On the non-thermal emission of the microquasar 1E 1740.7-2942

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The microquasar 1E 1740.7-2942 is a mysterious source located in the direction of the Galactic Center. It has been detected at X-rays, soft gamma-rays, and in the radio band, showing an extended radio component in the form of a double-sided jet. To study the origin of the hard X-rays, we have modeled the source emission, from radio to gamma-rays, in a cold-matter dominated jet scenario. We have compared the computed spectrum with the observed one. Predictions about the gamma-ray spectrum are made, and some physical parameters of the jet are explored. We find out that jet emission could hardly explain the high fluxes observed at hard X-rays. Also, 1E 1740.7-2942 might be detected by GLAST or AGILE at GeV, and by the ground-based Cherenkov telescope HESS beyond 100 GeV.

Introduction

The source 1E 1740.7-2942 is a very bright X-ray binary located at less than one degree from the Galactic Center. 1E 1740.7-2942 was considered to be the first microquasar when extended radio jets reaching 0.5' from the core were observed (Mirabel et al. 1992). Hints of correlation between the X-ray and the core radio emission, and X-ray state changes, have been observed with timescales similar to those of other X-ray binaries. A 12.7-days periodical modulation of a 3-4% in the X-ray emission could be produced by orbital motion (Smith et al. 2002) close to circularization, and its X-ray spectrum looks like other galactic black-hole candidates (Sunyaev et al. 1991), all this pointing to its galactic nature. The stellar companion in 1E 1740.7-2942 might be a low-mass star (Martí et al. 2000), which altogether with the bright X-ray emission hint to Roche-lobe overflow accretion mechanism. The source could be embedded within a molecular cloud in the galactic center region (Yan & Dalgarno 1997), which would locate the source at ~8 kpc. The source has not been detected at GeV nor TeV energies yet, but strong emission is observed >100 keV (Del Santo et al. 2005 and references therein).

Table 1. Parameter values

Parameter [units]	value
Orbital semi-major axis [$R_\odot$]	43
Disk inner part temperature [keV]	0.5
Disk luminosity [erg s^{-1}]	1.5×10^{36}
Corona photon index	1.6
Corona emission peak [keV]	300
Disk inner radius [$R_{\rm Sch}$]	50
Jet initial point (compact object RF) [$R_{\rm Sch}$]	50
Jet semi-opening angle tangent	0.1
Max. ratio hot to cold lepton number	0.1
Compact object mass [$M_\odot$]	5
Stellar mass [$M_\odot$]	2
Stellar bolometric luminosity [erg s^{-1}]	10^{36}
Stellar surface temperature [K]	10^4
Jet Lorentz factor	1.25
Jet viewing angle [°]	45

$q_{\rm jet/accr}$	accel. eff.	diss. eff.	prediction
0.2	0.1	0.01	up to TeV
0.2	10^{-5}	0.003	up to GeV
0.04	0.1	0.1	”bright” at 100 GeV
0.01	10^{-5}	0.1	up to 100 MeV

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A cold matter jet model for 1E 1740.7-2942

We want to explain the emission of this object in the context of microquasars during the low hard state (Fender et~al. 2003), when emission at radio and higher energies from a compact jet is produced and accretion processes are likely contributing or even dominant at X-rays. We have applied a model of a cold-matter dominated and magnetized jet whose radiation mechanisms are powered by internal shocks (for details concerning the model, see Bosch-Ramon et al. 2006). We aim at explaining the data and making predictions to give some constraints about the physics of the processes involved in the broadband emission.

In Table 1, we show the adopted parameter values, inferred from observations or set to typical values in the literature, and summarize predictions. $q_{\rm jet/accr}$ is the two-jets/accreted matter ratio, acceleration efficiency is the factor multiplying qBc, and the dissipation efficiency is the fraction of kinetic energy transferred to relativistic particles (see Bosch-Ramon et al. 2006). If the source were detected >100 GeV energies, it might imply that the jet is moderately heavy ($0.04<q_{\rm jet/accr}<0.2$), with high energy dissipation and particle acceleration efficiencies. If the source were detected only at high-energy gamma-rays (e.g. by GLAST/AGILE), it would imply that the jet power is likely high, with moderate energy dissipation and low acceleration efficiency. Since no high fluxes are predicted, it seems unlikely that 1E1740.7-2942 could be a significant contributor to the nearby EGRET source. Finally, if emission at energies higher than those fo the corona photons is not detected, it will imply that either the jet is light ($q_{\rm jet/accr}$~0.01), or radiatively inefficient regardless its kinetic power. For the importance of the corona and disk photons attenuating gamma-rays, see Fig. 1. Large-scale radio jets would require more complicated modeling, although we note that an enhanced magnetic field seems necessary to explain them. In Table 2, the values of the unconstrained parameters to produce the SEDs shown in Figs. 2 and 3 are given. In the context of our model, corona emission appears to explain better the observed hard X-rays than jet emission. A jet dominant at X-rays should carry huge amounts of energy, which seems to be at odds with the weak observed radio emission at any spatial scale.

