Cosmic
UHE Neutrino
Sources

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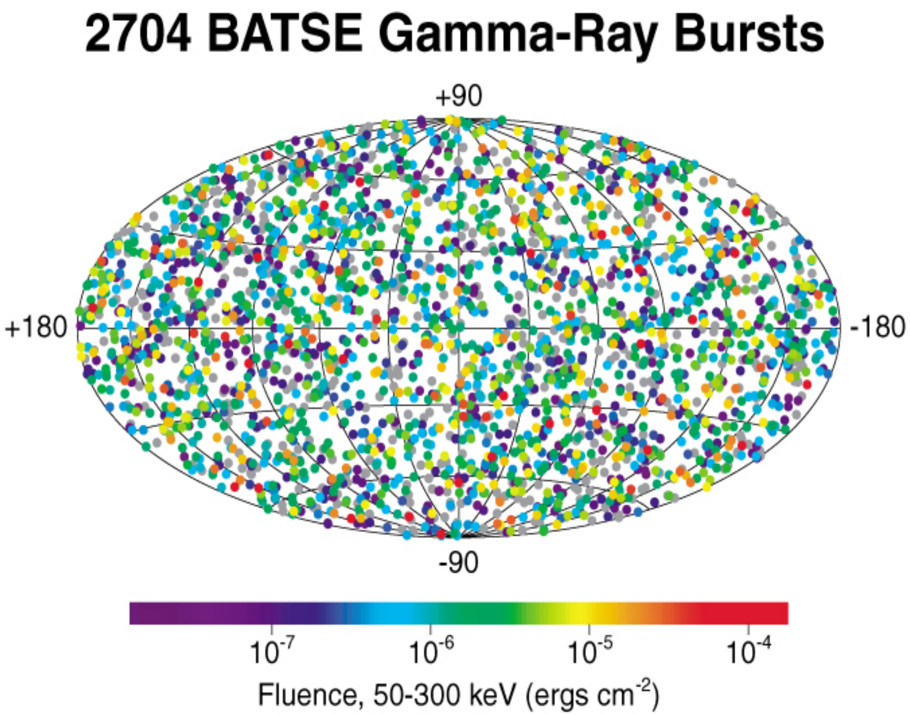
Astrophysical Bestiary
of potential UHE ν sources

- GRB (also collapsars, pop.III $*$, ..)
- AGN, particularly Blazars, RLQ,..)
- Microquasars
- SNR (particulary young, GRB/SNR,..)
- Accreting NS-BH sources?
- Magnetars?
- ..???...

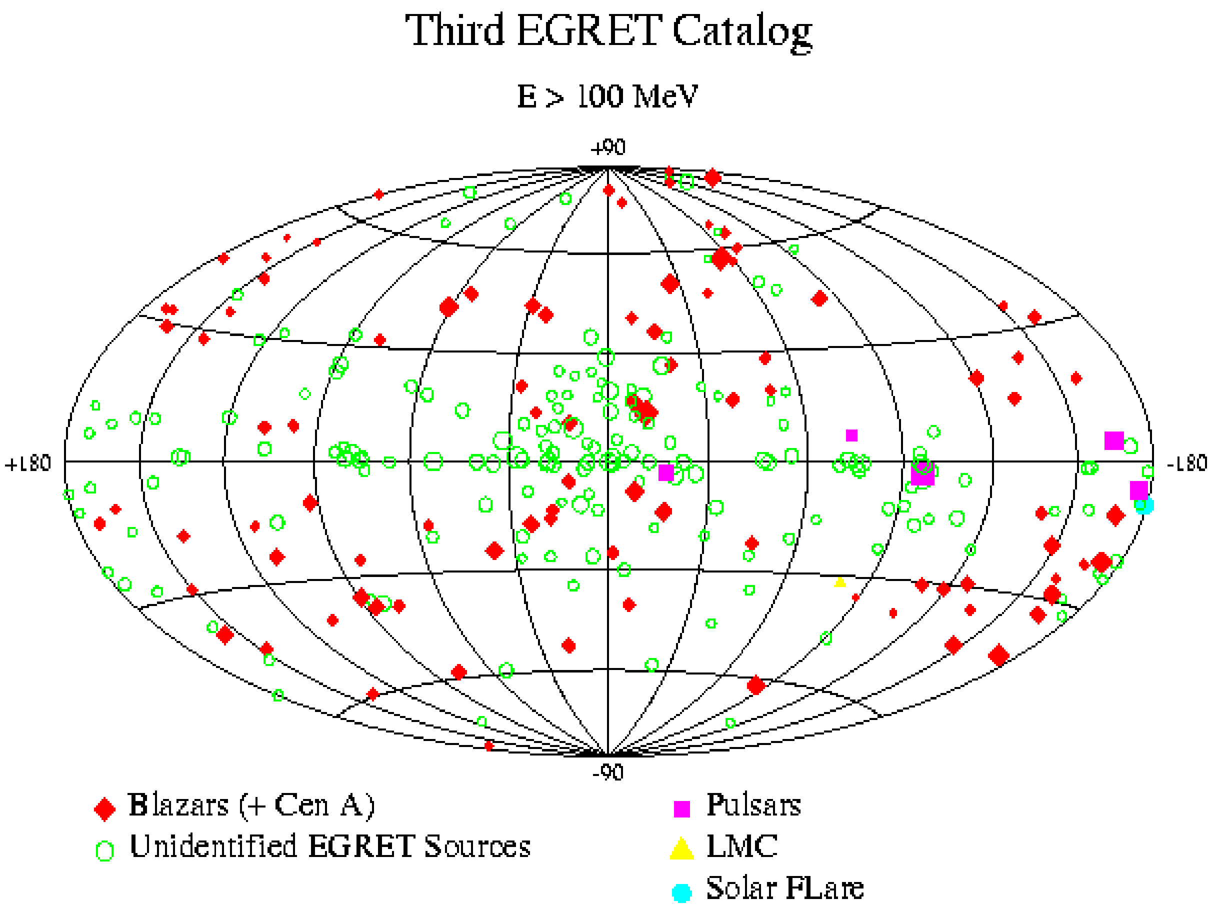
GRB Sky & Temporal Distrib.



- Cosmological (isotropic) distribut.
- Out to z $\gtrsim$ 4.5 (20?)
- ~ 1/day @ z $\lesssim$ few
- ~ 1/3 “short” (<2s)

  → NS mergers/mag?
- ~ 2/3 “long” (>2s)

  → massive coll/SN?



GeV emission from Blazars

(and other galactic & unidentified sources)

- EGRET: 66 + 27 blazars @ $\lesssim$ 10GeV
- ACTs: Whipple, HEGRA, CAT, CANGAROO…:

  ~6 AGN @ $\lesssim$ 10 TeV

AGNs: GeV-TeV γ - Spring '03

GeV : (from space)

3C273 RLQ z=0.185 (no TeV)

BL Lac BL Lac z=0.0686 (no TeV)

3C 279 OVV z=0.538 (no TeV)

Etc. …($\gtrsim$ **66**, e.g. in Egret catalogue)

(many are **superluminal** , mod. to high Γ, mod. θ)

TeV: (ACT, ground)

Mkn 421 XBL z= 0.03 (yes Egr)

Mkn 501 XBL z=0.03 (yes Egr)

(appear to be **subluminal** , high Γ, very small $\theta \leq 1^{o}$)

1ES2344+514 XBL z=0.044 (no Egr)

H1426+428 XBL z=0.129 (no Egr)

1ES1959+650 XBL z=0.046 (no Egr)

PKS2155-304 XBL z=0.116 (yes Egr)

-------- (not only blazars.. ↓) -------

3C66A RBL z=0.4 (yes Egr)

NGC 253 **SRB/Sp!** , D~2.5Mpc (no Egr)

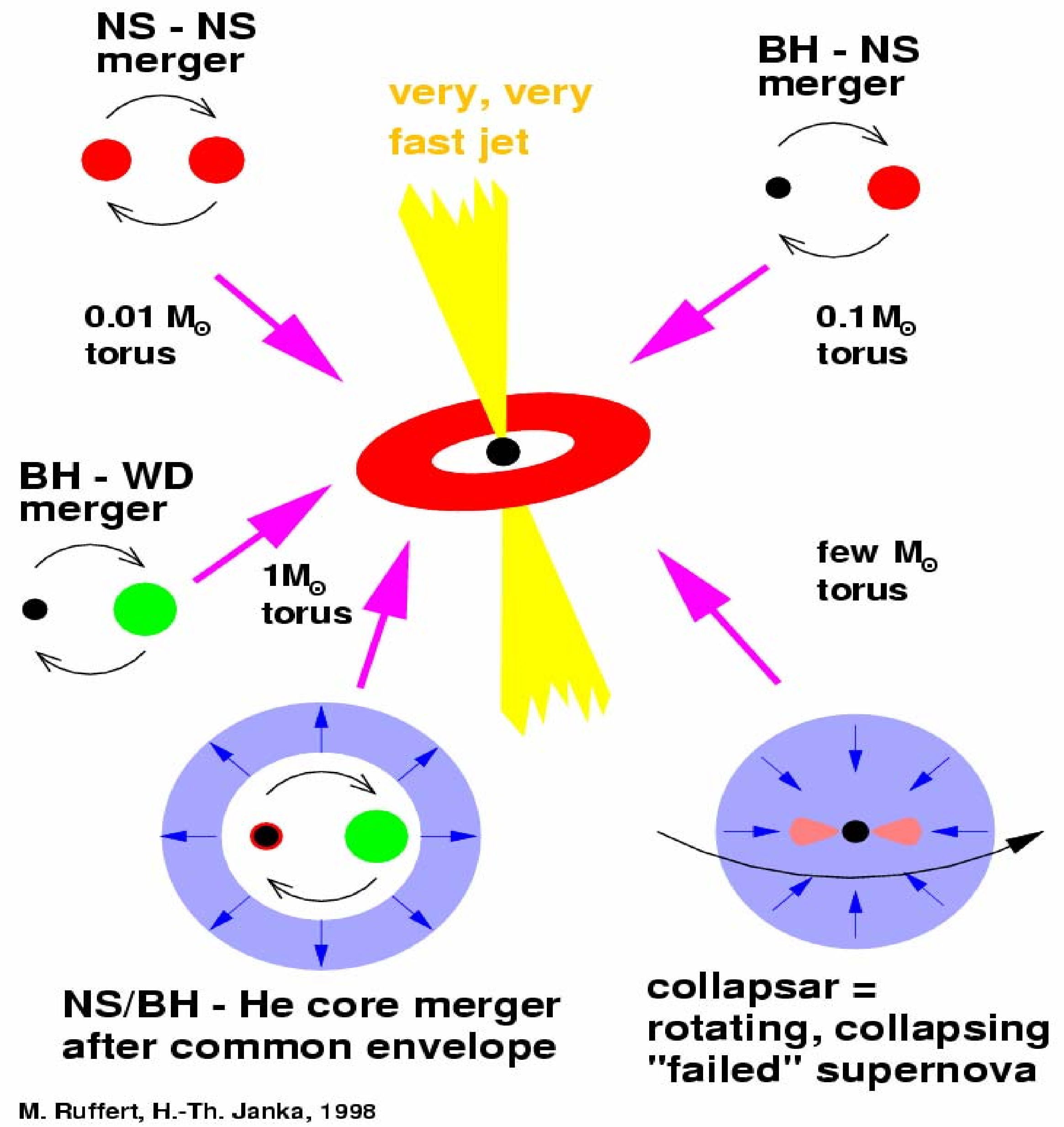
Other (confirmed) TeV γ galactic sources

(mainly Supernova Remnants / Pulsars)

• SNR/PSR	morph.	TeV	GeV-Egret?
Crab	plerion	y	y
PSR 1706-44	plerion?	y	-
Vela	plerion	y	-
SN1006	shell	y	-
RXJ1713.7-3946	shell	y	-
Cassiopeia A	shell	y	-
Centaurus X-3	accr. PSR	y	y

- + ~25 other **Unidentified** Egret γ-ray sources

GRB:→ Hyperaccreting Black Holes



Short

Long

Explosion → FIREBALL

- $E_\gamma \gtrsim 10^{51}\ \Omega_{-2}\ D^2_{28.5}\ F_{-5}$ erg
- $R_0 \sim c\, t_0 \sim 10^7\ t_{-3}$ cm

  ⇒ Huge energy in very small volume
- $\tau_{\gamma\gamma} \sim (E_\gamma / R^3_0 m_e c^2)\sigma_T R_0 >> 1$

  → Fireball: $e^\pm, \gamma, p$ relativistic gas
- $L_\gamma \sim E_\gamma / t_0 >> L_{Edd}$ → expanding (v~c) fireball

(Cavallo & Rees, 1978 MN 183:359)

- Observe $E_\gamma > 10$ GeV …but

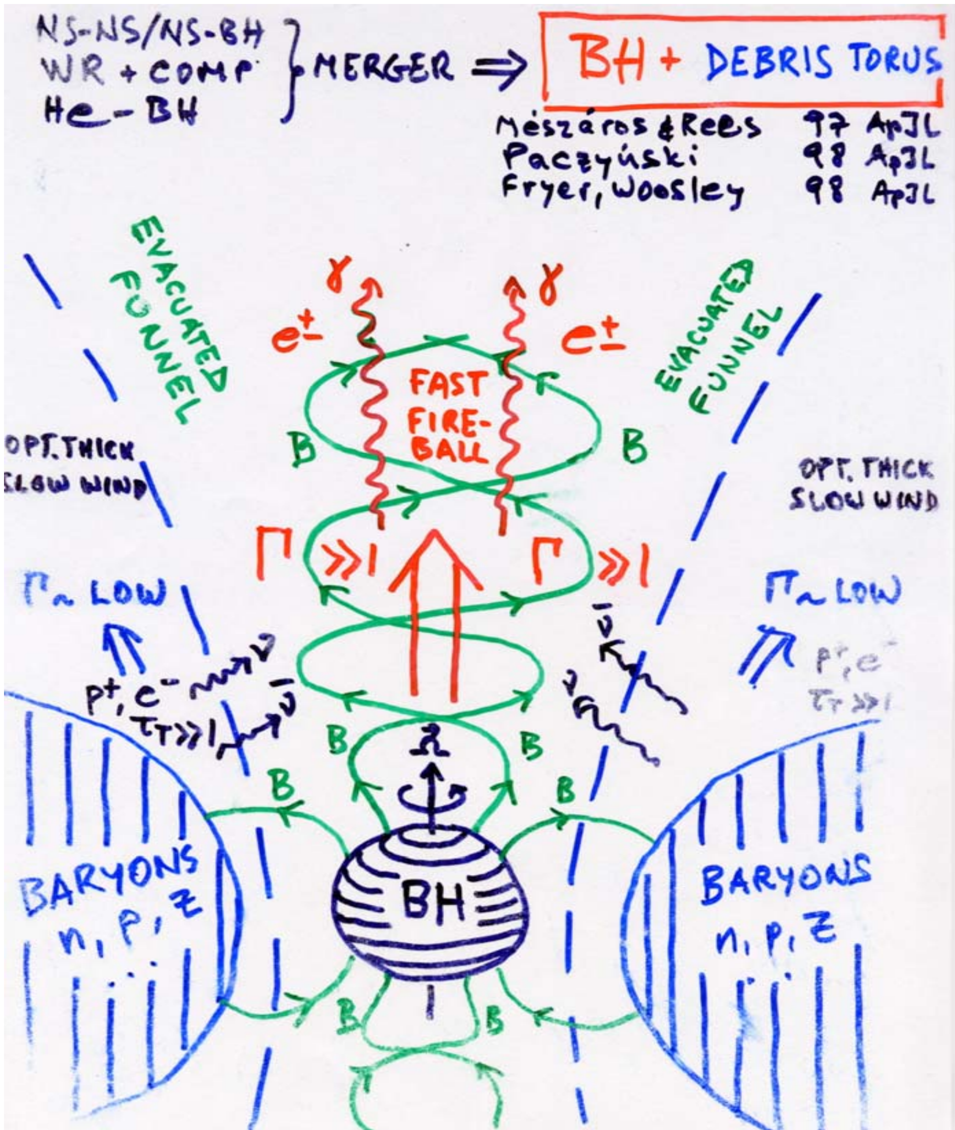
  $\gamma\gamma \to e^\pm$, degrade 10 GeV → 0.5 MeV?

