SWIFT

in the context of understanding

GRB

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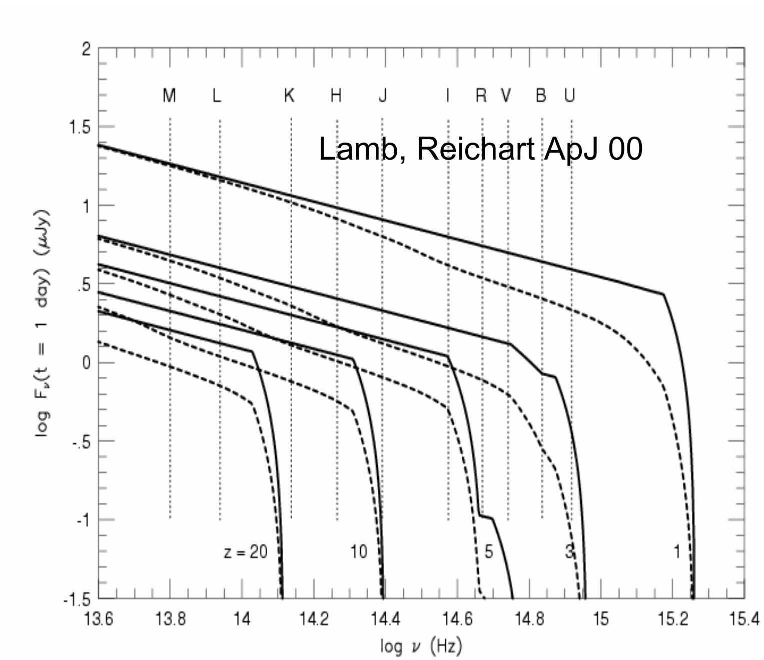
How far can we see GRBs?

High-z GRB distance measures

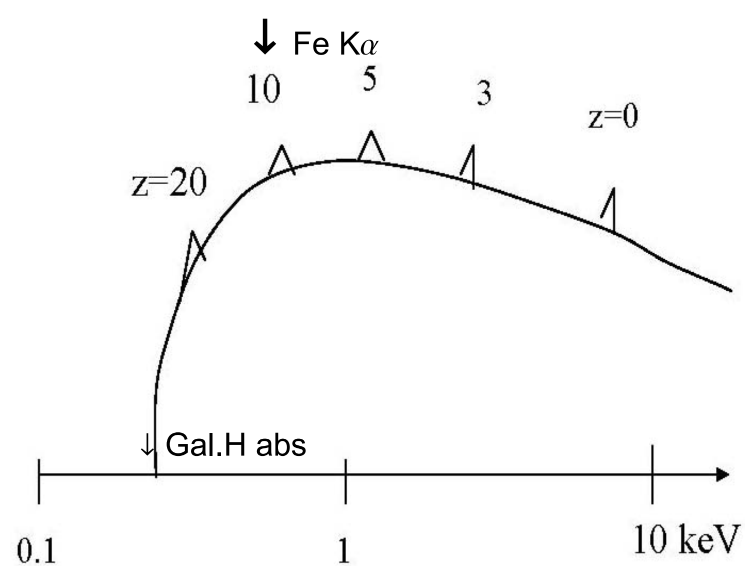
- Positive K-correction:
  $\rightarrow$ flux ~ constant at $z \gtrsim 5$
- Optical/UV: Ly α cutoff $\rightarrow$ redshift out to $z \lesssim 5$ for Swift
- Forward shock exp. fluxes↓



O/IR

- XR cont: detect with Swift for $z \lesssim 20$ @ $t \lesssim 1$ dy
- Fe Kα XR line unabsorbed by gal. for $z \lesssim 20$
- Swift det. Fe Kα to $z \lesssim 3$ @ $t \lesssim 3$ hrs , 3σ level
- XMM det. Fe Kα to $z \lesssim 15$ @ $t \lesssim 1$day, 3σ level

↕ Meszaros, Rees 03 ApJ 591, L91



XR

Mészáros, HEAD04

Other z-measures?

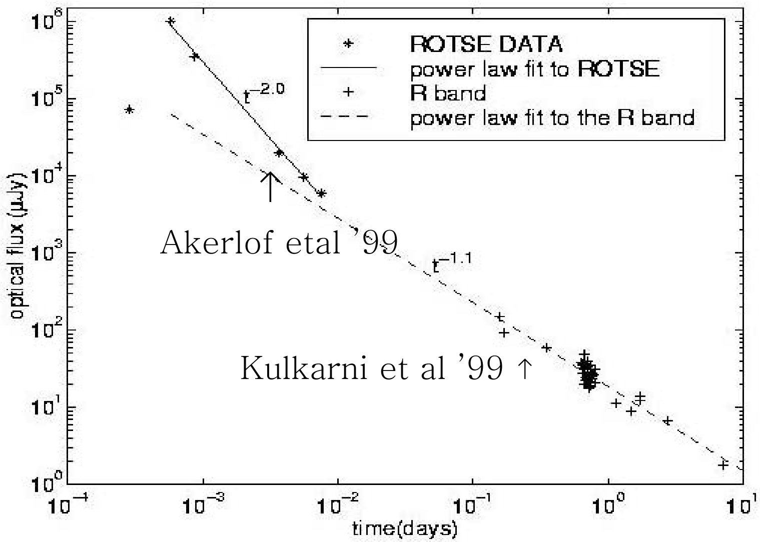
- Variability measure V vs. $E_{\gamma iso}$

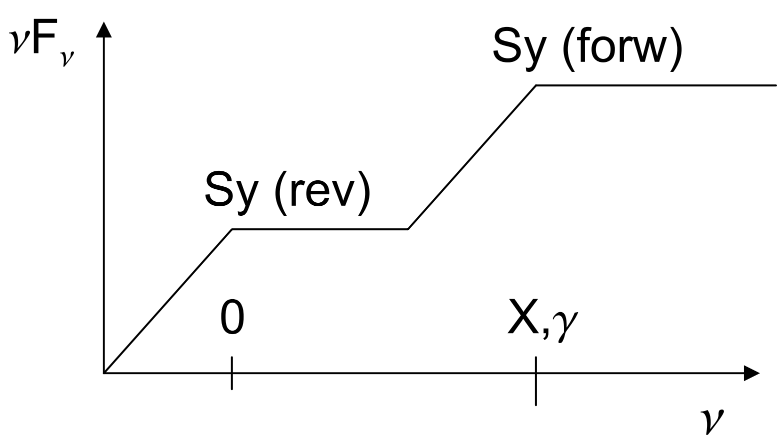
  (Fenimore, Ramirez-Ruiz, Lamb, Reichart..)
- Lag vs. $E_{\gamma iso}$ (Norris, Bonnell,..)
- Spectral break (hardness ratio) vs $E_{\gamma iso}$

  (Amati etal, Bagoly etal, Schmidt..)
- AND more recently: E_{pk} vs $E_{\gamma tot}$ correl

  (Ghirlanda et al 04)

Prompt Optical Flashes

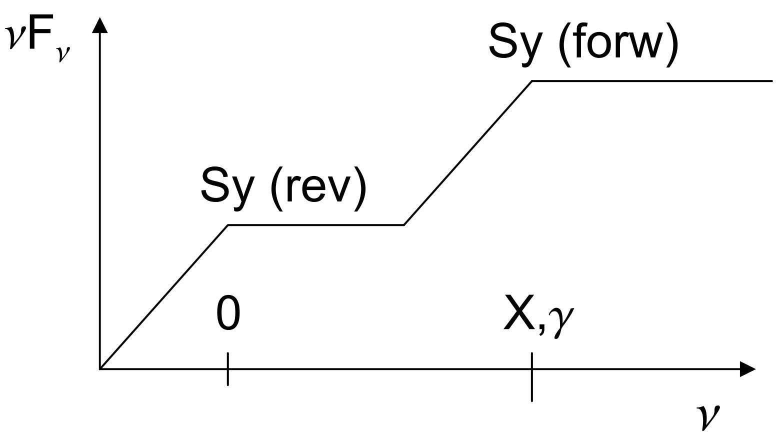




- **GRB 990123** → bright (9th mag) **prompt opt. transient** (Akerlof etal 99)
  – 1st 10 min: decay steeper than forw. shock
- Interpreted as **reverse external shock**
- (predicted : Mészáros&Rees '97)
- **99-02**: **Great Desert:** **Lack of flashes**, **upper limits m_v~12-15**
- **but:** **New** generation robotic tels: **ROTSE III, Super-LOTIS, RAPTOR, KAIT, TAROT, NEAT, Faulkes, REM**; etc
- ⟶ some prompt optical flashes: **GRB 021004, 021211:** similar to GRB 990123
- ⟶ some **"semi- prompt"** flashes, (**ROTSE IIIa** (AU), **ROTSE IIIb** (TX)): **GRB 030418, 30723 :** ≠ from GRB 990123 !
  → t >211, 50 s resp, see f**orw**. shock only?
  steep rise (ascribed to dusty stell. wind)
  m_R ~ 17 at t~ 30 min, then PL -1.35 decay
  (Rykoff etal astro-ph/0310501)

Reverse Shock light-curve

- Previously, rev O/IR neglected in estimates of detectability
- Reverse O/IR light curve is *brighter* (while it lasts) than forward l.c
- At high-z, reverse l.c. ***lasts longer*** (in obs. frame) $\Longrightarrow$ easier to detect at high z!



