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QUASAR HOST ORIENTATION AND POLARIZATION: INSIGHTS INTO THE TYPE 1/TYPE 2 DICHOTOMY

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RESUMEN

Investigamos correlaciones entre el ángulo de posición de la polarización lineal óptica y la orientación de la galaxia huésped/emisión extendida de cuásares Tipo 1 y Tipo 2 radio fuertes (RL) y radio callados (RQ). Hemos utilizado datos de alta resolución del Telescopio Espacial Hubble (*HST*) y un proceso de deconvolución para obtener una buena determinación de la orientación de la galaxia huésped. Con estas nuevas mediciones y datos compilados de la literatura, encontramos una correlación significativa entre el ángulo de posición de la polarización y el ángulo de posición del eje mayor de la galaxia huésped/emisión extendida. La correlación es distinta para objetos Tipo 1 y Tipo 2 y depende del corrimiento al rojo de la fuente. Se discuten interpretaciones en el marco del modelo unificado.

ABSTRACT

We investigate correlations between the optical linear polarization position angle and the orientation of the host galaxy/extended emission of Type 1 and Type 2 Radio-Loud (RL) and Radio-Quiet (RQ) quasars. We have used high resolution Hubble Space Telescope (*HST*) data and deconvolution process to obtain a good determination of the host galaxy orientation. With these new measurements and a compilation of data from the literature, we find a significant correlation between the polarization position angle and the position angle of the major axis of the host galaxy/extended emission. The correlation appears different for Type 1 and Type 2 objects and depends on the redshift of the source. Interpretations in the framework of the unification model are discussed.

Key Words: quasars : general — polarization

1. INTRODUCTION

There is a huge diversity of quasars in the Universe. In particular, some of them harbor broad and narrow emission lines in their spectrum (Type 1) while other ones only possess narrow emission lines (Type 2). One can wonder whether the physical processes at the origin of all quasars are the same.

In the intrinsically less powerful AGN that are the Seyfert galaxies, the discovery of broad emission lines in the polarized spectrum of Type 2 objects provided strong support to the presence of a dusty torus oriented edge-on that blocks the direct view of a Type 1-like central engine and broad emission line region (e.g. Antonucci & Miller 1985). A key question is whether this unification model (UM) also applies to quasars since the presence of a dusty torus may be affected by the higher radiation flux. The study of optical polarization is an interesting tool to get some insights into the quasar inner structure.

The question we investigate relates to the possible existence of a correlation between the linear optical polarization position angle ($\theta_{\rm pola}$) and the orientation of the major axis of the host galaxy/extended emission ($PA_{\rm host}$) in the case of quasars. Such a study was already undertaken by Berriman et al. (1990), using ground-based data and showing a marginally significant correlation. Our aim is to investigate the $\theta_{\rm pola}/PA_{\rm host}$ on the basis of high resolution images of quasars (essentially from *HST* observations).

2. DEFINITION OF THE SAMPLE

2.1. *Origin of data*

Our initial sample was defined following one criterion: we searched for Type 1 and Type 2 quasars (RL and RQ but no blazars) for which high resolution visible/near-IR images (or derived host galaxy parameters) and optical polarization data were available in the literature. These samples are detailed in Borguet et al. (2008).

2.2. *Determination of $PA_{\rm host}$*

As several objects from this sample do not possess a $PA_{\rm host}$ determined in the literature, we used the MCS deconvolution method (Magain et al. 1998)

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to model and derive the host galaxy morphological parameters (the $PA_{\rm host}$ and the ellipticity a/b).

The image processing proceeds in two steps: first the proper subtraction of the bright central source from the images of (Type 1) quasars. This step generally allows the detection of the underlying host. The second step consists in the fitting of an analytical Sérsic galaxy profile properly convolved with the HST PSF to the point-source subtracted image. This process allows us to derive $PA_{\rm host}$ and b/a for a large part of the sample.

2.3. *The polarimetric data*

The polarimetric data mainly come from a compilation of polarization degree (P) and $\theta_{\rm pola}$ measurements (Hutsemékers et al. 2005). The P and $\theta_{\rm pola}$ measurements for the 2MASS and Type 2 RQ quasars are respectively taken from Smith et al. (2002) and Zakamska et al. (2006).

