Extinction process in GRB host galaxies

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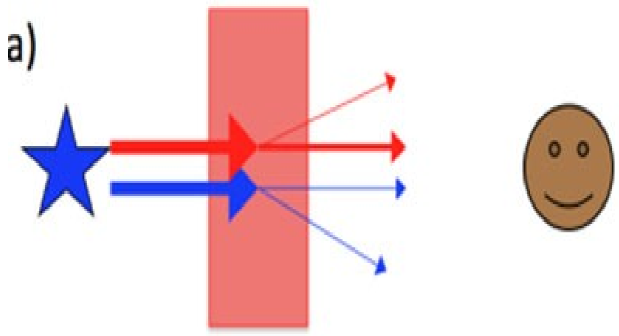
Aim : Constrain dust geometry, distribution and composition in a set of distant GRB-selected galaxies

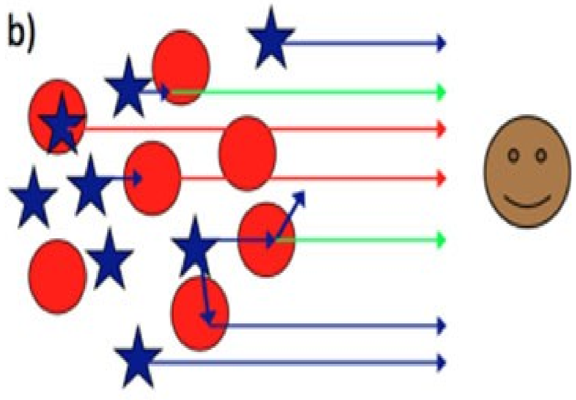
Method : - comparing extinction and attenuation curves
- never done with observationnal data only

Definitions:

- Extinction curve :
  (GRB l.o.s)
- Attenuation curve :
  (integration over all Galaxy l.o.s)



Credit : Calzetti (2012)



Credit : Calzetti (2012)

1. Context: GRB extinction curve

Why GRBs are excellent probes of the extinction process at high redshift ?

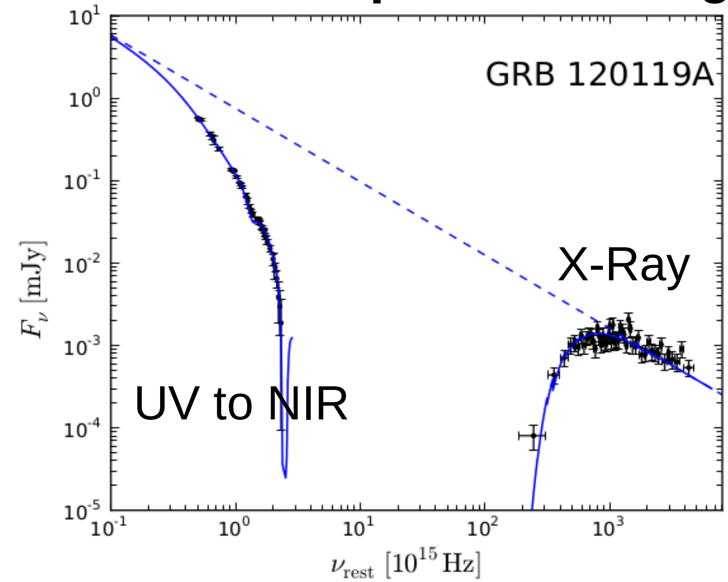
1) GRB emission spectrum known

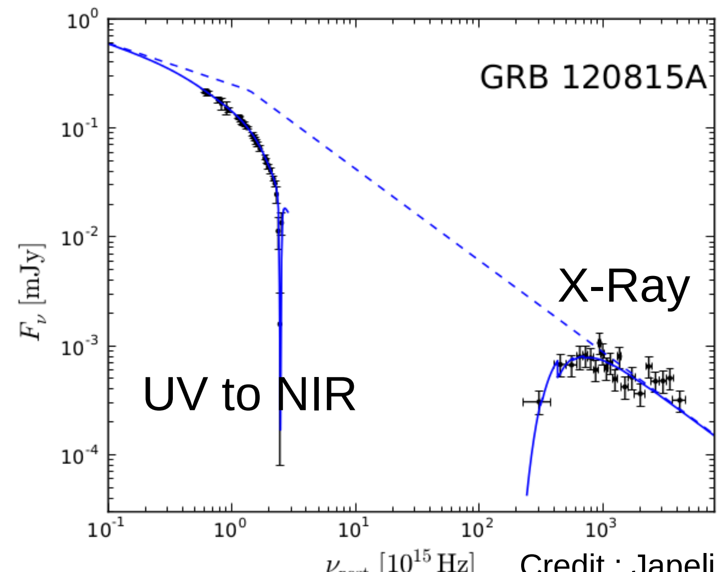
- GRB emission well described by a synchrotron emission
- it follows that the SED is well described by a power law
- or a broken power law

2) Gives us thus a direct acces to the extinction

$$F_{\nu,obs} \propto F_\nu \cdot 10^{-0.4 \cdot A_\lambda}$$

Either scaling a template (LMC, SMC, MW) or using a flexible fit (e.g. Fitzpatrick & Massa)

