Measures and comparisons of extinction and attenuation curves in GRB hosts

V. Buat (LAM)
essentially based on the PhD work
of David Corre

french-mexican LIA workshop, june 2019

outline

- The framework of the study:
  dust extinction and attenuation in galaxies, what are the challenges?
- The attenuation laws : recipes and variability
- Extinction curves along the l.o.s of GRBs
- Pilot study: Extinction and attenuation curves for a small sample of GRB hosts
- What do we need to go further with SVOM?

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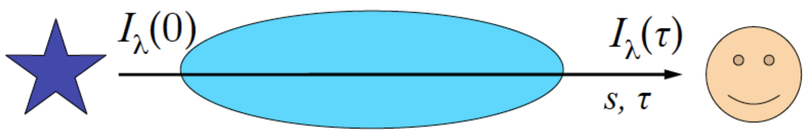
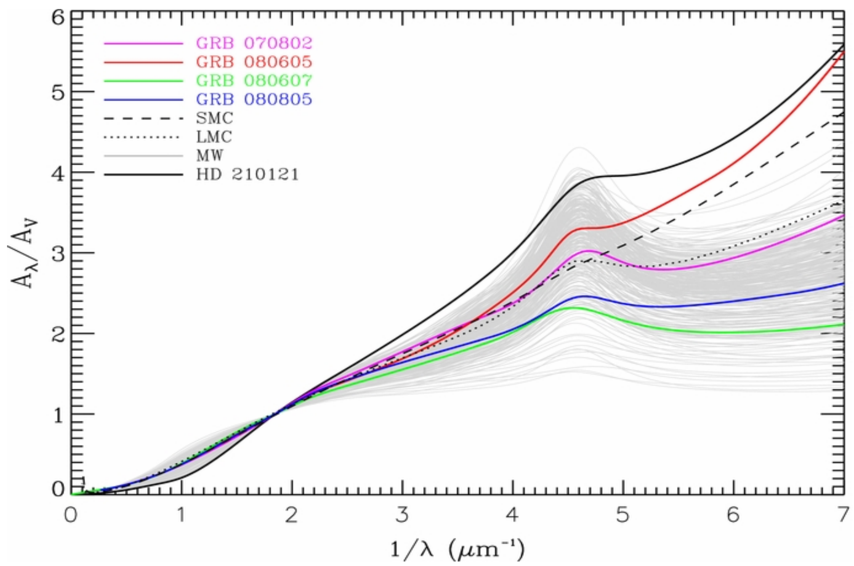
Attenuation & extinction laws in galaxies

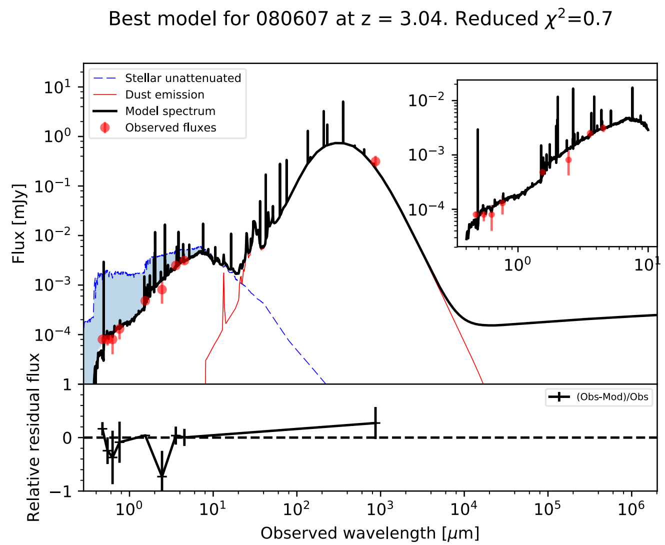
Extinction Only (UV, Opt, NIR)



Attenuation in a galaxy, stars and dust are mixed

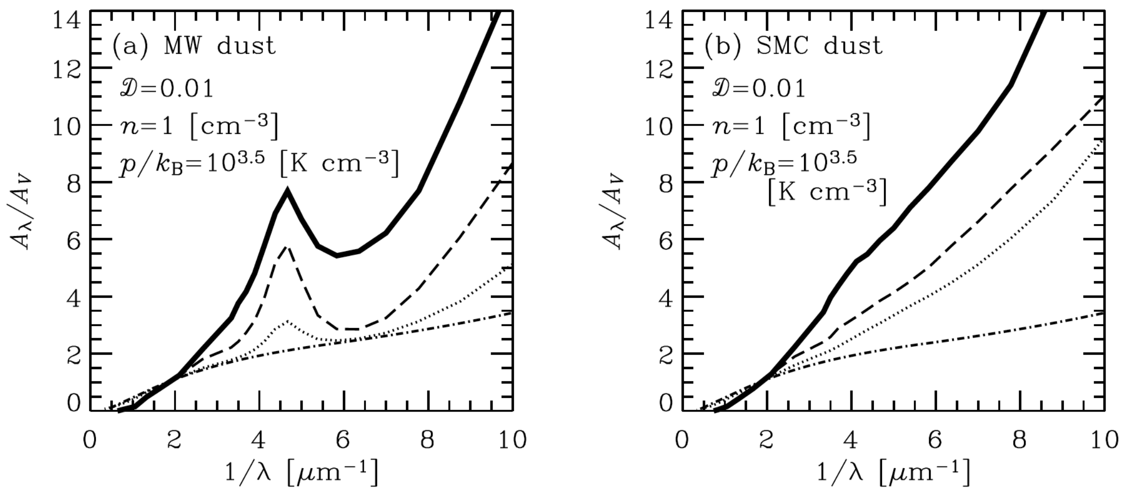
Both can be measured in GRB hosts





Attenuation & extinction laws in galaxies:
The link between extinction and attenuation is complex

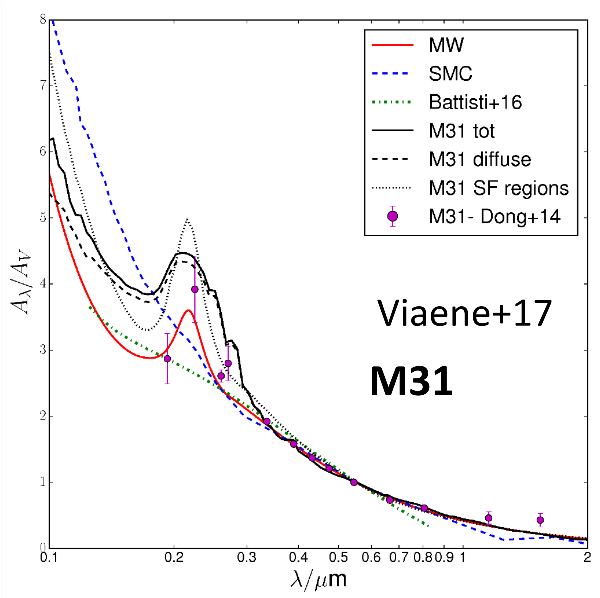
Inoue, 2005



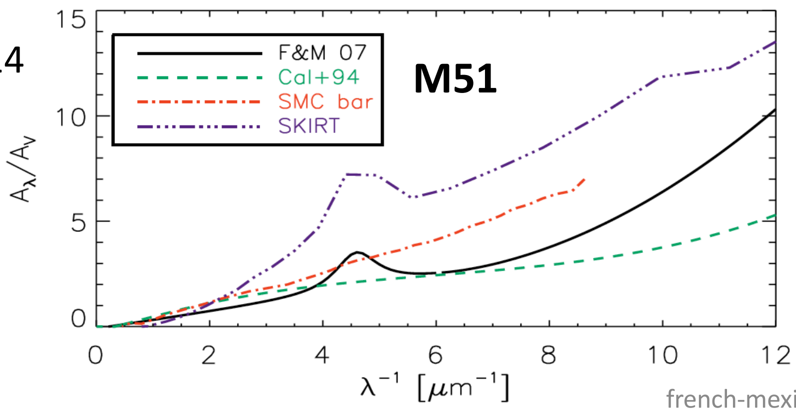
Attenuation law for extended objects depends on dust properties ,dust-stars (old/young) geometry

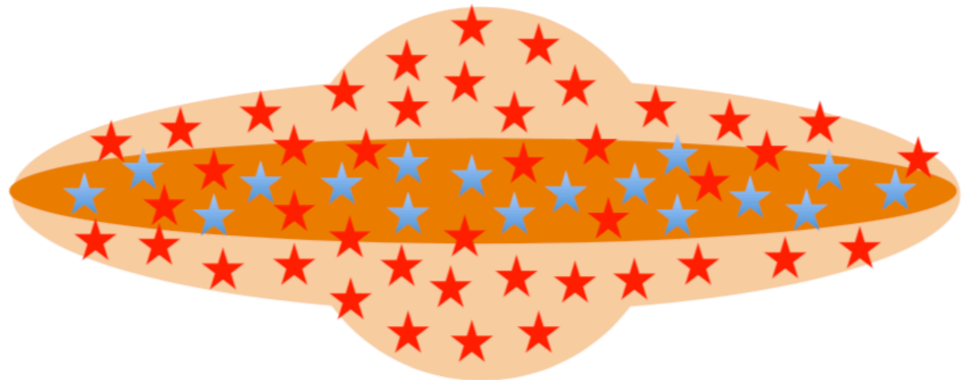
What do we know today?

