GRB 030329 from a rotating black hole?

Maurice H.P.M. van Putten (MIT-LIGO)

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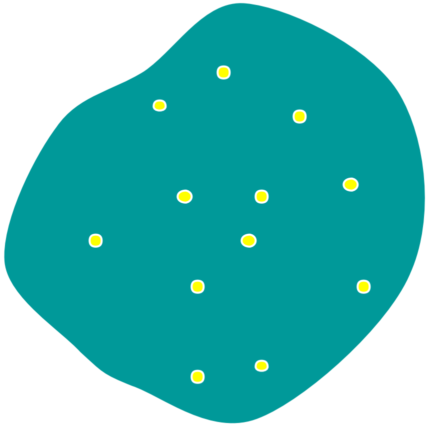
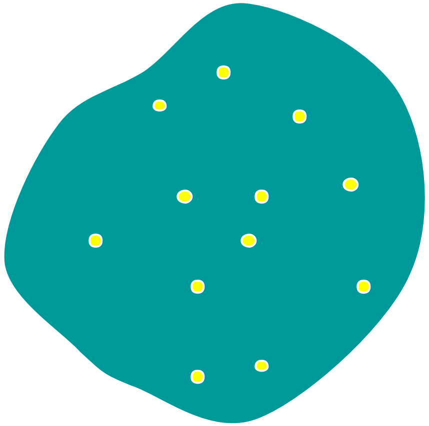
Star-formation in a molecular cloud

