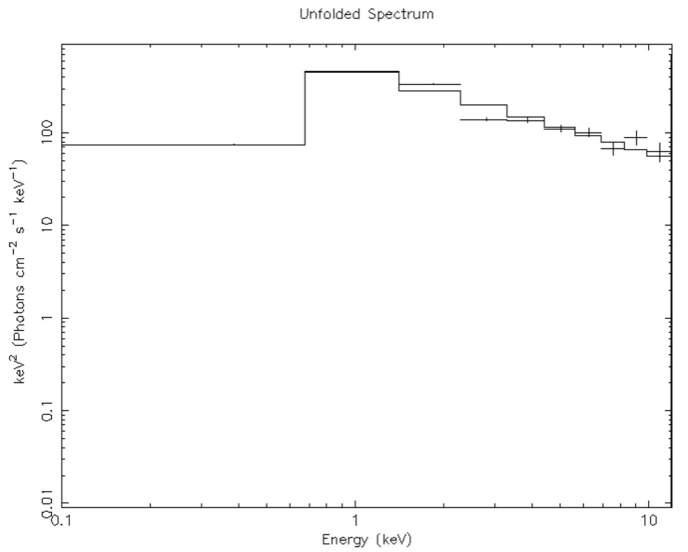
MXT afterglow count spectrum simulation



grppha

count rate
to
energy flux

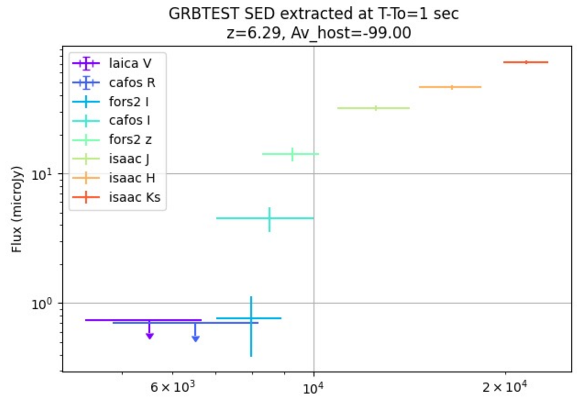
Rebinned MXT afterglow physical spectrum simulation

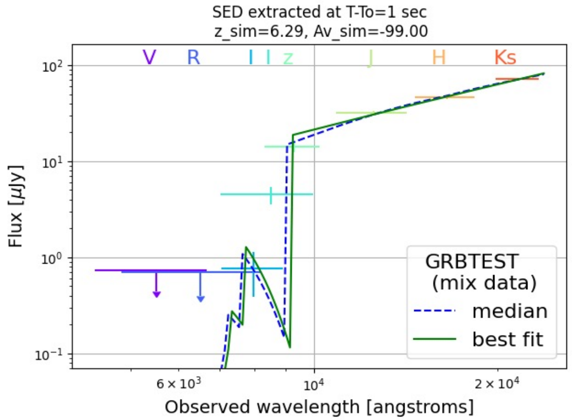


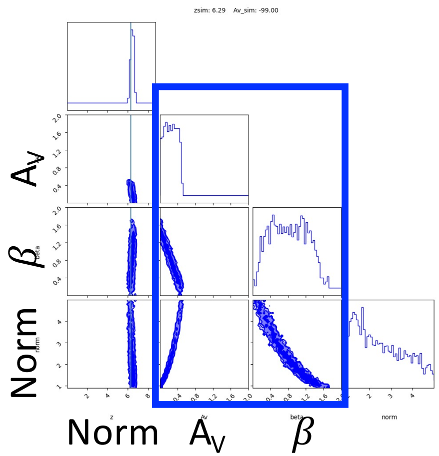
Used for our global GRB afterglow sim COLIBRI+MXT

Preliminary test: Impact of adding X_ray data on GRB 050904 afterglow at z=6.29
With an additional simulated X-ray flux