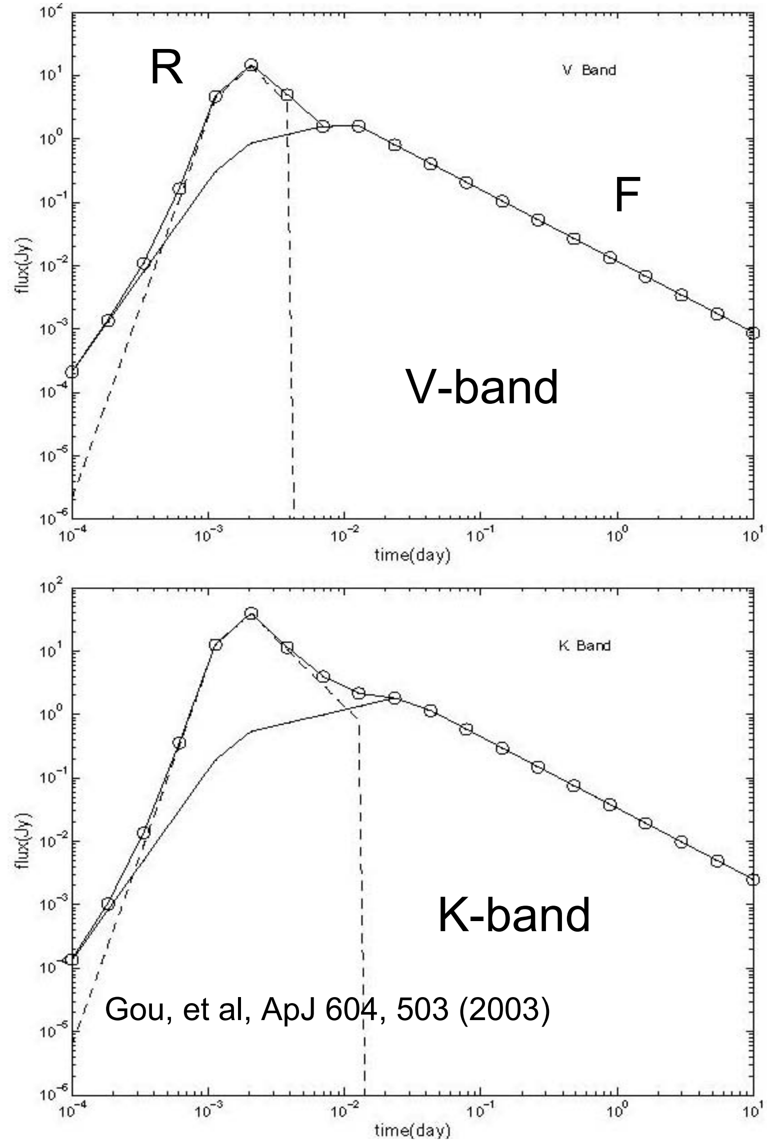


Fig. 1.— Typical light curves, for a redshift $z = 1$. Reverse shock emission (dashed), forward shock emission (solid). total flux (symbols). Parameters:$\epsilon_{B,f} = 0.001, \mathcal{R}_B = B_r/B_f = 5, \epsilon_e = 0.1, E_{52} = 10, p = 2.5, \eta = 120, n_0 = 1$ cm^{-3}. a): V band ($\nu = 5.45 \times 10^{14}$ Hz); b): K band ($\nu = 1.36 \times 10^{14}$ Hz).

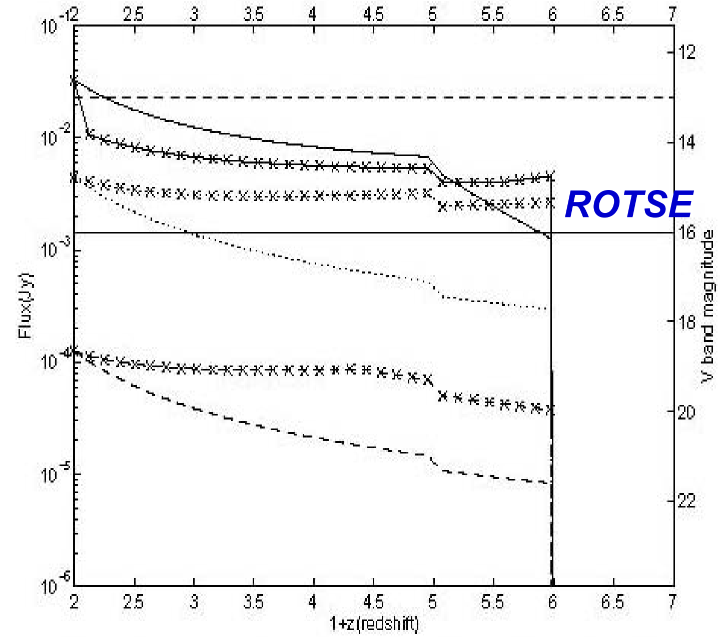
Mészáros, HEAD04

IR
hi-z detectability

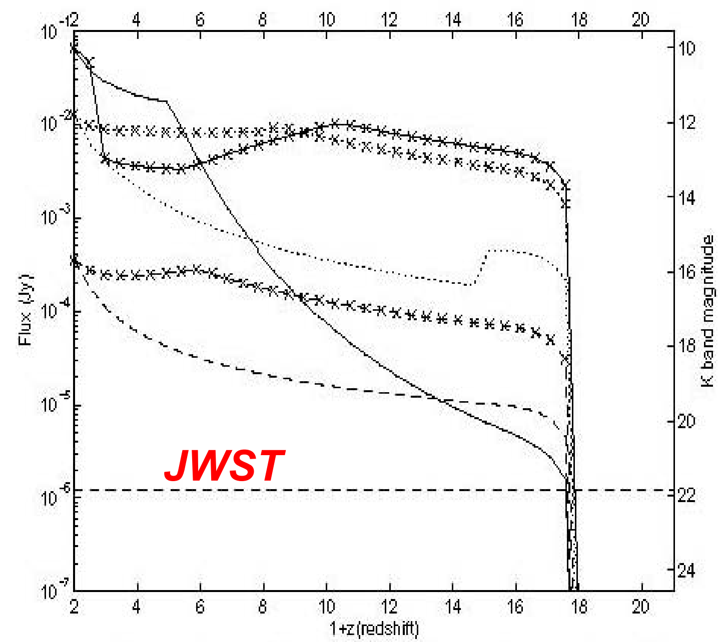
- Reverse shock dominates early l.c.
- Two density profiles:
  w/o symbols: n_{ext} = const;
  w. symbols: $n_{ext} \propto (1+z)^4$
- At different obs. times:
  Solid: 10 min
  Dashed: 2 hrs
  Dotted : 1 dy
- Params:
  E_{52}=10, η=120, p=2.5,
  $\epsilon_{Bf}=10^{-3}$, B_r/B_f=5, ϵ_e=0.1
- JWST K-sensit for R=1000, S/N=10, t_{int}=1hr

O/IR → ↓ detectability

V-band

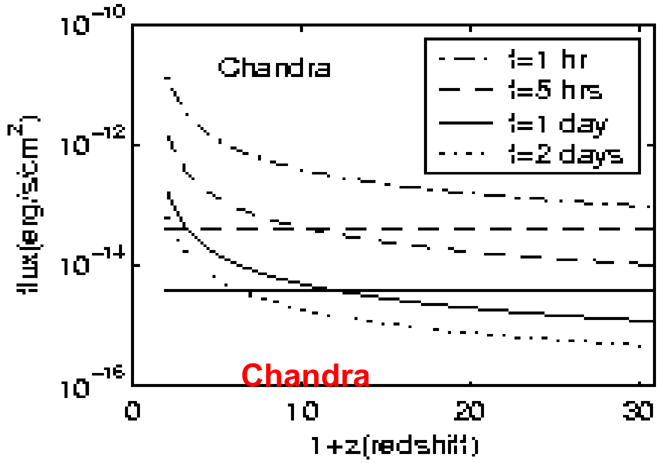


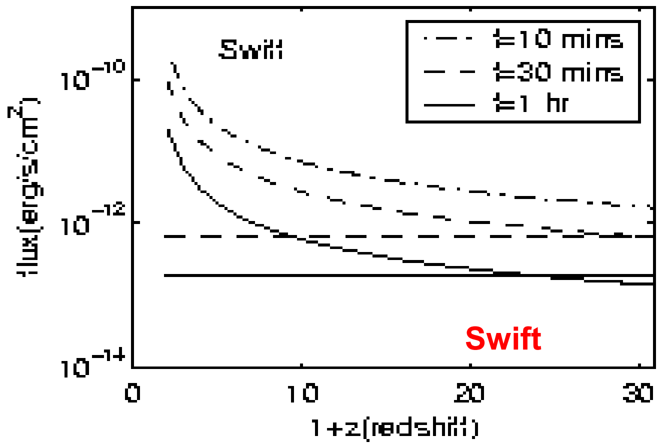
K-band



Gou et al 03, ApJ 604, 503

XR
hi-z detectability

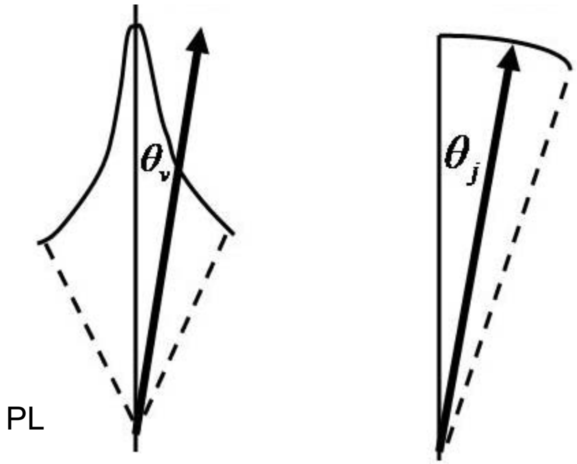




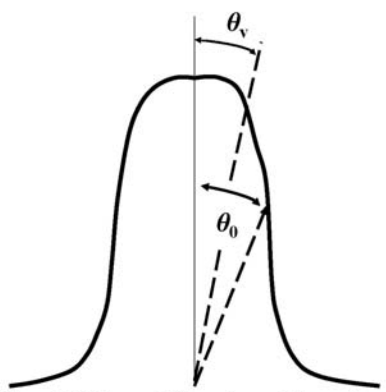
- •XR light curve: dominated by forward shock (simpler);
- •Emission same for both density profiles because it is above cooling freq, hence density indep.

