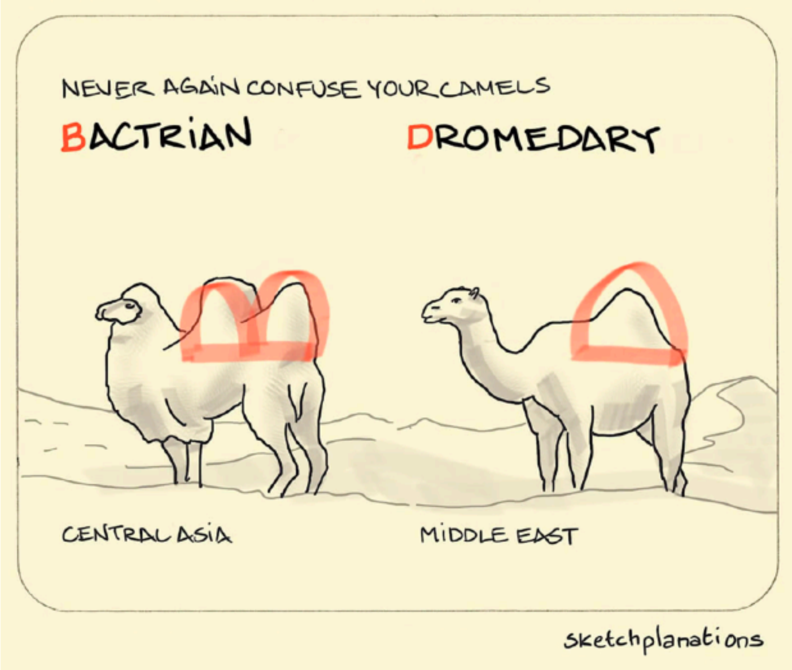
Probing the multiwavelength emission scenario of GRB 190114C

A tale of two camels



Sylvia J. Zhu (DESY), Marc Klinger (DESY), Dongguen Tak (DESY), Andrew Taylor (DESY)

arXiv:2206.11148 [astro-ph.HE]

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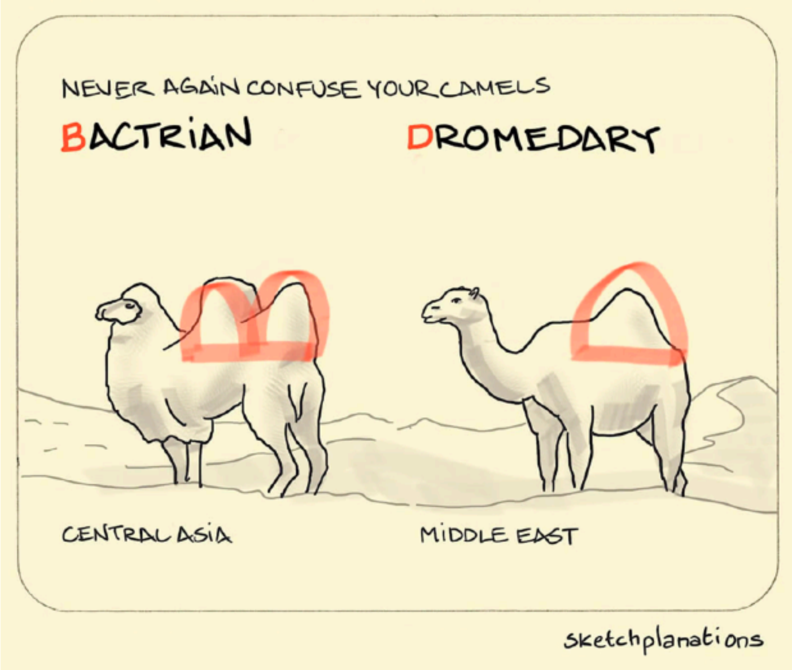
marc.klinger@desy.de



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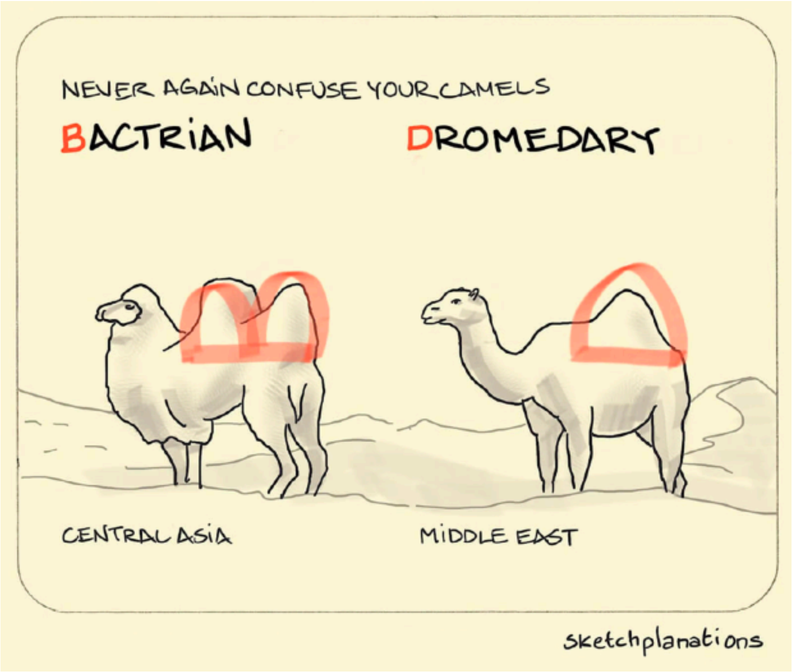
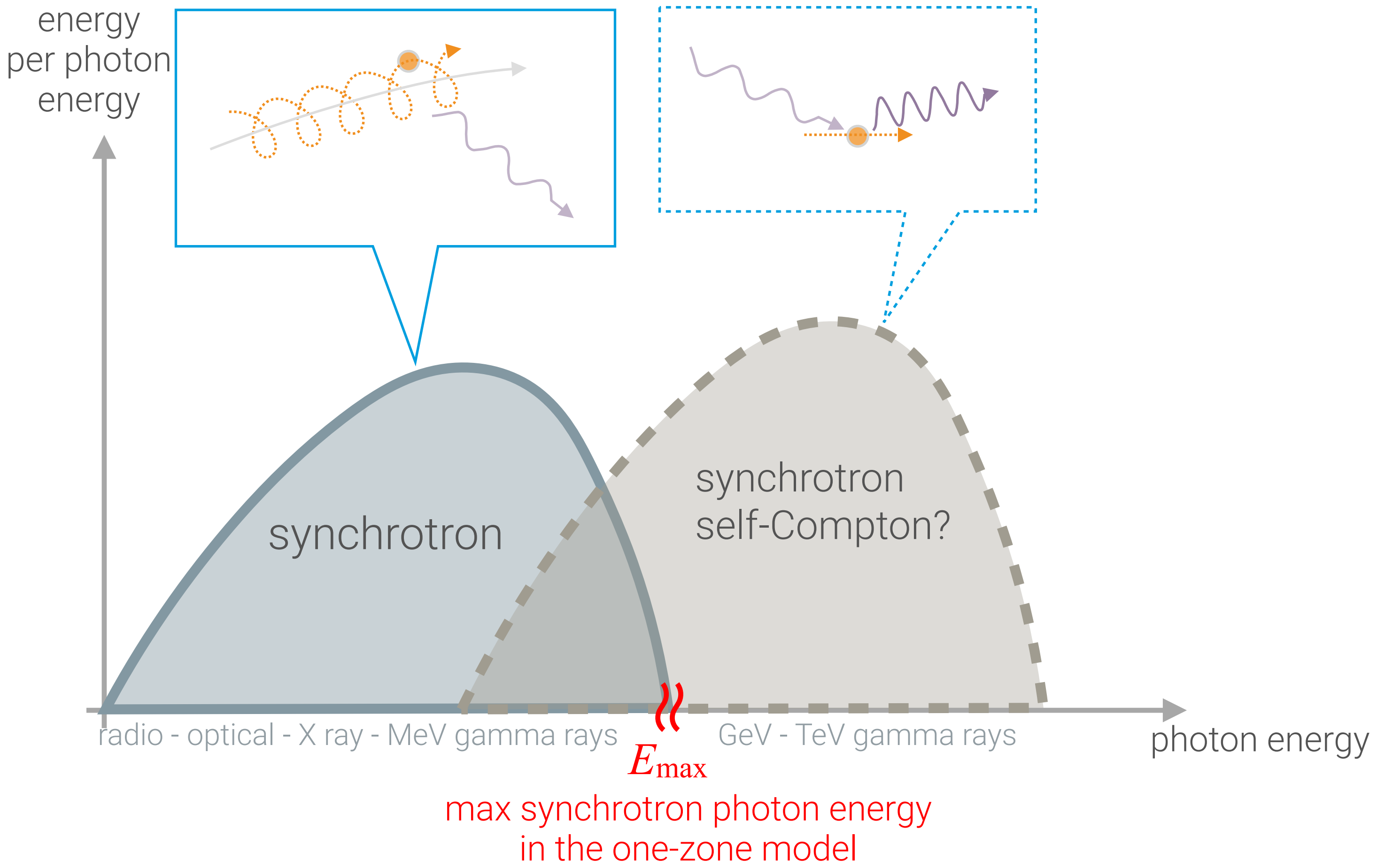
Are GRBs Bactrian camels or dromedaries?

