Gaia GraL II – Gaia DR2 Gravitational Lens Systems: The Known Multiply Imaged Quasars *

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ABSTRACT

Context. Thanks to its spatial resolution the ESA/Gaia space mission offers a unique opportunity to discover new multiply-imaged quasars and to study the already known lensed systems at sub-milliarcsecond astrometric precisions.

Aims. In this paper, we address the detection of the known multiply-imaged quasars from the *Gaia* Data Release 2 and determine the astrometric and photometric properties of the individually detected images found in the *Gaia* DR2 catalogue.

Methods. We have compiled an exhaustive list of quasar gravitational lenses from the literature to search for counterparts in the *Gaia* Data Release 2. We then analyze the astrometric and photometric properties of these *Gaia*'s detections. To highlight the tremendous potential of *Gaia* at the sub-milliarcsecond level we finally perform a simple Bayesian modeling of the well-known gravitational lens system HE0435-1223, using *Gaia* Data Release 2 and HST astrometry.

Results. From 478 known multiply imaged quasars, 200 have at least one image found in the *Gaia* Data Release 2. Among the 41 known quadruply-imaged quasars of the list, 26 have at least one image in the *Gaia* Data Release 2, 12 of which are fully detected (2MASX J01471020+4630433, HE 0435-1223, SDSS1004+4112, PG1115+080, RXJ1131-1231, 2MASS J11344050-2103230, 2MASS J13102005-1714579, B1422+231, J1606-2333, J1721+8842, WFI2033-4723, WGD2038-4008), 6 have three counterparts, 7 have two and 1 has only one. As expected, the modeling of HE0435-1223 shows that the model parameters are significantly better constrained when using *Gaia* astrometry compared to HST astrometry, in particular the relative positions of the background quasar source and the centroid of the deflector. The *Gaia* sub-milliarcsecond astrometry also significantly reduces the parameter correlations. *Conclusions*. Besides providing an up-to-date list of multiply imaged quasars and their detection in the *Gaia* DR2, this paper shows that more complex modeling scenarios will certainly benefit from *Gaia* sub-milliarcsecond astrometry.

Key words. Gravitational lensing: strong, Quasars: general, Astrometry, Methods: data analysis, Catalogues, Surveys

1. Introduction

The ESA/Gaia space mission (Gaia Collaboration et al. 2016b) constitutes an exceptional opportunity to characterize and to discover multiply-imaged quasars, although this was not put forth as one of the science objectives in the mission proposal. With a spatial resolution of ~0.18" Gaia is roughly comparable to HST for this particular feature (e.g. Bellini et al. 2011). However Gaia being a scanning mission is unique in providing an all-sky coverage with that angular resolution. Thus, by the final Gaia Data Release (DR), a whole population of such multiplyimaged quasars would be revealed, providing an all-sky, and the

first of this kind, survey of multiply imaged quasars with well understood source detection biases (e.g. de Bruijne et al. 2015; Arenou et al. 2017, 2018).

Several programs dedicated to systematic searches for lenses in large astronomical surveys such as SDSS, WISE, DES, PanSTARRS, among others, have been developed in recent years (e.g. More et al. 2016; Lin et al. 2017; More et al. 2017; Ostrovski et al. 2018), and many of them rely on supervised machine learning algorithms trained on simulations to handle the large volume of imaging data (e.g. Petrillo et al. 2017; Perreault Levasseur et al. 2017; Hartley et al. 2017; Pourrahmani et al. 2018; Lanusse et al. 2018). Naturally, even if *Gaia* does not provide images of the observed sources, contrary to the previously mentioned surveys, its high angular resolution over the entire sky is a major asset to contribute to the discovery and the study of multiply-imaged quasars.

^{*} Table of lenses (confirmed and candidates, detected or not in *Gaia* DR2) is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/gcat?J/A+A/

Finet & Surdej (2016) have investigated the potential of Gaia for gravitational lensing and compared it to the detectability with seeing-limited observations for the same limiting magnitude (G = 20). They expect at maximum about ~1600 multiply imaged quasars with an angular separation large enough to be resolved from the ground in an optimal seeing scenario, while scarcely ~80 would be composed by more than two images. However, they predict that detections from space are much more encouraging, raising the number of multiply imaged quasars detectable by a Gaia-like survey to ~2900, thanks to the improved resolving power alone.

The first Gaia Data Release (DR1; Gaia Collaboration et al. 2016a), besides providing the best available two-parameter astrometry (positions only) at the epoch of its publication, did not reach the effective angular resolution necessary to include most of the multiply-imaged quasars. This happened due to data processing issues and final astrometric quality reasons (Fabricius et al. 2016; Arenou et al. 2017). Yet, several multiply-imaged quasars discovered from other large surveys such as Pan-STARRS, DES, SDSS-III BOSS, HSCS or VST-ATLAS, were subsequently identified with at least one *Gaia* DR1 detection (e.g. Agnello et al. 2015; Agnello 2017; Lemon et al. 2017; Agnello et al. 2018).

The Gaia Data Release 2 (DR2; Gaia Collaboration 2018) on the other hand, starts to reach effective angular resolutions that are capable of resolving more multiply-imaged quasars (expected with typical separations below 1"). The Gaia DR2 effective resolution reaches ~ 0.4 ", with completeness for separations larger than ~ 2.2" (Gaia Collaboration 2018). However this resolution applies strictly only to astrometry and G band photometry; color data are available for objects with separations down to ~ 2", but its completeness reaches ~ 3.5" (Gaia Collaboration 2018). Even if it is still far from the ultimate resolving power of the Gaia instrument, the Gaia DR2 is a significant advance over DR1, as beyond its much improved effective angular resolution, it contains five-parameters astrometric data (positions, proper-motions, parallax) and also color information for most objects. This simplifies significantly the extraction of genuine extragalactic sources from the galactic stellar contaminants. Only the faintest or most problematic objects are characterized by just a two-parameters solution in this data release, which is unfortunately the case for several multiply imaged quasars since their magnitudes are often close to the Gaia limiting sensitivity at $(G \sim 20.7)$.

As part of a larger effort to discover and study multiplyimaged quasar candidates from the various Gaia Data Releases, our group first searched for new lensed systems around known or candidate quasars, enabling the discovery of highly probable multiply-imaged quasar candidates for the first time from Gaia data alone (Gaia GraL Paper I; Krone-Martins et al. 2018). In the present work, we report our findings regarding the identification of known gravitationally lensed quasars in Gaia DR2. We analyze the statistical astrometric properties of the detected lensed images and provide improved relative astrometry for them. We also derive soft astrometric filters that will be applied, as part of a global blind search (Gaia GraL paper III; Delchambre et al. in prep), to differentiate foreground stars from extragalactic objects without rejecting the faint components of known lensed systems. To illustrate how the exquisite optical astrometry of Gaia at the sub-milliarcsecond level may help to better constrain the lenses, we perform a simple modeling of the quadruple lens HE0435-1223 in a Bayesian framework, both using Gaia and HST astrometry, for comparison purposes.

The paper is organized as follows: In Sect. 2 we describe the construction of our list of gravitationally lensed quasars and candidates from published data. Sect. 3 presents the matching statistics of this list of known systems with the *Gaia* DR2. Sect. 4 presents the astrometric properties of the *Gaia* DR2 data for the known systems. A simple modeling within the Bayesian framework of a known lens using *Gaia* DR2 astrometry is described and discussed in Sect. 5. Finally, we summarize our findings in Sect. 6.

2. Compiled list of gravitationally lensed guasars

We have attempted to compile an as-complete-as-possible list of known gravitationally lensed quasars published in the literature prior to the Gaia DR2, including some recent candidates that are not yet spectroscopically confirmed. The major source of known gravitational lenses included in our list is the CASTLES (CfA-Arizona Space Telescope LEns Survey of gravitational lenses) site (Kochanek et al. 1999)¹ providing information for about 100 lenses, most of them observed with HST. Another important single source of known multiply imaged quasars is the SDSS Quasar Lens Search site (SQLS)², aimed to discover lensed quasars from the large homogeneous data of the Sloan Digital Sky Survey (SDSS) providing data on 49 additional lensed systems. We also included several quasar systems from the Master Lens Database (Moustakas 2012)³, a community-supported compilation of all discovered strong gravitational lenses. Finally we complemented our list with recent and more scattered discoveries from the literature. This list is being kept up-to-date, and will be maintained at least until the final Gaia Data Release. For the sake of completeness, we also included in this list the candidates with indication in the literature of just one image (usually spectroscopic candidates) expecting from the exceptional resolving power of Gaia that it may resolve some of them into multiple images in one of its Data Releases.

Our resulting list of published lensed or lens-candidate quasars contains 478 systems (234 confirmed systems and 244 lensed quasar candidates). This list is only available in electronic form at the CDS, including access through Virtual Observatory ready tools, it comprises lens identifiers, references and the Gaia astrometry and photometry when a match was found in the DR2. The summarized statistical properties of our list in terms of number of systems with 1, 2, 3 and 4 and more images and status are given in Table1.

3. Gravitationally lensed quasars in Gaia DR2

We extracted sources from the *Gaia* Data Release 2 within a radius of 10" around each source of our compiled list of known gravitationally lensed quasars using ADQL and the *Gaia* archive facility at ESAC (Salgado et al. 2017). We obtained the positions (α, δ) , parallaxes (ϖ) , proper-motion components $(\mu_{\alpha}, \mu_{\delta})$ and fluxes in the G, $G_{\rm BP}$ and $G_{\rm RP}$ pass-bands (Evans et al. 2018) along with their respective uncertainties.