Gou et al 03, ApJ 604, 503

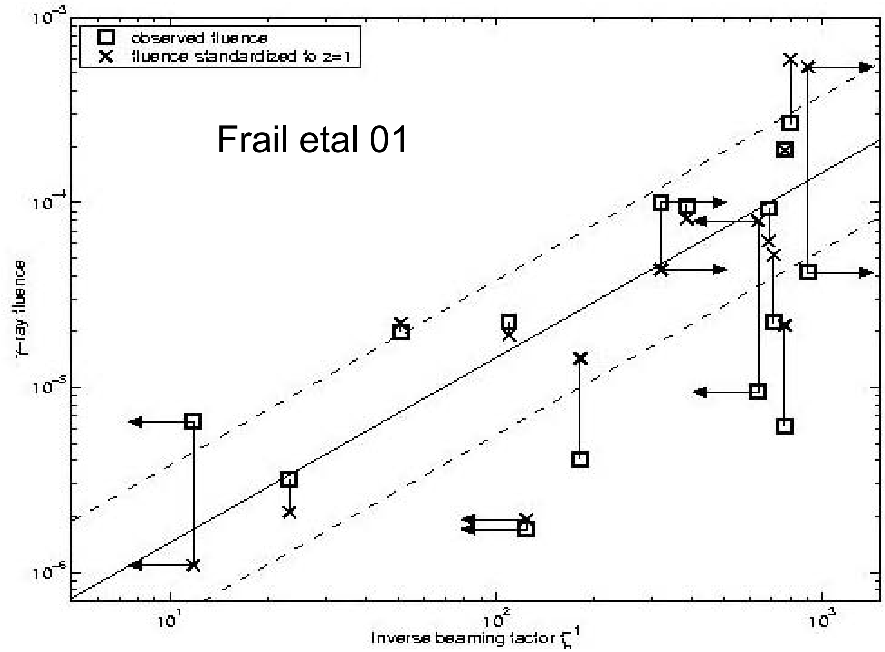
Jet breaks & shapes



Quasi-universal structured jet　　　Uniform jet



Quasi-Universal Structured Gaussian



- Obs. inv. corr. $L_{\gamma(iso)} \propto \theta_j^{-2}$
- $\rightarrow$ **$L_{\gamma(tot)}$ ~ const.**
- Can be understood as
  - a) ***Uniform*** jet on-beam
    with $E(\theta_j)$~const, $P(\theta_j) \propto \theta_j^2$

Or - b) ***Structured*** (**PL**) jet on/off axis,
with $E(\theta) \propto \theta^{-2}$, $P(\theta)$ ~cons

Or - c) ***Structured*** (**Gauss**) jet w.
charact. θ_0 with dispersion
$\log(\theta_0 /\mathrm{rad})$~-1.0±0.2

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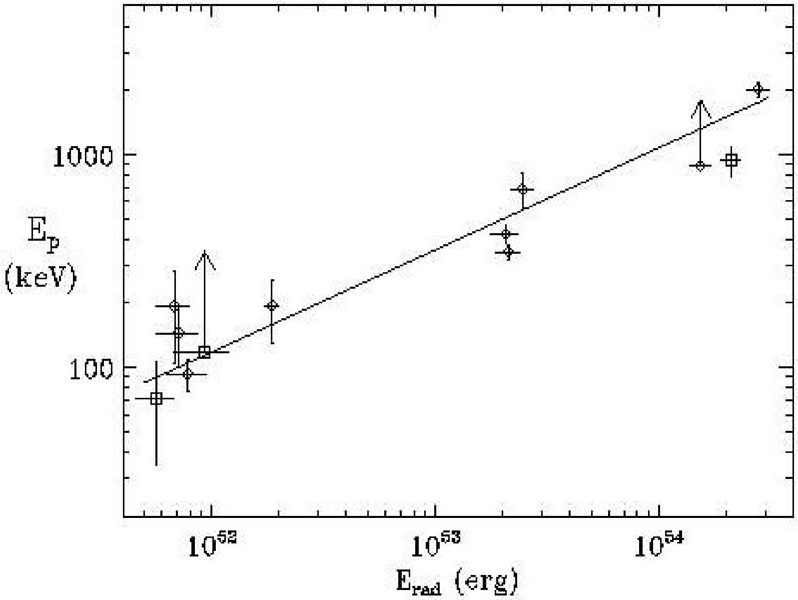
X-ray Flashes - XRF

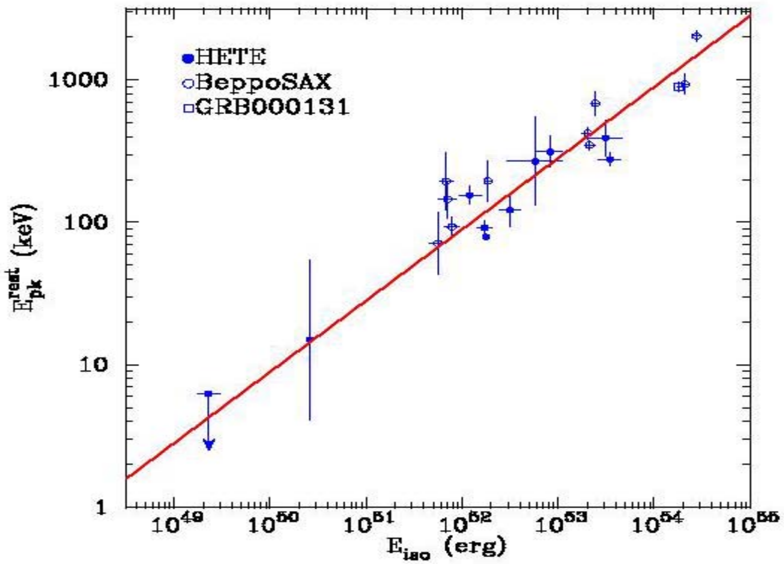
- Similar in all properties to GRB, except that they are softer
  3 keV $\lesssim E_p \lesssim$ 40 keV (Heise et al 02, Kippen et al 02)

- Several possibilities:
  (a) Usual int. shock, but w.low Γ and/or high z (Heise etal '02; Kippen etal'02)
  (b) Pair-thick internal shocks (Meszaros et al, a-ph/0205144; Kobayashi et al aph/0110080)
  (c) Jet/bubble break-out therm.emiss. (Ramirez-Ruiz etal, a-ph/0111342, a-ph/0205108)
  (d) Uniform jet seen on-beam but w. larger opening angle (Kobayashi etal a-ph/0110080, Lamb et al 03, aph/0312634)
  (e) Uniform jet seen off-beam (Yamazaki, etal 03 & 04, aph/0401044)
  (f) Universal power-law jet at large angles (Perna etal 03 ApJ594:379; Nakar etal aph/0311545)
  (g) Quasi-Universal Gaussian jet at intermed. angle (Zhang etal aph/0311190)

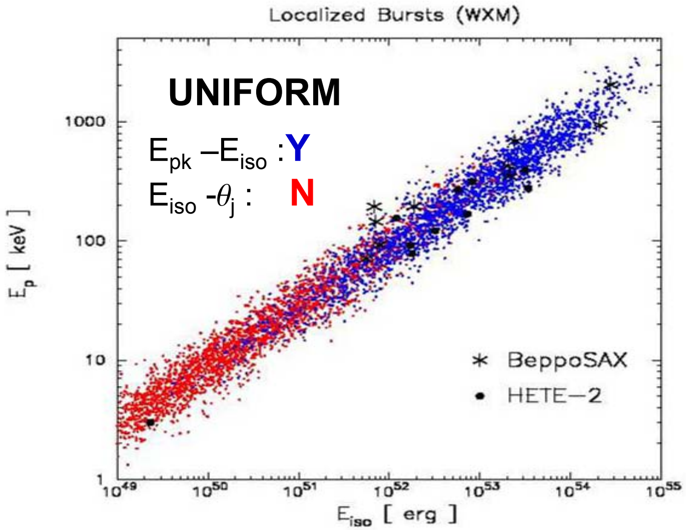


E_{pk} –E_{iso}: GRB .. & XRF?

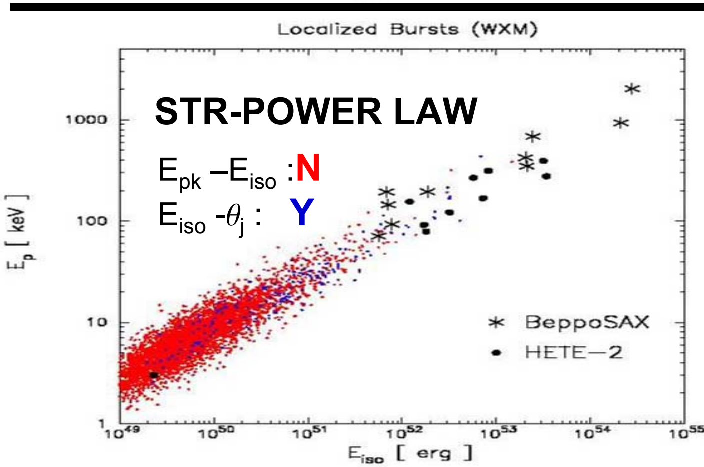
- ← $E_{pk} \propto E_{\gamma iso}^{1/2}$ obs. in **GRB**
  (Amati et al, 02 AA390:81)
- **Reason?** E.g., internal shocks predict $E_{pk} \propto \Gamma^{-2} t_v^{-1} L^{1/2}$
  (Zhang & PM '02 apj581:1236) ;
  but $\Gamma^{-2} t_v^{-1}$ ~ const? (not obvious)
- ←**Question**: can one extrapolate this relation down to **XRF?**
- If add 2 XRF with known/constr. z, → $E_{pk} \propto E_{iso}^{1/2}$, may extend down.
- E_{pk}-Fluence plot of 40 HETE-2 GRB + XRF w. & w/o z also suggests so
  (Lamb et al aph/0312634)
  (more recently:also: Ghirlanda et al 04; Friedman, Bloom 04)



Uniform vs. Structured: E_{pk}-E_{iso} and E_{iso}-θ_j (both?)

