Modelling X-ray afterglows with time-evolving photoionisation

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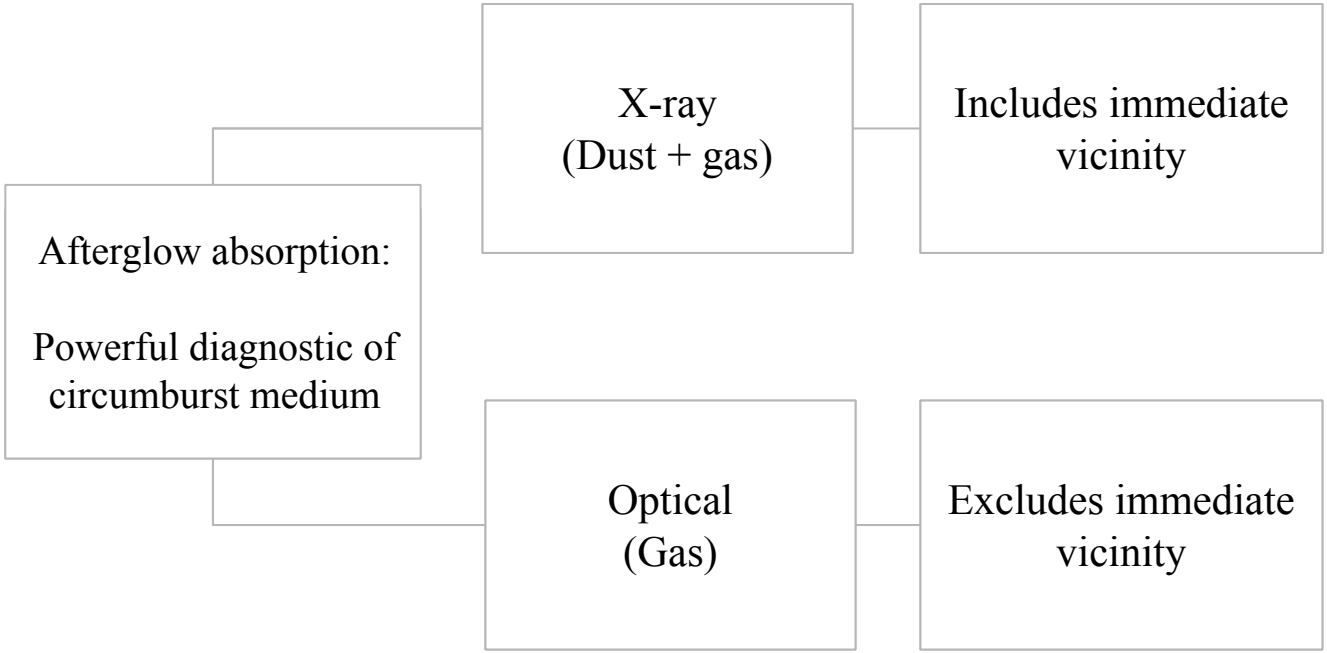
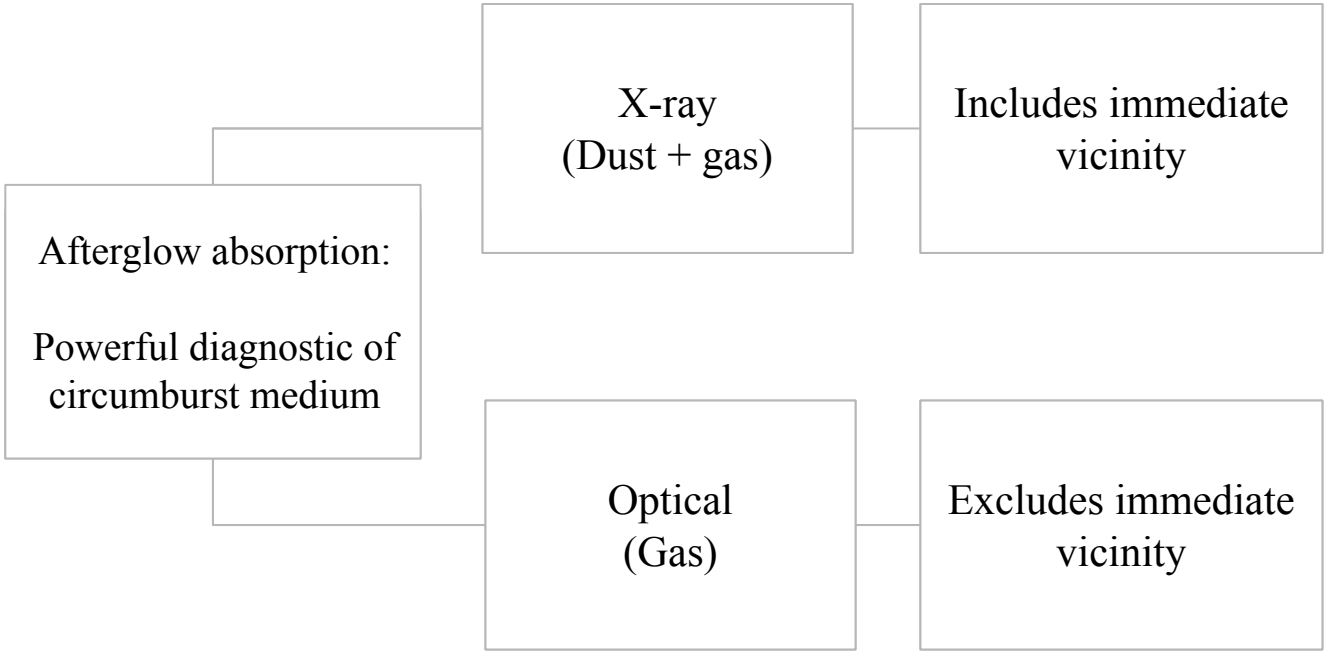
Background