Extinction versus attenuation curves in nearby galaxies: Radiation transfer



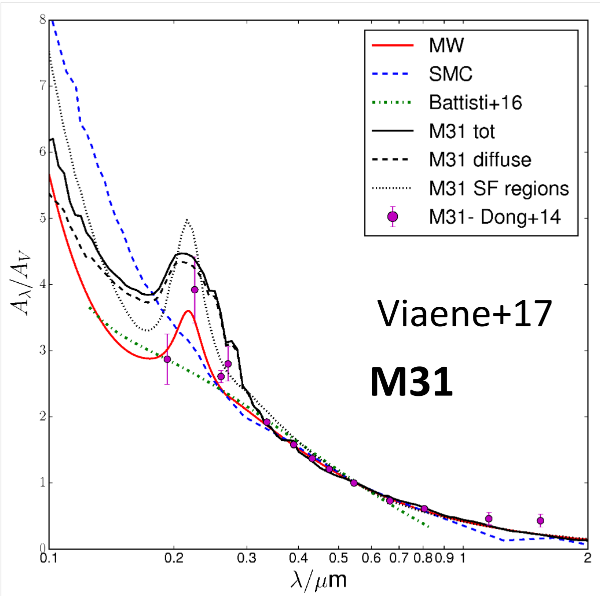
De Looze+14



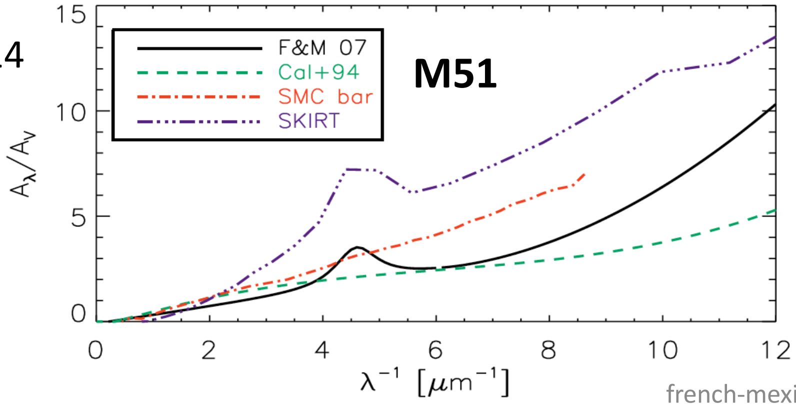


What do we know today on the topic?

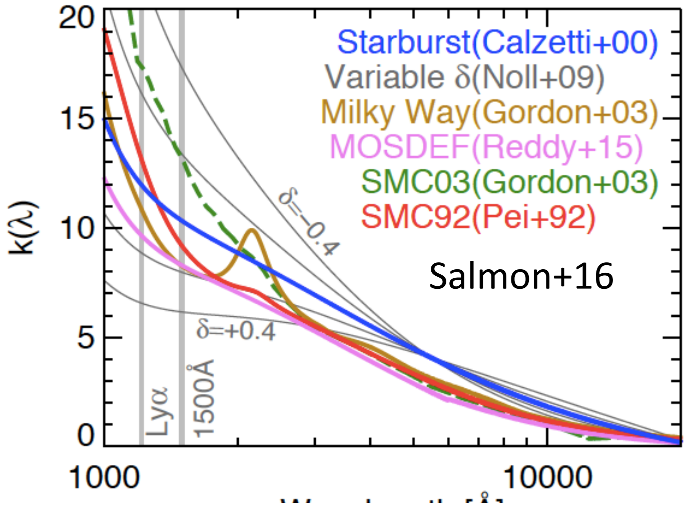
Extinction versus attenuation curves in nearby galaxies: Radiative transfer

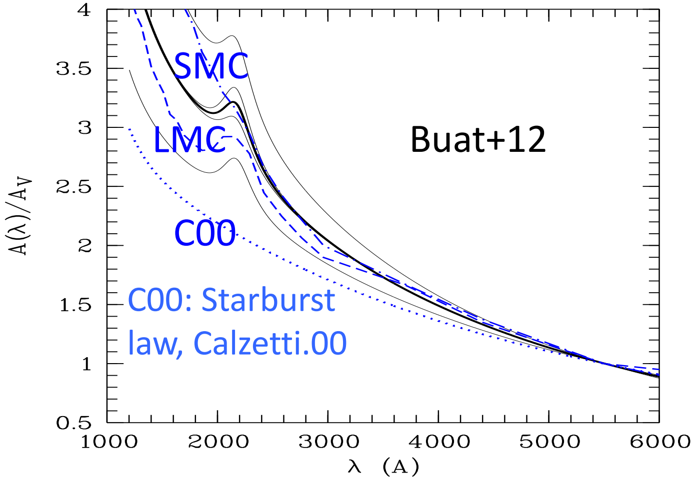


De Looze+14



For more distant galaxies various attenuation curves but no extinction curve





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The most usual attenuation law: Calzetti+2000 (C00)
& a flexible recipe → free slope of the C00 law

$$k(\lambda) = \left(\frac{A(\lambda)}{E(B-V)}\right) \times \left(\frac{\lambda}{\lambda_V}\right)^{\delta}$$

$$k(\lambda) = \left(\frac{A(\lambda)}{E(B-V)} + \frac{E_b \lambda^2 \gamma^2}{(\lambda^2 - \lambda_0^2) + \lambda^2 \gamma^2}\right)\left(\frac{\lambda}{\lambda_V}\right)^{\delta}$$

