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INFRARED AND OPTICAL POLARISATION OF MICROQUASARS

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RESUMEN

La polarización de la luz de binarias de rayos X no ha sido muy estudiada. Sin embargo, puede dar mucha información sobre la geometría de la fuente así como de la extensión posible de emisión de chorros relativistas hacia las longitudes de onda ópticas. Presentamos aquí un programa preliminar para buscar estas características observacionales.

ABSTRACT

Polarisation of light coming from X-ray binaries has been the object of very few studies. However, polarisation can give insights on source geometry and potential extension of relativistic jet emission up to optical wavelengths. We present here a preliminary programme to search for these signatures.

Key Words: **INFRARED: STARS — STARS: BINARIES: CLOSE — TECHNIQUES: POLARIMETRIC — X-RAYS: BINARIES**

1. INTRODUCTION

Astronomical observation still largely consists in measuring photon energy, direction and arrival time. One can also measure polarisation and determine if electric field associated with electromagnetic wave exhibits a particular oscillation direction. This direction can be rich in information about the source geometry.

If polarisation is due to synchrotron radiation, its direction gives information on magnetic field orientation. For instance, succession of longitudinal and transverse radio polarisations in active galactic nuclei (AGN) relativistic jets gives constraints on models about emission knots (internal or transverse shocks? Gabuzda 2003).

Scattering can also produce a net polarisation. Observation of polarised light in Seyfert 2 spectra shows that they are similar to those of Seyfert 1. In Seyfert 2 light emitted by central regions of the AGN is absorbed by a dust torus while Seyfert 1 are seen face-wise. Similarity of light scattered on the top of Seyfert 2 torus with that coming from Seyfert 1 allows to unify these sources (Antonucci 1993).

2. WHY STUDY MICROQUASAR POLARISATION?

There exists very few polarisation measures in X-ray binaries, systems constituted of a neutron star or a black hole accreting matter from a stellar companion. Microquasars are a sub-class identified by the observation of a relativistic radio jet. These systems are typically in outburst, their emission being dominated by the accretion disc at the peak and by the stellar companion in quiescence. The relativistic jet observed in radio could also exhibit an emission extending up to optical wavelengths, and even have an X-ray contribution. Existence of a jet contribution at high frequency is not established yet, but is crucial for source models. Jet emission being due to synchrotron radiation of a non-thermal electron population, a detection at high-frequency requires very high energy particles and an efficient acceleration mechanism. This detection would indicate that a substantial part of accretion energy goes away via non-thermal channels instead of being thermally dissipated in the disc.

2.1. *Synchrotron polarisation*

One of synchrotron radiation characteristics is that it allows to obtain strong linear polarisations. For an electron power law distribution $N(E) \propto E^{-\alpha}$, the fraction of polarised light is $p = (\alpha{+}1)/(\alpha{+}7/3)$, independent on the wavelength. Field lines can be entangled and orientation modified by Faraday rotation when crossing enshrouding plasma, contributing to decrease observed net polarisation. However, we still observe radio polarisation of the order 1-10%, emanating from relativistic jets. A first aim is therefore to see if microquasars present polarisation of the same order of magnitude in IR/optical. A variable polarisation, independent on the wavelength, would be a signature of synchrotron emission.

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2.2. *Scattering polarisation*

Another possible source of linear polarisation, less speculative, is light scattering inside the binary. During scattering, the electromagnetic wave being transverse, the electron or atom is excited perpendicularly to incident radiation. There exists therefore a favoured direction of the reemitted photon electric field. For a Thomson or Rayleigh scattering polarisation is null for a frontal scattering (no favoured direction) and maximal (100%) for a scattering at 90^o ($p = (1-\mu^2)/(1+\mu^2)$ where $\mu = \cos\theta$). Light is scattered perpendicularly to the plane containing incident and reflected waves.

Scattered photons can originate from the disc or the star and be scattered in the disc atmosphere, the corona or the hot spot (intersection point between matter coming from the companion and the accretion disc). In massive binaries the optical emission is dominated by the flux of the O/B type star. The linear polarisation measured in these systems (a few 0.1-1%) likely comes from scattering of stellar photons on the accreting flow. We can expect the same effect in microquasars in quiescence. Spectropolarimetry would allow to more accurately study the geometry. If scattered light emanates from a K or M companion (therefore no-polarised at first), disc emission lines (Hα, β, HeI etc) must be depolarised (because un-scattered) compared to the continuum (at least partially scattered). If lines and continuum exhibit the same polarisation, scattering must be at bigger scale (circum-binary?). On the other hand, comparing polarisation between star and disc lines would allow to determine the contribution of accretion in the total emission (veiling). Concerning Rayleigh scattering (particle size small compared to λ), the expected polarisation strongly depends on the wavelength λ^{-4}.