Are there one or two components?

In the standard one-zone model, a single magnetic field strength is assumed for both acceleration and cooling.

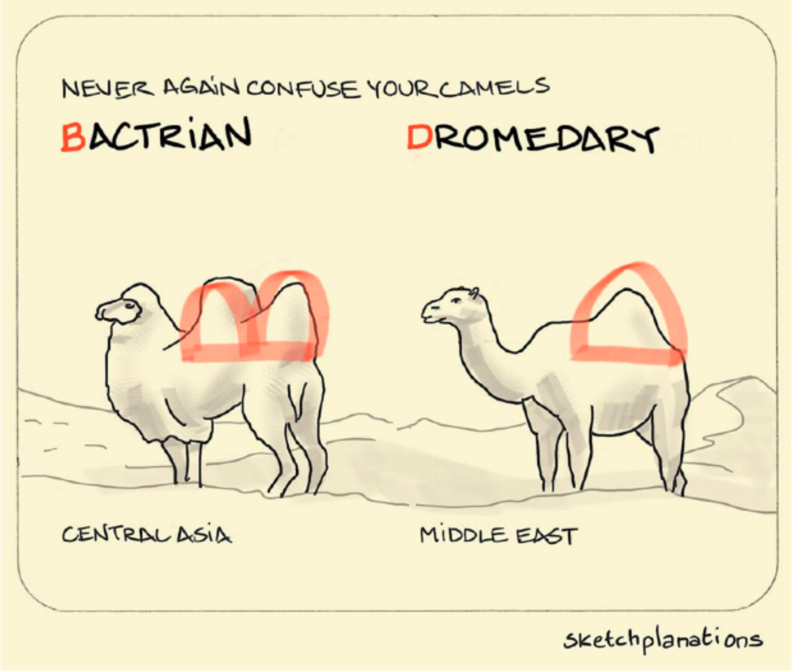


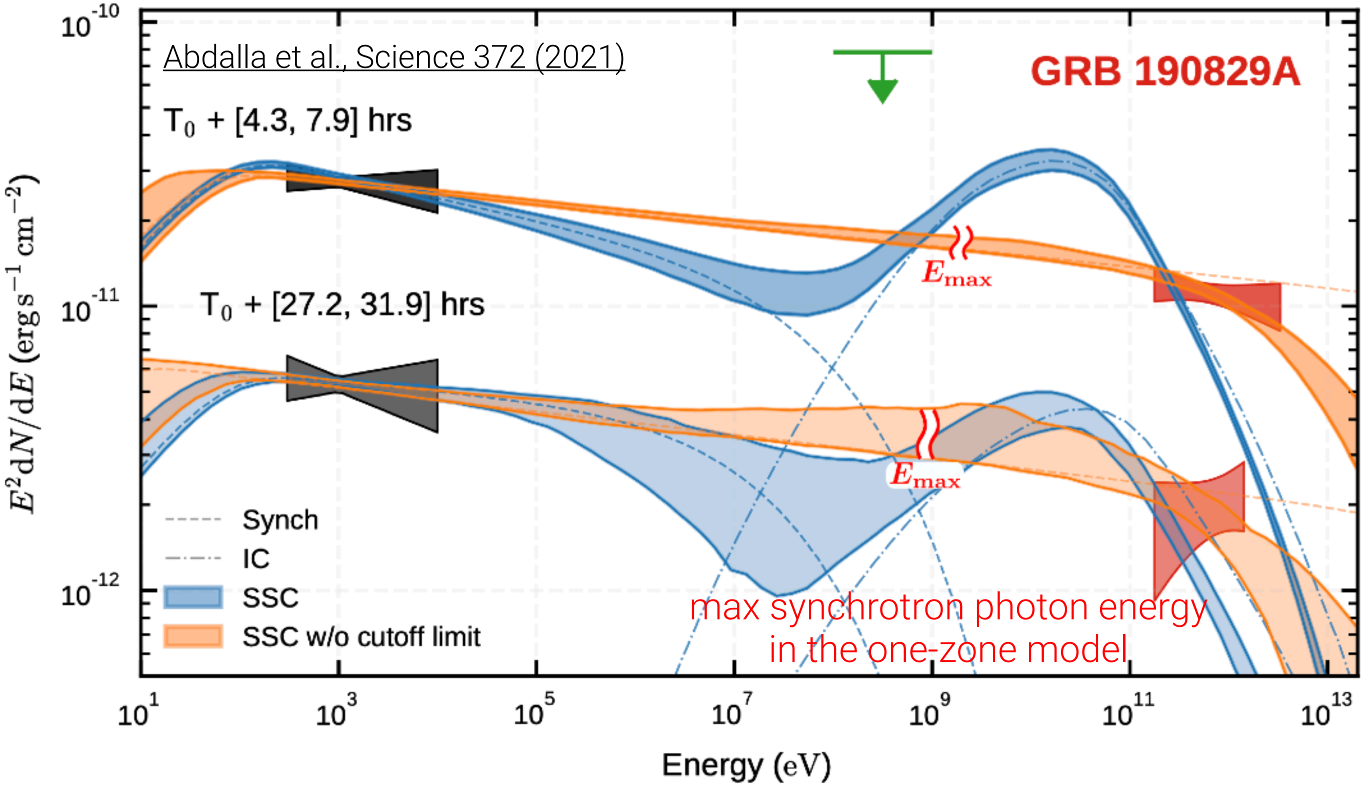


Are GRBs Bactrian camels or dromedaries?

GRB 190829A is better fit (>5σ) by a single component than by two

This suggests that we can start to move beyond the standard one-zone models.

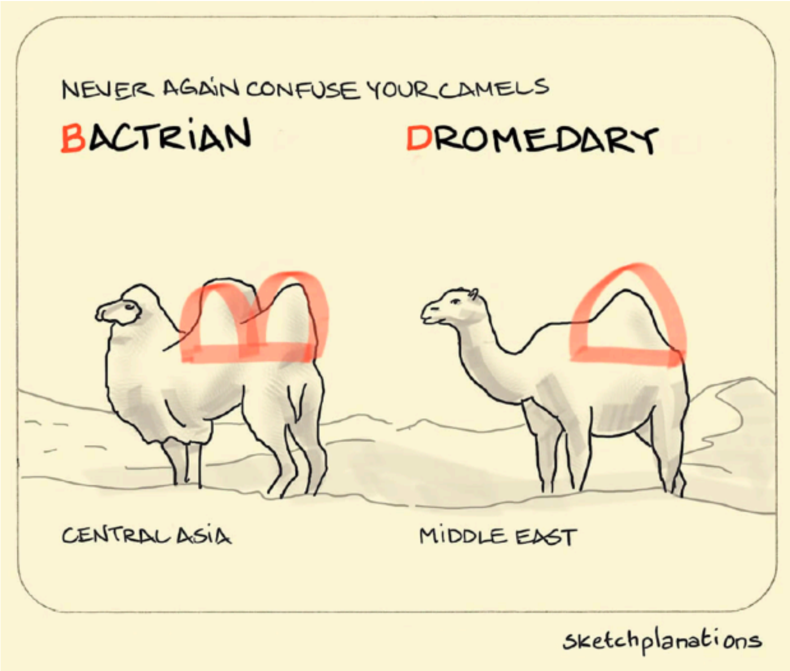




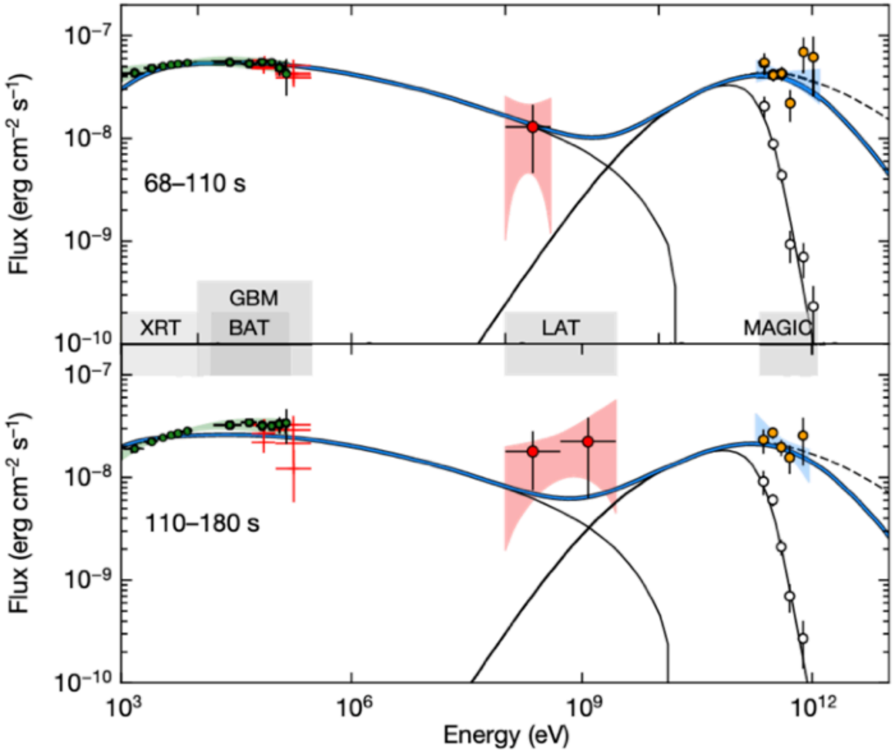
Are GRBs Bactrian camels or dromedaries?

