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Gamma-ray emission from binaries in context

Emission gamma des systèmes binaires

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ABSTRACT

More than a dozen binary systems are now established as sources of variable, high-energy (HE, 0.1–100 GeV) gamma rays. Five are also established sources of very-high-energy (VHE, ⩾100 GeV) gamma rays. The mechanisms behind gamma-ray emission in binaries are very diverse. My current understanding is that they divide up into four types of systems: gamma-ray binaries, powered by pulsar rotation; microquasars, powered by accretion onto a black hole or neutron star; novae, powered by thermonuclear runaway on a white dwarf; colliding wind binaries, powered by stellar winds from massive stars. Some of these types had long been suspected to emit gamma rays (microquasars), others have taken the community by surprise (novae). My purpose here is to provide a brief review of the current status of gamma-ray emission from binaries, in the context of related objects where similar mechanisms are at work (pulsar wind nebulae, active galactic nuclei, supernova remnants).

RÉSUMÉ

Plus d'une douzaine de systèmes binaires sont maintenant identifiés comme des sources variables de rayonnement gamma de haute énergie (0.1–100 GeV). Cinq systèmes binaires sont également des sources de rayonnement gamma de très haute énergie (⩾100 GeV). Les processus menant à l'émission de ce rayonnement sont variés. On peut néanmoins diviser ces systèmes en quatre grandes classes : les binaires gamma, dont le moteur est la rotation d'un pulsar ; les microquasars, dont le moteur est l'accrétion sur un trou noir ou une étoile à neutrons ; les novae, dont l'énergie provient de la combustion nucléaire à la surface d'une naine blanche ; les binaires à collision de vents, qui dissipent l'énergie cinétique de vents d'étoiles massives. On soupçonnait depuis longtemps que certaines classes de systèmes binaires devaient être associées à de l'émission gamma (les microquasars) ; pour d'autres classes, la découverte d'émission gamma a été une surprise (les novae). Je propose ici une brève revue de nos connaissances sur l'émission gamma de haute et très haute énergie dans les systèmes binaires, avec le souci de souligner les liens avec d'autres objets astrophysiques dans lesquels des processus similaires sont à l'oeuvre (nébuleuses de pulsar, noyaux actifs de galaxie, restes de supernova).

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Table 1
Binary systems identified with sources of variable HE or VHE gamma-ray emission.

Name	Binary components		P_{orb} (d)	HE	VHE	Refs.[a]	Notes
(high-mass) gamma-ray binaries							
PSR B1259–63	pulsar	Be	1236.7	✓	✓	[12,13]	47.7 ms
HESS J0632+057	?	Be	315		✓	[14,15]	
LS I +61°303	?	Be	26.5	✓	✓	[16,17]	magnetar?
1FGL J1018.6–5856	?	O	16.6	✓	✓	[18,19]	
LS 5039	?	O	3.9	✓	✓	[20,21]	
(low-mass) gamma-ray binaries[b]							
XSS J12270–4859	pulsar	red dwarf	0.29	✓		[22,23]	1.7 ms
PSR J1023+0038	pulsar	red dwarf	0.20	✓		[24]	1.7 ms
2FGL J0523.3–2530	?	red dwarf	0.69	✓		[25,26]	
PSR B1957+20	pulsar	brown dwarf	0.38	✓		[27]	1.6 ms
PSR J0610–2100	pulsar	brown dwarf	0.29	✓		[28]	3.8 ms
PSR J1311–3430	pulsar	brown dwarf	0.065	✓		[29,30]	2.6 ms
microquasars (X-ray binaries)							
Cyg X-3	black hole?	Wolf–Rayet	0.20	✓		[31,32]	
Cyg X-1	black hole	O	5.60	✓	?	[33,34]	
novae							
V407 Cyg	white dwarf	red giant	14000?	✓		[35,36]	N Cyg 2010
V1324 Sco	white dwarf	red dwarf	0.07?	✓		[37]	N Sco 2012
V959 Mon	white dwarf	red dwarf	0.30	✓		[37]	N Mon 2012
V339 Del	white dwarf	red dwarf	0.13?	✓		[37]	N Del 2013
V1369 Cen	white dwarf	red dwarf	?	✓		[38]	N Cen 2013
colliding wind binary							
Eta Car	LBV	O/WR?	2014	✓		[39,40]	

[a] I only give one or two recent references as entry points to the HE/VHE literature.
[b] Not including another >50 *Fermi*-LAT pulsars in binaries.

1. Introduction

Detections of binaries punctuated high-energy and very-high-energy gamma-ray astronomy in the 1970s and 1980s. Binaries had been discovered to be the brightest sources in the newly-opened X-ray sky and were thus likely candidates for emission at even higher energies. Most of these detections did not withstand the test of time, as independent confirmation could not be obtained [1]. Yet, they fostered great interest and participated in the development of the field from the 1980s onwards.

The latest generation of gamma-ray instruments, from the mid-2000 onwards [2,3], have brought back binaries to the forefront. Many binaries are now established sources of high-energy (HE, 0.1–100 GeV) and very-high-energy (VHE, $\geqslant$100 GeV) gamma rays: I have listed in Table 1 the names and main characteristics of those that are reported as secure gamma-ray detections *and* display variability on a timescale that can be related to the binary nature of the source. I have also listed one or two references to the most recent HE and/or VHE studies as a point of entry into the literature. Some of these binary gamma-ray sources are of the type that had long been suspected to emit gamma rays (microquasars), others have taken the community by surprise (novae). There is no simple extrapolation between the HE and VHE domains. At present, the only binaries detected in VHE gamma rays appear to be composed of a pulsar and a massive star. There is much more diversity in HE gamma rays, perhaps because the higher fluxes and the instrumental sensitivity at these energies give access to more objects.

My purpose here is to sketch a status of gamma-ray emission from binaries as of early 2015 and how it is understood in the broader context of related objects and high-energy emission models. More in-depth accounts of the observations and models may be found in other reviews [4–7]. My current understanding is that the binaries detected in HE or VHE gamma rays divide up into four classes, illustrated in Fig. 1:

– *gamma-ray binaries*, powered by pulsar rotation;
– *microquasars*, powered by accretion onto a black hole or neutron star;
– *novae*, powered by thermonuclear runaway on a white dwarf;
– *colliding wind binaries*, powered by stellar winds from massive stars.

The last three classes were well-established prior to the detection of gamma rays. Gamma-ray binaries are still rather new and, although some of the systems had been known for some time, the motivation to treat them as a separate class is an outcome of the last decade of gamma-ray observations. The contours of this class are not fixed: sometimes the term “gamma-ray binary” is used in the literature to designate all binaries that have been detected in HE or VHE gamma rays (all the above), sometimes it encompasses only the systems listed as high-mass gamma-ray binaries in Table 1, sometimes