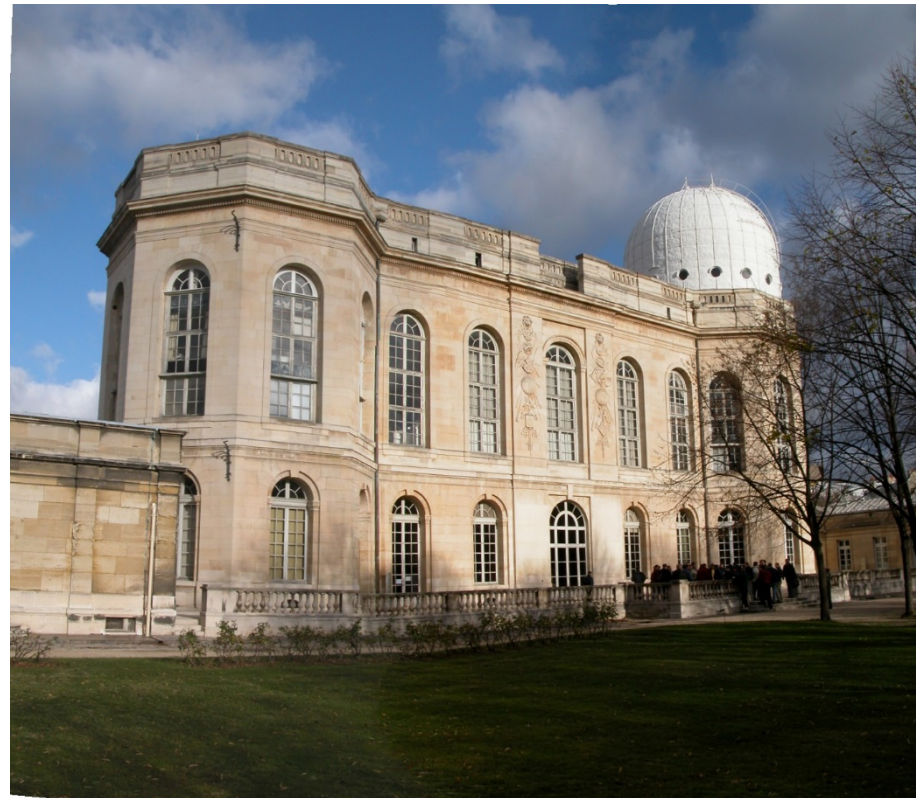


GAIA & les Systèmes de Référence

*J. Souchay ⁽¹⁾
A.H.Andrei, C.Barache
F.Taris, S.Bouquillon
C.Gattano (Thèse)*

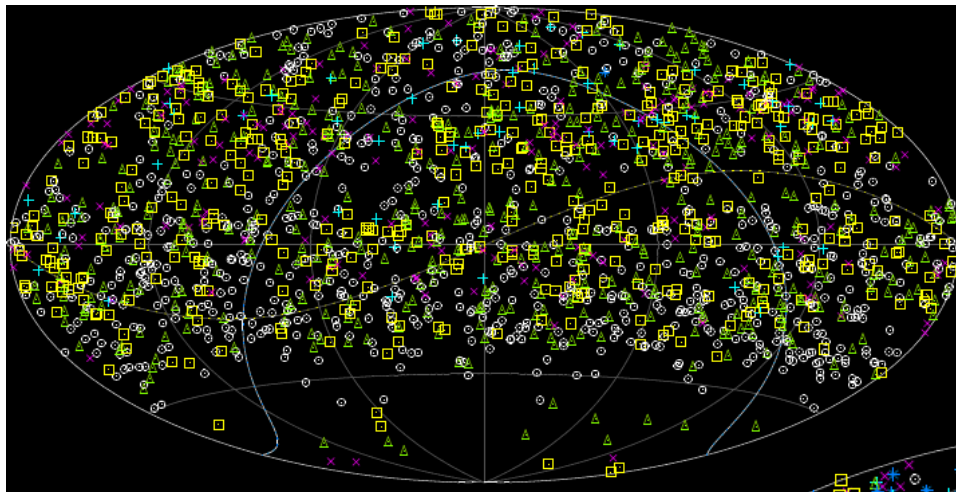
⁽¹⁾ SYRTE, Observatoire de Paris
Jean.Souchay@obspm.fr



Journées «Forum GAIA » Paris / 5 Mai 2014

IAU Resolution B3, August 13th. 2009, Rio

The ICRF2 is the fundamental celestial reference frame from 2010, January 1st.