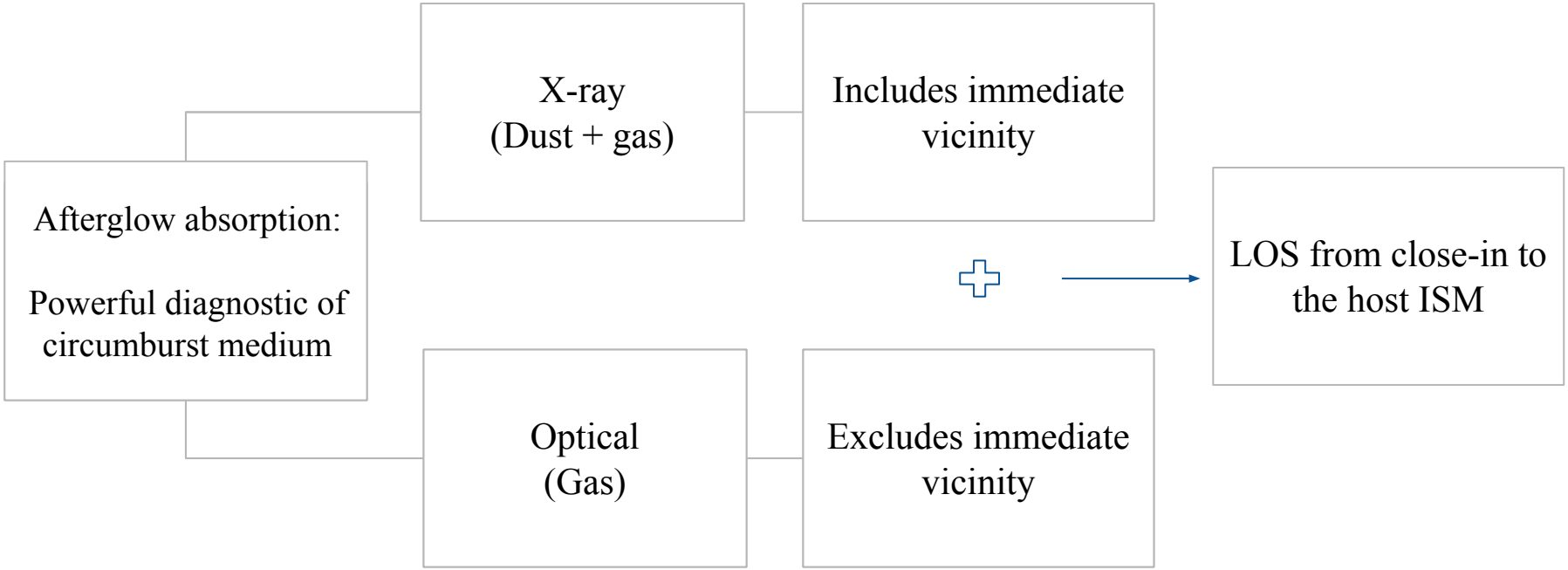

Afterglow absorption:
Powerful diagnostic of circumburst medium
X-ray
(Dust + gas)
Includes immediate vicinity
Optical
(Gas)
Excludes immediate vicinity

