IDS Report

GLAST SWG meeting

Sept. 2, 2005

Chuck Dermer (NRL)

GLAST grant supports costs of research with

1. **Dr. Armen Atoyan (frequent visitor to NRL; travel to GLAST Symposium)**
   UHECRs and ν from GRBs and blazars, Chandra jets, Sgr A*
2. **Dr.Truong Le (NRL/NRC postdoctoral associate)**
   Particle acceleration theory
3. **Prof. Govind Menon (Summer Sabbatical Faculty and future vists)**
   Black-hole research
4. **Prof. Markus Böttcher (grad student support to Ohio U, visit to NRL)**
   Microquasars
5. **Jeremy Holmes (Summer hire) Cosmic ray propagation in the Galaxy**

Plans for Coming Year

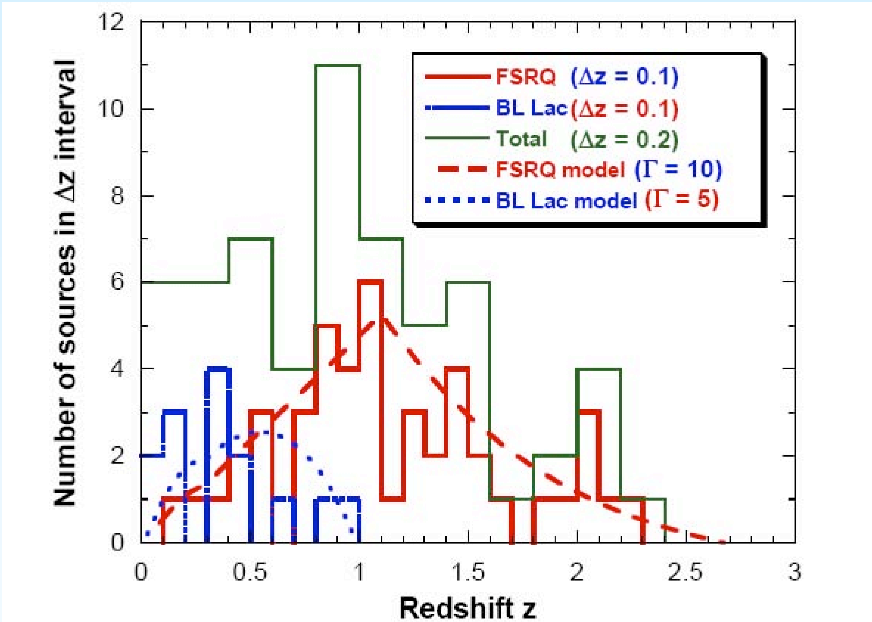
1. GLAST Science Working Groups:
   GRBs (ISSS Course, L'Aquila, Italy)
   Solar System
   Blazars

2. New hire

3. Book: "High Energy Radiation from Black Holes:
   γ-rays, cosmic rays, and neutrinos"

4. HESS results
   "THE MULTI-MESSENGER APPROACH TO HIGH ENERGY GAMMA-RAY SOURCES" July 4-7, 2006 - Barcelona, Spain

Statistics of Gamma-Ray Blazars



• Peak of activity of cosmological γ-ray sources (blazars, gamma-ray bursts) at redshift z ~ 1

• Population evolution is strongly non-Euclidean, so large number of sources near threshold for BL Lac objects and clusters of galaxies

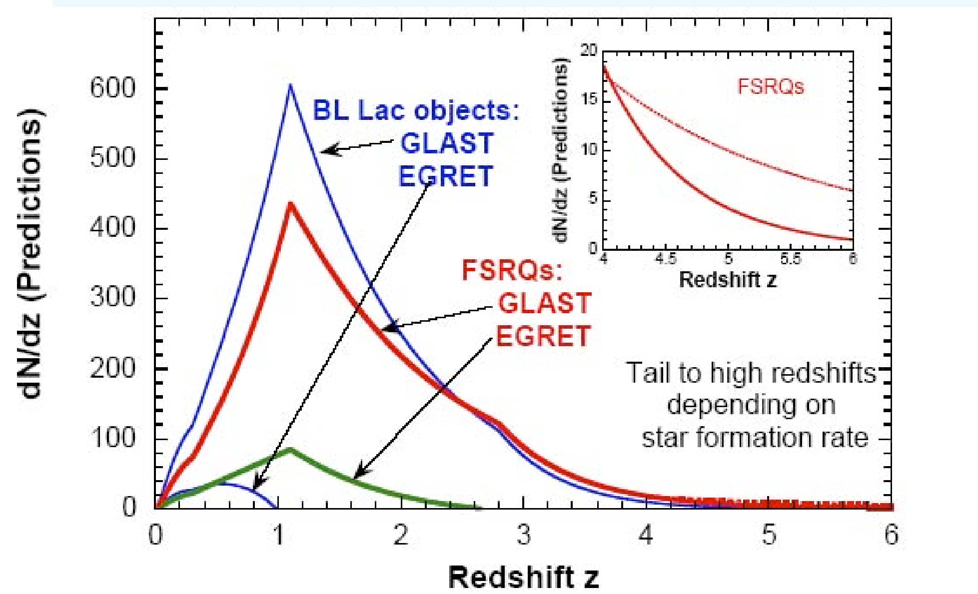
(C.D. and Stan Davis, 2001)