For each individual image of each system, we performed a positional cross-match within a maximum angular separation of 0.5" between the astrometry found in the literature and the *Gaia* DR2. We visually inspected all systems one by one, by comparing the *Gaia* DR2 detections to the system discovery papers

https://www.cfa.harvard.edu/castles/

² http://www-utap.phys.s.u-tokyo.ac.jp/ sdss/sqls/lens.html

³ http://admin.masterlens.org/index.php?

and/or archival images from Aladin (Bonnarel et al. 2000; Boch & Fernique 2014).

Of the 478 gravitational lens systems (including candidates), 200 have at least one image matched with a *Gaia* DR2 source. The overall detection statistics of known systems that result from our examination is given in Table 1. An all-sky chart in galactic coordinates of the known lenses is shown in Fig. 1 along with a specification of the *Gaia* detection.

In Table 4 we present an extract of our list containing the lenses with three and more images for which at least one match was found in the *Gaia* DR2. The complete list of lenses and detection is available in electronic form only at the CDS.

Of the 41 known systems with four images (or more), 26 have at least one image detected in *Gaia* DR2. Within this group, one system has just one image detected, 7 have two images, 6 have three images and 12 are fully detected with four image seen in the *Gaia* data around the target direction. In Fig. A.1, we provide charts for the 12 systems with four detections with the Gaia DR2 positions referred to the A image (the brightest image in the system discovery passband) together with flux ratios. Of those which are fully detected, only five are characterized by sub-milliarcsec astrometry, and are reported in Table 2. The fainter image (in *G* band) of the others is detected but poorly constrained.

Table 1. Statistics of the known multiply imaged quasars present in our reference list (col. 2) and of the corresponding detected systems in the *Gaia* Data Release 2 (col. 3). A lensed system is considered to be detected in the *Gaia* DR2 if at least one of its images is detected. Numbers in parentheses correspond to the gravitationally lensed quasar candidates not spectroscopically confirmed yet.

Lensed	Number of	Number detected
images	known lenses	in Gaia DR2
1	55 + (213) = 268	11 + (17) = 28
2	133 + (28) = 161	112 + (28) = 140
3	6 + (2) = 8	4 + (2) = 6
4+	40 + (1) = 41	25 + (1) = 26
Total	234 + (244) = 478	152 + (48) = 200

4. Astrometric properties of the Gaia DR2 gravitationally lensed quasars

The images of a quasar produced by strong gravitational lensing are peculiar since they are not independent astronomical sources but multiple images of the same source, possibly with part of the host galaxy visible as small segments of an arc. Accordingly, they can produce some particular astrometric signatures in the *Gaia* DR2 solution, that could be helpful to discover further lensed quasar systems in the *Gaia* data.

Of the 382 individual images found in the *Gaia* DR2 coming from the 152 *confirmed* gravitationally lensed quasars with two or more images, 65 have a *Gaia* 2-parameter astrometric solution, i.e. right ascension and declination only (see Lindegren et al. 2018, for a description of the *Gaia* DR2 astrometric solution selection). The other 317 images have complete 5-parameter solutions $(\alpha, \delta, \mu_{\alpha} cos(\delta), \mu_{\delta}, \varpi)$. We investigated the statistical properties of the *Gaia* DR2 parameters of the multiple images of the known gravitationally lensed quasars, with results shown in Fig.2. This figure shows that parallaxes and proper motions of the images resulting from lensing occasionally reach large values for sources expected to have neither parallax nor motion. However, this results from the fact that these images are rather faint,

Table 2. Relative astrometry for five known quadruply imaged quasars fully detected in the *Gaia* DR2. The image references have been chosen to match those reported either in https://www.cfa.harvard.edu/castles/ or in their reference papers. They are not necessarily the brightest images in the *Gaia* G-band.

$\Delta \alpha \cos(\delta)$ (mas)	$\Delta\delta$ (mas)
0.0 ± 0.16	0.0 ± 0.14
-1476.56 ± 0.19	552.94 ± 0.16
-2466.27 ± 0.21	-603.05 ± 0.16
-938.66 ± 0.30	-1614.43 ± 0.25
0.00 ± 0.35	0.00 ± 0.52
1315.29 ± 0.36	3531.57 ± 0.49
11039.10 ± 0.47	-4494.69 ± 0.68
-8403.23 ± 1.21	9701.47 ± 1.50
588.68 ± 0.36	1118.89 ± 0.23
617.52 ± 0.39	2305.97 ± 0.25
0.0 ± 0.47	0.0 ± 0.30
-2522.23 ± 1.60	1993.80 ± 0.80
0.0 ± 0.11	0.0 ± 0.07
729.32 ± 0.11	1755.49 ± 0.07
-1947.39 ± 0.11	-772.70 ± 0.07
-1247.12 ± 0.28	1366.93 ± 0.20
-2196.54 ± 0.33	1261.42 ± 0.34
-1483.18 ± 0.26	1375.75 ± 0.30
0.0 ± 0.27	0.0 ± 0.24
-2113.84 ± 0.33	-277.84 ± 0.32
	-1476.56 ± 0.19 -2466.27 ± 0.21 -938.66 ± 0.30 0.00 ± 0.35 1315.29 ± 0.36 11039.10 ± 0.47 -8403.23 ± 1.21 588.68 ± 0.36 617.52 ± 0.39 0.0 ± 0.47 -2522.23 ± 1.60 0.0 ± 0.11 729.32 ± 0.11 -1947.39 ± 0.11 -1247.12 ± 0.28 -2196.54 ± 0.33 -1483.18 ± 0.26

at the limit of the *Gaia* DR2 sensitivity where the uncertainties from random noise are also large. In addition it may be also the case that some sources/images are embedded in extended and diffuse structures.

In a search for multiply imaged quasars in the *Gaia* DR2, applying a straight astrometric filter aiming at excluding stars from the deviation from zero parallaxes and proper motions weighted by the expected uncertainties, would likely also exclude a large number of images of lenses. So, based on the distribution of these parameters for the known lenses, we established the following softer astrometric cuts, that at the expense of a certain level of stellar contamination, avoid the rejection of genuine lens systems or of one or several images within a system.

Gaia DR2 sources that should be accepted to such a search would likely comply with ϖ -3 σ_{ϖ} < 4 mas and $|\mu|$ - $3\sigma_{\mu}$ < 4 mas/yr). We note here that μ stands for $\mu_{\alpha}cos(\delta)$ and μ_{δ} .

Indeed, we also adopted these soft filters in *Gaia* GraL Paper I (Krone-Martins et al. 2018), where we presented the first ever discoveries of quadruply imaged quasar candidates from data of an astrometric space mission. These statistical astrometric properties derived from *Gaia* measurements are also being used in a large, machine learning based, systematic blind-search for lenses in *Gaia* DR2 (*Gaia* GraL Paper III; Delchambre et al., in prep).

5. Gravitational lens modeling with sub-mas astrometry

Gravitational lensing provides an efficient tool to explore various aspects of our universe and several of its components. In the strong regime, the inference of physically meaningful quantities

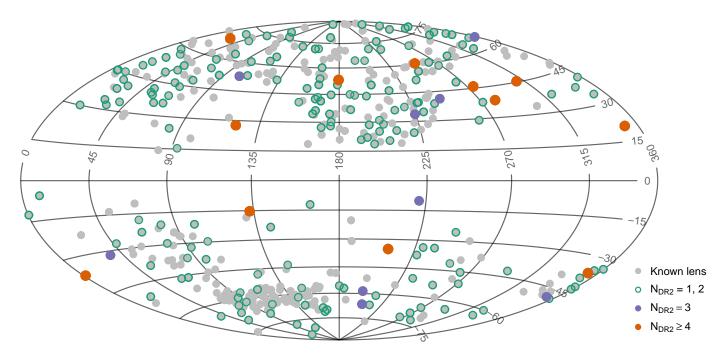


Fig. 1. All-sky chart in galactic coordinates with the galactic anti-center in the middle. The known multiply-imaged quasars are indicated in gray. The systems presenting one or two counterparts in *Gaia* DR2 are surrounded by a green open circle. The systems with three *Gaia* DR2 detections are indicated with purple filled circles, while the systems with four or more detections are indicated with orange filled circles.

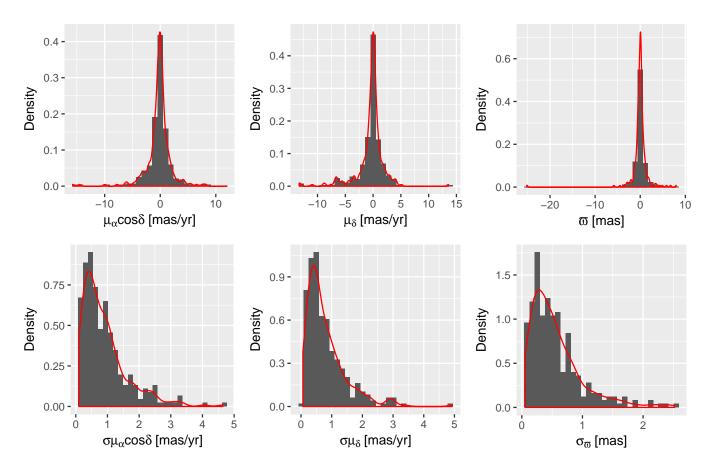


Fig. 2. Distributions of the astrometric parameters and their uncertainties for all the *Gaia* DR2 counterparts of the individual images of known multiply-imaged quasars with five parameter astrometric solutions.