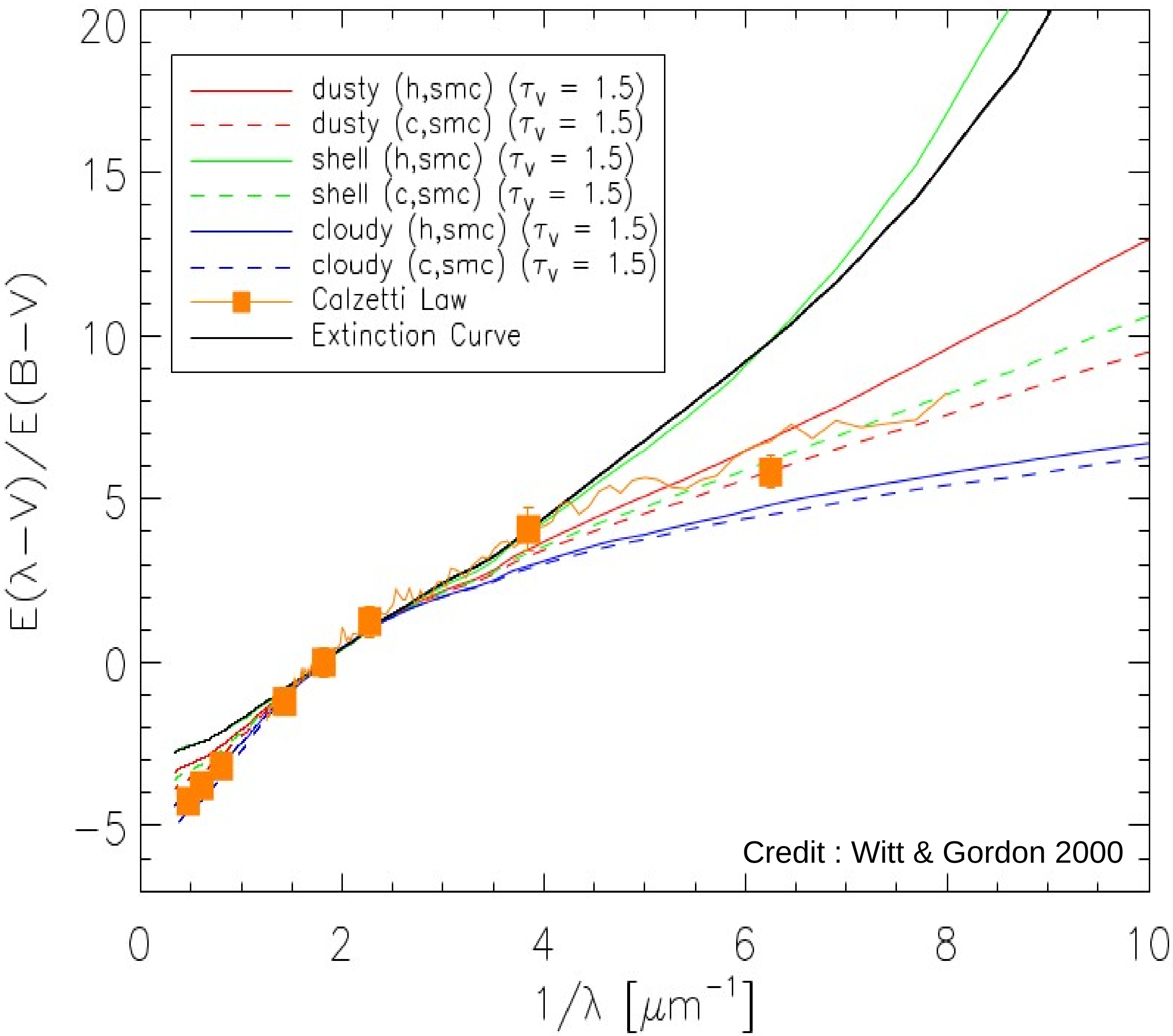


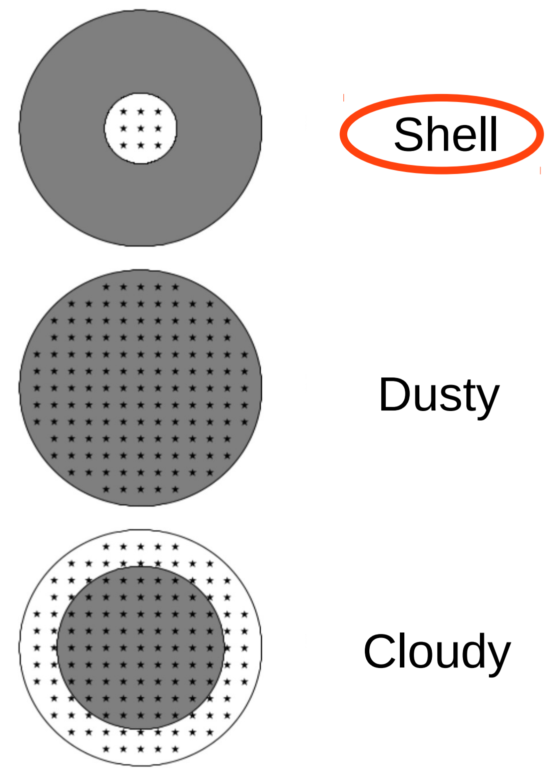


Credit : Japelj 2015

1. Context: Typical case

SMC extinction curve ↔ Calzetti attenuation curve
(clumpy shell geometry, Witt & Gordon 2000)





2. Sample selection criteria : GRB extinction curves

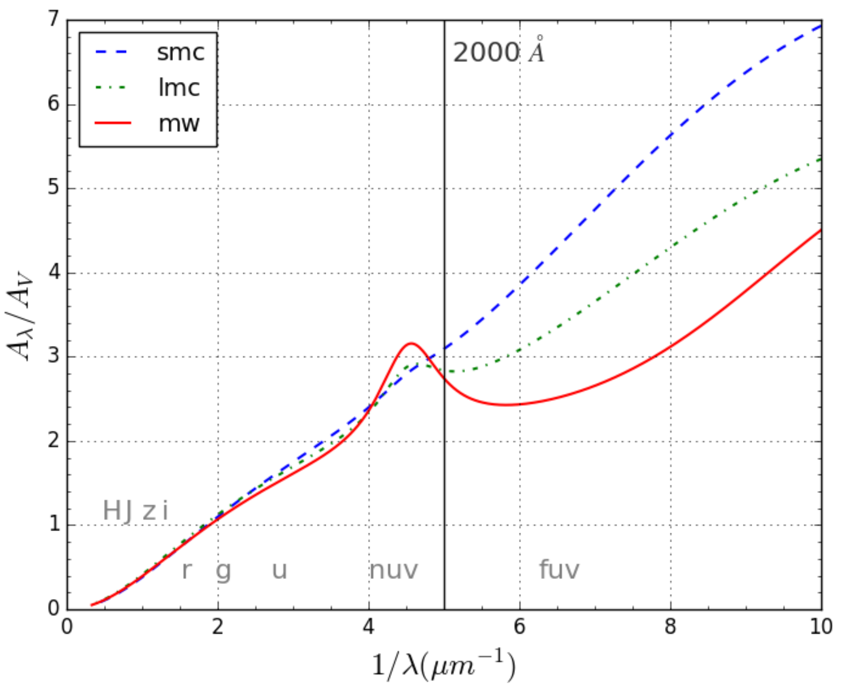
Dust effects are particularly strong in UV, so we require an accurate estimation of the rest-frame UV extinction

GRB selection criteria

→ rest-frame UV coverage is required.