HESS obs. of high-z HBLs

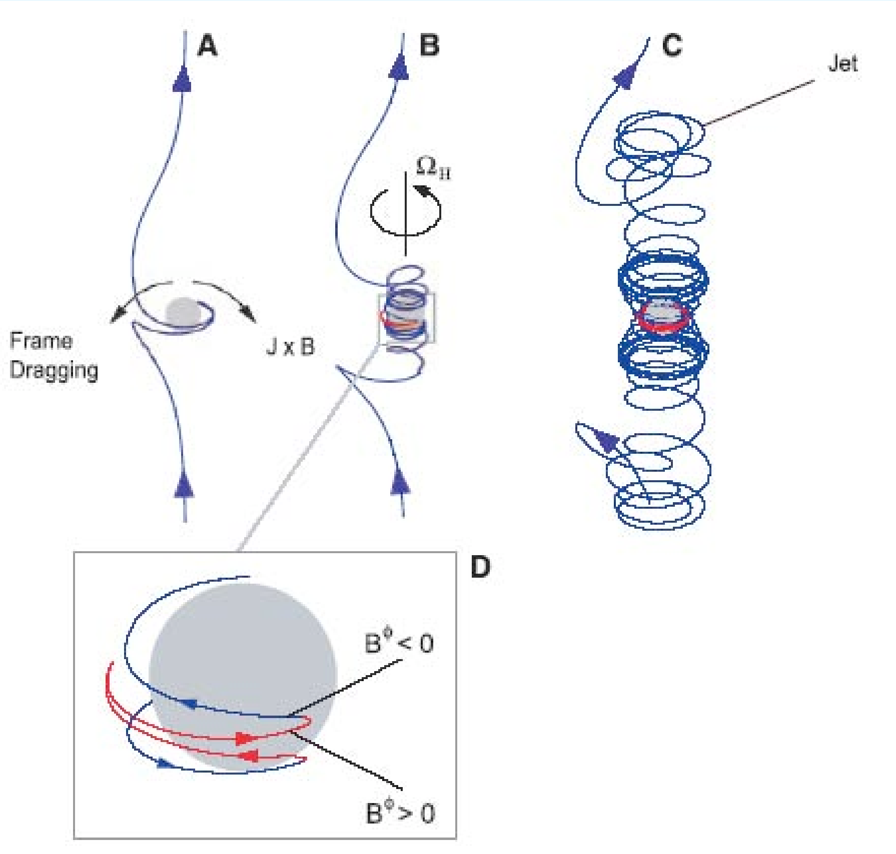
GLAST studies of EBL;

internal absorption

HBLs, LBLs, and the EBL



Energy Extraction from Rotating Black Holes



Energy from Black Holes

Rotating Black Holes

Reducible vs. Irreducible mass

Penrose process

Blandford-Znajek process

Force-free magnetosphere

$$E \cdot J = 0,$$

$$\rho E + J \times B = 0.$$

Maxwell's equation in 3+1 formalism

(Komissarov 2004)

Energy Extraction from Rotating Black Holes

Analytic Solutions to the Constraint Equation for a Force-Free Magnetosphere around a Kerr Black Hole

Govind Menon[1,2,3] & Charles D. Dermer[2]

$$\frac{1}{2\Lambda}\frac{dH_\varphi^2}{d\Omega} = \frac{\alpha\gamma_{\varphi\varphi}}{\sqrt{\gamma}}[\Omega\partial_r(\frac{\Lambda}{\alpha\sqrt{\gamma}}(\gamma_{\varphi\varphi}\Omega+\beta_\varphi)\gamma_{\theta\theta}\Omega_{,r})+$$

$$\Omega\partial_\theta(\frac{\Lambda}{\alpha\sqrt{\gamma}}(\gamma_{\varphi\varphi}\Omega+\beta_\varphi)\gamma_{rr}\Omega_{,\theta})+ \quad \rho_+^2 = r_+^2 + a^2\cos^2\theta$$

$$\partial_r(\frac{\Lambda}{\alpha\sqrt{\gamma}}(\beta^2-\alpha^2+\beta_\varphi\Omega)\gamma_{\theta\theta}\Omega_{,r})+$$

$$\partial_\theta(\frac{\Lambda}{\alpha\sqrt{\gamma}}(\beta^2-\alpha^2+\beta_\varphi\Omega)\gamma_{rr}\Omega_{,\theta})].$$