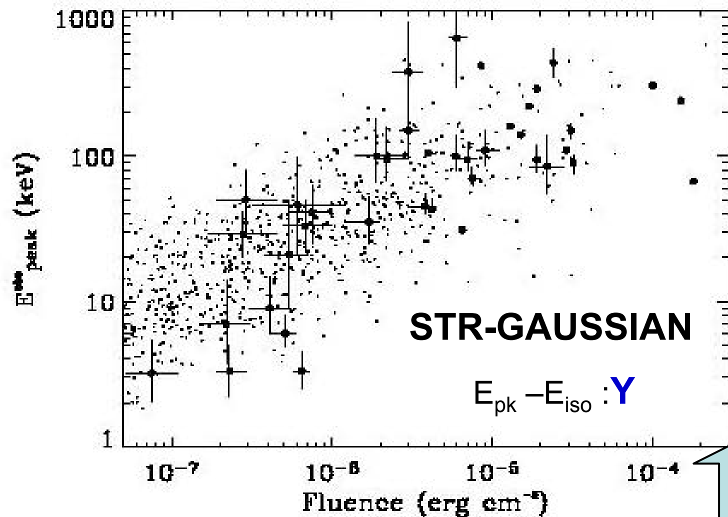


Y
N

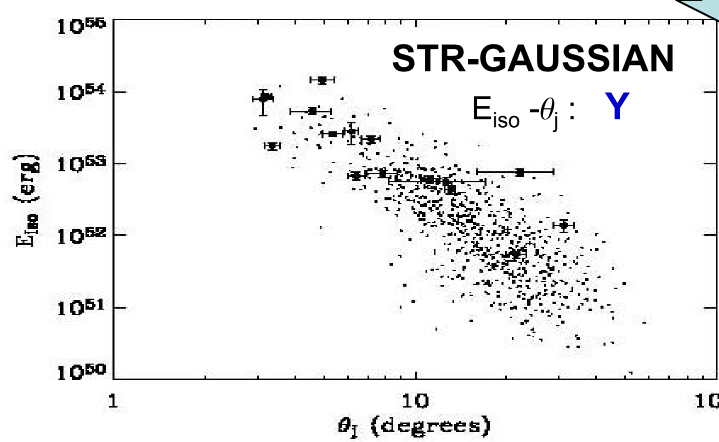


N
Y

Lamb etal aph/0312634



Y



Y

Zhang etal, 04, ApJ 601, L119

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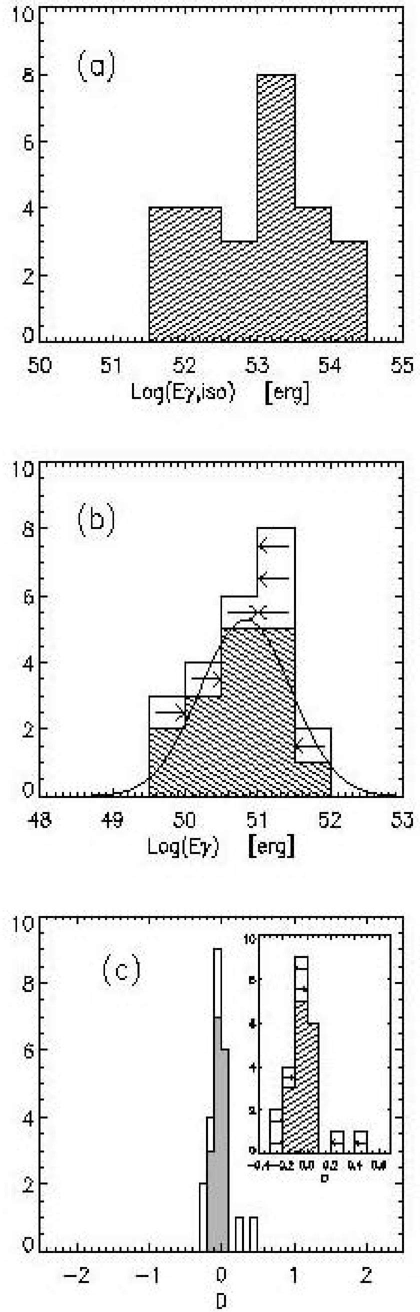
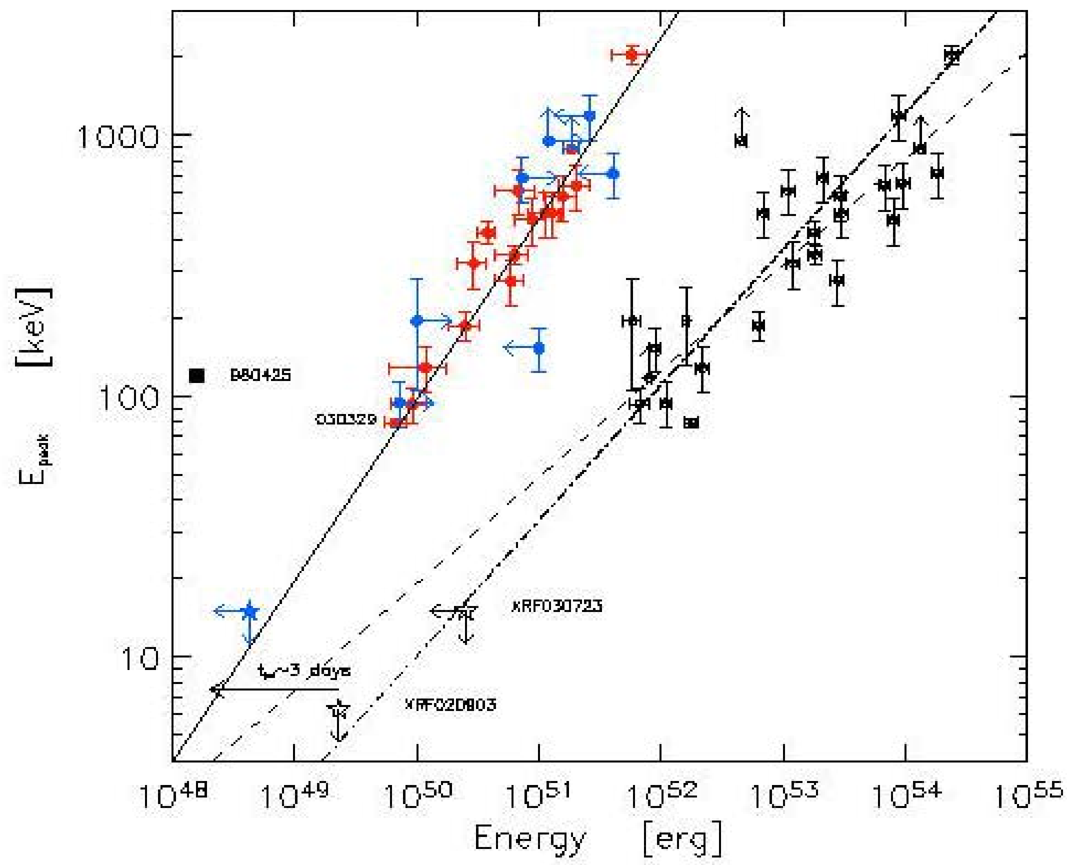
E_{pk} vs $E_{\gamma tot}$

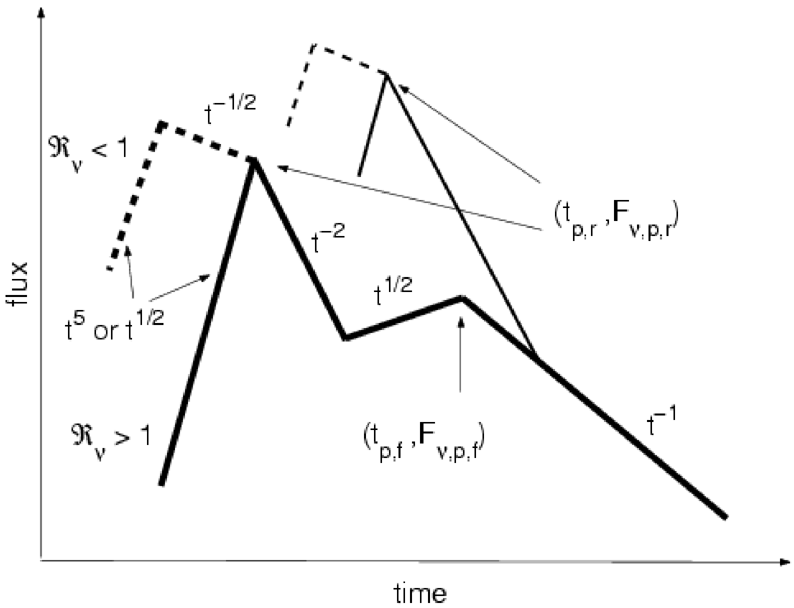
Better correl. than E_{pk} vs $E_{\gamma iso}$ (?)