What about GRB 190114C?

This very bright GRB was observed by MAGIC, and was announced as having an inverse Compton peak.



Acciari et al., Nature 575 (2019)



Our aim is to examine this result and test its stability.

GRB 190114C: a rich multiwavelength data set

For the next few slides: Focus on the first time bin.

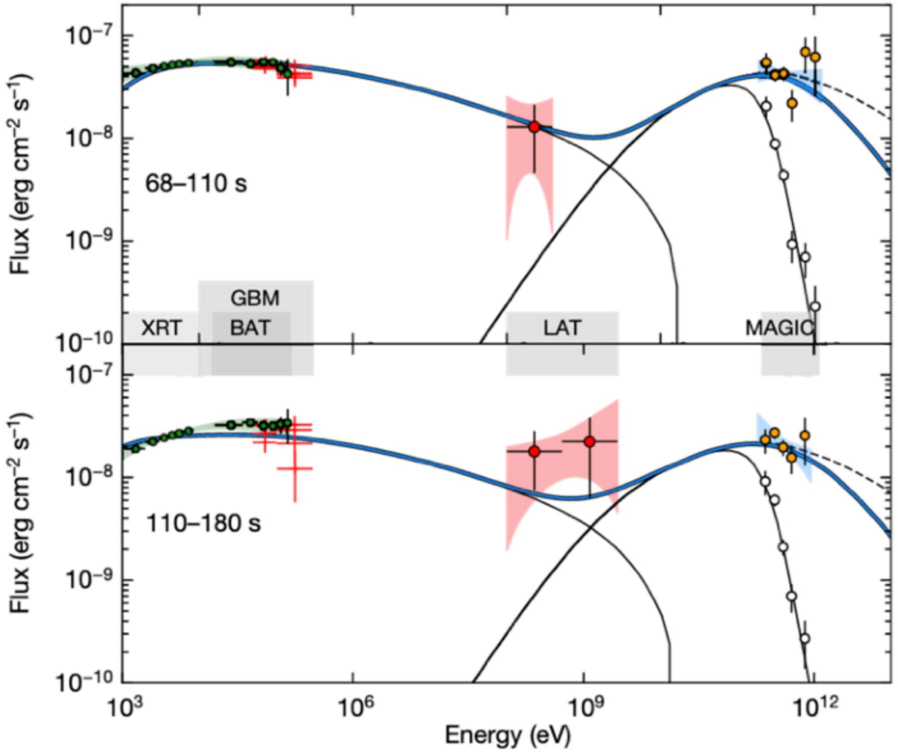
First: Best-fit power law for each instrument on its own.

Then: Full likelihood analysis of the multiwavelength data set, using a reduced afterglow radiation model.

Finally: Examine the significance of this result and test its stability under perturbations.

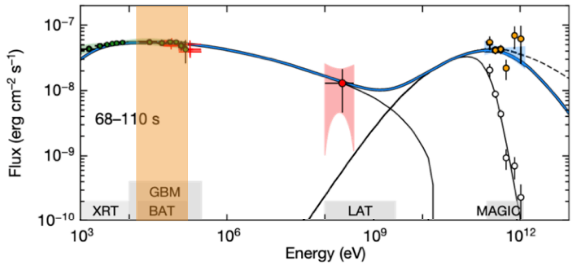
3ML Multi-Mission Maximum Likelihood Framework

Acciari et al., Nature 575 (2019)



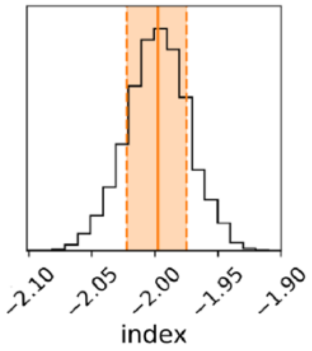
GRB 190114C: a rich multiwavelength data set

Let’s first fit each instrument’s data set on its own with a power law

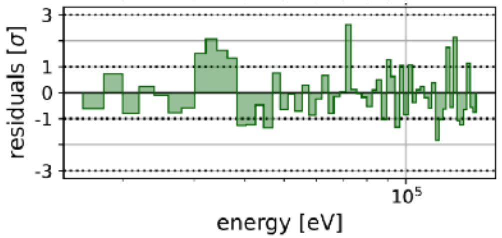


Swift/BAT

15-150 keV

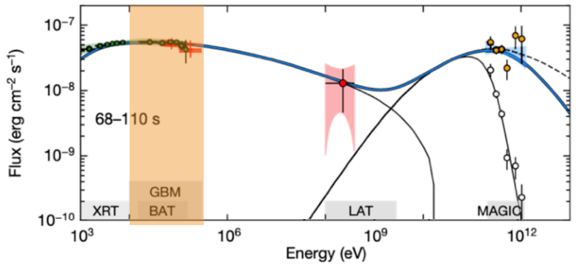


$-1.998^{+0.023}_{-0.024}$

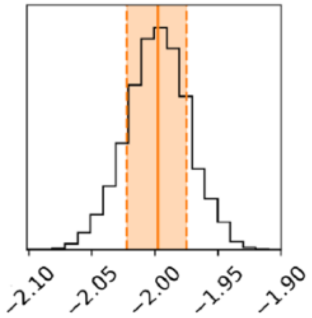


GRB 190114C: a rich multiwavelength data set

Let’s first fit each instrument’s data set on its own with a power law

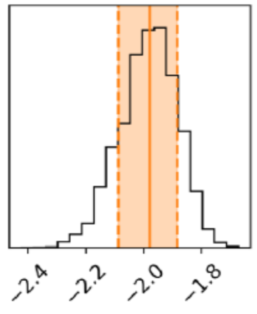


Swift/BAT
15-150 keV



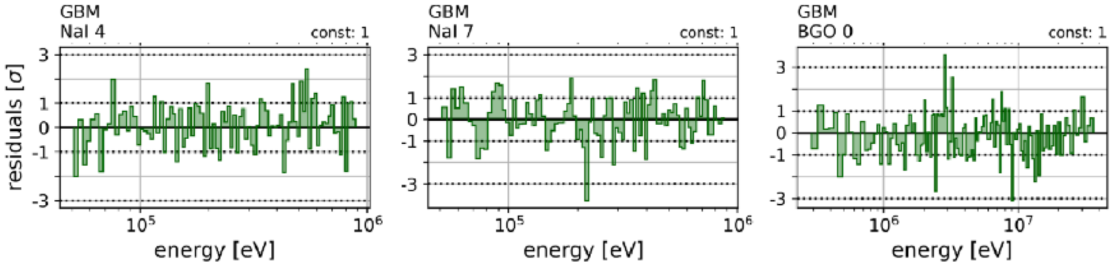
$-1.998^{+0.023}_{-0.024}$

Fermi/GBM
8 keV - 40 MeV



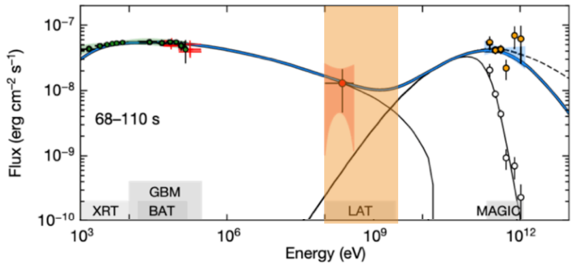
-1.98 ± 0.1

For these time bins, the lower energy limit is actually 50 keV, due to partial blockage by the spacecraft [M. Ajello et al 2020 ApJ 890 9]