Constraint equation in 3+1 formalism

$$\Omega_+ = \frac{a}{2Mr_+ + \rho_+^2},$$

$$(r_+ = M + \sqrt{M^2 - a^2})$$

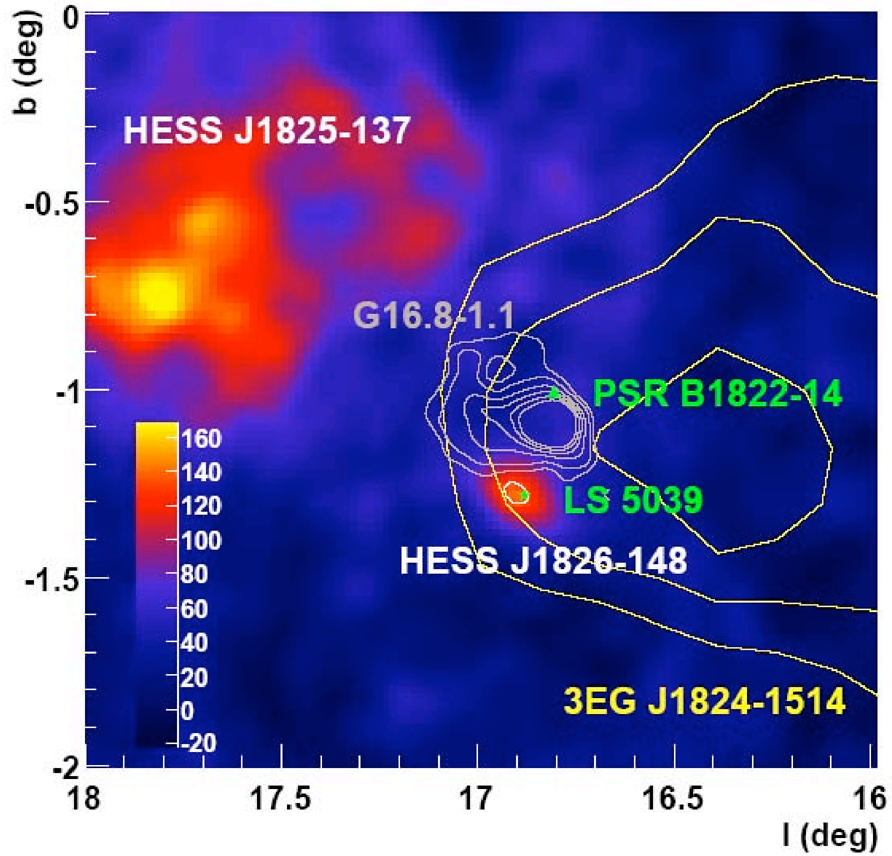
$$\rho_+^2 = r_+^2 + a^2\cos^2\theta$$

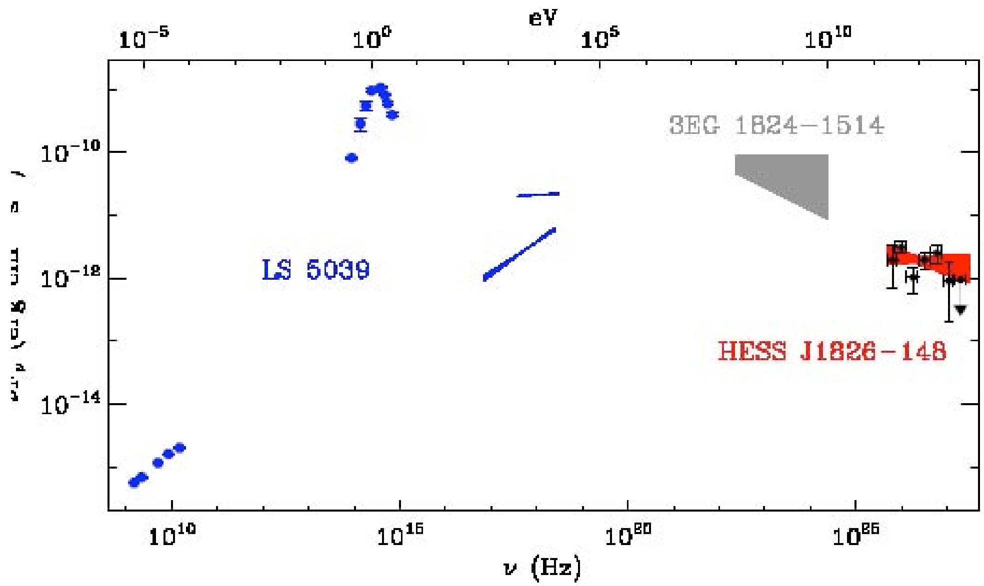
$$\Omega_+ \rightarrow \frac{a}{8M^2}$$ for a « M

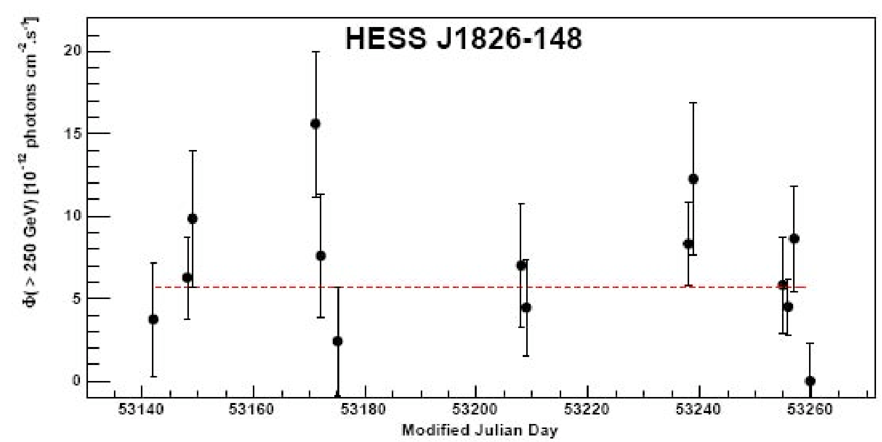
Generalizes monopole solution of BZ77 to a→M

$$\frac{d^2\mathcal{E}}{dAdt} \approx \frac{a\Omega_H}{r^2}(\frac{B_0}{2})^2\frac{\sin^2\theta}{\rho_+^2}$$