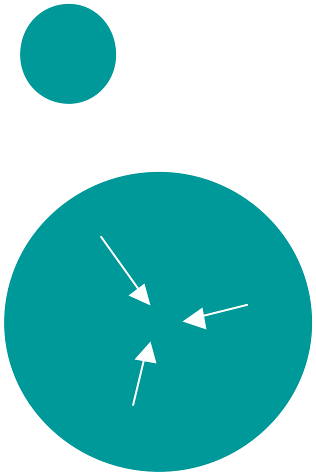


Molecular cloud

Core-collapse in a rotating massive star in a binary

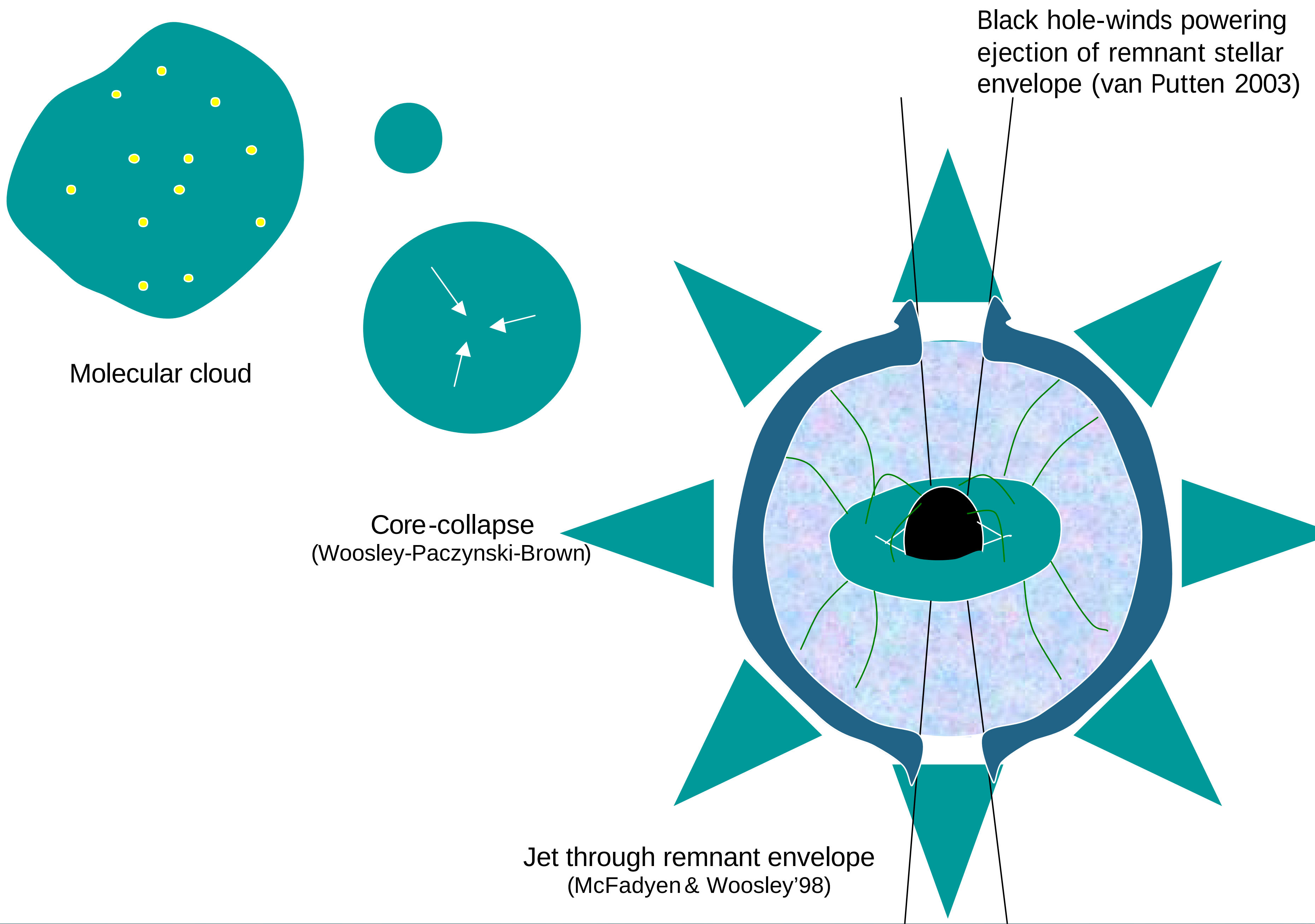


Molecular cloud



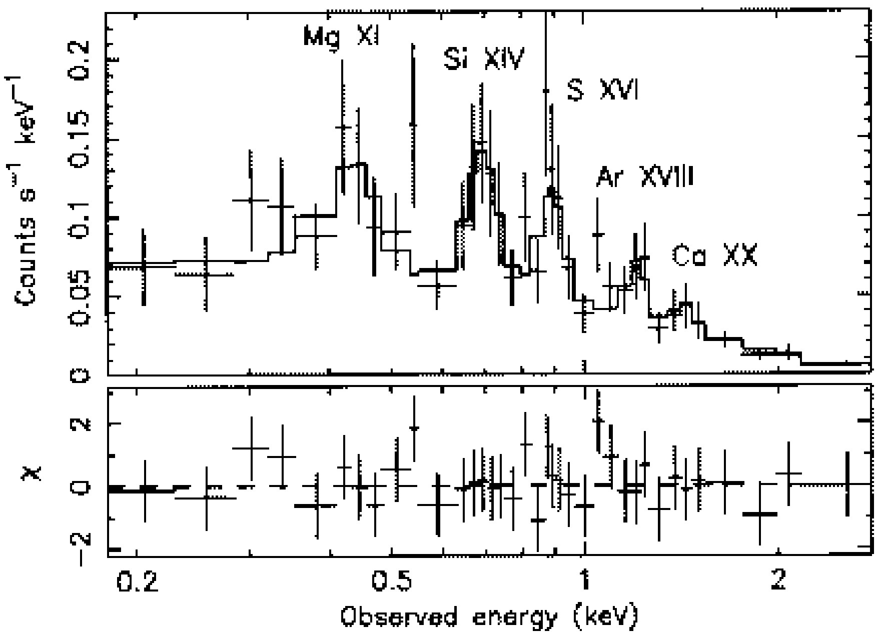
Core-collapse
(Woosley-Paczynski-Brown)

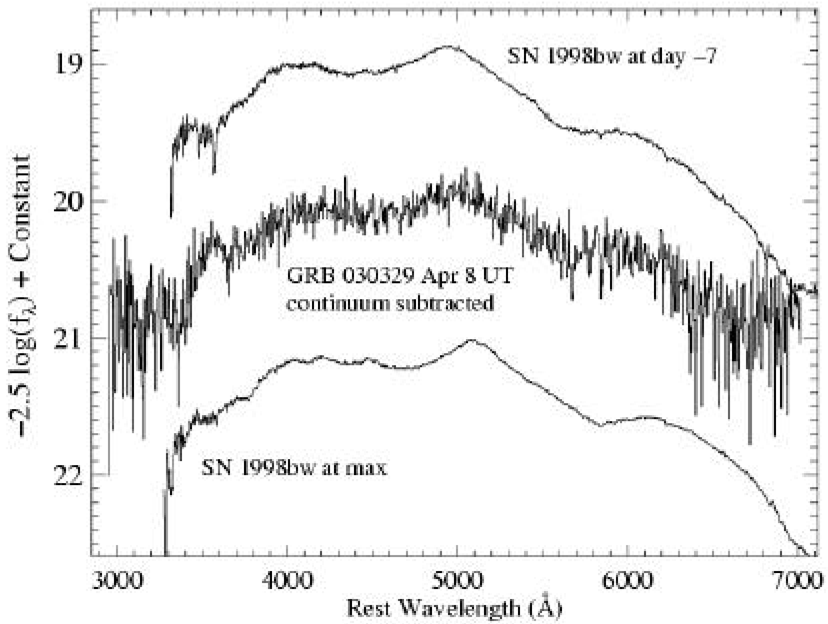
GRB-SN association from black holes as nuclei of massive stars