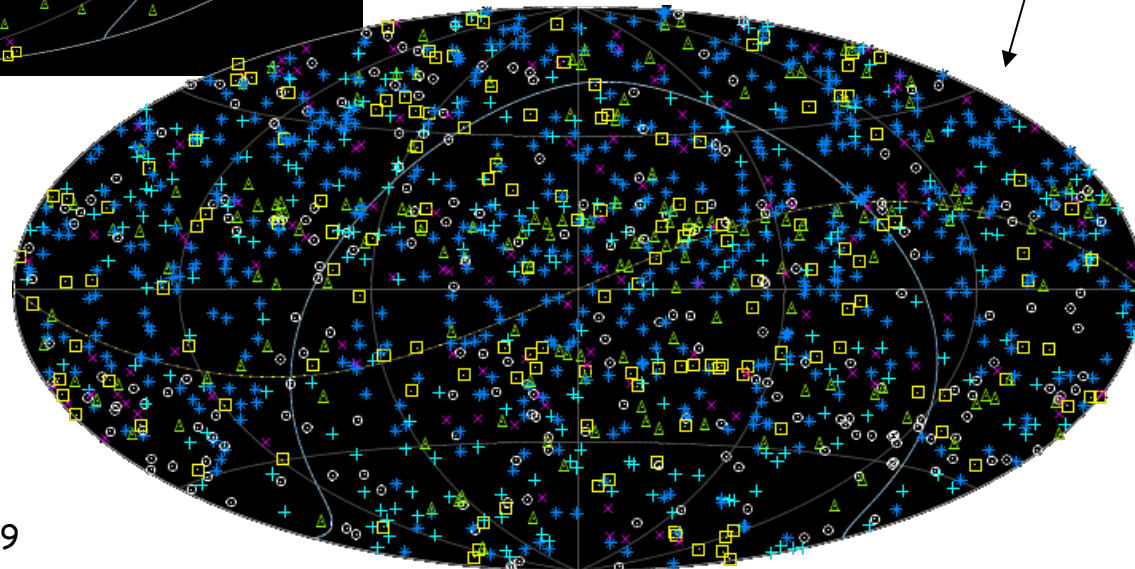


3414 sources

(1 source per 12.3 sq. deg)

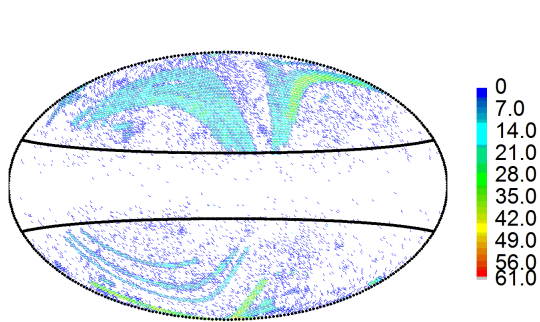
2197 sources VCS, $s_{\text{médian}} = 0.75$ mas

1217 sources non VCS, $s_{\text{médian}} = 0.17$ mas



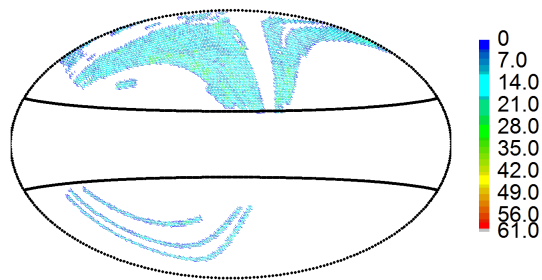
Quasars' sky distribution – 1deg² cells count

(courtesy : A.H. Andrei)



