# 相対論的ジェット

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理論懇シンポ (基研)

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- BH天体に普遍的
  - GRB　　超相対論的
  - AGN（電波銀河）　　相対論的
  - AGN（セイファート）　　非相対論的
  - マイクロクェーサー　　準相対論的
- アクリションとの相関
  - エネルギー源は重力
  - 光学的に薄い高温プラズマに起源

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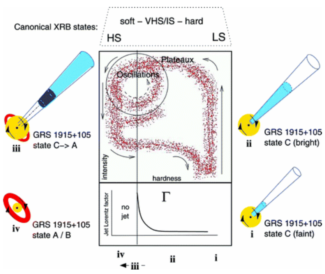
## Fender & Belloni (2004)
## 1915+105

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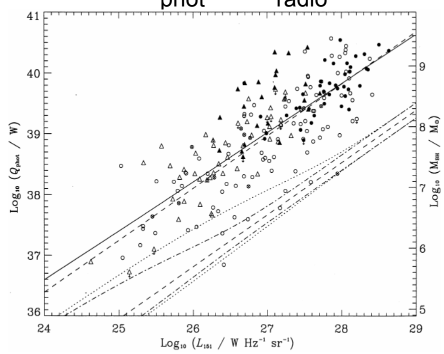
## Willott et al 1999
## $L_{phot}$ vs $L_{radio}$

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## AGNの相対論的ジェット

- モデル
  - 相対論的ビーミング
  - Synchrotron＋Compton（SSC+External)
  - 内部衝撃波＋外部衝撃波

    GRBとの対応　　Blazar ⇔ Prompt
    　　　　　　　　Cocoon ⇔ Afterglow
- 物理的性質
  - $\Gamma \backsim 10-30$
  - Particle Dominated　（ $U_{rel} \backsim (5\text{-}50)U_{mag}$ ）
  - 組成　（ e/p or $e^{\pm}$ ）
  - フレアの成因　（Γの時間変動にスケーリング）

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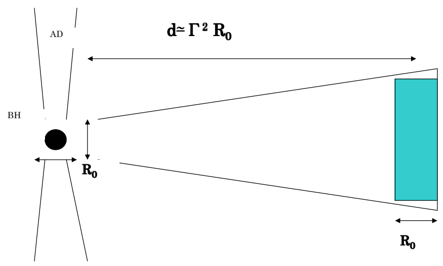
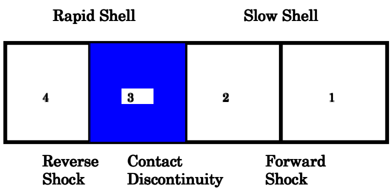
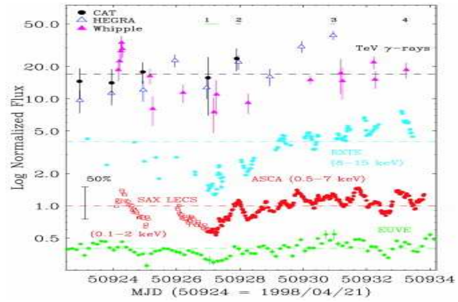


## Internal Shock Model




$$\eta \equiv \frac{\Gamma_m E}{m_s \Gamma_s + m_f \Gamma_f} = 1 - \frac{m_s + m_f}{\sqrt{m_s^2 + m_f^2 + 2 m_s m_f \Gamma_{rel}}}$$

