Gamma-ray emission from mini radio lobes

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Abstract:
We investigate gamma-ray emission associated with parsec size radio lobes in active galactic nuclei (AGN). Here we focus on two possible emission regions. (I) The lobes are composed of shocked jet plasma and expected to be filled with high energy particles. We calculate the photon spectra from the lobes including hadronic processes. Proton synchrotron component arises at ~MeV band. The synchrotron emission radiated from secondary $e^{\pm}$ pairs produced via photo-meson cascade emerges in ~GeV-TeV energy ranges. (II) We explore Inverse-Compton (IC) emission from the surrounding mini-shell composed of shocked ambient matter. Since IC emission due to dense photon-field near the AGN core is brighter while synchrotron one is dim at a mini-shell, it may be a new class of radio-dark TeV-gamma emitter.

Introduction

The progress of VLBI observations reveal the existence of mini radio lobes in radio-loud active galactic nuclei those are understood as young progenitor of large radio galaxies Recent investigations shed light on the existence of mini radio lobes with LS~O(10 pc) (e.g., Orienti et al. 2008, Stawarz et al. 2008; Ostorero et al .2010, Nagai et al. 2010). High energy emissions are one of the most important keys for understanding the physics of particle accelerations in young AGN jets. Here we newly explore (1) hadronic emission from mini-lobes taking account of *pγ* interaction, and (2) IC emission from mini-shell embedded in IR photon field due to a dust-torus.

