Modeling Intermediate BL Lac Objects detected by VERITAS

Markus Boettcher (Ohio University)

Abstract: Modeling implications of recent VERITAS discoveries of Intermediate BL Lac Objects (IBLs) are presented. Leptonic jet models for the IBLs W Comae (z = 0.102) and 3C66A (z = 0.444?) are, in principle, viable with only synchrotron and synchrotron-self Compton (SSC) components, but more plausible parameters can be achieved including an external infrared radiation field as source for Compton upscattering to produce the observed VHE γ-ray emission. The unknown redshift of PKS 1424+240 makes a theoretical interpretation difficult. A pure SSC model seems to be sufficient to represent its SED, and modeling results favor a low redshift, z ≤ 0.1.

Introduction

Until about 3 years ago, all blazars detected at very-high-energy (VHE: E > 100 GeV) γ-rays were High-Frequency Peaked BL Lac Objects (HBLs). However, the recent VHE discoveries of blazars belonging to the lower-peaked blazar types of Intermediate (IBLs) and Low-frequency (LBL) peaked BL Lac objects and even the flat-spectrum radio quasar (FSRQ) 3C279 suggest that most blazars are intrinsically emitters of VHE γ-rays.

When interpreted in terms of leptonic jet models, the classical TeV blazars (HBLs) can generally well be fit with pure synchrotron-self-Compton (SSC) models, while FSRQs and LBLs required external radiation fields as sources for Compton scattering to produce the observed (MeV – GeV) γ-ray emission. With the detection of non-HBL VHE blazars, a critical question for their model interpretation is whether all VHE blazars are still SSC dominated, while non-VHE blazars are external-Compton (EC) dominated, or whether the new classes of VHE blazars also require EC components, as expected for FSRQs and LBLs.

Based on the recent detections of the IBLs W Comae, 3C66A, and PKS 1424+240 by VERITAS, I am here presenting and comparing modeling results of the simultaneous SEDs of these new VHE blazars.

The Model

For modeling the SEDs of the three IBLs detected by VERITAS, a time-independent leptonic jet model is used. The radio-through soft X-ray emission is interpreted as synchrotron emission from relativistic electrons in a spherical emission region, moving relativistically along the jet, closely aligned with the line of sight. The γ-ray emission is produced as Compton emission from the same electrons, up-scattering either their own synchrotron photons (SSC), or photons from an external photon field (EC). The nonthermal electron distribution in the emission region is determined self-consistently as an equilibrium between injection of a power-law distribution, radiative cooling, and escape.

W Comae

The IBL W Comae was detected in VHE γ-rays by VERITAS during observations around a major flare on March 14, 2008. The simultaneous SED obtained during that time is shown in Fig. 1, along with model fits.

The solid curve shows a pure SSC fit to the SED. While it seems to represent the SED reasonably well, it requires an implausibly low magnetic field of B = 0.007 G, which is about a factor of 20 lower than corresponding to equipartition with the nonthermal electron distribution.

Alternatively, the γ-ray emission can be reproduced with an external-Compton component. However, this can only be efficient of Compton scattering out to > 100 GeV energies can occur in the Thomson regime. This requires seed photons to have energies $h\nu_s$ ~ 0.1 – 1 eV, which could plausibly represent photons from a near-central warm dust torus. Adopting a model including an IR-EC component, as shown by the dashed curve in Fig. 1, allows the choice of a magnetic field of B = 0.25 G, in exact equipartition with the nonthermal electron distribution.