## Mrk421 1998April
## Takahashi et al 1998




## Correlation with Γ

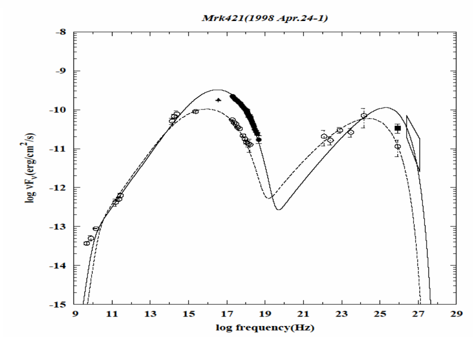
- $d \propto \Gamma^2$ フレアはより遠方で起こる
- $\delta \propto \Gamma$
- $R \propto \Gamma$ $\Delta t_{ob\,s}$ は変化せず
- $B \propto \Gamma^{-2}$
- $\gamma_{max} \propto \Gamma$
- $\gamma_{br} \propto B^{-2} R^{-1} \propto \Gamma^3$
- $\nu_{syn,\,max,\,ob} \propto B \gamma_{max}^2 \delta \propto \Gamma$
- $\nu_{syn,\,br,\,ob} \propto B \gamma_{br}^2 \delta \propto \Gamma^5$
- $\nu_{Com,\,max,\,ob} \propto \gamma_{max} \delta \propto \Gamma^2$

- $u_B \propto \Gamma^{-4}$ $L_{Poy} \propto \Gamma^2$ $(R_j \propto \Gamma^2)$
- $u_e \propto \Gamma^{-4}$ $L_{kin} \propto \Gamma^2$ $(R_j \propto \Gamma^2)$
- $u_{syn} \propto \Gamma^{-4}$ $L_{syn,\,ob} \propto \Gamma^2$ (s=2)
- $u_{ssc} \propto \Gamma^{-4}$ $L_{ssc,\,ob} \propto \Gamma^2$ (s=2)
- $u_{ext} \propto \Gamma^2 d^{-2} \propto \Gamma^{-2}$

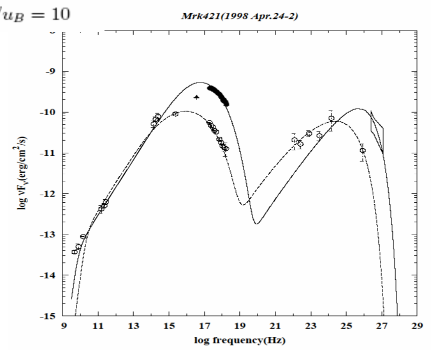
・ $f = \Gamma_f / \Gamma_q$ :single controlling parameter

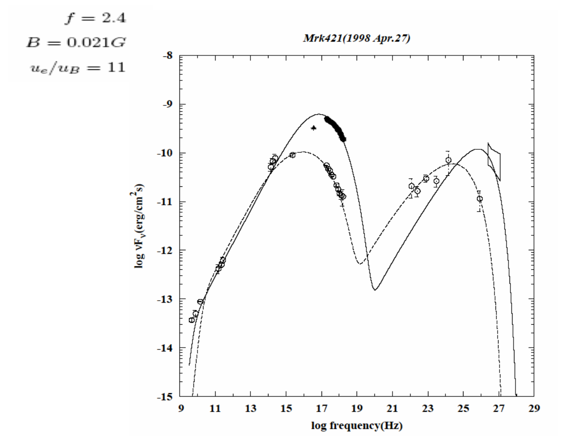
## Mrk421 Iwashimizu (Master Thesis 2002)