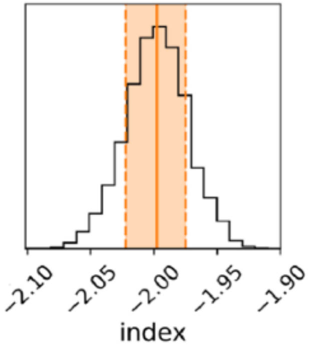


GRB 190114C: a rich multiwavelength data set

Let’s first fit each instrument’s data set on its own with a power law

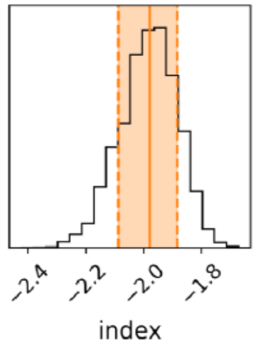


Swift/BAT
15-150 keV



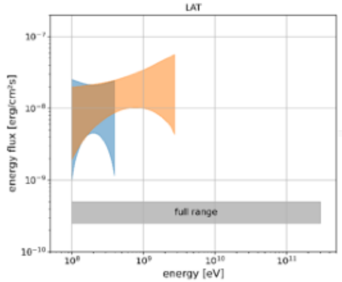
$-1.998^{+0.023}_{-0.024}$

Fermi/GBM
50 keV - 40 MeV

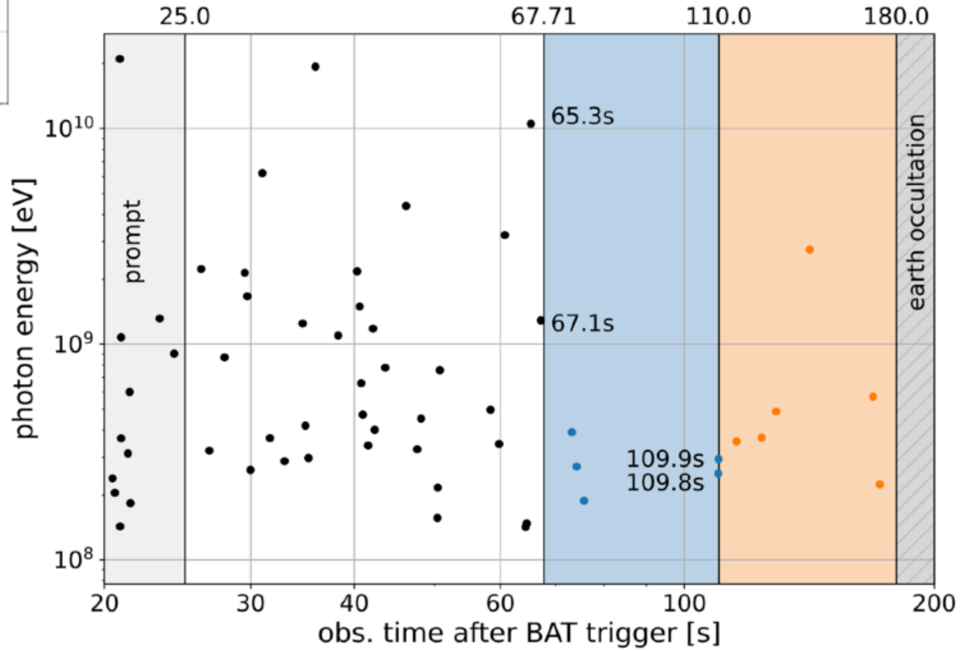


-1.98 ± 0.1

Fermi/LAT
>100 MeV

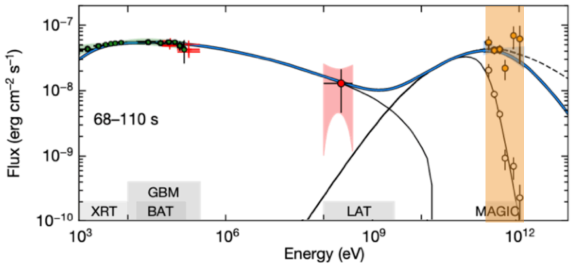


-2 ± 1

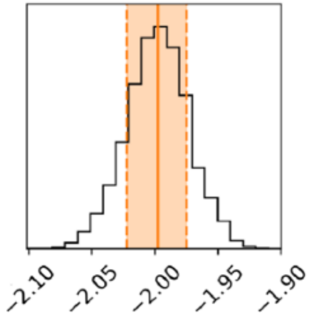


GRB 190114C: a rich multiwavelength data set

Let’s first fit each instrument’s data set on its own with a power law

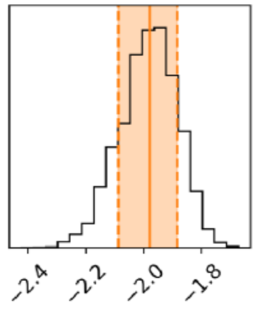


Swift/BAT
15-150 keV



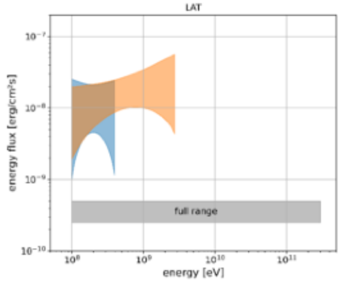
$-1.998^{+0.023}_{-0.024}$

Fermi/GBM
50 keV - 40 MeV



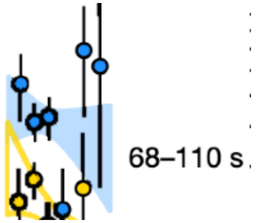
-1.98 ± 0.1

Fermi/LAT
>100 MeV



-2 ± 1

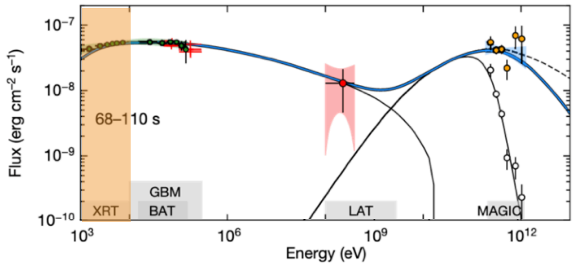
MAGIC
0.3 - 1 TeV



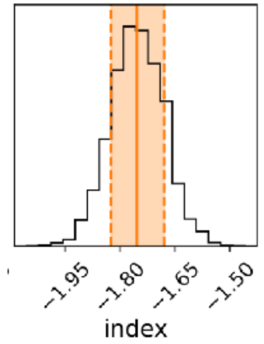
$-1.86^{+0.36}_{-0.40}$ (stat) $^{+0.12}_{-0.21}$ (sys)
Acciari et al., Nature 575 (2019)

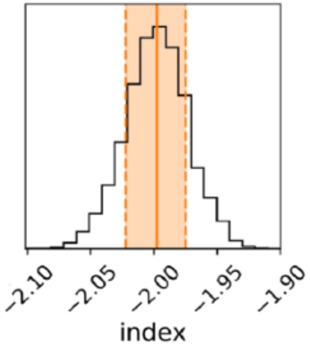
GRB 190114C: a rich multiwavelength data set

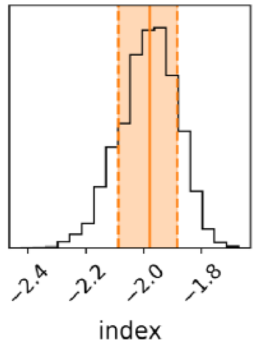
Let's first fit each instrument's data set on its own with a power law

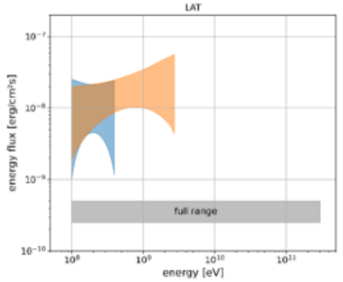


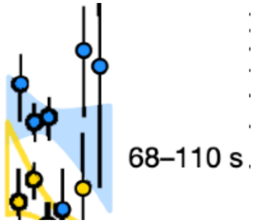
Swift/XRT 0.3-10 keV	*Swift*/BAT 15-150 keV	*Fermi*/GBM 50 keV - 40 MeV	*Fermi*/LAT >100 MeV	MAGIC 0.3 - 1 TeV





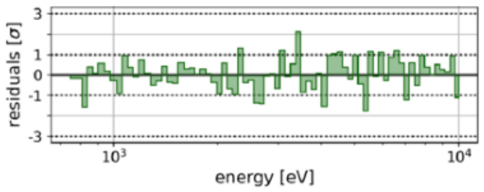






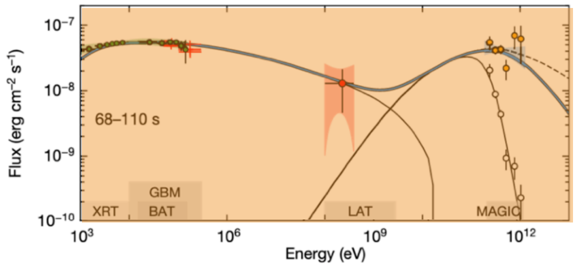
Swift/XRT	*Swift*/BAT	*Fermi*/GBM	*Fermi*/LAT	MAGIC
-1.75 ± 0.07	$-1.998^{+0.023}_{-0.024}$	-1.98 ± 0.1	-2 ± 1	$-1.86^{+0.36}_{-0.40}$ (stat) $^{+0.12}_{-0.21}$ (sys)

Acciari et al., Nature 575 (2019)