Ghirlanda, Ghisellini, Lazatti, aph/0405602
(see also Friedman & Bloom, aph/0408413)

$E_{pk} \propto E_{\gamma tot}^{\ 0.7}$



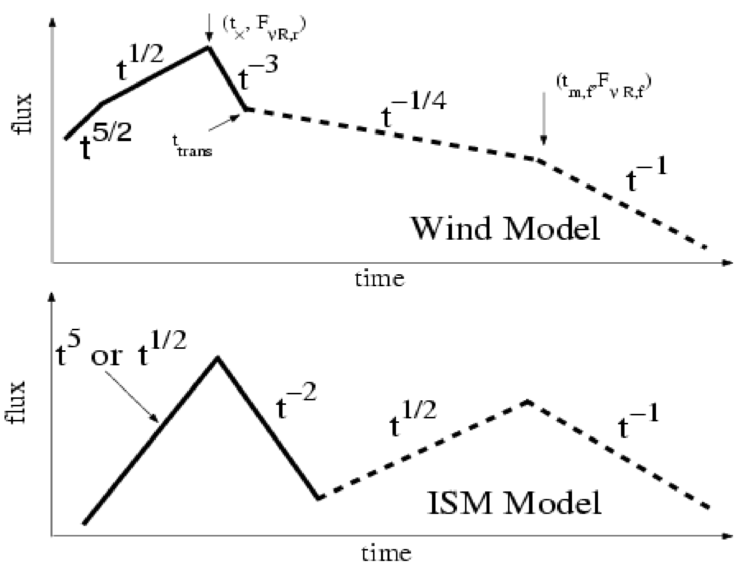




↑ Zhang, Kobayashi, PM, 03, ApJ 595, 950

Prompt optical flash

- Rev+For shock peak ⟹ provide **Lorentz factor** & ejecta **magnetization** diagnostics
- "Re-brightening LC: usual case (thick line)
- "Flattening" LC (thin line) : →either low Γ or high B_r/B_f ; ; e.g. GRB 990123
- ← LC provides **wind** vs. quasi-**uniform** external medium diagnostic



← Kobayashi & Zhang, 03, ApJ 597, 455

Prompt Optical Flash

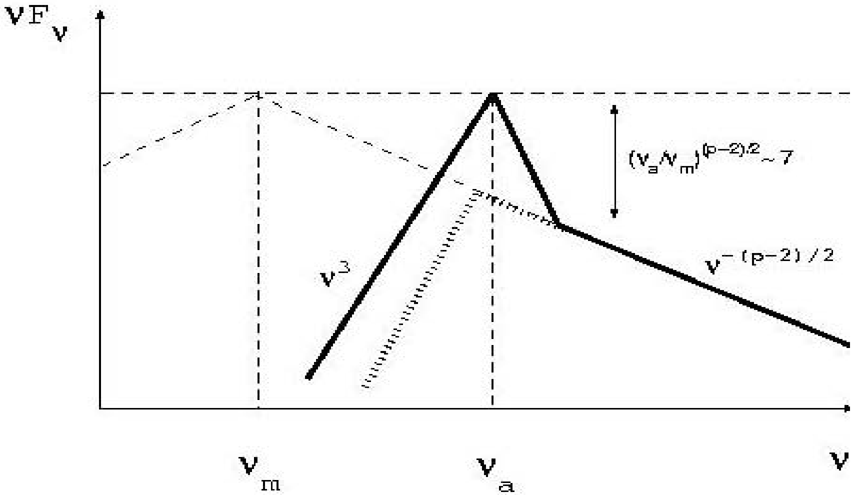


Fig. 1.— Reverse shock spectrum in a dense environment or wind when synchrotron lo
dominate: with self-absorption (thick solid) and without self-absorption (thin dashed).
schematic self-absorption maximum would appear as a rounded thermal peak. The prev
self-absorbed flux estimate is shown by hashed lines. The correction factor $2(\nu_a/\nu_c)^{(p-2)}$
$t^{(p-2)/7}$ is slightly larger at later times ($t \sim t_\times$), the value of ~ 7 is evaluated at t_a for typ
parameters.

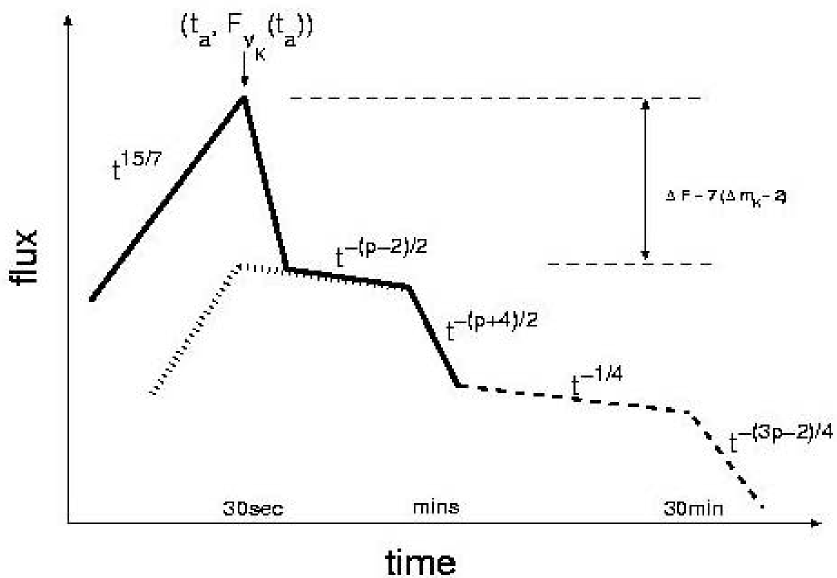
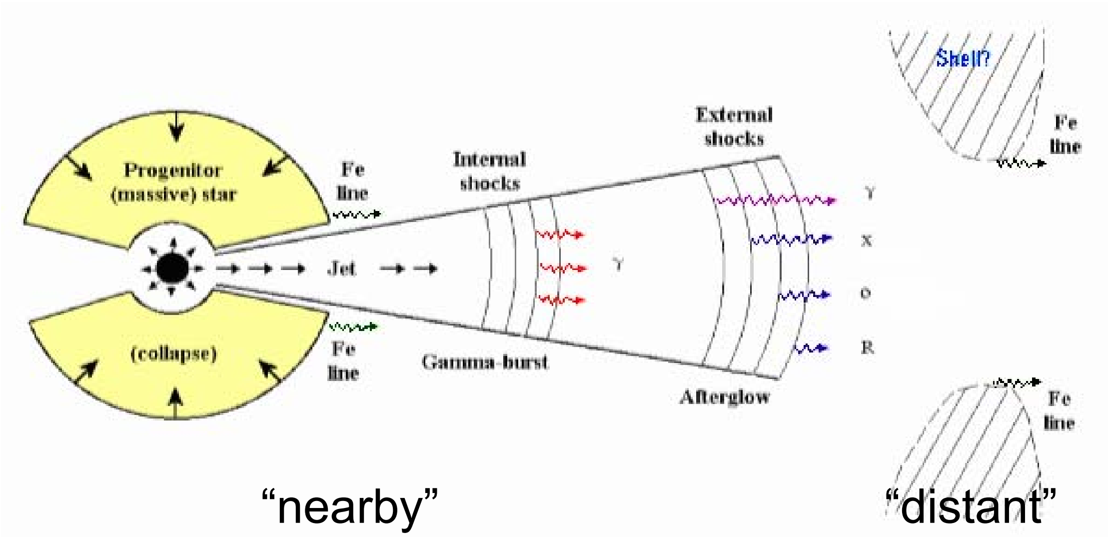


Fig. 1.— Schematic optical light curve for a synchrotron dominated fireball in a dense environment or wind: reverse shock emission (solid) and forward shock emission (dashed). The hashed line shows a previous estimate. Time scales are rough estimates for the typical parameters.

- High density external medium and mag. field diagnostic
- $\nu_c \lesssim \nu_m \lesssim \nu_a$: synchrotron absorpt. (if IC weak, ϵ_e/ϵ_B < 1) causes absorption bump in spectrum
- Also in LC, when go through obs. band (while go from blue to red spectrum)
- Constrain dM/dt (wind) or n_{ext}
- But If IC strong (ϵ_e/ϵ_B >1): $\Longrightarrow$X-ray prompt flash

Kobayashi, Mészáros, Zhang 04, ApJ 601, L13

Collapsar Jet & SN Shell XR Lines

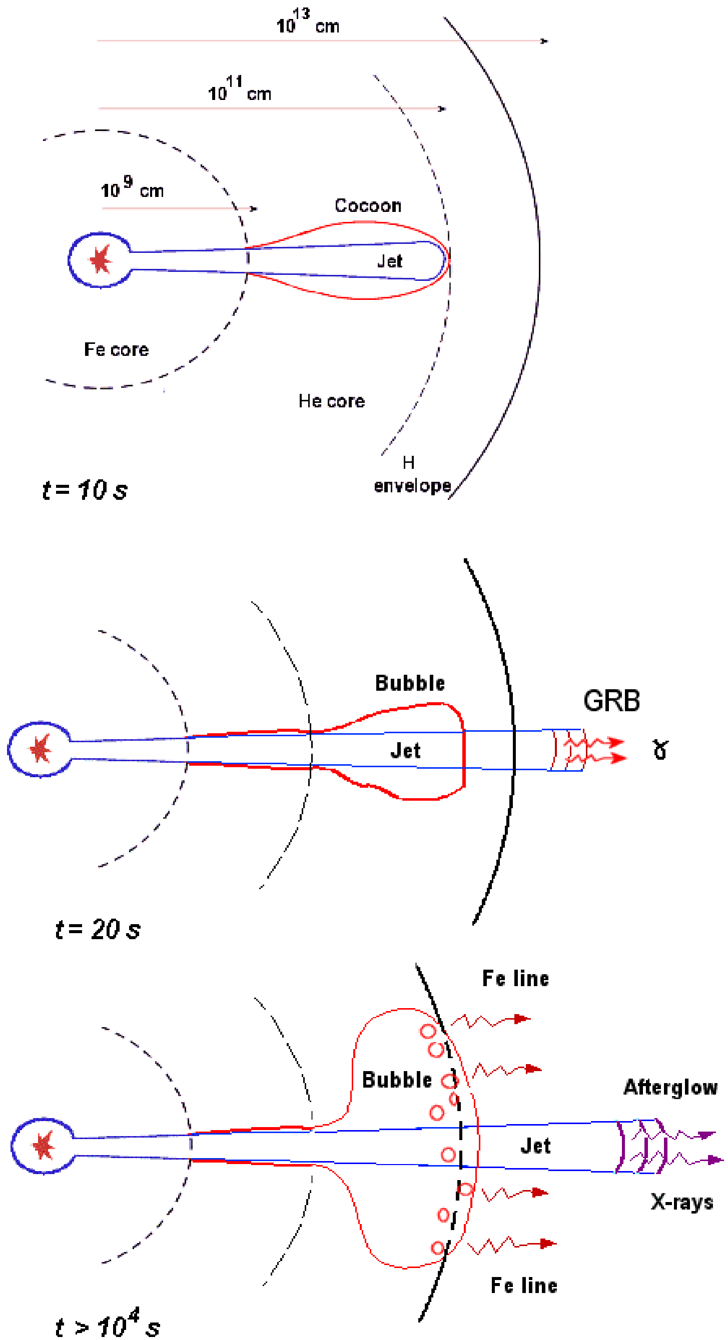


- "**Nearby**" model : Collapsar w., e.g. decaying jet($\gtrsim$dy),e.g from fall -back BH accretion, or magnetar
- Timescale: intrinsic, R~10^{13} cm
- L_x~10^{47} erg/s, $\propto t^{-1.3-1.5}$, n~10^{18}/cc,
- ξ~$10^3 \rightarrow$ **Fe Kα,** L_{Fe}~10^{45} erg/s
- Need M_{Fe} ~10^{-5} $M_\odot$ -solar or enrich. OK

(Rees & Mészáros 00, ApJ 545:L73)

•"**Distant**" model: super(supra)nova shell (wind? or from comp. remnant?)
•Timescale: geom., r~10^{15}-10^{16} cm, t~(r/c)(1-cos θ) ~dy
•Need M_{Fe} ~0.1-1 $M_\odot$, 10-10^2 x solar
•70 day for Ni→Fe?

