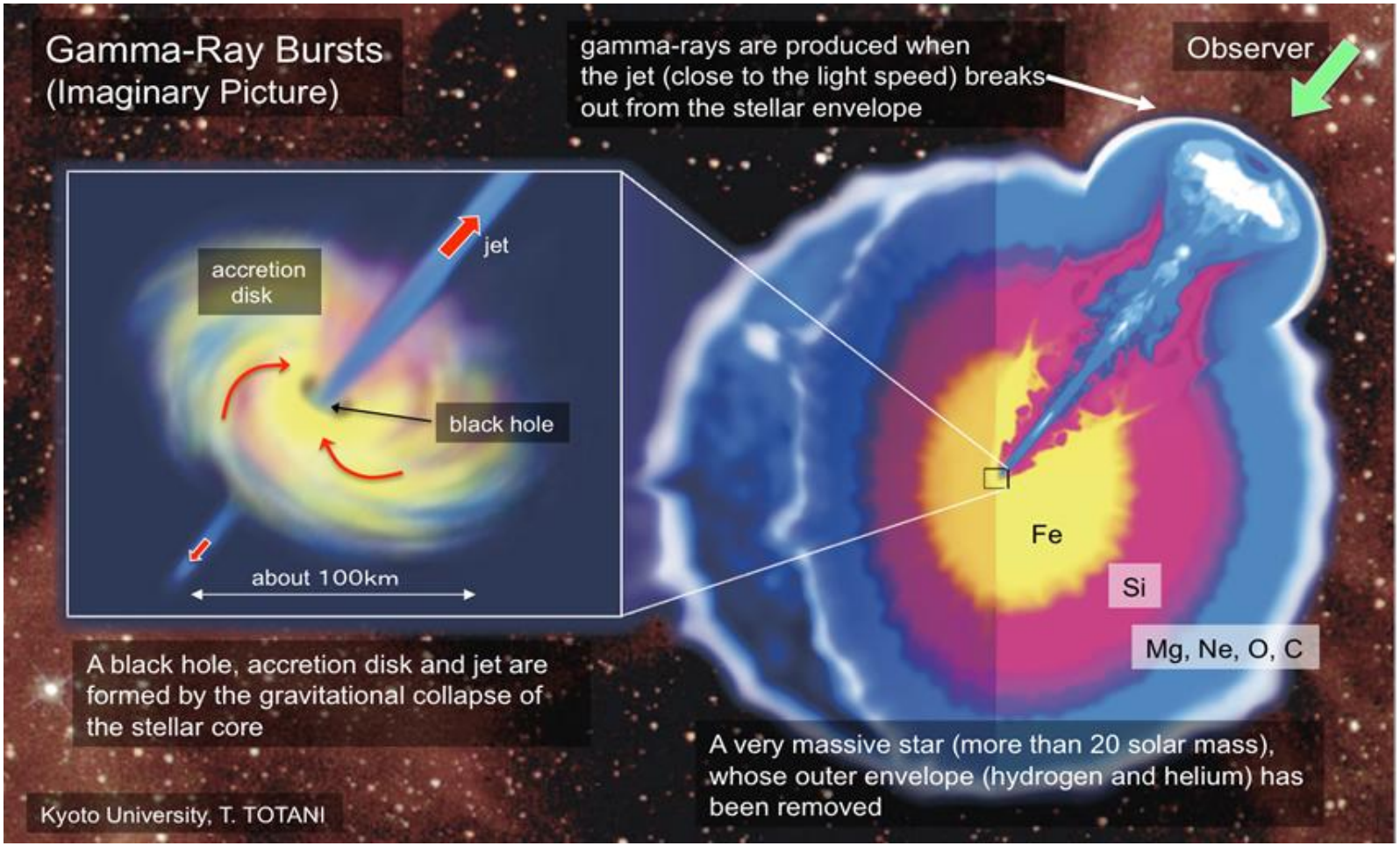
A LARGE EXTINCTION FOR A "DARK" GRB 080325 IN A DUSTY MASSIVE GALAXY

Tetsuya Hashimoto, Kouji Ohta (Kyoto Univ.), Kentaro Aoki, Ichi Tanaka (NAOJ), Kiyoto Yabe (Kyoto Univ.), Nobuyuki Kawai (TITech), and Subaru GRB Team

Outline

- What is a dark GRB?
- Subaru ToO observation of dark GRB 080325
- Dust extinction for GRB 080325
- Summary

(Long) Gamma-Ray Burst (GRB)



	GRB	X-ray, optical, near infrared, and radio afterglow
Time scale	Several tens of seconds	Several minutes ~ several tens of hours

What is a dark GRB?

http://www.mpe.mpg.de/~jcg/grbgen.html

GRBs and afterglow (AG) statistics (yearly sums of the table above)

Year	No of GRBs	No of X-ray AGs	No of optical AGs	No of radio AGs
1997	10	9	4	2
1998	11	6	6	5
1999	21	10	7	5
2000	59	8	8	5
2001	26	4	4	5
2002	46	6	10	6
2003	37	8	15	3
2004	38	8	10	1
2005	109	84	47	14
2006	122	106	64	5
2007	109	76	46	6
Sum	**588**	**325**	**220**	**55**

Jochen Greiner, last update: 25-Aug-2009

Optical afterglow is often missing!

Why are they dark?

