

FACULTÉ DES SCIENCES Institut d'Astrophysique et Géophysique de Liège

COSMIC ANISOTROPIES FROM QUASARS FROM POLARIZATION TO STRUCTURAL-AXIS ALIGNMENTS

Dissertation présentée par **Vincent PELGRIMS**

pour l'obtention du grade de Docteur en Sciences

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COSMIC ANISOTROPIES FROM QUASARS FROM POLARIZATION TO STRUCTURAL-AXIS ALIGNMENTS

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Dissertation présentée par Vincent PELGRIMS en vue de l'obtention du grade de Docteur en Sciences Je sais que, curieusement, ceci a un sens et qu'on peut s'amuser à voir jusqu'où on comprend, comme par-dessus les cols.

ITO NAGA

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Résumé

La comparaison des orientations des vecteurs de polarisation de la lumière visible provenant de quasars séparés par des milliards d'années-lumière a mené à une découverte surprenante. Ces vecteurs sont alignés au lieu d'être orientés aléatoirement comme on pouvait s'y attendre. La découverte de ces corrélations qui impliquent des échelles de l'ordre du gigaparsec a été confirmée et renforcée par de nouvelles observations et de nouvelles analyses. À ce jour, cependant, aucun scénario n'a pu rendre compte de ces corrélations de manière satisfaisante.

Nous avons dedié cette thèse de doctorat à l'étude minutieuse de ces observations qui se révèlent être potentiellement en désaccord avec le modèle cosmologique actuel. Il nous a semblé important de confirmer de façon indpendante ces alignments à grande échelle qui n'avaient été caractérisés qu'à l'aide des deux mêmes méthodes statistiques. À cette fin, nous élaborons une nouvelle méthode statistique dans le Chapitre 1. Celle-ci est dédiée à l'analyse et à la caratérisation de la distribution de vecteurs axiaux perpendiculaires aux lignes de visée d'un échantillon de sources dispersées sur la sphère céleste. Cette nouvelle méthode statistique nous permet, dans le Chapitre 2, de confirmer indépendamment la présence des alignments à grandes échelles des vecteurs de polarisation optique des quasars, mais aussi de redéfinir objectivement les régions d'alignement. Nous dédions le Chapitre 3 à une analyse détaillée d'un échantillon de données polarimétriques obtenues en longueur d'onde radio. Celle-ci révèle le même genre d'alignement des vecteurs de polarisations. Les régions du ciel dans lesquelles se concentrent les alignements radio se trouvent au voisinage de celles définies dans le visible. Ceci suggère que les axes des quasars eux-mêmes pourraient être alignés. Afin d'explorer cette possibilité, nous analysons dans le Chapitre 4 de nouvelles données de polarisation obtenues pour des quasars se trouvant dans deux grands amas de quasars. En tenant compte du lien entre l'orientation des vecteurs de polarisation optique et l'orientation des quasars par rapport à la ligne de visée, nous concluons que les axes de rotation des trous noirs supermassifs situés au centre des quasars sont alignés avec la structure de l'amas auquel ils appartiennent. Dans le Chapiter 5, nous confirmons notre découverte en utilisant un échantillon d'amas de quasars et des mesures de polarisation radio. Nous observons également que l'orientation préférentielle des axes de rotation des trous noirs supermassifs dépend de la richesse de l'amas de quasars dans lequel ils sont contenus.

L'ensemble de ces résultats suggère que les alignements à très grandes échelles des vecteurs de polarisation des quasars soient liés aux corrélations au sein des amas de quasars.

Ces corrélations qui seraient elles-mêmes dues aux alignements des axes de rotation des trous noirs dans la toile cosmique.

Abstract

The comparison of the orientations of the optical-polarization vectors of quasars that are separated by billions of light-years has led to the striking discovery that they are aligned instead of pointing in random directions as expected. This discovery has been confirmed and the significance of the correlations enhanced but no satisfactory scenario has been provided so far to account properly for the specificities of these gigaparsec-scale correlations.

We devoted this doctoral thesis to an in-depth analysis of these observations that may constitute an anomaly to the current cosmological paradigm. As the large-scale polarization alignments had always been characterized through the two same statistical methods, we found it important to independently confirm them. Therefore, in Chapter 1, we develop a new and independent statistical method which is dedicated to the study and the characterization of the distribution of the orientations of vectorial quantities that are perpendicular to the lines of sight of a set of sources spread on the celestial sphere. This allows us, in Chapter 2, to confirm independently the large-scale optical-polarization-vector alignments and, further, to refine the limits of the aligned regions through an unbiased characterization of the signal. In Chapter 3, we provide a detailed analysis of a large sample of polarization measurements made at radio wavelengths. We report on similar polarization-vector alignments. The regions of alignments of the quasar-radio-polarization vectors are found to be close to the regions of optical alignments. This suggests that quasar axes themselves could be aligned. Thus, in Chapter 4, based on new observations, we analyse the optical-polarization vectors of quasars that belong to two large groups. Taking into account the link between the optical-polarization vectors and the morphologies of the quasars, we find that the spin axes of the supermassive black holes located at the centres of quasars align with the axis of the large-quasar group to which they belong. We use radio-polarization data to reinforce our findings in Chapter 5 where we consider a sample of quasar groups drawn from the Sloan Digit Sky Survey. We additionally find that the preferred orientations of the spin axes of the supermassive black holes depend on the richness of their host large-quasar groups.

These results suggest that the very-large-scale alignments of quasar-polarization vectors and the correlations with the large-quasar groups could be due to the alignments of the supermassive black hole spin axes within the cosmic web.

Vincent Pelgrims