Model

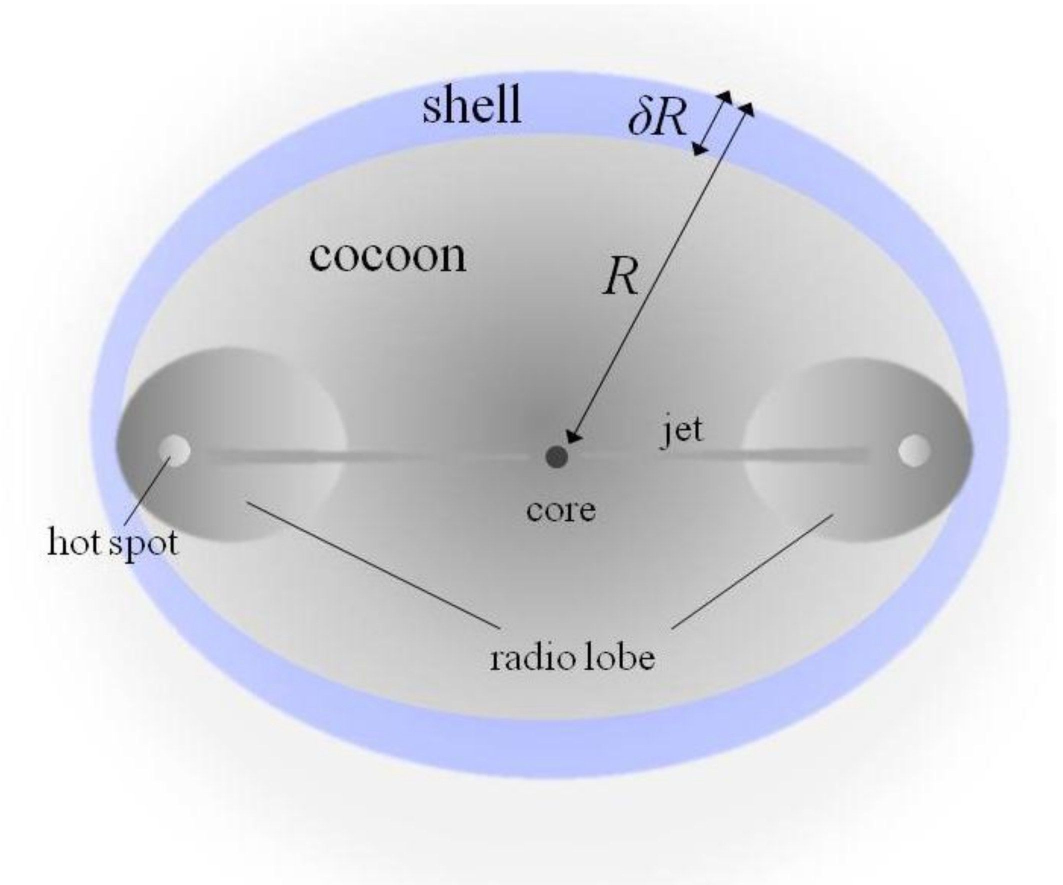

Fig. 1
A cartoon of mini radio lobes immersed in radiation field due to the accretion disk. Here we focus on a mini lobes and associated a mini-shell with R=10pc.

(I) Model of mini-lobes

The accelerated protons at the hot spots escape from the spot and they fill the mini lobes together with relativistic electrons. The model parameters of mini-lobes as follows For Gyro-factors, we set $\xi_e=\xi_p=1\times10^2$ .The injection indices are assumed as s=2 both for electrons and protons. The radii of the lobe and the hot spot radius are respectively R_{lobe}=2 pc, R_{hs} = 0.3 pc. The magnetic field strength and lobe expansion velocity is B=0.1G, v_{exp}= 0.1c, respectively. Luminosities and temperature of the accretion disk are assumed as $L_{disk}=3\times10^{45}$ erg/s, and kT_{disk}=10 eV. $L_p=5\times10^{46}$ erg/s.),

The following physical processes are included : photo-pion production from protons and neutrons ($p+\gamma\rightarrow p/n+\pi^0/\pi^+$), pion and muon decays ($\pi^0\rightarrow2\gamma$), ($\pi^{\pm}\rightarrow\mu^{\pm}+\nu$), ($\mu^{\pm}\rightarrow e^{\pm}+\nu$), photon-photon pair production ($\gamma+\gamma\rightarrow e^++e^-$), Bethe-Heitler pair production ($p+\gamma\rightarrow p + e^+e^-$), synchrotron and inverse Compton processes of charged particles, synchrotron self-absorption for e^+e^- pairs, and adiabatic expansion loss.

(II) Model of mini-shells

The expanding cocoon is highly overpressured against the ambient ISM/ICM and a strong shock is driven and shocked ambient matter forms the thin shell around the cocoon. We explore the non-thermal emissions as an extension of the previous work of Ito et al. (2011.)
The model parameters are shown below tables. Here we include synchrotron and inverse Compton of IR photon from dust-torus and adiabatic expansion loss.

Table 1. Parameters of Shell and Ambient Matter

parameters	symbols	values
mass density of ambient matter	ρ_0	$0.1m_p$ cm^{-3}
magnetic field strength in ambient matter	B	10 μG
fraction of non-thermal electrons	$\epsilon_{e,shell}$	0.05
Distance from core to shell	R	10 pc
luminosity of IR emissions from dust-torus	L_{IR}	1×10^{45} ergs s^{-1}
power-law index of injected electrons (shell)	p_{shell}	2
gyro-factor	ξ_{shell}	1
distance	D	1000 Mpc

Table 2. Parameters of Jet and Lobe

parameters	symbols	values
jet power	L_j	5×10^{46} ergs s^{-1}
B energy fraction	$\epsilon_{B,lobe}$	0.1
fraction of non-thermal electrons	$\epsilon_{e,lobe}$	0.1
power-law index of injected electrons	p_{lobe}	2.2
gyro-factor	ξ_{lobe}	10^7