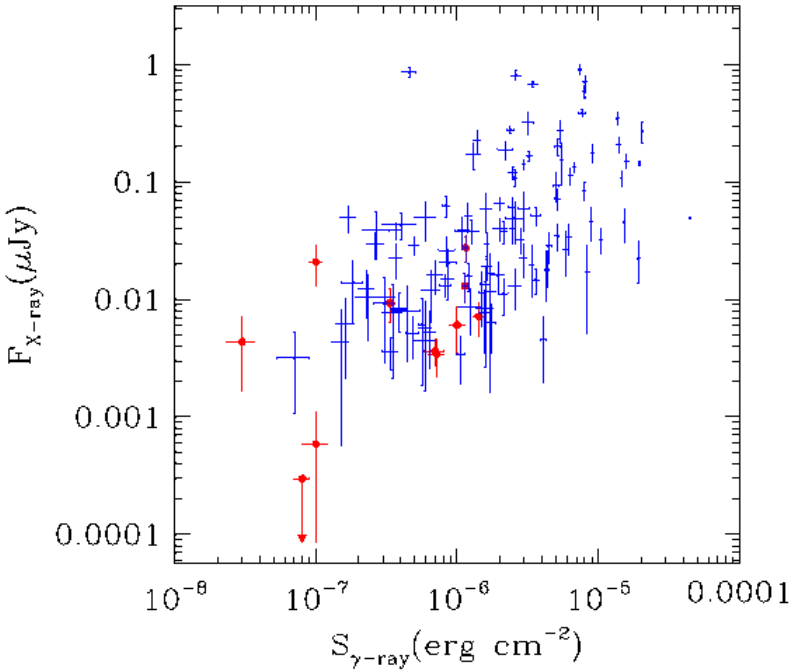
Possible Origins of Dark GRBs

- Low density environment around GRB

GRBs exploding in galaxy halos are predicted to have afterglows orders of magnitude fainter than those occuring in galactic disks (e.g., Kumar & Panaitescu 2000).

- Intrinsically low luminosity GRB

Gehrels et al. 2008



- Large extinction
  along the line of sight to GRB

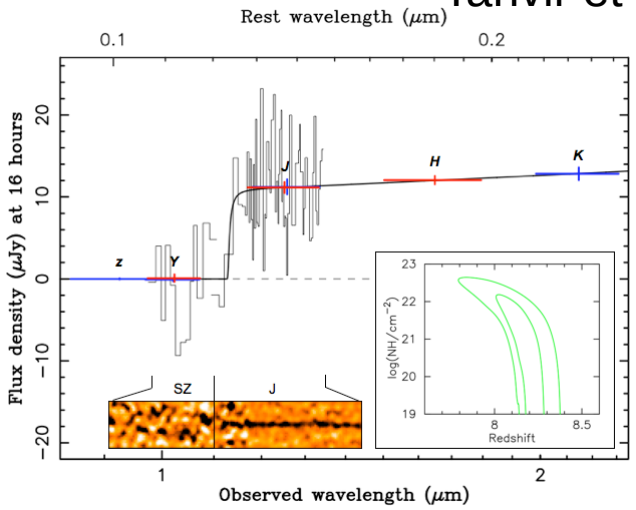
for reference

long GRB host = faint and blue

(Le Floc'h et al. 2003, A&A 400, 499)

- High redshift

Tanvir et al. 2009

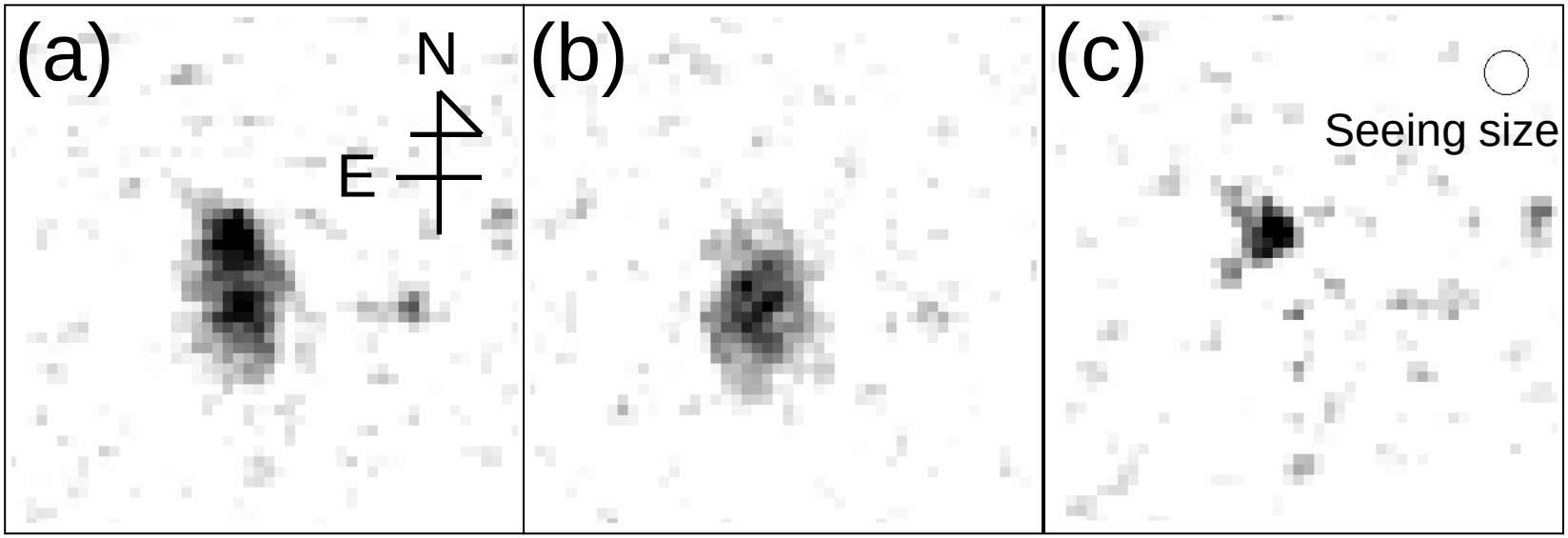


Subaru/MOIRCS ToO observation of GRB 080325

No optical detection of the afterglow within Swift XRT error circle

Subaru/MOIRCS J, Ks band ToO obs. → Detection in Ks band (Ks=22.8)