+ UV bump

A single attenuation law for all the stellar continuum

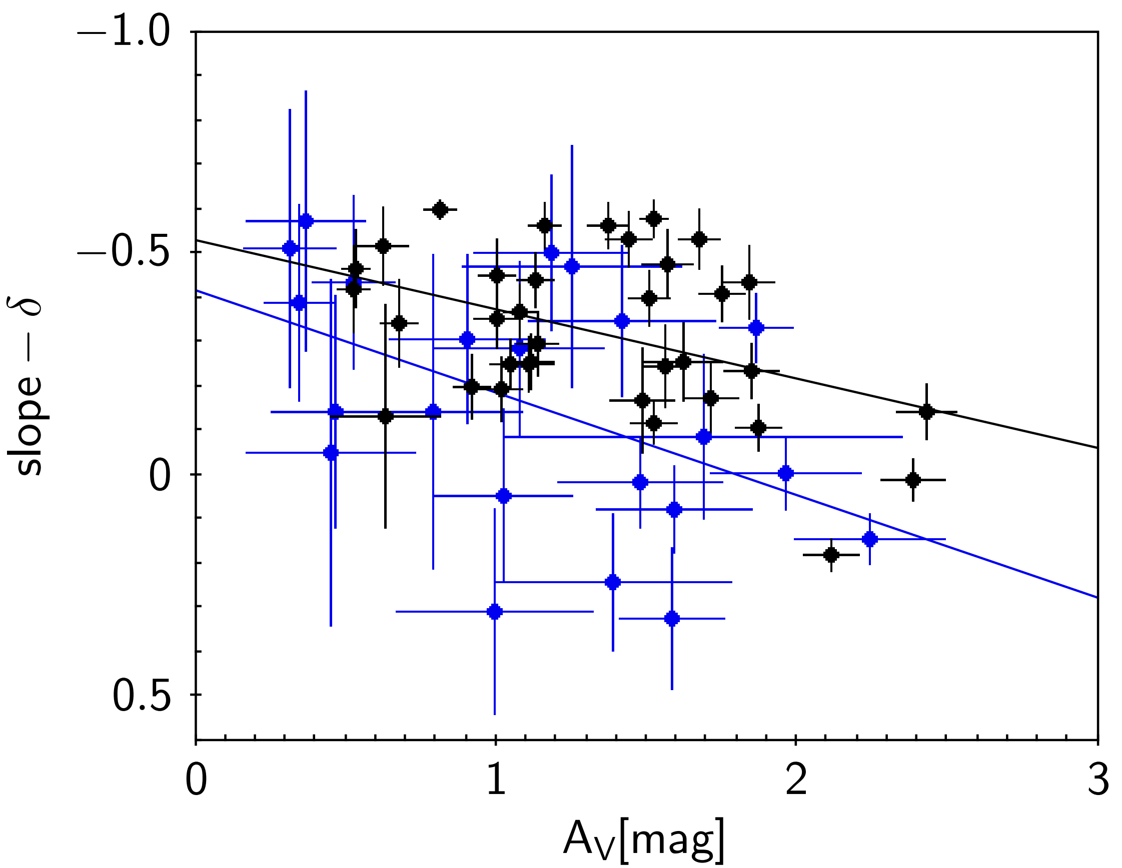
MW extinction+screen for nebular lines

EBV-factor= E(B-V)$_{star}$/E(B-V)$_{lines}$

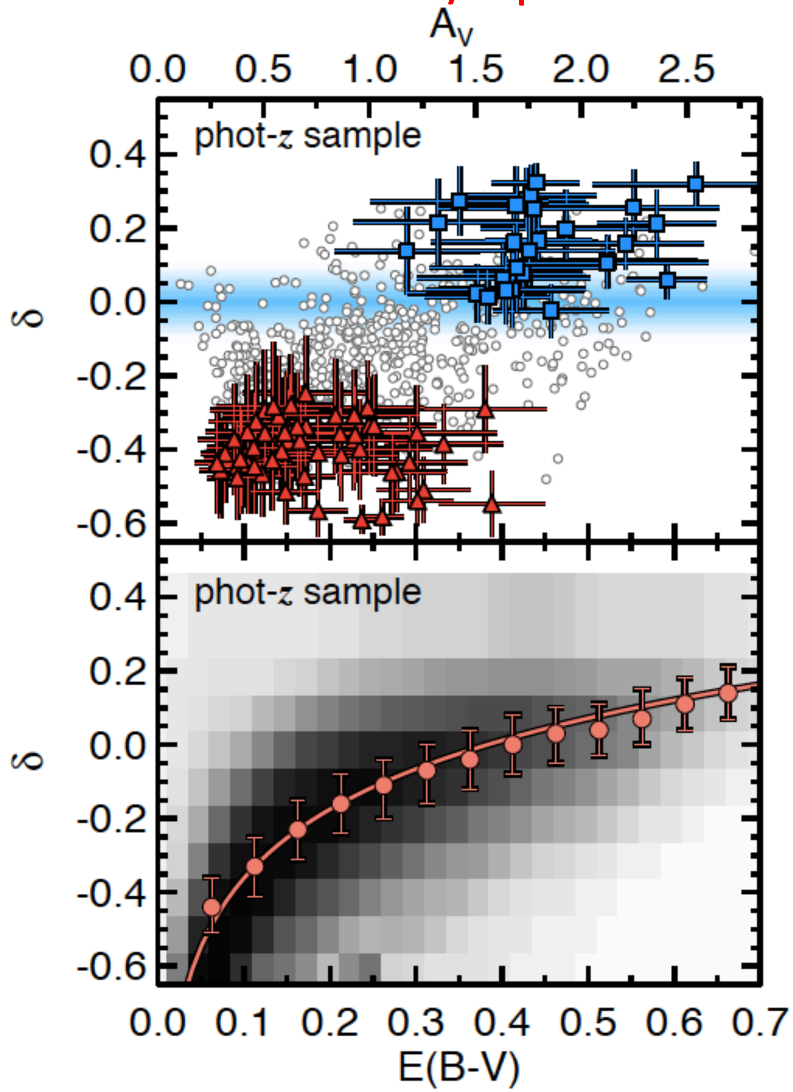
C00 : δ = 0, EBV-factor = 0.44

(Buat+11,12, Kriek&Conroy 13, Salmon+15, Zeimann+15, Seon & Draine 2016, Corre+18, Wang+18)

Attenuation laws of Herschel-3DHST galaxies (Buat+18) slightly steeper than those for GRBHs (Corre+18)



Salmon+16, CANDELS data, 1.5<z<3 galaxies detected with **MIPS/24 µm**

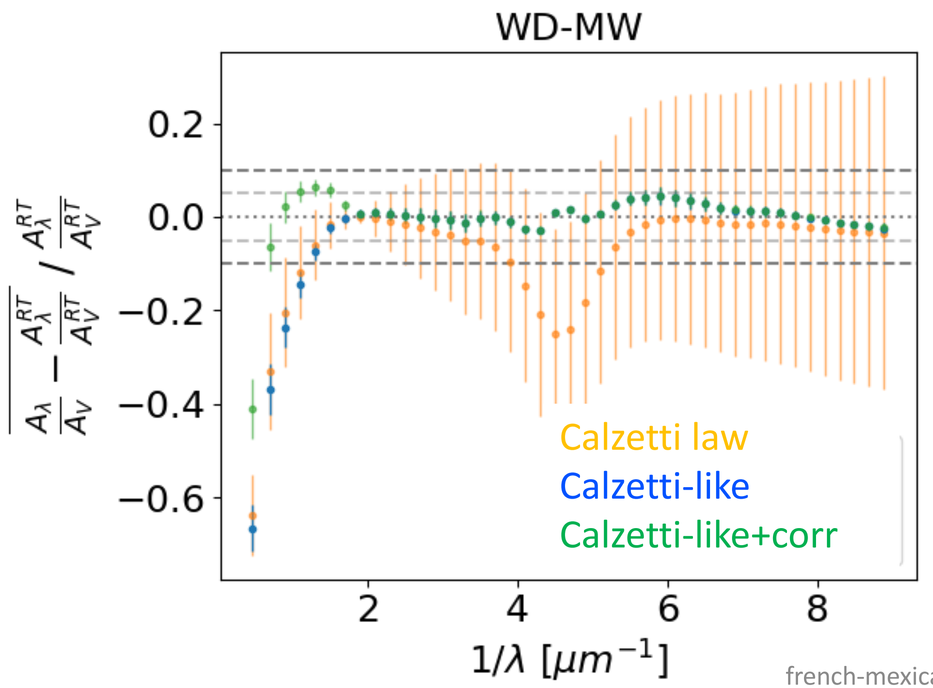


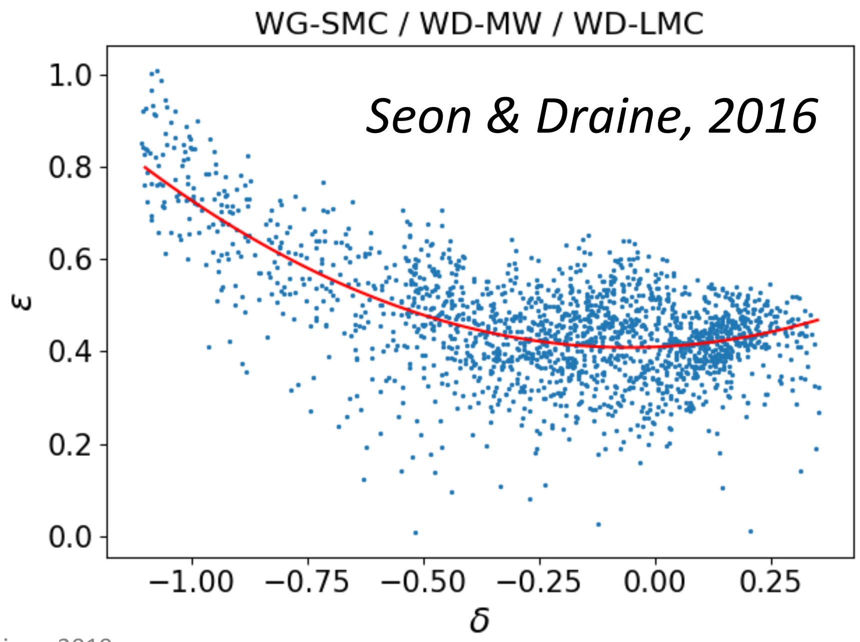
The flexible Calzetti-like recipe has to be modified in the NIR to be consistent with radiation transfer modeling

Buat+18, Corre & Buat in preparation

The Calzetti-like recipe is able to reproduce the variety of attenuation curves found with radiation transfer modelling (see also *Seon and Draine 2016*), except in the NIR.

- $\lambda < \lambda_V$ $K(\lambda)_{mod} = K(\lambda)_{C00} * (\lambda / \lambda_V)^{\delta}$
- $\lambda > \lambda_V$ $K(\lambda)_{mod} = K(\lambda)_{C00} * (\lambda / \lambda_V)^{\delta+\varepsilon}$





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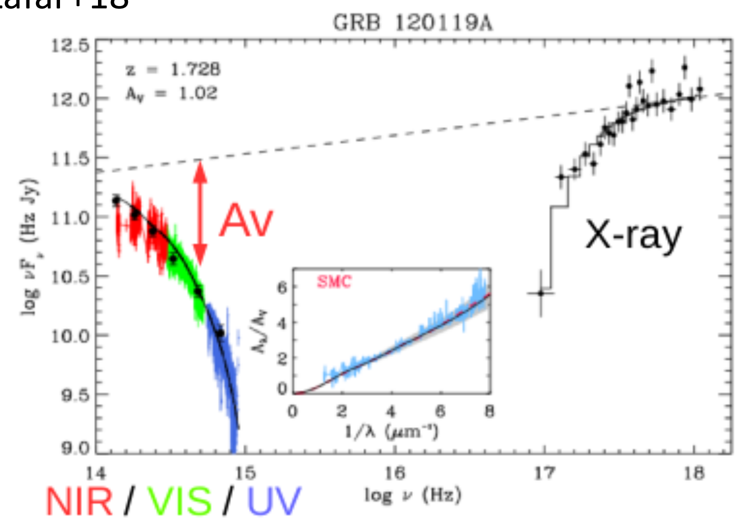
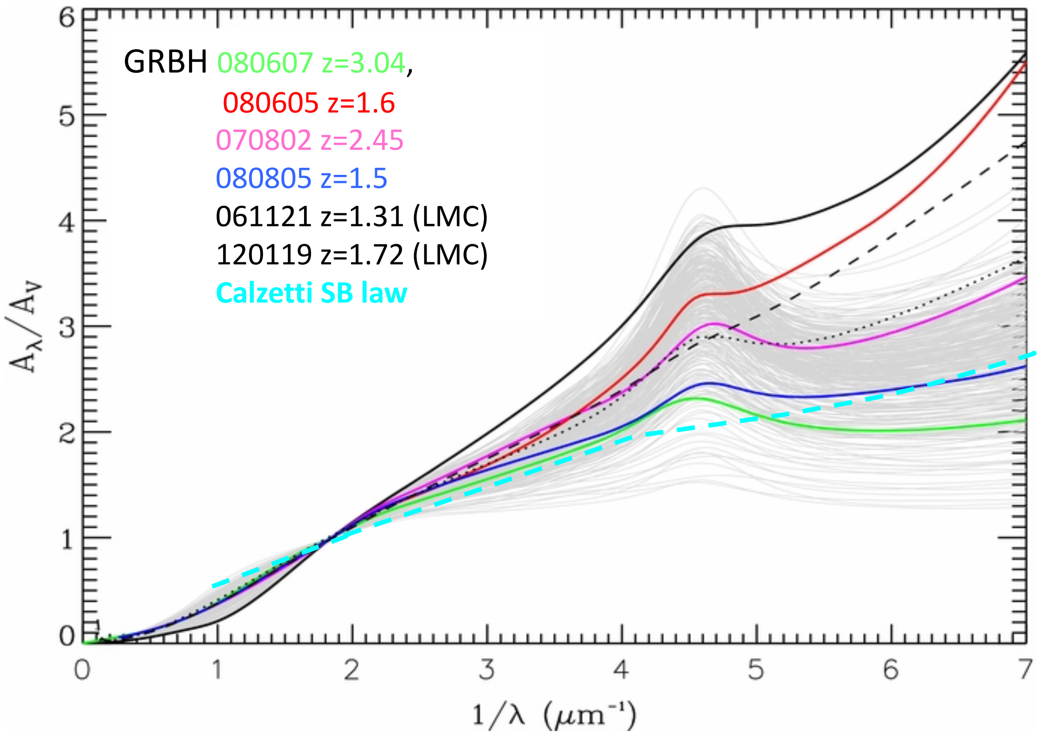
Extinction curves measured in galaxies hosting γ-rays bursts