- Spectroscopic measurement is preferred
  Zafar et al (2011,2012)
  Japelj et al (2015)

- Photometric measurement : at least one band < 2000 A rest-frame
  Schady et al (2012)



- Spectroscopic sample : 25 GRBs

- Photometric sample : 32 GRBs

2. Sample selection criteria : GRB host galaxies

Dust effects are particularly strong in UV, so we require an accurate estimation of the rest-frame UV extinction

No attenuation curve in the literature, need to derive it using SED fitting

GRB Hosts selection criteria

- at least 6 bands in the UV-to-NIR spectrum
- Robust SFR measurement requires rest-frame UV observations
- Recombination lines *Kruehler et al (2015)*
- Match GRB ext. curve samples

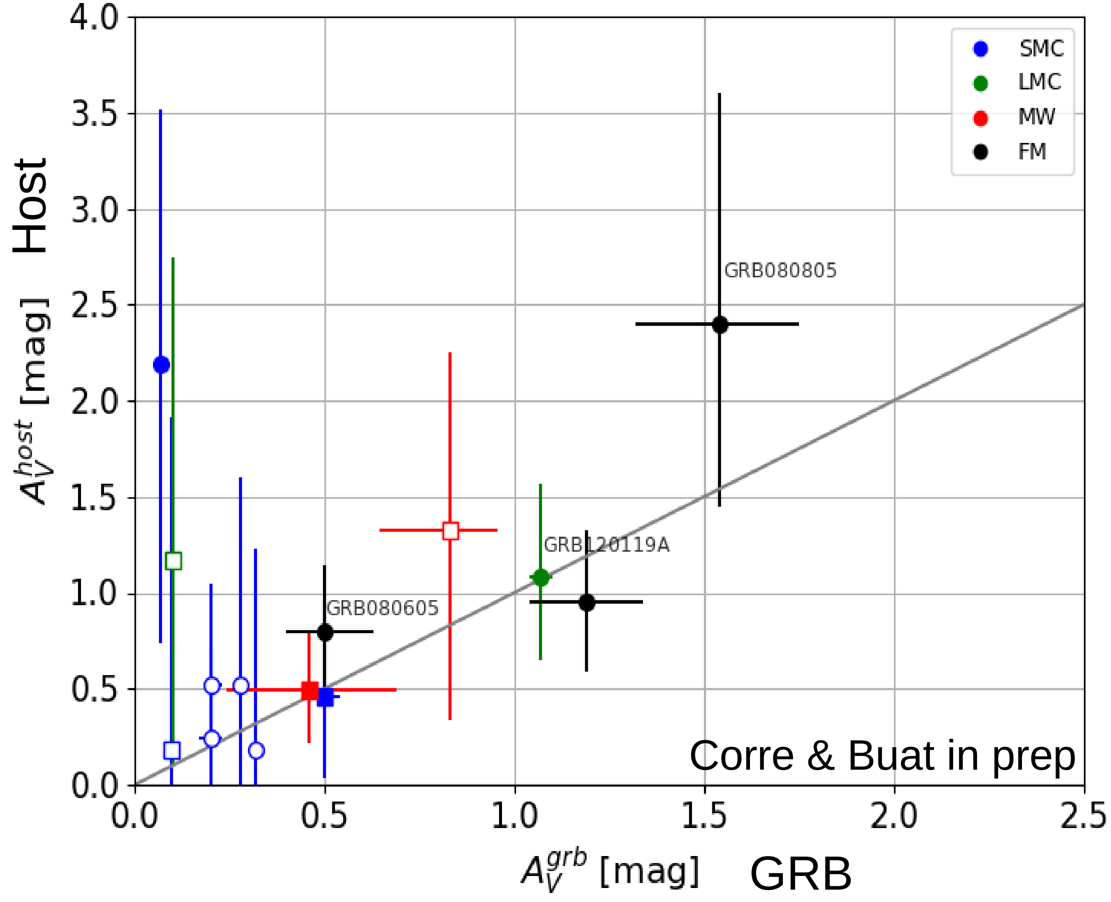
Final sample (matching the GRB extinction curves samples**):**

Name	redshift	Ext. curve	data
120119	1.72	LMC	6 bands
080607	3.04	flat+bump	9 bands (incl. ALMA)
080605	1.64	steep+bump	8 bands
080805	1.51	flat+bump	6 bands
061121	1.31	LMC	10 bands (incl. VLA)