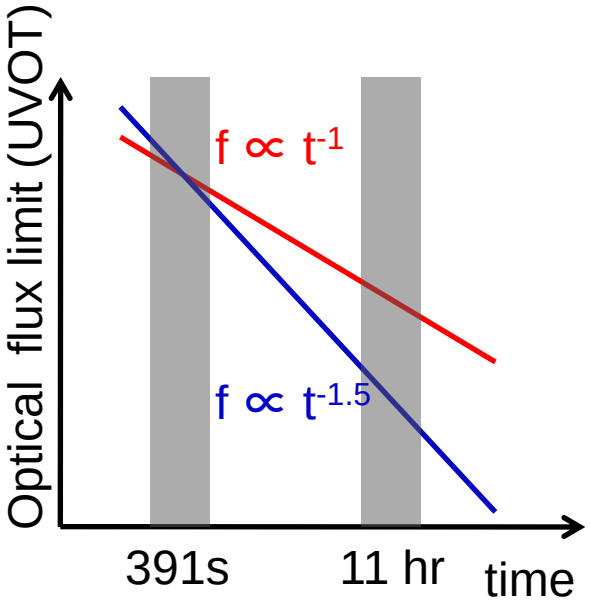
MOIRCS Ks band (5”.0 x 5”.0)



8.7 hours after the burst 33.5 hours after the burst afterglow (a)-(b)

Dark GRBs Defined by β_{OX} (Jakobsson et al. 2004)

$\beta_{OX} = \log\{f_\nu(3keV)/f_\nu(R)\}/\log(\lambda_{3keV}/\lambda_R)$

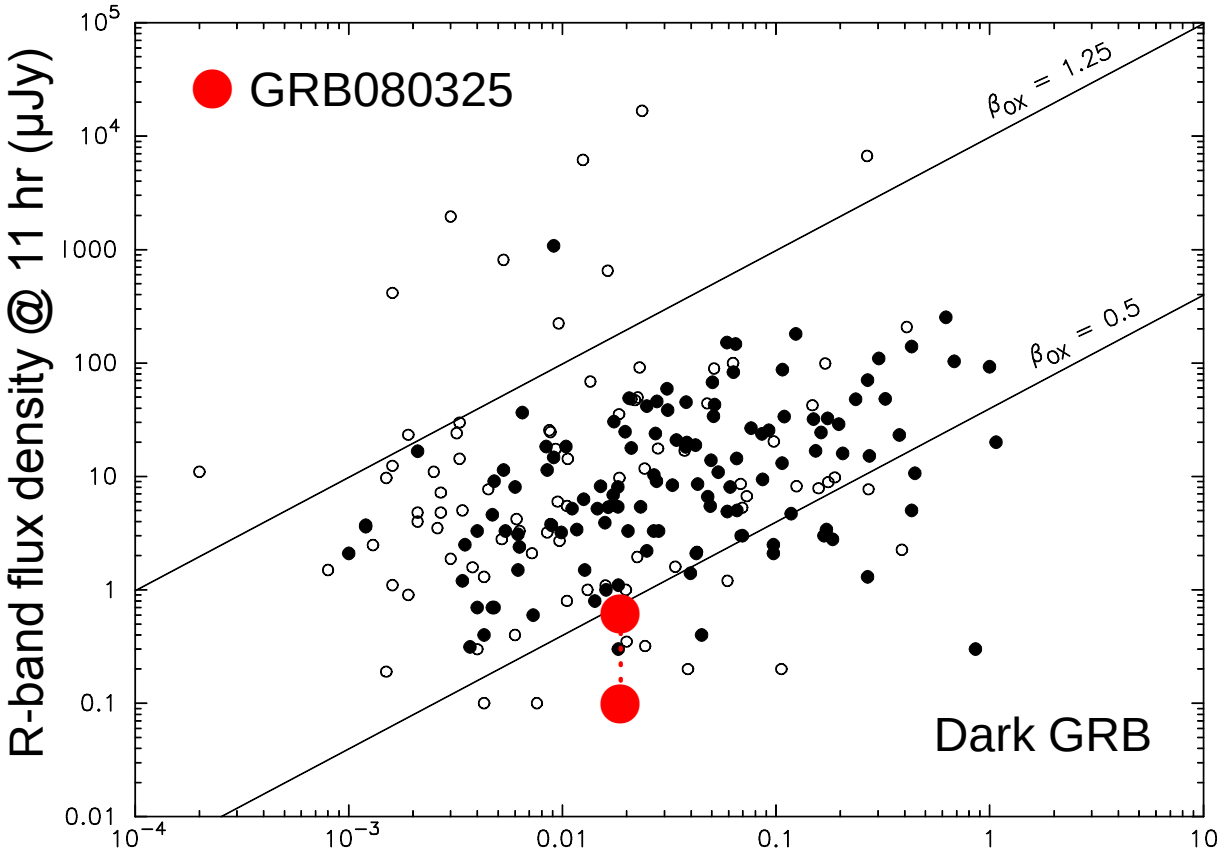


- Low density environment
- Intrinsically low luminosity

- Large extinction
- High redshift

→ ?