Microquasars as Gamma Ray Sources



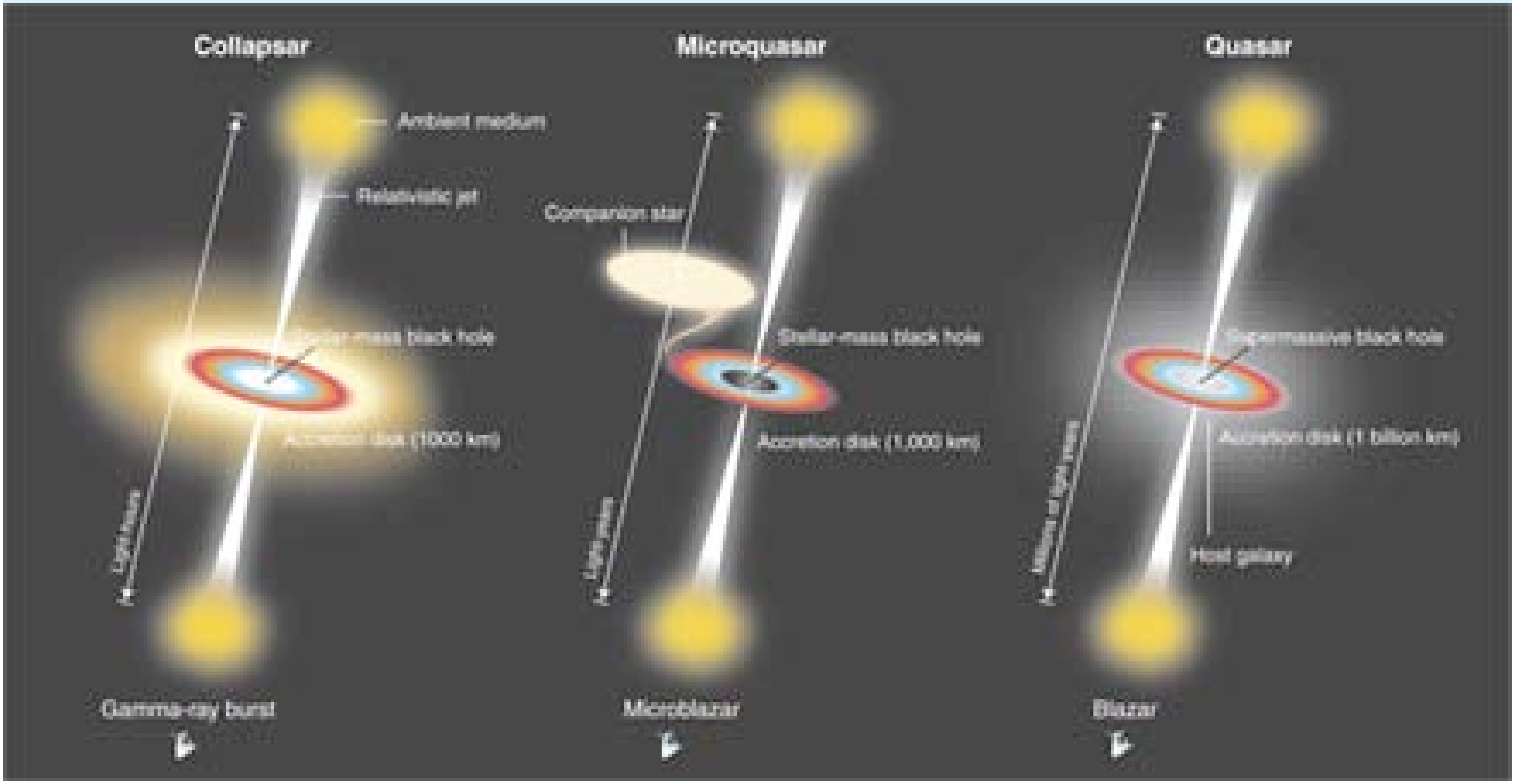




Microquasars known for ~11 years

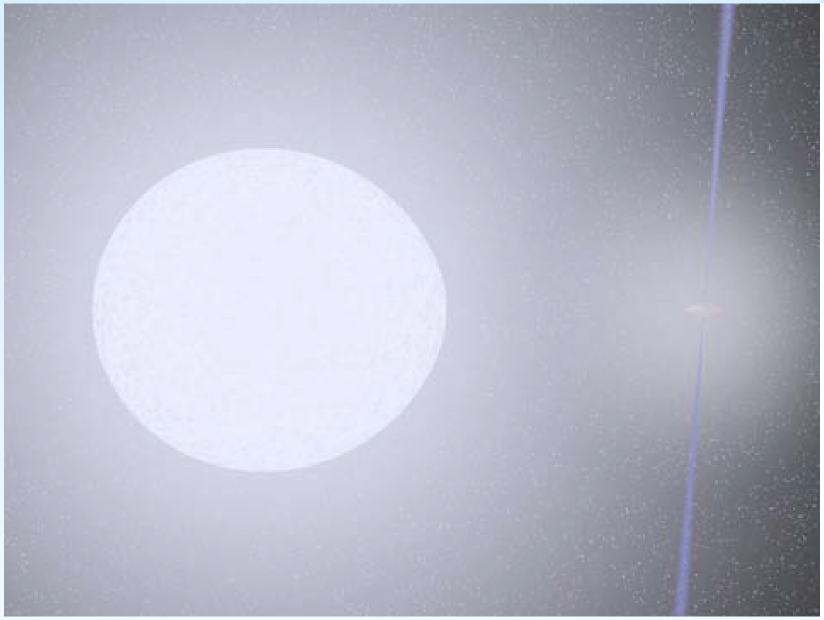
HESS detection of LS 5039

Gamma Rays from Jet Sources



Bread and butter physics

Model for High Mass Microquasars



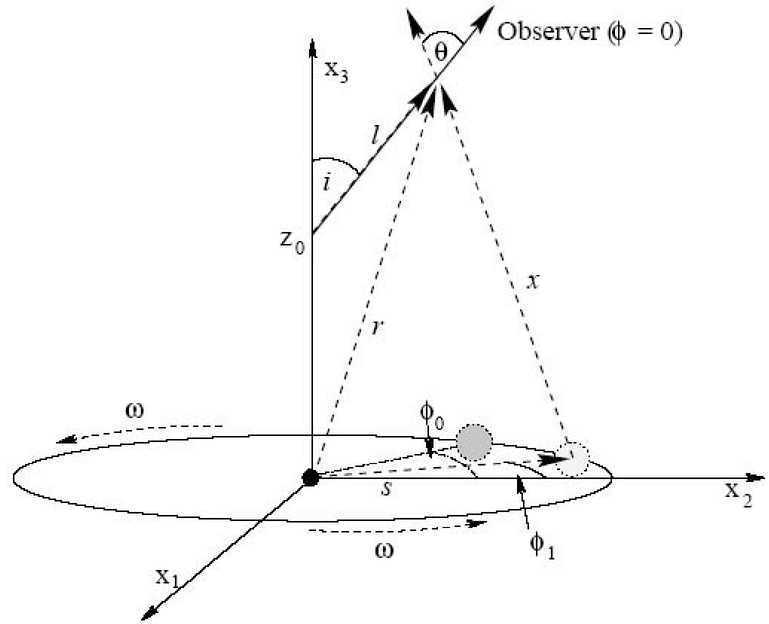
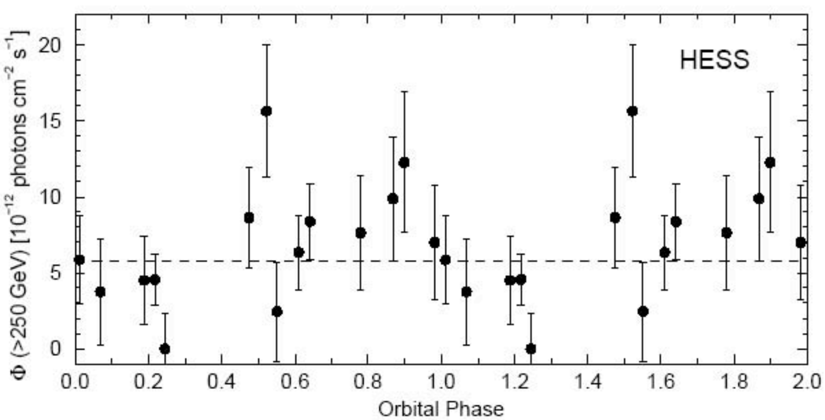


Fig. 1.— Geometry of the model. The direction of the radio jets defines the x_3 axis. The orbital plane of the binary system is the (x_1, x_2) plane, defined in such a way that line of sight towards the observer lies in the (x_2, x_3) plane, where the azimuthal angle $\phi = 0$.