3. Our sample properties

Host attenuation vs GRB extinction

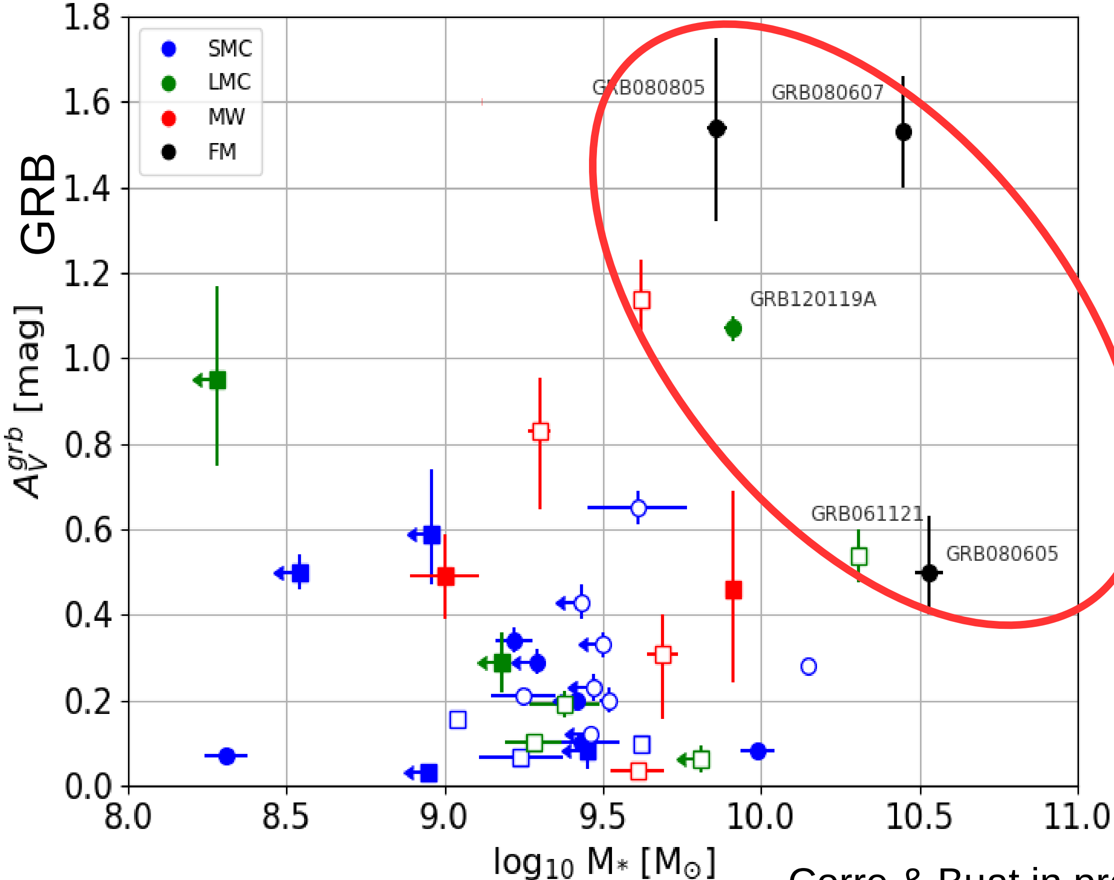
- Almost all data consistent with the 1:1 relation
- Indicator of a relatively homogeneous dust distribution in the host



3. Our sample properties

Mass – obscuration relation

- Selected dusty massive hosts
- Masses from Perley et al (2016)



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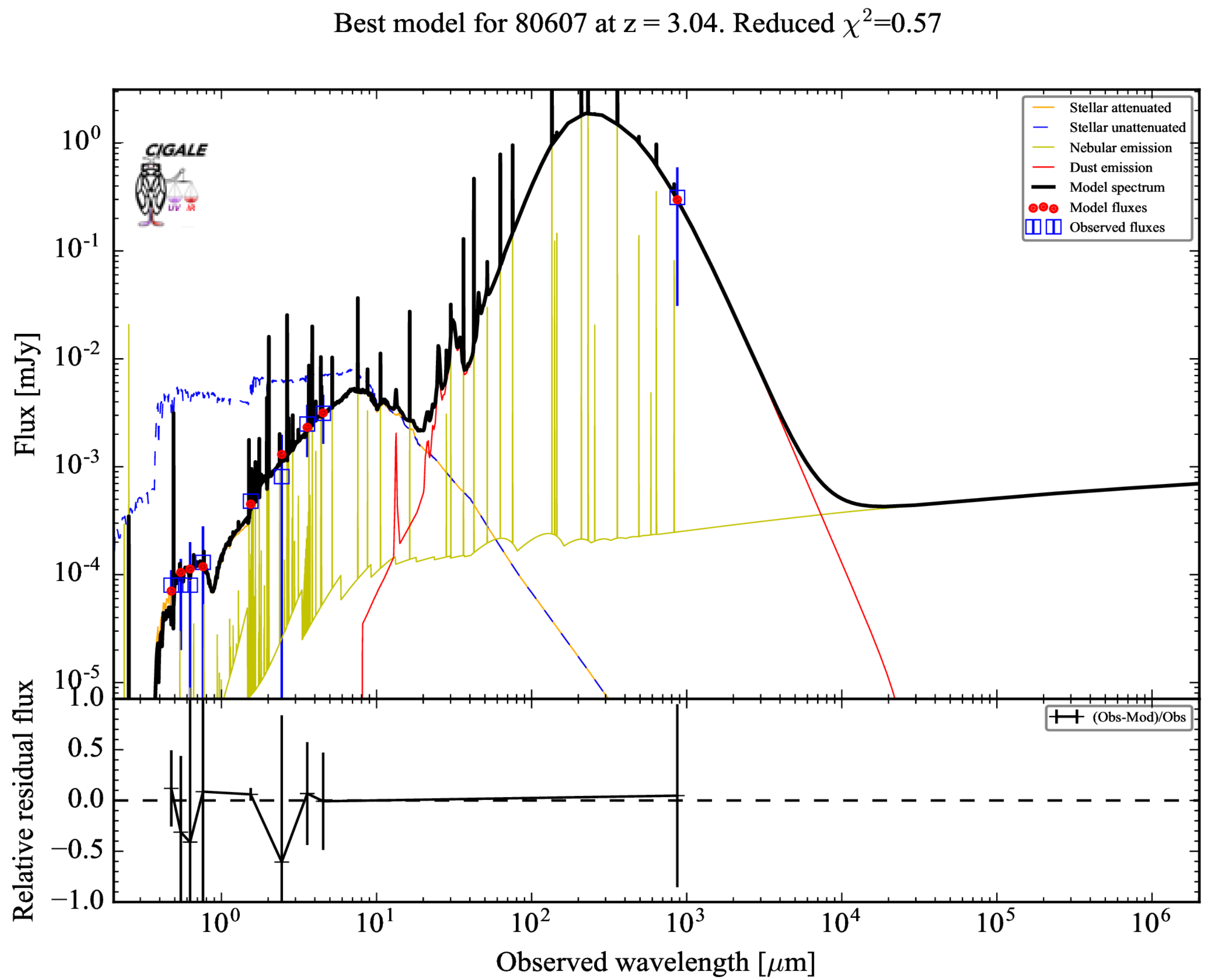
4. SED fitting : GRBH080607

Using CIGALE code

Literature :
- No SFR (Halpha)
- M = 2.8 10^{10} (Perley2016)

Our result:
- SFR = 46 ± 13 M.yr^{-1}
- M = 2.6 10^{10}
- sSFR = 1.8 10^{-9} yr^{-1}