Background



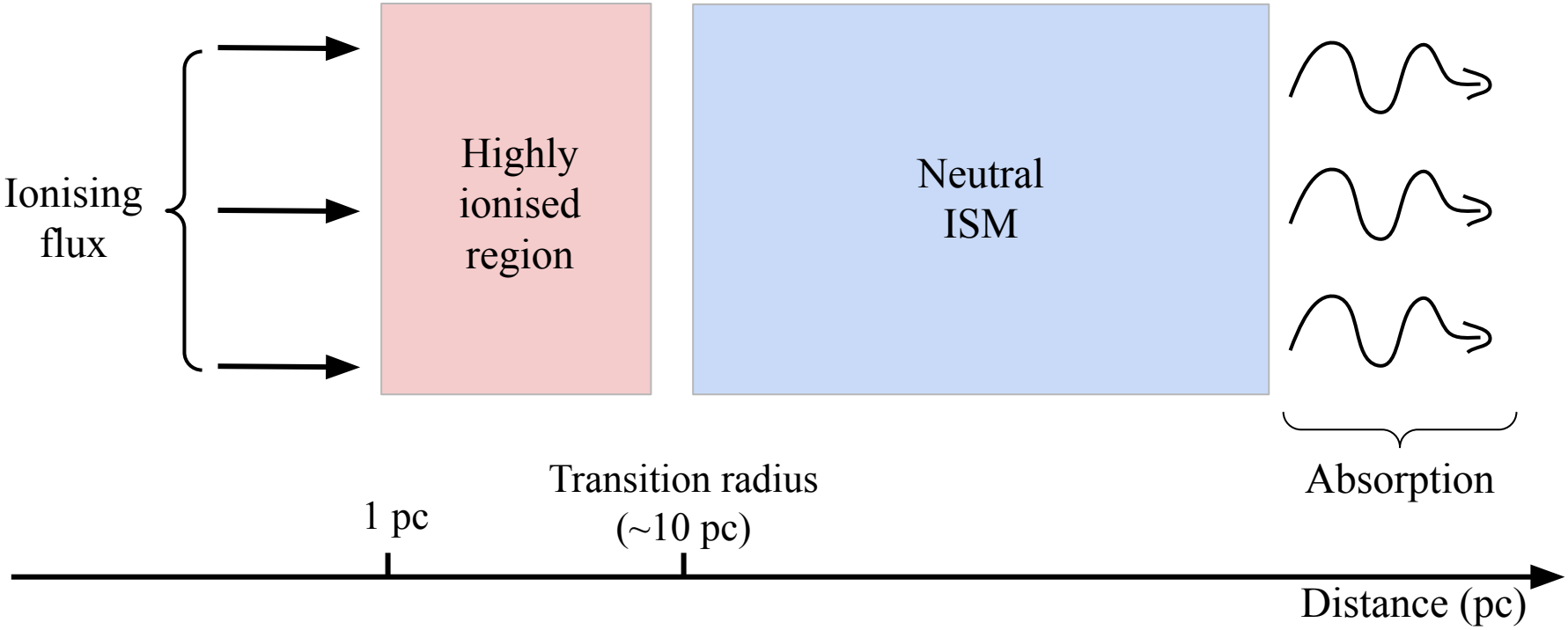
X-ray and optical absorption provide complementary diagnostic

Background



X-ray and optical absorption provide complementary diagnostic

Scheme of absorbers



Golden Sample: X-ray data

- Selection of sample:
  - XMM observed GRBs with redshift
  - Integrated counts ~ 1e5 over duration of observation
- Perform time-evolving photoionisation calculations
  - GRB-specific isotropic energy
- Fit XMM spectrum using calculated model
  - TBabs (single cold screen)
  - TEPID only
  - TEPID + optically derived neutral column

Golden Sample: Optical data

- Optical absorption probes aggregate of LOS within host
- Estimate column density
  - COG fit for equivalent widths
  - Correct for dust depletion
  - Correct for ionisation
- Model in Xspec through zTBabs
  - Column density range determined from optical

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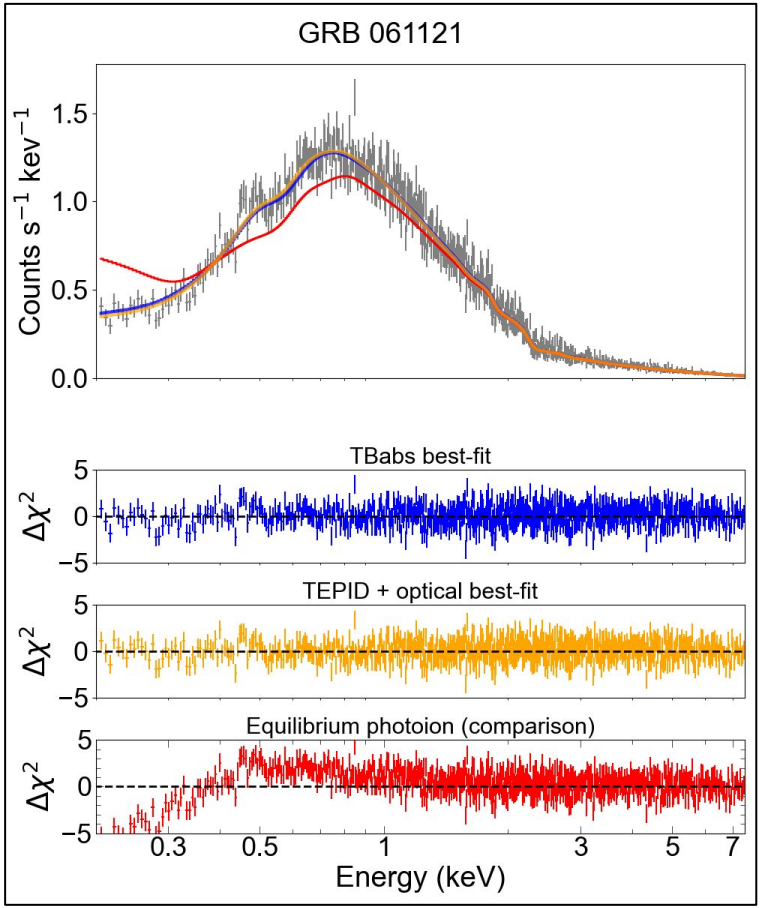
All derived neutral column in agreement with TBabs best-fit

Four out of six consistent within order of magnitude, three consistent within limits!