  $E\gamma\ Et > 2(m_e c^2)^2/(1-\cos\Theta) \sim 4(m_e c^2)^2/\Theta^2$

  ⇒ Ultrarelativistic flow $\rightarrow \Gamma \gtrsim \Theta^{-1} \sim 10^2$

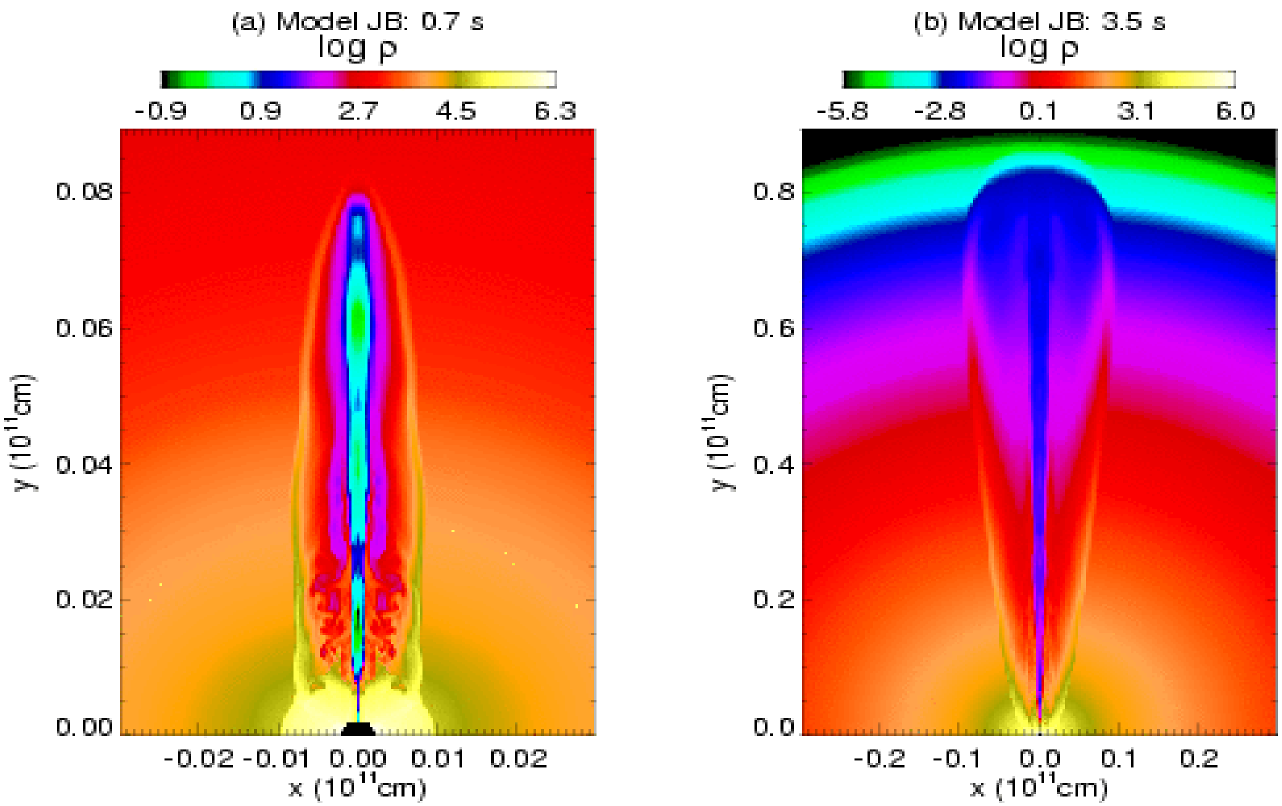
(Fenimore etal 93; Baring & Harding 94)

BH + accr. Torus ⇨ Jet



- Collapsar or merger →BH+accr.torus
- Nuclear density hot torus → $\nu\nu$→e±
- Hot infall →conv.
- Dynamo → B~10^{15} G, twisted (thread BH?)
- →Alfvénic or e±pγ jet
- (Note: magnetar might do similar)

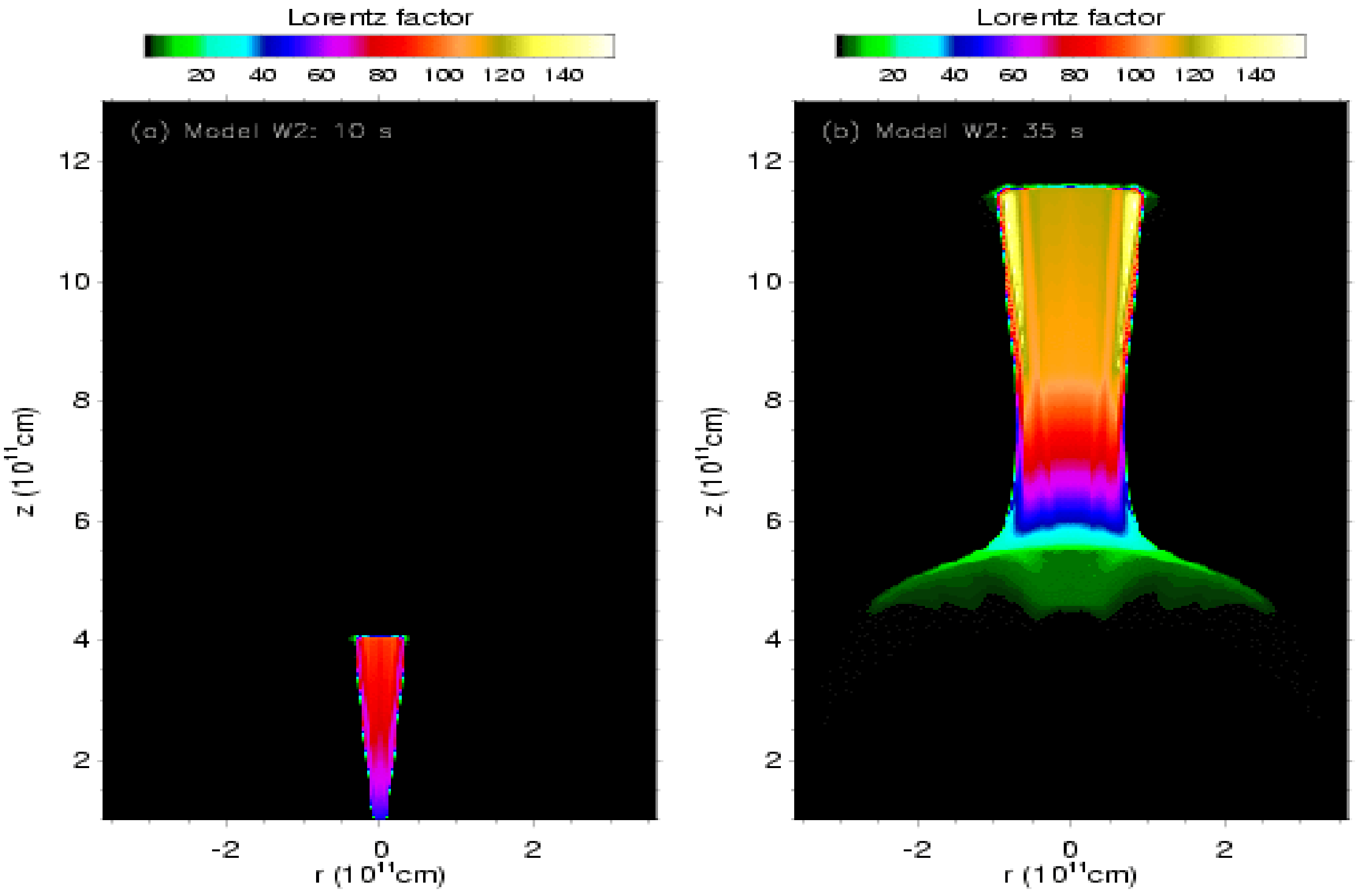
Jet emergence from star



Zhang, et al astro-ph/0207436

- Num.simulations: (Aloy et al 00 ; Zhang, Woosley, McFadyen 02)
- So far: 2D, SR; jet first $v_h \lesssim c$, then $v_h \to c$ as analytical calc's indicated $\to$ OK
- KH instab: variable power output, Γ
- Prelim. (num.) concl.: jets emerge only from stars of $R_\star \lesssim 10^{11}$cm; but larger stars not calculated num'ly;
- analyt. est. indicate larger radii may be possible (Meszaros, Rees 02, ApJ 556, L37)

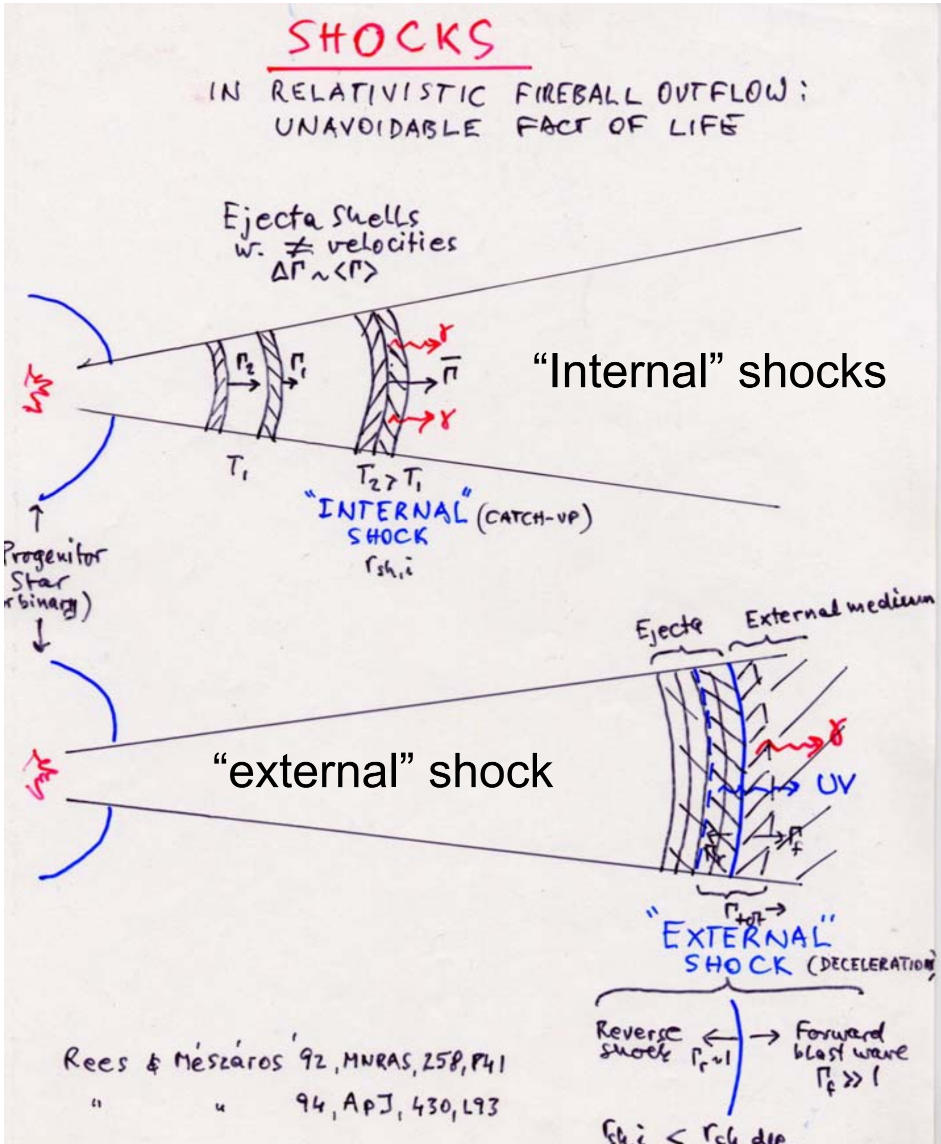
Jet Emergence through stellar wind



- Jet emerge into stellar wind $\rho \propto r^{-2}$;
- details dep on various assumed parameters, but..
- Jet emerge with Γ_f~150, decr. w. angle → OK

Zhang, et al astro-ph/0207436

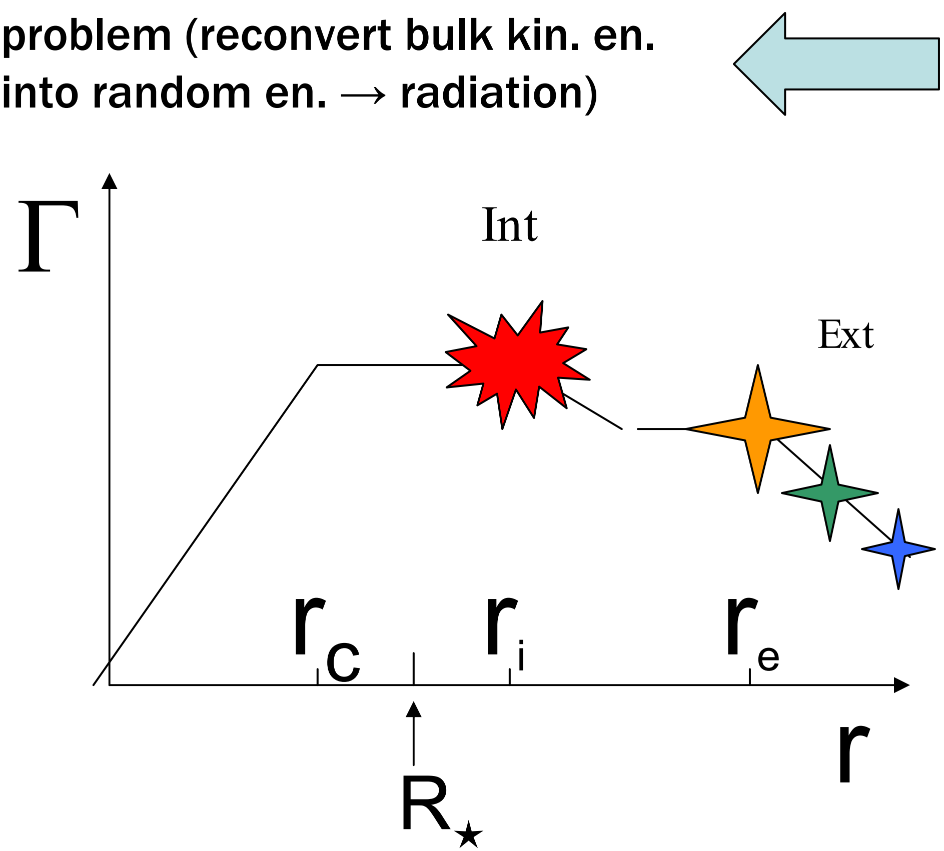
Shocks in Fireball Outflow



- Shocks expected in any unsteady supersonic outflow (esp. in a non-vacuum environment)
- Internal shocks: fast shells catch up slower shells (unsteady flow)
- External Shock: flow slows down as plows into external medium
- NOTE: “ext.” termination shock & internal shocks might be expected also while jet is still inside star

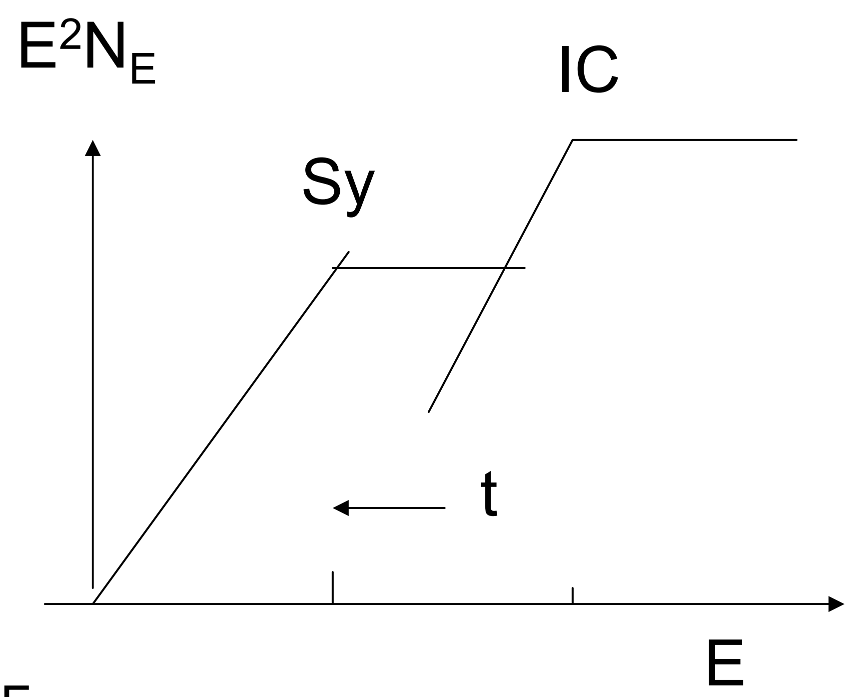
Internal & External Shocks

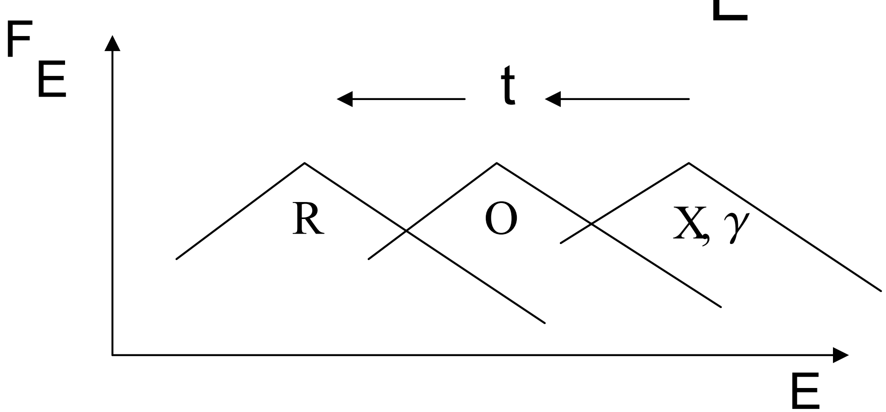
Shocks solve radiative inefficiency problem (reconvert bulk kin. en. into random en. → radiation)



- Lorentz factor Γ first grows $\Gamma \propto r$, then coasts $\Gamma \propto$constant, until …
- **Outside** the star, after jet is opt. thin: Internal shocks: $r_i \sim 10^{12}$cm
  →**γ-rays** (burst, t~sec)
- Externals shocks start at $r_e \sim 10^{16}$cm, progressively weaken as it decelerates
- External **forward** shock spectrum softens in time:
  X-ray, optical, radio …
  →**long fading afterglow !**
  (t ~ min, hr, day, month)
- External **reverse** shock (less relativistic):
  Optical → **quick fading** (t ~ mins)