- No recent burst needed
- Attenuation ~ Calzetti



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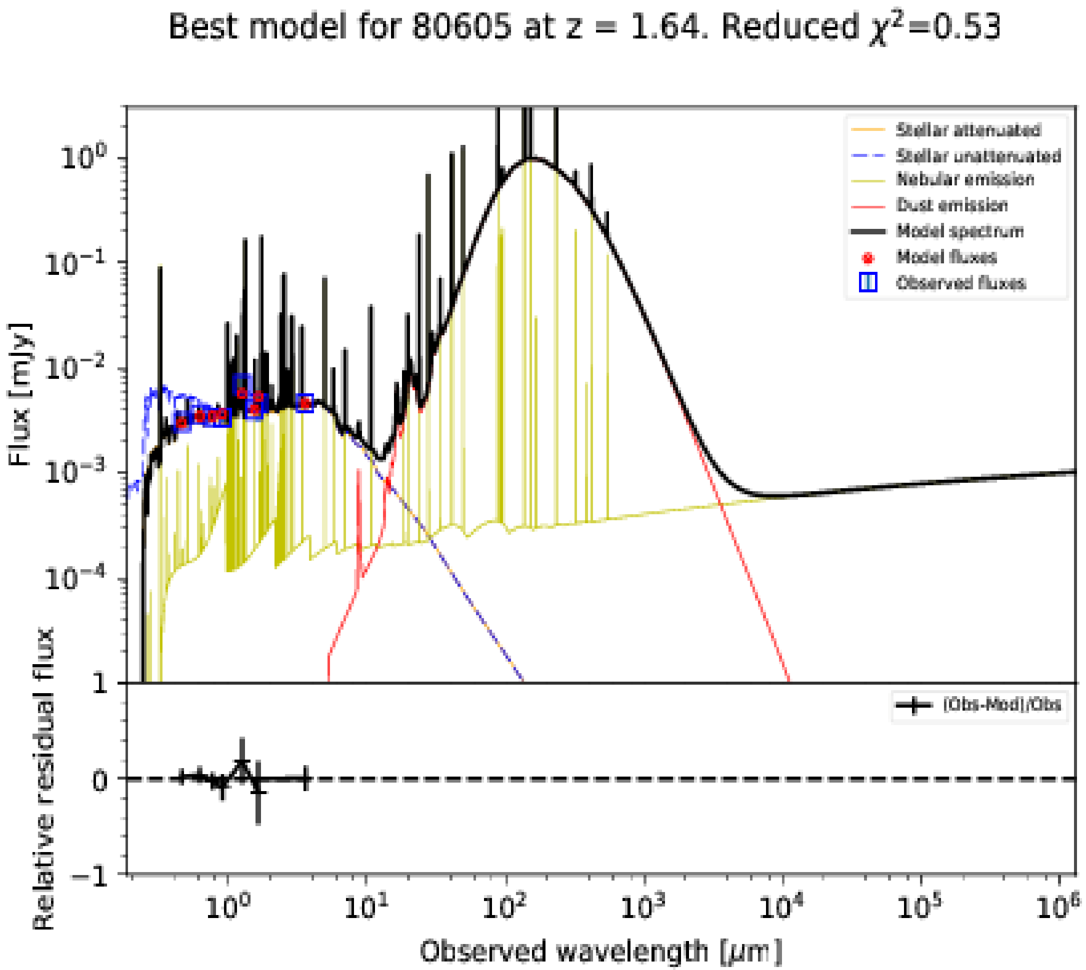
4. SED fitting : GRBH080605

Using CIGALE code

Literature :
- SFR (Halpha) = 47 [35-64]
- M = 3.4 10^{10} (Perley2016)

Our result:
- SFR = 37 ± 6 M.yr^{-1}
- M = 4.4 10^{9}
- sSFR = 8.4 10^{-9} yr^{-1}



- **recent strong burst**
- **Emission lines needed**
- Steep attenuation

Each case is different

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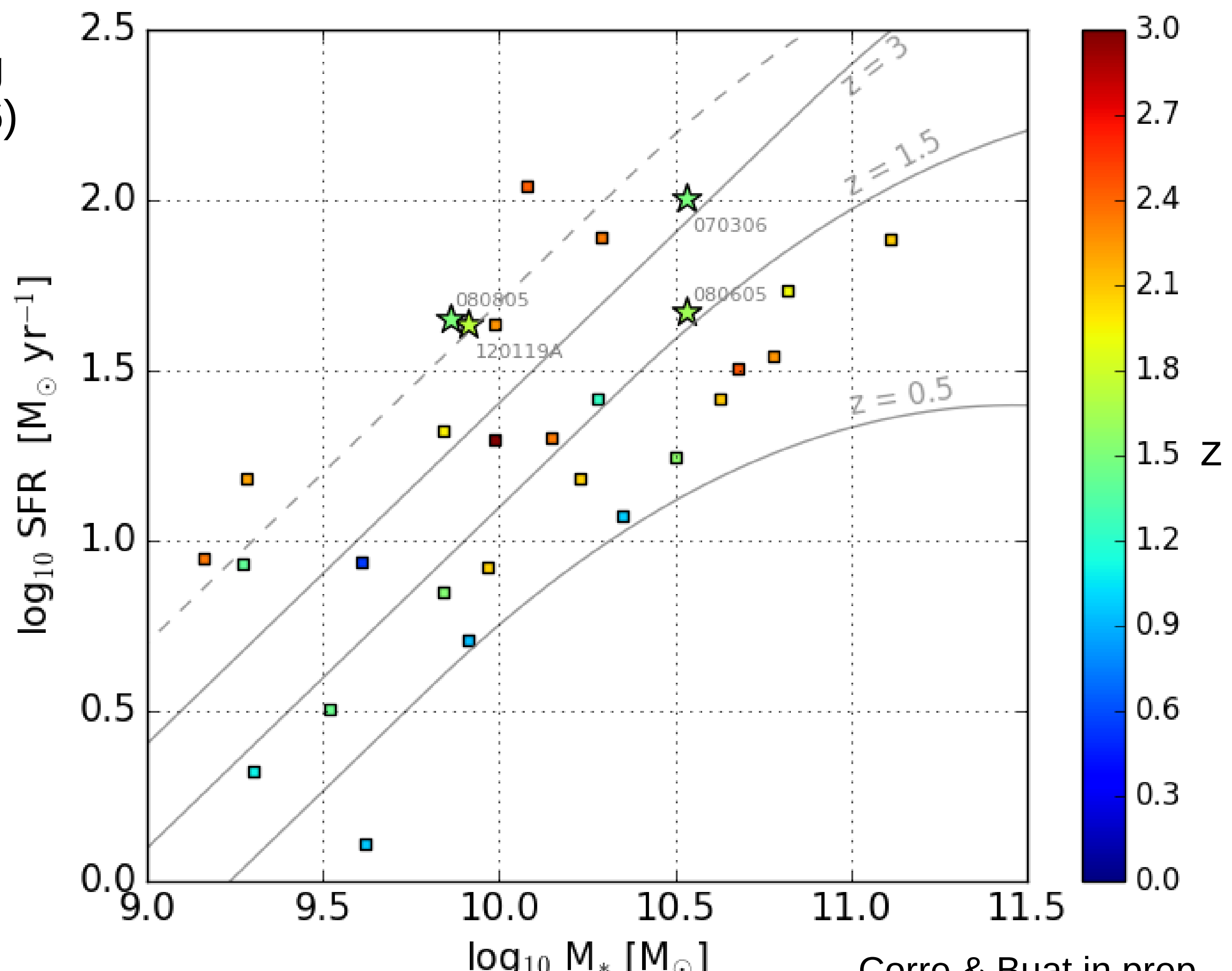
5. Starburst Galaxies ?