GRB 061121

Thakur et al., in prep



- $z = 1.314$
- $NH_{Optical} = 4.0e21\ cm^{-2}$
- $NH_{TBabs} = 5.3e21\ cm^{-2}$

  χ^2/DOF: 767/783

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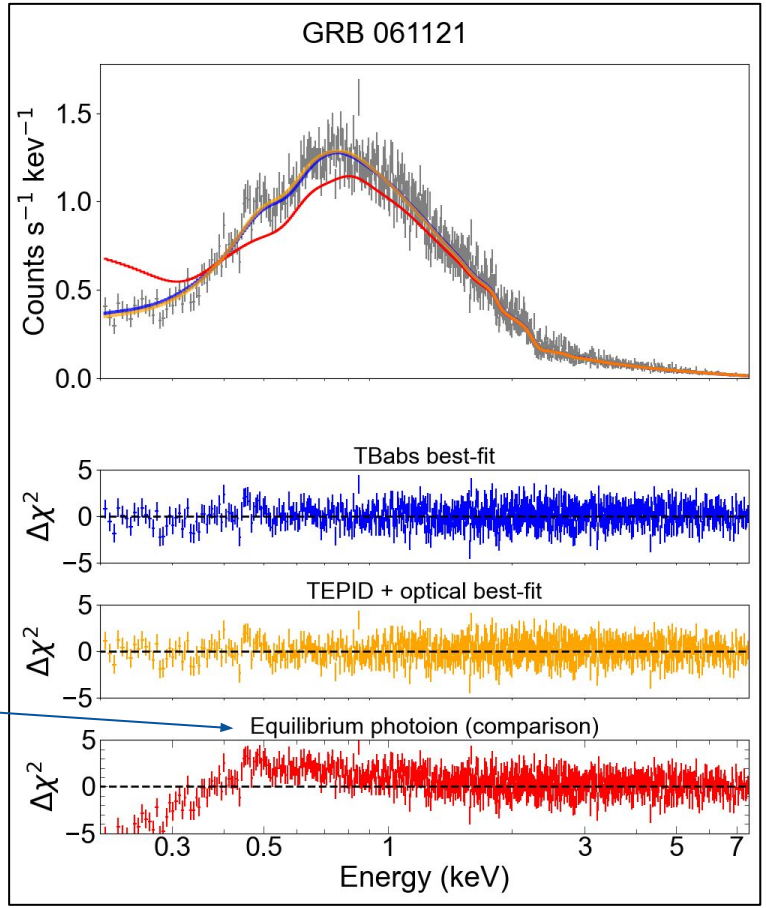

NB: Absori best-fit reproduces TBabs best-fit.

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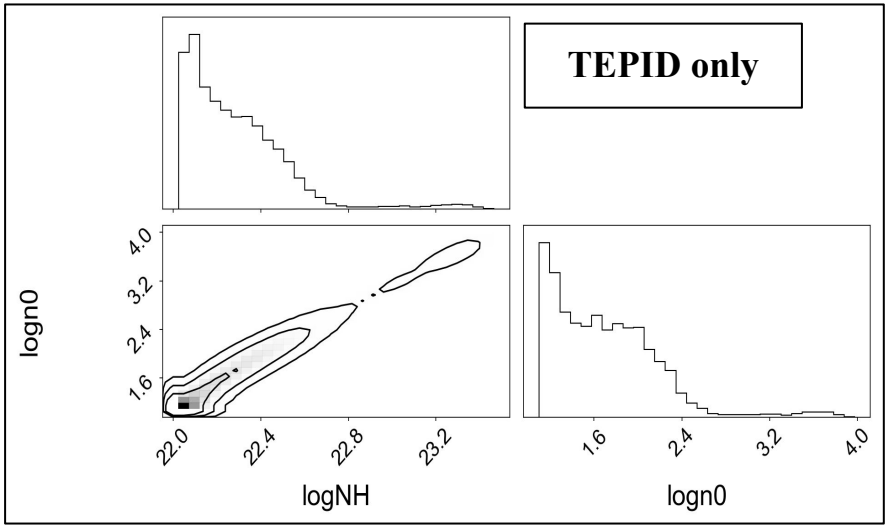
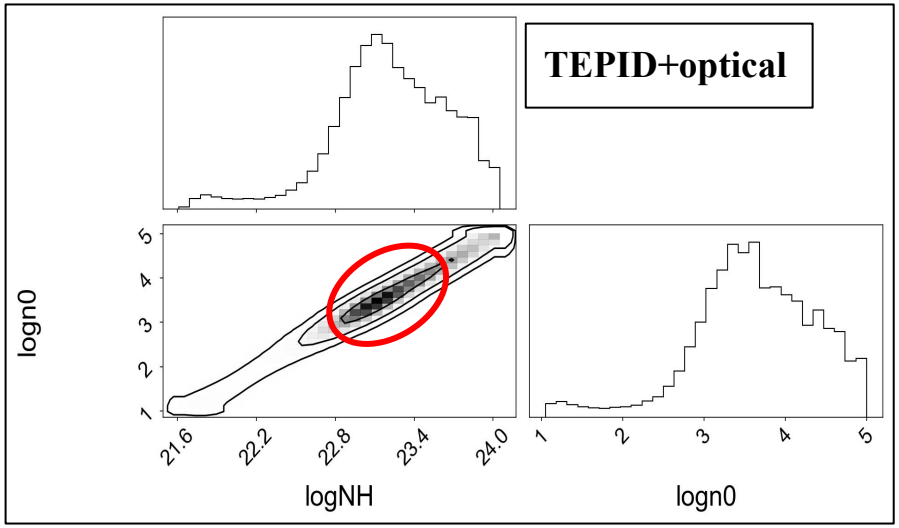