O6.5V, 23 M_o primary

T = 39000 K (3.5 eV)

S = 2.5×10^{12} cm, i = 25°

Period = 3.91 days

Claimed orbital variations of TeV radiation

Phase-dependent γ–γ Opacity

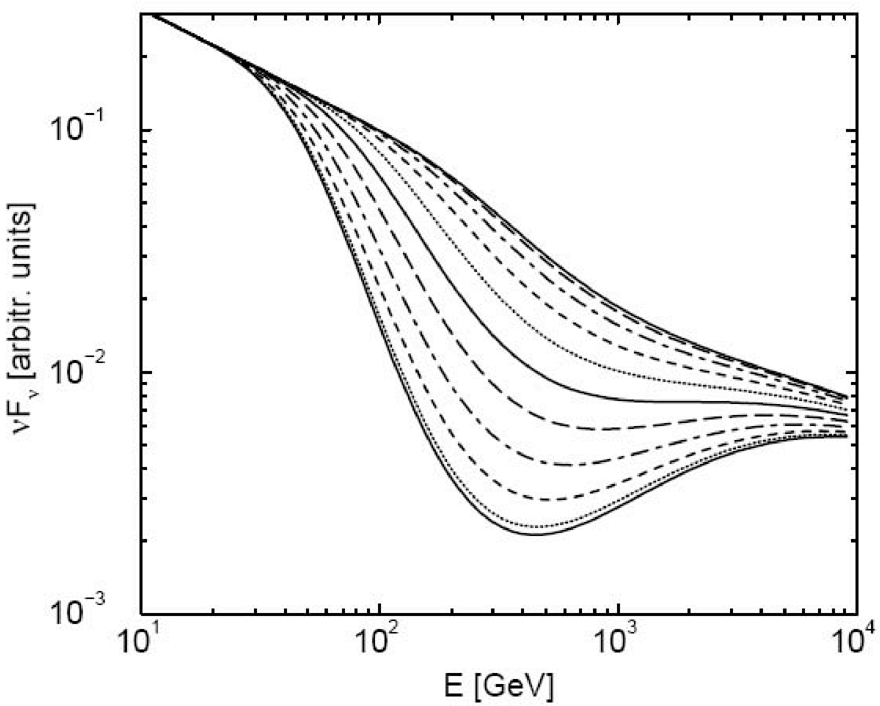


Fig. 2.— Orbital modulation of the expected $\gamma\gamma$ absorption trough, assuming a power spectrum with photon index $\alpha_{\rm ph} = 2.5$ and a photon production site at $z_0 = 10^{12}$ The different curves represent the escaping photon spectrum at various orbital phases, f $\phi_0 = 0$ (lowest curve) to $\phi_0 = \pi$ (highest curve) in steps of $\pi/10$.

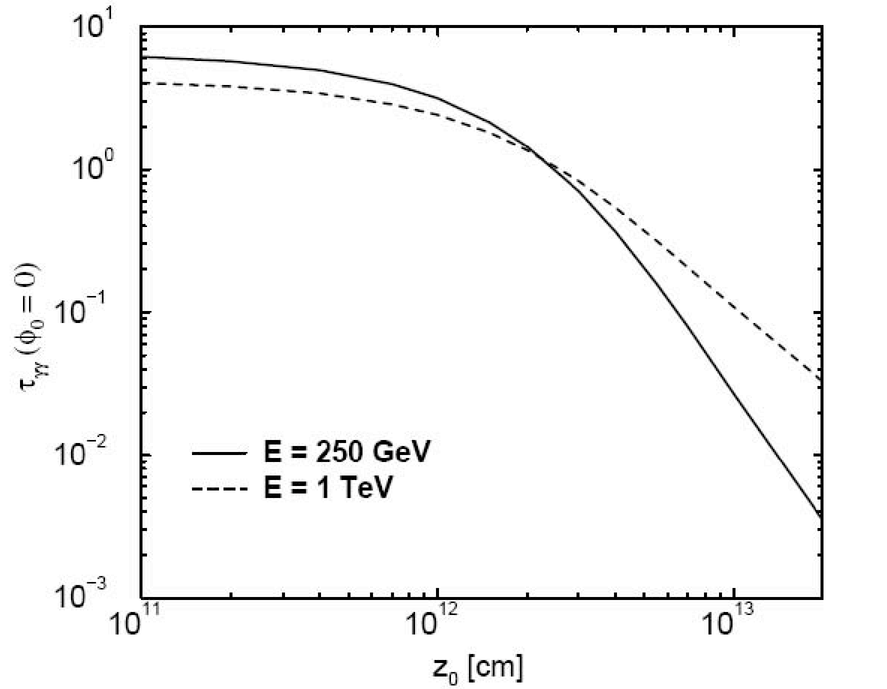


Fig. 3.— $\gamma\gamma$ opacity at 250 GeV and 1 TeV as a function of the distance of the photon production region from the central compact object at phase $\phi_0 = 0$. The figure illustrates that (1) VHE photons produced within a few $\times 10^{12}$ cm (i.e., of the order of the orbital separation of the binary system) would be subject to substantial $\gamma\gamma$ absorption; (2) the minimum of the absorption trough (maximum of $\tau_{\gamma\gamma}$ as a function of photon energy) is shifting towards higher energies for larger distances from the central source.