- Grey lines : star-forming galaxies (Schreiber 2016)
- Dashed line : starburst 4*star-forming (z=1.5)
- Squares :
  Mass from Perley 2016
  SFR from Kruehler 2015



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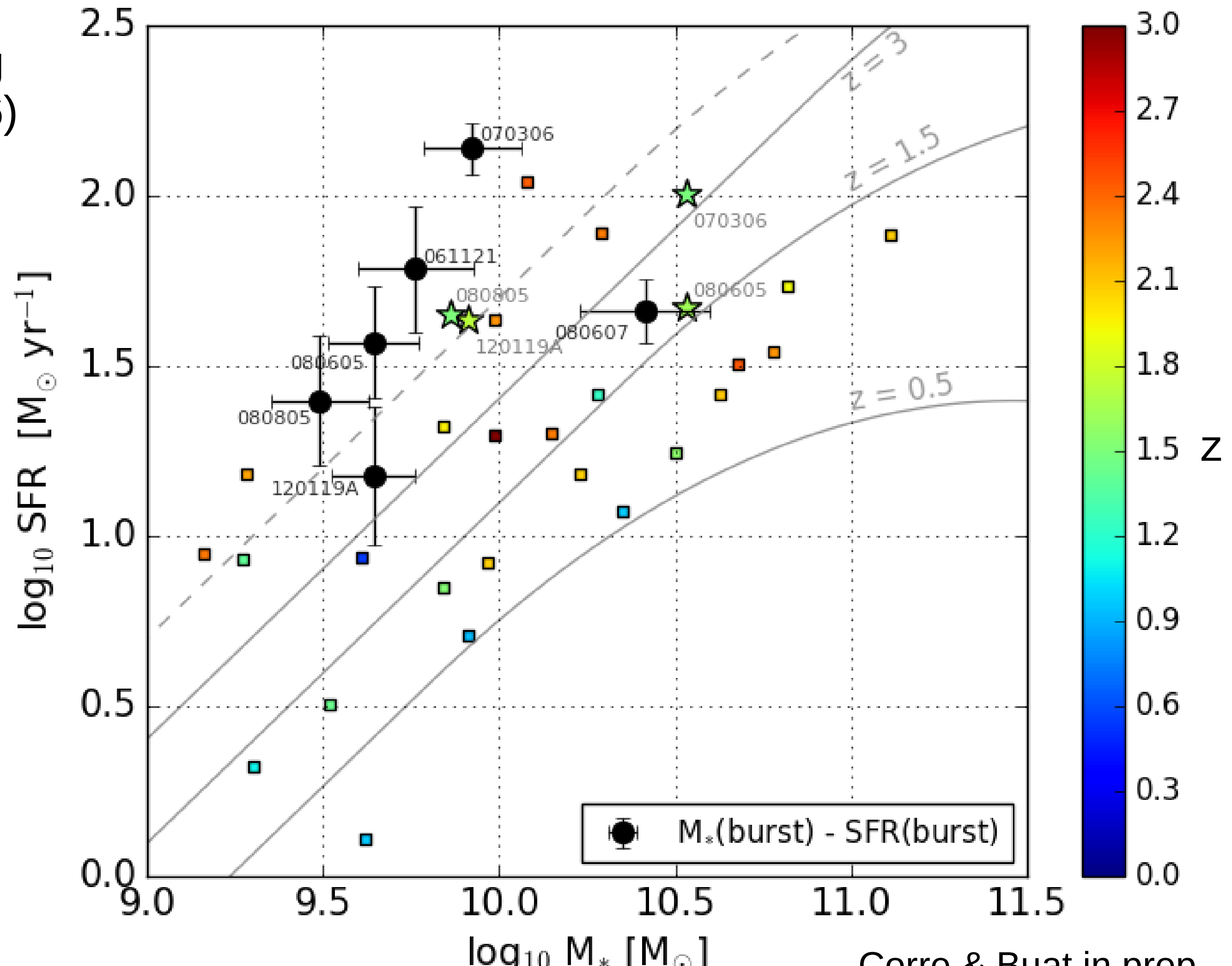
5. Starburst Galaxies ?

shift to lower masses

- Grey lines : star-forming galaxies (Schreiber 2016)
- Dashed line : starburst 4*star-forming (z=1.5)
- Squares :
  Mass from Perley 2016
  SFR from Kruehler 2015
- SED fitting with burst