Zheng et al . 2009, arXiv:0906.2244

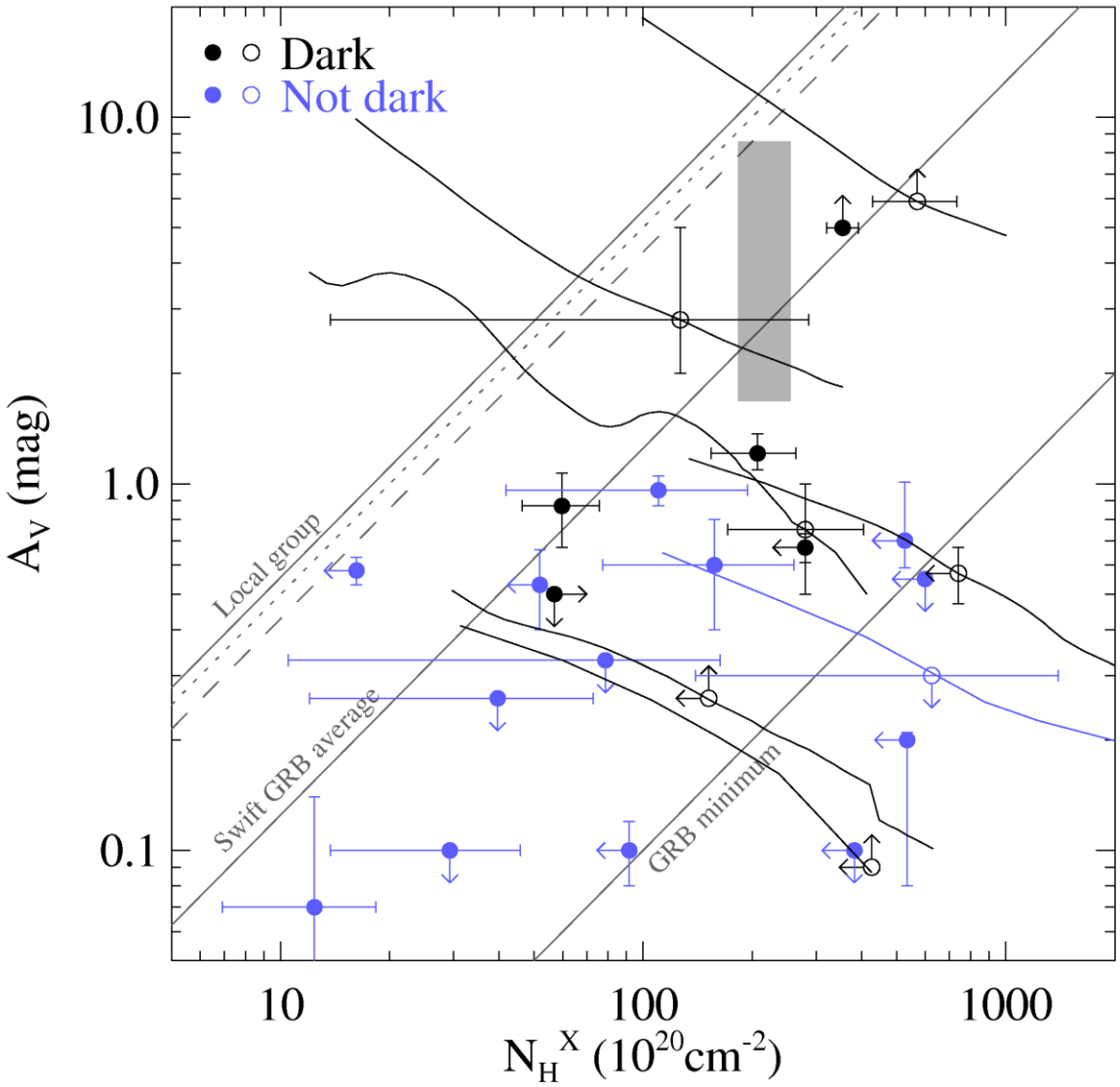


Extinction along the line of sight to the GRB

$0.5 < \beta_{OX} < 1.25 \rightarrow 1.7 < A_{V,AG} < 9.2$

Dust Extinction along the Line of Sight to GRBs

Perley et al. 2009, arXiv:0905.0001



GRB080325

$A_{v,AG}$ (line of sight to GRB)

$A_{v,AG}$: $0.5 < \beta_{OX} < 1.25$

N_H^X :Spectral fitting of X-ray afterglow

$A_{v,AG}$ is larger than $A_{v,AG}$ of not dark GRBs

and

is consistent with $A_{v,AG}$ of other dark GRBs

How about the host galaxy?

J-Ks Color of the Host

$J\text{-}Ks_{,host} = 1.3$ mag (AB magnitude)

- Long GRB host (Levan et al. 2006; Berger et al. 2007; Jaunsen et al. 2008; Savaglio et al. 2009)

→ Long GRB host (unknown z)

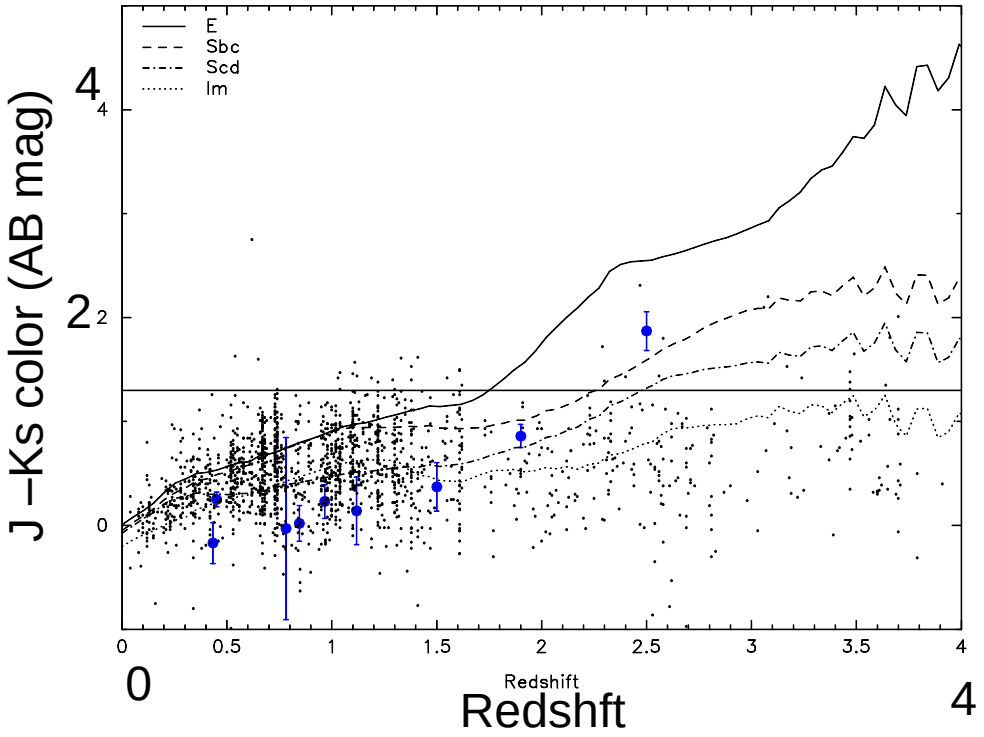
- GOODS South galaxies (spec-z; Grazian et al. 2006)

Typical GRB hosts (including "dark") (Le Floc'h et al. 2003, A&A 400, 499; Perley et al. 2009)