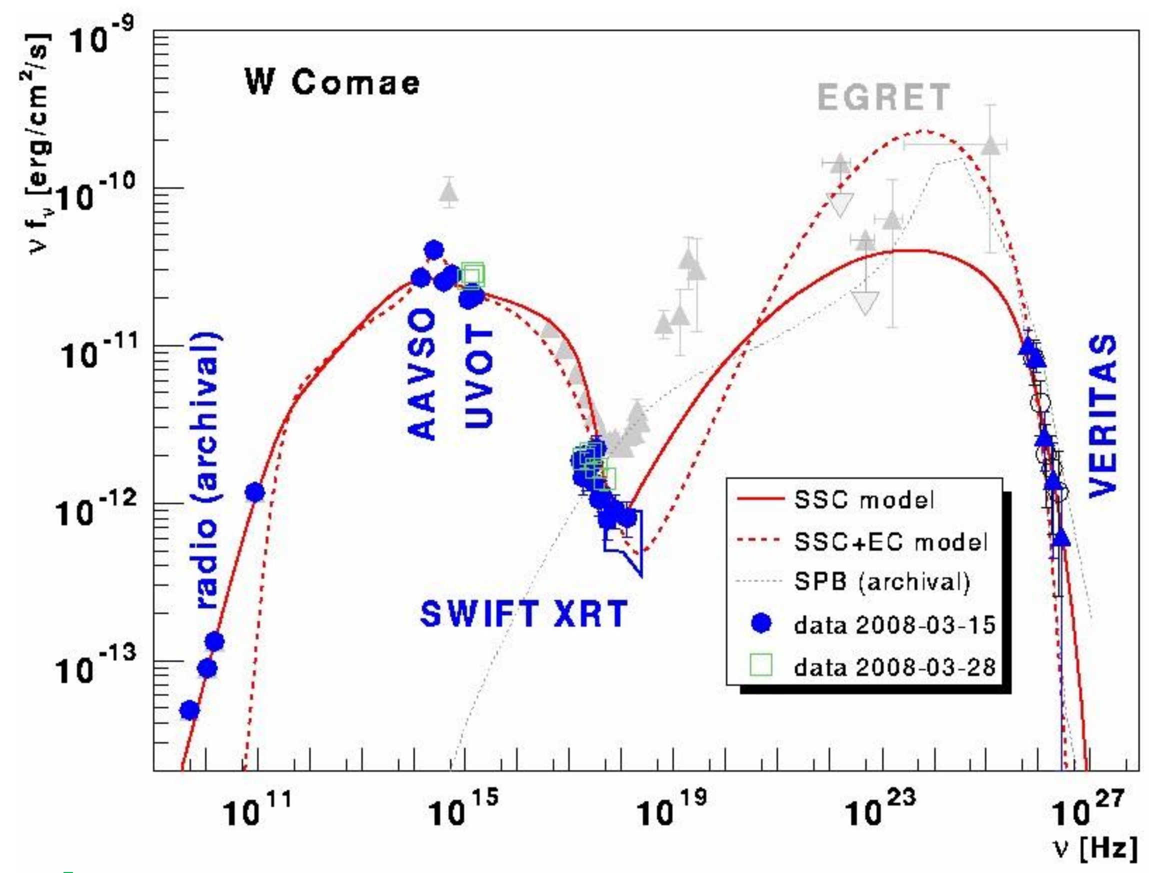

Fig. 1: *Fits to the SED of W Comae during its initial VERITAS detection in March 2008 (Acciari et al. 2008).*

W Comae was again the target of coordinated multiwavelength observations during a major γ-ray flare in October 2008. The SED and model fits are shown in Fig. 2, and the conclusions from the modeling results are consistent with the ones found during the March 2008 flare.