logNH = 22.4, $\log n_0$ = 1.9, inferred size ~ 100 pc

Large, diffuse and less ionised

$\delta\chi^2$ = -3, δDOF=1



logNH = 23.2, $\log n_0$ = 3.7, inferred size ~ 11 pc

Compact, dense and highly ionised

$\delta\chi^2$ = 7, δDOF=2

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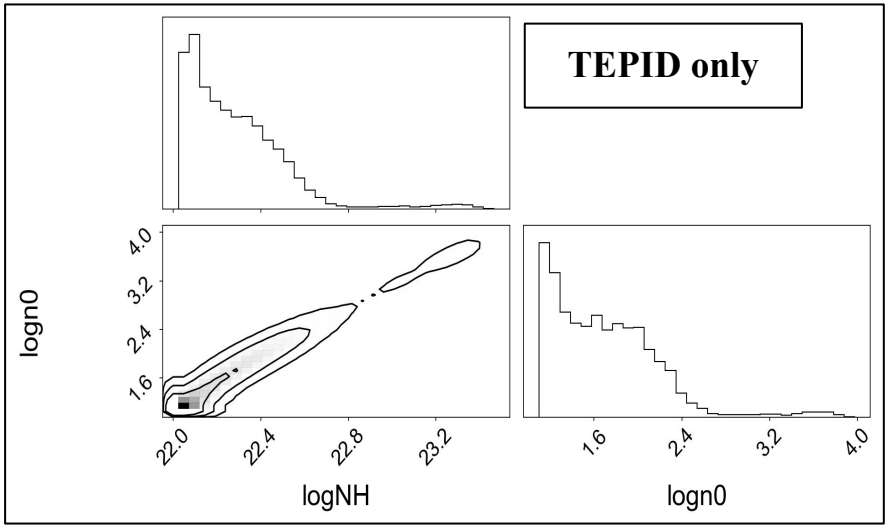
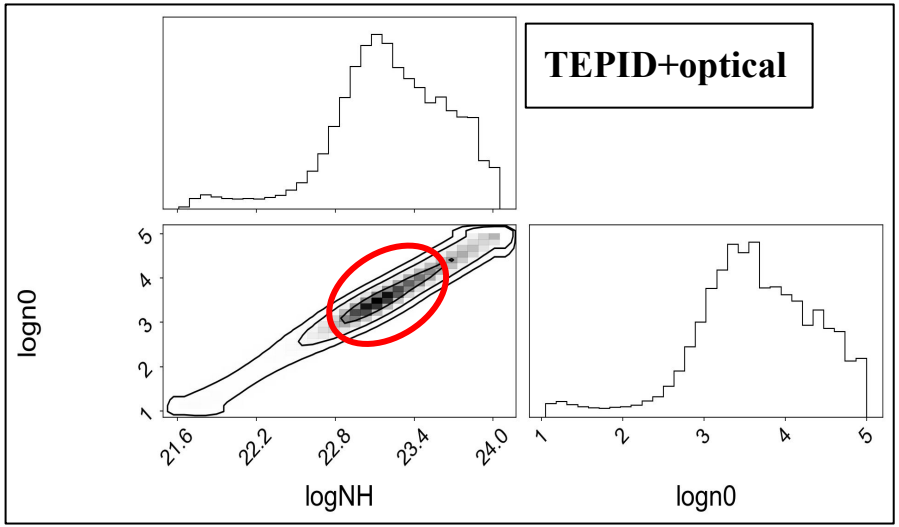
Including neutral absorption from host is significantly changing the best-fit