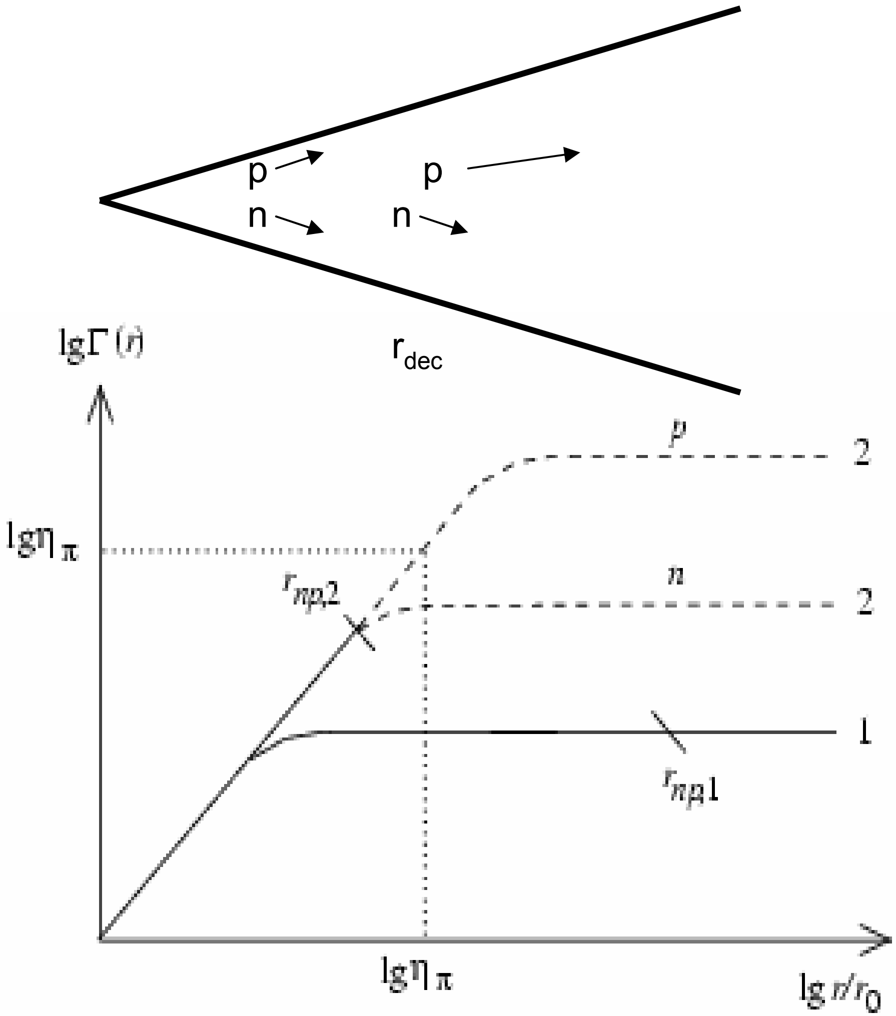
Shock Photon Spectrum





- Non-thermal power law spectrum, both in int. and ext. shocks, due to
- Synchrotron, peak at ~200 keV (or ~ eV?)
- Inv. Compton, peak ~ GeV (or ~200 keV ?
- Sy peak location, ratio Sy/IC dep. on B_{sh} , $\gamma_{e,m}$
- Peak softens with time
- Ratio Sy/IC decr w. time

"Thermal" Proton-Neutron Effects in GRB Fireball



(Bahcall & Meszaros 2000 PRL 85:1362)

- **p-n** in f'ball move together while $t_{pn} > t_{exp}$ (rad. press. acts on p, elastic scattering couples p,n)
- p-n decouple when $t_{pn} \gtrsim t_{exp}$ (also $\tau_{pn} \sim 1$, $v_{rel} \rightarrow c$) $\sigma_{pn} \rightarrow$ inelastic; occurs for $\Gamma \gtrsim \Gamma_\pi \sim 400$
  (Derishev etal 99; Bahcall,Meszaros 00; Fuller etal 00)
- Inelastic $pn \rightarrow \pi^\pm \rightarrow \mu^\pm, \nu_\mu \rightarrow e^\pm, \nu_e, \nu_\mu$
  $\epsilon_{\nu\mu} \sim$5-10 GeV
- **ICECUBE**: det @ z~1, $R_\nu \sim 7$/yr from all GRB, in coinc.w. γ -rays (but only if larger PMT density)
- **GLAST**: $\pi^0 \rightarrow 2\gamma$,
  ϵ_γ ~10 GeV, det @ z~0.1

UHE ν 's from p,γ in γ-detected GRBs

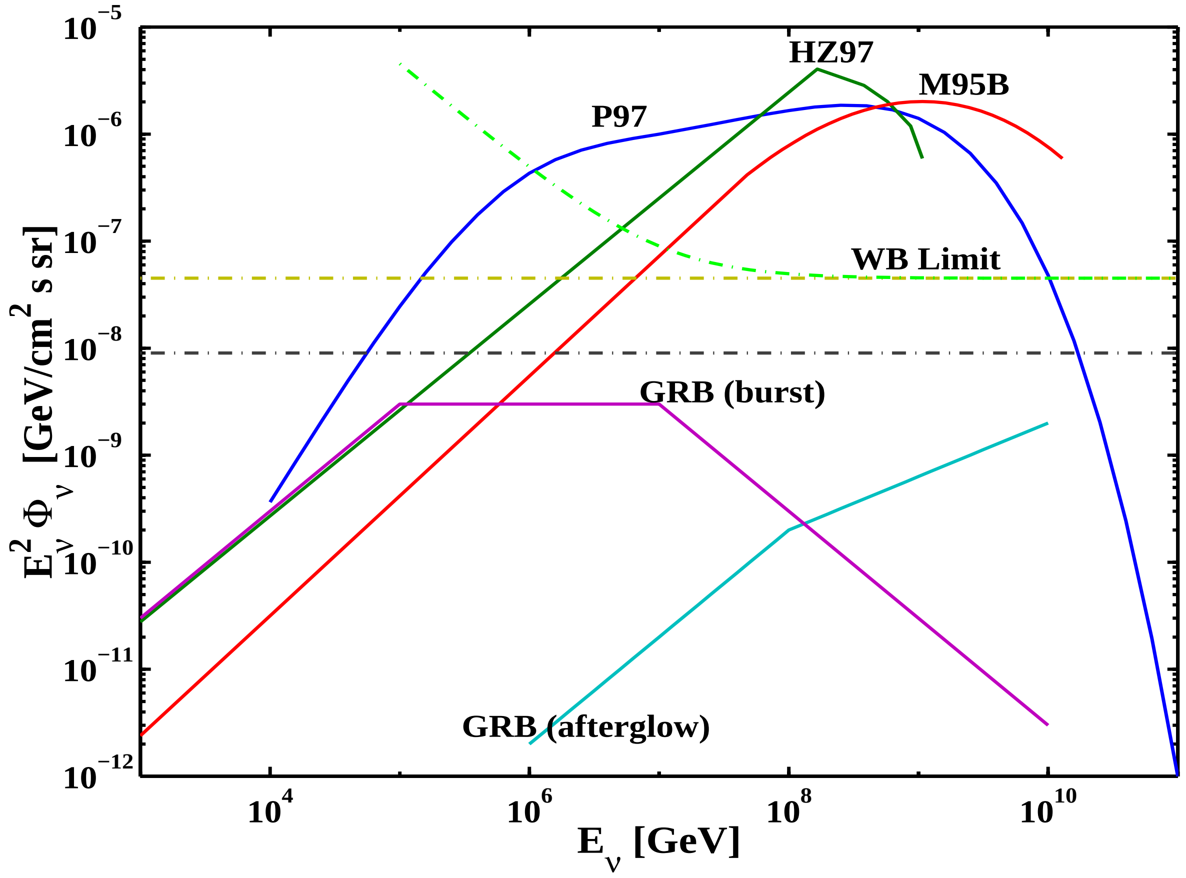
- Relativistic jet expands beyond stellar debris, where it is optically thin
- "Internal" N.R. shocks in jet accelerate p,e to relativistic power law (Fermi: index -2)
- e,B $\rightarrow \gamma$ (MeV, broken power law), and

$$p,\gamma \rightarrow \pi^{\pm} \longrightarrow \mu^{\pm}, \nu_{\mu} \longrightarrow e^{\pm}, \nu_e, \nu_{\mu} \quad (\Delta\text{-res.})$$

$$E_{\nu} \sim 5.10^{14} \text{ eV } \Gamma_{300} (E_{\gamma}/1\text{MeV})^{-1},$$

$$E_{\nu}^2 \, dN/dE_{\nu} \sim 3.10^{-9} (E\nu/E\nu_b) \text{ GeV/cm}^2 \text{ s sr}$$

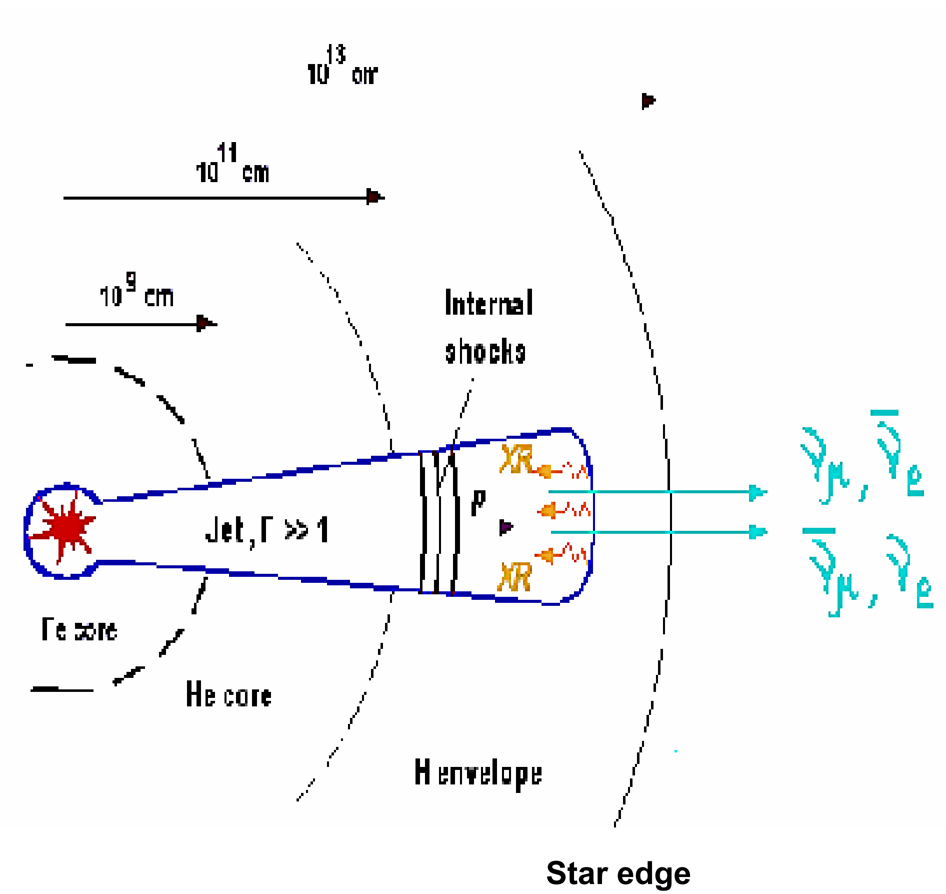
UHE ν 's from p,γ in (EM-detectable) GRBs



UHE ν 's from p,γ in GRBs with optical afterglows

- Jet interacts with external medium, decelerates $\rightarrow$ reverse shock moves into ejecta
  $\rightarrow$ optical prompt flash (ROTSE…)
- This "external" (N.R.) shock also accelerates
  p,e to relativistic power law
- p,$\gamma \rightarrow \pi^{\pm} \rightarrow \mu^{\pm}, \nu_{\mu} \rightarrow e^{\pm}, \nu_e, \nu_{\mu}$
  $E_p > 10^{19}$eV, $E_{\gamma} \sim 10$eV, $\Longrightarrow$ **$E_{\nu} \sim 5.10^{17}$ -10^{19} eV**,
  $E_{\nu}^2\, dN/DE_{\nu} \sim 10^{-10}\, (E_{\nu}/10^{17}\mathrm{eV})^{\beta}$ GeV/cm^2 s sr

TeV ν from bursting & choked GRB



- Jet in massive collapsar has "external" (termination) shock and **internal** shocks , even **while inside the star**
- Int. shocks accel. protons to $E_p > 10^5$ GeV, which collide with thermal X-rays in jet cavity
- → **$E\nu \gtrsim 2(2/1+z)$ TeV**

$F_\nu \approx 10^{-5}\, E_{53}/D_{28}^2$ erg/cm²

$N\mu \sim 0.2$ /km² (avg., 10^5 /yr)

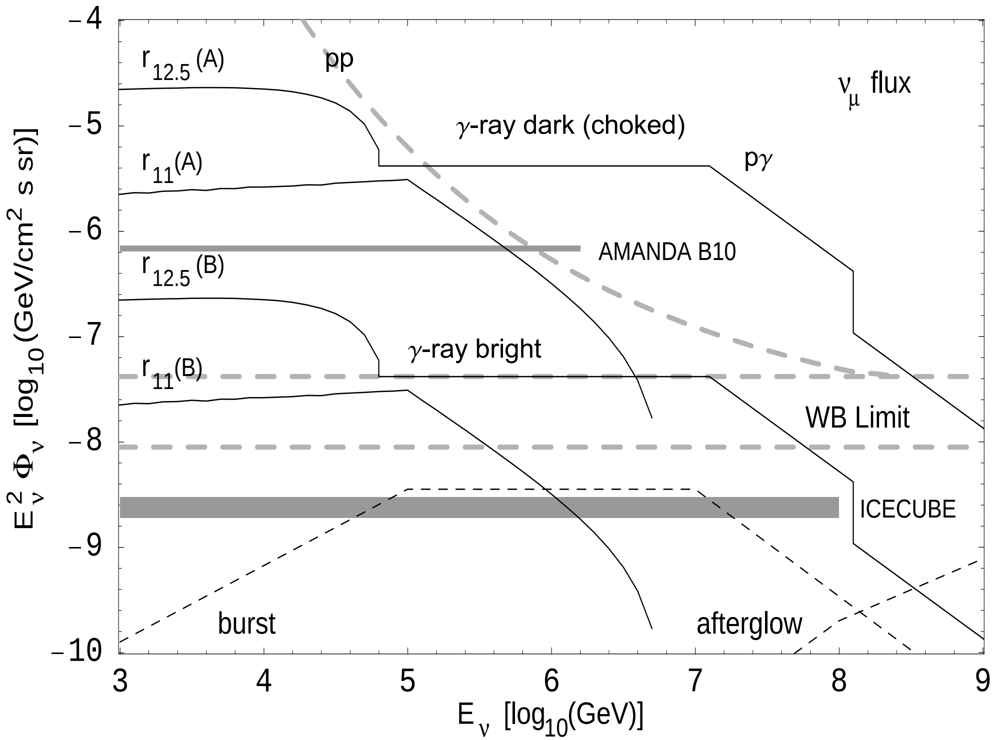
~ 10 /km² (rare, ~ 3 /yr)

- ν-precursor in γ-bright GRB, or
- ν- burst in γ-dark (choked) GRB

→ new "EM unseen" source! (e.g. pop. III ⋆ ?)