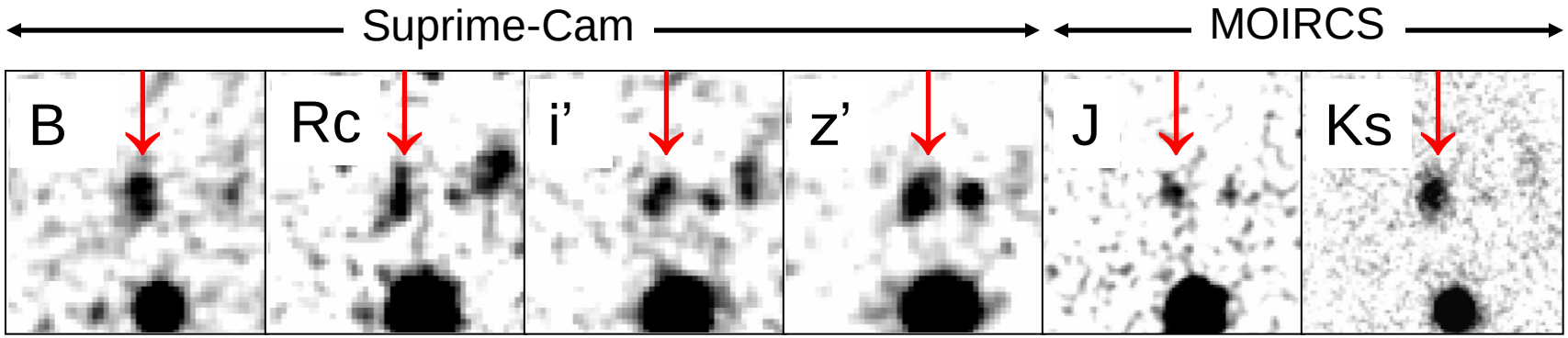
Blue color
Faint (Sub L*)

GRB080325 host

Red color, strong extinction (low z)
or
Luminous (z > 3)



Subaru/Sprime-Cam (1 year after the burst)

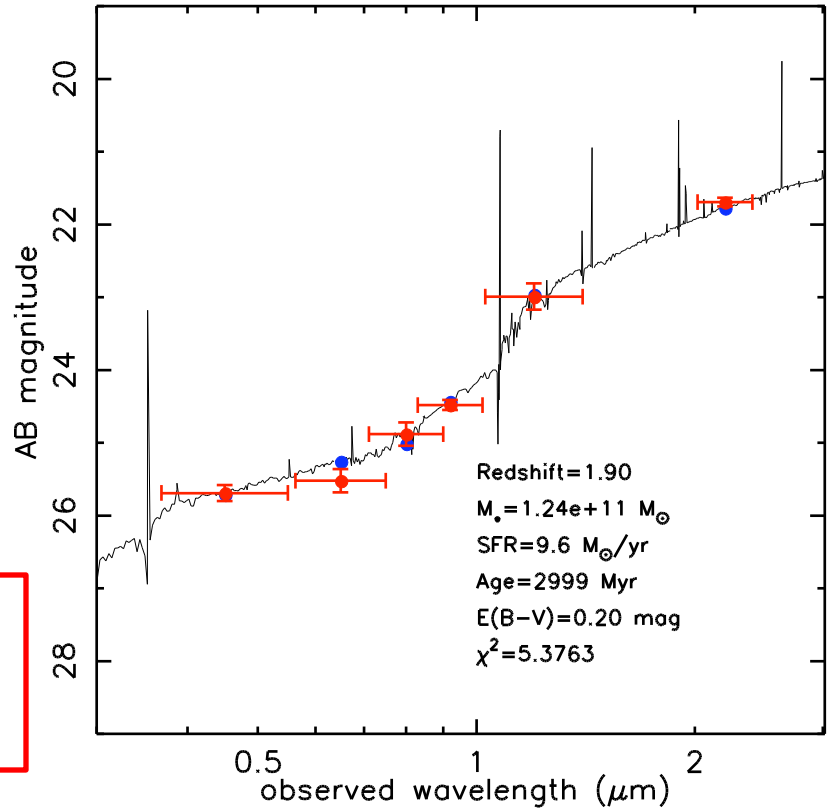


Subaru/Sprime-Cam 10" x 10"

SFH = constant SFR
tau =10Myr, 100Myr, 1Gyr, 10Gyr
instantaneous burst

IMF = Salpeter

Stellar population synthesis model
= PEGASE.2

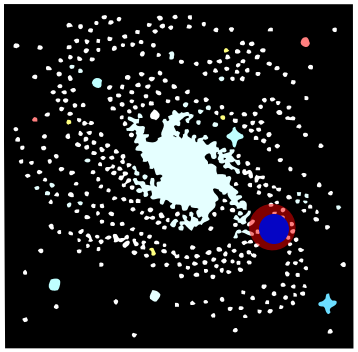


Redshift $= 1.9^{+0.3}_{-0.15}$ SFR $= 9.6^{+41}_{-5}$ M_{sun}/yr

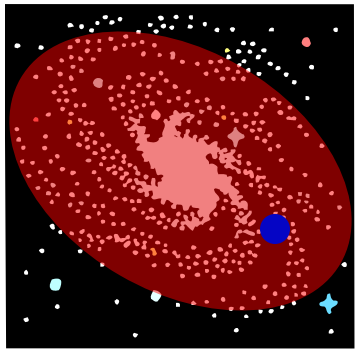
Av,host $= 0.8^{+0.6}_{-0.2}$ mag $M_* = 1.2^{+0.6}_{-0.3} \times 10^{11}$ M_{sun}

Dust Extinction for GRB 080325

Case 1



Case 2



Dust distribution

GRB position

Blue Dark GRB hosts with small Av,host
(Perley et al. 2009, Dark GRB sample)

Av,host (entire hosts)
～0.25- 0.5?