(I) Hadronic emission from min radio lobe

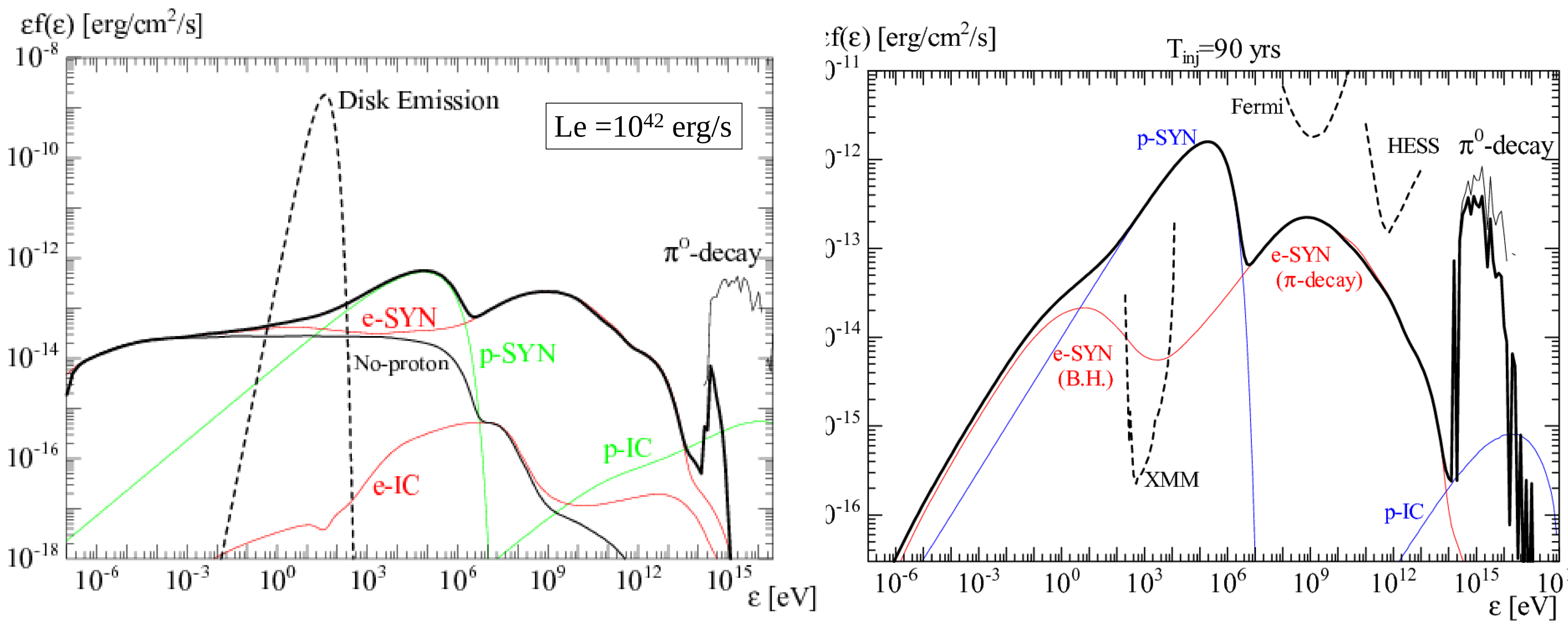

Fig.2 Left: Predicted photon spectrum from the mini radio lobe for $L_p=5\times10^{46}$ erg/s $L_e=1\times10^{42}$ erg/s and $L_{disk}=3\times10^{45}$ erg/s (the thick solid line). The thin solid line presents the case for no-proton injection. Right: Same as the left one but for purely proton injection.. The lobes are located at the distance D=100 Mpc. The proton synchrotron bump sub MeV and the secondary pair's synchrotron bump appears at ~GeV .

Results

Fig. 2 shows the resultant photon spectra from the mini lobes.
(1) The bump at ~PeV is the emission due to the π^0 decay photons (thin solid line). They are partially escaped from the lobe (thick solid line) without intrinsic $\gamma\gamma$ absorption.
(2) The proton synchrotron (p-SYN) component arises at sub MeV. Below ~keV, the synchrotron emission from the primary electrons overwhelms the proton component.
(3) The synchrotron emission from secondary $e^{\pm}$ pairs (e-SYN-sec.-pair) which are produced via cascade processes emerges in ~GeV-TeV.