Table 2. Specific parameter values for different models

Parameter [units]	corona	jet
Accretion rate [$M_\odot$/yr]	1.2×10^{-8}	2×10^{-8}
Corona luminosity [erg s^{-1}]	3.5×10^{37}	10^{35}
$q_{\rm jet/accr}$	0.04	0.2
Shock dissipation efficiency	0.1	0.7
Acceleration efficiency	0.1	0.002
Electron power-law index	2.2	1.7
Equipartition parameter	0.1	0.3

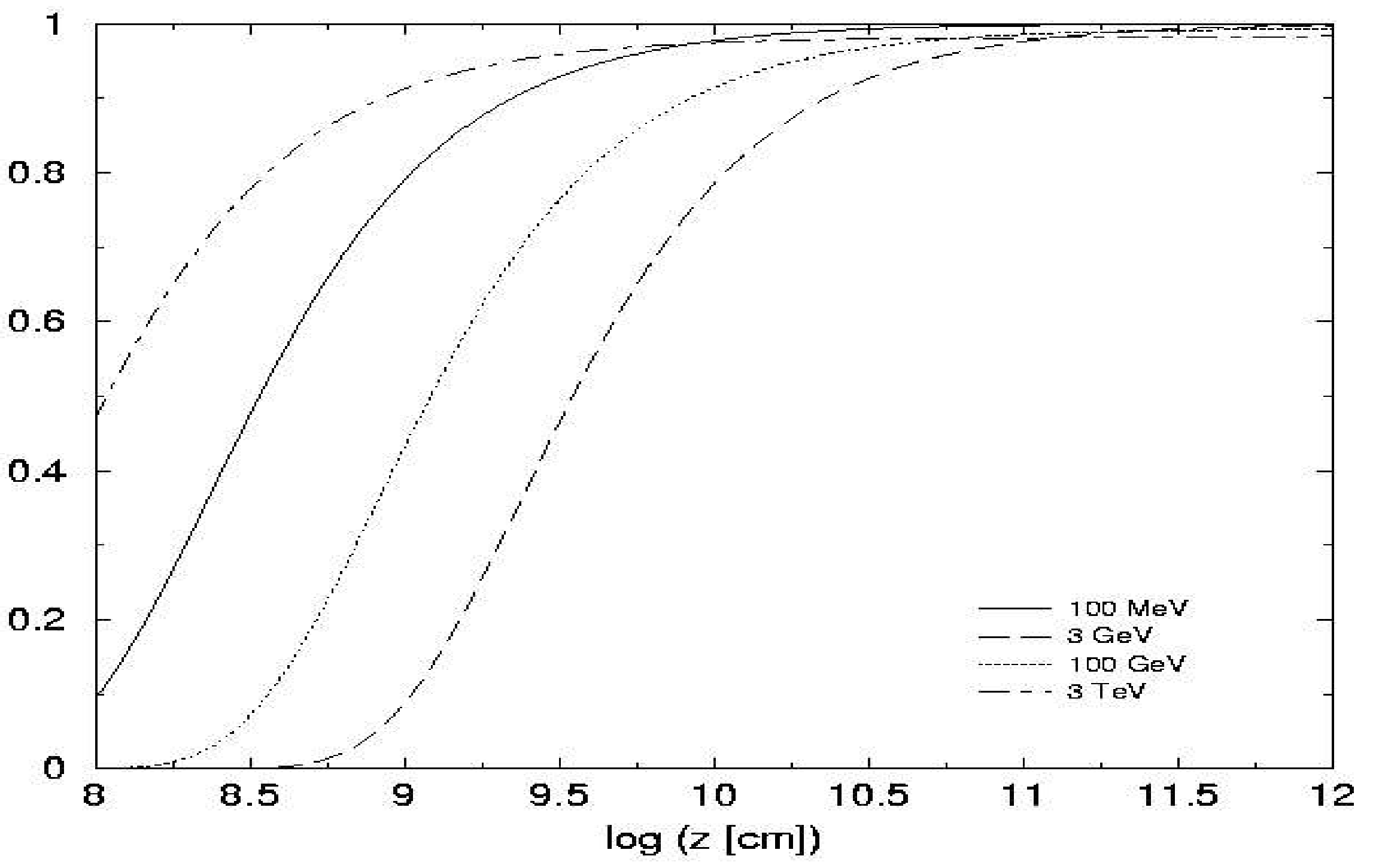

Fig. 1 Attenuation factor of the emission at different energies and distances from the compact object. Photon photon absorption is dominated by the corona and disk photon fields.