Thakur et al., in prep





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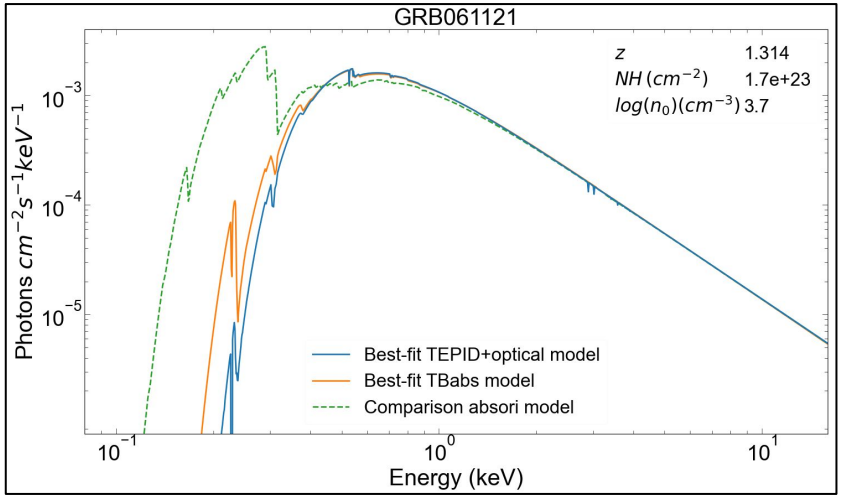
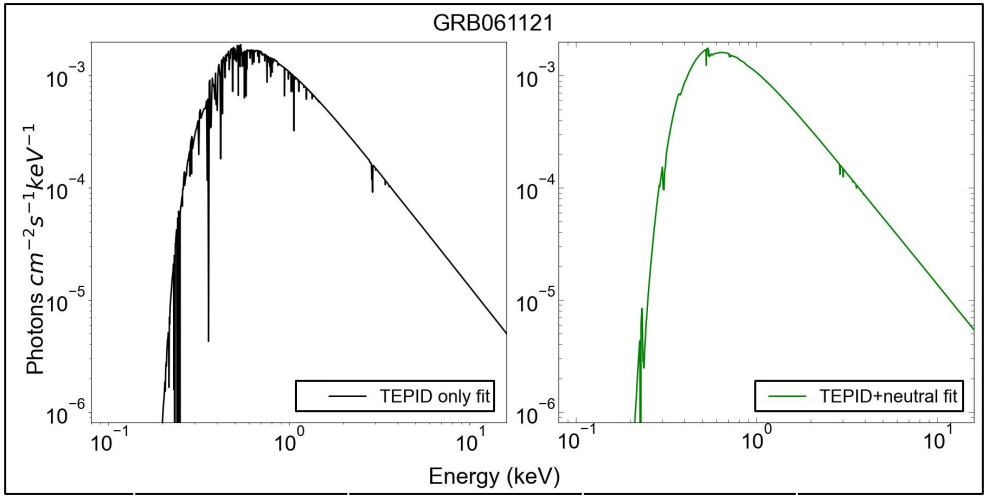
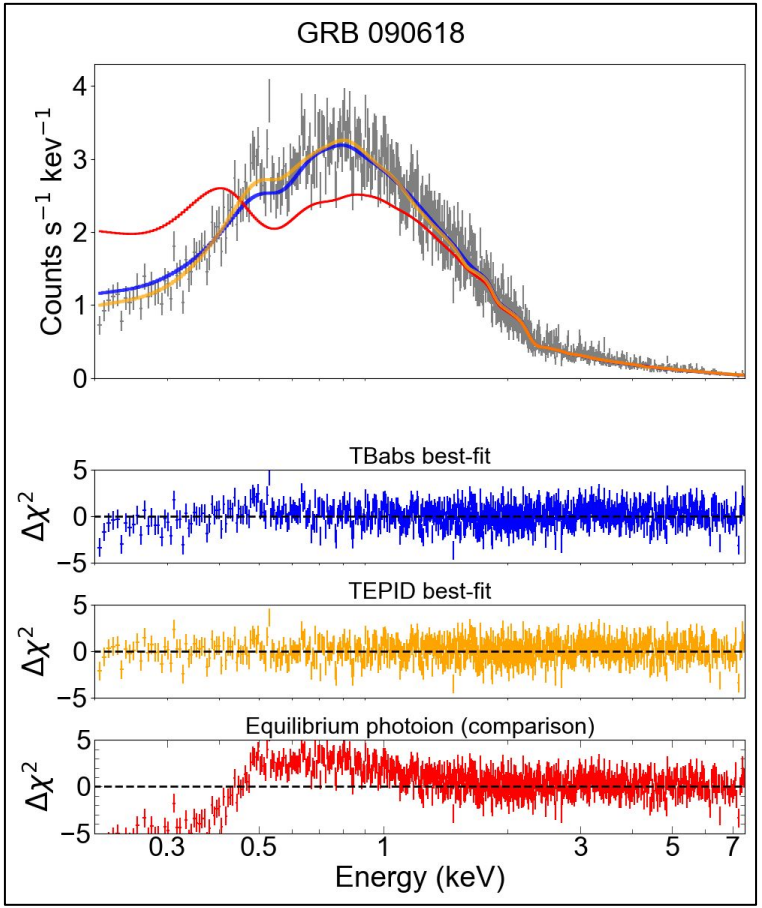




$$\frac{NH[O\ VIII]}{NH[O]} = 0.3 \quad V/S \quad \frac{NH[O\ VIII]}{NH[O]} = 0.9$$