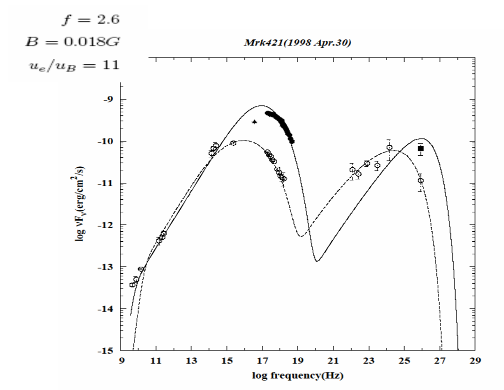
$f = 1.7$
$B = 0.042G$
$u_e/u_B = 8$

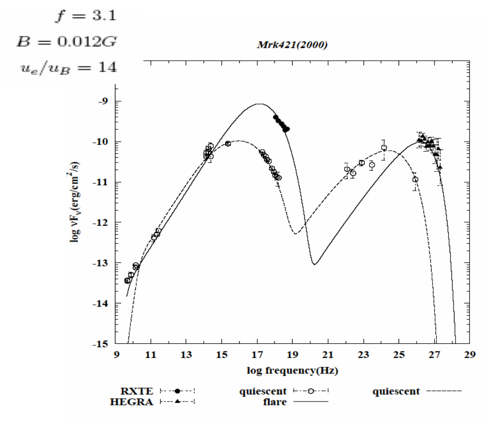



$f = 2.2$
$B = 0.025G$
$u_e/u_B = 10$

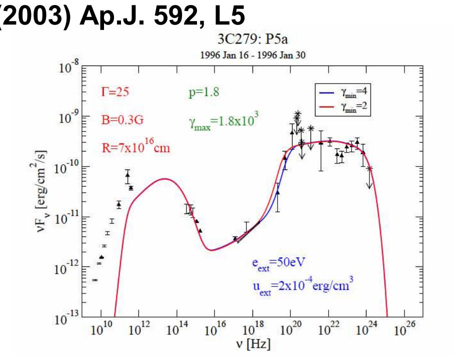


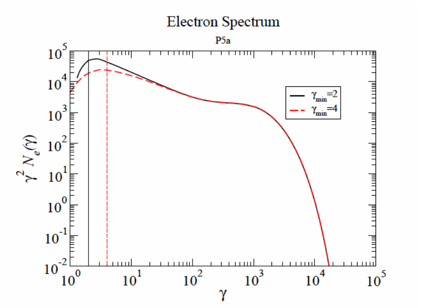


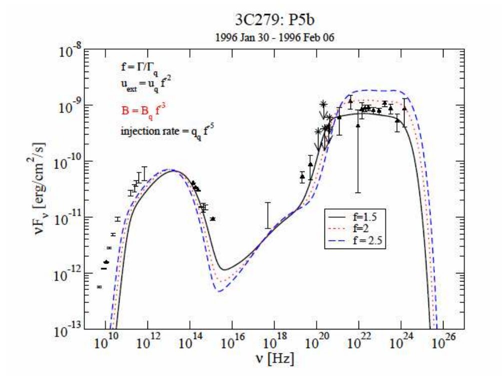



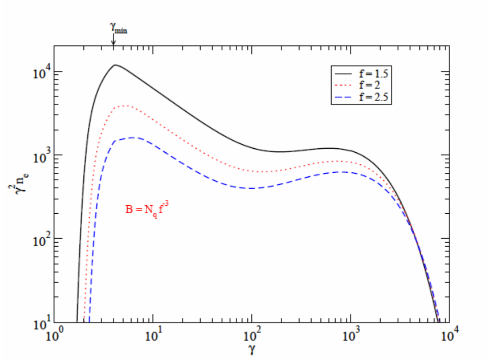




## 3C279 Kusunose, Takahara & Kato (2003) Ap.J. 592, L5



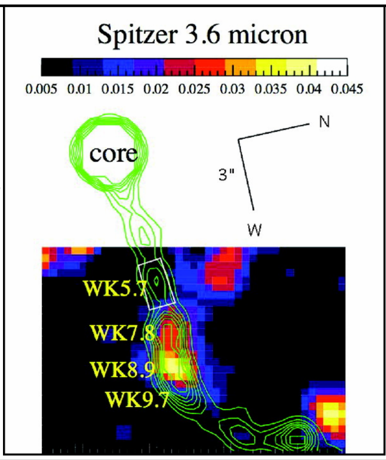



# 組成問題

- 運動学的光度からの制限(e.g. Hirotani )
- 電波の偏光度(e.g. Wardle)
- 衝撃波力学と輻射との整合性(Kino & F.T.)
  いずれも電子陽電子対優勢を示唆
- Bulk Compton 問題(Sikora)
  - 外部光子のバルクコンプトンによるジェットの減速
  - 軟X線(Blazar),赤外線(kpc scale)に強い成分

  これらが観測されないことは慣性として陽子成分優勢を示唆

PKS0637−752
Utiyama et al.
Ap.J.L. 631, L113




# 形成機構:光学的に薄い高温のアクリシションプラズマに起源

$$L_{tot} = \eta \dot{M}_{acc} c^2$$
$$L_{kin} = \Gamma \dot{M}_{jet} c^2$$
$$\dot{M}_{jet} < \frac{\eta}{\Gamma}\dot{M}_{acc} \approx 10^{-2} \sim 10^{-3}\dot{M}_{acc}$$