GRB-SN 011211 and 030329

GRB 011211 (z=2.41) Reeves et al. '02

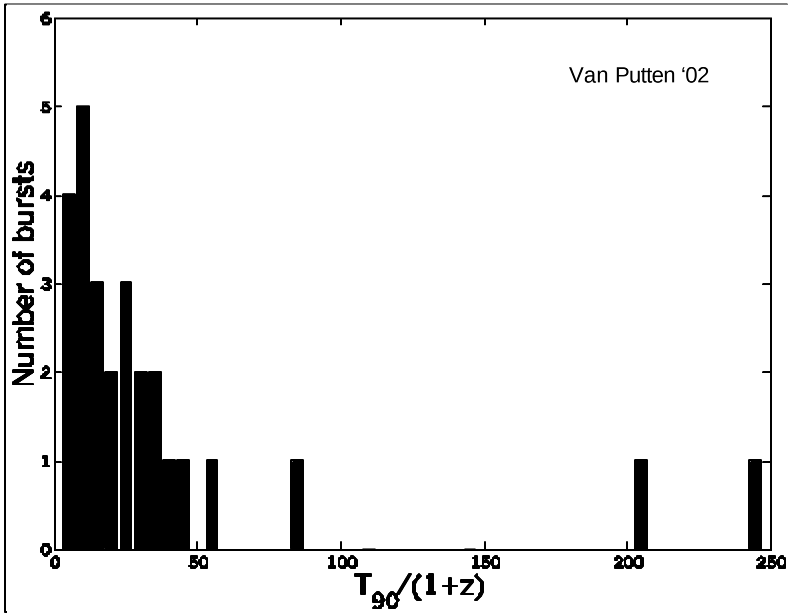




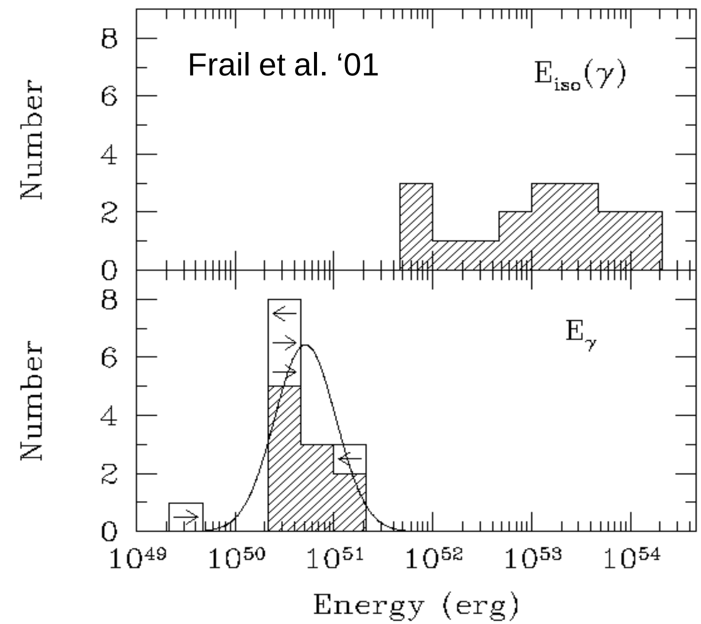
$E_r \cong 4\times10^{52}$ (G. Ghisellini 2002)