Mészáros, Waxman 01 PRL 87:171102

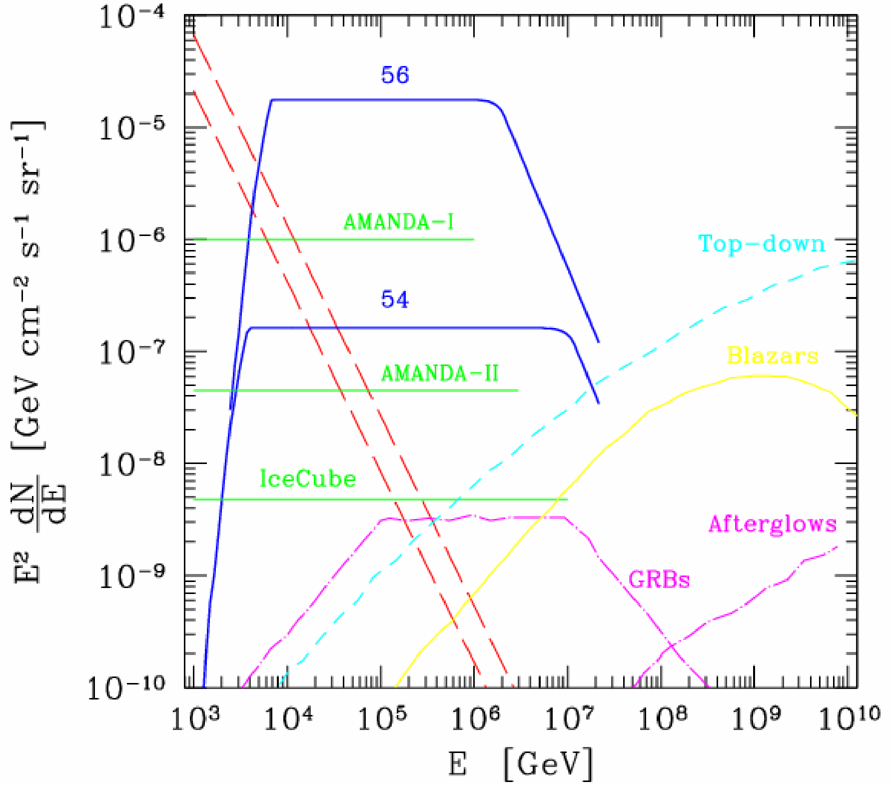
Choked & Successful GRB UHEν



Razzaque, Meszaros & Waxman 2003

- A) He core + H env progenitor
  (log r*=12.5 cm)
- B) He core (no H env) progenitor : log r* = 11 cm
- Upper curves: choked jets ("gamma-dark" coll);
  Lower curves: succesfull ("gamma-bright", i.e.GRB)
- Two contribs: pγ from sub-surface int. shocks, at higher E
- pp and pn from accel. jet protons with p,n in stellar envelope- these are domin. By multipion decays → low energy shoulder

Diffuse UHE ν from pop.III collapse



Schneider, Guetta, Ferrara aph/0201342

- At z~5-30(?) pop.III , M~ 30-300 $M_\odot$, E_{iso}~10^{54}-10^{56}(?) erg
- Buried jets→pγ→ν_μ , → ν-bursts, **AMANDA/ICECUBE**
- "low-z" GRB, AGN etc too
- Detect highest z ⋆form'n, get primordial IMF,

GRB w. pre-supernova shell

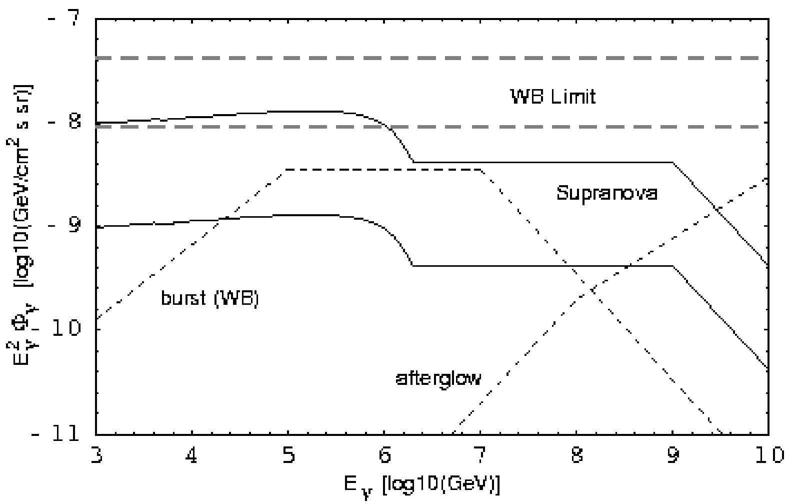


Fig. 1.— Diffuse neutrino flux ($E_\nu^2\Phi_\nu = E_\nu^2 dN/dE_\nu$) from post-supernova (supra-nova) models of GRBs (solid curves), assuming that all GRBs have an SNR shell (top curve) or 10% of all GRBs have an SNR shell (bottom curve). Long dashed straight lines correspond to the Waxman-Bahcall cosmic-ray limit, short short dashed curves are the diffuse ν flux from GRB internal shocks and afterglows.

Razzaque, Meszaros, Waxman a-ph/021536

- GRB may be assoc. w. supernova-like events → SNR shell;
- But: simultaneeous, or precursor SN? (“supranova” hypoth.)
- If precursor SN, the SNR shell is ideal target (beam dump) for p accel in same shocks that produce γ-rays
- Below pγ(Δ-res) thr. have pp, above have p$\gamma \rightarrow \pi\mu e\nu$
- Distinctive ν-spectrum, break energy dep. on age of SNR
- Extend to harder energies than pγ from usual internal (γ)shock

Prediction model-dependence & Detectability of GRB ν

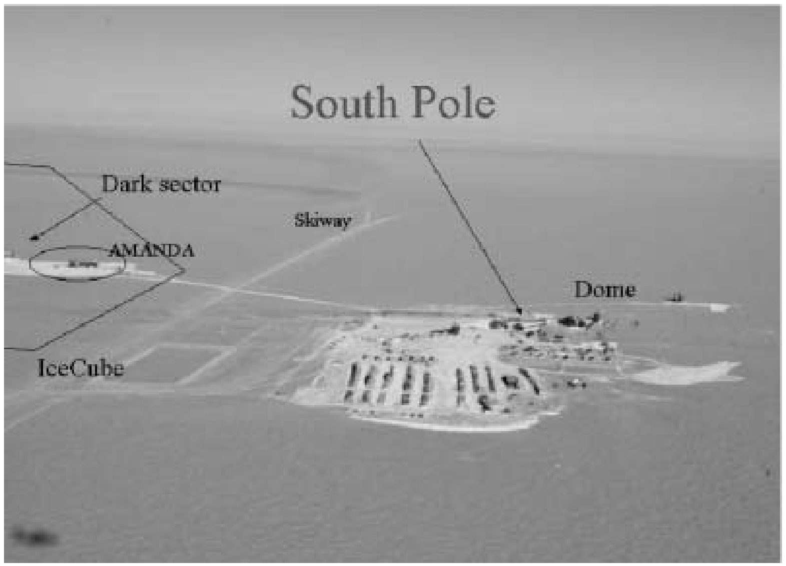
- E_ν~100 TeV are least model dependent
  (use observed MeV γ & same shocks as accelerate $e^\pm$)
- E_ν~1 TeV : more model dependent,
  (assume collapsar, sub-stellar jet, and $R_\star \gtrsim 10^{11}$ cm)
- $E_\nu \sim 10^{17}$ eV : need assume reverse shock prompt opt flash is ubiquitous (?)
- $E_\nu \sim 10^{12} - 10^{18}$ eV : need assume SNR shells are ejected weeks in advance
- $E_\nu \sim 5$ GeV: p,n likely, but detection needs special instrumentation

Other Implications of GRB/AGN

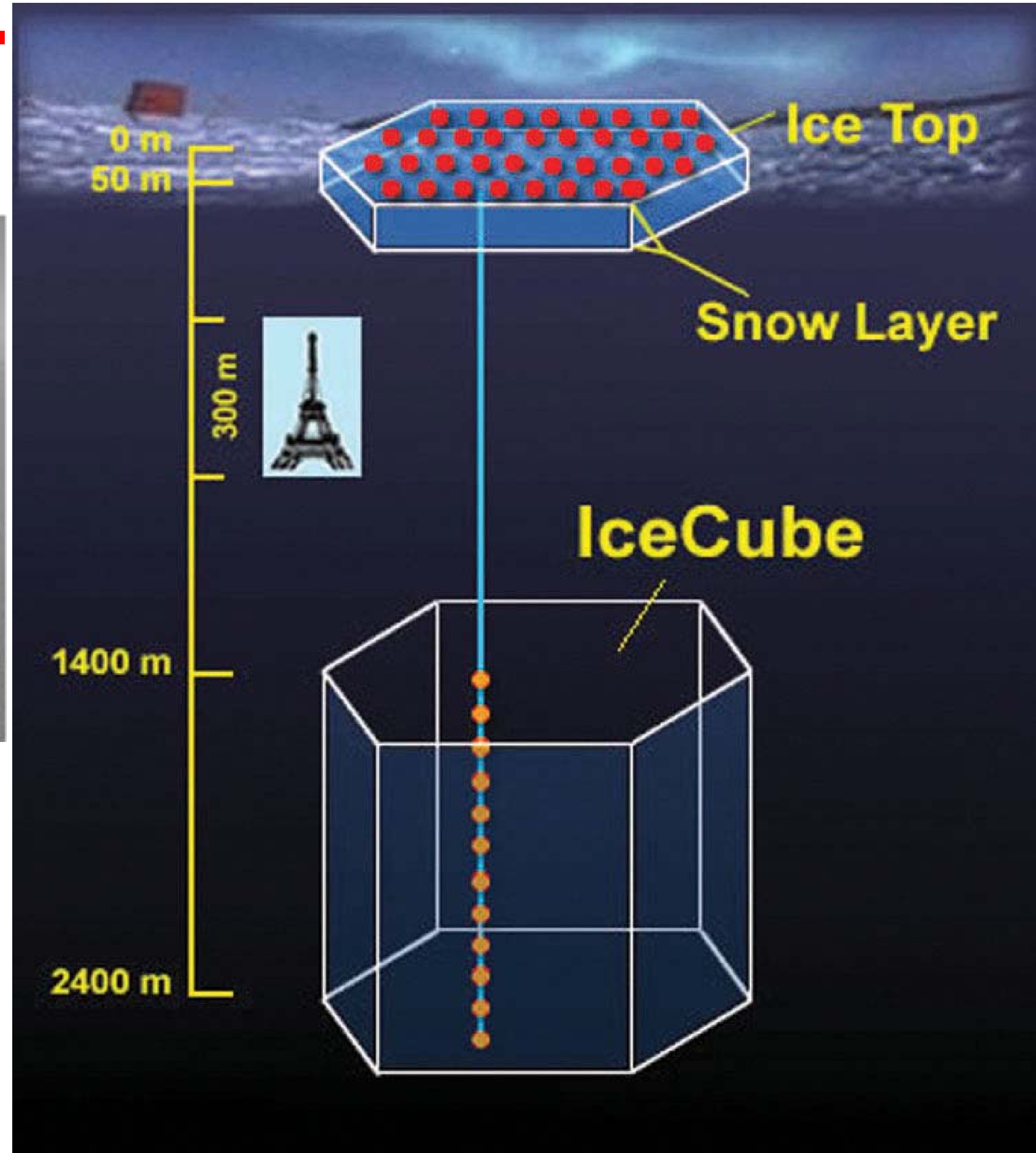
UHE ν

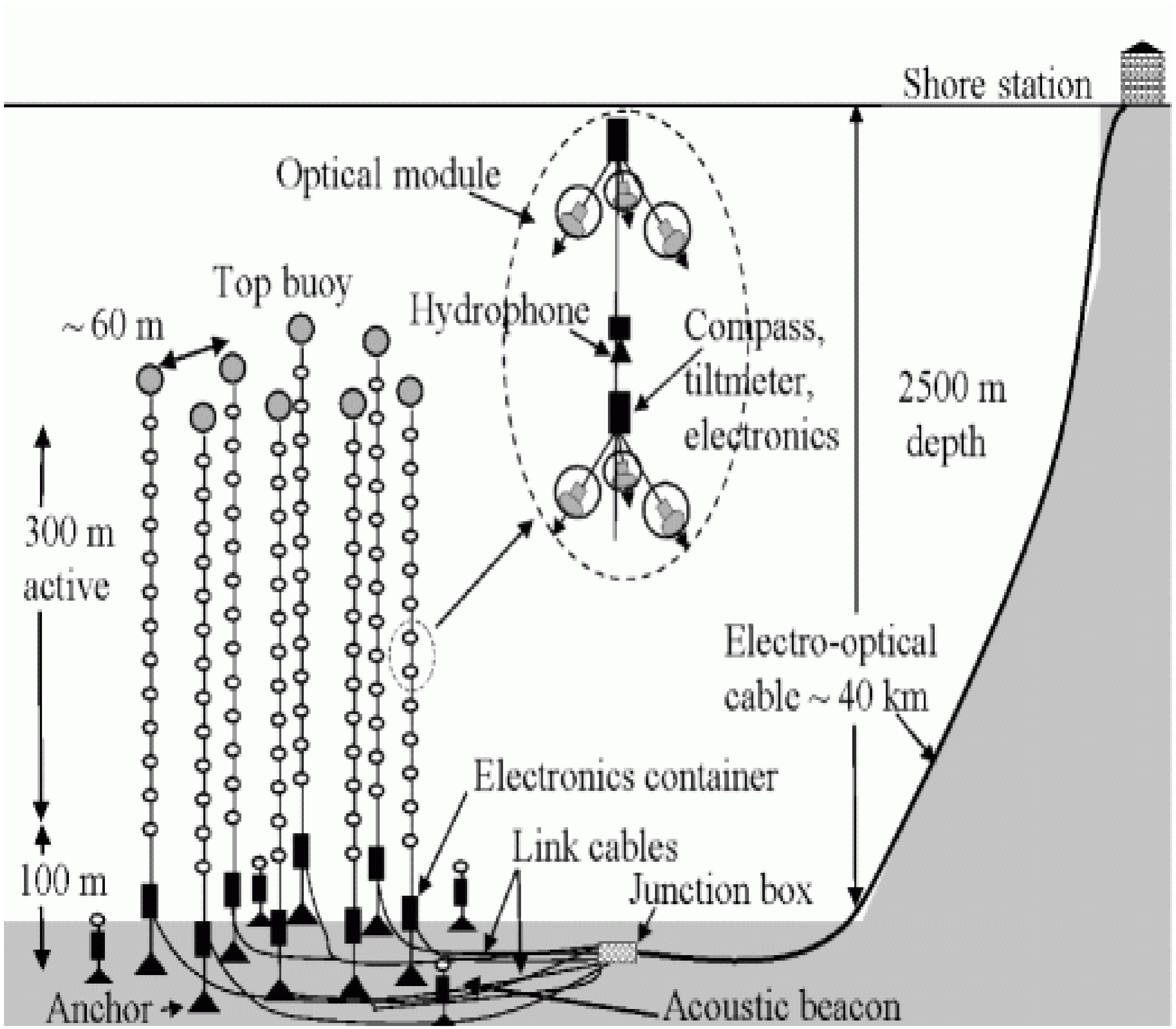
- **Special relativity**: simultaneity of arrival of ν,γ tested to $\Delta t \lesssim 1$ s (10^{-3} s in short bursts)
- **Time delay** due to ν_i mass:
  $\Delta t\ (\nu_i) \sim 10^{-12} (D/100\mathrm{Mpc})(E_{\nu i}/100\mathrm{TeV})^{-2}(m_{\nu i}/\mathrm{eV})^2$ s
  (whereas for SN 1987a $\Delta t\ (\nu_i) \sim 10^{-8}$ s)
- **Vacuum oscillations**: at source exp. $N\nu_\mu \sim 2N\nu_e$, at observer exp. $\approx$ ratios , and upgoing τ appear.
- $\rightarrow$ sensitive to
  $\Delta m^2 \gtrsim 10^{-16}\ (E_\nu/100\mathrm{TeV})(100\mathrm{Mpc}/D)\ \mathrm{eV}^2$
  (for $m_\nu \gtrsim 0.1$ eV due to finite pion life mixing is caused by decoherence rather than oscillation)

ICECUBE: km^3



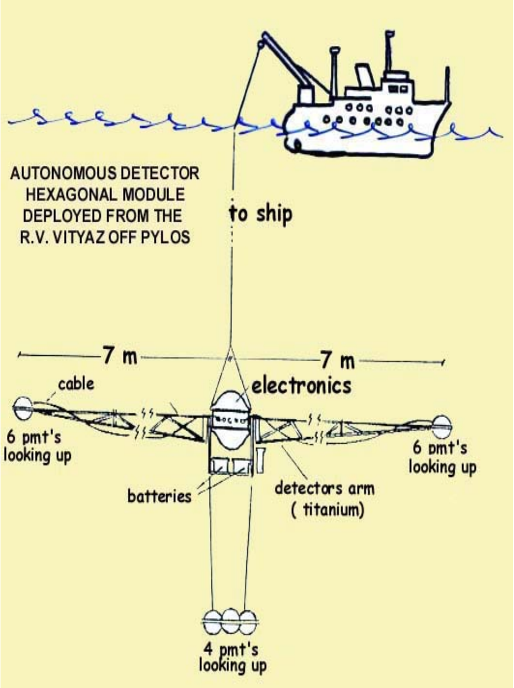
- Extension of Amanda
  0.15 km^3 → km^3=1Gton
- Initial funds for 2002 √
- 80 strings , 4800 PMTs (ice)
  + air shower surface array
- Design for det.all flavor ν's , from 10^7 eV (SN) to 10^{20} eV





←Antares

•French/Italian/UK.. collaboration
•Site off Toulon
• Other: **NESTOR** ↓ Greek/German/Russian



- Km^3 water Cherenkov detector
- Deployment approx. 2010
- Complement ICECUBE: $\lambda_{sc,abs}$~(100,10) $H_2$0, $\lambda_{sc,abs}$~(20,100) Ice
- Northern site: at lower E complementary sky coverage