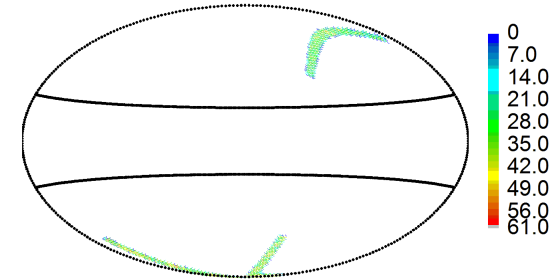
V&V

2006 / 85,221 QSO's
2010 / 133,336 QSO's



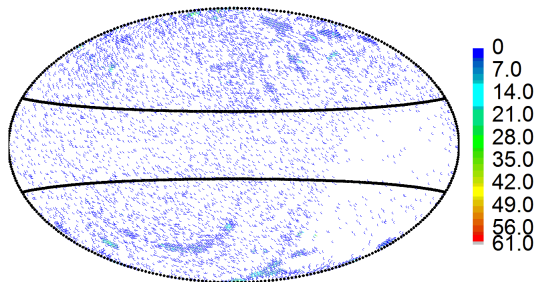
SDSS

2010 (DR8) / 126,577 QSO's
2013 (DR10) / 374,035 QSO's



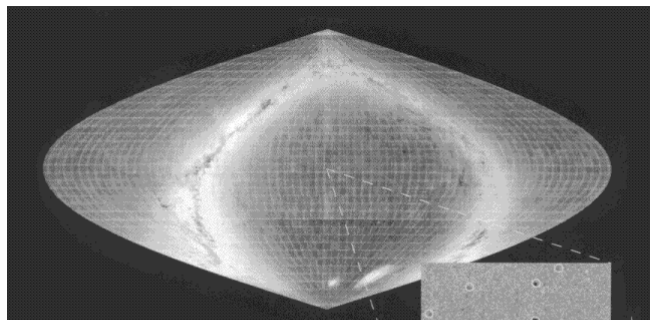
2dF – QSO (2QZ)

23,803 sources



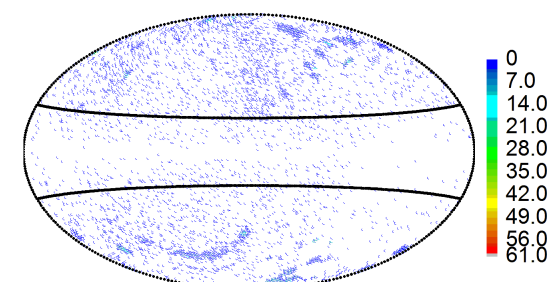
All Radio QSOs

2009 / 11,781 sources



B1.0

All sky up to V=21



Radio QSOs found in
B1.0

2009 / 6,941 sources

Construction du **LQAC** (Large Quasars Astrometric Catalogue)

LQAC-3 prévu fin 2014

Objectifs

- Compilation de **tous** les QSO's répertoriés
- Stratégie insistant sur la **qualité astrométrique**
- Catalogue avec **drapeau (A=>M)** pour cross-identifications
- Complétude photométrie & redshift
- **Calcul des** magnitudes absolues M_I & M_B
- **Base** pour up-dates réguliers (=> GAIA)
- **Final ASCII file** with **V.O. tools** in parallel
- **Comparisons / statistiques / cohérence**

Improvements of the LQAC-3 (2014) % LQAC-2 (2012)

- Plus de QSO's **374,000** QSO's vs. **187,000 (+100%)**
- Plus de cross-identifications (ex. entre ICRF2 et autres)
- Numéro d'identification pour chaque QSO (LQAC.....)
- Astrométrie refaite => coordonnées **LQRF** (Andrei et al.,2009)
- Addition d' **indices morphologiques**
normalness, skewness, roundness
- Calcul d'un indice spectral (sous réserve)

=> **EXCELLENT OUTIL** POUR LA **VALIDATION**
DU CATALOGUE DE QUASARS **GAIA (CU9)**

COMPILATION DE TOUS LES QSO's répertoriés :

LQAC-2 Catalogue (39 parameters)