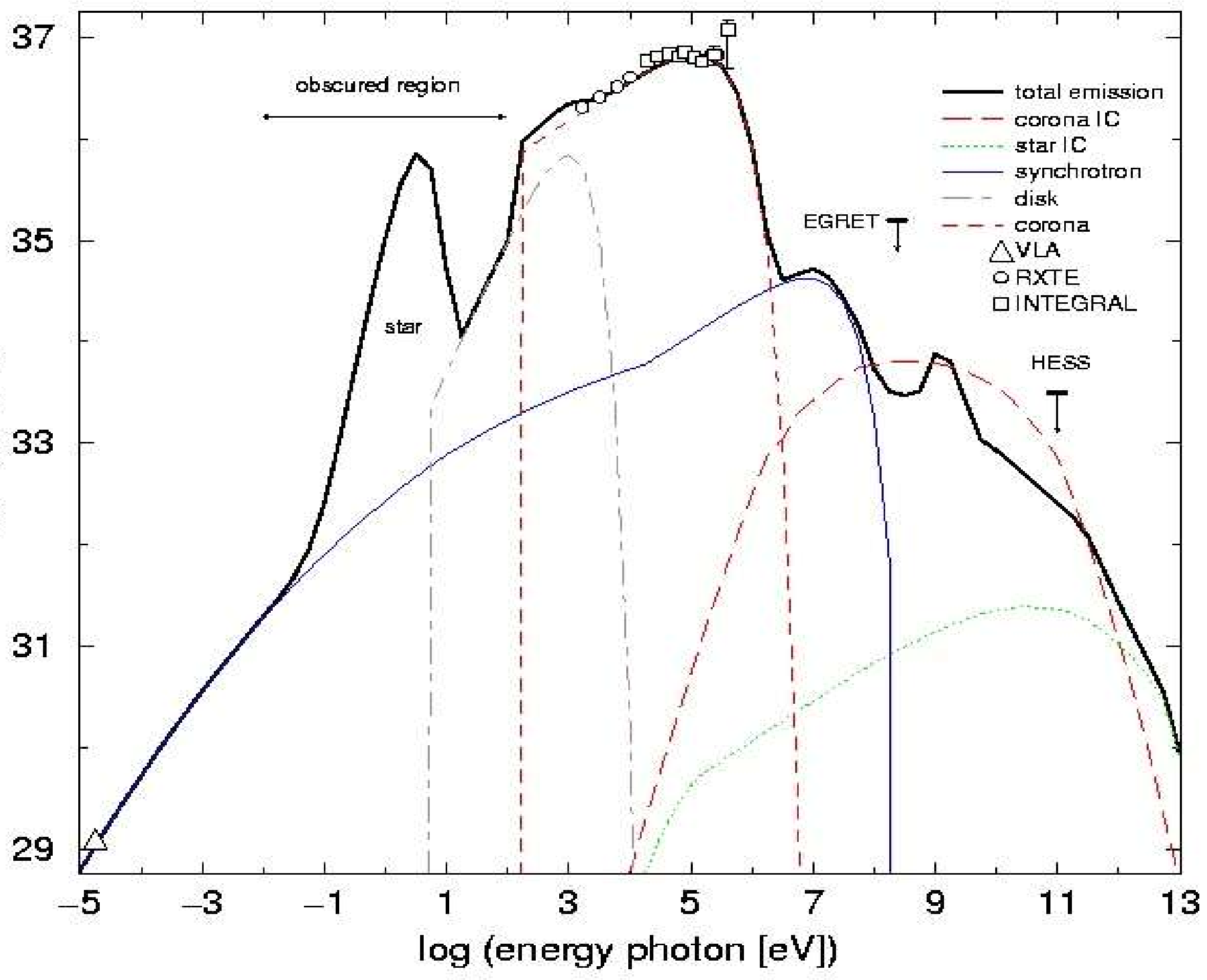

Fig. 2 Computed broad-band SED for 1E 1740.7-2942, when corona is dominant at X-rays (see Table 1), plotted along with the data points and observational upper-limits (only core radio emission is taken into account). The radio slope at this range is similar to that observed, which is not shown explicitly. Radio data is from Fender et al. (2001) and references therein. X-ray data is from Del Santo et al. (2005). EGRET and HESS upper limits are from Hartman et al. (1999) and Aharonian et al. (2006), respectively.

