强磁场中相对论电子系集体的共振逆康普顿散射谱

Collective spectra ofthe resonant inverse Compton scattering ofthe assembly of relativistic electrons in an intense magnetic field

发布时间：2011-02-21 浏览量：212 收藏数：0 评论数：0

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摘要： 强磁场中相对论电子的共振逆康普顿散射(RICS)是产生伽玛射线的有效机制. 以前的工作曾论证, 伽玛暴的早期伽玛射线辐射可能主要由该机制产生.利用此辐射机制, 伽玛暴研究中的一些困惑有可能得到较好的解释, 例如, 观测统计给出的``Amati关系''的起源, 两段式(折断式)的幂律谱的形成, 特别是其中的``死线问题''的解决方案, 还有偏振的存在, 等等. 文章中将重点讨论折断幂律谱形成问题.基于单个电子的RICS谱功率公式,导出了强磁场中大量相对论电子穿过周边低频辐射场时产生的集体RICS的辐射谱(RICS谱光度)的简化解析公式, 并将它应用于中子星周边几种典型的低频场(如黑体辐射场, 幂律辐射场, 以及热韧致辐射场), 以便与实际观测谱形比较.计算表明: 在满足匹配条件(即近似共振条件)下, RICS辐射效率很高, 其谱形普遍为两段式的(折断的)幂律谱形式, 与周边低频场性质无关. 文中还论证RICS机制可能是伽玛暴, 软伽玛重复暴和伽玛射线脉冲星在高能射线波段(硬X-射线和伽玛射线)的一个理想的高效辐射机制.

关键词： 高能天体物理学辐射机制: 非热；方法:解析；gamma射线: 一般

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Abstract： The resonant inverse Compton scattering (RICS) of relativistic electrons inan intense magnetic field of a neutron star is an efficient mechanism forproducing the high-energy $gamma$-rays due to its high efficiency, high frequency,highly beaming behaviour and comparatively good monochromaticity, concentrating mostradiation in the high-frequency band(hard X-ray and $gamma$-ray). In our previous work,we argued that thedominant radiation mechanism responsible for the prompt $gamma$-ray emissionof gamma-ray bursts in the early stage could be the resonant inverse Compton scattering of relativisticelectrons. By using this mechanism, some puzzles in the study of gamma-ray bursts couldbe clarified, e.g., the origin of the Amati relation, the formation of the observedbroken power-law spectra, the related deadline problem, and the polarization property, etc.The simplified analyticalformulae of collective RICS spectra of the resonant inverse Compton scattering forassembly of relativistic electrons in an intense magnetic field are derived in this paper, based on thesimple RICS spectral power of a single fast electron given in our previous paper. By using theseformulae, a series of collective RICS spectra for various typical ambientlow-frequency radiation fields around the central neutron star are calculated, e.g.the black body radiation, the nonthermal field with power law form spectrum, andthe bremsstrahlung field. The collective RICS spectra are all in quite simpleanalytical expressions, which is convenient for comparison with the observed spectra.Our calculations show that the RICS process is really a very efficient radiation mechanismin the hard X-ray and $gamma$-ray bands if the `accommodation condition' (or the `matching condition')is satisfied. Our calculation shows that various collective RICS spectra havecommon broken power-law forms with different power-indices in the low- and high-frequency bands respectively,despite what kind of ambient soft-photon field is related. Finally, we discussthe potential applications of RICS mechanism in high-energy astrophysics, i.e., in the explorations oforigin of radiation in the gamma-ray bursts(GRBs), soft gamma-ray repeaters (SGRs) andgamma-ray pulsars(GRPs), etc.

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Keywords： High-energy astrophysics;radiation mechanism: non-thermal --- methods:analytical --- gamma-rays: general

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发表期刊： 暂无