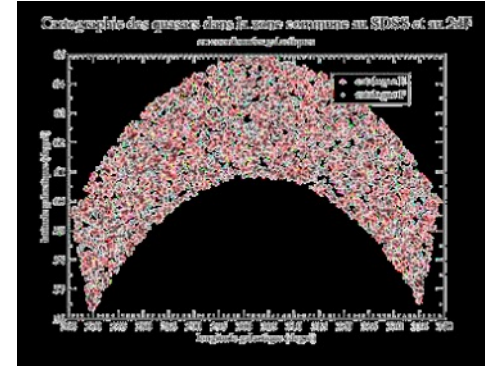
LQAC Nb.	Original coord.	LQRF coord.	cat. flags	u	B	V	g	r	i	z	J	K
LQAC_000-000_001	0.000000000 -0.032800000	359.9998660 -0.0328680	-----M -	0	0.00	19.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000-000_002	0.001996551 -0.451102400	0.0020170 -0.4510710	----E----KLM -	0	21.69	21.08	20.09	21.19	20.50	20.14	19.85	0.00	0.00
LQAC_000-002_001	0.005187500 -2.033383330	0.0053030 -2.0332680	-----H--KLM -	0	0.00	19.64	0.00	0.00	18.31	18.59	0.00	0.00	0.00
LQAC_000-030_001	0.005750000 -30.607472222	0.0056940 -30.6074290	----F----KLM -	0	19.30	20.10	0.00	0.00	19.50	0.00	0.00	0.00	0.00
LQAC_000-031_001	0.007333333 -31.373833333	0.0072330 -31.3736930	----F----K-M -	0	19.70	20.69	0.00	0.00	19.86	0.00	0.00	0.00	0.00
LQAC_000+014_001	0.007748564 14.024511000	0.0111330 -25.1935080	----E----KL- -	0	24.71	21.64	0.00	22.47	20.99	20.23	19.52	0.00	0.00
LQAC_000-025_001	0.011200000 -25.193600000	0.0111330 -25.1935080	-----M -	0	0.00	0.00	0.00	0.00	21.00	0.00	0.00	0.00	0.00
LQAC_000-035_001	0.011700000 -35.059200000	0.0227550 -27.4195250	-----M -	0	0.00	16.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000-027_001	0.022875000 -27.419555555	0.0227550 -27.4195250	----F----KLM -	0	18.35	19.43	0.00	0.00	19.14	18.69	0.00	0.00	0.00
LQAC_000+000_001	0.027230760 0.515331640	0.0272260 0.5153110	----E----KL- -	0	20.58	20.42	0.00	20.59	20.49	20.17	20.19	0.00	0.00
LQAC_000-063_001	0.033300000 -63.593300000	0.0339460 0.276291600	-----M -	0	0.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000+000_002	0.033946060 0.276291600	0.0339460 0.2762820	----E----KL- -	0	20.30	20.41	0.00	20.36	20.02	19.53	19.31	0.00	0.00
LQAC_000+015_001	0.038609500 15.298489000	0.0386040 15.2984570	----E----KL- -	0	19.90	19.87	0.00	19.77	19.38	19.15	19.31	0.00	0.00
LQAC_000+013_001	0.039099260 13.938458000	0.0390840 13.9384300	----E----KL- -	0	19.25	18.74	18.49	18.89	18.43	18.30	18.08	0.00	0.00
LQAC_000+023_001	0.039200000 23.954400000	0.0420760 30.933300000	-----M -	0	0.00	0.00	0.00	0.00	18.93	0.00	0.00	0.00	0.00
LQAC_000-010_001	0.039264450 -10.464410000	0.0392580 -10.4643970	----E----KL- -	0	19.21	19.67	0.00	19.00	18.97	18.78	18.70	0.00	0.00
LQAC_000-031_002	0.040375000 -31.279972222	0.0403780 -31.2799450	----F----KLM -	0	18.40	19.05	0.00	0.00	18.65	18.10	0.00	0.00	0.00
LQAC_000-030_002	0.041250000 -30.924944444	0.0412790 -30.9248570	----F----KLM -	0	17.93	19.12	0.00	0.00	18.37	18.30	0.00	0.00	0.00
LQAC_000+030_001	0.042100000 30.933300000	0.0420760 30.9331550	-----M -	0	0.00	0.00	0.00	0.00	0.00	19.30	0.00	0.00	0.00
LQAC_000-031_003	0.042375000 -31.997222222	0.0423410 -31.9971400	----F----KLM -	0	20.28	20.44	0.00	0.00	20.78	0.00	0.00	0.00	0.00
LQAC_000+014_002	0.047551210 14.929367000	0.0475600 14.9293430	----E----KLM -	0	19.64	19.80	19.03	19.47	19.36	19.18	19.02	0.00	0.00