GRB 090618

Thakur et al., in prep



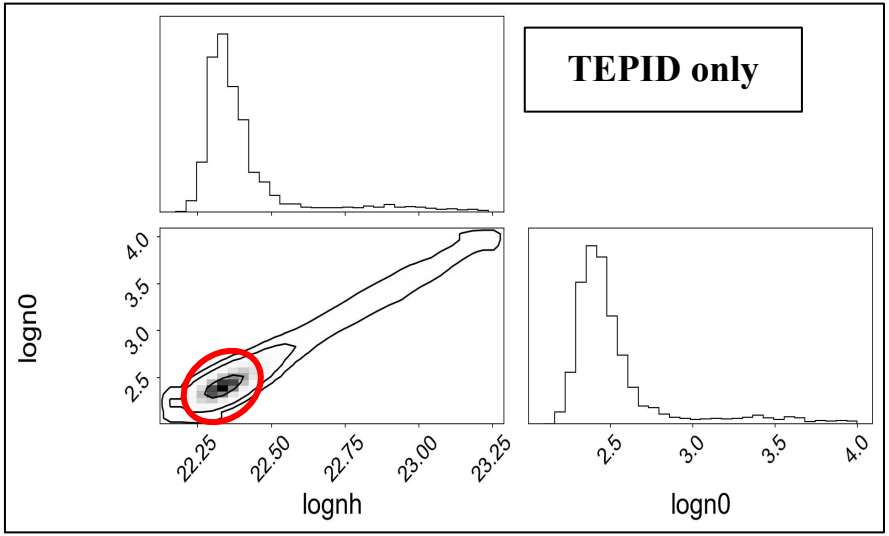
- $z = 0.54$
- $NH_{Optical} = 1.2e21\ cm^{-2}$
- $NH_{TBabs} = 1.7e21\ cm^{-2}$