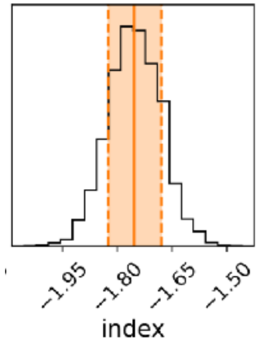


GRB 190114C: a rich multiwavelength data set

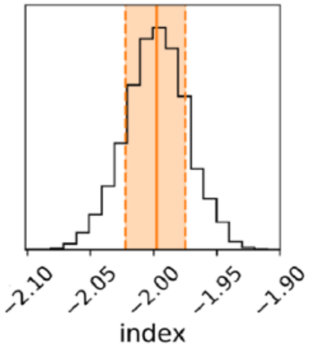
Putting it all together



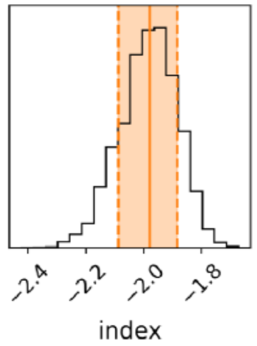
Swift/XRT
0.3-10 keV



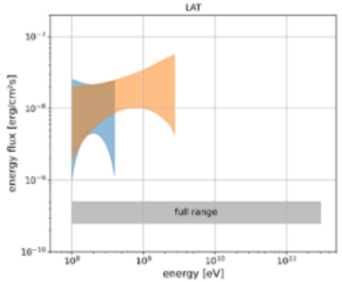
Swift/BAT
15-150 keV



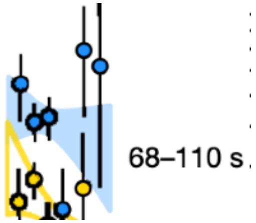
Fermi/GBM
50 keV - 40 MeV

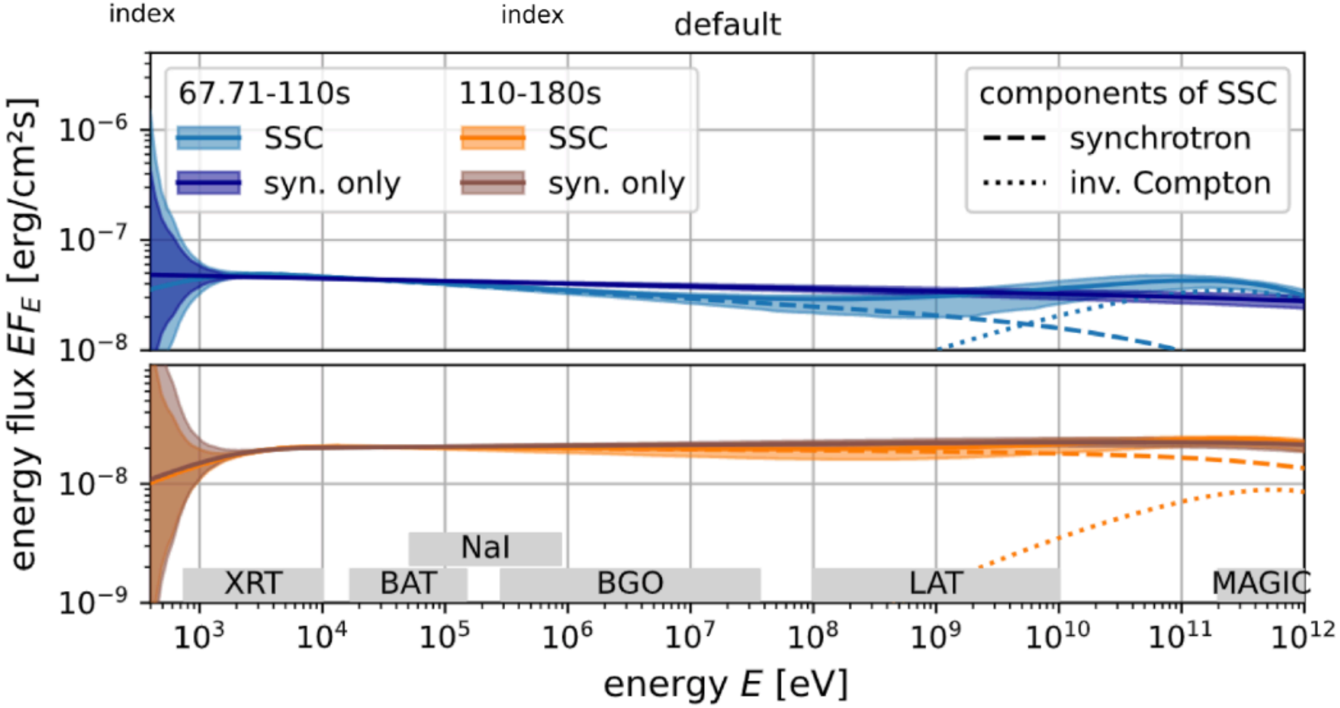


Fermi/LAT
>100 MeV



MAGIC
0.3 - 1 TeV





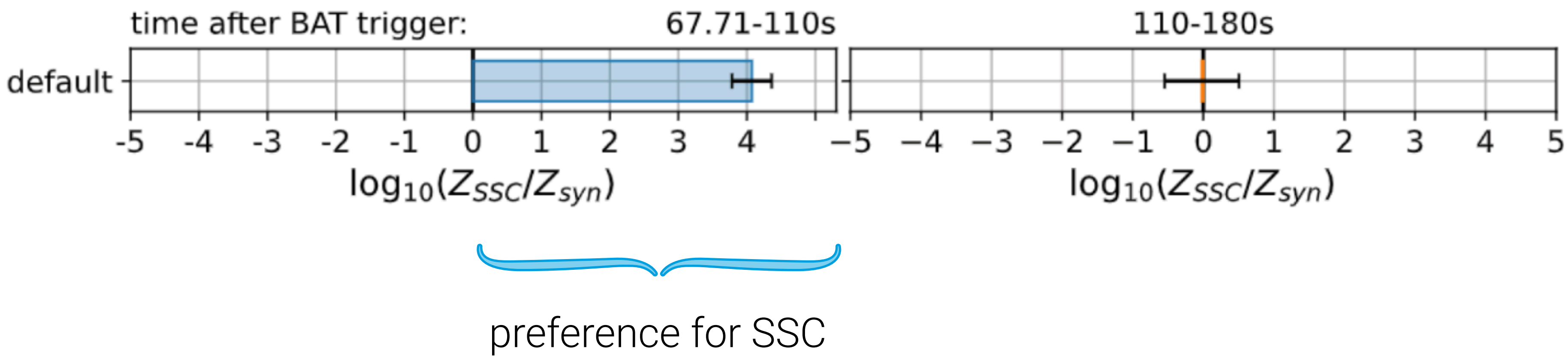
In the first time bin, there seems to be a preference for an additional component.

Can we quantify this?

GRB 190114C: a rich multiwavelength data set

How stable is this result?

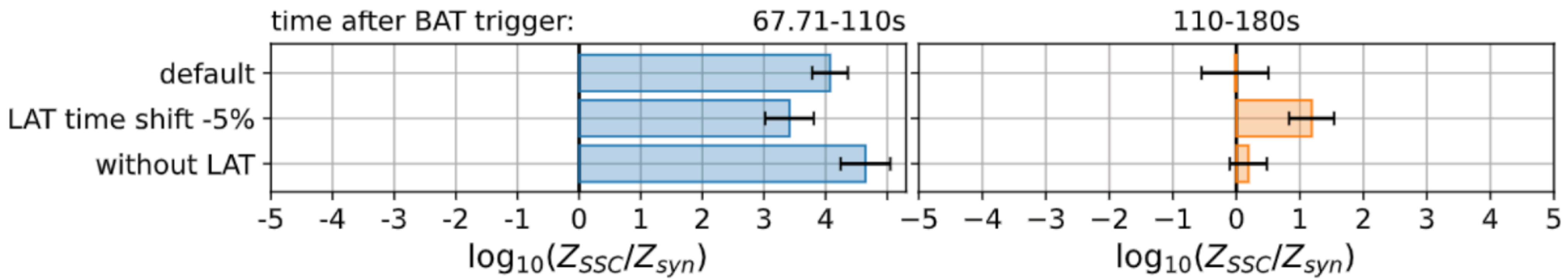
In the first time bin, there is a strong preference for SSC over synchrotron-only.



GRB 190114C: a rich multiwavelength data set

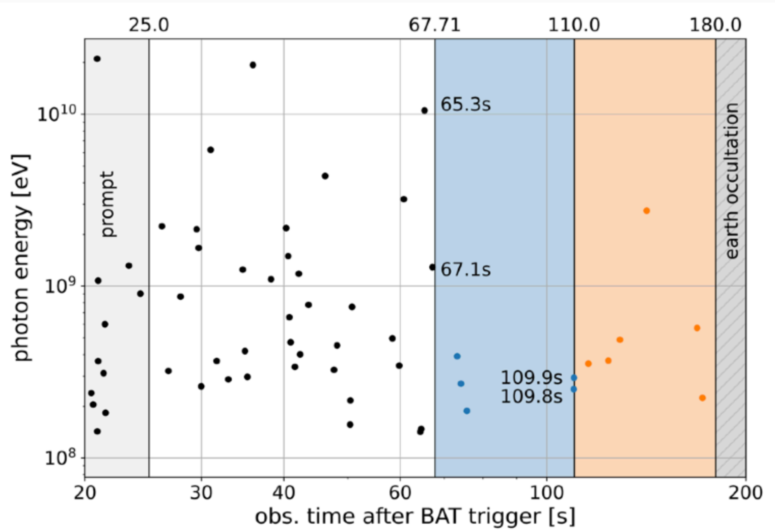
How stable is this result?