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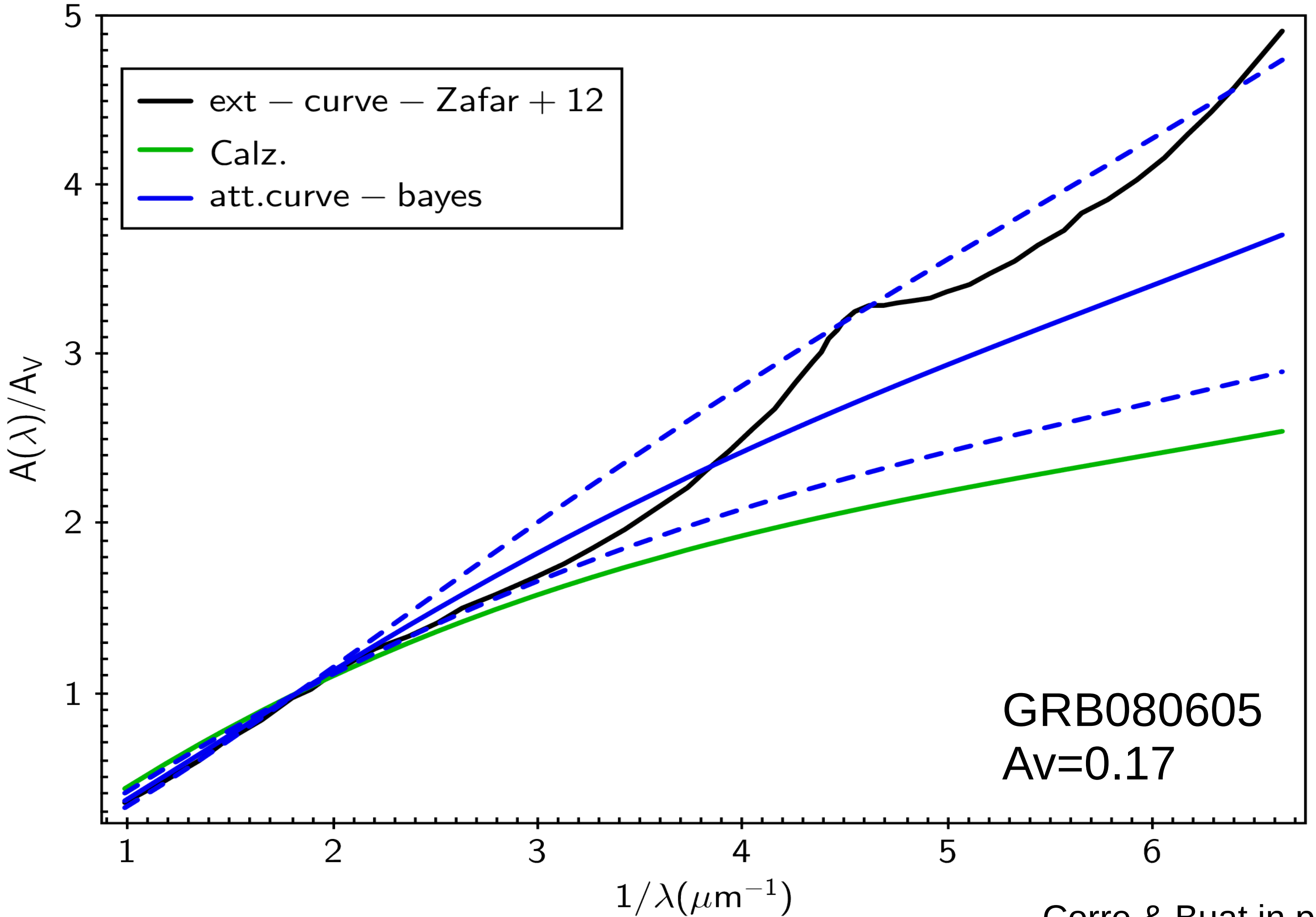
6. Attenuation curve vs extinction curve



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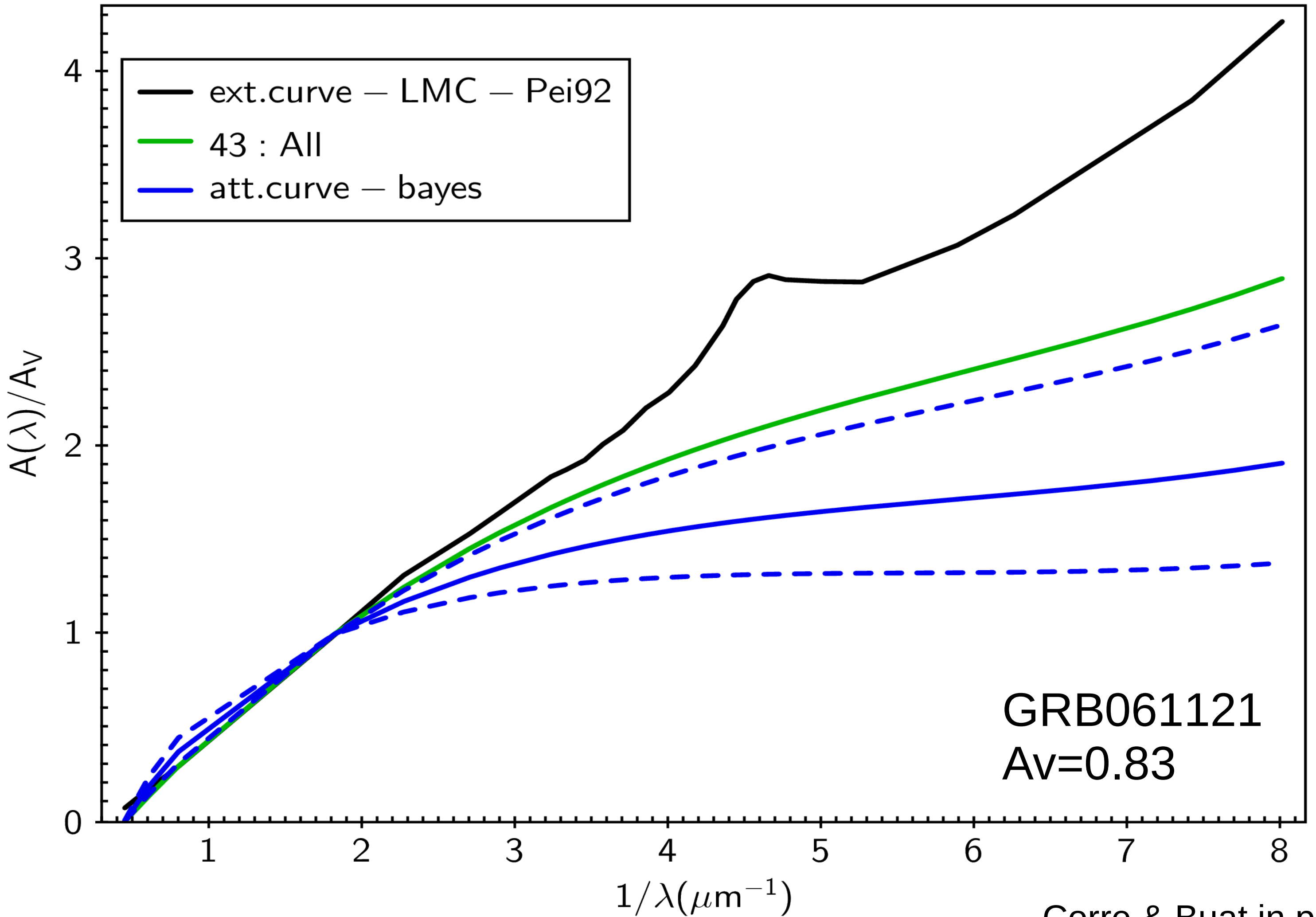
6. Attenuation curve vs extinction curve