Zafar+18

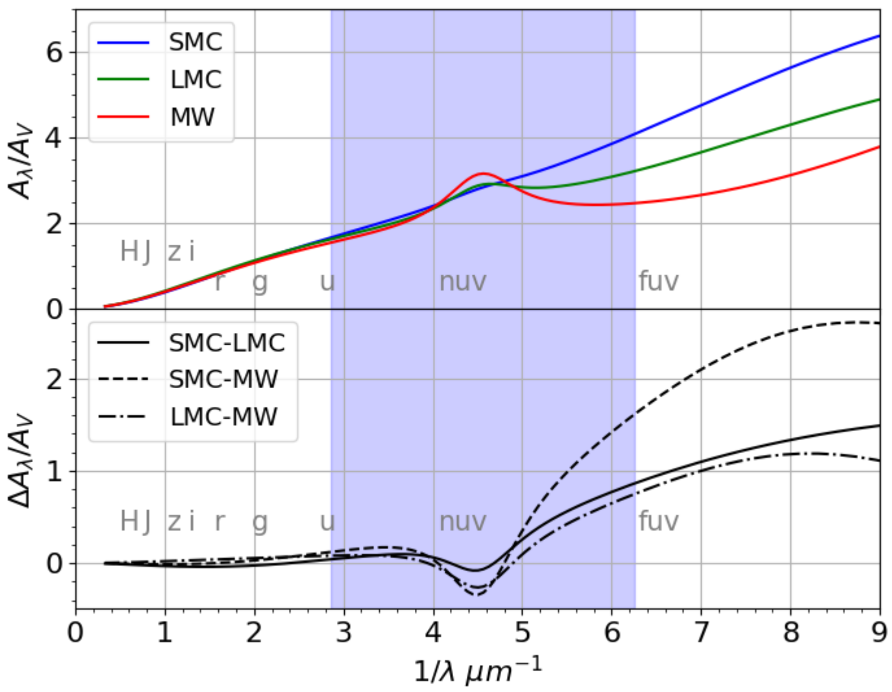


The afterglow is modelled by a single or double power-law: any deviation is due to dust extinction

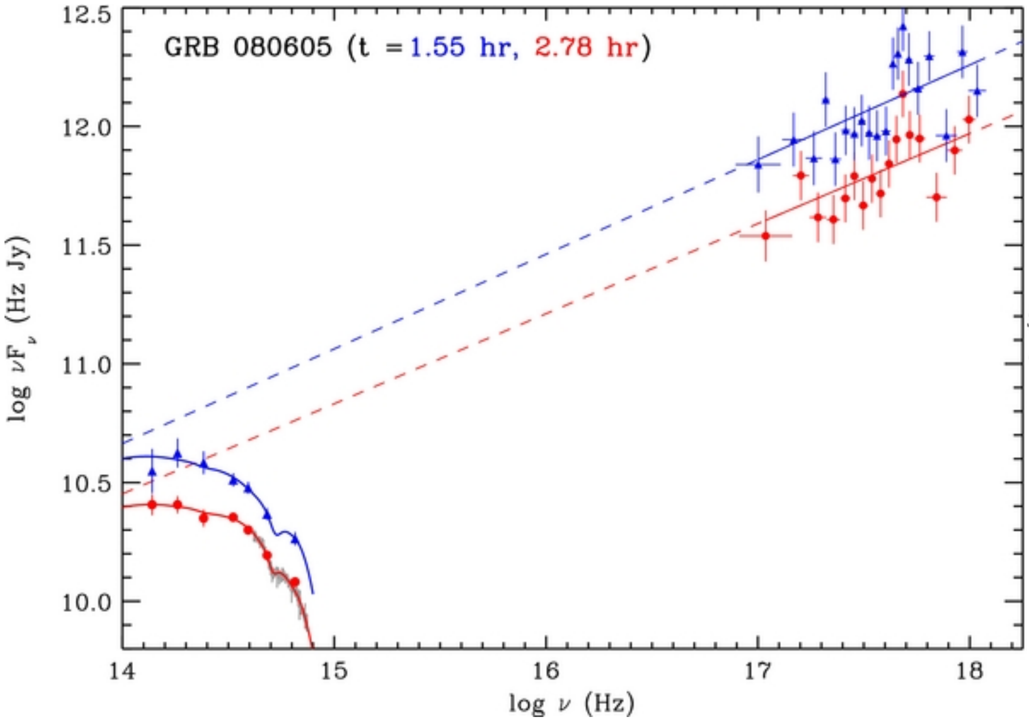


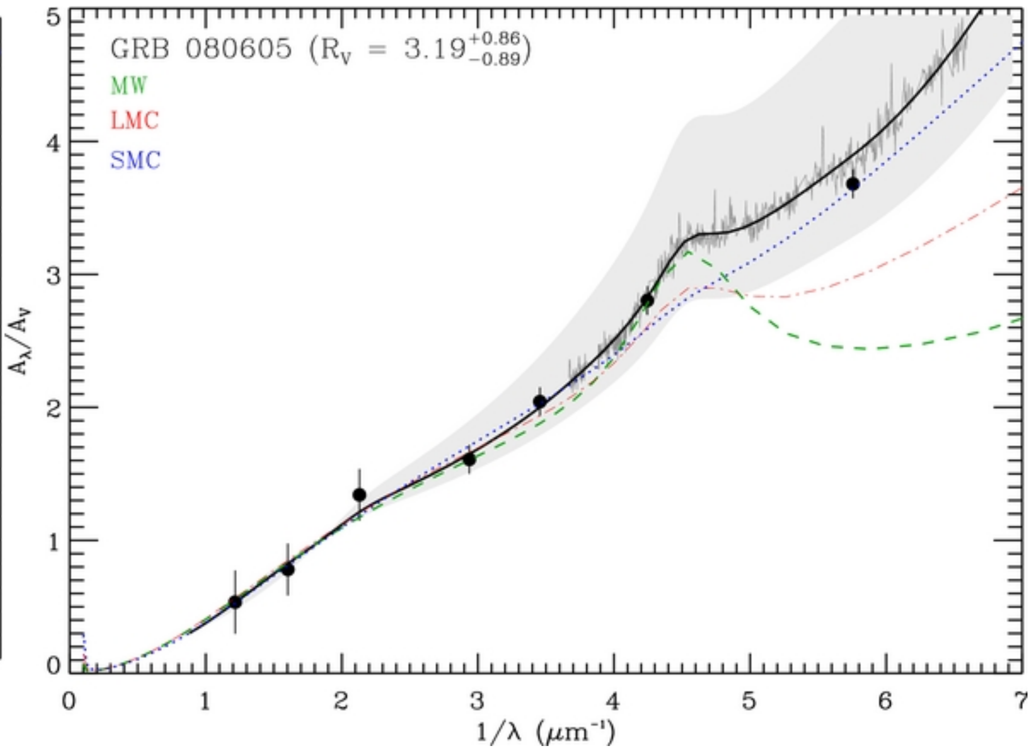
D. Corre, PhD thesis

For our study : the UV range is crucial to discriminate between different extinction curves

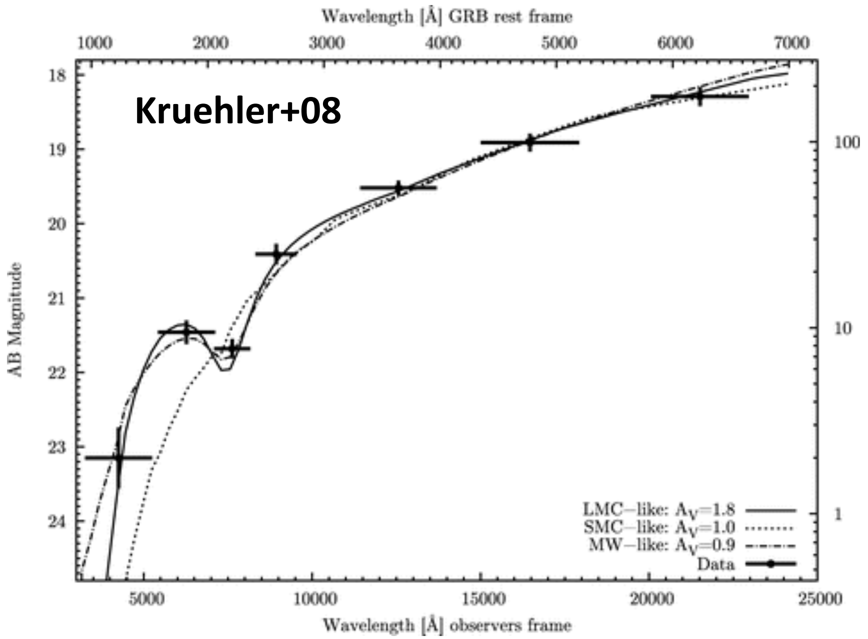


With spectroscopic observations of the afterglow: shape and bump for the extinction law





Photometric data only: it is much more difficult to measure the extinction law



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

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

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Our selection of GRB extinction curve & host galaxies SEDs:

- Spectroscopic or Photometric data (several bands) for the afterglow from 160 to 350 nm