(Piro etal 00, Sci.290:955; Vietri etal 01, ApJ 550:L43)



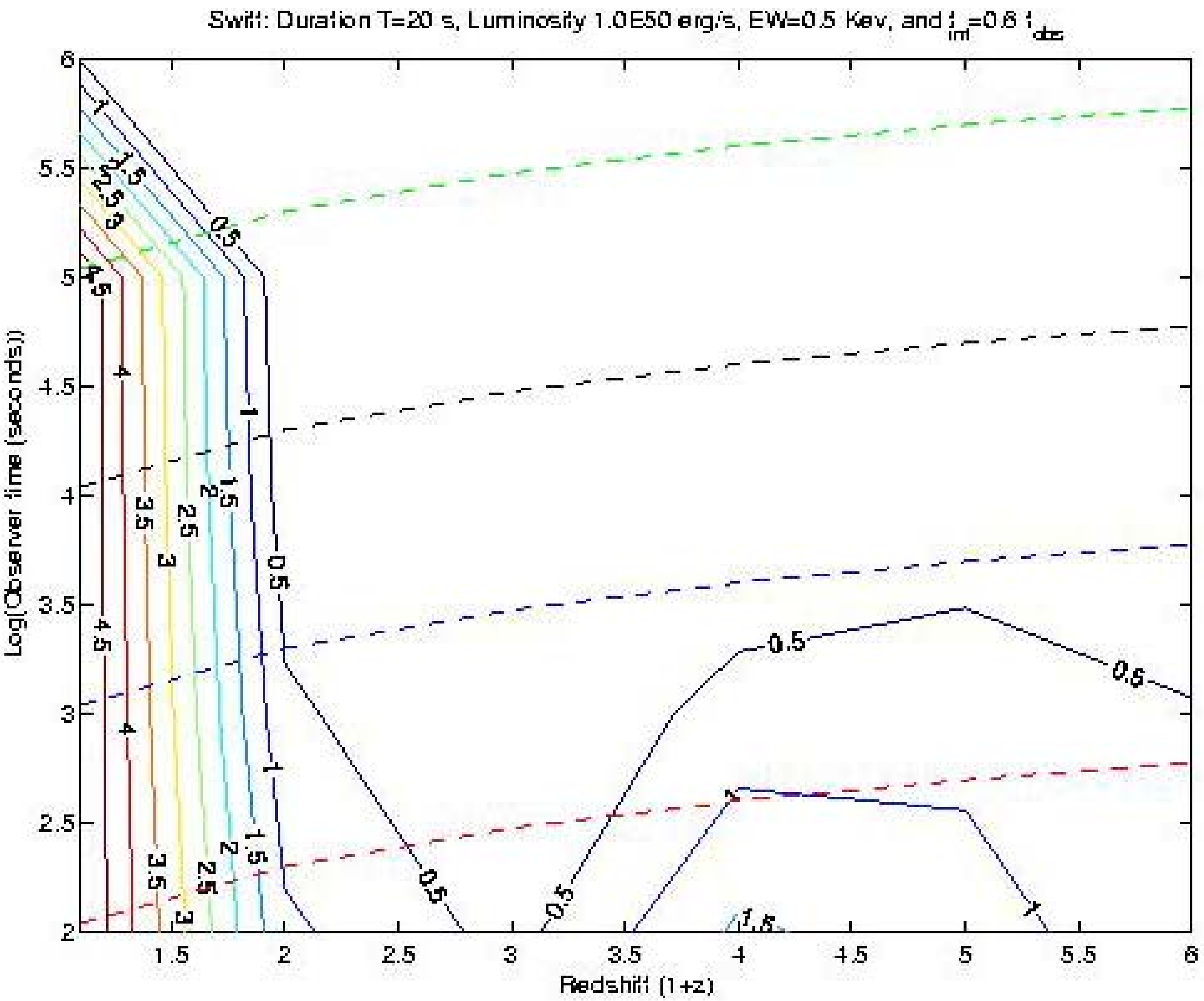
Jet + Bubble XR Line Model

- "**Nearby**" model (b):
  jet produces cocoon
  →relativistic "bubble" of magn. relativistic plasma,
- At breakout ~0.5-1 dy
  B ~10^5 G, sy.cont. on n~10^{18}/cc envelope,
  →L_{Fe} ~$10^{44.5}$ x $_{Fe\odot}$,
  need M_{Fe}~10^{-4} $M_\odot$
- Bubble scatt. depth: need very high clumpiness for
  XR line + PL
- EW/continuum ratio OK

(Mészáros, Rees 01 ApJ 556:L37

Kallman, Mészáros, Rees O2, ApJ 593, 946)

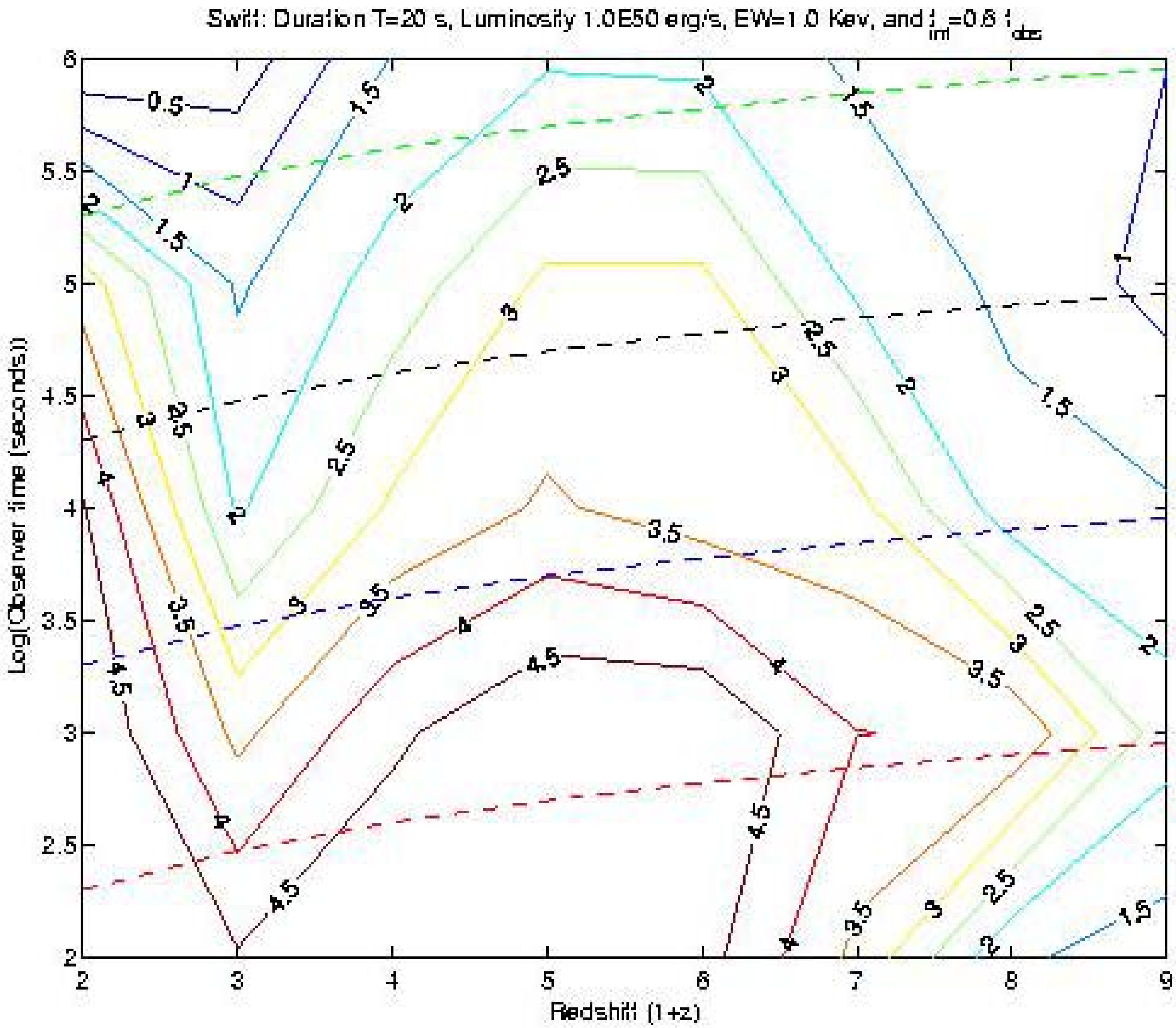
Swift Fe Kα line detection



- Use standard GRB afterglow LC decay with K-corrections, incl. jet break, placed at various z
- Phenomenol. Fe Kα line assumed .
- ← This case: $L_{x0}=10^{50}$ erg/s , EW=0.5 keV, T=20s