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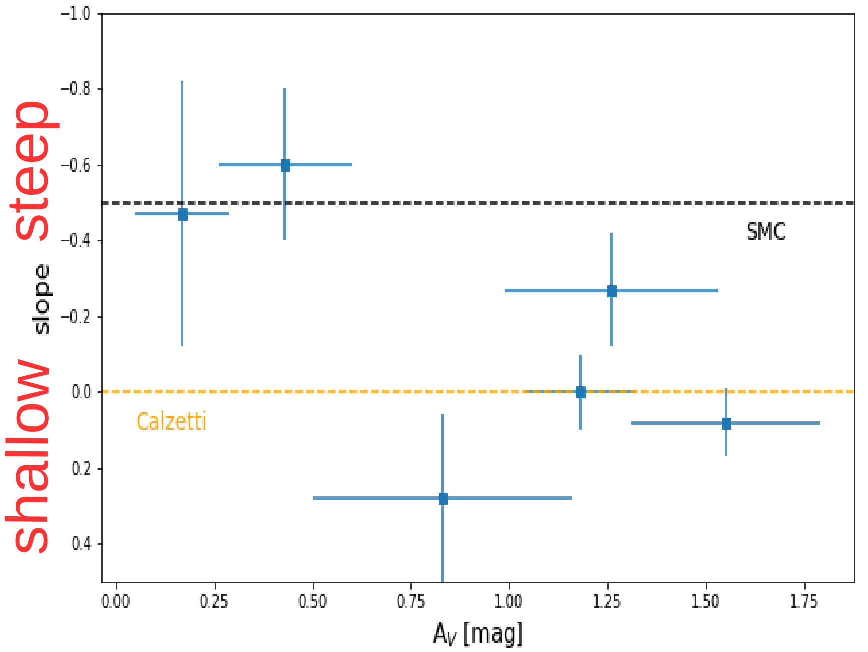
7. Relation optical depth – Attenuation steepness



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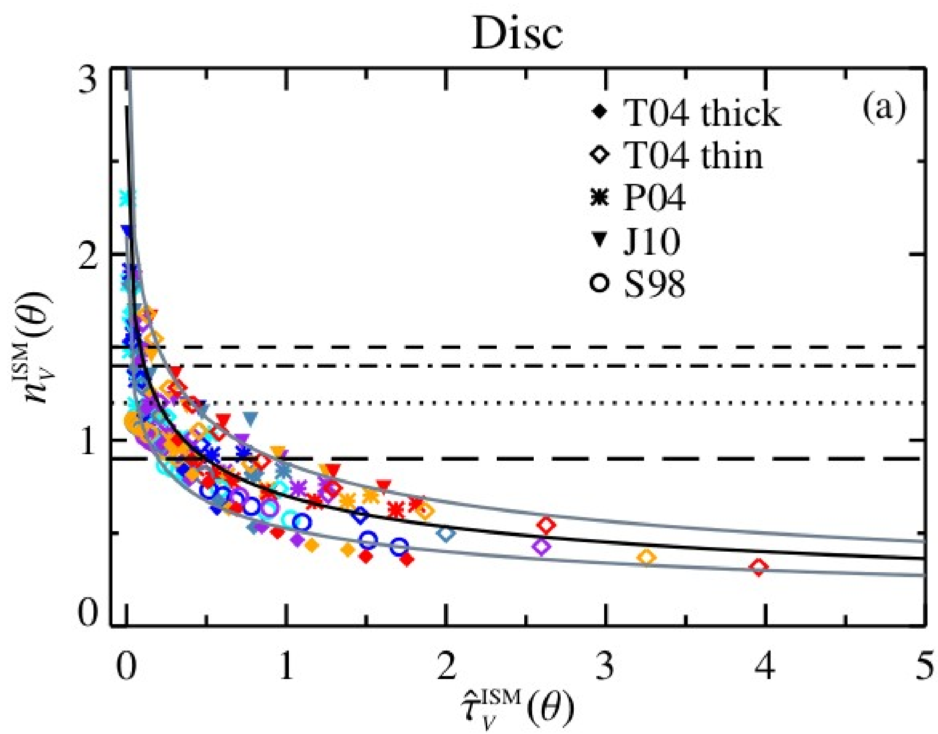

Credit : Chevallard 2013

$$A_\lambda = E(B-V)\,\left(k'(\lambda) + D_{\lambda_0,\gamma,E_\mathrm{b}}(\lambda)\right)\left(\frac{\lambda}{\lambda_V}\right)^{\delta}$$

Summary

- Our sample is composed of rather dusty GRBs compared to normal population

- Rather homogeneous dust distribution in the host

- Attenuation curves marginally compatible with the Calzetti law but great variabilty when compared to the extinction curves

- Correlation between optical depth and attenuation curve steepness

- Evidence for the hosts in our sample to be starburst galaxies (except 080607)

Future work

- Use of radiative transfer code in order to constrain :
  - the dust geometry, composition, distribution of our GRBHs
  - the temporal evolution of extinction curves

  (in collaboration with V. Buat, T. Takeuchi, H.Hirashita, A. Inoue, R. Asano)

- Check whether re-evaluation of GRBH masses is needed
  (S. Vergani, R. Salvaterra, S. Boissier)

- F-GFT will be able to detect more dusty GRB l.o.s and hence help to increase the sample size

Thank you !