13 GRBs extinction curves from spectroscopy
17 GRBs extinction curves from photometry

- Adding photometry for the host : at least 6 bands from UV to NIR (rest-frame)

→ 7 objects

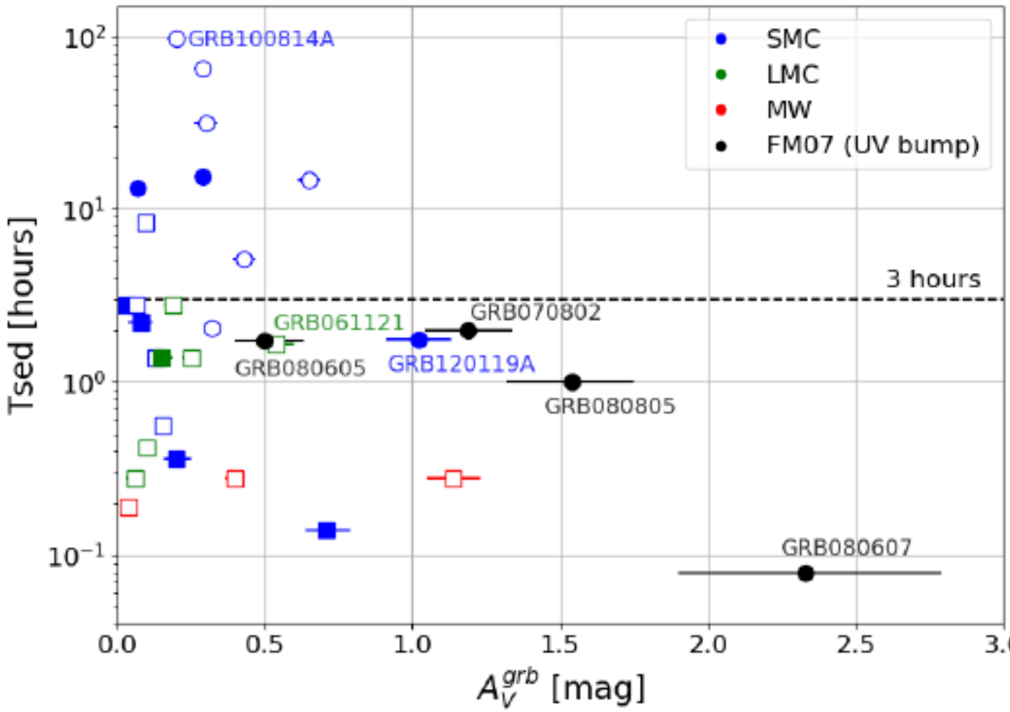
After a very careful selection

Name	redshift	Ext. curve	Host data
061121[(a)]	1.31	LMC	10 bands (incl. VLA)
070802	2.45	relatively steep + UV bump	7 bands
080605	1.64	steep + UV bump	8 bands
080607	3.04	flat + UV bump	9 bands (incl. ALMA)
100814	1.44	SMC-like	6 bands
120119	1.72	SMC-like	6 bands
080805	1.51	flat + UV bump	6 bands

photometry

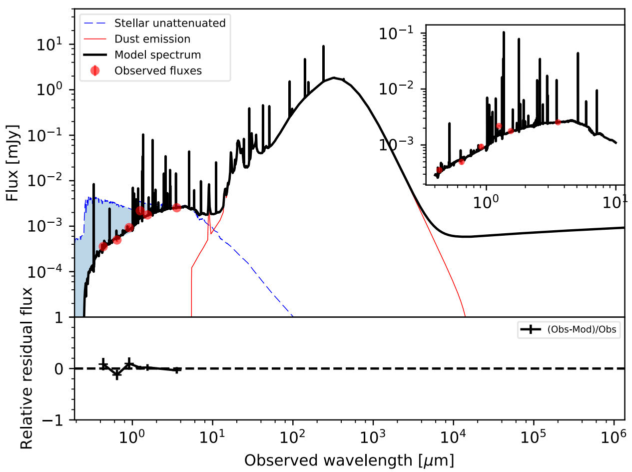
spectrosopy

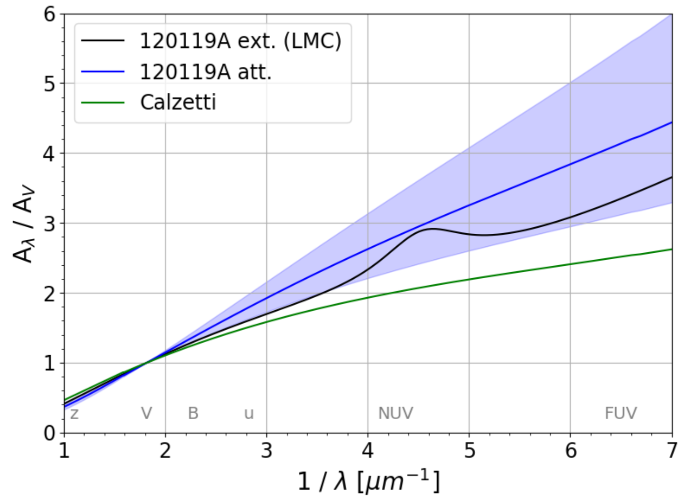
The afterglow has to be observed less than 3 hours after the burst to get a large variety of extinction curves



We use the photometric data for the host galaxies to measure the shape of the attenuation law with the code CIGALE. (Boquien et al. 2019)

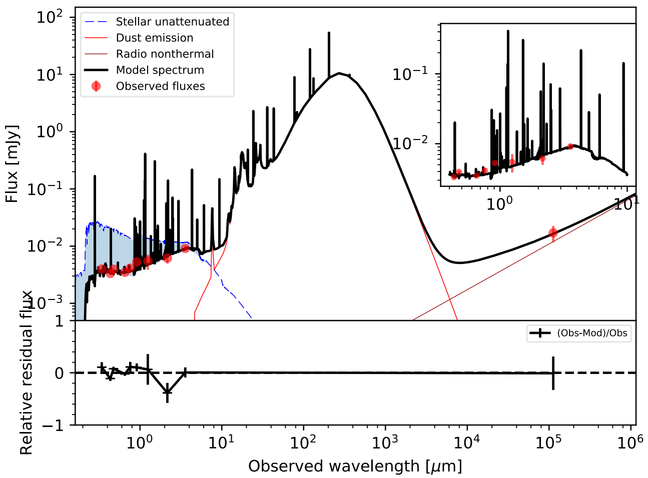
Best model for 120119A at z = 1.72. Reduced χ^2=0.32

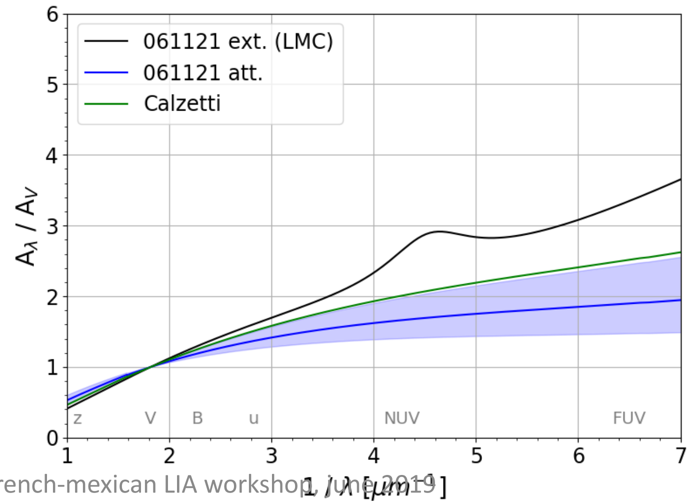




Steep att. Curve
Steeper than C00

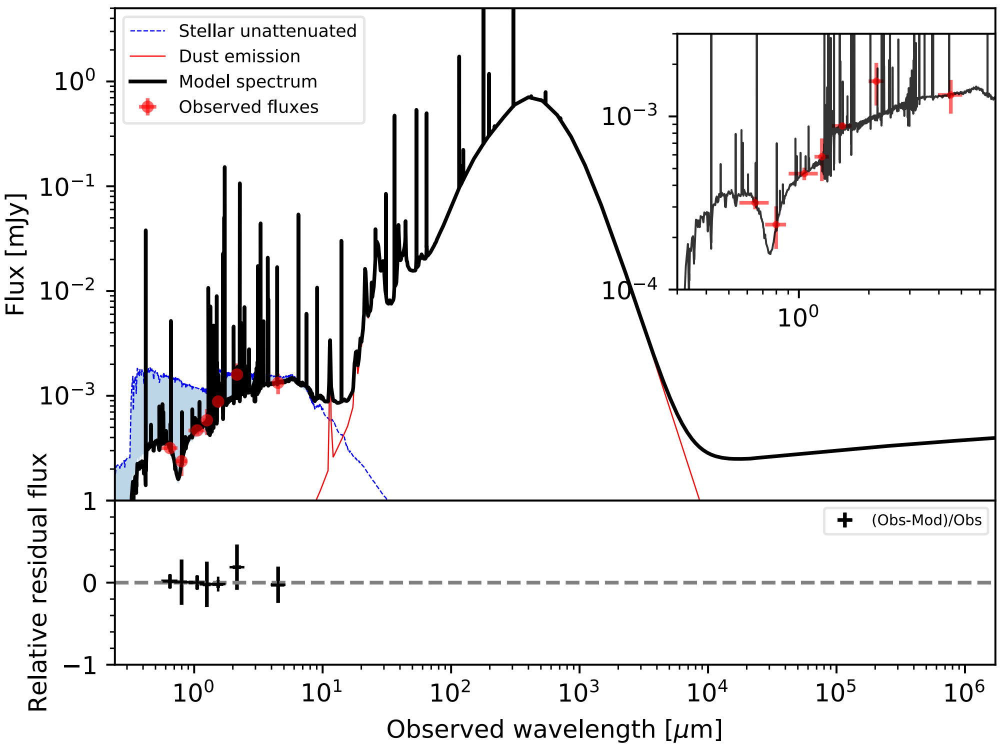
Best model for 061121 at z = 1.314. Reduced χ^2=0.74