Red Dark GRB hosts with large Av,host

GRB000210 (z=0.8)
GRB051022 (z=0.8)
GRB030115 (z=2.5)

Av,host (entire hosts)
～1.0

GRB080325 --> Av,host (entire hosts) = $0.8^{+0.6}_{-0.2}$

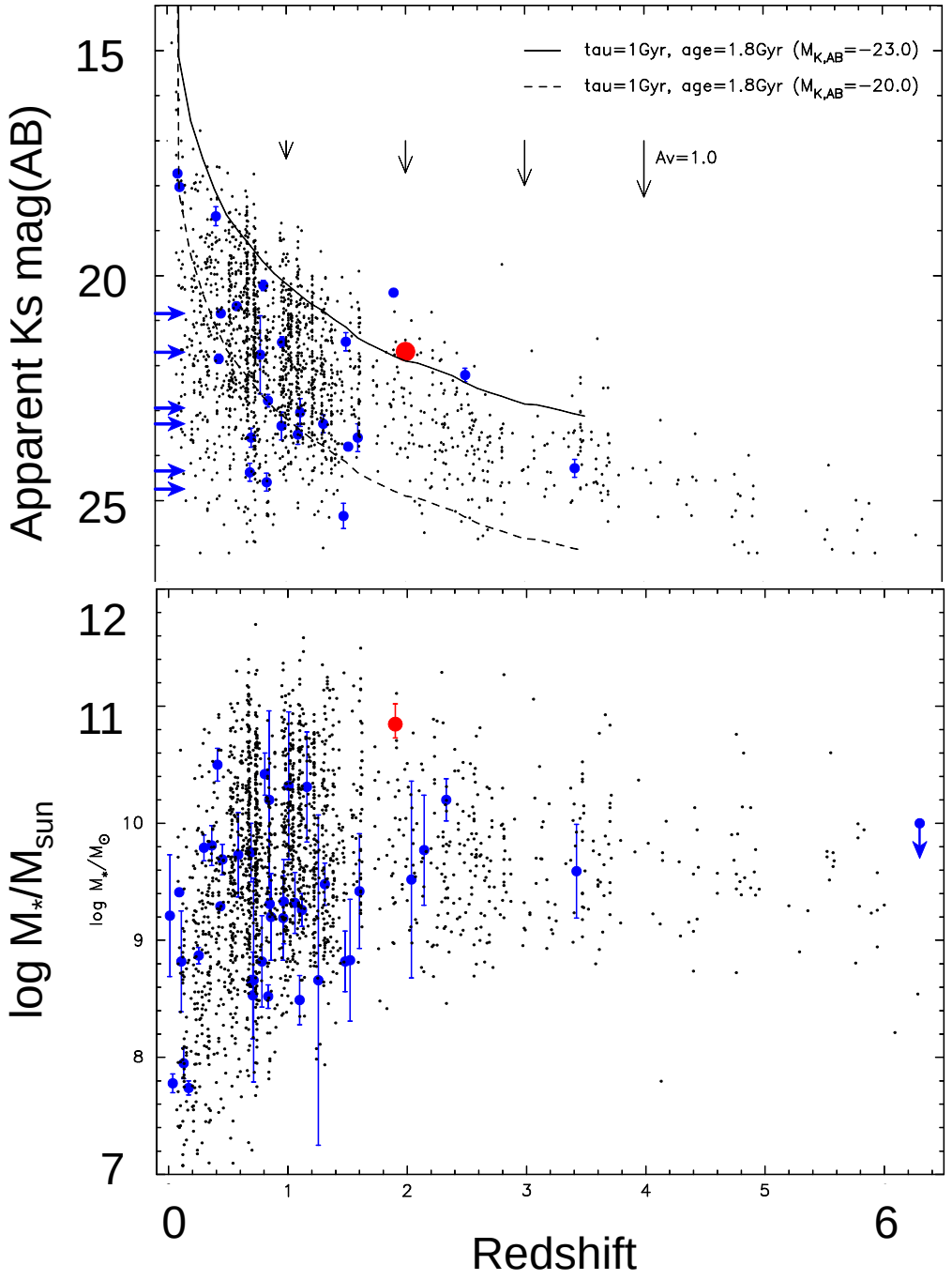
Case 1or 2 or both?

Massive GRB host

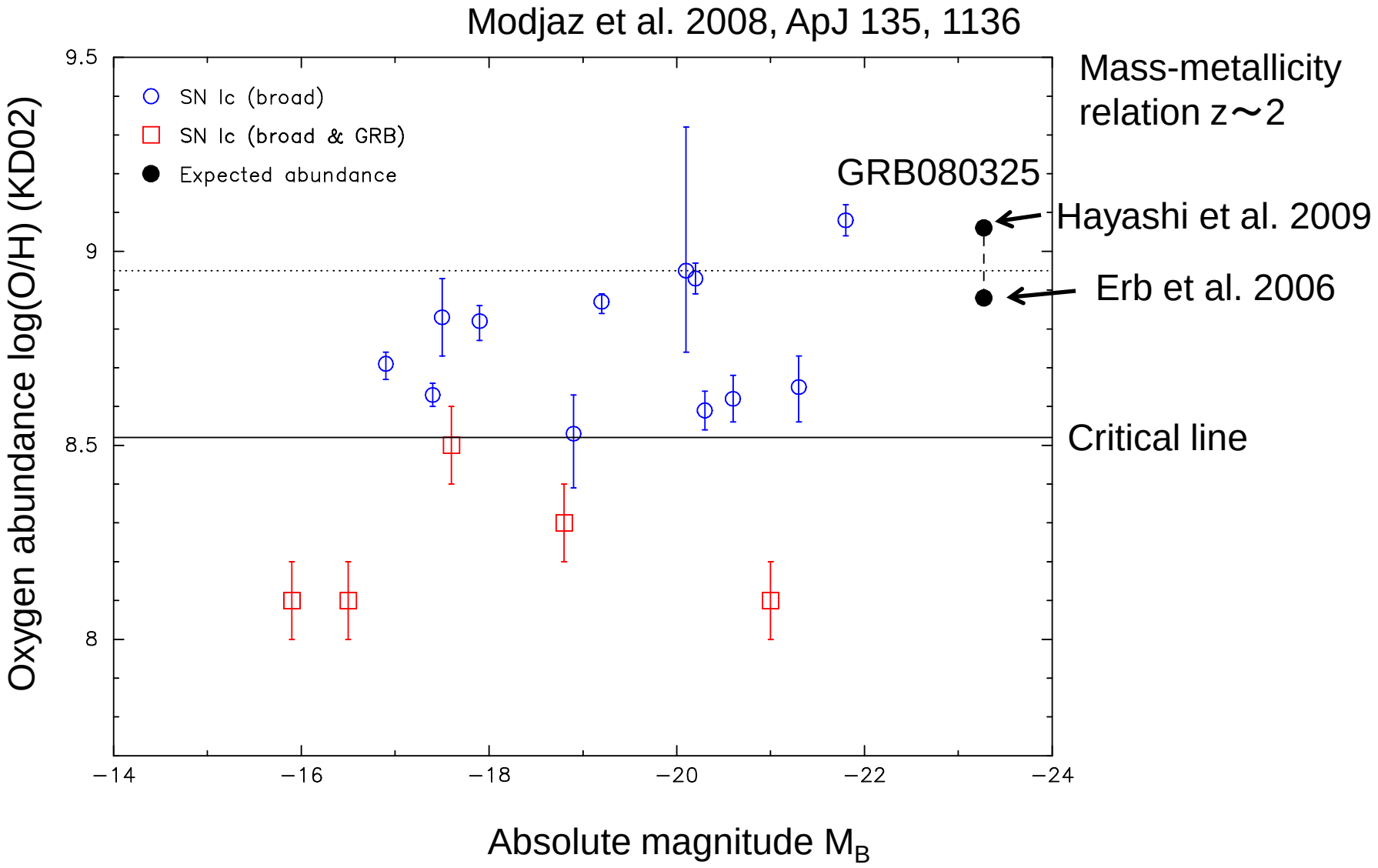
- GRB080325
- Long GRB host (Savaglio et al. 2009)
- → Long GRB host (unknown z)
- GOODS South galaxies (spec-z; Grazian et al. 2006)