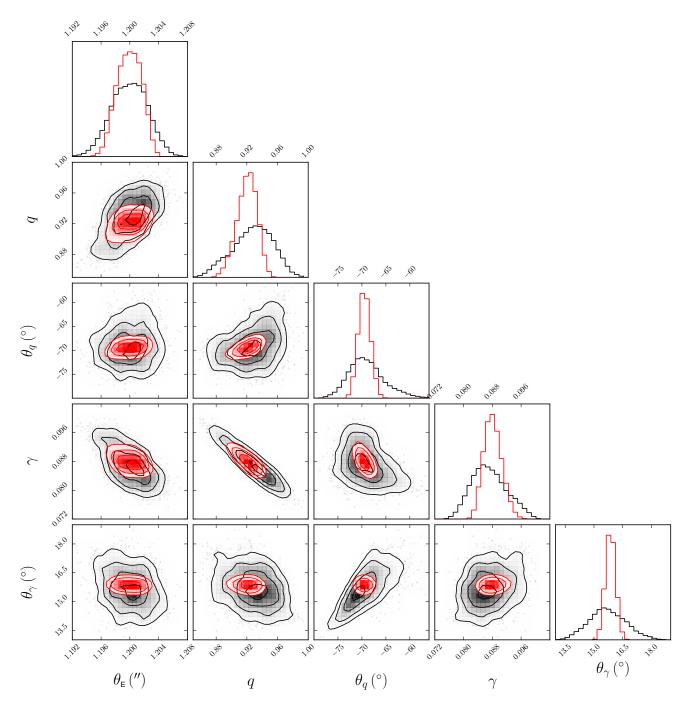


Fig. 3. Results of the MCMC simulations for HE0435-1223, displayed as a corner plot for the five model parameters. The diagonal panels illustrate the posterior PDFs while the off-axis panels illustrate the correlation between the parameters. We show the results obtained from *Gaia*'s data with shaded red contours and red histograms and with HST data with shaded black contours and black histograms. The three inner contours represent the 68.3%, 95.4%, and 99.7% confidence intervals.

from observational data usually requires the accurate modeling of the gravitational potential of the deflector. For example, the ability of modern time delay cosmography to infer the Hubble constant H_0 with a competitive precision relies significantly on its capacity in dealing with families of degeneracies existing between different plausible lens mass profiles (Saha 2000; Wucknitz 2002; Liesenborgs & De Rijcke 2012; Schneider & Sluse 2013). To probe the deflector mass distribution in the region where multiple images are formed, simple parametrized mass models are commonly used whose parameters are fixed by the observational constraints (e.g. Keeton 2001, 2010; Lefor & Fu-

tamase 2013; Lefor 2014), typically the lensed quasar image positions, the morphology of extended components, microlensing-free flux ratios, and time delays between image pairs. Naturally, a better accuracy in the observed parameters leads to a more reliable model. For the five known lenses RXJ1131-1231, SDSS1004+4112, 2MASS J1134-2103, HE0435-1223, and WFI2033-4723, the *Gaia* DR2 provides quasar image position measurements with an unprecedented precision of a few tenths of a milliarcsecond. With an order of magnitude improvement over typical HST astrometric accuracy, these new astrometric data should help to better constrain the lens models. Consid-

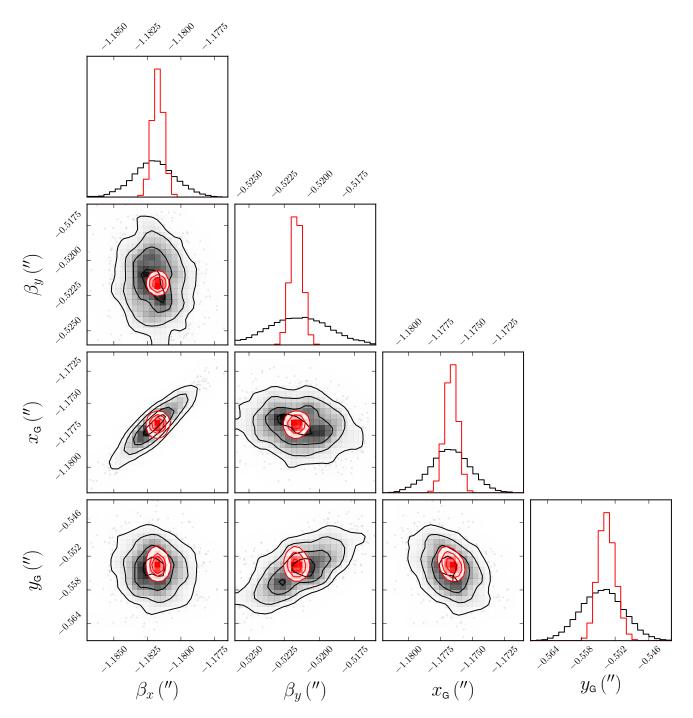


Fig. 4. Results of the MCMC simulations for HE0435-1223, displayed as a corner plot for the source and deflector positions. The diagonal panels illustrate the posterior PDFs while the off-axis panels illustrate the correlation between the parameters. We show the results obtained from *Gaia*'s data with shaded red contours and red histograms and with HST data with shaded black contours and black histograms. The three inner contours represent the 68.3%, 95.4%, and 99.7% confidence intervals.

ering four of the five known quadruply imaged quasars reported in Table 2 for which Gaia and HST astrometric data are available, the average of the Gaia astrometric uncertainties affecting the equatorial coordinates of the four lensed quasar images is found to be 0.43 mas compared to 3.29 mas using the corresponding HST data. This represents a huge gain (by more than a factor 7) in astrometric precision.

In this section, we illustrate how the improved astrometric accuracy obtained with *Gaia* may impact the lens modeling. To this end, we propose to optimize a smooth model to the ob-

served image positions only, within the Bayesian framework. The idea consists in simultaneously sampling the posterior Probability Density Functions (PDFs) for all model parameters using a Markov Chain Monte Carlo (MCMC) method, and then comparing the PDFs obtained from Gaia's astrometry with the ones derived from the astrometry found in the literature. We want to point out that our objective here is not to construct a set of realistic lens models in the sense that they could be used to perform time delay cosmography. Instead, we focus on how *Gaia* astrometric uncertainties may positively affect the goodness of

a more complex fit, which would include microlensing-free flux ratios, time delays, non-lensing data related to the main deflector, or even simultaneous reconstruction of the source and deflector surface brightnesses.

We model the main deflector as a singular isothermal ellipsoid (SIE, see e.g. Kormann et al. 1994) which effectively describes the mass distribution of a massive early-type galaxy in the region where multiple images are formed (Gilman et al. 2017). An SIE is characterized by five free parameters; the Einstein radius $\theta_{\rm E}$, the elliptical axes ratio q and position angle θ_q , and the lens centroid (x_G, y_G) with respect to image A. Since the lensed quasar image positions are generally most sensitive to the local mass distribution, we model the large-scale contributions and possible close line-of-sight galaxy perturbing effects with an external shear term characterized by its absolute value γ and position angle θ_{γ} . The model is thus kept simple, which limits the number of free parameters and avoids the use of the full multi-plane lensing formalism (Schneider 2014; McCully et al. 2014, 2016). In addition, we consider the position of the pointlike source (β_x, β_y) with respect to image A that is also free to vary during the optimization process, bringing the number of free parameters n_k to nine.

To draw samples from the posterior PDFs, we used emcee⁴ (Foreman-Mackey et al. 2013), a python package which implements the affine invariant ensemble sampler for MCMC proposed by Goodman & Weare (2010). Since we only use the lensed image positions $\theta_{\rm obs}$ as observational data to fit, the log-likelihood function simply reads

$$\ln p(\boldsymbol{\theta}_{\text{obs}}|\boldsymbol{k}) = -\frac{1}{2} \sum_{j=1}^{2N} \left(\frac{\left(\theta_{\text{obs},j} - \theta_{\text{model},j}(\boldsymbol{k})\right)^2}{\sigma_{\text{obs},j}^2} - \ln\left(\sigma_{\text{obs},j}^2\right) \right), \quad (1)$$

where k is the vector of free parameters, N the number of lensed images (hence 2N constraints), $\sigma_{\rm obs}$ the astrometric uncertainties, and $\theta_{\mathrm{model}}(k)$ the lensed image positions obtained from the free parameters k and generated with the python package pySPT⁵ (Wertz & Orthen 2018). To control the sampling, only two hyperparameters need to be tuned: an adjustable scale parameter a and the number N_w of walkers. The scale parameter a has a direct impact on the acceptance rate of each walker, namely the ratio of accepted to proposed candidates, and was set to a = 2, following Goodman & Weare (2010). A walker can be seen as a Metropolis-Hastings chain (see, e.g., MacKay 2003) whose associated proposal distribution depends on the positions of all the other walkers (Foreman-Mackey et al. 2013). Prior to run the MCMC, we initialized $N_w = 350$ walkers in a small n_k dimensional ball of the parameter space around a highly probable solution, formerly obtained using the public lens modeling code lensmodel⁶ (v1.99, Keeton 2001). Obviously this initial model may not be the most appropriate one and is more likely a local solution in the parameter space. Nevertheless, it constitutes a valid starting point to illustrate our intention.

The analysis has been performed for the five lenses from Table 2 for which HST image position measurements are available, namely HE0435-1223, SDSS1004+4112, RXJ1131-1231, 2MASS J1134-2103, and WFI2033-4723. In Figs. 3 and 4, we illustrate the MCMC results in the form of corner plots for HE0435-1223, which are representative of each of the five quadruply imaged quasars that we have preliminary modeled. The HE0435-1223 image positions measured with the Wide

Table 3. The SIEg lens model parameters derived for HE0435-1223. The reported values are medians within 1σ error bars.