Stanek, K., et al., 2003 astro-ph/0304173

Durations of GRB-SNe



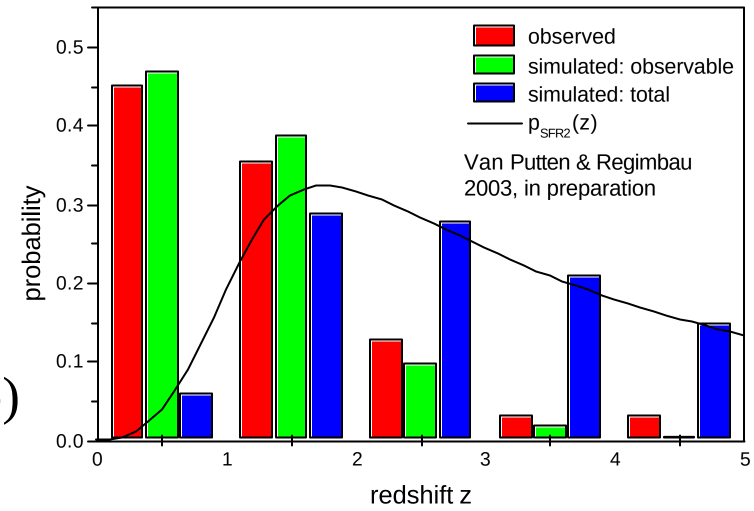
True energy in gamma-rays



Phenomenology

$$T_{90} = \text{few} \times 10 \text{ s}$$

$$E_g = 3 \times 10^{50} \text{ erg}$$



Unseen - but - true / Observed GRB - event rate

$$1/\ f_b = 500\ \ \text{(Frail et al. 2001)}$$

$$1/\ f_r = 450\ \ \text{(van Putten \& Regimbau, 2003, in prep)}$$

$$\text{True GRB event rate} \cong 0.5\times 10^6\ /\ \text{year}$$

$$\cong 1/\text{year within } D = 100\text{Mpc}$$

Energy emissions from the torus

Asymptotic results for small slenderness

$$g_2 = \frac{E_{gw}}{E_{rot}} \sim h \qquad g_3 = \frac{E_w}{E_{rot}} \sim h^2 \qquad g_4 = \frac{E_{diss}}{E_{rot}} \sim dh$$

Burst of 4e53 erg in gravitational radiation over tens of seconds

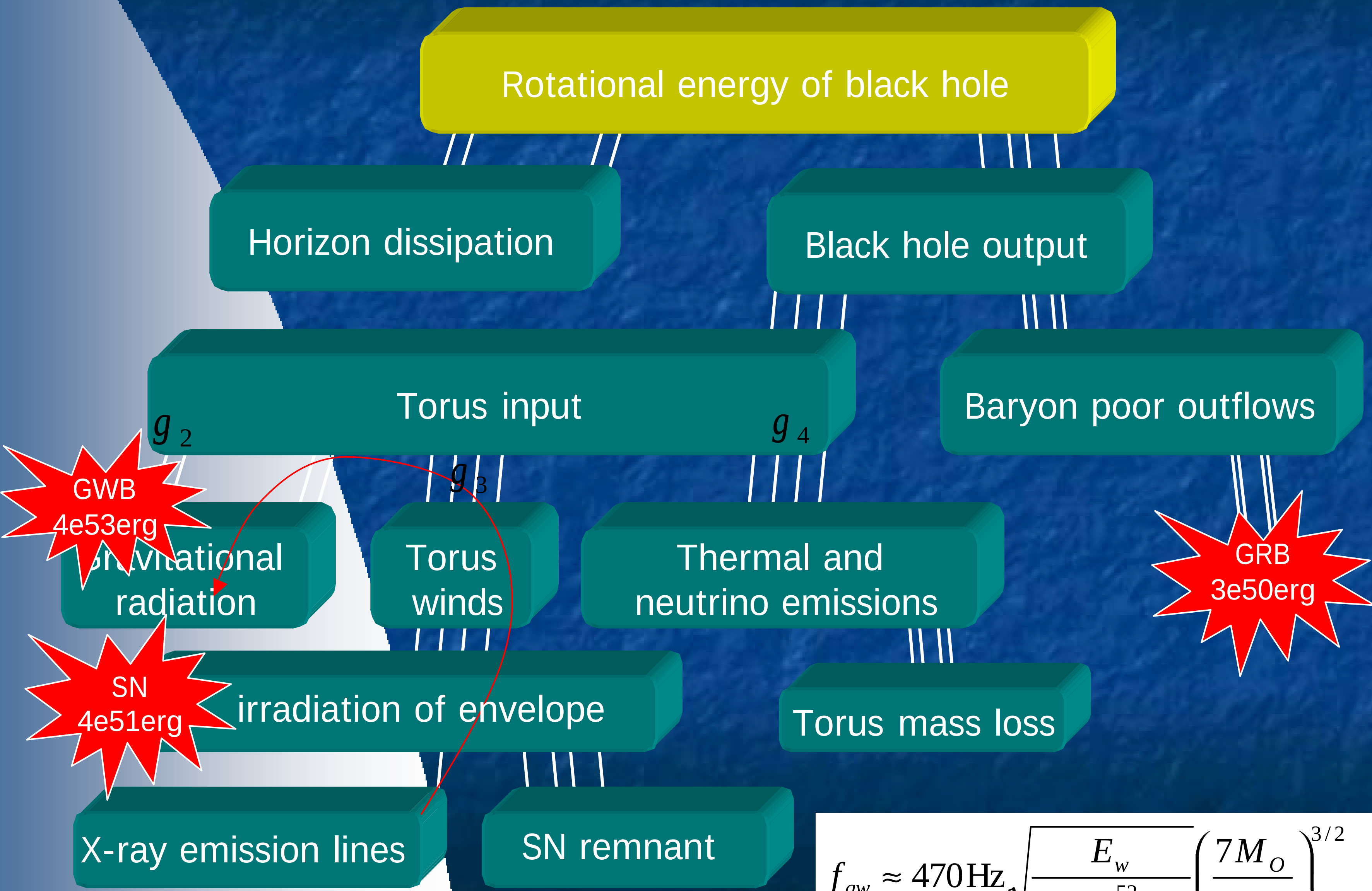
4e52 erg in torus winds producing a supernova