What happens to the Bayes factor if something is perturbed?



preference for SSC

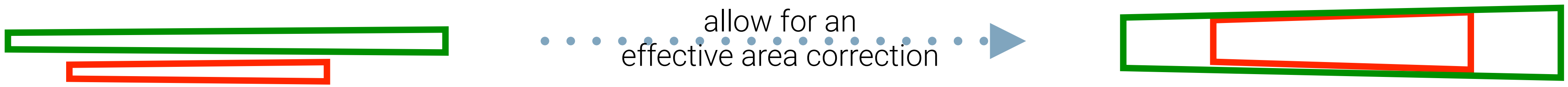
The LAT data doesn't seem to have much of an effect on the fit results



Note: How well do we understand our instruments?

A brief interlude about instrumental uncertainties

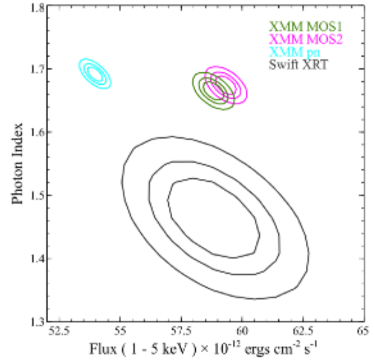
For instruments with overlapping energy ranges, the need for some kind of additional uncertainty is ~obvious.



Depending on the spectrum, this can manifest as e.g. offsets in index and/or flux.

Tsujimoto et al. 2011 A&A 525

Madsen et al 2017 AJ 153 2



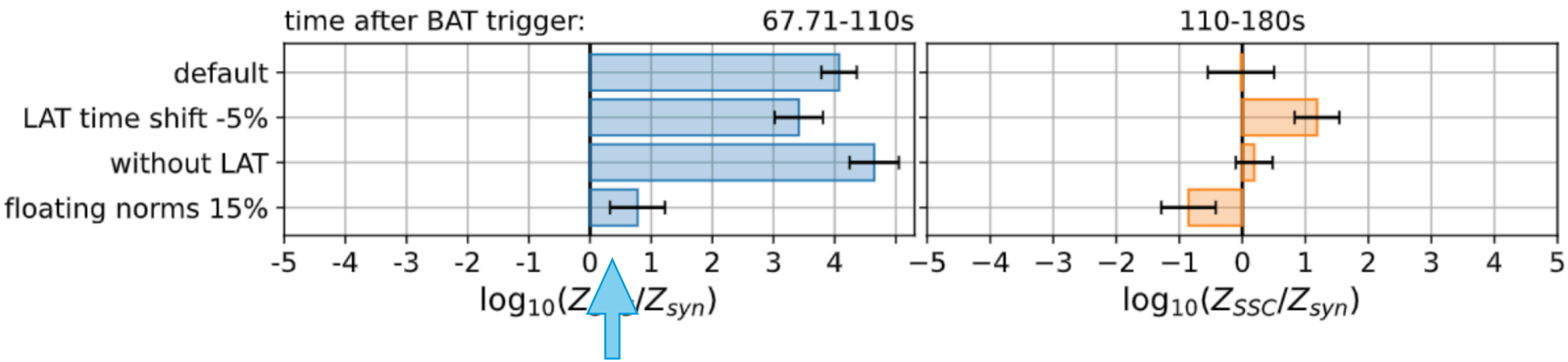
For instruments with disjoint energy ranges, we should at least allow for systematic uncertainties.

Krimm et al 2013 ApJS 209 14, Bissaldi et al 2011 ApJ 733 97, Fermi-LAT P8R3_V3 caveats, Ahnen et al. 2017 Astroparticle Physics 94

GRB 190114C: a rich multiwavelength data set

How stable is this result?

What happens to the Bayes factor if something is perturbed?



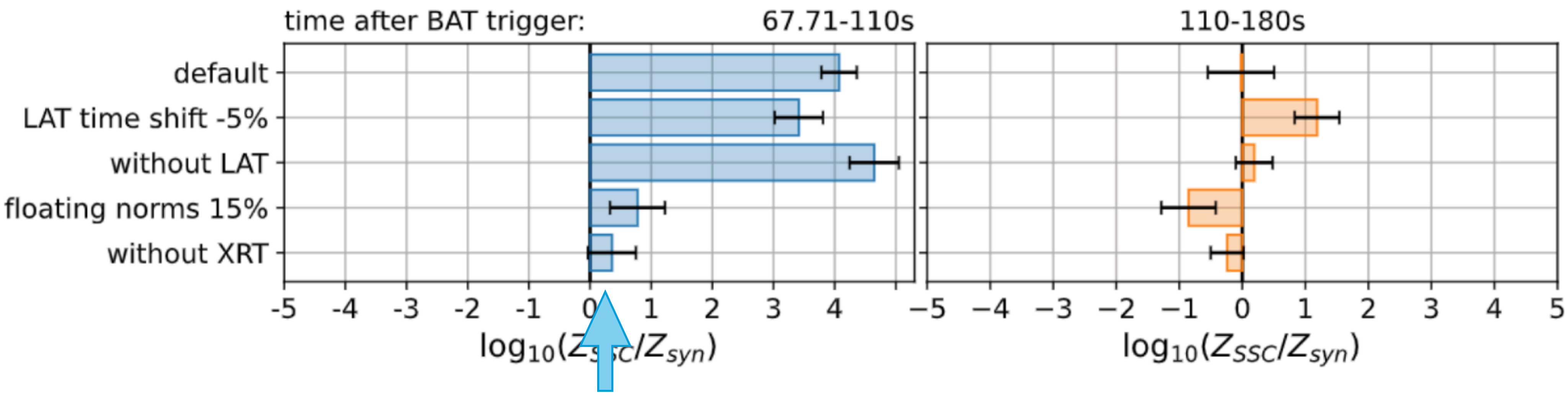
no more preference for SSC

When we allow for systematic uncertainties within the best understood limits, the preference for SSC vanishes.

GRB 190114C: a rich multiwavelength data set

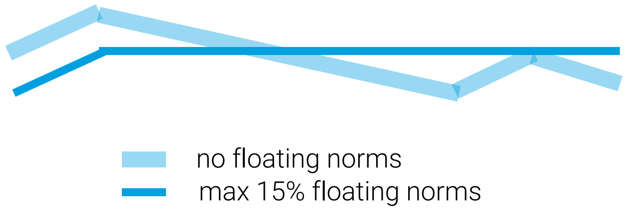
How stable is this result?

What happens to the Bayes factor if something is perturbed?



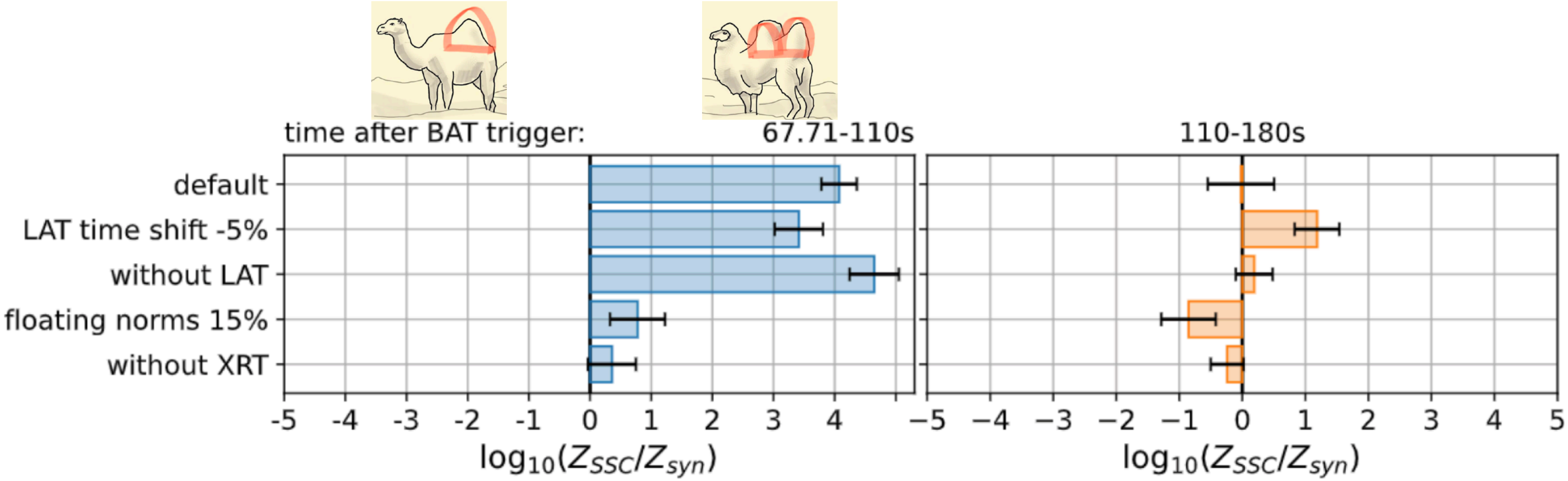
no more preference for SSC

The XRT data is driving the requirement for two components.



Summary

Is GRB 190114C a Bactrian camel or a dromedary?



