AAP China Scholarship Council - CSC 2023

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Multiwavelength astrometry of AGN: from nuclear jets to celestial reference frames

DIRECTION de THESE

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Nombre de doctorants actuellement encadrés : 1

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Nombre de doctorants actuellement encadrés : 0

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

Context. The quasi-inertial celestial reference system is realized through compact extragalactic sources (AGN) of blazar type, whose angular coordinates are measured with precisions of a few tens of microarcseconds by very long baseline radio interferometry (VLBI; Charlot et al. 2020) in geodetic mode and, since 2016, in optical by the European Gaia space mission with comparable precision. Both ensembles form the ICRF (International Celestial Reference Frame; Prusti et al. 2016, Vallenari et al. 2022, Klioner et al. 2022) that, especially the radio part, has many scientific and societal applications, including the operation of space and geodetic techniques. The coordinates of centroids in radio and optical differ, however, from few microarcseconds to several milliarcseconds (mas) because of systematic errors and other factors intrinsic to the sources: extended structure, opacity of the jet, optical emission of the accretion disk, halo... preventing from a perfect link between the radio and optical reference frames. Nevertheless, the exploitation, on a sample of thousands of sources, of these “radio-optical geometries” offers, from the astrophysical point-of-view, subtle views on emission zones, activity type, and their link with both astrometric and photometric variability.

Objectives. The scientific objectives of this project are to use global astrometry of the AGN made by geodetic VLBI and Gaia complemented by radio structure given by various VLBI surveys for

• Identifying the emission mechanisms and regions leading to the “geometries” observed between the astrometric positions of AGN at the various wavelengths and according to the classes of objects;

• In the context of improving the celestial reference frames and contribute to their next international realization, defining AGN “profiles” and populations with which the connection between reference frames of different wavelengths will be optimal and the radio or optical reference frames will be individually the most stable.

We identified several tasks within this project.

Task 1. Absolute astrometry versus structures. This task is dual and aims to (i) ensure the statistical relevance of the radio-optical offsets and (ii) align the radio and optical centroids onto the structure maps given by imaging VLBI. (i) The accuracy of radio-optical offsets depends on large-scale deformations between VLBI and Gaia catalogs. These deformations will be modeled by means of vector spherical harmonics and the presence of outliers will have to be taken into account. The project will benefit from the constant increase in VLBI measurements within the framework of the international VLBI service (IVS) and the VLBI astrometric catalogs produced yearly at SYRTE and by its IVS partners (mainly USNO, NASA/GSFC, Geoscience Australia). (ii) The alignment of the structure maps on absolute positions of radio centroids is not obvious because the two are not produced with the same technique. At this stage, there is no consensus on how to do it with the best accuracy. Nevertheless, compromises can be found to get an approximate alignment with an adequate handling of the various sources of errors. The source sample depends on the number of sources in common between Gaia and VLBI (3000+) and the available structure maps (few hundreds in the MOJAVE database; Lister et al. 2021). There are unexploited structure maps available in databases of partner institutes such as the USNO which makes them available to us or the BVID (Bordeaux VLBI Image Database). It will be necessary to identify on these maps the components of the jet and if possible, define a dynamic (stationary components or in relativistic motion). Observation time will be requested from the USNO on the VLBA or from partners of the Australia-New Zealand network (AuScope), if images are deemed necessary. At the end of this axis, we will have a consistent database giving for a maximum of sources of the radio ICRF, the radio structure – including the dynamics of the jet – on which the VLBI and Gaia optical radio positions are superimposed.

Task 2. Population properties versus radio-optical geometry. This task consists of an extensive comparison between the radio-optical geometry and the astrophotometric properties (spectral class, jet dynamics, color indices B-R, polarization, radio flux, optical and very-high-energy (gamma) emission) of the sources in order to identify whether this geometry contains trends or characterizes populations. The impact on statistical results of observational biases (Gaia magnitude limitation, sensitivity of VLBI to the jet only) potentially leaving underrepresented spectral classes must be studied. At the end of this task, the optical emission processes will have been better identified (e.g., from disk, from jet) thanks to color indices, polarization, and optical imaging if necessary (e.g., SDSS or PanSTARRs).

Task 3. Astrometric and photometric variability. The most crucial variability in terms of reference frames is astrometric variability (position of the centroid) and the question of finding sources whose stability is guaranteed over at least few years. Time series of radio centroid positions are produced at SYRTE using geodetic VLBI and constitute an absolute measurement independent from Gaia or VLBA imaging (Gattano et al. 2018). In addition, photometric variability (G, BP, RP) is provided by Gaia and through ground telescopes. It is proposed to examine the relationship between these two types of variability and how it correlates with the various quantities examined in the Task 2. This will allow one to identify the role of transient phenomena (for example the appearance of a new VLBI component) inducing successive dominations of the jet or disc on radio or optical centroids and divergences in behavior between optical and radio. In addition, photometric variability can constrain the sizes and locations of emission zones, especially at very high energies. We propose to study particularly the correlations between gamma (Fermi-LAT data) eruptions and VLBI centroid displacements. This should allow to confirm or refute a scenario currently much debated according to which the very powerful emission in gamma would be related to the appearance of a new component at the base of the VLBI jet, and to verify whether the reciprocal is true for certain types of sources. At the end of this task, we will have refined the criteria defining a subclass of more stable sources in the astrometric sense.

References. Charlot P., et al. A&A 644:A159, 2020 - Gattano C., et al. A&A, 2018 - Klioner S., et al., A&A, 667:A148, 2022 - Lister M., et al., AJ, 874(1):43, 2019 - Prusti T., et al., A&A, 595:A1, 2016. - Vallenari A., et al., A&A, in press, 2022

Team. The PhD student will work in the Celestial reference frame team at SYRTE, Paris Observatory, a team specialized in high precision absolute astrometry and large astrometric catalogs of extragalactic objects. The team benefits from the hosting of international services (IERS, IVS) related to geodesy and astrometry and the facilities concerning the analysis of VLBI data. The team is also member of the Gaia collaboration and contributes to Gaia CU3 and CU9. The PhD student will be in constant and close interaction with the High-energy phenomena team at LUTH, Paris Observatory, which is more specialized in the physics of the extragalactic compact objects and nuclear jets.

AVIS de l'Ecole Doctorale :

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