Unseen burst of 6e54 erg in MeV-neutrinos

$$h = \Omega_T / \Omega_H \cong 10\%$$

$$d = \tfrac{1}{2}\,\text{minor-to-major radius of torus}$$

Calorimetry



$$f_{gw} \approx 470\,\mathrm{Hz}\sqrt{\frac{E_w}{4\times 10^{52}\,\mathrm{erg}}}\left(\frac{7M_O}{M}\right)^{3/2} \quad (m=2)$$

Observational opportunities for Adv LIGO

Matched filtering

$$\left(\frac{S}{N}\right)_{mf} \cong 8\left(\frac{S_h^{1/2}(500\text{Hz})}{4\times10^{-24}\,\text{Hz}^{-1/2}}\right)^{-1}\left(\frac{h}{0.1}\right)^{-3/2}\left(\frac{M_H}{7M_{Solar}}\right)^{5/2}\left(\frac{d}{140\text{Mpc}}\right)^{-1}$$

Correlating two detectors

$$\left(\frac{S}{N}\right)_{cs} = 1.5\times\left(\frac{S_h^{1/2}(500\text{Hz})}{4\times10^{-24}\,\text{Hz}^{-1/2}}\right)_{D1}^{-1}\left(\frac{S_h^{1/2}(500\text{Hz})}{4\times10^{-24}\,\text{Hz}^{-1/2}}\right)_{D2}^{-1} h_{0.1}^{-5/3} M_{H7}^{5} d_8^{-2} B_{0.1}^{-1} m_{0.03}^{1/4}$$

$$\left\langle\frac{S}{N}\right\rangle = \begin{cases} 8.5 & \text{averaged over } M_H = 4-14\times M_S \\ 1.2 & \text{averaged over } M_H = 5-8\times M_S \end{cases}$$

Van Putten (2003), in preparation

Lower bound on black hole-mass in GRB 030329

Spp we use matched filtering and define "no detection": S/N<1

$$\text{Entertain the possibility of a rapidly rotating torus}: h = 0.2$$

$$\text{Current Livingston sensitivity}: \left(\frac{S_h^{1/2}(500\text{Hz})}{4\times 10^{-24}\,\text{Hz}^{-1/2}} \right)^{-1} = 0.01$$

$$\left(\frac{S}{N} \right)_{mf} \cong 8 \times 0.01 \times 2^{3/2} \times \left(\frac{M_H}{7 M_{Solar}} \right)^{5/2} \times (140\text{Mpc}/800\text{Mpc}) < 1$$

$$M_H < 25 M_{Solar}$$

Van Putten, Burst Digest (2003)

Conclusions

- Durations of tens of seconds in long durations stem from the lifetime of black hole-spin (set by the Van Putten-Levinson stability criterion for the torus).
- A GRB-SN event produces about 4e53 ergs in gravitational radiation at a nominal frequency around 500Hz
- A non-detection of S/N<1 of GRB 030329 by matched filtering gives a limit 0f 25MSolar for its central black hole