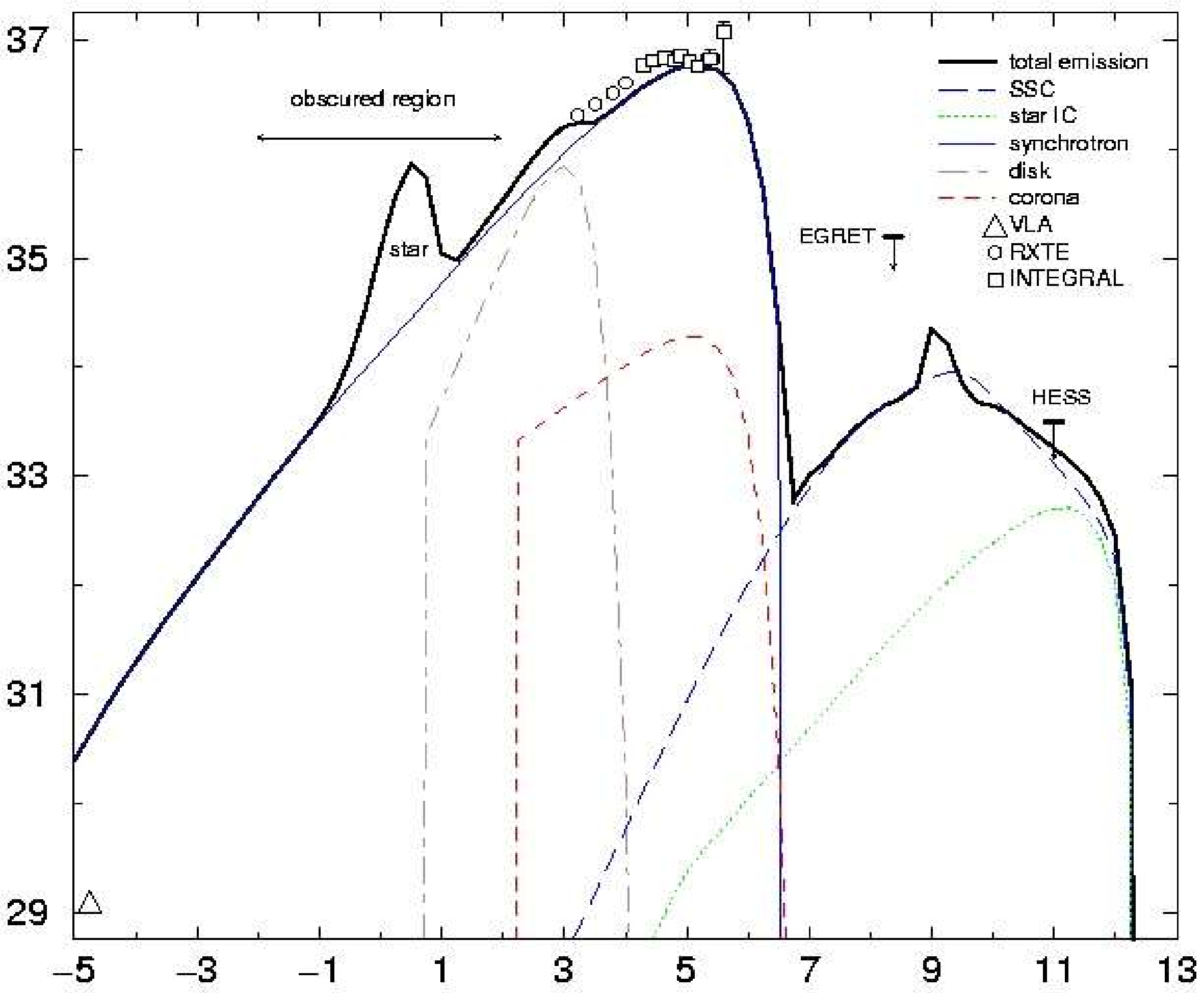

Fig. 3 The same as in Fig. 2, but for the case when X-rays are dominated by synchrotron emission from the jet. Notice that the radio constraints are violated.

Acknowledgements. J.M.P. and V.B-R. acknowledge partial support by DGI of the Ministerio de Educaci\'on y Ciencia (Spain) under grant AYA-2004-07171-C02-01, as well as additional support from the European Regional Development Fund (ERDF/FEDER). During this work, V.B-R has been supported by the DGI of the Ministerio de (Spain) under the fellowship BES-2002-2699. G.E.R is supported by the Argentine Agencies CONICET (PIP 5375) and ANPCyT (PICT 03-13291). A.B., L.B and MDS acknowledge partial support by ASI under contract I/R/046/04.

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