Diffuse UHE ν : CR bound and sensitivity, bckg

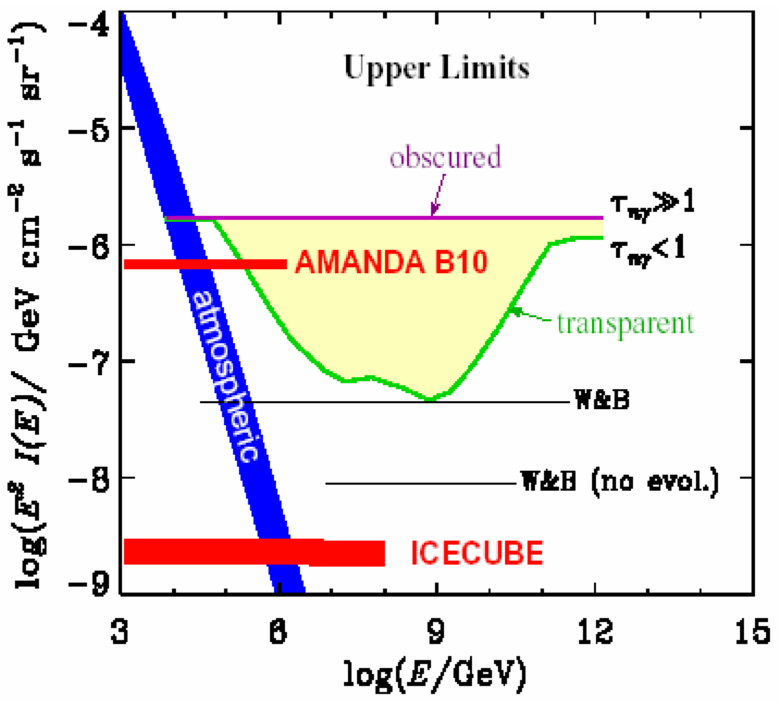
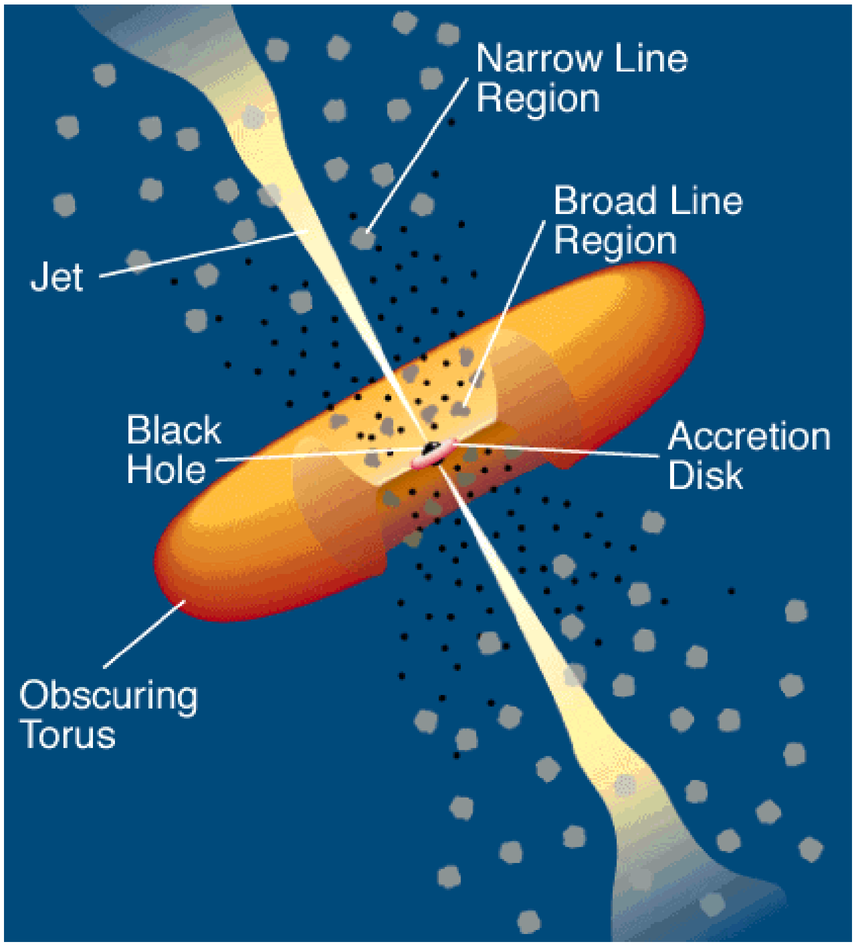


FIG. 6: The neutrino flux from compact astrophysical accelerators. Shown is the range of possible neutrino fluxes associated with the the highest energy cosmic rays. The lower line, labeled "transparent", represents a source where each cosmic ray interacts only once before escaping the object. The upper line, labeled "obscured", represents an ideal neutrino source where all cosmic rays escape in the form of neutrons. Also shown is the ability of AMANDA and IceCube to test these models.

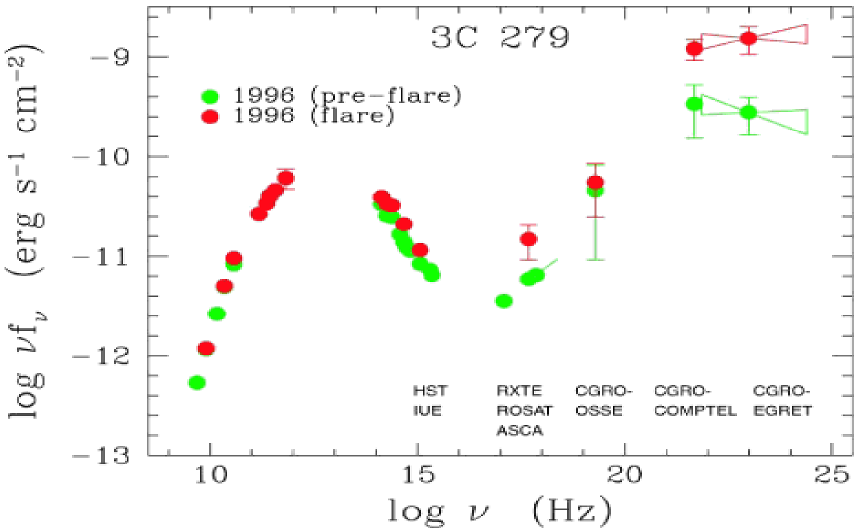
AGN as UHE ν sources

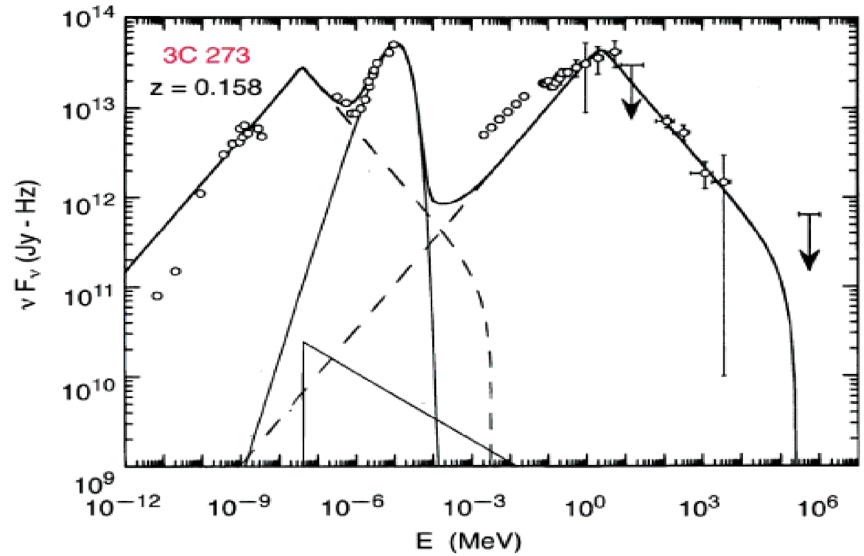


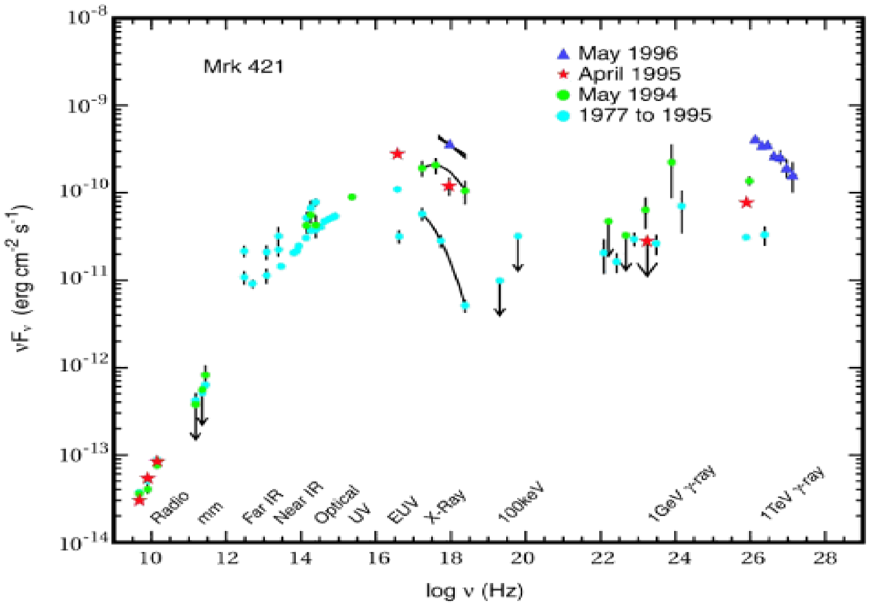
- Big brother of GRB: massive BH (10^7-10^8 $M_\odot$) fed by an accretion disk → jet –
- But, jet $\Gamma_{jet,agn} \lesssim$10-20 (while $\Gamma_{grb} \sim 10^2$-10^3)
- UV photons from disk; in addition, line clouds provide extra photons (+back-scatter)
- Typical (lepton) model:

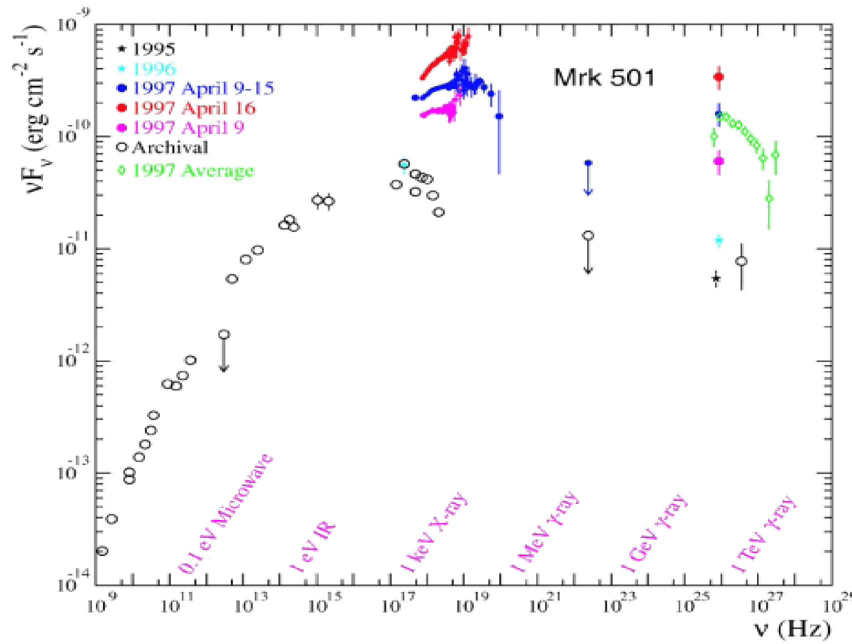
  SSC (sync-self-compton); SEC(sync-exter.compton)

Some AGN γ SED'S



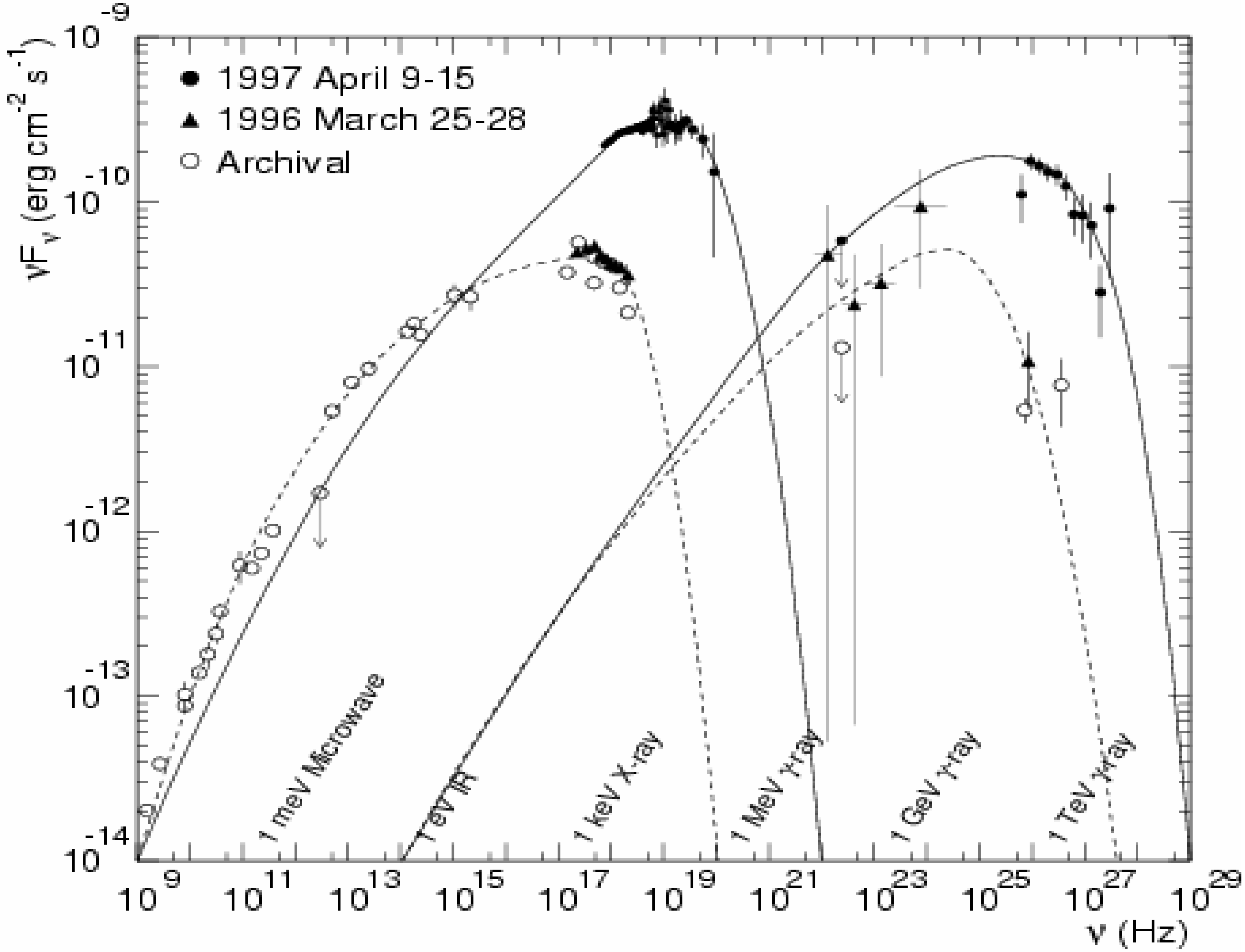






Mészáros, ITP-nu03

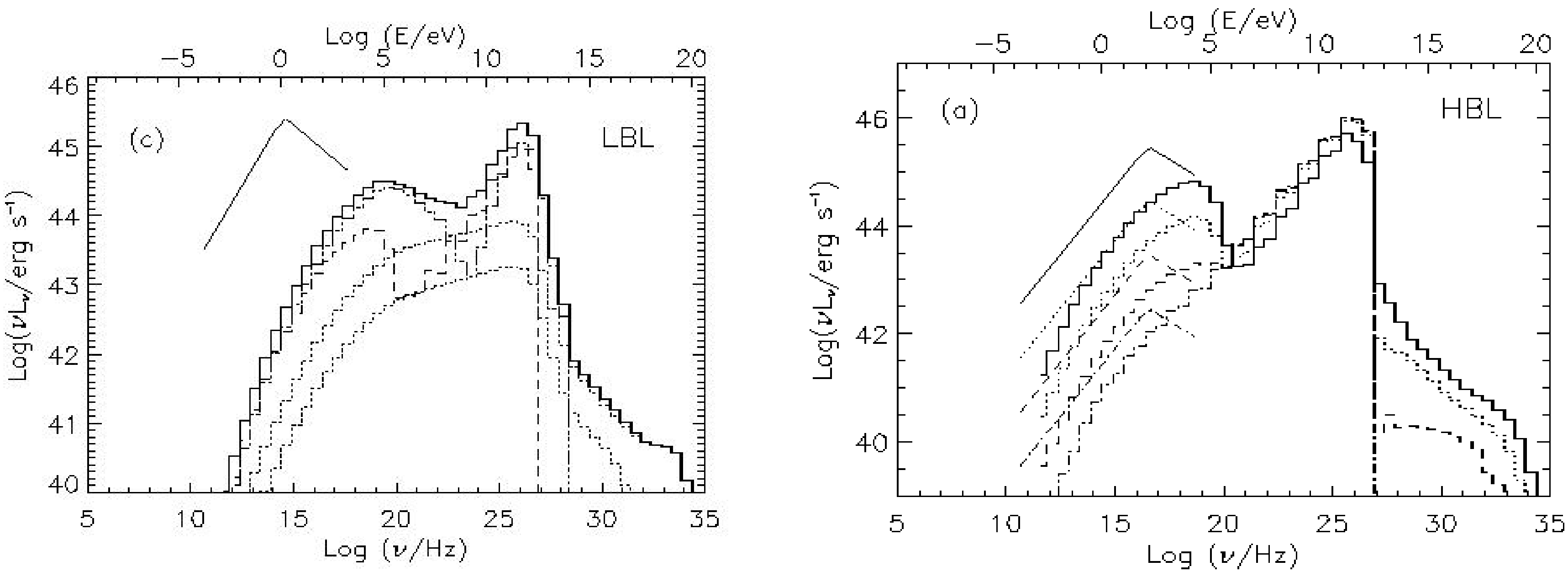
Mrk 501



- 1997 flare: TeV seen; GeV upper lim only w EGRET
- GeV det. sometime@ quiescence
- ←"Typical" astrophys. SSC or ESC "leptonic jet" model fit