3. THE $PA_{\rm HOST} - \theta_{\rm POLA}$ CORRELATION

From the compilation, we selected only relevant and accurate data. Here are the criteria used:

- We separated the quasars from the Seyfert galaxies by applying the $M_V \lesssim -23$ criterion.
- We rejected objects with low ellipticity of the host galaxy ($b/a > 0.9$) since the deduced $PA_{\rm host}$ would have too large error bars.
- We considered objects for which significant polarization is detected, meaning objects such that $P/\sigma_P \geq 2$ (implying $\sigma_{\theta_{\rm pola}} \leq 14°$).

For each quasar of the selected sub-sample, we computed the acute angle $\Delta\theta$ between the directions defined by the $PA_{\rm host}$ and $\theta_{\rm pola}$ angles: $\Delta\theta = 90 - |90 - |\theta_{\rm pola} - PA_{\rm host}||$, $\Delta\theta \in [0°, 90°]$. In the following, we consider separately RQ and RL quasars as well as the visible and near-IR $PA_{\rm host}$.

3.1. *The Radio-Quiet objects*

The behavior of the angle $\Delta\theta$ as a function of the redshift is illustrated in the upper panel of Figure 1 for both Type 1 and Type 2 RQ quasars. While there seems to be no particular behavior of $\Delta\theta$ at small redshifts ($z \lesssim 0.2$), a clear separation between Type 1 and Type 2 objects appears for objects lying at higher z ($z \gtrsim 0.2-0.3$). Indeed, for Type 1 quasars we observe that the polarization angle is preferentially aligned with the host major axis ("alignment" meaning $\Delta\theta < 45°$), while for the Type 2 quasars an anti-alignment ($\Delta\theta > 45°$) is observed (as already noted by Zakamska et al. 2006). The difference between the distribution of $\Delta\theta$ for Type 1 and Type 2 samples at $z > 0.2$ is statistically significant (probability $\leq 0.1\%$ with a 2 sample K-S test).

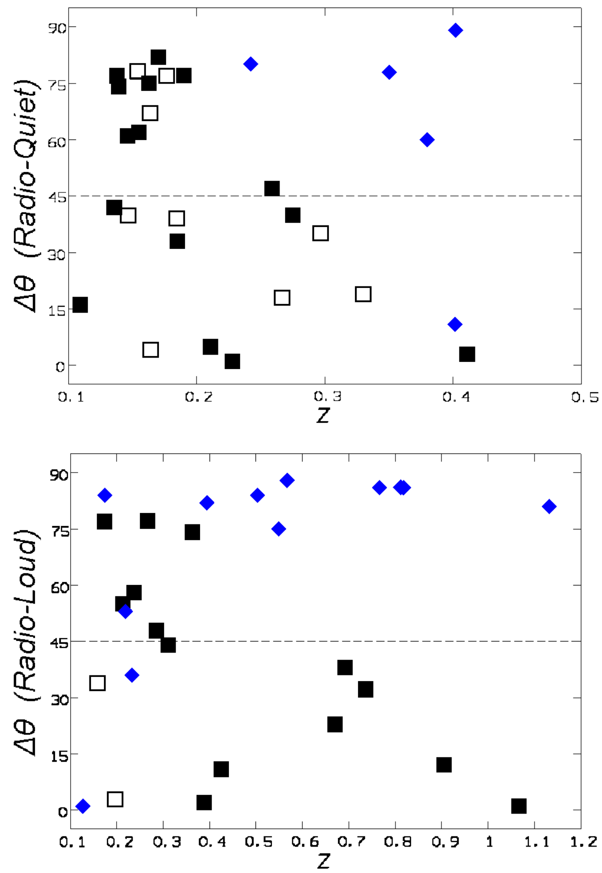

Fig. 1. The acute angle $\Delta\theta$ between the polarization position angle $\theta_{\rm pola}$ and the host galaxy position angle $PA_{\rm host}$, as a function of the redshift z. The upper panel refers to Radio-Quiet objects while the lower panel refers to Radio-Loud objects. Type 1 objects are represented in both panel by squares and Type 2 objects by diamonds. The filled symbols refer to objects with a polarization degree $P \geq 0.6\%$