LQAC_000-008_001	0.048196750 -8.835659400	0.0483680 1.0307250	----E----KL- -	0	19.46	19.17	0.00	19.12	19.06	19.13	19.32	0.00	0.00
LQAC_000+001_001	0.048300000 1.030600000	0.0483680 1.0307250	-----M -	0	20.43	0.00	19.37	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000-031_004	0.048583333 -31.644416666	0.0485590 -31.6443790	----F----KLM -	0	19.66	20.27	0.00	0.00	19.38	0.00	0.00	0.00	0.00
LQAC_000+005_001	0.048700000 5.388100000	0.0488640 5.3881690	-----M -	0	0.00	16.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000+000_003	0.049839430 0.040358720	0.0498430 0.0403840	----E---IJKLM -	0	17.99	17.60	17.80	17.78	17.85	17.79	17.71	16.65	14.82
LQAC_000-000_003	0.051083480 -0.539051090	0.0510860 -0.5390290	----E----K-- -	0	20.69	20.99	0.00	20.61	20.33	20.19	20.26	0.00	0.00
LQAC_000+014_003	0.054787210 14.176304000	0.0547890 14.1763000	----E----KL- -	0	19.53	18.94	18.86	19.30	19.12	19.15	19.08	0.00	0.00
LQAC_000-002_002	0.056700000 -2.172200000	0.0568390 -2.1720740	-----M -	0	0.00	19.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000-000_004	0.057513340 -0.913001400	0.0575340 -0.9129930	----E----KL- -	0	20.50	20.13	0.00	20.22	20.06	19.59	19.45	0.00	0.00
LQAC_000-001_001	0.061780730 -1.175212200	0.0617870 -1.1752070	----E----KL- -	0	19.48	19.49	0.00	19.42	19.42	19.21	19.13	0.00	0.00
LQAC_000+000_004	0.064516770 0.879696740	0.0645210 0.8796560	----E----KL- -	0	19.60	20.30	0.00	19.41	19.33	19.03	19.14	0.00	0.00
LQAC_000-027_002	0.066375000 -27.649083333	0.0663900 -27.6490020	----F----KLM -	0	17.92	18.38	0.00	0.00	17.69	17.21	0.00	0.00	0.00
LQAC_000-031_005	0.068041667 -31.743861111	0.0680360 -31.7438690	----F----KLM -	0	17.99	19.08	0.00	0.00	18.16	17.79	0.00	0.00	0.00
LQAC_000-000_005	0.068473000 -0.309276000	0.0684900 -0.3092950	----E---JKL- -	0	18.70	18.63	0.00	18.12	17.89	17.76	17.68	16.55	15.09
LQAC_000-008_002	0.072430900 -8.856605600	0.0724170 -8.8566180	----E--H--KLM -	0	19.21	18.93	18.63	18.75	18.27	18.27	18.26	0.00	0.00
LQAC_000+000_005	0.074540060 0.436830590	0.0745500 0.4368380	----E----KLM -	0	20.28	20.47	19.85	20.08	19.98	19.74	19.56	0.00	0.00
LQAC_000-032_001	0.084999781 -32.350342643	0.0850110 -32.3503360	AB-----I-KLM *	0	0.00	18.57	17.00	0.00	17.99	17.86	0.00	0.00	0.00
LQAC_000-025_002	0.088300000 -25.136700000	0.0881390 -25.1368820	-----M -	0	0.00	0.00	0.00	0.00	20.90	0.00	0.00	0.00	0.00
LQAC_000-002_003	0.095400000 -2.454200000	0.095400000 -2.454200000	-----M -	0	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000-025_003	0.095400000 -25.206100000	0.095400000 -25.206100000	-----M -	0	0.00	0.00	0.00	0.00	19.70	0.00	0.00	0.00	0.00
LQAC_000+002_001	0.098700000 2.211400000	0.098700000 2.211400000	-----M -	0	0.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LQAC_000+015_002	0.100117290 15.334846000	0.1001140 15.3348460	----E----KLM -	0	19.38	19.91	19.15	19.21	18.97	19.05	19.13	0.00	0.00