PSB model

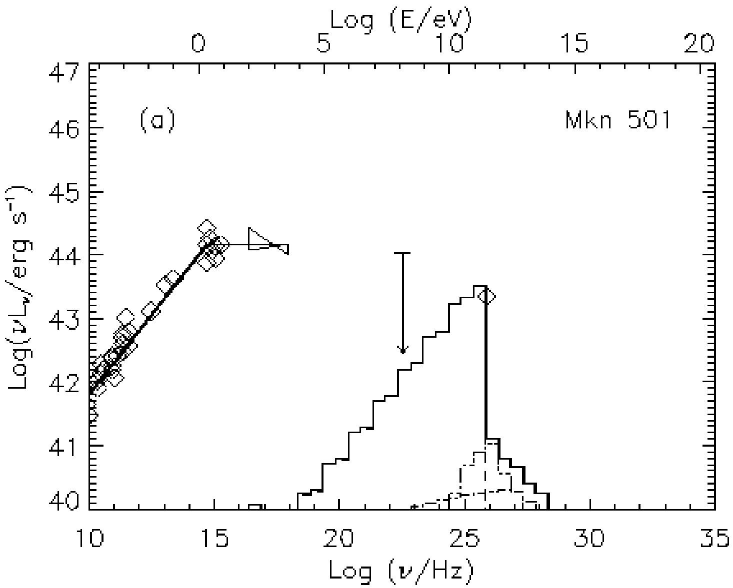
(proton synchrotron blazar) - γ-ray spectrum from cascades

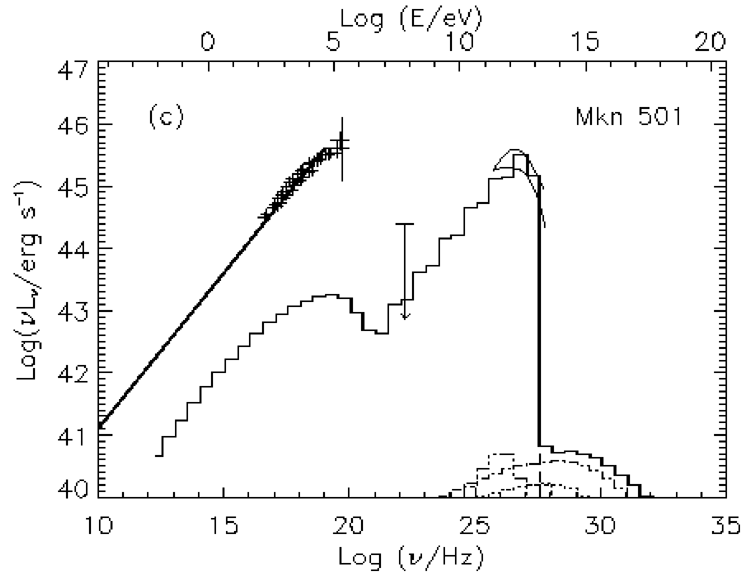


- Full : synchrotron γ SED (target photons)
- Dash: p-sync. casc.; Dash-3 dot: $\mu^{\pm}$-sync. casc; Dots: π^0 casc; Dash-dot: $\pi^{\pm}$ casc

(Muecke, et al, Apph, astro-ph/0206164)

Mrk 501 : protypical HBL



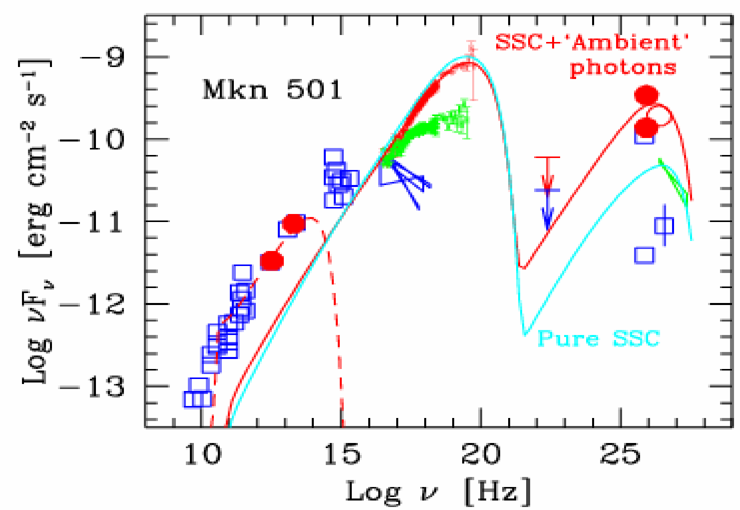


- a) ↑ PSB: Quiet state γ
- b) ↑ PSB: Flare state γ

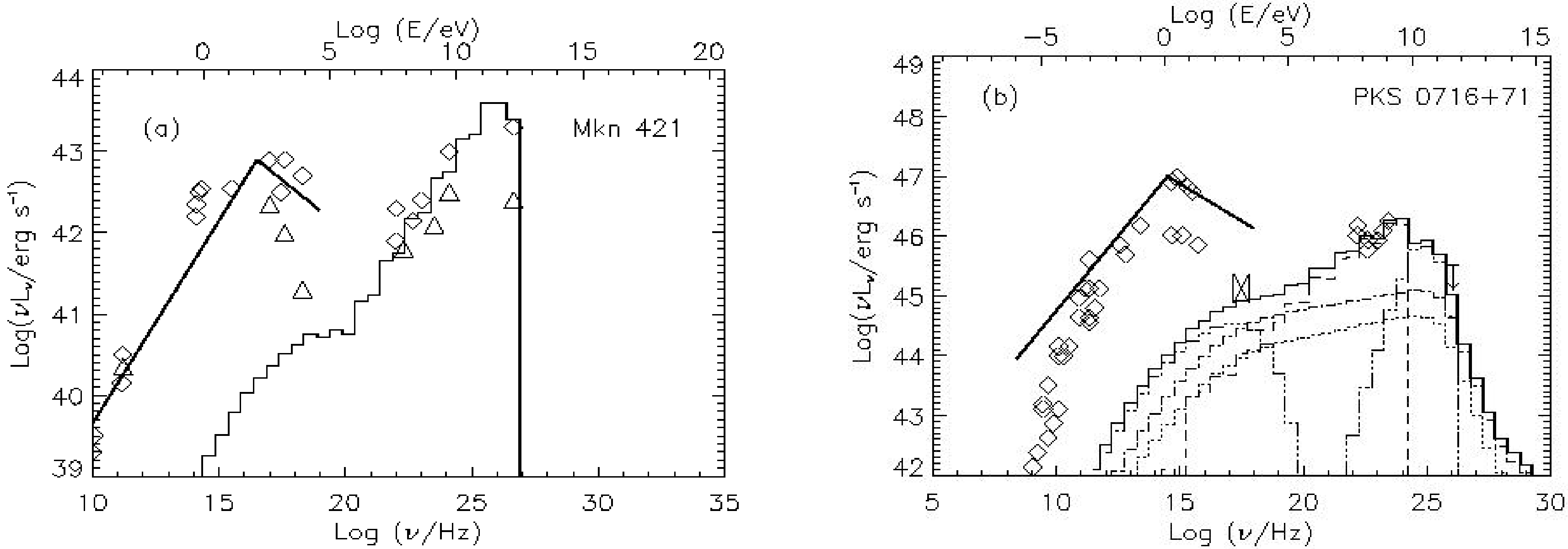
↑ e-sync γ targets + p-sync γ + p,γ casacdes, $\pi\mu$ casacdes & sync (Muecke et al, a-ph/0206164)

- c) → LEP:Flare state γ

→ e-sync γ + e-Inv. Compton scatt (Ghisellini et al, e.g. A&A 386, 833 (2002) etc – "standard" astrophysical. picture



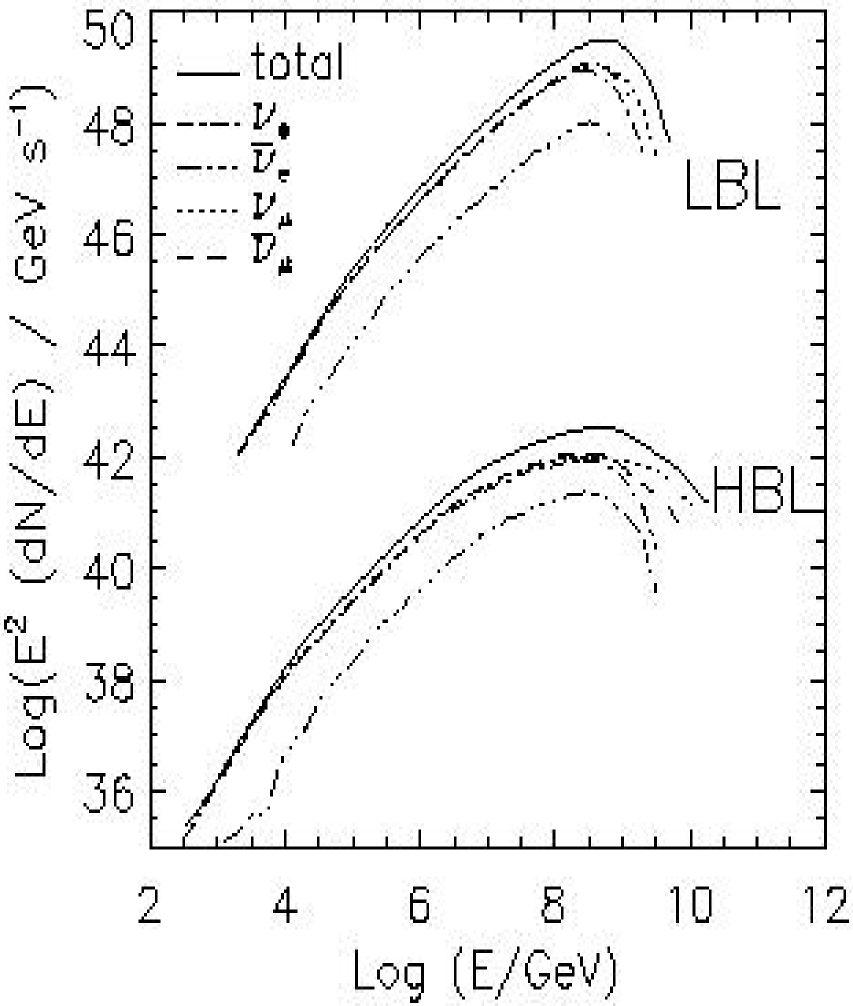
Mrk 421, PKS 0716+71: LBLs



- Specific PSB fits using target photons spectra (full lines left) as low energy sync. targets

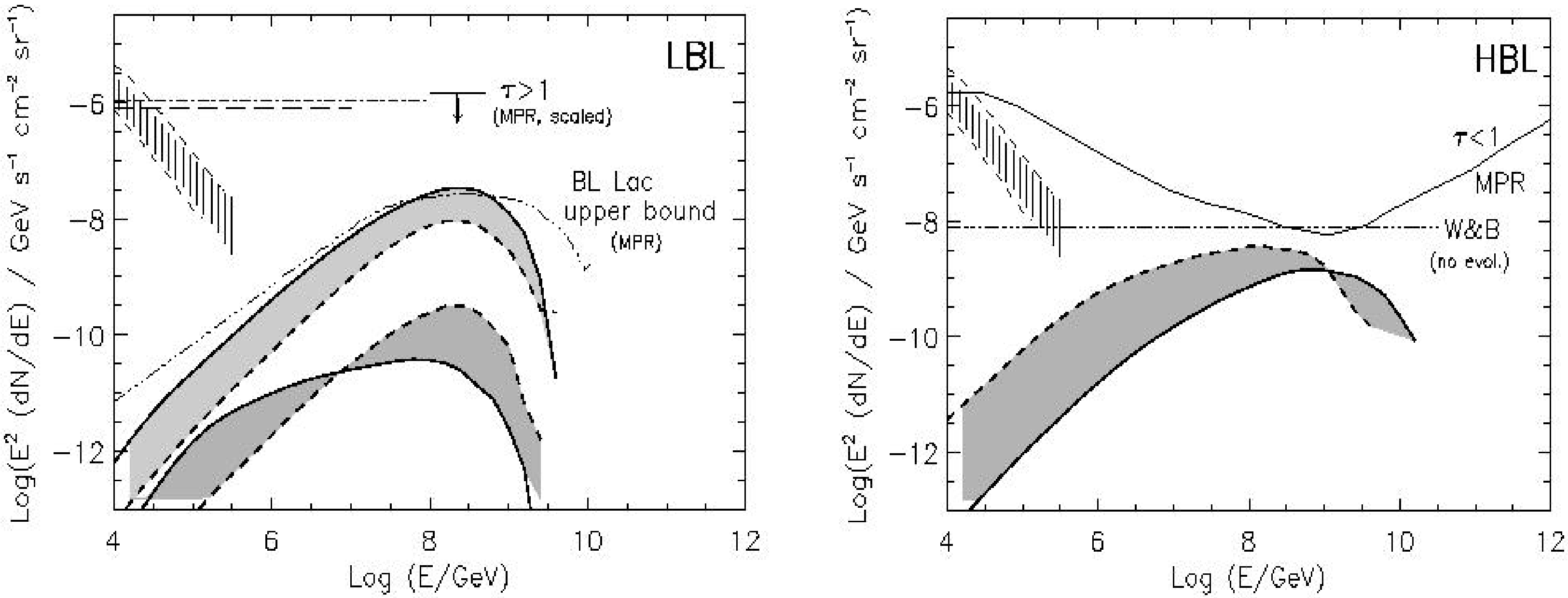
(Muecke etal 2002)

UHE ν spectra of indiv. AGN: SPB



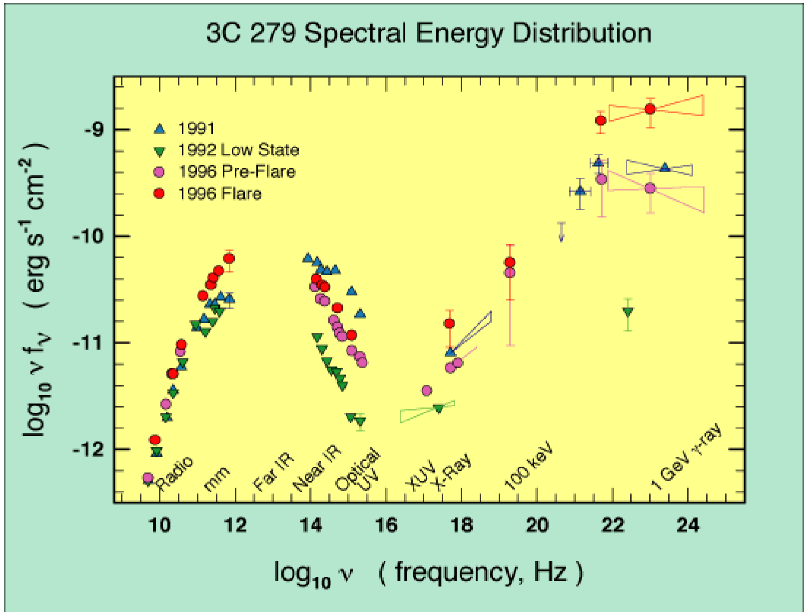
- Generic neutrino spectra in LBL, HBL from pγ interactions with softer/harder target synchrotron spectra
- "Internal" synchrotron low hump assumed + proton sync contrib to high hump
- "External+internal" target photons yields alternative models

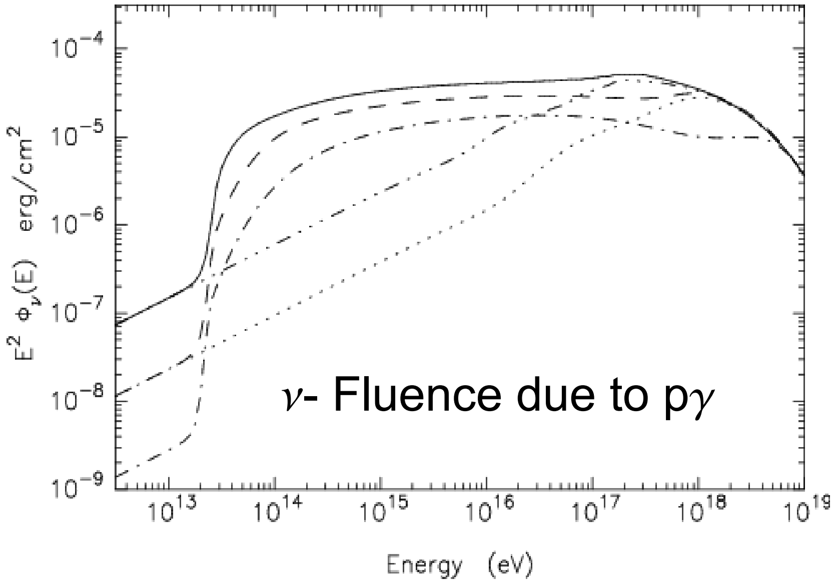
LBL-HBL diffuse ν_μ flux: PSB



- a) LBL diffuse ν_μ + bar ν_μ flux assuming a PKS0716+714 template , typical BL Lac lum.fcn
- b) HBL ν_μ + bar ν_μ flux, assume HBL= 10% of BL Lacs

AGN : leptonic, but with pγ





- 3C279 : FSRQ (flat sp. radio quasar)
- leptonic γ-model: external (and internal) sync + IC
- But: include p-acc. as well, same γ as targets:→ pγ
- Dot, 3-Dot: internal sync targets only
- Solid: external UV (jet Doppler factor δ=7, Dash: δ=10, Dot-dash: δ=15)

Atoyan, Dermer astro-ph/0108053

Galactic microquasar >TeV ν Flux ?