Parameters	HST	Gaia
$\theta_{\rm E}$ (")	1.2 ± 0.003	1.2 ± 0.001
q	0.93 ± 0.03	0.9210 ± 0.01
θ_q (°)	-69.4 ± 3.8	-69.5 ± 0.8
γ	0.087 ± 0.005	0.088 ± 0.002
θ_{γ} (°)	15.7 ± 0.9	15.9 ± 0.1
β_x (mas)	-1182.0 ± 1.6	-1181.7 ± 0.1
β_{y} (mas)	-521.4 ± 2.1	-521.6 ± 0.1
$x_{\rm G}$ (mas)	-1176.7 ± 1.5	-1176.6 ± 0.3
$y_{\rm G}$ (mas)	-554.2 ± 3.7	-553.6 ± 1.2

Field Camera 3 (IR/F160W, Robberto et al. 2002) mounted on the HST come from Kochanek et al. (2006), showing astrometric uncertainties between 3 and 5 mas. As expected, all the posterior PDFs obtained from Gaia's data show narrower widths than those obtained from HST data, while some of them are slightly shifted. Thus the use of Gaia's astrometry significantly reduces the ranges of valid model parameters around a highly probable solution, as shown in Table 3. The least sensitive parameter is the Einstein radius, even if it is improved three-folded with respect to HST observations. In particular, the source position is constrained within a σ -error ellipse of $(\sigma_{\beta_1}, \sigma_{\beta_2}) = (0.1, 0.1)$ mas. This one order of magnitude improvement indicates that the sub-mas astrometry of Gaia clearly helps to better constrain the position of the point-like source as well as the source surface brightness reconstruction as part of a more realistic modeling scenario.

We also note that the *Gaia* DR2 astrometry reduces significantly the resulting correlation structure between the modeled parameters, in comparison with the correlations obtained from the modeling using HST data: the absolute value of the correlation coefficients between θ_q and θ_γ , and θ_q and q, in Fig. 3 and between β_y and y_G , and β_x and x_G in Fig. 4, are clearly reduced thanks to the improved astrometry.

A more advanced version of the lens modeling within the Bayesian framework described in this section will be consistently applied to all the known lenses and to the highly probable lens candidates discovered from the systematic blind-search for lenses in the entire *Gaia* DR2 (*Gaia* GraL Paper III, Delchambre et al., in prep), and this will be presented in a forthcoming work (*Gaia* GraL Paper IV, Wertz et al., in prep).

6. Conclusions

The availability of high-precision and high-accuracy astrometric data as provided by the ESA/Gaia space mission opens a new window to detect and model gravitationally lensed quasar systems with an unprecedented refinement. This is bound to impact on fundamental applications in astronomy that are derived from this phenomena, such as the study of the lensing galaxy populations, distant quasars, dark matter and dark energy properties and consequently the determination of cosmological parameters. To exploit this new field with Gaia data we have set up a collaboration group, the *Gaia* GraL team, to systematically analyze the gravitationally lensed quasar content throughout the Gaia Data Releases. The topics covered include searches for new multiply imaged quasar candidates, identifications of known lenses in the Gaia data, modeling of the lenses using the outstanding Gaia astrometry and multi-colour photometry, and fostering groundbased follow-up for final confirmation.

⁴ https://github.com/dfm/emcee

⁵ https://github.com/owertz/pySPT

⁶ http://physics.rutgers.edu/ keeton/gravlens/2012WS/

In this paper we explain how we first generated an up-to-date list of known gravitationally lensed quasars, including lensed quasars too faint to be observed by *Gaia*. The *Gaia* GraL list of known gravitationally lensed quasars will be kept up-to-date with respect to the astronomical literature at least until the final *Gaia* Data Release. Each *Gaia* Data Release will be analyzed to verify the detection of known gravitational lenses.

Then we provide here the first ever sub-milliarcsecond astrometric data for hundreds of known gravitationally lensed quasars. The search is based on the aforementioned list matched to the *Gaia* DR2 astrometric catalogue, the largest and most precise astrometric reference available to date. Our lens results bring almost one order of magnitude improvement in astrometric precision compared to a typical HST observation. Moreover, even if *Gaia* DR2 is still an early Data Release lacking many lensed images, it brings high-precision astrometry complemented with photometric data for most known lensed systems. Thus, it provides a glimpse of the content that will become available in the forthcoming Gaia Data Releases.

Of the 478 presently known — or candidate — gravitationally lensed quasars, we have found in the *Gaia* DR2 at least one counterpart for 200 of them. From these objects, the quadruply-imaged quasars occupy a specially relevant place, as they provide the more stringent physical parameter inferences. There are 41 presently known quads. From these, 25 have been found with at least one entry in *Gaia* DR2 and 12 of them are fully detected with all four images. As the images of many of these objects have smaller angular separations than the *Gaia* DR2 best angular resolution, we expect however the forthcoming Data Releases to provide information for most of them when the releases gradually reach the expected *Gaia* best spatial resolution. We provide also *Gaia* DR2 astrometric and photometric data for all known lenses to date.

Finally, we show that the adoption of high-precision astrometry from *Gaia* DR2 to model the well-known lens system HE0435-1223 results in a significant improvement in constraining the lens parameters of a NSIEg model around a highly probable solution, and that it also significantly reduces the parameter correlations, in comparison to standard HST astrometry. Such constraints will certainly be further improved with the increased precision of *Gaia*'s forthcoming nominal mission Data Releases, expected for 2020 (DR3) and 2022 (DR4), and the still to be announced Data Release(s) of the *Gaia* mission extension.

As a final conclusion this work vividly demonstrates the significant impact of high-precision astrometry from *Gaia* and future mission concepts as the JASMINE series (Gouda 2011), GaiaNIR (Hobbs et al. 2016), and Theia (The Theia Collaboration et al. 2017), to the study of strong gravitational lensing. This paper also exemplifies the ever wider impact of the *Gaia* satellite, pushing its limits from its original goal of studying the Milky Way galaxy towards more distant extragalactic sources and associated phenomena.

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Table 4. List of known gravitationally lensed quasars with 3, 4 or 5 images and with at least one match in the *Gaia* DR2. (1)Name (with (*) see note at the bottom), (2) ref - bibliographic reference (* designates candidates), (3) N_{im} – number of images of the lens in the literature, (4) Gaia Sourceld, (5,6) ICRS positions from *Gaia* DR2 at epoch 2015.5, (7,8,9) *Gaia* G, G_{BP} , G_{RP} magnitudes and standard errors (calculated by CDS).

GRP	17.5129 ± 0.0107 14.8218 ± 0.0441	17.7388 ± 0.0336	17.6442 ± 0.0325	19.6238 ± 0.0610 18.7889 ± 0.0462	17.8801 ± 0.0610 17.6339 ± 0.0220	18.4840 ± 0.0277 18.1779 ± 0.0373 18.0411 ± 0.0467	15.1723 ± 0.0078	19.1918 ± 0.1998 17.8027 ± 0.0263	17.6076 ± 0.05273	19.3598 ± 0.0514	18.6081 ± 0.0268 18.7456 ± 0.0579	16.5761 ± 0.0121	16.3431 ± 0.0227 16.4789 ± 0.0240	15.9208 ± 0.0158 17.8989 ± 0.0371 15.9258 ± 0.0007	16.5723 ± 0.0442	16.6770 ± 0.0627 16.2567 ± 0.0323	16.4024 ± 0.0313 18.4332 ± 0.0394	19.1140 ± 0.0335	17.8071 ± 0.0252	18.9536 ± 0.0674	18.5691 ± 0.0525
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GBP	18.3850 ± 0.1694 15.5900 ± 0.0548	18.3755 ± 0.0226	18.9059 ± 0.0573	20.2464 ± 0.0971 19.7080 ± 0.0480	18.5996 ± 0.0952 18.0642 ± 0.0452	19.5704 ± 0.2020 19.5925 ± 0.0622 19.2062 ± 0.1361	16.1982 ± 0.0176	19.8129 ± 0.0927 18.3875 ± 0.0383	18.3105 ± 0.0502	19.8931 ± 0.0883 20.2623 + 0.2021	$\begin{array}{c} 2.2525 \pm 0.023 \\ 19.3055 \pm 0.0434 \\ 19.2207 \pm 0.0422 \end{array}$	17.2033 ± 0.0118	16.7641 ± 0.0348 16.8367 ± 0.0507	16.5405 ± 0.0126 18.5038 ± 0.0603 16.5525 ± 0.0223	17.1130 ± 0.0505	17.4714 ± 0.0083 16.8801 ± 0.0043	17.1767 ± 0.0759 19.0469 ± 0.0387	20.3333 ± 0.0690	18.5397 ± 0.0371	19.8397 ± 0.1231	$19.56/0 \pm 0.0685$ 19.7893 + 0.0433
G		19.3041 ± 0.0078 19.0355 ± 0.0047 18 20.0651 ± 0.0141		20.8249 ± 0.0222 20.4514 ± 0.0101 20 19.7447 ± 0.0071 15	18.8373 ± 0.0067 18 18.8942 ± 0.0104 19.3013 ± 0.0104 18.5754 ± 0.0060 18	20.0917 ± 0.0083 19.9856 ± 0.0067 19.0078 ± 0.0071 19.0078		$19.8927 \pm 0.0085 \qquad 19$ 19.7670 ± 0.0157 $18.7832 \pm 0.0120 \qquad 18$	18.3811 ± 0.0141 18 19.9453 ± 0.0145	19.9953 ± 0.0087 19			17.4980 ± 0.0266 16 17.3972 ± 0.0137 16	18.9413 ± 0.0109 17.1502 ± 0.0146 16 18.5837 ± 0.0070 18 17.1702 ± 0.0110		$17.2709 \pm 0.0045 \qquad 17.18.9371 \pm 0.0061$					19.7662 \pm 0.0084 15
Declination [°]±[mas]		$-21.29074906026 \pm 0.4626$ 1-21.290749450 ± 0.3369 1-21.29024032275 ± 0.6378 2-6550403683 ± 0.6378			-12.28748166882 ± 0.1294 1 -12.28716055854 ± 0.1249 1 -12.28776263363 ± 0.2298 1 -12.28731415348 ± 0.0978 1	-12.02241686045 ± 2.1094 2-12.02225598303 ± 1.0049 1-12.02194351373 ± 0.6697 2		5.84851723352 ± 0.4200 1 5.84856614310 ±21.7528 1 5.84840999370 ± 0.5057 1	2.32371368311 ± 0.2048 1 2.32321168663 ± 0.6246 1				-6.96068252038 ± 1.8016 T	7.76614341006 ± 0.2882 1 7.76625027119 ± 0.3194 1 7.76668844843 ± 0.1872 1 7.76612506243 ± 2.9684 1		$\begin{array}{c} -21.05664892265 \pm 0.0510 \\ -21.05605458128 \pm 0.1929 \\ 1.0563333362 \pm 0.0506 \\ \end{array}$					$-17.25007184536 \pm 0.4609$ 1
Right ascension [°1±[mas]	77656 ± 0.1330 59485 ± 0.2699 16590 ± 0.4754 24025 ± 4.7897	38.13811782066 ± 0.2498 38.13832537061 ± 0.1989 38.13847486587 ± 0.4449			69.56160351805 ± 0.1802 69.56188488232 ± 0.1534 69.56203780095 ± 0.2818 69.56230465346 ± 0.1145	97.53784635400 ± 1.6412 97.53799106290 ± 0.8450 97.53808564125 ± 0.5711		137.86423190910 ± 0.6464 37.86506252061 ±48.4513 137.86513579392 ± 0.5169	141.23256103405 ± 0.2185 141.23257901195 ± 0.5972				$169.09802843301 \pm 6.0376$ $169.09816765399 \pm 7.0797$	169.57015797740 ± 0.4371 169.57066712476 ± 0.3243 169.57025413596 ± 0.3157 (69.57062805579 ±24.4805		173.66852228570 ± 0.0768 173.66873072407 ± 0.2741 173.66873073174 ± 0.0750		16747 ± 0.2836 31033 ± 3.4623			197.38402962339 ± 0.7637 = 107.8840296233 ± 0.7637
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Table 4. continued.