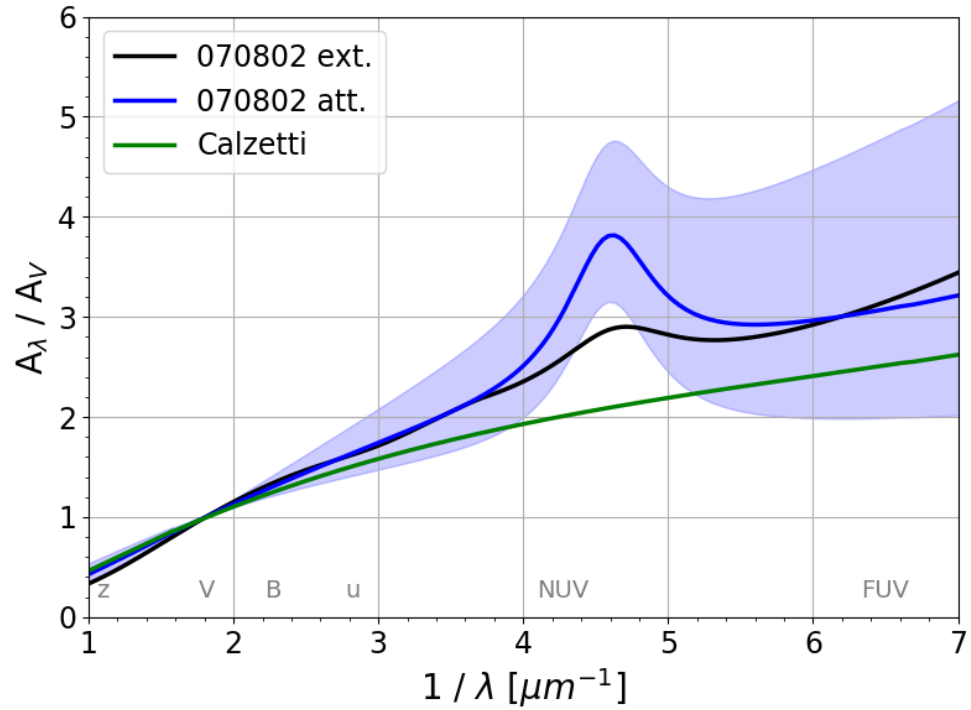


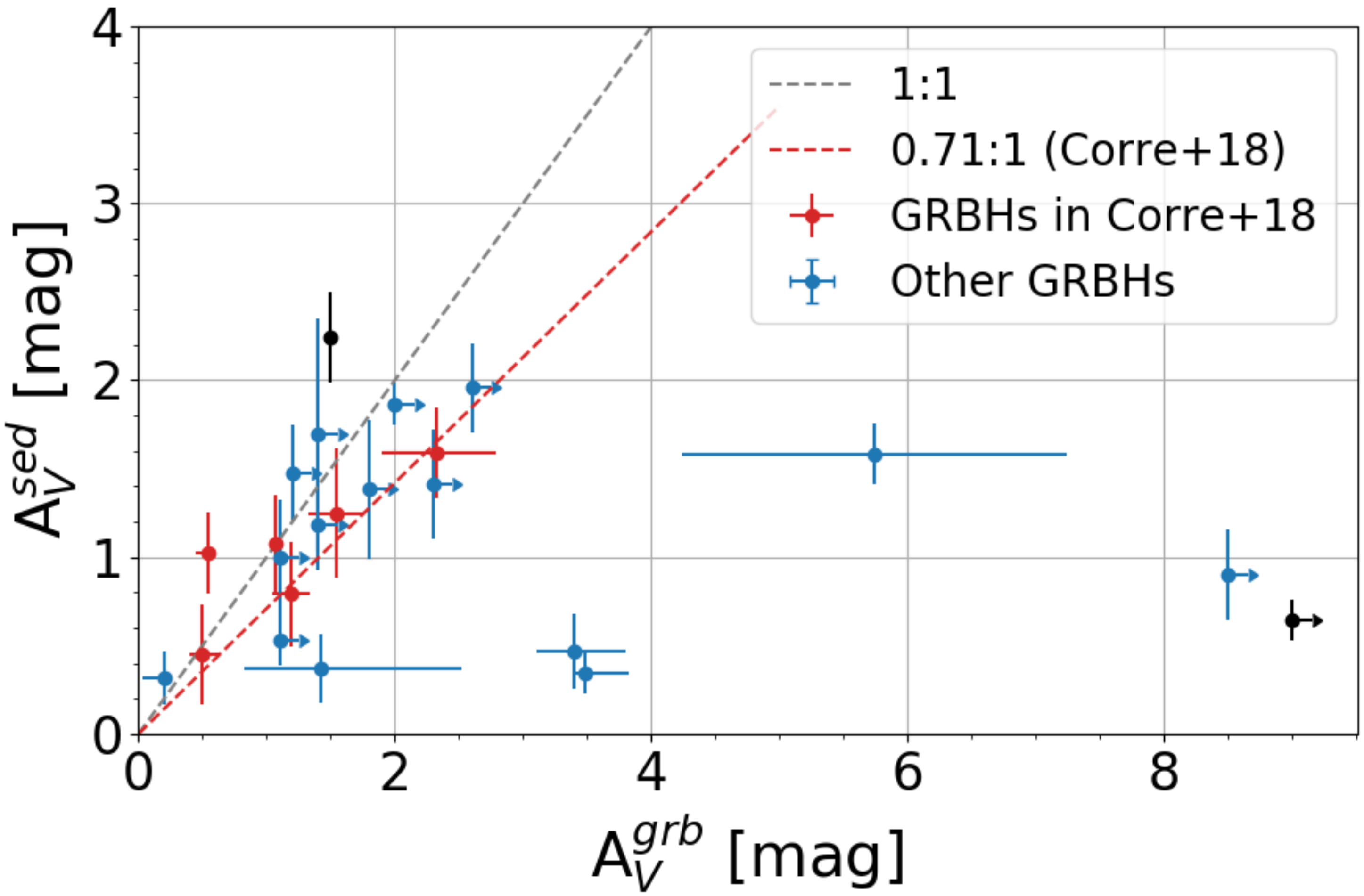
Flat att. Curve
Flatter than C00

Best model for 070802 at z = 2.454. χ^2 (N_{data}) = 0.50 (7)

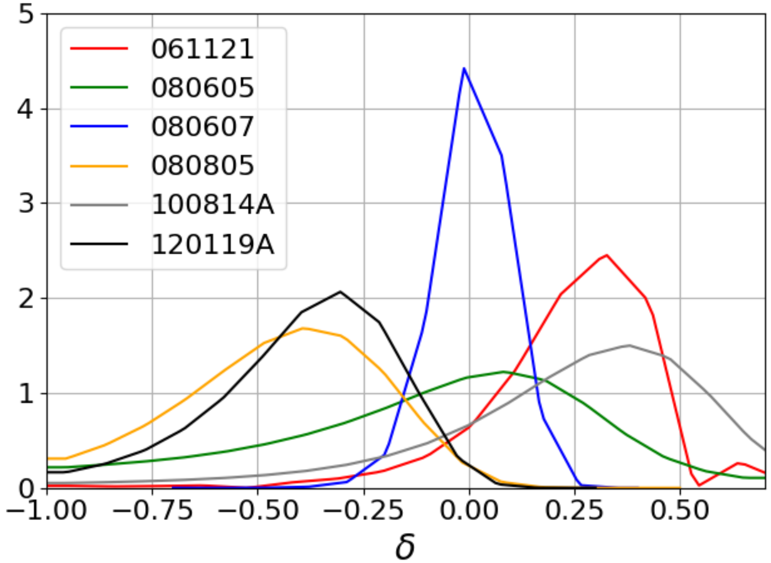


Presence of a bump in the attenuation curve



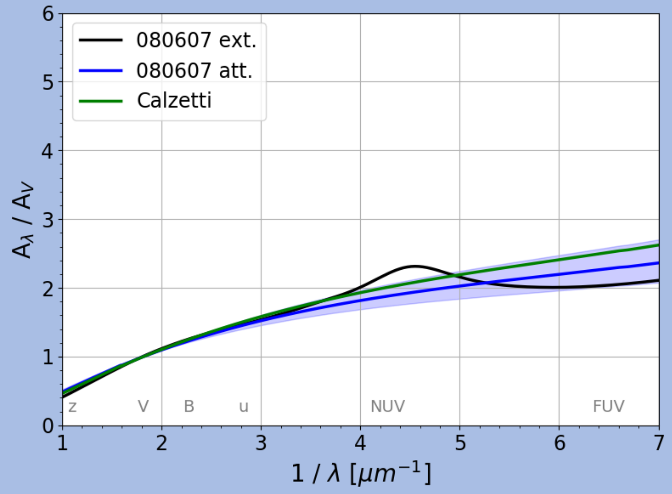


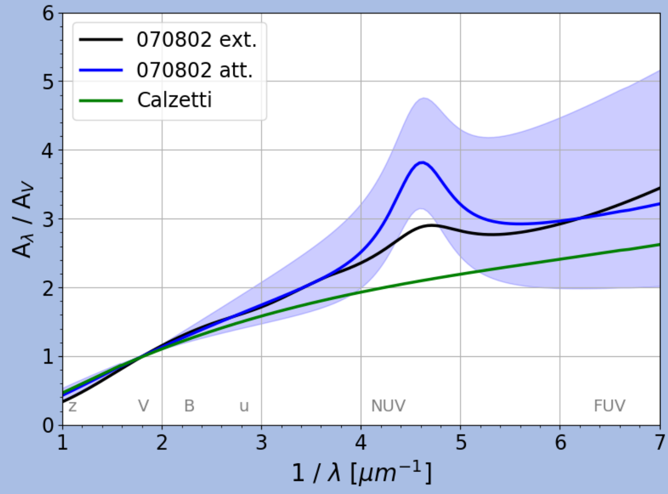
4
3
2
1
0
0
2
4
6
8
A_V^{sed} [mag]
A_V^{grb} [mag]
1:1
0.71:1 (Corre+18)
GRBHs in Corre+18
Other GRBHs