- Microquasars: galactic jet sources: subclass of X-ray binaries (NS and BH)
- Several with $\Gamma_{jet} \sim$ 2-3
- XR, IR,radio outbursts, $L \gtrsim L_{Edd}$, $t_{var} \sim$ days
- Jet content: uncertain ($e^{\pm}$ or e,p?)

  SS433 confirmed e,p (atomic lines vary)
- For ep jets, $\rightarrow$ p,$\gamma \rightarrow \pi^{\pm}, \mu^{\pm}, \nu_{\mu}, e^{\pm}, \nu_e, \nu_{\mu}$

(Levinson, Waxman a-ph/0106102)

Galactic microquasar >TeV ν_μ (N_μ) flux predictions

Source	D(kpc)	δ	Δt	N_μ /km^2	$N_{\mu,bkg}$ (deg/0.3^o)^2
SS433	3	β=0.3	year	250	1
GRO J1655-40	3.1	0.46	6	2	0.02
Cyg X-3	10	2.7	3	5	0.01
GRS 1915+105	12.5	0.6	6	0.5	0.02
XTE J1748-29	8	1.01	20	2.5	0.05

Distefano, Guetta, Waxman, Levinson , astro-ph/0207359)

Plerions (Crab-like SNRs)

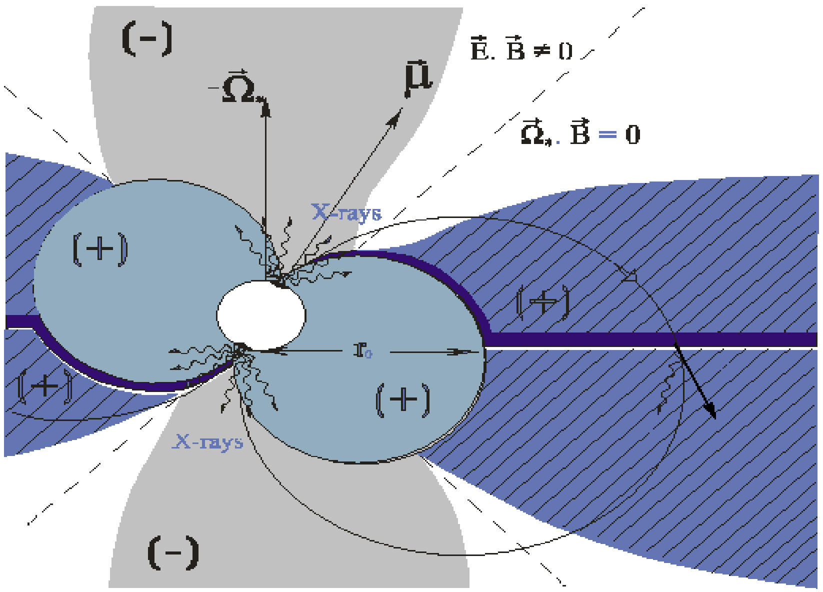
- Plerions: “filled” supernova remnants (SNR), e.g. Crab $\rightarrow$ “young” ($\lesssim$few 10^3 yr)
- 220 in galaxy, 10% are plerions, 5 detected at TeV γ, one claimed as candidate for π^0 decay (hadronic cascade as opposed to “standard” e-sy/inv.Compt)
- Energy source: MHD relativistic wind from pulsar drives shock wave into remnant
- Acceleration: Fermi at shock (wakefield..?)

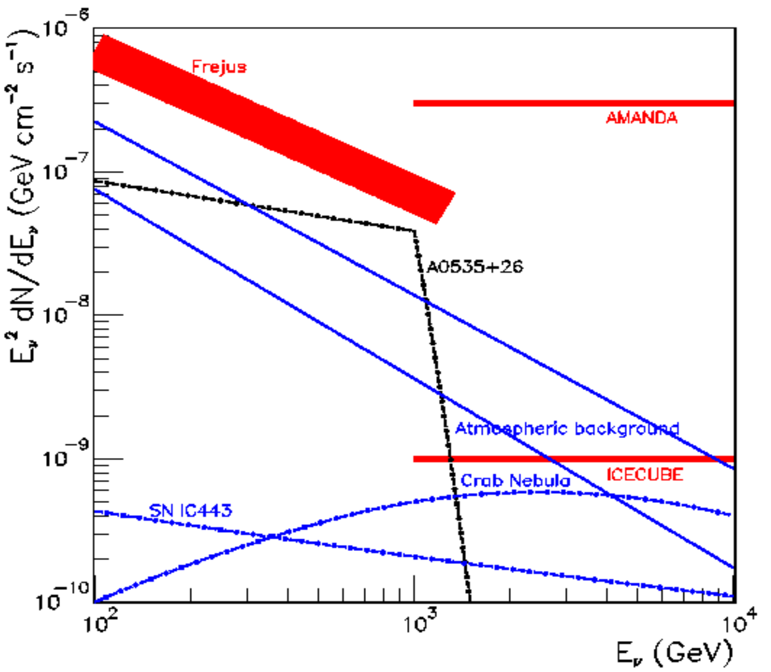
Plerions, predicted >TeV ν_μ (N_μ)

Pulsar	SNR	L_{bol} 10^{38} erg/s	D (kpc)	dN/dE_γ 10^{-11}/cm^2/s/TeV	N_μ /km^2 (year obs)
B0531+21	Crab	5	2	2.8 $E^{-2.6}$	12
B0833-45	Vela	0.07	0.5	1.2 $E^{-2.4}$	9
B1706-44	**G343.1-2.3**	0.034	1.8	0.23 $E^{-2.5}$	1.2
B1509-58	**MSH15-52**	0.18	4.4	1.15 $E^{-2.5}$	6
…	**RX J1713.7-3946**	(0.1)	6	1.6 $E^{-2.8}$	30

Guetta & Amato, a-ph/0209537; Alvarez-Muniz & Halzen, a-ph/020508

UHE ν from accreting NS





- Be/X-ray transient accreting X-ray pulsar, outbursts at periastron
- Idea of EM accel. adapted from radio-pulsars, which however do not have dense accreting gas surrounding them
- need both good vacuum at poles for long accel. path AND dense disk target → likely to be difficult

Anchordoqui et al, hep-ph/0211231

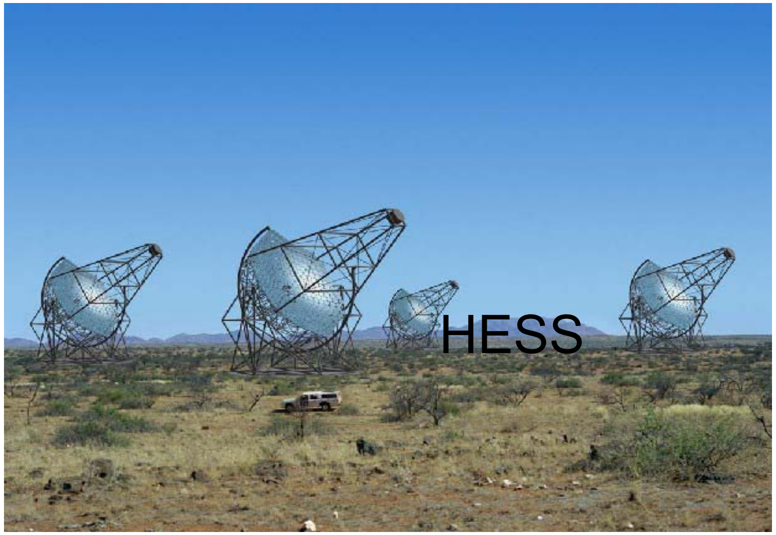
GeV-TeV Facilities underway

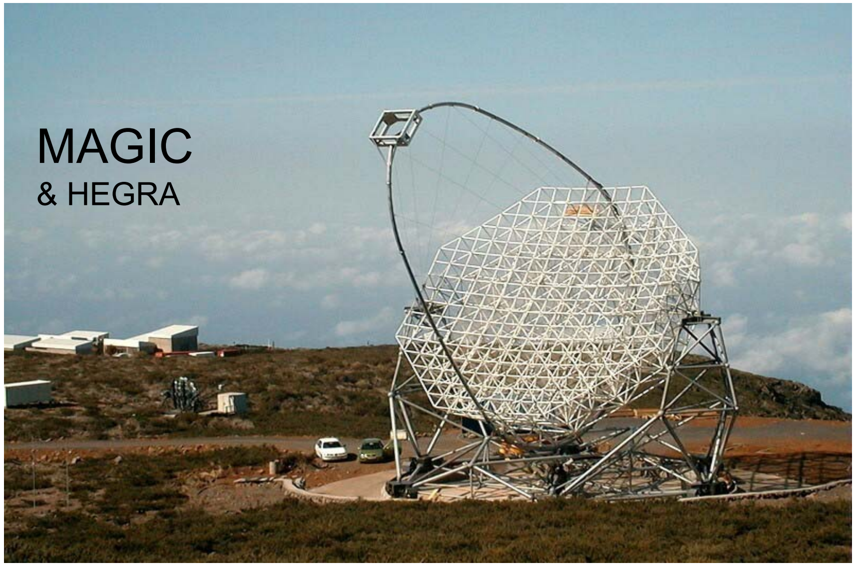
Cherenkov Telescopes

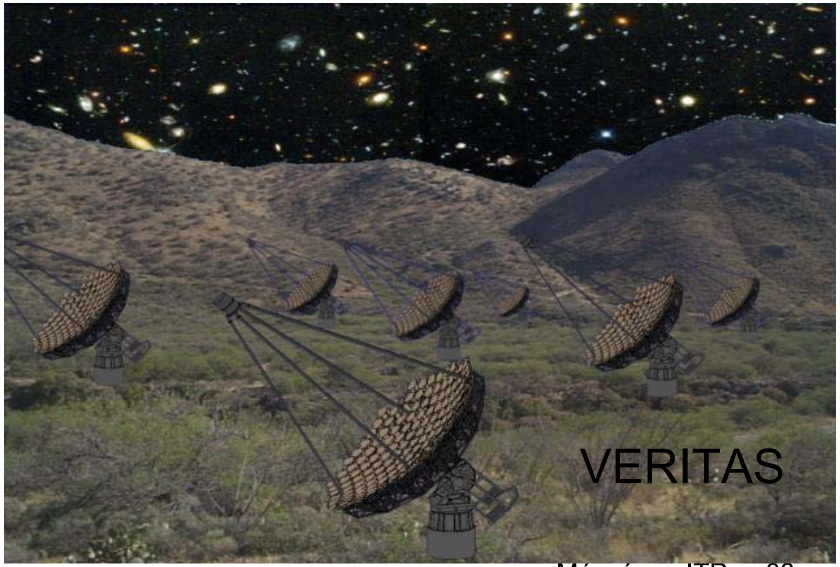
← **Water**

Air →

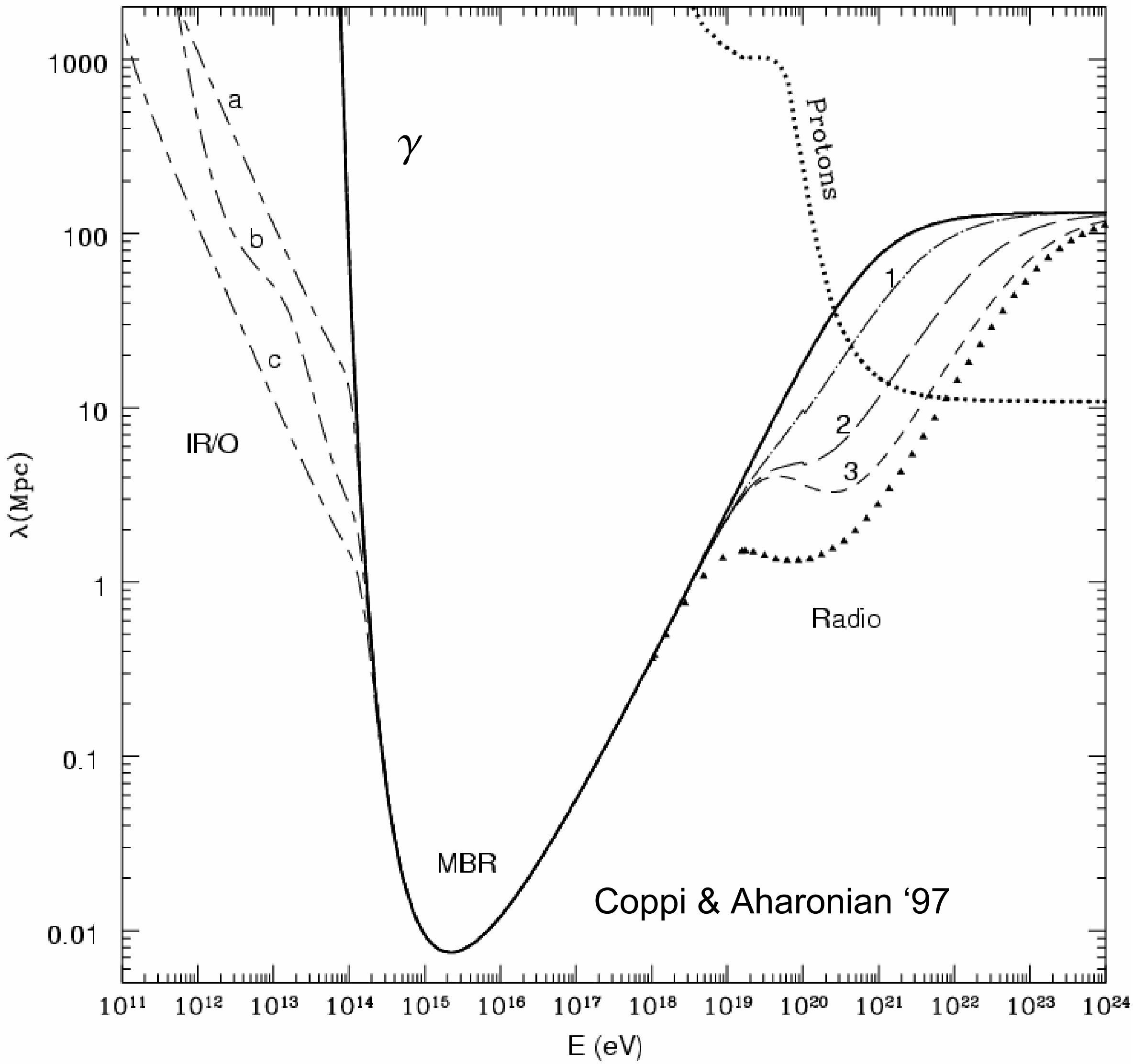
↓ ↓







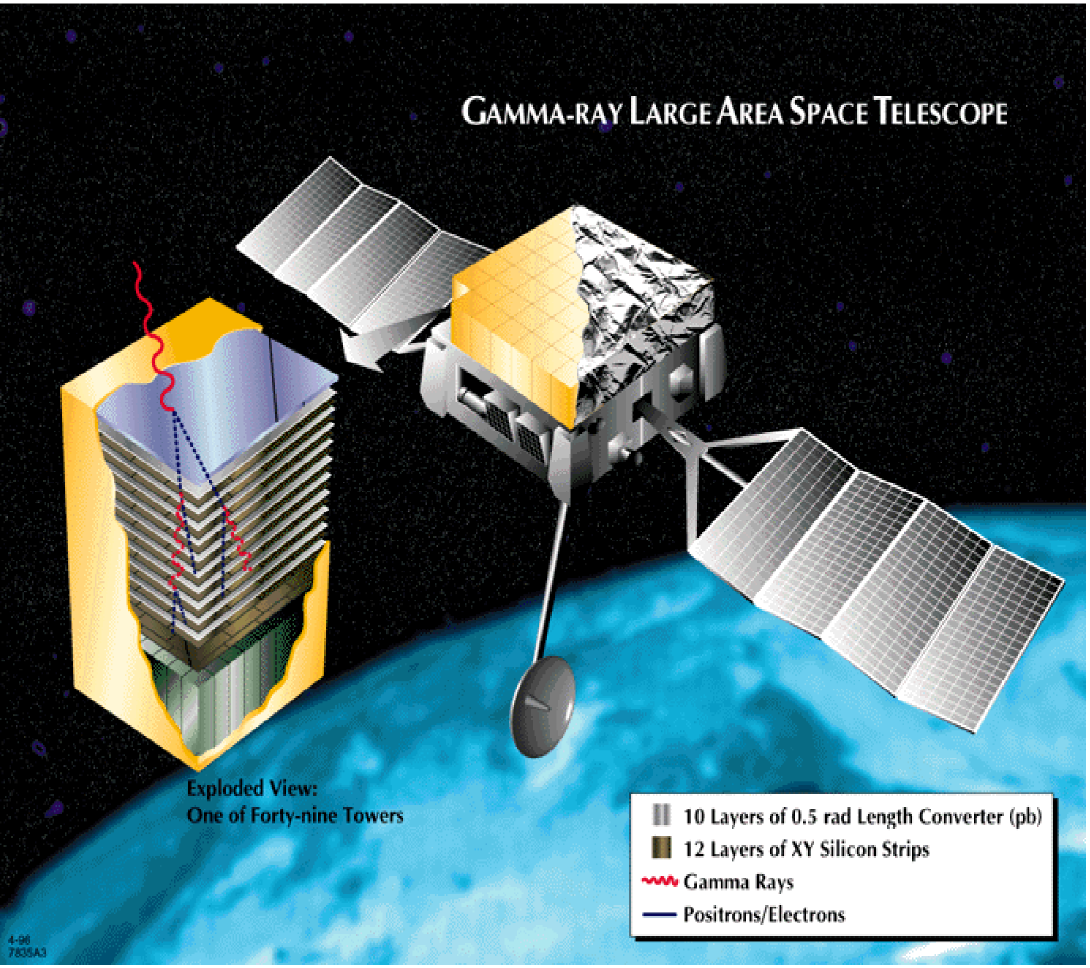
$\gamma\gamma$ Opacity of the Universe



- In all but the densest (veiled) AGN sources (e.g. gal.nuc?), $\tau_{\gamma\gamma} \leq 1$ for >TeV on "local" target photons, but..
- In IGM, $\tau_{\gamma\gamma} \geq 1$ for >TeV on IR bkg γ (D$\lesssim$100Mpc) $\rightarrow$test IR bkg spectral density,
- constrain early star formation rate &