GRB080325

GRB 080325 host is
brighter ($L \geq L^*$ at z=2)
and
massive
compared with typical GRB hosts



High metallicity environment of GRB?



Summary

- Near-infrared observations with Subaru/MOIRCS provided a clear detection of ”Dark” GRB 080325 afterglow in Ks band, although no optical counterpart was reported.

- GRB 080325 host is a luminous (massive) dusty star-forming galaxy in contrast to the less dusty and sub-L* property of typical GRB hosts at lower redshift.

- The “dark” nature of GRB 080325 is attributed to the local dusty environment around the GRB or extinction by foreground dust distributed over the entire host, or both.

- The large stellar mass of GRB 080325 host suggests high metallicity environment around GRB.
But spectroscopic observation is essential.

Dust Extinction

$A_{V,host}$

Total brightness of a host

SED fitting

(Flux weighted) Extinction for a whole host galaxy

$A_{V,AG}$

Obscuration-free flux density of a X-ray afterglow

+

Afterglow model ($0.5 < \beta_{OX} < 1.25$)

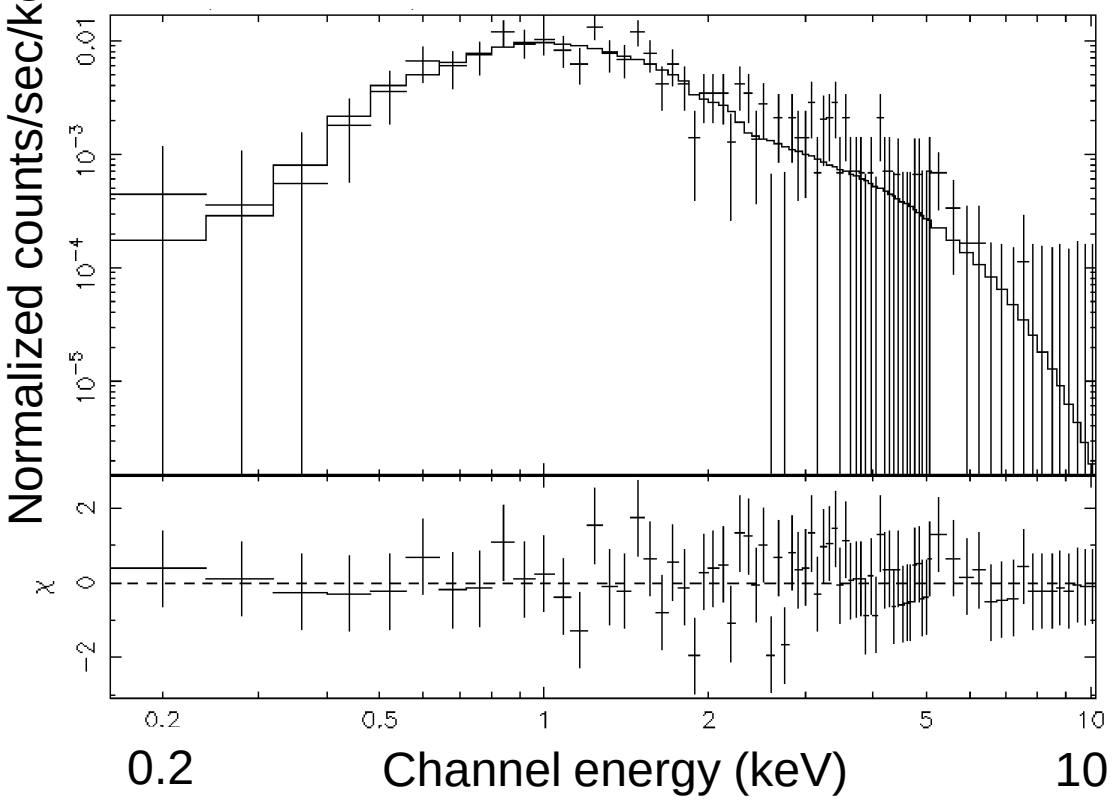
Upper and lower limits on obscuration-free flux density of an optical afterglow