2.3. *Orbital modulation*

If properties of light scattering are constant in the system (angles, intensity, scattered ratio...), geometry variation as seen by the observer, with respect to the orbital phase, produces a modulation of measured polarisation. For a symmetric envelope of particles scattering light, the curve described by the Stokes parameters (measuring the polarisation vector in the plane) during a complete orbit is an ellipse whose eccentricity depends on the inclination $e = \sin^2 i/(1+\cos^2 i)$ (Rudy & Kemp 1978; Brown et al. 1978). Measuring one orbital modulation therefore allows to determine the inclination independently, for example, of the observation of ellipsoidal modulations or of eclipses. Combined with stellar radial velocity, we can then measure the black hole or neutron star mass.

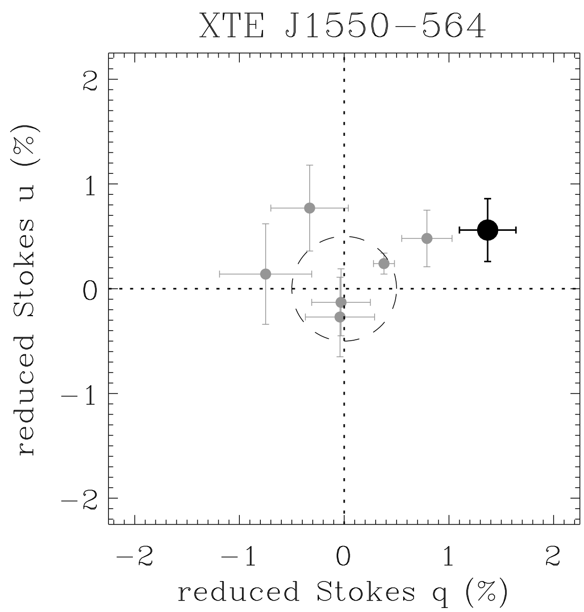

Fig. 1. K_s band polarimetry of stars in the XTE J1550-564 field based on the 2003 dataset. Only stars brighter than the target are shown. These cluster around the origin with a dispersion of 0.5% (dashed circle). The position of XTE J1550-564 in the (q, u) plane (highlighted in black) is inconsistent with that from the other stars at the 2.5 σ level, suggesting XTE J1550-564 has intrinsic infrared polarisation at a level 0.9-2.0% (Figure taken from Dubus & Chaty 2005).

2.4. *Interstellar polarisation*

Finally, light is polarised by travelling across the interstellar medium. Properties of dust scattering (optical) or absorption (IR) differ whether the electric vector of the incident wave is parallel or perpendicular to the main axis of the grain (dichroism). Grains are in average aligned following the interstellar magnetic field lines, which results in a net linear polarisation depending on both line of sight and distance. Statistical relations exist linking on average the expected interstellar polarisation to the extinction in different bands (cf. Jones 1989; Fosalba et al. 2002). For a small field constituted of stars with similar magnitude (distance) the interstellar polarisation is roughly identical. A substantial deviation of orientation or amplitude of polarisation of one star with respect to mean properties of its neighbours can therefore be interpreted as a sign of intrinsic polarisation.

3. OBSERVATIONS

Measuring polarisation is not technically difficult (most of all in optical), requiring essentially a good S/N ratio, the sensitivity to polarisation being $\Delta p \approx \sigma_I/I$. We performed two programmes.

The first one consisted in measuring K band (2.2 μm) polarisation at NTT in the context of a ToO programme of follow-up of X-ray binaries in outburst (PI Chaty). Measures of polarisation are less accurate in IR but the hope is to have a better chance to detect the jet, since X-ray binaries are generally at a few kpc and distributed around the galactic center. Moreover, interstellar polarisation is reduced in IR. Three microquasars (H1743-322, XTE J1550-564, GRO J1655-40) were then observed. Polarisation of H1743-322 is certainly interstellar. No intrinsic polarisation is measured in GRO J1655-40. However, XTE J1550-564 exhibits a polarisation deviating from the field average at 2.5σ, maybe intrinsic and related to a small flare seen in X-rays. A measure in quiescence would allow to confirm this result, reported in Figure 1. Results are published in Dubus & Chaty 2005.

The second programme allowed to measure polarisation in V band of A0620-00 in quiescence (3.6m ESO). During its 1976 outburst, a measure showed a 1.7% polarisation of interstellar origin (Dolan 1976). In 1989, Dolan & Tapia found a 3% polarisation in quiescence with an orbital modulation of 2%. Our aim was to verify this result and measure the inclination thanks to a S/N ratio ten times better. We confirm a 3% polarisation, certainly intrinsic taking into account polarisation of other stars (which exhibit $p \approx 1.7\%$) and A0620-00 distance, relatively close < 1 kpc and whose light is not much absorbed (Dubus, Kern, & Chaty in preparation). Polarisation varies on the orbit but with an amplitude of only a few tenths of %. Curiously, while large intensity variations are observed (factor 2+), polarisation remains constant. Maybe this is because observed polarisation comes from larger scale than regions where emanate these variations? Spectro-polarimetry at VLT is foreseen for end of 2005.

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