Spectral variations with phase

Opacity vs. location of gamma-ray production site

Predictions for TeV Telescopes

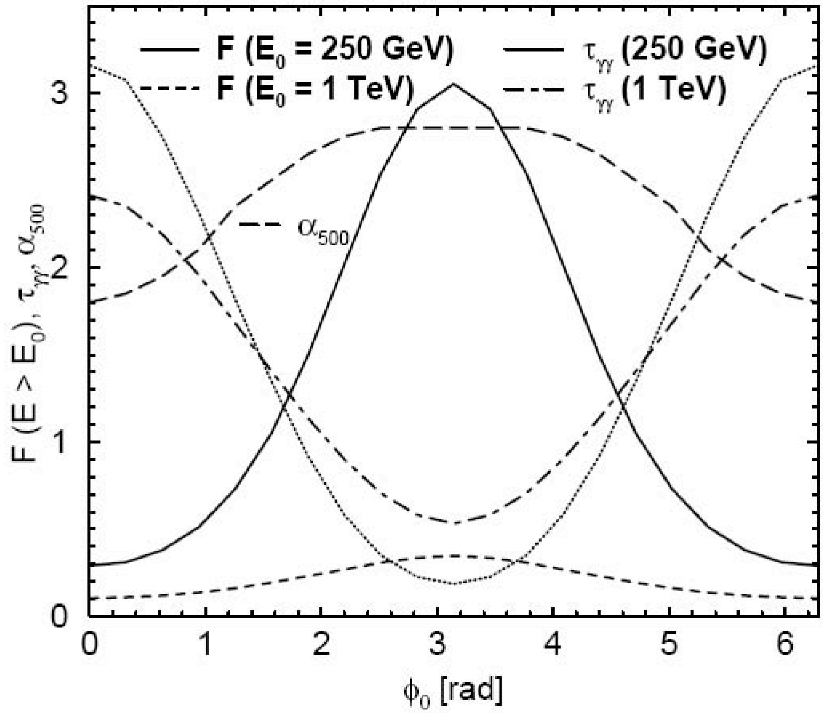
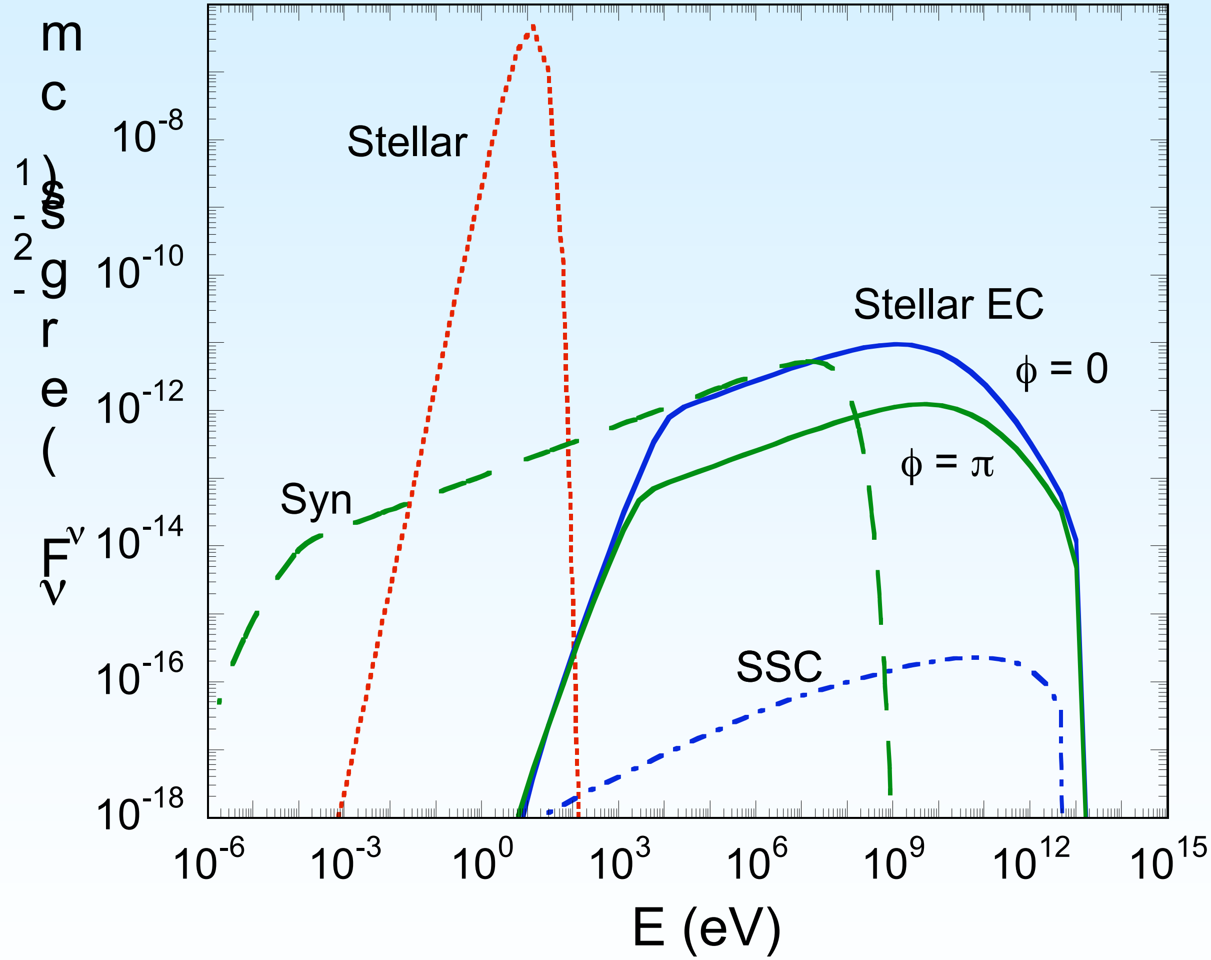