解放されたエネルギーをごく一部の物質に集中させる

表層物質: 多くの場合脱出速度程度

電子陽電子対プラズマ: 相対論的速度の可能性

# Wien Fireball
## Iwamoto & Takahara

(2002) Ap.J.565,163 (2004)Ap.J.601,78
浅野講演

- Wien equilibrium at relativistic temperature $\theta_0$ with Thomson thickness $\tau_0$
- $L/L_{edd}=72(R_0/R_g)(m_e/m_p)\Gamma_0^3\theta_0\tau_0$ $=0.144\tau_0\theta_0$
- $\Gamma_\infty=4\theta_0$
- $L_{kin}=(2/3)L$

- Annihilation problem is avoided because of relativistic photospheric temperature
- Radiation drag problem is avoided because radiation field is also relativistically beamed
- Strong MeV emission from the photosphere is predicted

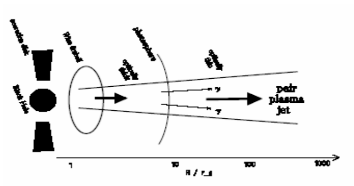


FIG. 1.—Schematic diagram of a pair plasma flowing out from the optically thick regime to the thin one. In the optically thick regime, pairs and photons behave as a single fluid and expand together. In the optically thin regime, photons stream out almost freely from the photosphere, and pairs and photons do not form a single fluid any longer.

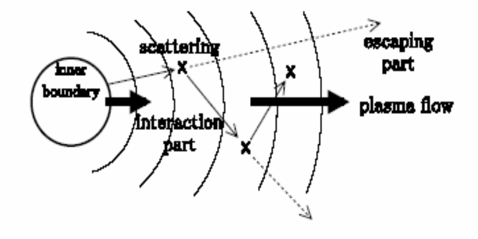
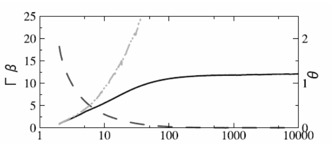



FIG. 2.—Schematic picture of the trajectory of a simulated photon propagating in the pair plasma outflow. Since the flow and photon distribution are highly nonuniform, the spatial region divides into many spherical shell elements.



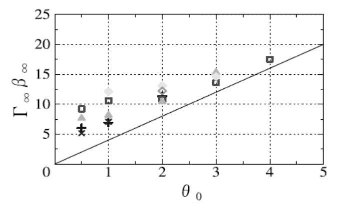


FIG. 12.—Terminal Lorentz factor $\Gamma_\infty\beta_\infty$. The abscissa is the temperature at the boundary $\theta_0$. The configuration of the symbols is the same as in Fig. 9.

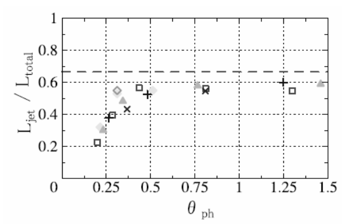


FIG. 13.—Ratio of the terminal kinetic luminosity of pairs to the total luminosity. The abscissa is the photospheric temperature. The configuration of the symbols is the same as in Fig. 9, and the dashed line denotes the canonical value of $\frac{2}{3}$.

# Summary

- **Successes**
  - **Internal Shock Scenario**
  - **Leptonic Scenario（Synchrotron & Compton：One－Zone Model）**
  - **Γ as the unique controlling parameter for flare events**
  - **Thermal acceleration (Wien fireball) as a promising jet formation mechanism**

- **Problems & Prospects**
  - **Beyond one–zone model**
    - **Seed photons for Compton scattering**
    - **Connection with VLBI jets （Spine－Sheath　Structure. . ）**
    - **....**
  - **Missing Emission Components**
    - **MeV emssion (residual fireball, bremsstrahlung of thermal shocked plasma)**
    - **Sub-TeV emission (electron spectra, pair absorption against IR background)**
    - **Sub-MeV emission (low energy cutoff, amount of thermal pairs)**
    - **.....**
  - **Composition Determination (Normal plasma or Pair Dominated?)**