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## 6044 B. 1759043450 p. 6.0328 20.0199 p. 6.0047 B. 6.812 # 0.0191 B. 1759043450 p. 6.0329 20.0827 # 0.0045 B. 21.88 E. 0.0191 E. 0.0476 S. 21.88711055446 p. 6.0448 E. 0.0877 E. 0.0970 E. 0.0878 E. 0.0877 E. 0.0970 E. 0.0878 E. 0.0872						[~]±[mas]	[mag]	[mag]	[mag]
## 68.822 81.815/902714 ## 0.5860 18.4218 # 0.019] ## 6.0133 31.8811/06/21446 # 0.4428 19.00857 # 0.0007 ## 6.0313 31.8811/06/21446 # 0.4428 19.555 # 0.0007 ## 6.0313 31.8811/06/2144 # 0.4429 17.3918 # 0.0007 ## 6.0360 11.4955/412121 # 4.0459 17.3918 # 0.0007 ## 6.0361 1.4955/412121 # 4.0459 17.3918 # 0.0002 ## 6.0360 11.4955/412121 # 4.0459 17.4124 # 0.016 17.0120 # 0.017 ## 6.0340 1.4953/142484 # 1.7245 17.4124 # 0.016 17.0120 # 0.017 ## 6.0340 12.0333/421808 # 1.7245 16.535 # 0.0002 15.987 # 0.017 ## 6.0340 12.0333/421808 # 1.7245 10.010 # 0.0169 15.874 # 0.017 ## 6.0340 10.1208164197 # 0.4310 18.734 # 0.0002 15.874 # 0.0829 ## 6.0340 10.1208164197 # 0.4310 18.734 # 0.0002 15.834 # 0.0829 ## 6.0340 10.1208164197 # 0.4310 18.734 # 0.0002 18.265 # 0.0882 ## 6.0340 10.1208164197 # 0.4310 18.734 # 0.0002 18.265 # 0.0882 ## 6.0340 10.1208164197 # 0.4310 18.825 # 0.0002 18.265 # 0.0389 ## 6.0340 10.1208164197 # 0.4310 18.825 # 0.0002 18.334 # 0.035 # 0.017 ## 6.0340 10.1208164197 # 0.3241 18.825 # 0.0002 18.334 # 0.035 # 0.017 ## 6.0340 10.1208164197 # 0.2387 19.610 # 0.0163 18.265 # 0.0389 ## 6.0388 10.0209444 # 0.2481 10.0310 # 0.0003 18.265 # 0.0389 ## 6.0388 10.021994924 # 0.2497 18.228 # 0.0003 18.238 # 0.0075 19.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.334 # 0.0173 18.326 # 0.0146 19.304 # 0.0265 19.344 # 0.085 19.344 #	SDSS J1330+1810 C	13	4	3746665350016537088		$18.17590345192 \pm 0.3528$	20.0199 ± 0.0097		
## 6.0.3133 31.81.31960237 ± 0.2089 20.8875 ± 0.0087 19.6481 ± 0.0657 1.4085712121 ± 0.4095 17.5591 ± 0.0087 1.408572121 ± 0.4095 17.591 ± 0.0075 1.408572121 ± 0.4095 17.591 ± 0.0075 1.408572121 ± 0.4095 17.591 ± 0.0075 1.408572121 ± 0.4095 17.591 ± 0.0075 1.4085772121 ± 0.4095 17.4443 ± 0.0161 1.70122 ± 0.1567 1.4085772121 ± 0.4095 1.4085772121 ± 0.4095 1.4085772124 ± 1.7026 1.70122 ± 0.1567 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.40857724 ± 0.0075 1.4087724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.408724 ± 0.0075 1.409724 ± 0.	SDSS J1330+1810 AB	13	4	3746665345725273472		$18.17557927148 \pm 0.5600$	18.9459 ± 0.0045	18.5218 ± 0.0191	17.6031 ± 0.0119
14.0.3133 31.58.11340602374 e.0.099 19.5753 e.0.0077 19.6481 ± 0.0573 18.0530 11.49554201201 ± 4.0495 17.5318 ± 0.0077 19.6481 ± 0.0573 18.0532872431221 ± 4.0495 17.5318 ± 0.0080 11.4955420121 ± 4.0495 17.5318 ± 0.0080 11.4955372488 ± 1.0421 17.3422 ± 0.012 17.0120 ± 0.1567 1.0120 ± 0.1578 1.0120 ± 0.	J1400+3134 B	13	3	1454504422981470976		$31.58171057446 \pm 0.4428$	20.0857 ± 0.0089		
## 1.873	J1400+3134 A	13	3	1454504418686043904		$31.58131960237 \pm 0.2969$	19.5755 ± 0.0077	19.6481 ± 0.0573	18.9430 ± 0.0411
## 1.7339 11.495377124845 ## 1.7926 7.4442 ## 0.0107 16.7056 ## 0.0129 ## 0.0877 22.9333372661 ## 0.1121 16.8977 ## 0.0026 ## 0.0877 22.9333372661 ## 0.1121 16.8977 ## 0.0026 ## 0.0877 22.933372645 ## 0.1121 16.8977 ## 0.0026 ## 0.0877 22.933372645 ## 0.0104 ## 0.0258 ## 0.0129 ## 0.0104 ## 0.0258 ## 0.0104 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0128 ## 0.0104 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0128 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005 ## 0.0258 ## 0.0005	H1413+117 C	43	4	1225461582386033536		$11.49554421221 \pm 4.0495$	17.5918 ± 0.0096		
## 1,00877 22,9338372661 # 0.1121	H1413+117 A	43	4	1225461582386571008		$11.49530779513 \pm 1.6421$	17.3422 ± 0.0127	16.7056 ± 0.0129	15.9767 ± 0.0151
## 0.0877 2.9 3338754972 16.6887 ± 0.0036 15.987 ± 0.017 16.8977 ± 0.0136 15.987 ± 0.017 16.8977 ± 0.0136 15.987 ± 0.017 16.897 ± 0.0187 16.788 ± 1.2745 16.788 ± 1.0246 16.2555 ± 0.0080 15.987 ± 0.017 19.814 ± 0.0149 19.7110 ± 0.0149 19.7110 ± 0.0149 19.7110 ± 0.0149 19.8346 ± 0.0180 19.7110 ± 0.0149 19.8346 ± 0.0882 19.8861 ± 0.0099 19.8346 ± 0.0882 19.8861 ± 0.0099 19.8346 ± 0.0889 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8346 ± 0.0899 19.8342 ± 0.0999 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0189 19.8342 ± 0.0174 ± 0.8399 19.8342 ± 0.0017 19.8343 ± 0.0811 19.8343 ± 0.0811 19.8343 ± 0.0174 ± 0.8399 ± 0.2726 ± 0.0399 18.7252 ± 0.0079	H1413+117 B	43	4	1225461582386033792		$11.49537124845 \pm 1.7926$	17.4443 ± 0.0161	17.0120 ± 0.1567	16.1650 ± 0.1682
+ 0.5497 22.934921184 + 1.745 16,678 ± 0.0021 15.987 ± 0.017 15.84.4208 15.93492188 + 1.745 16,678 ± 0.0029 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.017 15.987 ± 0.0187 15.987 ± 0.0187 15.988 ± 0.0117 15.988 ± 0.0187 15.988 ± 0.0117 15.988 ± 0.0187 15.988 ± 0.0187 15.988 ± 0.0187 15.988 ± 0.0187 15.988 ± 0.0187 15.988 ± 0.0187 15.988 ± 0.0087 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0383 18.2855 ± 0.0384 19.0116 ± 0.0163 18.2855 ± 0.0384 19.0116 ± 0.0163 18.2855 ± 0.0394 19.0116 ± 0.0163 18.2855 ± 0.0394 19.0116 ± 0.0163 18.2855 ± 0.0394 19.0116 ± 0.0163 18.2853 ± 0.0394 19.2910 ± 0.0394 19.2910 ± 0.0394 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.0394 ± 0.13994 ± 0.13994 ± 0.1394 ± 0.0394 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.13994 ± 0.0394 ± 0.13994	B1422+231 C	43	4	1254357435158834560		22.93328372661 ± 0.1121	16.8977 ± 0.0036		
## 0.5397 2.2933369457 ±34.3800 19.7110 ± 0.0149 ## 0.63781 60.12083336845 ± 1.6440 20.2585 ± 0.00180 ## 0.63781 60.1208336845 ± 1.6440 20.2585 ± 0.01094 ## 0.63781 60.1208336845 ± 1.6440 20.2585 ± 0.017094 ## 0.6334 60.12042437659 ± 0.5872 ± 0.0096 19.8344 ± 0.0899 ## 0.6312 62.35601230462 ± 0.5872 ± 0.0096 19.8344 ± 0.0899 ## 0.6334 60.12142437659 ± 0.5872 ± 0.0096 19.8345 ± 0.0396 ## 0.6334 60.12142437659 ± 0.5872 ± 0.0016 18.8351 ± 0.0356 ## 0.6472 2.3.55601230462 ± 0.5877 19.6110 ± 0.0163 ## 0.6472 2.3.55601230462 ± 0.5877 19.6110 ± 0.0163 ## 0.6472 2.3.556012304024 ± 0.6489 19.265 ± 0.0016 18.8351 ± 0.0356 ## 0.6473 2.3.55601294025 ± 0.1969 18.8525 ± 0.0016 18.8351 ± 0.0356 ## 0.6472 2.3.55601230462 ± 0.2481 19.0310 ± 0.0016 18.8351 ± 0.0356 ## 0.6472 2.3.55601230462 ± 0.2481 19.0310 ± 0.0057 18.8343 ± 0.0811 ## 0.6472 2.3.55601230402 ± 0.1360 18.1755 ± 0.0063 18.8343 ± 0.0811 ## 0.6472 2.0660390446 ± 0.2481 19.0310 ± 0.0059 18.8343 ± 0.0811 ## 0.6472 2.0660390446 ± 0.2481 19.0310 ± 0.0059 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0173 18.8343 ± 0.0059 18.8343 ± 0.0173 18.8343 ± 0.0059 18.8343 ± 0.0059 18.8343 ± 0.0059 18.8358026692 ± 0.1300 18.1755 ± 0.0059 18.934 ± 0.1356 18.8362 ± 0.0477 ± 0.0059 18.934 ± 0.1356 18.8362 ± 0.0471 ± 0.0059 18.934 ± 0.1356 ± 0.1368010424 ± 0.1368 19.9210 ± 0.0053 19.264 ± 0.0422 19.2443 ± 0.0053 19.24	B1422+231 B	43	4	1254357435159465088		$22.93349211808 \pm 1.2745$	16.6783 ± 0.0021		
#\$8.4203 22.93326929457 ±34.3890 19.7110 ± 0.0149 #£6.40781 60.1208380457 ±34.3890 19.7110 ± 0.0149 #£7.818 60.1208380457 ±34.3890 19.7110 ± 0.0149 #£7.834 60.12042437659 ± 0.5872 19.861 ± 0.0094 19.8346 ± 0.0889 #£7.835 60.12042447659 ± 0.5872 19.861 ± 0.0094 19.8346 ± 0.0889 #£7.836 7.23.559172472 ± 7.837 19.6110 ± 0.01063 #£4.337 2.23.559172472 ± 7.837 19.6110 ± 0.01063 #£7.828 8.76589729174 ± 0.4895 19.265 ± 0.0033 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0035 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0035 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0037 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0035 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0035 #£7.838 8.87689729174 ± 0.4895 19.265 ± 0.0035 #£7.839 8.87689729174 ± 0.2481 19.0310 ± 0.0050 #£7.830 8.87689729174 ± 0.2481 19.0310 ± 0.0050 #£7.830 8.87689729174 ± 0.2491 ± 0.0064 #£7.830 8.87689729174 ± 0.2491 19.0310 ± 0.0050 #£7.84 6.73987289107 ± 0.2491 ± 0.0064 #£7.8489	B1422+231 A	43	4	1254357435158834688		$22.93357549720 \pm 0.6104$	16.2555 ± 0.0080	15.987 ± 0.017	14.962 ± 0.011
### 60.12083308456 # 1.0440	B1422+231 D	43	4	1254357435158834816	$216.15899268510 \pm 58.4203$	22.93326929457 ±34.3890	19.7110 ± 0.0149		
1 ± 0.4977 (60.12038164197 ± 0.4310 19.8749 ± 0.0076 19.6307 ± 0.0682 4.10.6334 4.10.4376694 ± 0.0872 19.8746 ± 0.0094 19.8346 ± 0.0089 4.10.8346 ± 0.0089 4.10.872 19.816 ± 0.0094 19.8346 ± 0.0089 4.10.872 19.8216 ± 0.0094 19.8346 ± 0.0089 4.10.806 4.10.80	SDSS J1433+6007 C	38	4	1618050348046583680		$60.12083308456 \pm 1.0440$	20.2585 ± 0.0117		
1+17.893	SDSS J1433+6007 A	38	4	1618050348048027648		$60.12038164197 \pm 0.4310$	19.8749 ± 0.0076	19.6307 ± 0.0682	19.1394 ± 0.0539