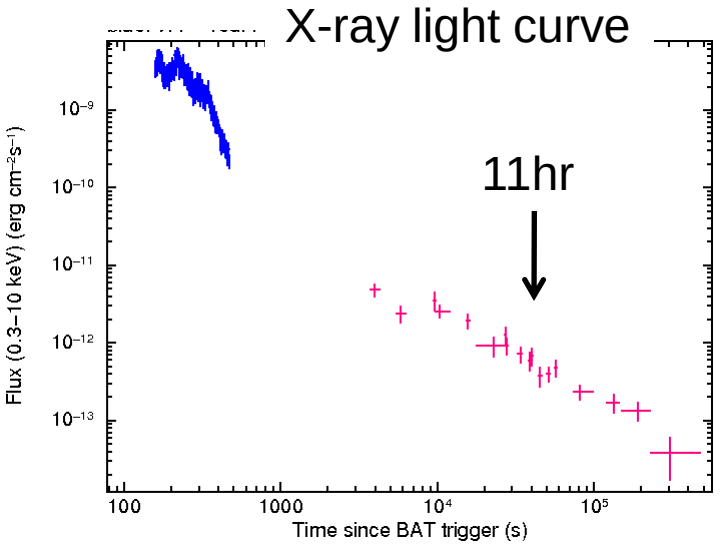
Comparison with observed (rest-wavelength) optical afterglow

Extinction along the line of sight to a GRB

X-ray Light Curve and Spectrum (Swift/XRT)

X-ray spectrum
(1-16 hours after the burst)





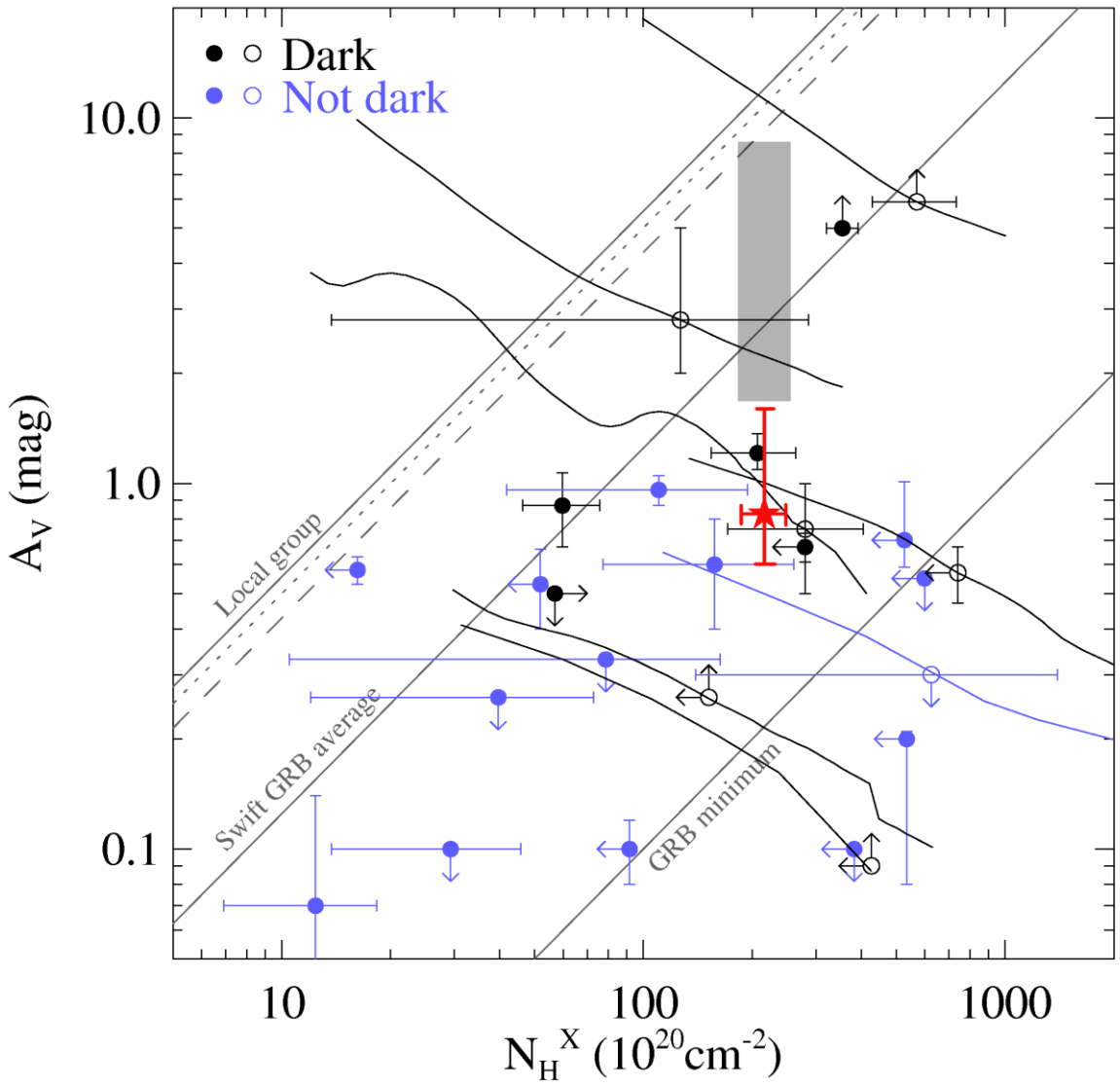
- Galactic extinction (N_H=3.8x10^{20} m^{-2})
- Extinction by GRB host at z=2
- power law spectral index
  $\beta_X = (f_\nu = \nu^{-\beta_X})$

- Extinction by GRB host
  N_H=2.4x10^{22} cm^{-2}

- power law spectral index
  $\beta_X = (f_\nu = \nu^{-\beta_X}) = 1.5$

Dust Extinction along the Line of Sight to GRBs

Perley et al. 2009, arXiv:0905.0001



GRB080325

Av,AG (line of sight to GRB)

★ Av,host (entire the host)

Perley et al. 2009
Dark GRB sample

Av,AG (line of sight) → large
Av,host (entire hosts) → small

GRB 080325

Av,AG (line of sight) → large
Av,host (entire host) → large