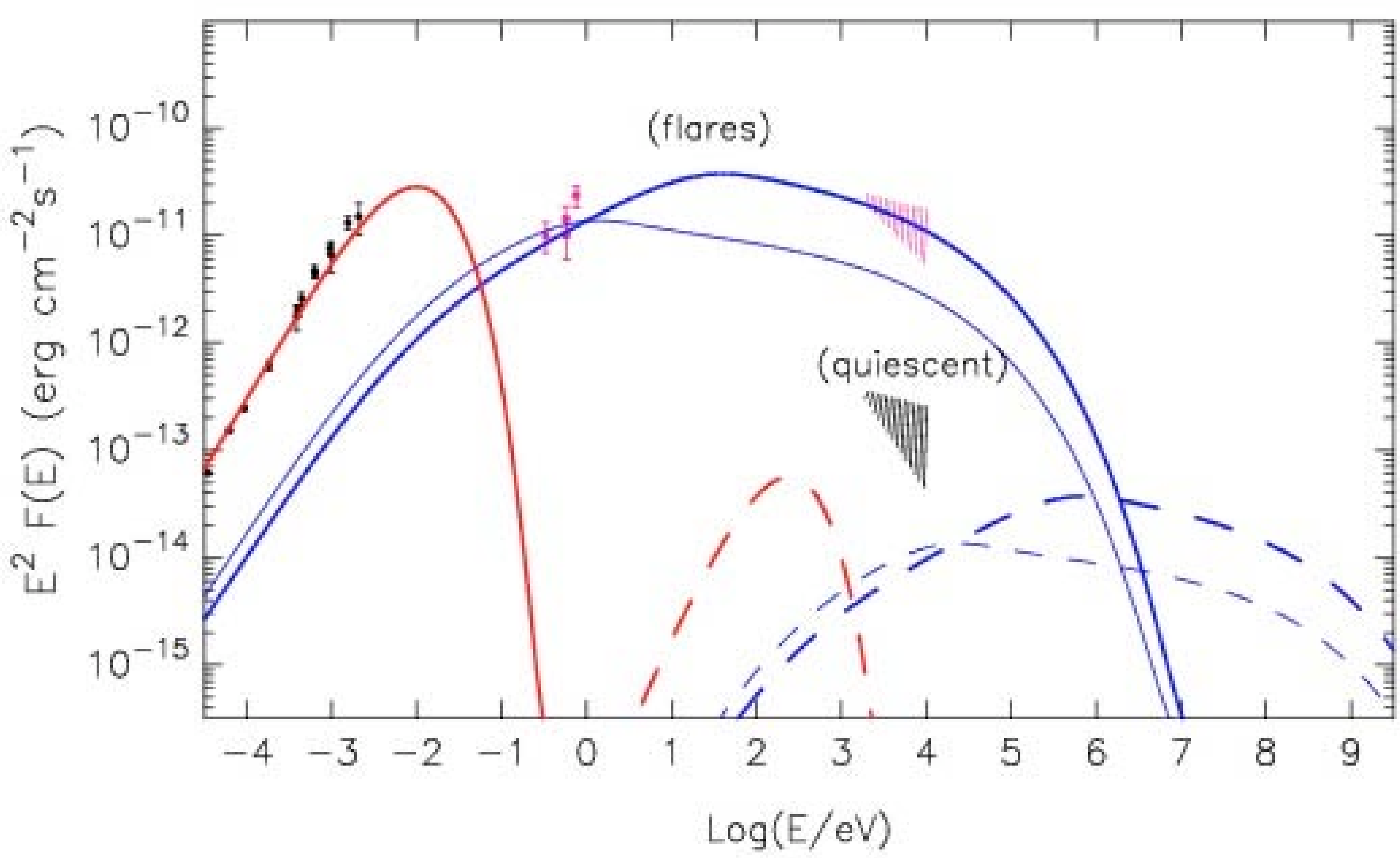
Fig. 4.— Orbital modulation of the integrated photon number flux above energies E_0 = 250 GeV (solid) and $E_0 = 1$ TeV (short-dashed), the $\gamma\gamma$ opacity at $E = 250$ GeV (dotted) and $E = 1$ TeV (dot-dashed), and the local photon spectral index α_{500} at 500 GeV (long-dashed). As in Fig. 2, an underlying power-law of photon index $\alpha_{ph} = 2.5$ and a photon production site at $z_0 = 10^{12}$ cm has been assumed. A periodic flux modulation is expected to be accompanied by positive spectral-index/flux correlation (spectral softening as the flux increases) at $E_0 \gtrsim 300$ GeV.

Multiwavelength Spectrum of Microquasars



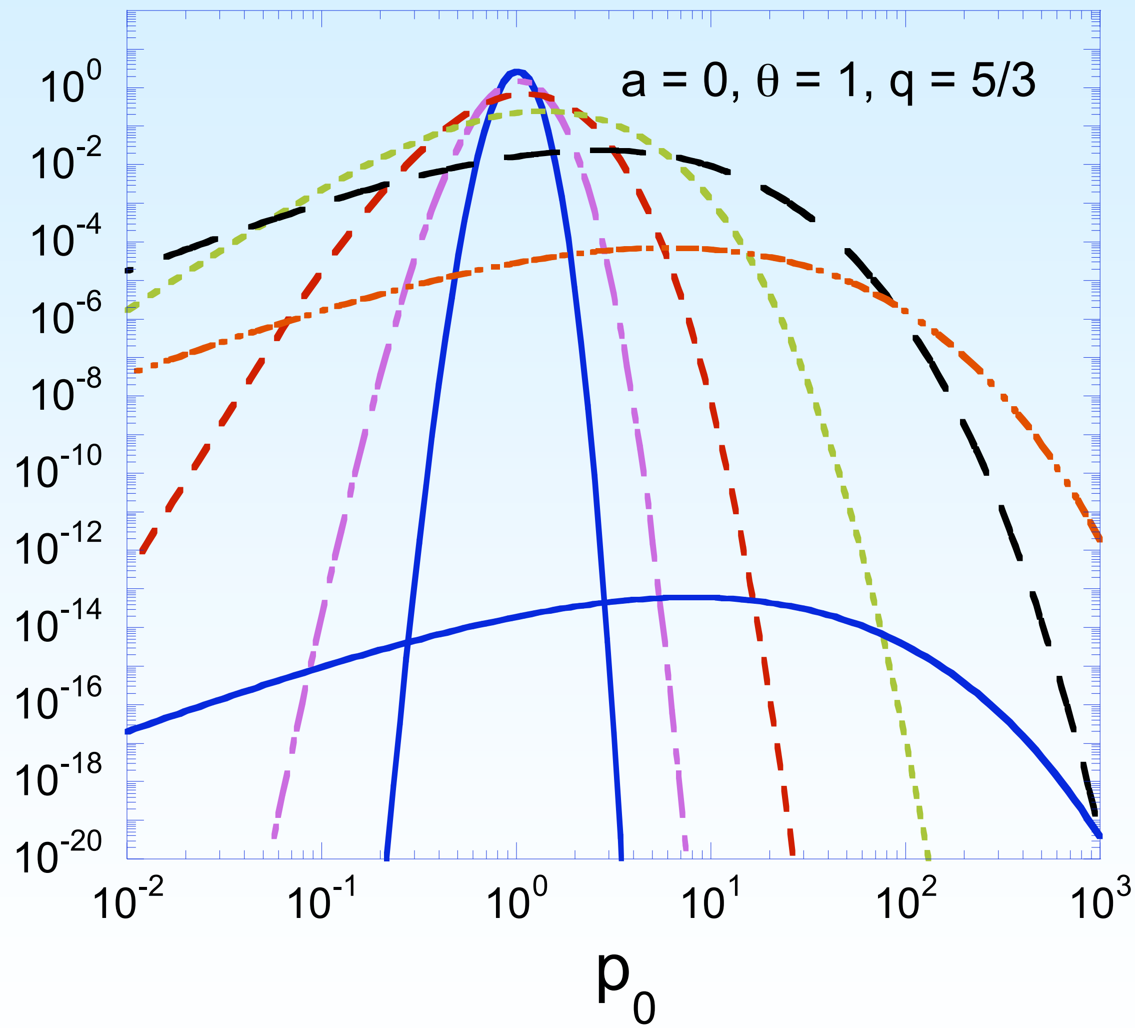
Spectral variations with phase both due to scattering kinematics and γ–γ absorption