### 2.3.65621065040 ±13.6665 19.3273 ± 0.0097	SDSS J1433+6007 B	38	4	1618050554206457984		$60.12142437659 \pm 0.5872$	19.9861 ± 0.0094	19.8346 ± 0.0989	19.3034 ± 0.0479
### 1.337	J1606-2333 C	32	4	6242307087212540160	241.50098822162 ±17.8936	$-23.55621065040 \pm 13.6665$	19.3273 ± 0.0097		#
## 1.337 -23.55595910220 ± 0.1969 18.8525 ± 0.0053 18.2655 ± 0.0383 18.2655 ± 0.0336 18.355124162 ± 0.3274 18.9721 ± 0.0115 18.3551 ± 0.0356 18.3551 ± 0.0356 19.2056 ± 0.0072 19.20582 ± 0.0374 19.0310 ± 0.00072 18.351 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.3551 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0356 18.351 ± 0.0357 18.3525 ± 0.0075 18.3525 ± 0.0075 18.3525 ± 0.0075 18.3525 ± 0.0084 18.4834 ± 0.0811 18.3537 ± 0.0173 18.3537 ± 0.0173 18.3537 ± 0.0173 18.3537 ± 0.0084 18.4834 ± 0.0811 17.333 ± 0.0173 18.3537 ± 0.0357 19.247 ± 0.0092 17.333 ± 0.0173 19.247 ± 0.0092 19.247 ± 0.0092 18.8262 ± 0.0002 18.8262 ± 0.0002 18.8262 ± 0.0002 19.344 ± 0.0052 19.244 ± 0	J1606-2333 D	32	4	6242307087220282624	241.50089149589 ±43.2108	$-23.55591724742 \pm 7.8737$	19.6110 ± 0.0163		+1
## 1.3337 -23.55612324162 ± 0.3274 18.9721 ± 0.0115 18.3351 ± 0.0536 ## 0.0103 88.70660390446 ± 0.2481 19.0310 ± 0.0050 ## 0.0138 88.70660390446 ± 0.2481 19.0310 ± 0.0050 ## 0.0232 88.70621468902 ± 0.1300 18.1755 ± 0.0053 18.3643 ± 0.0387 ## 0.1535 88.70651468902 ± 0.1300 18.1755 ± 0.0053 18.3643 ± 0.0811 ## 0.1535 88.70651468902 ± 0.1721 18.3387 ± 0.0084 18.4834 ± 0.0811 ## 0.1535 88.70556239408 ± 0.1724 18.2387 ± 0.0079 ## 0.1535 88.70556239408 ± 0.1721 18.3387 ± 0.0079 ## 0.1535 47.39537499737 ± 0.2933 18.0677 ± 0.0079 ## 0.1748 47.39537499737 ± 0.2475 10.0079 ## 0.1860 47.395323862 ± 0.2447 = 0.0092 ## 0.1860 47.395323862 ± 0.2445 19.9010 ± 0.0055 ## 0.1860 47.3951323862 ± 0.4463 ## 0.1369 47.3951323801 ± 0.4463 ## 0.1369 40.13740086159 ± 0.4163 ## 0.1369 40.13740086159 ± 0.4163 ## 0.1369 40.13740086159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1369 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740986159 ± 0.4163 ## 0.1360 40.13740	J1606-2333 A	32	4	6242307087212540032		$-23.55595910220 \pm 0.1969$	18.8525 ± 0.0053	18.2655 ± 0.0383	17.5597 ± 0.0275
1 9.10.6103 88.70589729174 ± 0.4895 19.9265 ± 0.0072 19.0260388 8.70680390446 ± 0.2481 19.0310 ± 0.0050 19.0382 88.70660390446 ± 0.2481 19.0310 ± 0.0050 19.0387 19.0310 ± 0.0050 18.755 ± 0.0052 1.00992 10.06595 ± 0.0174 19.0310 18.1755 ± 0.0053 18.3063 ± 0.01206 18.70556237840 ± 0.1721 18.3287 ± 0.0034 18.4834 ± 0.0811 19.0328 4.5607187581 ± 0.2644 18.6226 ± 0.0073 18.0677 ± 0.0132 16.8025 ± 0.0290 17.1982 ± 0.0132 16.8025 ± 0.0290 17.1982 ± 0.0132 18.0677 ± 0.0071 17.7333 ± 0.0173 18.0677 ± 0.0071 17.7333 ± 0.0173 18.0677 ± 0.0071 17.333 ± 0.0173 18.0677 ± 0.0071 17.333 ± 0.0173 18.0677 ± 0.0050 18.8262 ± 0.0050 18.8262 ± 0.0050 18.8262 ± 0.0050 18.9346 ± 0.1256 18.8340 ± 0.1358 40.1369305210 ± 0.4364 19.9010 ± 0.0053 18.9346 ± 0.1256 18.9346 ± 0.1256 18.9346 ± 0.1256 18.9346 ± 0.1256 18.9346 ± 0.1256 19.9348 ± 0.1859 19.9348 ± 0.1859 19.9348 ± 0.1850 19.9348	J1606-2333 B	32	4	6242307087212539776		$-23.55612324162 \pm 0.3274$	18.9721 ± 0.0115	18.3351 ± 0.0536	17.5623 ± 0.0797
1 ± 0.238 88.70660390446 ± 0.2481 19.0310 ± 0.0050 19.0387 18.343 ± 0.0387 19.0310 ± 0.0053 18.3643 ± 0.0387 19.0310 ± 0.0053 18.3643 ± 0.0387 19.0310 ± 0.0053 18.3643 ± 0.0387 19.0310 ± 0.1300 18.1755 ± 0.0053 18.4834 ± 0.0811 19.0310 ± 0.1328 45.60718787581 ± 0.2604 18.526 ± 0.0079 18.4834 ± 0.0811 19.0323 18.0567 ± 0.0082 17.1982 ± 0.0132 16.8025 ± 0.0290 17.1982 ± 0.0132 16.8025 ± 0.0290 17.333 ± 0.0173 18.0577 ± 0.0071 17.7333 ± 0.0173 18.03580.556979 ± 0.2726 19.2447 ± 0.0092 18.7935 ± 0.0077 17.7333 ± 0.0767 17.393 ± 0.0767 17.393 ± 0.0767 17.393 ± 0.0767 19.0310 ± 0.0092 18.0366 ± 0.1850 19.0310 ± 0.0052 18.0346 ± 0.1256 19.0340 ± 0.0052 19.0340 ± 0.0052 19.0340 ± 0.0052 19.0340 ± 0.0052 19.0340 ± 0.1056 ± 0.1850 11.24509253971 ± 1.4157 20.2563 ± 0.0104 20.055 11.24509253971 ± 1.4157 20.7426 ± 0.0163 19.8634 ± 0.0637 11.24509252971 ± 1.4157 20.7426 ± 0.0118 21.6045 ± 0.2997 21.60431 ± 0.6330 19.8814 ± 0.6330 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8834 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8817 ± 0.0093 19.8834 ± 0.1826 19.3911 ± 0.0093 19.8817 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 19.0394 ± 0.0093 19.0394 ± 0.0118 1	11721+8842 C	32	4	1729026461820249728		88 70589729174 + 0 4895	2200 0 + 5926 1		+
1 3.438 88.7062199492 ± 1.0992 20.659 ± 0.0175	11721+8842 B	32	. 4	1729026466114871424		88 70660390446 + 0 2481	19.0310 ± 0.0050		1 +
1	11721+8842 D	32	- 4	1729026466114871296		88 70521994925 + 1 0992	20 6595 ± 0.0174		1 +
1 ± 0.1535 88.70556237840 ± 0.1721 18.3287 ± 0.0084 18.4834 ± 0.0811 18.2388 ± 0.0204 18.6226 ± 0.0079 18.6226 ± 0.0079 18.6226 ± 0.0079 18.6226 ± 0.0079 18.6226 ± 0.0079 18.6226 ± 0.0079 18.6226 ± 0.0071 17.7333 ± 0.0173 18.6077 ± 0.0092 19.247 ± 0.0092 19.247 ± 0.0092 19.247 ± 0.0092 19.247 ± 0.0092 18.8262 ± 0.02475 18.8196 ± 0.0092 18.7383 ± 0.0767 18.8196 ± 0.0092 18.2539107 ± 0.1672 18.8262 ± 0.0092 18.7383 ± 0.0767 18.8196 ± 0.1800 47.39572539107 ± 0.1672 18.8262 ± 0.0092 18.7383 ± 0.0767 18.8396 ± 0.0167 18.8262 ± 0.0092 18.7384 ± 0.1256 19.340161713 ± 0.5394 ± 0.0095 18.9346 ± 0.1256 19.9348 ± 0.1266 ± 0.0144 40.13740966159 ± 0.4163 19.6488 ± 0.0095 19.9348 ± 0.1826 11.24562339171 ± 0.3466 19.632 ± 0.0163 19.6488 ± 0.1826 11.24562339171 ± 0.3466 19.632 ± 0.0163 19.8634 ± 0.0637 11.24562339171 ± 0.346 19.6632 ± 0.0163 19.8634 ± 0.0637 19.8874 ± 0.0093 19.8874 ± 0.0837 19.8871 ± 0.449533407828 ± 1.4042 20.8928 ± 0.0109 16.2755 ± 0.0423 19.64253407828 ± 1.4042 20.8928 ± 0.0109 16.2755 ± 0.0423 19.8871 ± 0.3490 19.0393 ± 0.2599 16.7356 ± 0.0109 16.2755 ± 0.0423 19.64253407828 ± 1.4042 20.8928 ± 0.0109 16.2755 ± 0.0423 19.64253407828 ± 1.4042 20.8928 ± 0.0109 16.2755 ± 0.0423 19.64253407828 ± 0.2799 16.2755 ± 0.0423 19.64253407828 ± 0.2799 16.2755 ± 0.0423 19.64253407828 ± 0.2799 16.2755 ± 0.0492 19.8757 ±	11721+8842 A	35	4	1729026466116588544		88 70621468902 + 0 1300	$18\ 1755 \pm 0.0053$	18 3643 + 0 0387	$\frac{1}{1}$
1 ± 3.0726	11721+8842 ?*	32	4	1729026461820390400	260.45126749084 ± 0.1535	88.70556237840 ± 0.1721	18.3287 ± 0.0084	18.4834 ± 0.0811	17.3640 ± 0.0401
1 + 0.5726	WFI2026-4536 B	43	4	6675746940384195456	$306.54348562606 \pm 0.3228$	$-45.60718787581 \pm 0.2604$	18.6226 ± 0.0079		
5 ± 0.2748	WFI2026-4536 A	43	4	6675746940384195200		$-45.60752504082 \pm 1.6543$	17.1982 ± 0.0132	16.8025 ± 0.0290	16.2132 ± 0.0125
1 + 0.2748	WFI2033-4723 A1	43	4	6674418764699092736		$-47.39537499737 \pm 0.2933$	18.0677 ± 0.0071	17.7333 ± 0.0173	17.0862 ± 0.0127
1 ± 0.1850	WFI2033-4723 C	43	4	6674418764698005248	$308.42538394120 \pm 0.2748$	$-47.39580256979 \pm 0.2726$	19.2447 ± 0.0092		+1
1 ± 0.1890	WFI2033-4723 A2	43	4	6674418764698005376		$-47.39534323862 \pm 0.2475$	18.8196 ± 0.0050		+1
1 ± 0.5758	WFI2033-4723 B	43	4	6674418764698004992		$-47.39572539107 \pm 0.1672$	18.8262 ± 0.0023	18.7933 ± 0.0767	18.1817 ± 0.0680
1 ± 0.5785	WGD2038-4008 C*	35	4	6681326549578891648		$-40.13693605210 \pm 0.4304$	19.9010 ± 0.0055		
1 ± 2.1359 40.13683014244 ± 1.7719 20.2563 ± 0.0144 1 ± 0.5164 40.13740966159± 0.41463 ± 10.6480 ± 0.0053 1 ± 0.5607 -11.24502450839171 ± 0.3446 = 10.6632 ± 0.0052 1 ± 0.5207 -11.24509460838 ± 0.2868 = 10.9321 ± 0.0055 1 ± 1.5300 -11.24509460838 ± 0.2868 = 10.9321 ± 0.0053 1 ± 1.5300 -11.245094 ± 0.5277 ± 1.4157 20.7426 ± 0.0163 1 ± 1.5330 -46.49607609394 ± 0.5227 = 1.0405 ± 0.0101 1 ± 0.5327 = 4.649607609394 ± 0.5227 = 1.0405 ± 0.018 1 ± 0.532 = 1.0532 = 1.0402 = 20.8928 ± 0.018 = 21.6045 ± 0.2997 1 ± 0.5140 = 3.35831124314 ± 0.4528 = 17.6672 ± 0.0097 = 16.2755 ± 0.0423 = 0.0182 = 1.0402 =	WGD2038-4008 A*	35	4	6681326549580116864		$-40.13740161713 \pm 0.5994$	19.6071 ± 0.0095	18.9346 ± 0.1256	17.3375 ± 0.0376
1 ± 0.5164	WGD2038-4008 D*	35	4	6681326549578891392		$-40.13683014244 \pm 1.7719$	20.2563 ± 0.0144		
11.2456.2339171±0.3446 19.6632±0.0052 19.2664±0.0422 11.24509460838±0.2868 19.9321±0.0055 19.9348±0.1826 11.245092.25971±1.4157 20.7426±0.0163 12.10.253 46.4960760393±0.5227 19.8877±0.0091 12.10.253 46.4960760393±0.5227 19.8877±0.0093 12.10.272 46.49553407828±1.4042 20.8928±0.0118 21.6045±0.0637 12.10.372 46.49553407828±1.4042 20.8928±0.0118 21.6045±0.2997 12.10.372 46.49553407828±0.272 10.88728±0.0109 16.2755±0.0423 12.10.372 46.49533407828±0.272 10.88728±0.0109 16.2755±0.0423 12.10.372 46.4953407828±0.2799 16.7356±0.0109 16.2755±0.0423 12.10.372 46.040760393 40.2799 16.7356±0.0109 16.2755±0.0423 12.10.372 10.272	WGD2038-4008 B*	35	4	6681326549578891520		$-40.13740966159 \pm 0.4163$	19.6480 ± 0.0053		
11.24509460838 ± 0.2868 19.9321 ± 0.0055 19.9348 ± 0.1826 11.24509460838 ± 0.2868 19.9321 ± 0.0055 19.9348 ± 0.1826 11.245092460838 ± 0.2868 19.9321 ± 0.0063 11.24509252971 ± 1.4157 20.7426 ± 0.0163 19.8634 ± 0.0637 19.8877 ± 0.0937 2.46.49607609394 ± 0.5227 19.8877 ± 0.0093 19.8634 ± 0.0637 19.8877 ± 0.0979 2.46.49553407828 ± 1.4042 20.8928 ± 0.0118 21.6045 ± 0.2997 2.5 ± 0.5140 3.35831194908 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 16.7356 ± 0.0109 16.2755 ± 0.0423 16.7356 ± 0.0109 16.7356 ± 0.0109 16.7356 ± 0.0109 16.7356 ± 0.0109 16.7356 ± 0.0109 16.7356 ± 0.0423 16.7356 ± 0.0109 16.7356 ± 0.0459 16.7356	PS1 J205143-111444 A	*0*	4	6901910950299842688		$-11.24562339171 \pm 0.3446$	19.6632 ± 0.0052	19.2664 ± 0.0422	18.5697 ± 0.0377
11.24505252971 ± 1.4157 20.7426 ± 0.0163 12.10225 46.49607609394 ± 0.6141 20.3767 ± 0.0101 12.10235 46.49607609394 ± 0.6279 ± 0.0108 21.6045 ± 0.2997 12.10392 46.49534407828 ± 1.4042 20.8928 ± 0.0118 21.6045 ± 0.2997 12.10392 46.49534407828 ± 1.4042 20.8928 ± 0.0118 21.6045 ± 0.2997 12.10392 46.49534407828 ± 1.76672 ± 0.0097 12.10392 46.4953407828 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 12.10392 46.4953407828 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 12.10392 46.4953407828 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 13.3834194908 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 14.10292 46.4953407828 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423	PS1 J205143-111444 B	*0+	4	6901910950301201024		$-11.24509460838 \pm 0.2868$	19.9321 ± 0.0055	19.9348 ± 0.1826	18.8598 ± 0.0397
7 ± 1.0225	PS1 J205143-111444 C	*0+	4	6901910950299842560		$-11.24505252971 \pm 1.4157$	20.7426 ± 0.0163		
1 + 0.5330	WGD2141-4629 B	35*	3	6563636302411599104		$-46.49631823151 \pm 0.6141$	20.3767 ± 0.0101		
2 ± 0.9792	WGD2141-4629 A	35*	33	6563636302410205824		$-46.49607609394 \pm 0.5227$	19.8817 ± 0.0093	19.8634 ± 0.0637	18.8872 ± 0.0409
\$ ± 0.5140 3.35881124314 ± 0.4528 17.6672 ± 0.0097 16.2755 ± 0.0423	WGD2141-4629 C	35*	33	6563636302410673152		$-46.49553407828 \pm 1.4042$	20.8928 ± 0.0118	21.6045 ± 0.2997	20.4365 ± 0.1651
1 ± 0.3627 3.35834194908 ± 0.2799 16.7356 ± 0.0109 16.2755 ± 0.0423 10wing increasing <i>G</i> mag, and not following Agnello et al. (2017) since even considering the photometric	Q2237+030 B	43	4	2704542594213521664		3.35881124314 ± 0.4528	17.6672 ± 0.0097		
	Q2237+030 A	43	4	2704542589921820288		3.35834194908 ± 0.2799	16.7356 ± 0.0109	16.2755 ± 0.0423	15.1978 ± 0.0306
	Notes 1 WGD2038-40	08* · the ir	nages	(A B C D) have he		reasing G mag and not for	Mowing Agnello	et al (2017) since even considering the	he photometric data from the
מוסיבווניות סובים מקיבות של מוכי מכינים מכינים מינים מ	aforementioned naner t	iis would b	the	decreasing flux order		ICASIIIE O mae, and mor m	7110 W 1116 / 15 115 115		ne photomocare cara mom are
	arorententioned paper t	no would c	5	COLCASIIIS IIIA OLCA					