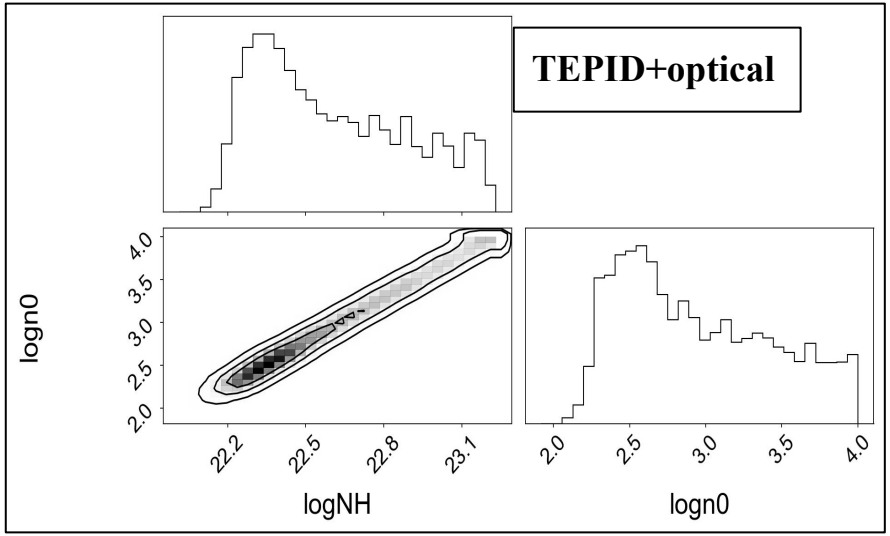
  χ^2/DOF: 807/741

GRB 090618

Acceptable fit after including absorption by host separately

Thakur et al., in prep





logNH = 22.2, logn0 = 2.4, inferred distance ~ 20 pc

Compact and highly ionised

$\delta\chi^2 = 48$, δDOF=1

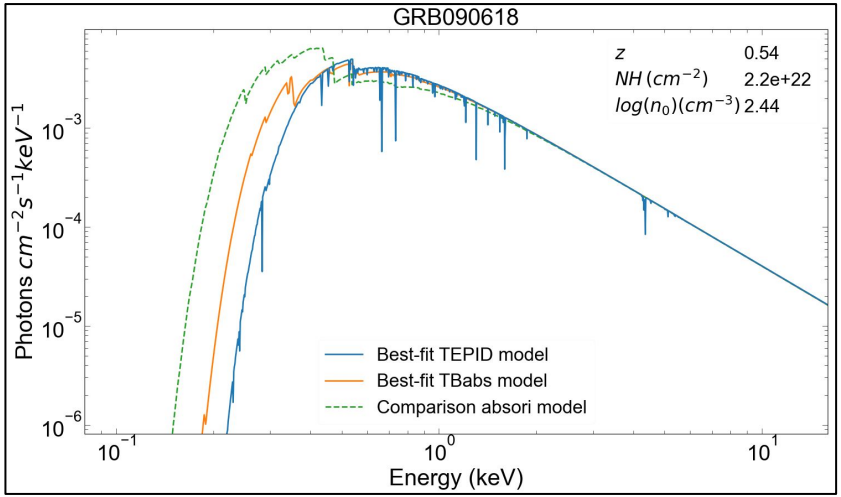
logNH = 22.2, logn0 = 2.5, inferred distance ~ 15 pc

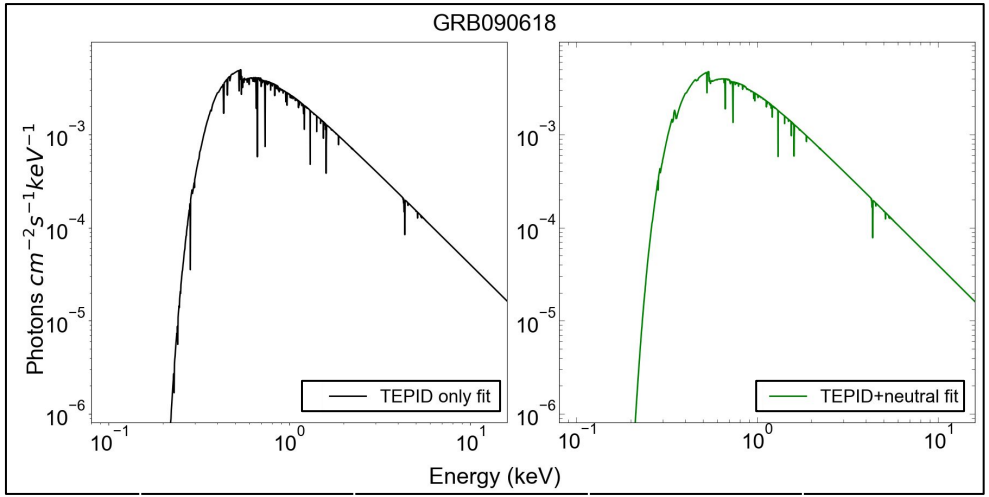
Smaller with higher ionisation

$\delta\chi^2 = 44$, δDOF=2

GRB 090618

Thakur et al., in prep





Marked improvement below 0.3 keV

$$\frac{\text{NH[O VIII]}}{\text{NH[O]}} = 0.8 \quad \text{V/S} \quad \frac{\text{NH[O VIII]}}{\text{NH[O]}} = 0.98$$

Conclusions

- Time-evolving ionised absorber model for GRBs
- Combination of X-ray and optical bands
  - Neutral column from optical
- Highly ionised dense region close-in
- Improved fits for 5 out of 6 GRBs v/s single-screen equilibrium absorbers

Parameters	Value				
Name	060729	061121	080411	090618	120711A
z	0.54	1.314	1.031	0.54	1.405
	TBABS fit				
$NH\,(cm^{-2})$	$9.1\pm0.3\times10^{20}$	$5.3\pm0.2\times10^{21}$	$2.5\pm0.1\times10^{21}$	$1.7\pm0.04\times10^{21}$	$9.8\pm0.1\times10^{21}$
χ^2/DOF	1249/1191	767/783	580/528	807/741	937/881
	TEPID fit				
distance (pc)	10	100	20	20	11
$log(n_0)\,(cm^{-3})$	$2.9^{+1.2}_{-0.1}$	$1.9^{+0.2}_{-0.7}$	$4.0^{+0.1}_{-1.1}$	$2.4^{+0.2}_{-0.1}$	$4.0^{+0.4}_{-0.3}$
$\delta\chi^2\ (\delta DOF = 1)$	126	-3	37	48	44
	TEPID + optically derived neutral column fit				
$NH_{Optical}\,(cm^{-2})$	3.2×10^{19}	4.0×10^{21}	2.5×10^{21}	1.2×10^{21}	1.3×10^{21}
distance (pc)	10	10	20	16	10
$log(n_0)\,(cm^{-3})$	$2.9^{+0.8}_{-0.1}$	$3.7^{+0.8}_{-0.7}$	$4.0^{+0.1}_{-1.2}$	$2.5^{+1.1}_{-0.1}$	$4.1^{+0.3}_{-0.4}$
$\delta\chi^2\ (\delta DOF = 2)$	128	7	24	44	44

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THANK YOU FOR LISTENING!

QUESTIONS?