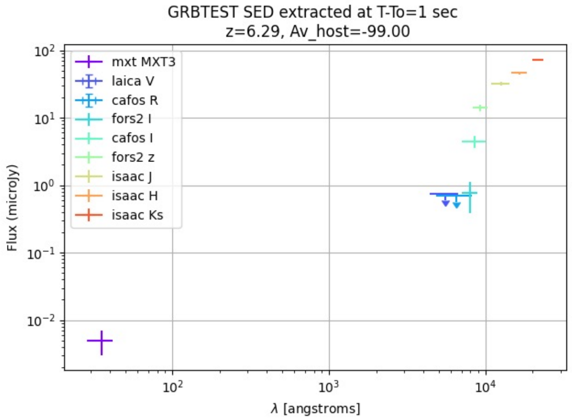
- A_v and β better constrained
- It could also help to break a degeneracy between A_V and z

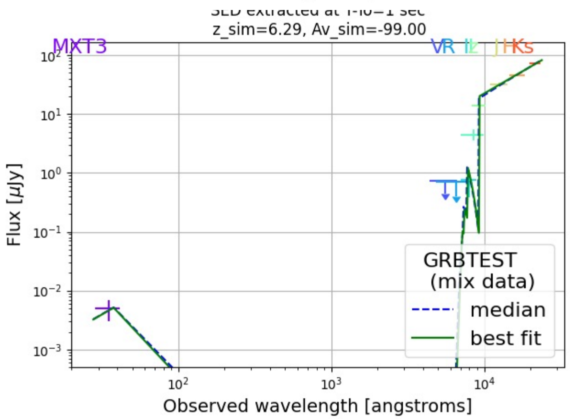


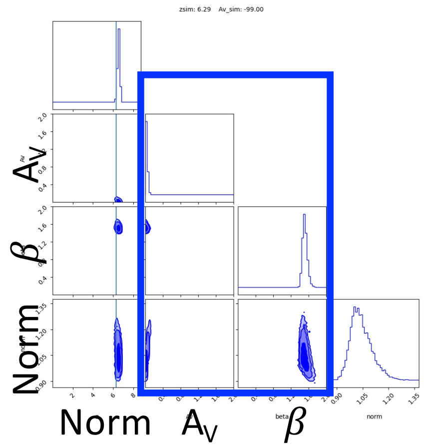




(Single power law)