  z-distr of SFR, LSS, cosmology

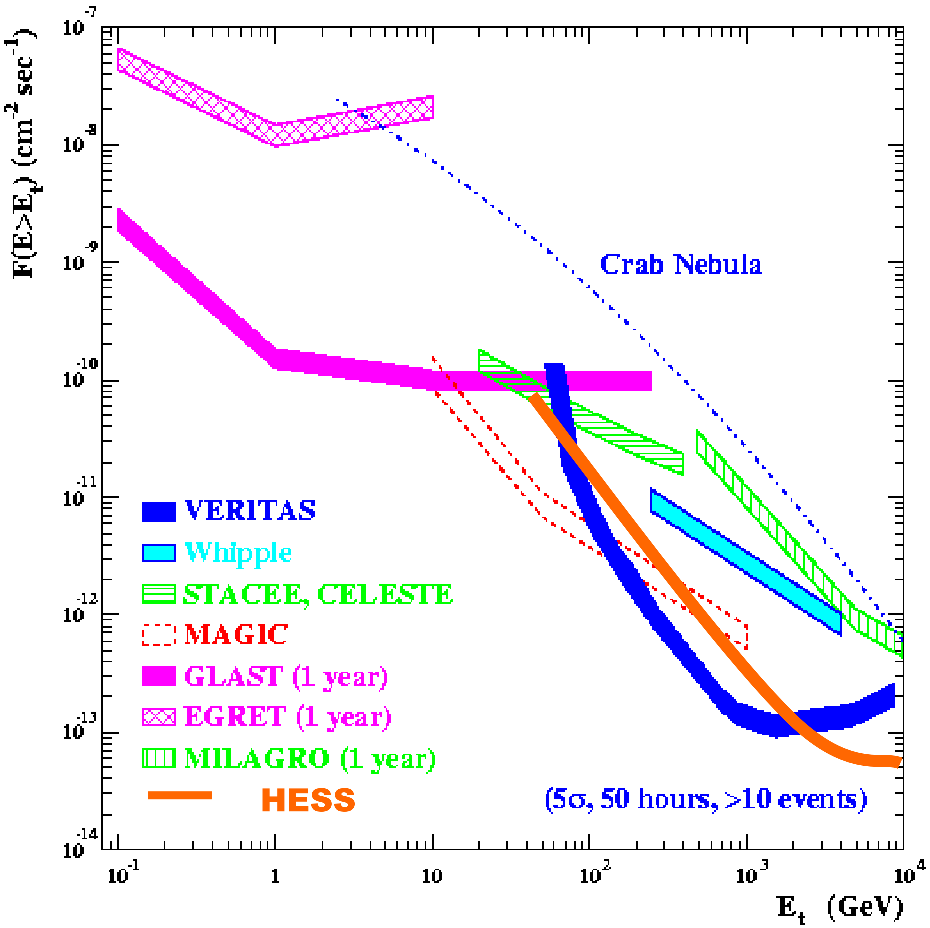
GLAST : LAT (Stanford +)



- LAT: launch exp '05, Delta II, 2-300 GRB/2yr
- Pair-conv.mod+calor.
- 20 MeV-300 GeV, $\Delta E/E \lesssim 10\%$@1 GeV
- fov=2.5 sr (2xEgret), θ~30"-5' (10 GeV)
- Sens $\gtrsim 2.10^{-9}$ph/cm^2/s (2 yr; $\simeq$ 50xEgret)
- 2.5 ton, 518 W

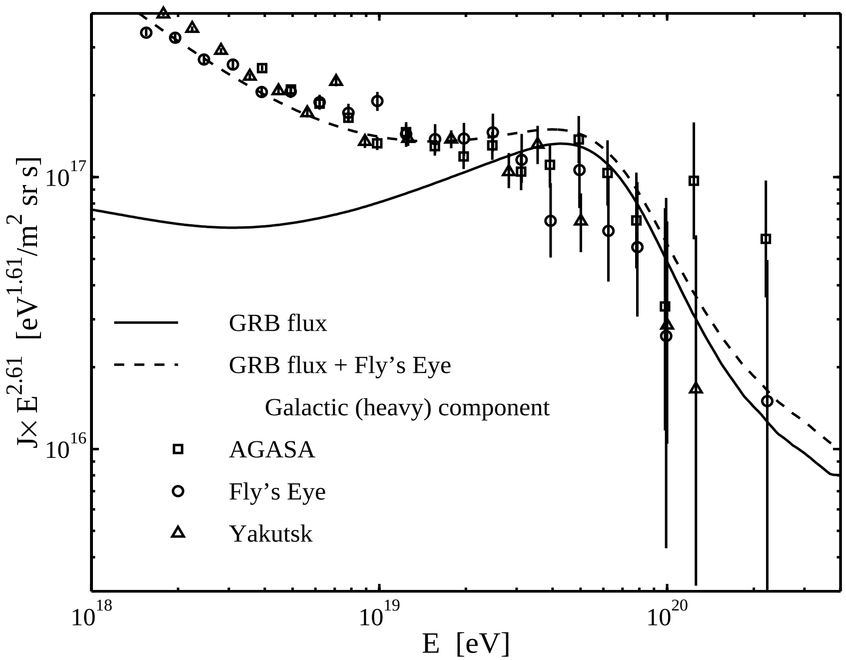
Also on GLAST: GBM (next slide)

Point Source Sensitivities



- **MAGIC**: La Palma (Munich)
  Monoc. 1x17m, >30 GeV, '01
- **HESS**: Namibia (Heidelberg)
  Stereo 4x12m, > 50 GeV, '02
- **CANGAROO-III**: Austral(Tokyo)
  Stereo 4x10m, >50 GeV, '03
- **VERITAS**: Arizona (SAO)
  Stereo 7x10m, >50 GeV, '05
- **STACEE**: Sandia (UCLA/Chic)
  solar tower, 20-300GeV, '01
- **MILAGR(ITO)O**, LANL, NM
  water, > 20 GeV, A~5.10^7 cm^2
- **GLAST** (LAT): space (Stanford)
  Silicon, 20 MeV-300 GeV, '06

Proton Acceleration in GRB



(Waxman, Neutrino 2000, hep-ph/0009152)

- Internal & extern.(rev) shocks NR Fermi acc. $\rightarrow$spectrum $N(E) \propto E^{-2}$
- Can reach $E \sim 10^{20}$ eV (for $\xi_B \xi_e \gtrsim 0.02$, $\Gamma \gtrsim 130$)
- CR energy input at10^{20}eV $dE/dtdV \sim 10^{44} \zeta$erg/$Mpc^3$/yr where $\zeta \sim 0.5$-3 (z-evol.)
- Entire $>10^{20}$eV CR flux from GRB? yes/no/possib

(Waxman NucPhS 87:345'00; Stecker APPh 14:207 '00)

UHECR total power in GRB?

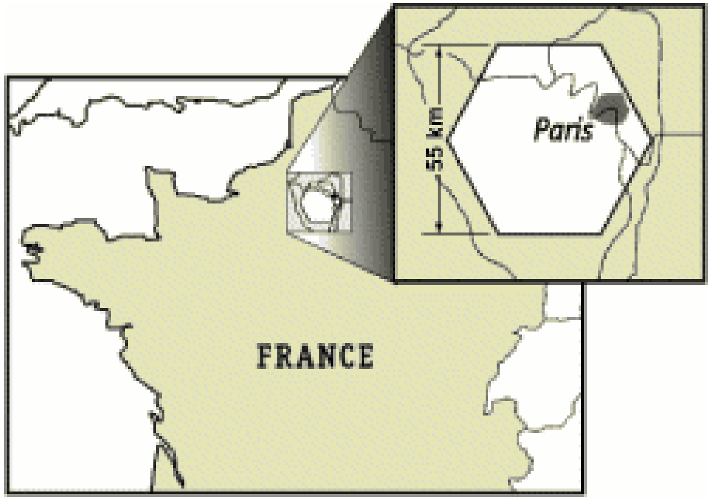
- Previous (1995-00): $E_\gamma \sim 10^{51}$ erg, $R(z=0) \sim 30/Gpc^3/yr$, $dE/dtdV \sim 0.3 \times 10^{44}$ erg/Mpc^3/yr
- New (>2000): $E_\gamma \sim 2.5 \times 10^{53}$ erg (isot.equiv);
  R (z=0) $\sim 5 \times 10^{-10}$ /Mpc^3/yr,
  $dE/dtdV \sim 1.3 \times 10^{44}\, \zeta$ erg/Mpc^3/yr . ($\zeta \sim$ 3-8 to z~1, evol)
  Jets: $4\pi/500$ ($E_\gamma \downarrow$, $R\uparrow$, $\surd$)
- $\rightarrow E_e^2\, dn_e^{GRB}/dE_e\, dt \sim 10^{44}\, \zeta$ erg/Mpc^3/yr

- UHECR exg obs: $dE_p^{CR}/dt \sim 3 \times 10^{44}$ erg/Mpc^3/yr
  $\rightarrow E_p^2\, dn_p^{CR}/dE_p dt \sim 0.7 \times 10^{44}$ erg/Mpc^3/yr, $\surd$, OK.

(Waxman, astro-ph/0210638)

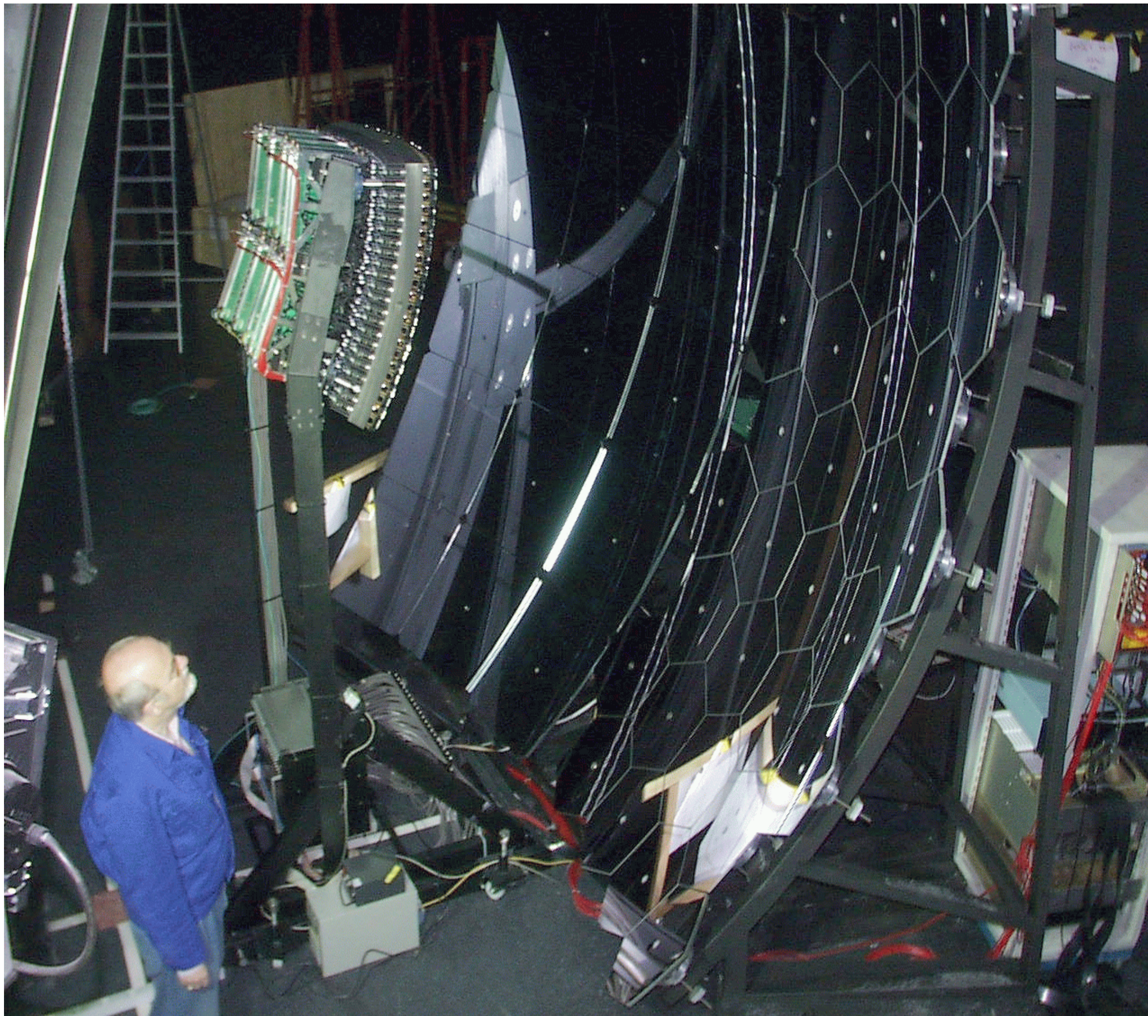
Pierre Auger

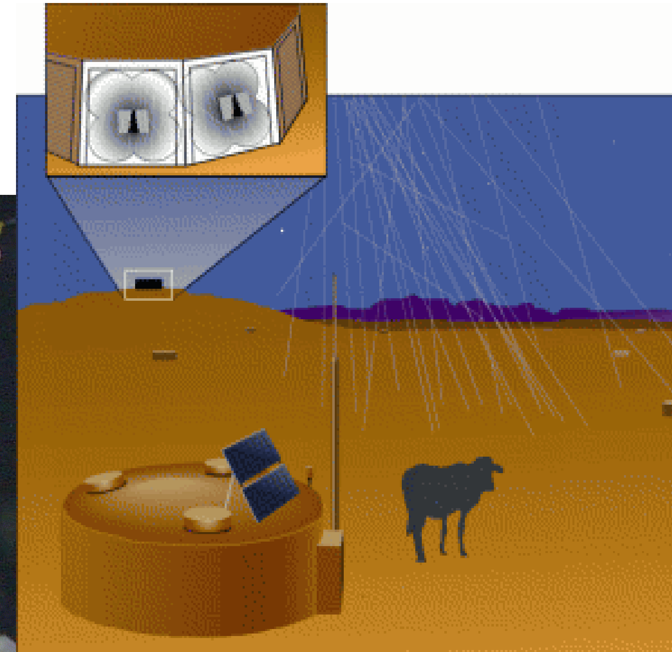
Ultra-high energy cosmic ray observatory



- NSF project, south : (Argentina) partly complete – north:planned
- Planned area 3,000 km^2 , sensitive to CR energies >10^{20} eV (GZK lim)
- 1600 ground particle detectors, 11,000 liters ea., 1.5 km apart, ea.
- In addition, several air fluorescence telescopes
- Also: tau-neutrinos (horiz.l showers- Earth-skimming & through Andes)

AUGER





- Prototype fluorescent telescope mirror & camera (440 pmt)
- Based on Fly’s Eye concept & experience
- Imbedded in and complementing ground particle detector array

EUSO

- ISS project (shuttle?)ESA/NASA/RSA/JSA ; precursor study for OWL (larger free-flyer)
- 5.10^{19} – 10^{21} eV EECRs, EENUs
- Detector: monocular 2.5m Fresnel lens, measure EAS through atmos. fluorescense
- Threshold: 3.10^{19} eV
- Full efficiency: 10^{20} eV (300-1000 event/yr)
- Alt: 380 km, FOV: 60^{o} , R_{surf}=230 km;
  Geom. Factor: 5.10^{5} km^{2} sr, air mass 10^{12} tons
- Begin op: 2008-2009? (as of last summer)

Conclusions

- UHE ν will allow test of proton content of jets, test shock accel.physics, magn. field
- If UHE ν NOT detected, $\rightarrow$ jets are MHD!
- Probe ν interactions at $\gtrsim$ PeV CM energies
- Test SR, oscillations, masses, vacuum disp.
- Constraints on stellar evolution and death, star formation rates at redshifts of first structures
- Could be probes of “pop III” first gen. objects
- New physics: need know boundaries of SM astrophysical UHECR, UHENU mechanisms