Takeaway messages:

The statistical preference for two components vanishes if instrumental effects are properly accounted for.
When we encounter such a rich dataset, we should treat it as carefully as possible.

backup

Full set of posterior distributions

time bin 1 (67.71 - 110s), SSC default fit

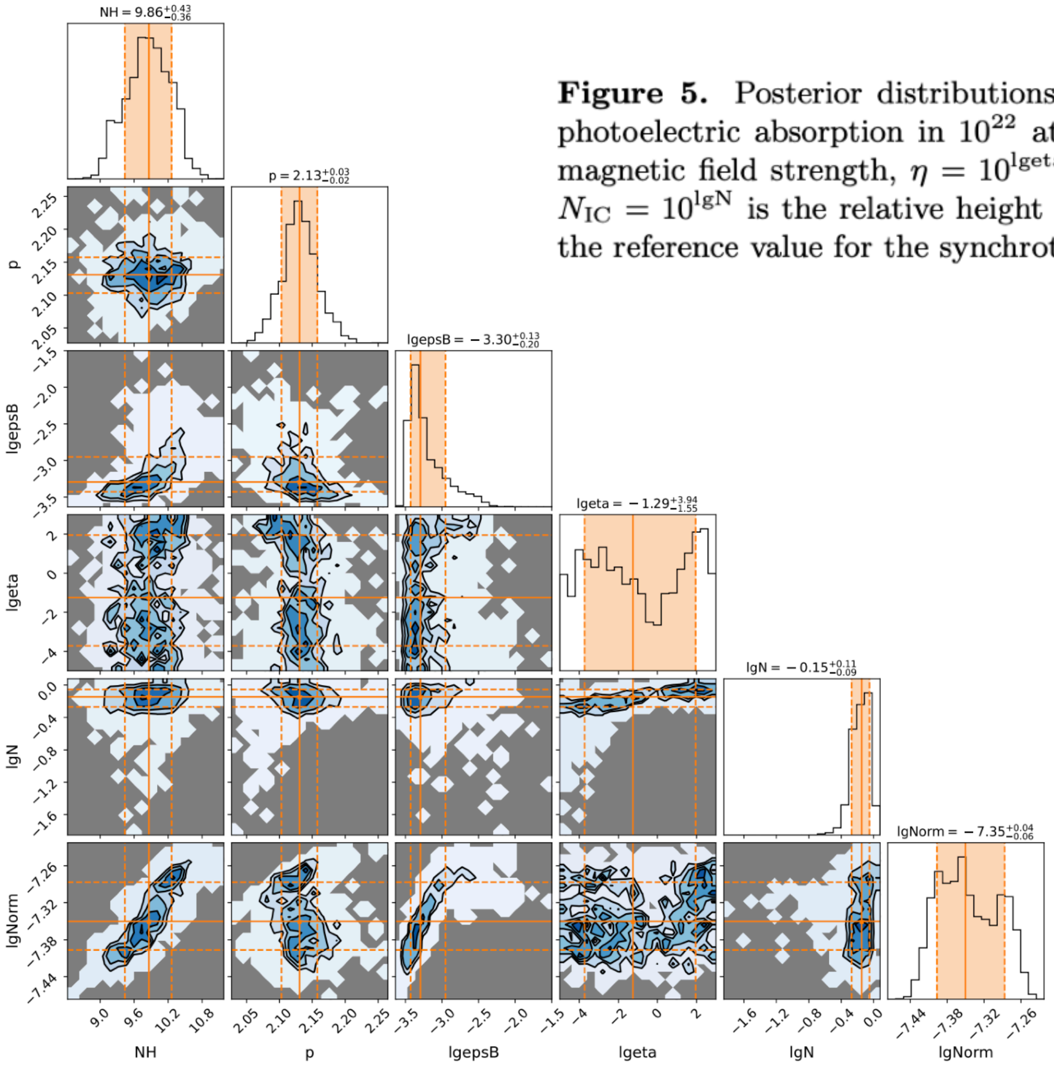
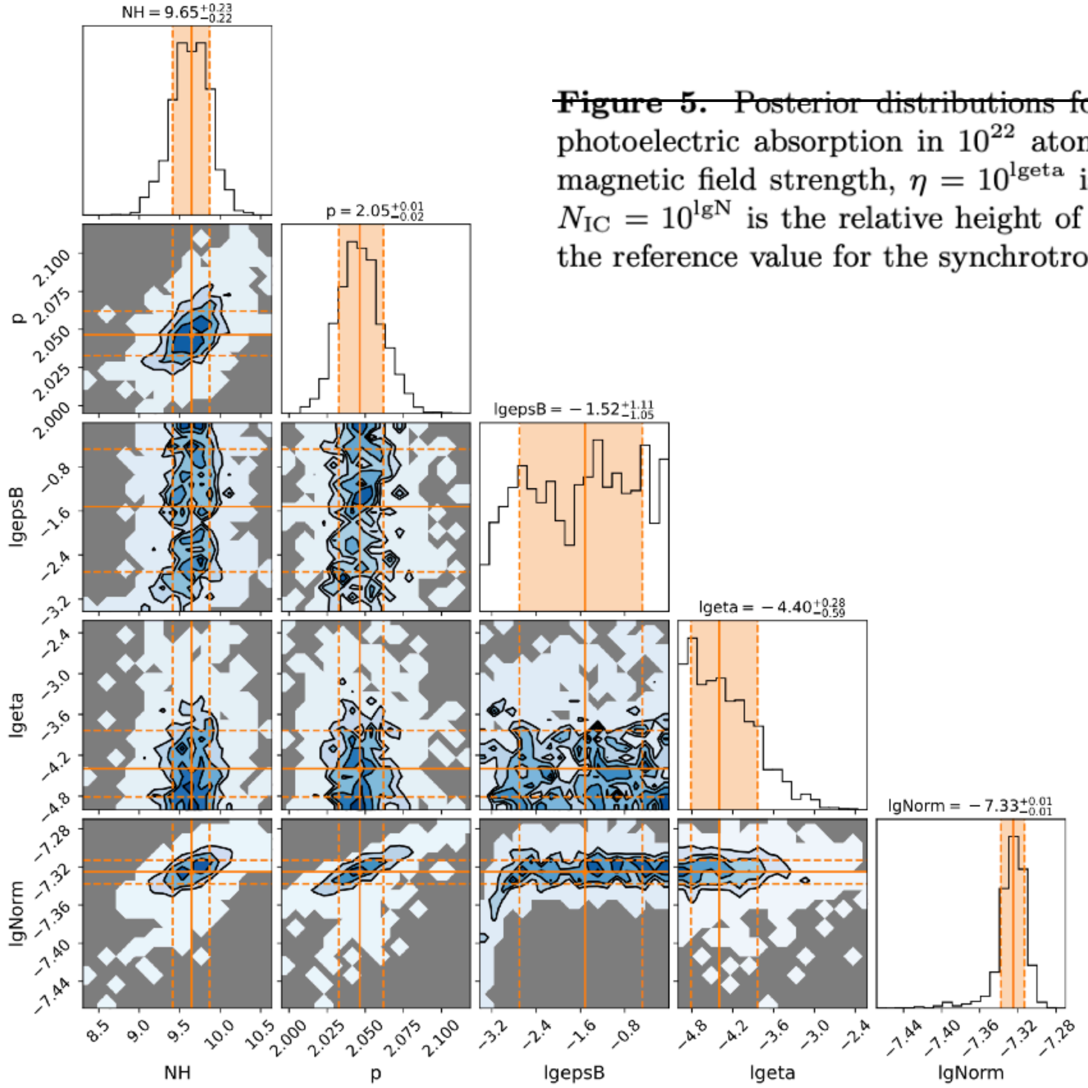


Figure 5. Posterior distributions for SSC default fit for the time interval 67.71 − 110s. NH is the column density of the photoelectric absorption in 10^{22} atoms per cm^2, p is the spectral index of the uncooled electrons, $\varepsilon_B = 10^{\mathrm{lgepsB}}$ defines the magnetic field strength, $\eta = 10^{\mathrm{lgeta}}$ is inversely proportional to the maximum energy of the electrons and thus also photons, $N_{\mathrm{IC}} = 10^{\mathrm{lgN}}$ is the relative height of the inverse Compton component to the syncchrotron component and $F_{\mathrm{syn}} = 10^{\mathrm{lgNorm}}$ is the reference value for the synchrotron photon flux in $erg/(cm^2 s)$ at $E_\gamma^{\mathrm{obs}} = 1$ keV.