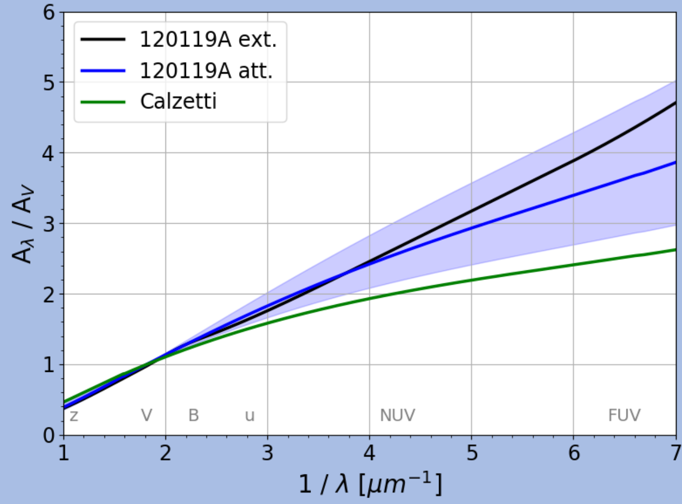


Probability distribution function for the slope of the attenuation curve

ident GRBH	z	SFR $M_\odot\ yr^{-1}$	$M_\star$ $10^9 M_\odot$	A_V mag	$\frac{E(B-V)_s}{E(B-V)_g}$	δ slope	sSFR Gyr^{-1}	f_b %	Burst age Myrs
061121	1.31	62.0 ± 25.7	6.9 ± 2.4	0.88 ± 0.30	–	0.22 ± 0.2	9.0 ± 4.9	29 ± 14	58 ± 31
080605	1.64	44.9 ± 22.9	12.3 ± 4.2	0.41 ± 0.29	0.35	-0.08 ± 0.38	3.6 ± 2.2	15 ±14	75 ±31
080607	3.04	49.7 ±14.3	23.5 ±10.5	1.55 ±0.23	–	0.06 ±0.09	2.1 ± 1.1	0.07 ± 0.11	69 ± 32
080805	1.5	21.0 ±11.6	3.3 ±1.5	1.06 ±0.34	0.47	-0.45 ±0.24	6.4 ± 4.5	22 ±16	60 ±33
100814A	1.44	4.0 ±2.31	2.9 ±0.8	0.35 ± 0.40	0.60	0.09 ± 0.51	1.4 ± 0.9	–	–
120119A	1.7	25.5 ±14.1	3.8 ±1.2	0.74 ±0.28	0.68	-0.39 ±0.22	6.7 ± 4.3	23 ±15	64 ±33