Gou, Mészáros, Kallman, astro-ph/0408414

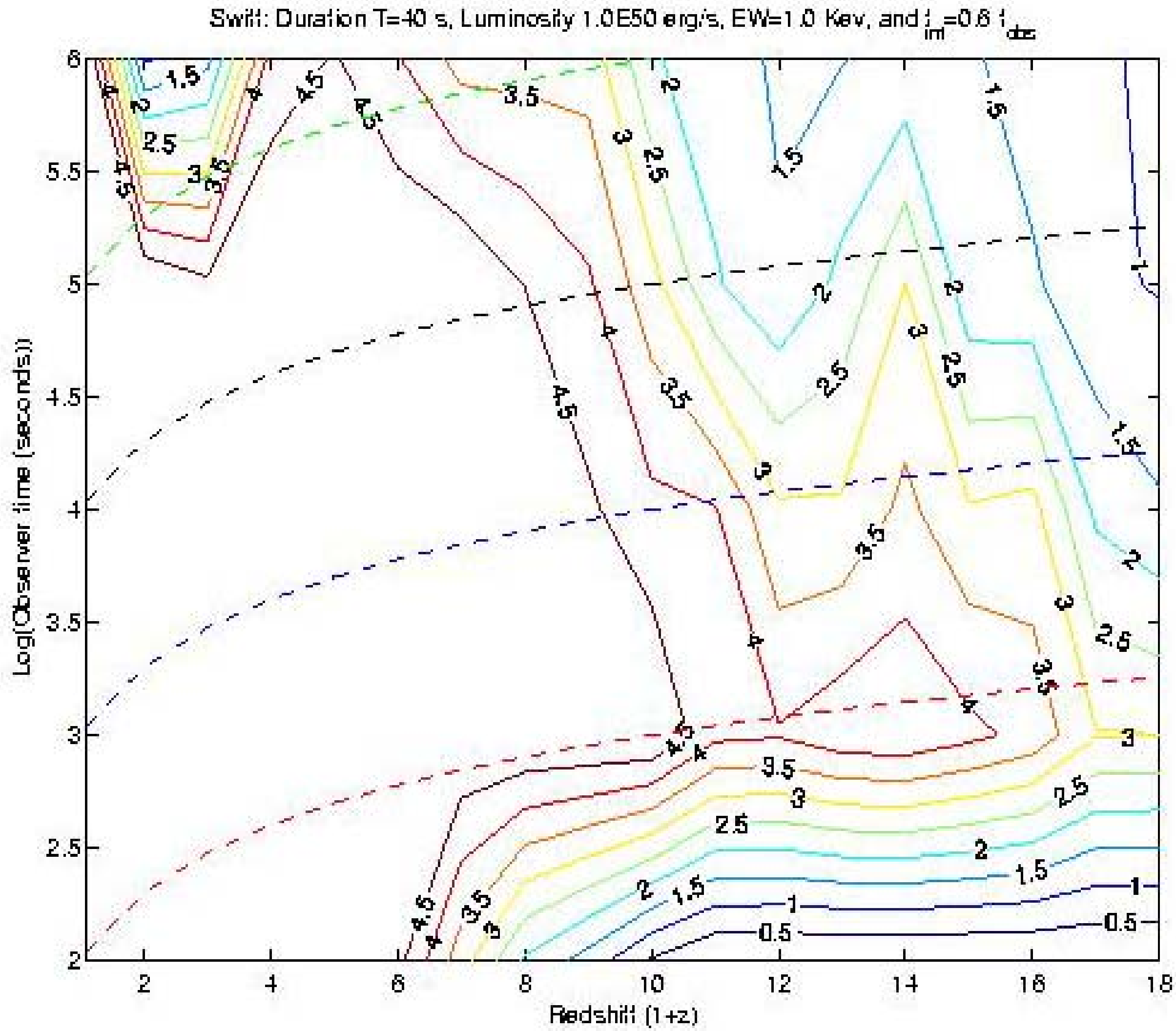
Swift Fe Kα line detection



$L_{x0}=10^{50}$ erg/s
EW=1.0 keV,
T=20s

Gou, Mészáros, Kallman, astro-ph/0408414

Swift Fe Kα line detection

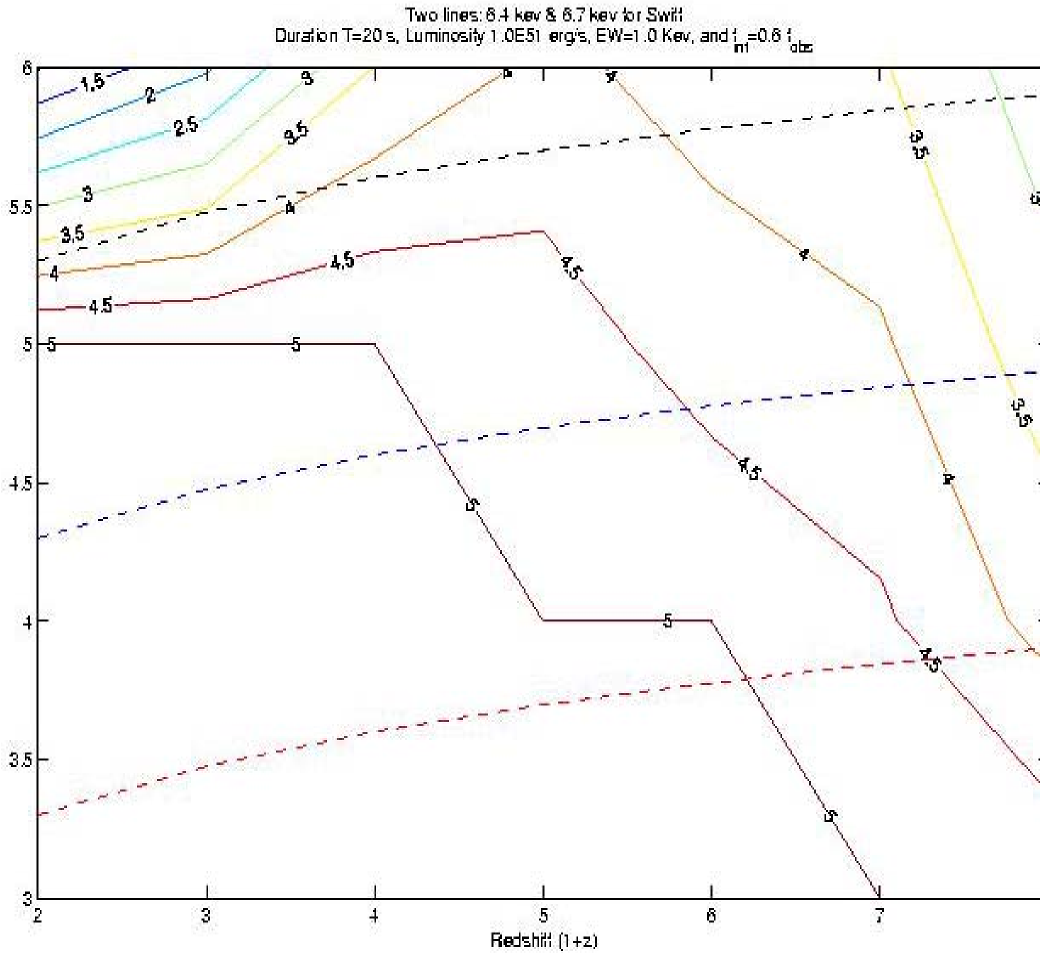


$L_{x0}=10^{50}$ erg/s,
EW=1.0 keV,
T=40s

Gou, Mészáros, Kallman, astro-ph/0408414

Swift

Fe line energy discrimination

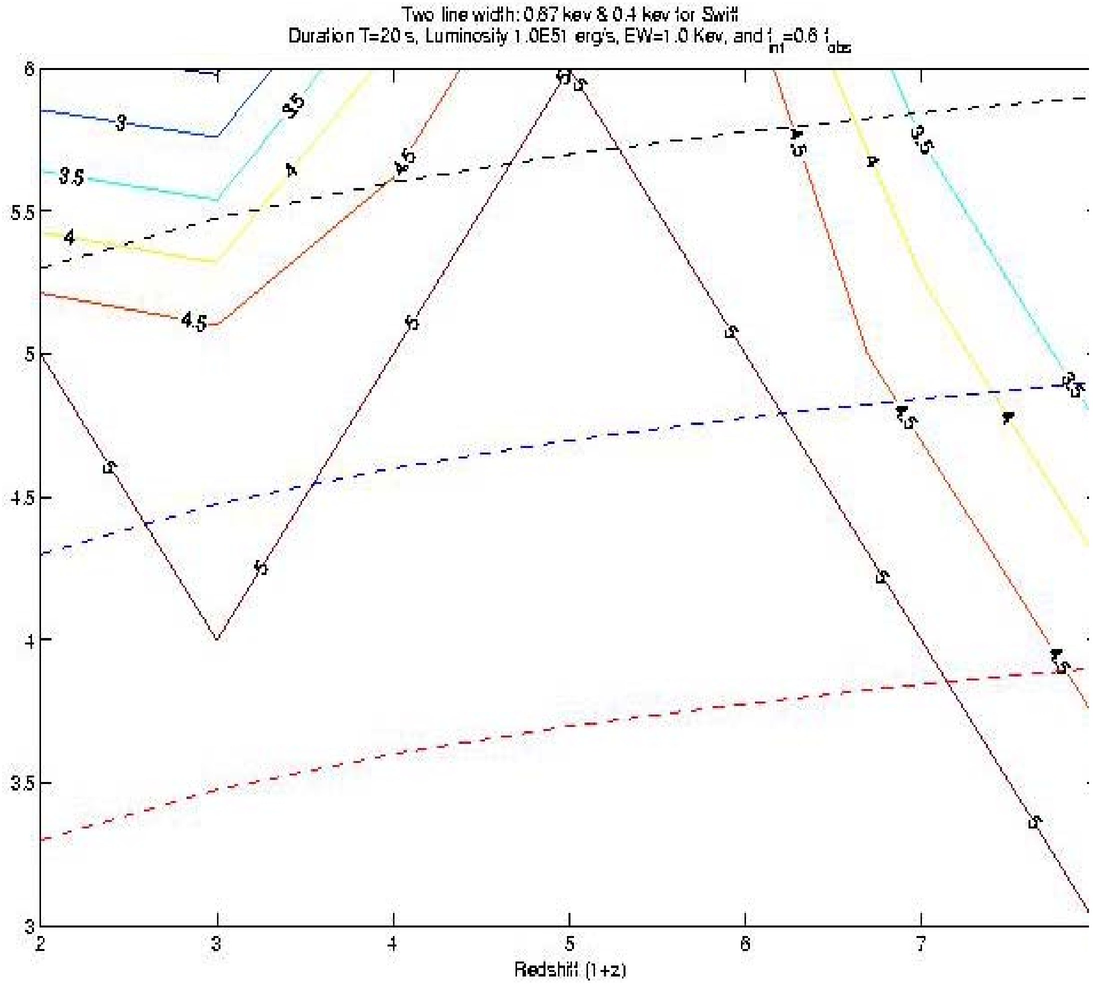


- Distinguish line energies of 6.7 vs 6.4 keV, EW=1 keV, $L_{x0}=10^{51}$ erg/s, T=20s

Gou, Mészáros, Kallman, astro-ph/0408414

Swift