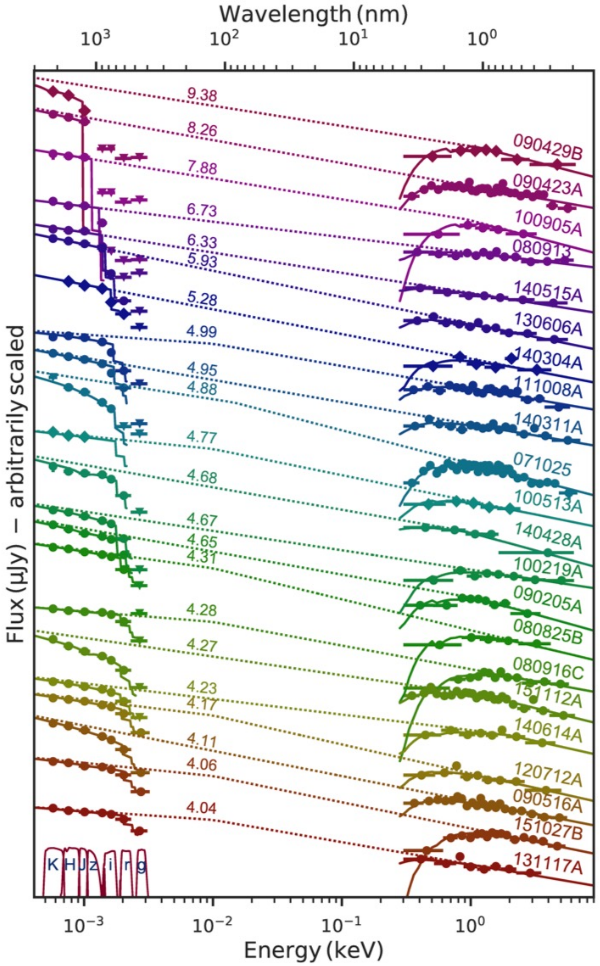


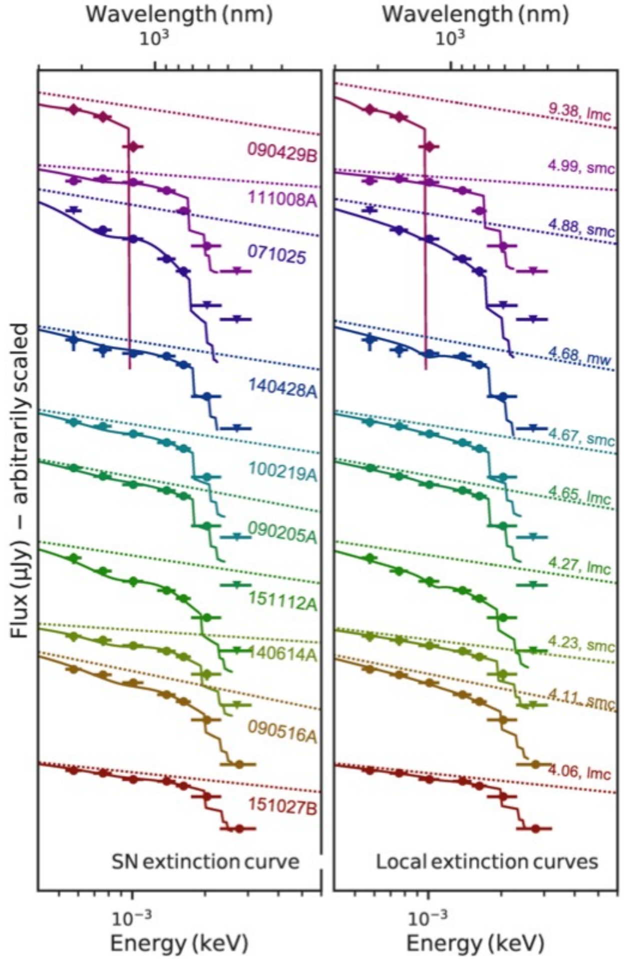




Courtesy of D. Corre

Bolmer+18: 22 GRB at z>4: XRT+GROND photometry





Results:

-low Av at z>4

-SMC, LMC, MW and SN ext curves tested

-For only 2 GRBs: better fits with SN curve

071025 not confirmed

-no bump is found

-candidate SNe extinction laws for 10 GRBs

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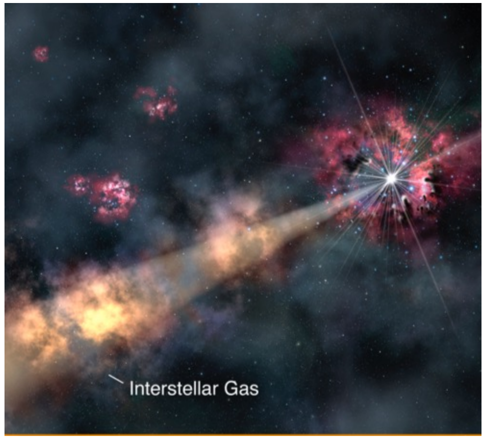
- **Further analysis: Extinction and attenuation curves of GRB hosts**