Notes. 2. 10408-5354*: the images (A, B, C) have been attributed following increasing G mag, and not following Lin et al. (2017).

References. (1) Blackburne et al. (2008), (2) Jackson et al. (2008), (3) Ghosh & Narasimha (2009), (4) Inada et al. (2010), (5) Inada et al. (2012), (6) Jackson et al. (2012), (7) Inada et al. (2014), (15) Leethochawalit et al. (2016), (16) Nayyeri et al. (2016), (17) Parry et al. (2016), (18) Sergeyev et al. (2016), (19) Shu et al. (2016), (20) More et al. (2017), (21) Agnello et al. (2017), (22) Agnello (2017), (23) Lin et al. (2017), (24) Ostrovski et al. (2018), (25) Kostrzewa-Rutkowska et al. (2018), (26) Lemon et al. (2018), (27) Lucey et al. (2018), (28) Williams et al. (2018), (8) Agnello et al. (2015),(9) Limousin et al. (2016), (10) More et al. (2016), (11) Inoue et al. (2016), (12) Aravena et al. (2016), (13) Rusu et al. (2016), (14) Goicoechea & Shalyapin (2016), (2017), (36) Dahle et al. (2013), (37) Schechter et al. (2018), (38) Agnello (2017), (39) Agnello et al. (2017), (40) Rusu et al. (2018), (41) Meyer et al. (2017), (42) Schechter et al. (2017), (29) Kostrzewa-Rutkowska et al. (2018), (30) Bordoloi et al. (2016), (31) Wisotzki et al. (2002), (32) Lemon et al. (2018), (33) Berghea et al. (2017), (34) More et al. (2017), (35) Agnello et al. (43) Kochanek et al. (1999), (44) Anguita et al. (2009)