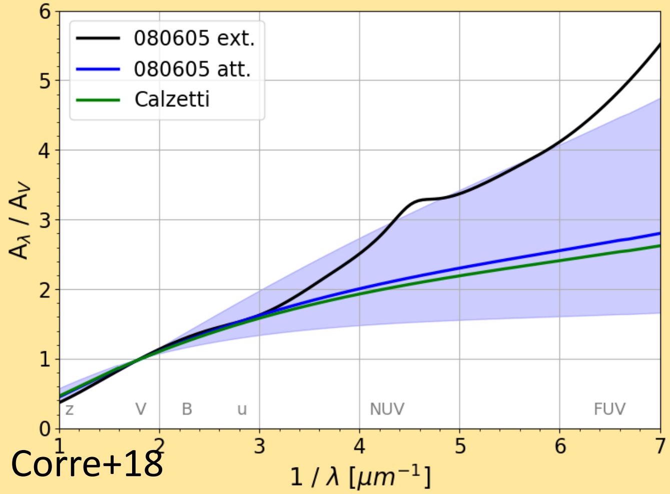


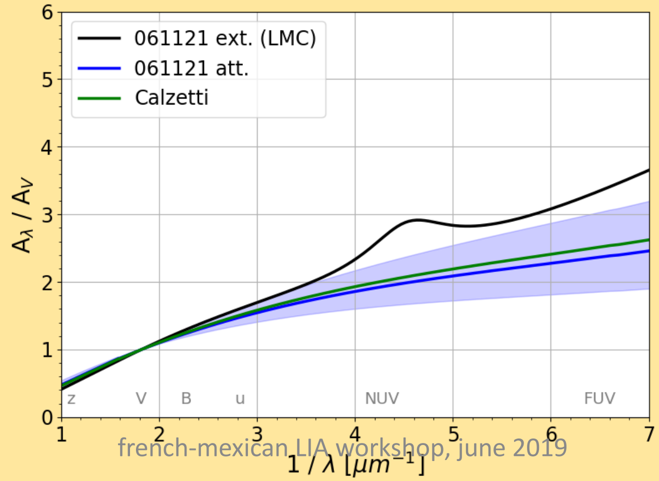




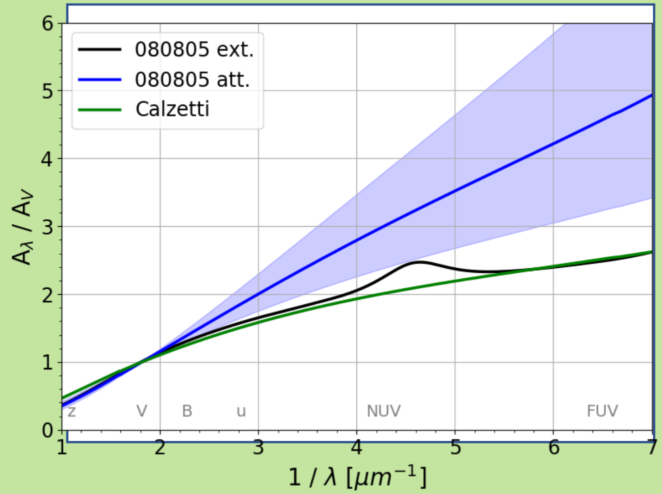
Att curve similar to Ext curve

Att curve flatter than Ext curve

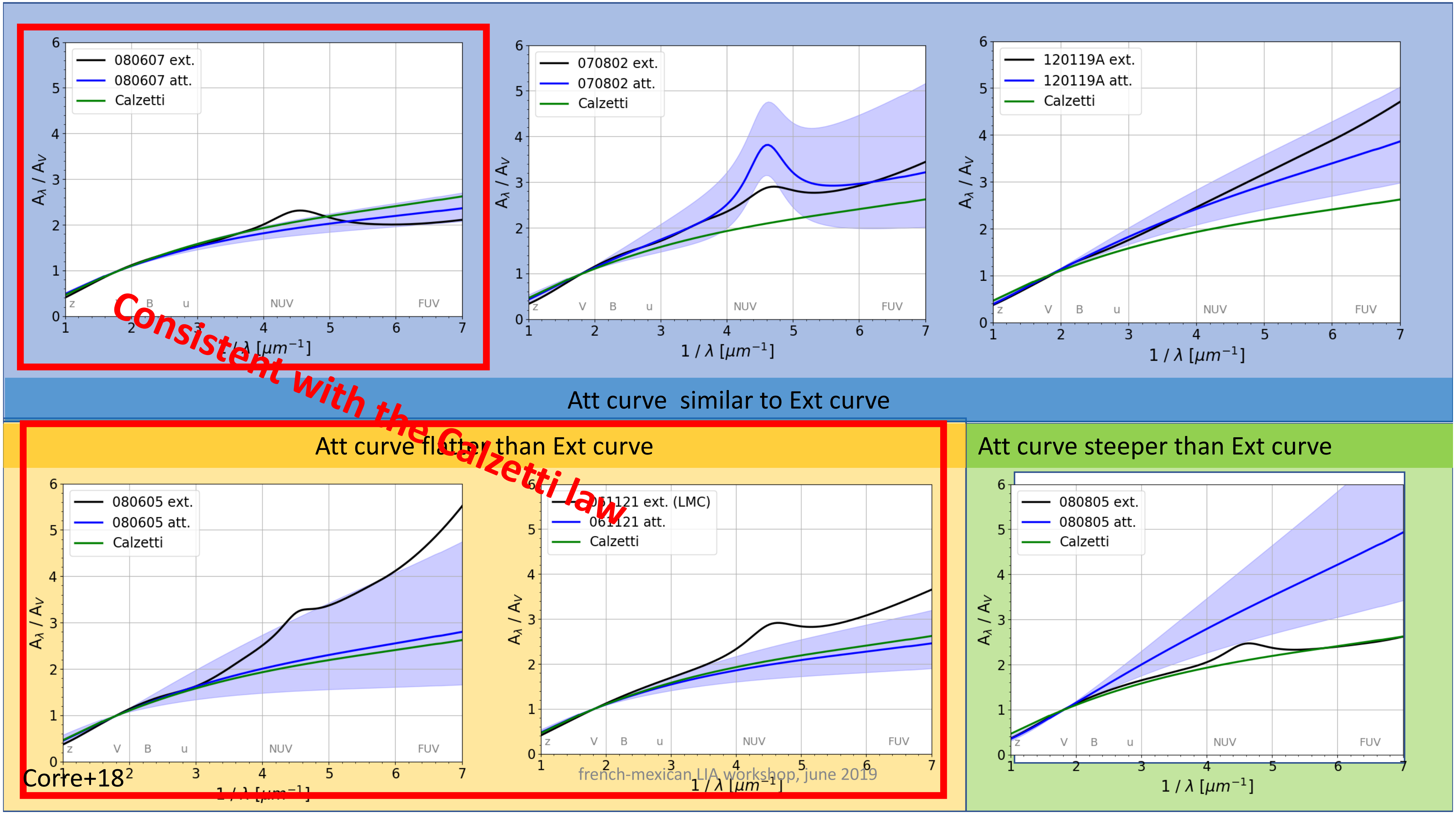




Att curve steeper than Ext curve



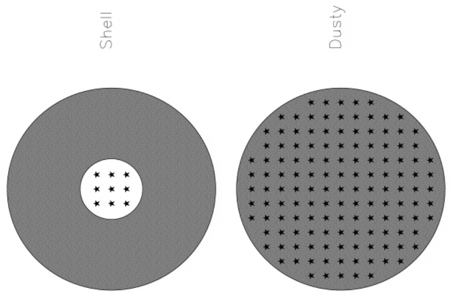
Corre+18



Consistent with the Calzetti law
080607 ext.
080607 att.
Calzetti
070802 ext.
070802 att.
Calzetti
120119A ext.
120119A att.
Calzetti
Att curve similar to Ext curve
Att curve flatter than Ext curve
Att curve steeper than Ext curve
080605 ext.
080605 att.
Calzetti
061121 ext. (LMC)
061121 att.
Calzetti
080805 ext.
080805 att.
Calzetti
A_λ / A_V
1 / λ [μm^{-1}]
z V B u NUV FUV
Corre+18
french-mexican LIA workshop, june 2019

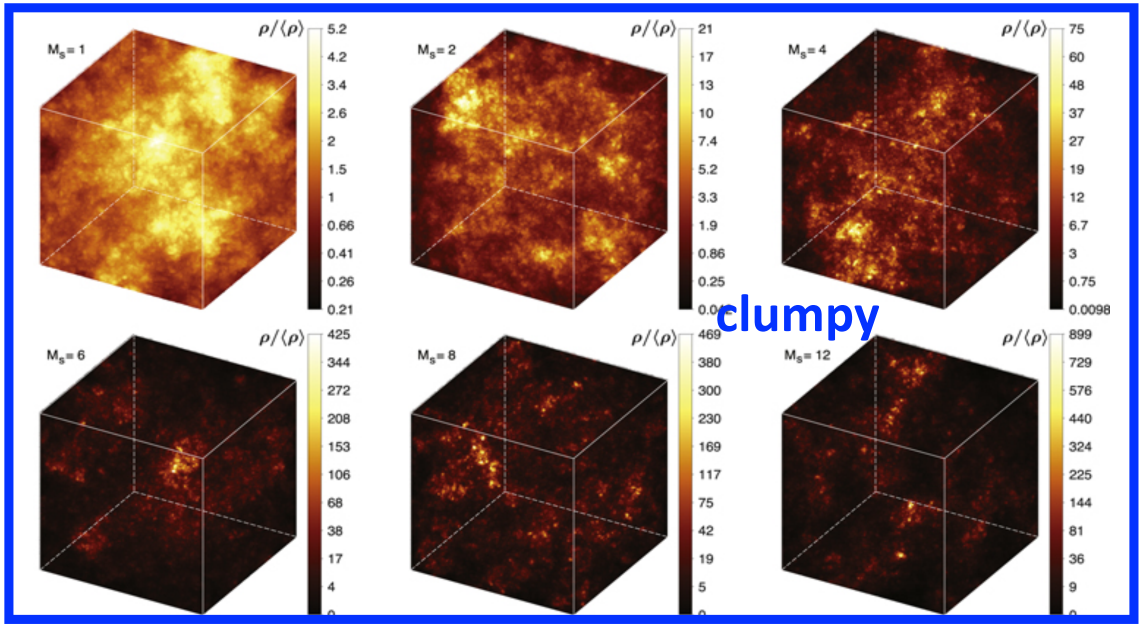
Comparison with the radiation transfer models of Seon & Draine 2015

shell



dusty

homogeneous



clumpy

	Dust model	ISM structure
061121	WD-LMC	Dusty + Very clumpy
070802	WD-LMC	Dusty + Very clumpy
080605	WD-LMC	Dusty + Very clumpy
080607	WD-MW	Shell + Clumpy
080805	WD-MW	Dusty + Homogeneous or Shell + Clumpy
120119A	WG-SMC	Dusty + Homogeneous or Shell + Clumpy

From our pilot study: we can extract information about the ISM conditions with the comparison of the extinction curve measured with the afterglow and the attenuation curve from the SED of the host

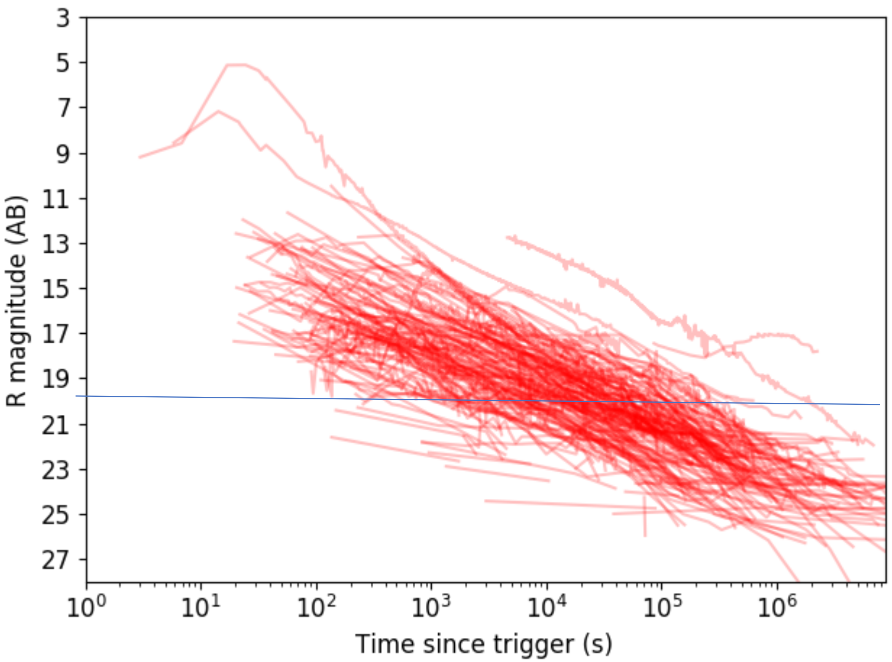
What do we need to go further with SVOM?

- ❑ **Extinction curves:**
  - **Requirement: LMC, SMC or MW type, or (better) fit of the extinction curve for each case → spectroscopy**
  - **UV range mandatory**
  - **Observations <3 hours after the burst**

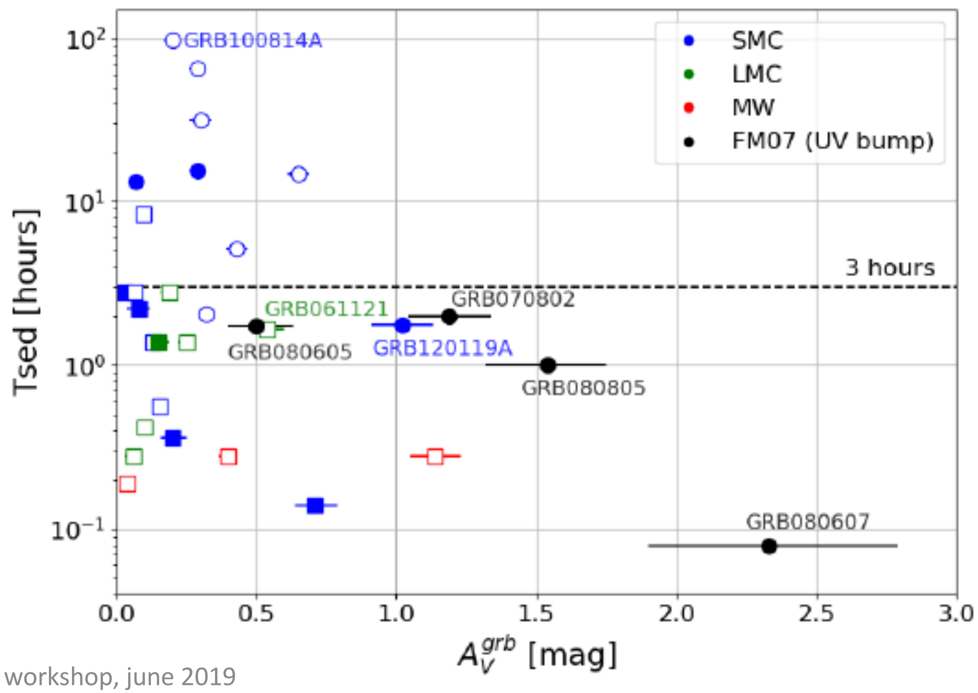
- ❑ **Photometry with COLIBRI: search for a bump in the extinction curve. Is it sensitive enough? To be explored**

- ❑ **Follow up of the host galaxy with at least several photometric bands**

A representative sample of GRBs:
R magnitudes as function of time.
From SWIFT statistics:
up to 2 GRBs/month observable
by Mistral 1<z<2



Mistral @ OHP, France
An observation between 30 mn and 1 h after the burst is optimal in terms of magnitude and attenuation



Thank you!