# 赤外線背景放射への制限

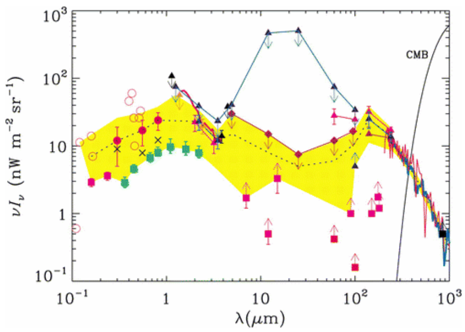
Tev Blazars

- Mrk421 z=0.031
- Mrk501 z=0.034
- 1ES2344+514 z=0.044
- 1ES1959+650 z=0.047
- PKS2005-489 z=0.071
- PKS2155-304 z=0.117
- H1426+428 z=0.129
- H2356-309 z=0.165
- 1ES1101-232 z=0.186

# Pair Absorption

- **$\gamma + \gamma \rightarrow e^+ + e^-$**
- **$E_{th}=m_e^2c^4/E=0.25(TeV/E)eV$**
- **観測結果**
  - **A few TeVまでHard Spectrum**
  - **SourceではdivergingTeV？　　TeV Crisis**
- **解釈**
  - **異常な電子スペクトル(Pile up)**
  - **CIB強度が非常に低い （Number Countでほぼ尽くされている）**

## Hauser & Dwek ARAA 2001




## Kato, Kusunose & Takahara Ap.J accepted 2005

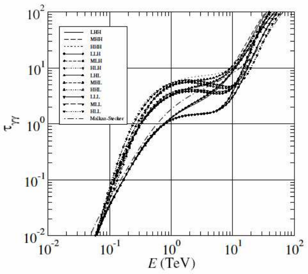
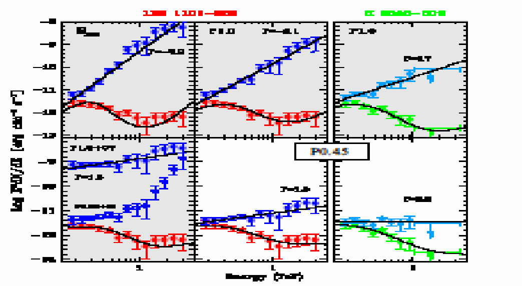



Fig. 1.— Optical depth calculated by the EBL models of Dwek & Krennrich (2005). The γ-ray energy in the observer's frame is denoted by $E$. The redshift of the γ-ray source is assumed to be 0.129. The optical depth calculated by Malkan-Stecker model is also shown for comparison (*dot-dashed*).

# HESS（



## Kato, Kusunose & Takahara 2005

Observed Frame　　Source Frame

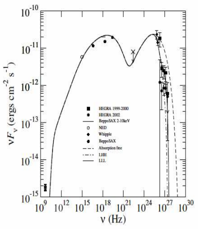



Fig. 2.— SED of H1426+428 and model spectra with different EBL models. Data obtained in 2002 by HEGRA are also shown for reference. The absorption free SED model is shown by a dashed line. The SEDs corrected by EBL models [LHH (*dot-dashed*) and LLL (*solid*)] are also shown.

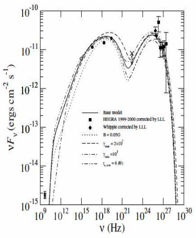



Fig. 5.— SED models calculated by different parameter values. Data from Whipple and HEGRA 1999-2000 are corrected by $\exp(\tau_{\gamma\gamma})$ with an EBL model, LLL. Base model denotes the SED shown in Fig. 2 by the dashed line.

## H1426+428 best fit

- B=0.1G
- Γ=20
- R=$10^{16}$cm
- $\gamma_{max}=10^7$
- **$u_e/u_{mag}$=188**
  - **Mrk421などより1桁大きい**
- **赤外線背景放射は低強度（ほぼ銀河計数で与えられるものと一致）である。**
- **強い赤外線背景放射を予言する宇宙論シナリオは否定される**