Appendix A: Gaia DR2 finding charts of known and confirmed quadruply-imaged quasars

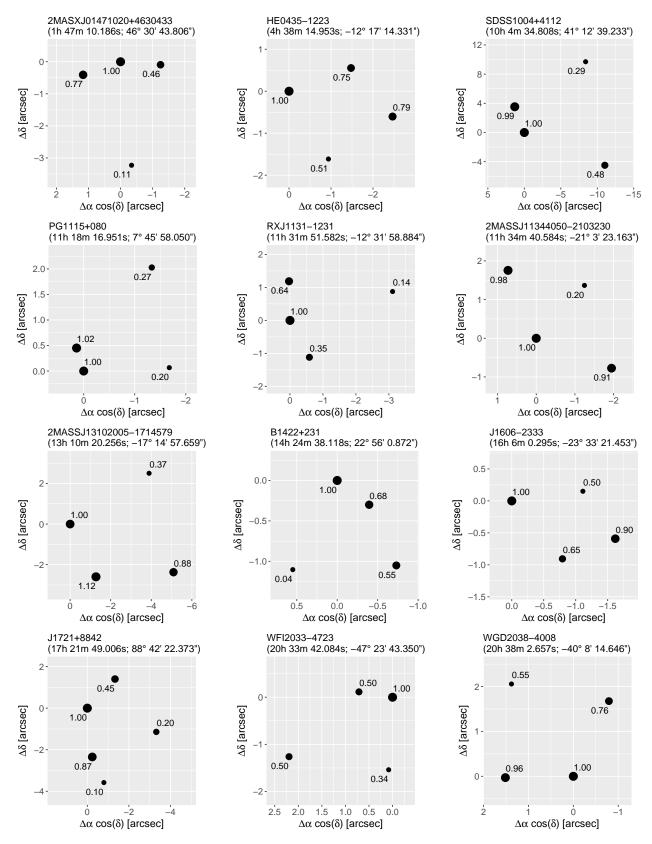


Fig. A.1. Finding charts for the 12 previously known multiply-imaged quasars with four counterparts in the *Gaia* Data Release 2. *Gaia* DR2 astrometry relative to the brightest image in the system discovery passband (image "A") is indicated by black points, except for WGD2038-4008, which is ordered by Gaia *G*-band fluxes (see footnote in Table 4). The numbers near each image, and the image size, indicate the flux ratios computed from *Gaia* DR2 data. North is up, East is left.