Full set of posterior distributions

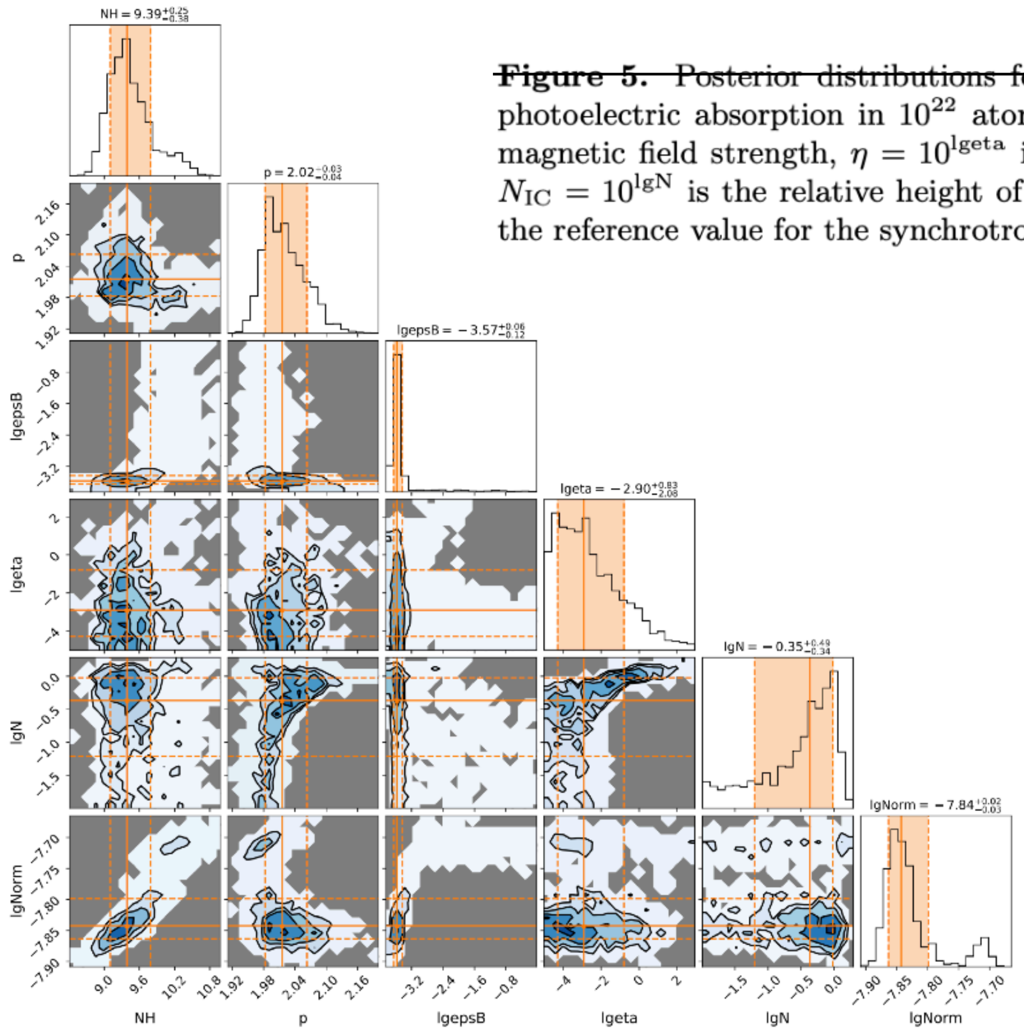
time bin 1 (67.71 - 110s), synchrotron only



~~**Figure 5.** Posterior distributions for SSC default fit for the time interval 67.71 − 110s.~~ NH is the column density of the photoelectric absorption in 10^{22} atoms per cm^2, p is the spectral index of the uncooled electrons, $\varepsilon_B = 10^{\mathrm{lgepsB}}$ defines the magnetic field strength, $\eta = 10^{\mathrm{lgeta}}$ is inversely proportional to the maximum energy of the electrons and thus also photons, $N_{\mathrm{IC}} = 10^{\mathrm{lgN}}$ is the relative height of the inverse Compton component to the syncchrotron component and $F_{\mathrm{syn}} = 10^{\mathrm{lgNorm}}$ is the reference value for the synchrotron photon flux in $erg/(cm^2 s)$ at $E_\gamma^{\mathrm{obs}} = 1$ keV.

Full set of posterior distributions

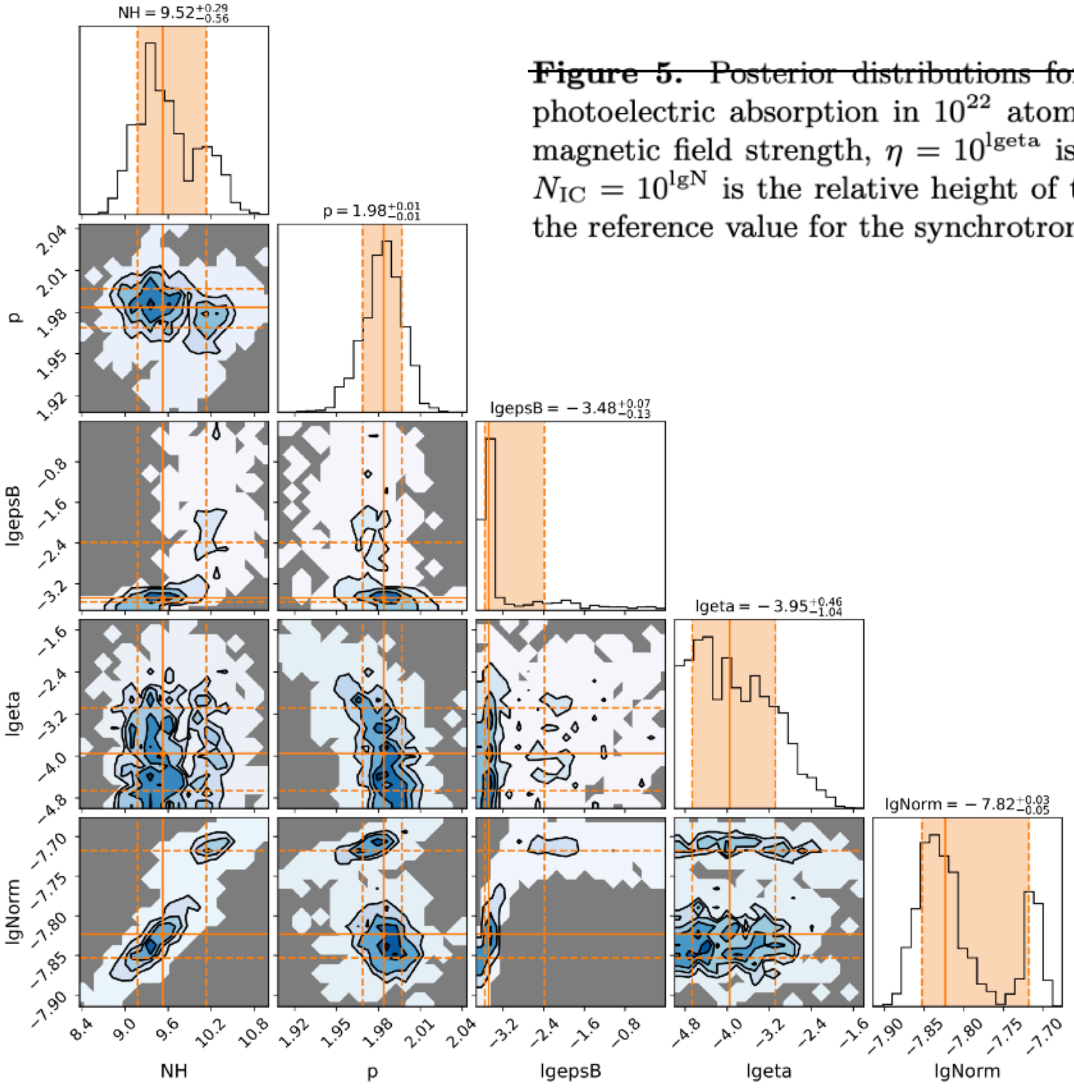
time bin 2 (110 - 180s), SSC default



~~**Figure 5.** Posterior distributions for SSC default fit for the time interval 67.71 − 110s.~~ NH is the column density of the photoelectric absorption in 10^{22} atoms per cm^2, p is the spectral index of the uncooled electrons, $\varepsilon_B = 10^{\mathrm{lgepsB}}$ defines the magnetic field strength, $\eta = 10^{\mathrm{lgeta}}$ is inversely proportional to the maximum energy of the electrons and thus also photons, $N_{\mathrm{IC}} = 10^{\mathrm{lgN}}$ is the relative height of the inverse Compton component to the synchrotron component and $F_{\mathrm{syn}} = 10^{\mathrm{lgNorm}}$ is the reference value for the synchrotron photon flux in $erg/(cm^2 s)$ at $E_\gamma^{\mathrm{obs}} = 1$ keV.

Full set of posterior distributions

time bin 2 (110 - 180s), synchrotron-only



~~**Figure 5.** Posterior distributions for SSC default fit for the time interval 67.71 − 110s.~~ NH is the column density of the photoelectric absorption in 10^{22} atoms per cm^2, p is the spectral index of the uncooled electrons, $\varepsilon_B = 10^{\mathrm{lgepsB}}$ defines the magnetic field strength, $\eta = 10^{\mathrm{lgeta}}$ is inversely proportional to the maximum energy of the electrons and thus also photons, $N_{\mathrm{IC}} = 10^{\mathrm{lgN}}$ is the relative height of the inverse Compton component to the syncchrotron component and $F_{\mathrm{syn}} = 10^{\mathrm{lgNorm}}$ is the reference value for the synchrotron photon flux in $erg/(cm^2 s)$ at $E_\gamma^{\mathrm{obs}} = 1$ keV.