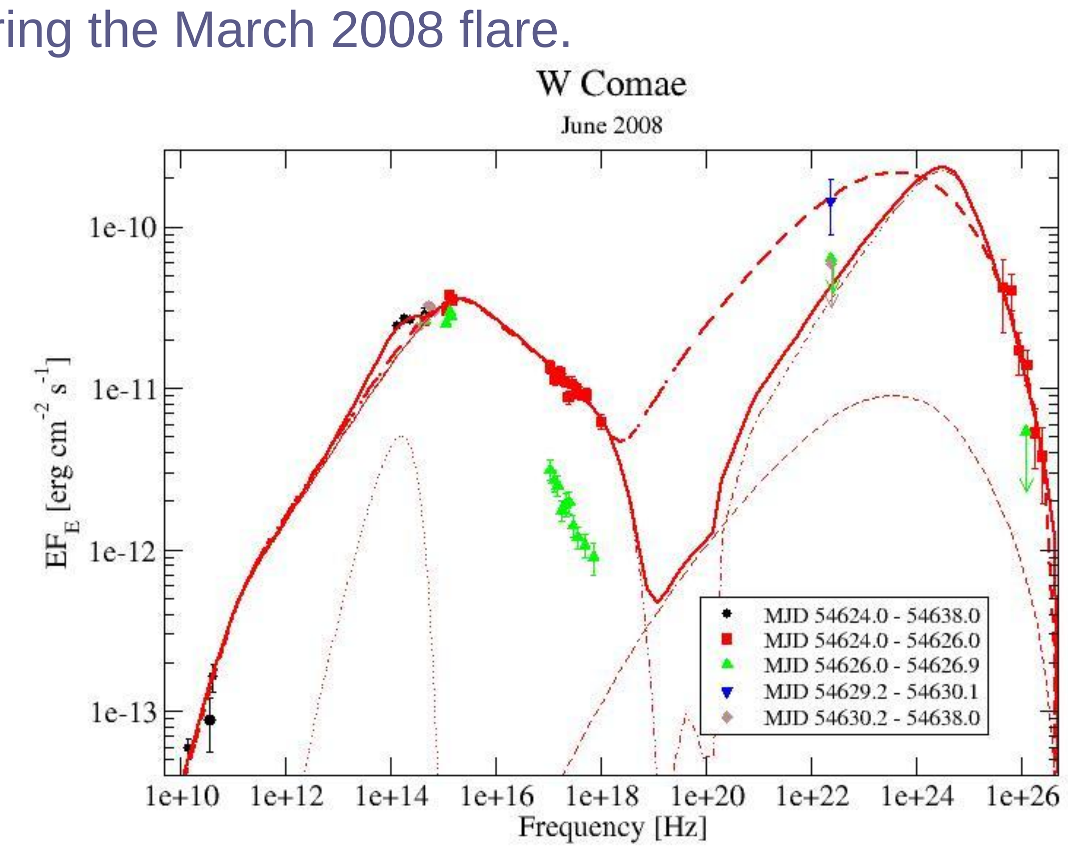

Fig. 2: *Fits to the SED of W Comae during the major flare in June 2008 (Acciari et al. 2009, submitted) Heavy dashed: SSC; heavy solid: SSC+EC fit.*

3C66A

The IBL 3C66A was detected in VHE γ-rays by VERITAS during a γ-ray flare on in October 2008. The simultaneous SED obtained during that time is shown in Fig. 3, along with model fits

3C66A

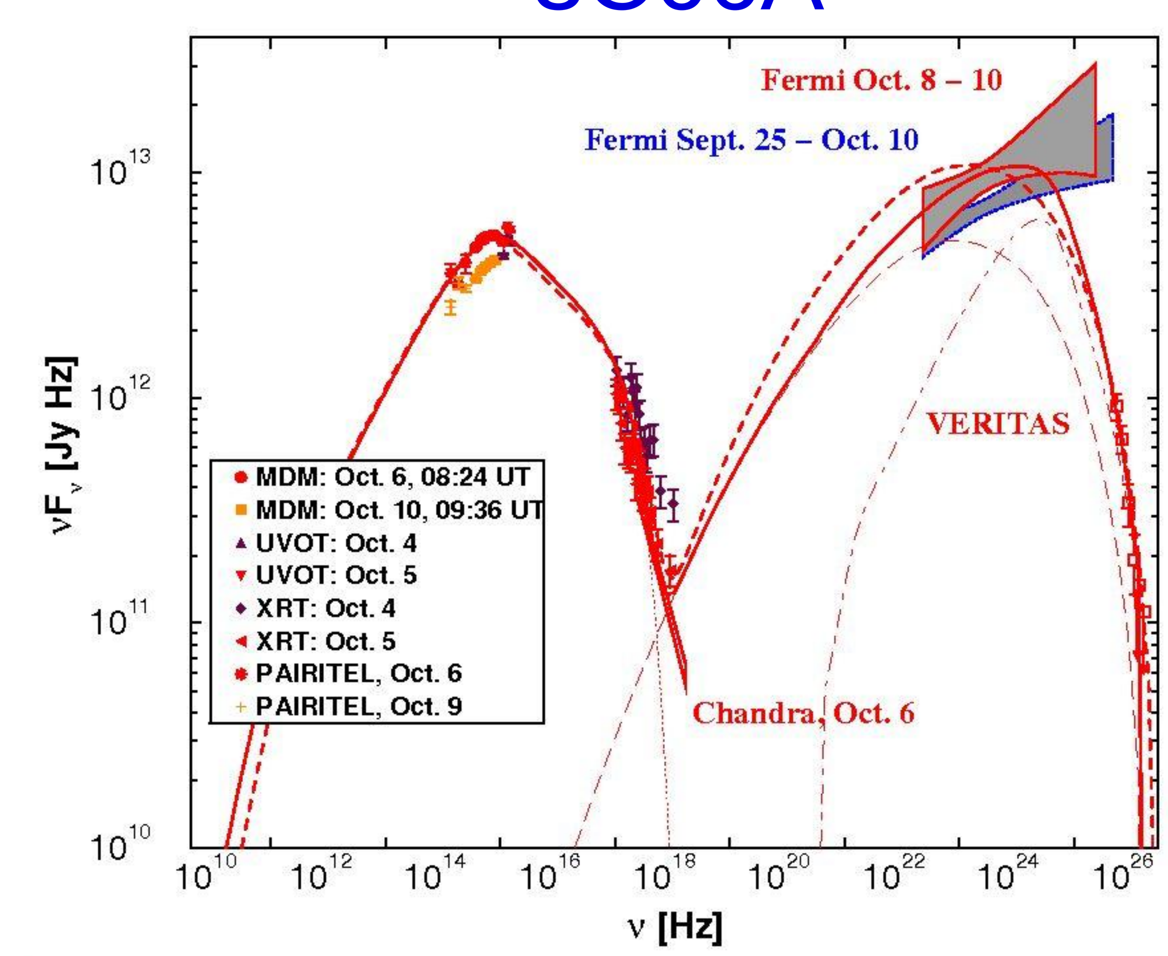

Fig. 3: *Fits to the SED of 3C66A during its detection in a γ-ray flare in October 2008 (Acciari et al. 2009, in prep.) heavy dashed: Pure SSC model; heavy solid: SSC+EC model.*