LQAC => complétude par donnée

Table 5. Comparison of the number of entries for each data item between the VV2010 catalog, the compilation of the catalogs A-L and the final LQAC-2 catalog.

	VV2010	A-L	LQAC-2	%
QSOs	168 941	165 065	187 504	100.00
<i>z</i>	168 324	160 399	183 652	97.94
<i>u</i>	152 624	156 178	167 983	89.58
<i>b</i>	32 085	156 799	164 721	87.84
<i>v</i>	131 934	75 713	102 774	54.81
<i>g</i>	0	134 881	134 881	71.93
<i>r</i>	3939	162 910	166 033	88.54
<i>i</i>	551	149 735	150 278	80.15
<i>z</i>	0	134 884	134 884	71.93
<i>J</i>	0	25 252	25 252	13.46
<i>K</i>	0	25 252	25 252	13.46
1.4 Ghz	18 111	1814	11797	6.29
2.3 Ghz	0	3482	3482	1.85
5.0 Ghz	5809	863	5358	2.86
8.4 Ghz	0	4551	4551	2.43
24 Ghz	0	61	61	0.03

Combien de QSO's détectés par GAIA?



Methodologie

(1) Isolation d'une zone Z du ciel de surface S déjà explorée avec grande densité

SDSS-2QZ zone commune $11^{\text{h}}40^{\text{mn}} < a < 14^{\text{h}}$ $-2^{\circ} < d < +2^{\circ}$

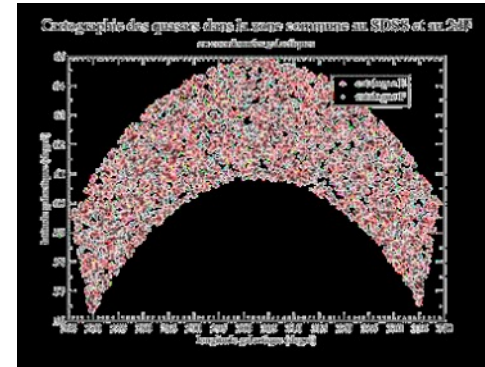
(2) Estimer dans Z le nombre N_Z de QSO's avec le seuil GAIA ($V < 20$)

(3) Extrapoler le nombre de quasars pour tout le ciel $N_{\text{Total}} = N_Z * [S_{\text{Total}} / S]$

(4) Prendre en compte un ratio r dû à l'extinction galactique

Combien de QSO's détectés par GAIA ?

Methodologie



SDSS-2QZ zone $11^{\text{h}}40^{\text{m}} < a < 14^{\text{h}}$ $-2^{\circ} < d < +2^{\circ}$

=> ~ 140 square deg. (% 42 150)

Surprise !!!!