Fe line width discrimination



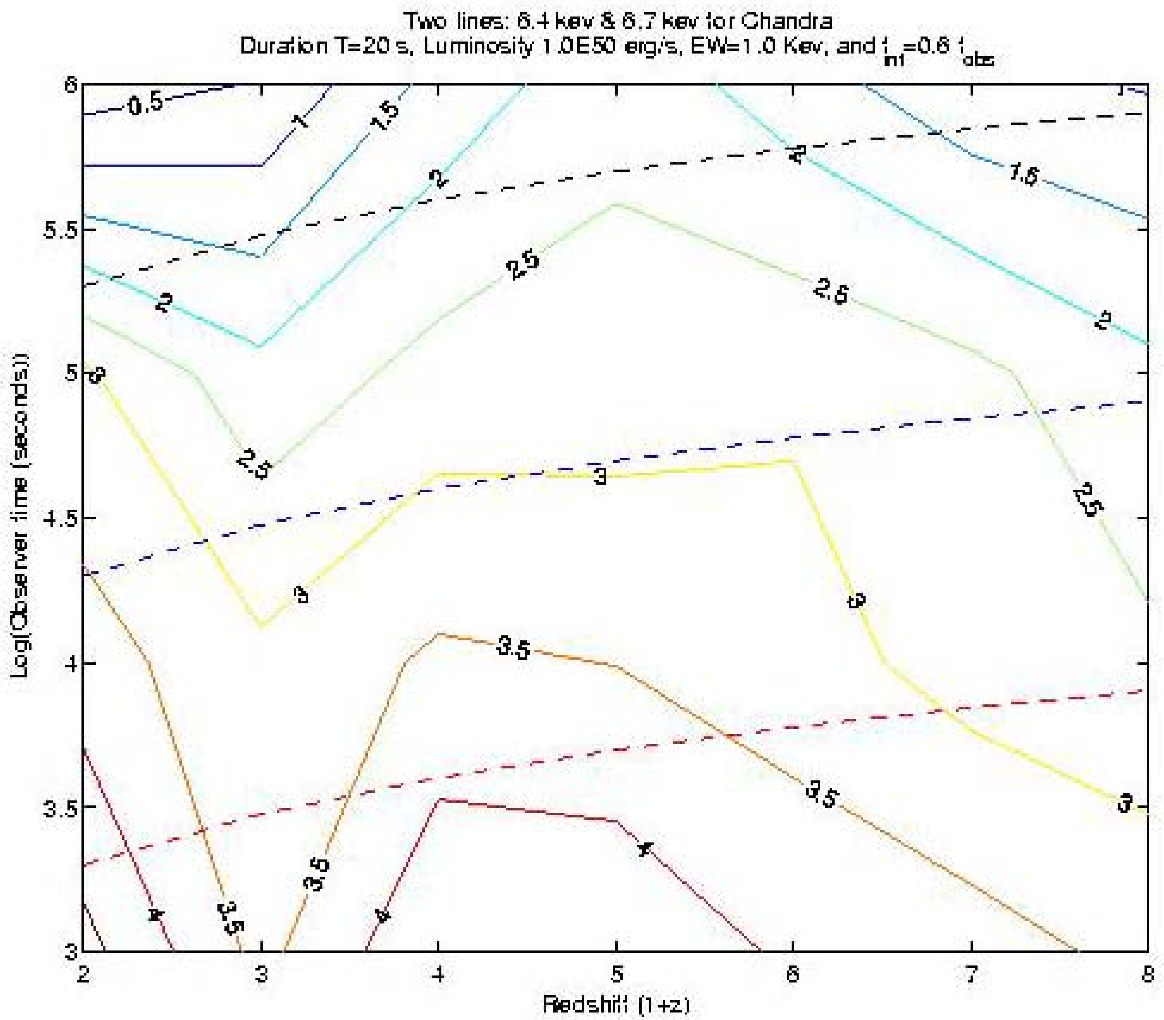
- Distinguish line widths $\Delta E=0.67$ vs 0.4 keV,

  EW=1 keV,
  $L_{x0}=10^{51}$ erg/s,
  T=20s

Gou, Mészáros, Kallman, astro-ph/0408414

Chandra

Fe line energy discrimination

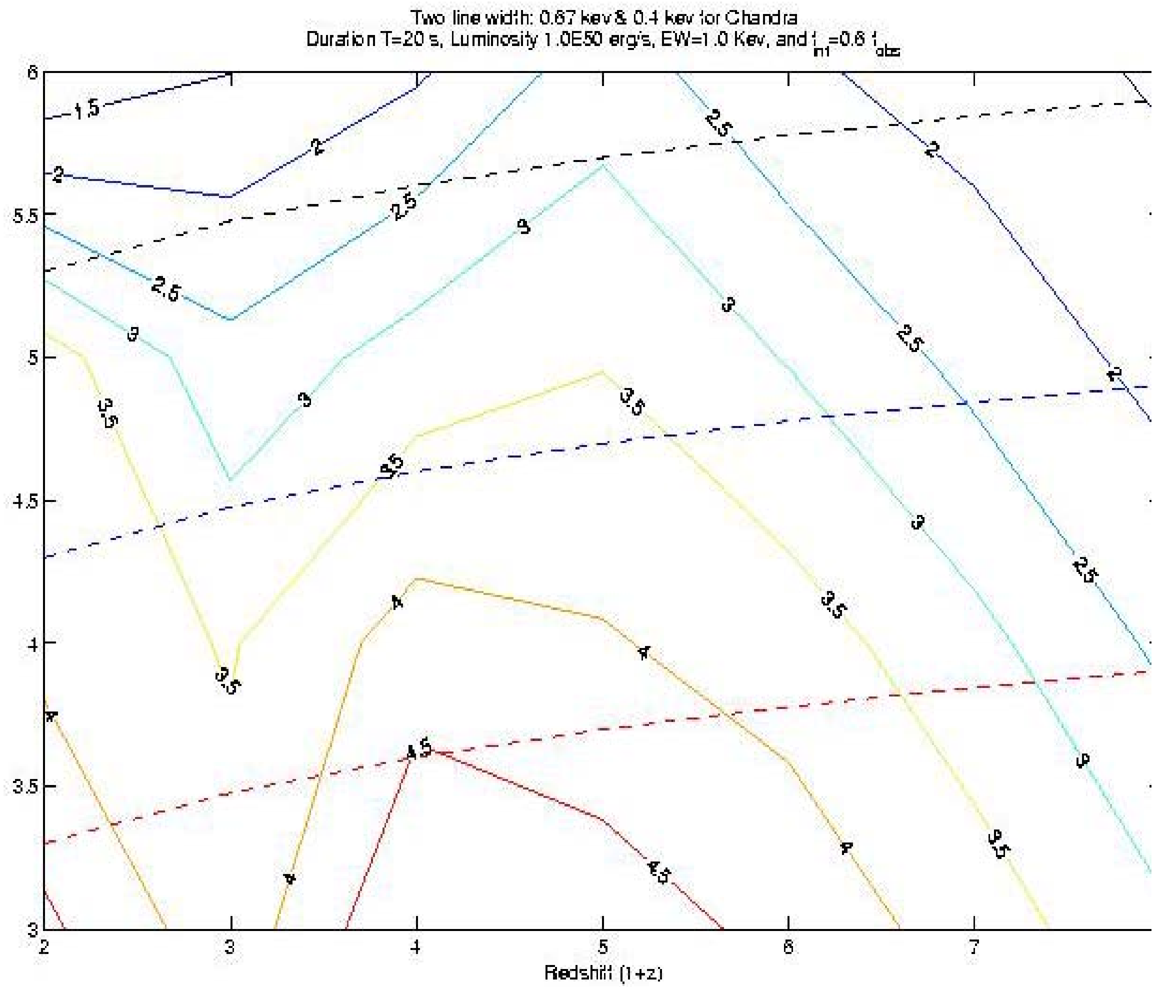


- 6.7 vs 6.4 keV, EW=1 keV, $L_{x0}=10^{50}$ erg/s, T=20s

Gou, Mészáros, Kallman, asrto-ph/0408414

Chandra

Fe line width discrimination



- ΔE=0.67 vs 0.4 kev, EW=1.0 keV, $L_{x0}=10^{50}$ erg/s, T=20s

Gou, Mészáros, Kallman, asrto-ph/0408414

The Swift Explorer in Orbit