Modeling conclusions are very similar to the ones from modeling of W Comae: A pure SSC fit fails to reproduce the (Fermi) MeV-GeV γ-ray spectrum and requires a magnetic field a factor ~$8{*}10^{-3}$ below equipartition, while an SSC+EC model produces a good fit to the entire SED and allows for a magnetic field close to equipartition.

PKS 1424+240

The discovery of PKS 1424+240 was motivated by the detection of a hard MeV – GeV γ-ray spectrum by Fermi. The redshift of this source is unknown, substantially hampering the theoretical interpretation. Therefore, a range of plausible redshifts was assumed for modeling the SED. In all cases, a pure SSC model with a magnetic field close to equipartition represents the overall SED reasonably well, but γ–γ absorption by the Extragalactic Background Light renders the model γ-ray spectrum systematically too steep for redshifts z > 0.1. Therefore, a redshift z ≤ 0.1 is preferred by the modeling.

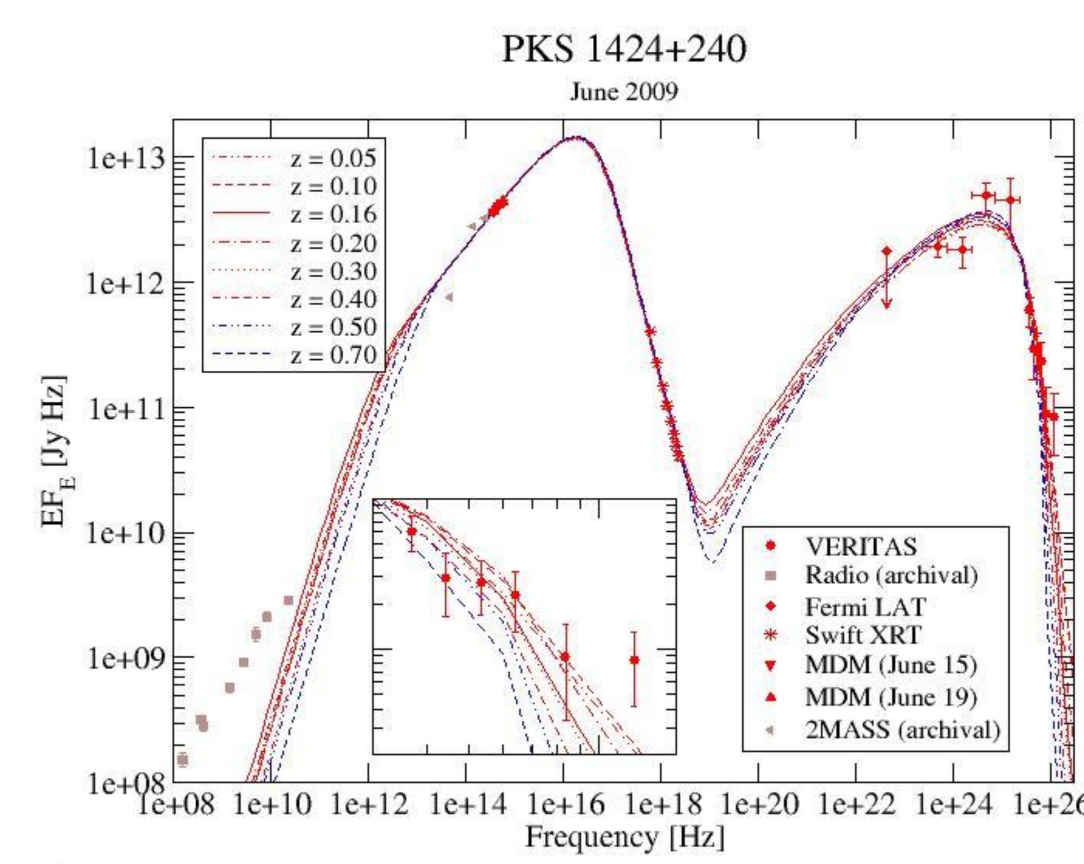

Fig. 4: *Fits to the SED of PKS 1424+240 during its detection in June 2009 (Acciari et al. 2009, submitted) for various values of assumed redshift.*