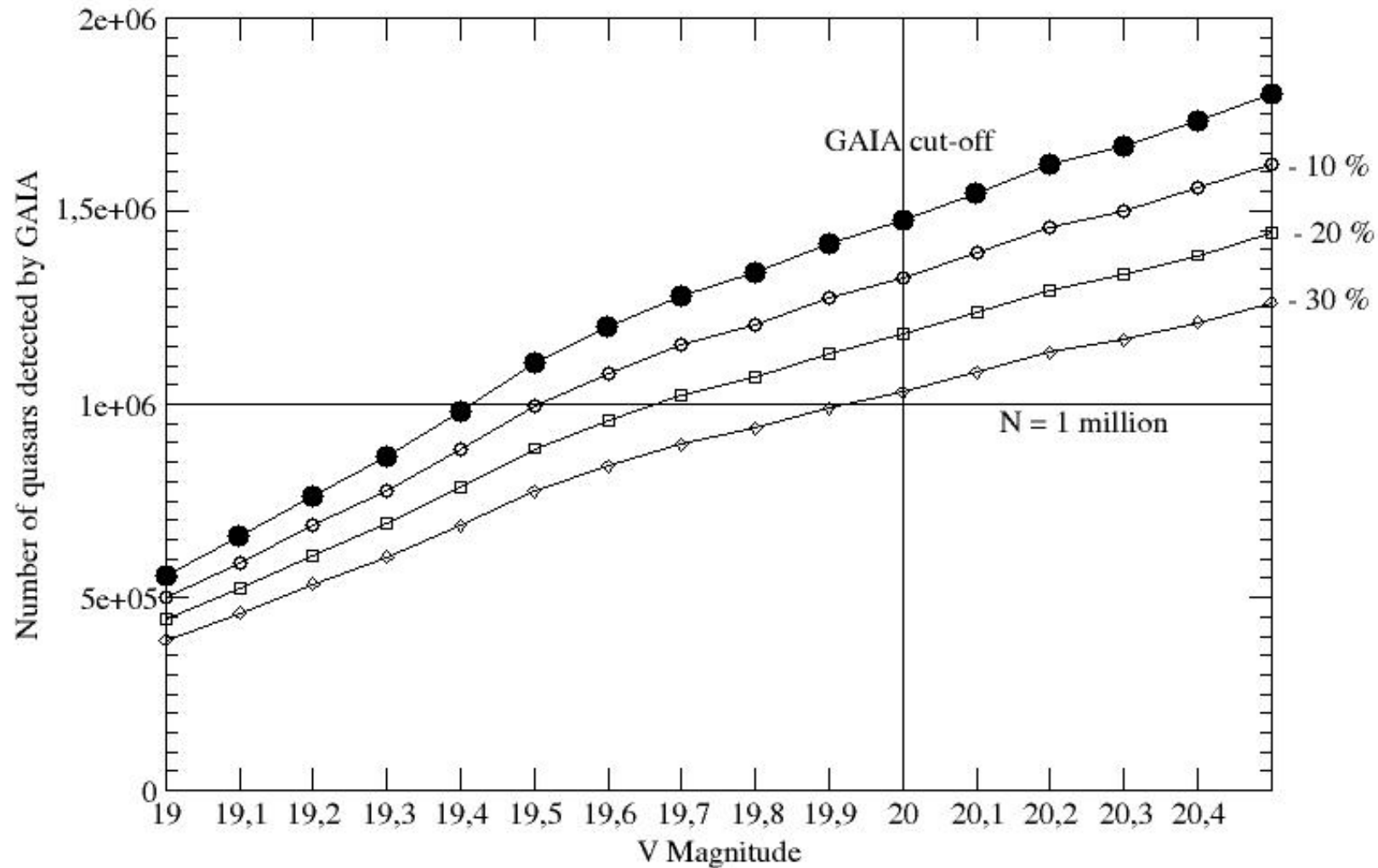
5 127 quasars SDSS - 2QZ

- 900 in common
- 831 in SDSS not in 2QZ
- 3426 in 2QZ not in SDSS

+ 2 563 quasars not in SDSS – 2QZ

7 690 quasars at all.

Expected number of QSO's detected by GAIA

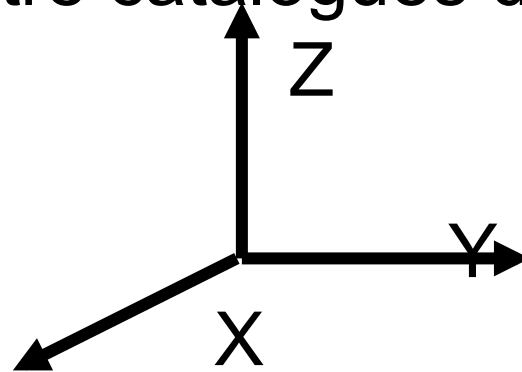


► **Plus d' 1 million de quasars** pourraient être détectés par **GAIA !!!**

(Gattano & Souchay, A&A, 2014)