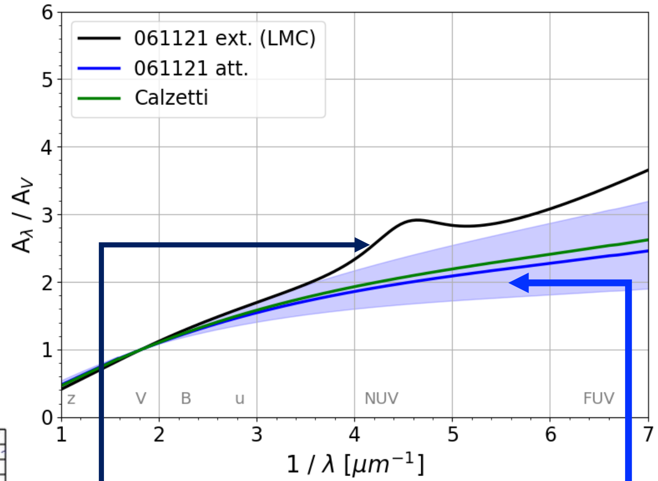
To go further: attenuation & extinction laws in galaxies

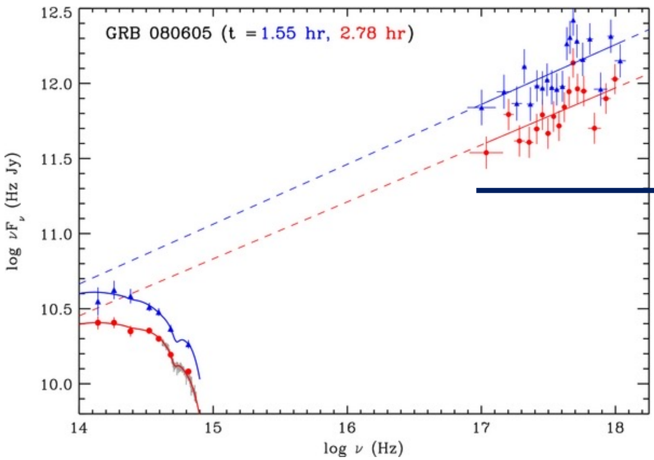
One line of sight (GRB)

Both can be measured in GRB hosts

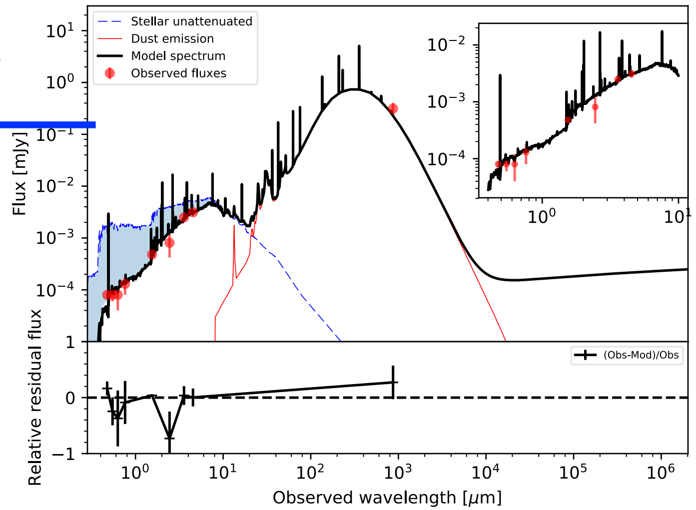
The whole galaxy: GRB host







- ISM of the GRBH
- Dust properties
- Dust/star geometry



To conclude

- Measuring the extinction curves along the line of sight of GRB afterglows with COLIBRI data is challenging
- We can search for specific features (UV bump), very distinct shapes (steep/flat curves)
- The combination of X-ray and vis-NIR data clearly improves the measurements by breaking degeneracies
- The UV rest-frame must be covered to differentiate between the extinction curves
- Spectroscopic follow-up data when available combined with photometric data will greatly improve the analysis.
- GRBs are the only sources to get lines of sight going through star-forming regions of galaxies up to high redshifts→ insight on dust evolution
- We would like to hire a PhD student in 2022 to work on simulated X-ray to NIR data and Damien's catalogue of observed afterglows