Summary

The hadronic-origin two-bump at ~MeV and ~GeV is newly predicted from the mini lobe. The hadronic emission can be dominated in γ-ray bands when the primary emission is not very bright. Especially, high energy tail of GeV bump could be detected by CTA. (Kino & Asano 2011)

(II) IC emission from mini-shell (preliminary)

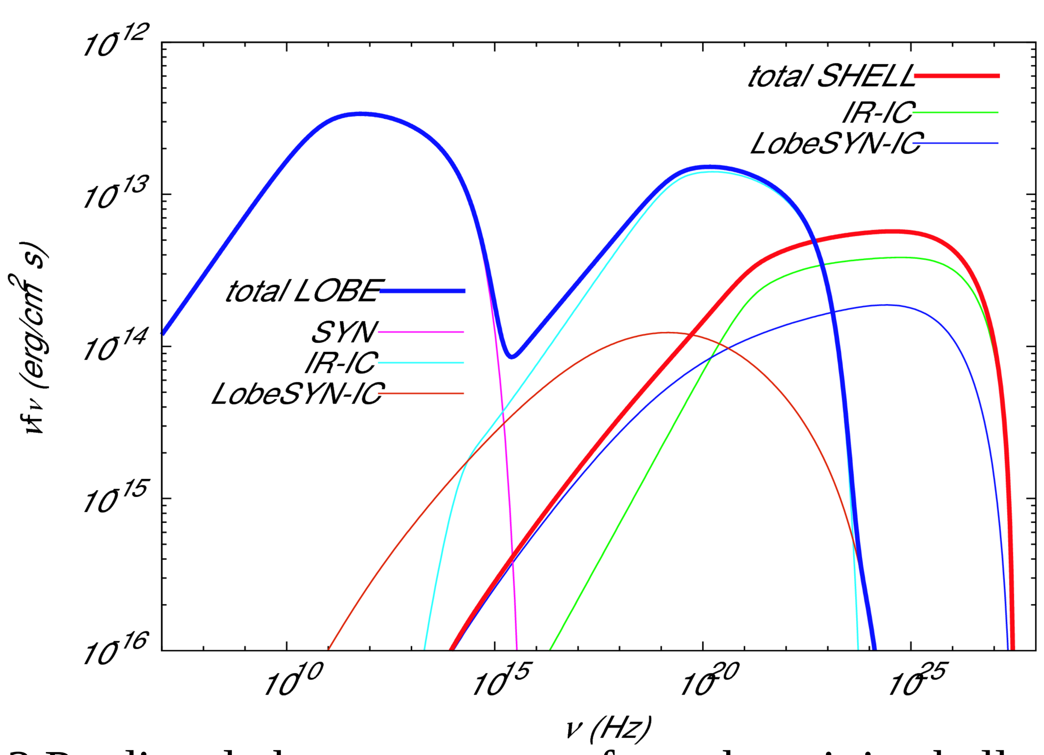

Fig.3 Predicted photon spectrum from the mini –shell with R=10pc. Model parameters are shown in the above . The lobes are located at the distance D=1000 Mpc. .

Results

Fig. 3 shows the resultant photon spectrum from the mini shell. The synchrotron emission from radio lobe is dominant below optical energy band. The mini-shell is radio-dark. Interestingly, at GeV gamma-ray band, the emissions from the lobe and the shell are comparable and produce the sharp break ~ 10^23 Hz spectrum. In TeV gamma energy range, the shell IC emission of IR photons from the dust-torus is dominant.

Summary

We show that the mini-shell associated with the mini-lobes is interesting targets for current and near-future high energy detectors. Therefore, the mini-shel l may be a new class of radio dark TeV emitter (Kino, Ito & Kawakatu *in prep*.)

Reference

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