3.2. *The Radio-Loud objects*

The lower panel of Figure 1 summarizes the $\Delta\theta$ behavior as a function of z for RL quasars. Once again, the distribution of $\Delta\theta$ for the high z objects is clearly non-random. While we note that Type 1 quasars are systematically found to lie at small offset angle ($\Delta\theta < 45°$), having their optical polarization preferentially parallel to their host galaxy major axis, Type 2 quasars are found at higher offset angles (as previously reported by Cimatti et al. 1993). Again, a 2 sample K-S test shows that there is a probability $\leq$ 0.3% that the Type 1 and Type 2 $\Delta\theta$ distributions come from the same parent sample.

3.3. *Summary of the observations*

We can summarize our results as follows:

- While Type 2 quasars are known to exhibit an anti-alignment between the host/extended emission major axis and the optical polarization, we find that an alignment dominates for Type 1 quasars.
- This behavior seems to be independent of the radio-loudness of the source.
- We note a redshift dependence of the alignment effect. Moreover the $PA_{\rm host} - \theta_{\rm pola}$ correlation using the $PA_{\rm host}$ derived from near-IR images do not show any particular behavior of the $\Delta\theta$ distribution.

4. DISCUSSION

The last observation of § 3.3 suggests that the alignment effect might be related to the rest-frame extended UV/blue part of the quasar emission as discussed below.

4.1. *The extended UV/blue emission*

Due to the absence of a bright point source, the morphology of Type 2 RL quasars has been extensively studied throughout the literature. An extended rest frame UV/blue emission has been observed in the optical images of the higher redshift objects ($z > 0.5$) showing a so-called "alignment effect" with the radio jet, both being preferentially co-linear (McCarthy et al. 1987; Chambers et al. 1987). Using polarimetric measurements of such targets, Cimatti et al. (1993) noted an anti-alignment between the directions defined by the polarization angle and the extended UV/blue emission. This observation suggested that at least part of the UV/blue light might be related to scattering in extended polar regions.

Due to their apparent faintness and absence of strong radio counterpart, Type 2 RQ quasars have long been searched for. The recent imaging and spectropolarimetric observations of these objects revealed, as in the case of Type 2 RL quasars, the presence of an extended UV/blue light, whose extension was found to be anti-aligned with the polarization angle, arguing in favor of a scattering origin of the blue light (Zakamska et al. 2006).

In the case of Type 1 quasars, the detection of an hypothetical UV/blue extension is hindered by the central source, whose contribution remains difficult to properly subtract. However, if the UM applies to quasars, such an extended polar scattering region may also be present in Type 1 objects but might lead to different polarization properties given the smaller viewing angle to the system.

4.2. *Interpretation in the framework of the UM*

Seyfert galaxies are known to exhibit a kind of "alignment effect" between their optical polarization and radio-jet position angle (Smith et al. 2002, and references therein). In order to describe their observations, Smith et al. (2002) introduced a two component scattering model in which the polarization is produced in two separate scattering regions. Polar regions produce a polarization direction anti-aligned with the symmetry axis of the accretion disk while an equatorial region located inside the torus produces a polarization aligned with the system axis.

Our observations fit this two component model. In Type 2 quasars (either RL or RQ) the observed polarization is only produced by the polar region (the equatorial one being masked by the obscuring material). In Type 1 quasars, the higher symmetry of the polar region let the equatorial region dominate the polarized flux, resulting in a polarization angle parallel to the polar extended UV/blue emission.

5. CONCLUSIONS

We can summarize our results as follow:

- While Type 2 RL and RQ quasars are known to exhibit an anti-alignment between the major axis of their host/extended emission and their optical polarization, we find that an alignment is mostly observed for Type 1 quasars.
- The redshift dependence of the alignment effect, and lack of correlation with the near-IR $PA_{\rm host}$, suggest that it might be related to the rest-frame extended UV/blue emission of quasars.
- We show that these observations can be interpreted in the framework of the unification model + a two component scattering model.

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