Multiwavelength Emission from Sgr A*



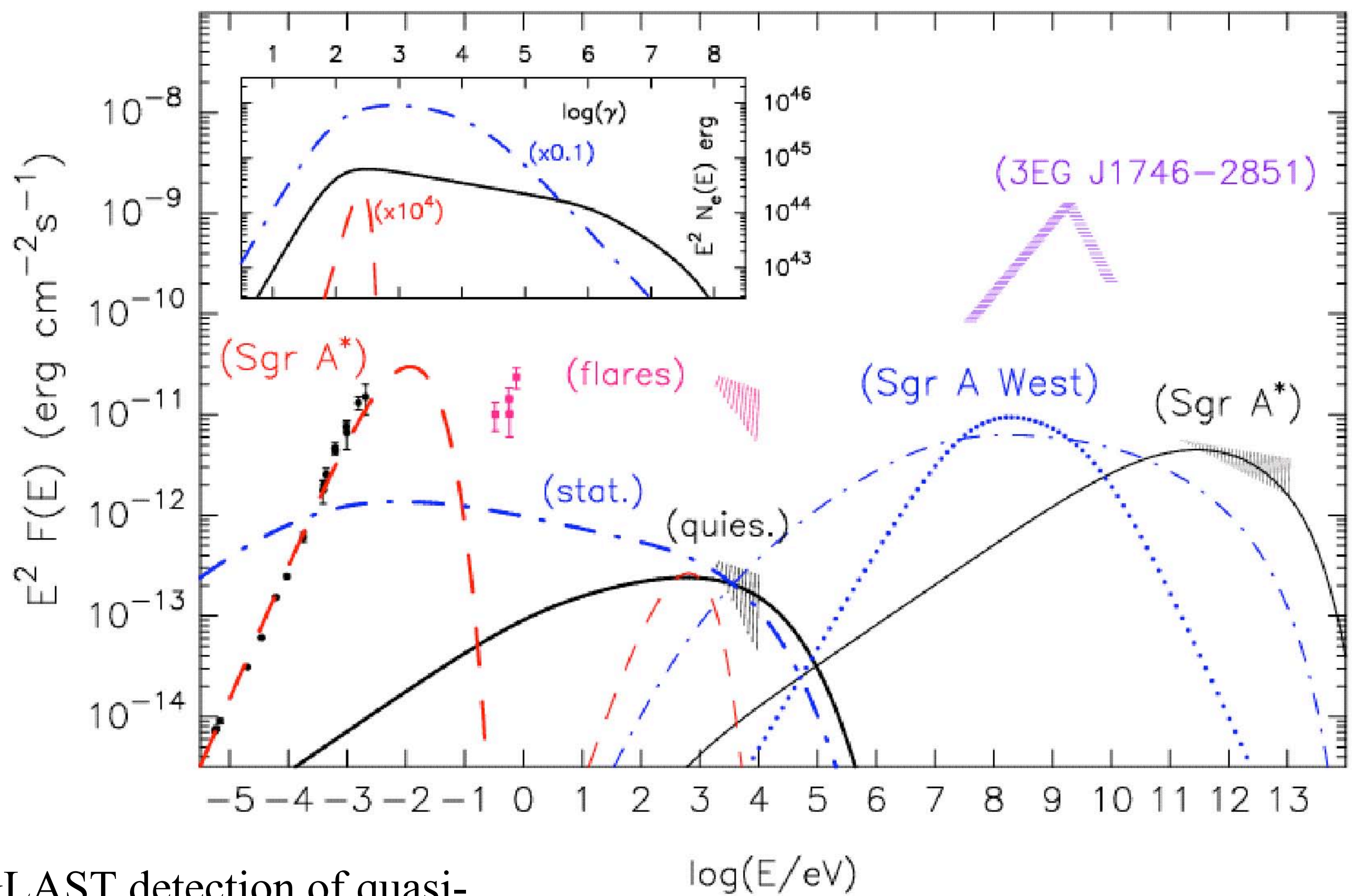
Very weak > 100 MeV γ-ray emission

Second-order Fermi acceleration



With Peter Becker (GMU) and Truong Le

Galactic Center Black Hole Emission:
Sgr A* ADAF + Black-Hole Plerion + Sgr A West, a black-hole remnant



Predict GLAST detection of quasi-stationary Compton and bremsstrahlung fluxes from pc-scale plerion.

Propagation of GeV electrons power Sgr A West EGRET emission from young pulsar