Systemes de Références

=> Rotations entre catalogues de quasars VLBI

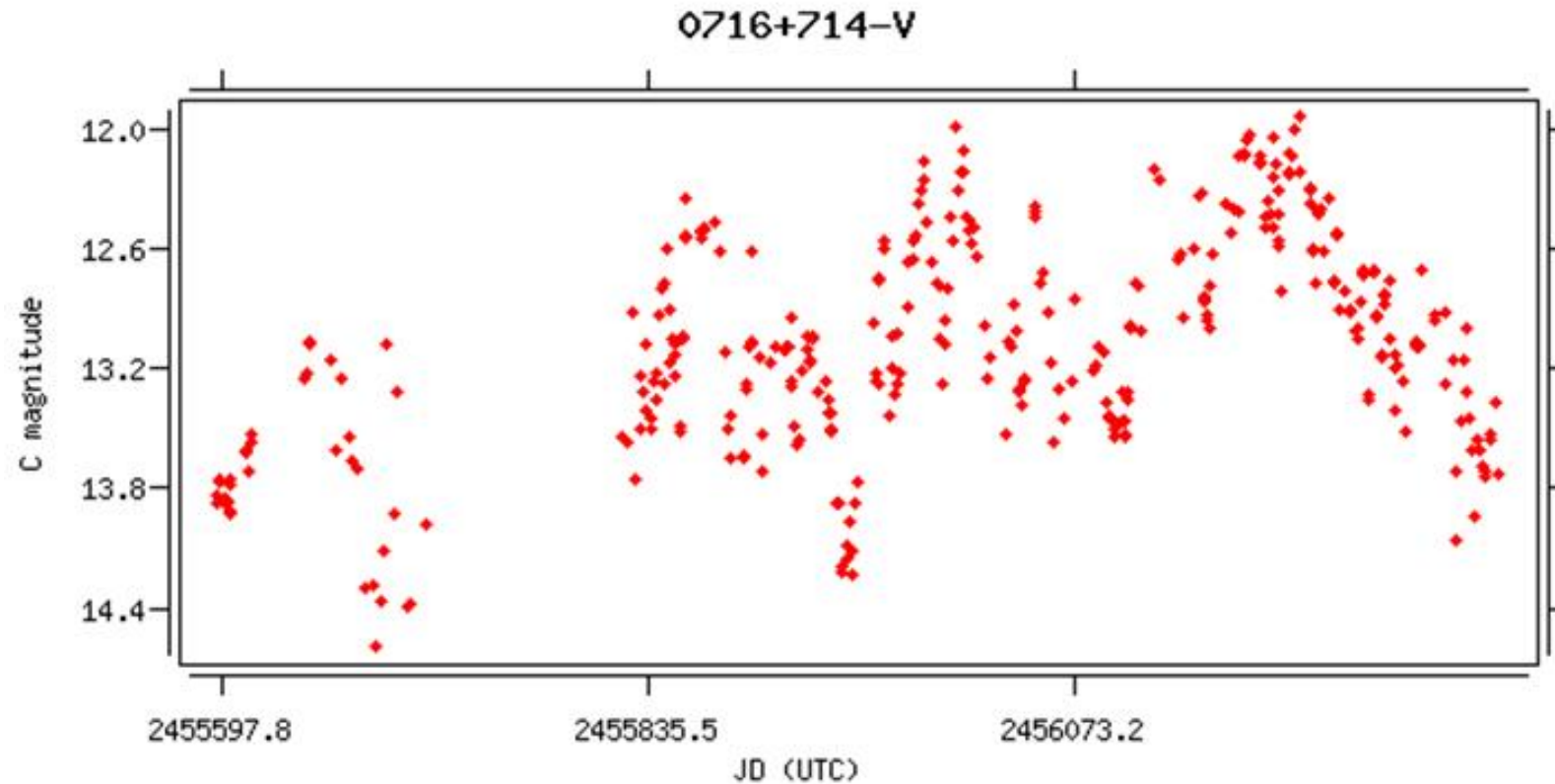


CATALOGUE VLBI	No. Sources		Difference % ICRF2				Paramètres de Transformation			
	All	Def.	Mean		Rms		A1	A2	A3	Bd
			a cos d mas	d mas	a cos d mas	d mas	mas	mas	mas	mas
aus2012b	2895	288	4	-7	78	84	-23	4	3	-14
±							5	5	5	5
bkg2012a	3253	287	-1	22	51	66	7	15	1	18
±							5	5	4	4
gsf2012a	3708	295	2	-8	46	54	-2	7	-3	-14
±							5	5	4	4
opa2012a	3526	295	6	10	53	52	-4	12	-7	10
±							5	5	4	4

=> ROTATION CATALOGUE ICRF2 (VLBI)

↔ CATALOGUE QUASARS GAIA

Suivi photométrique des sources ICRF / GAIA



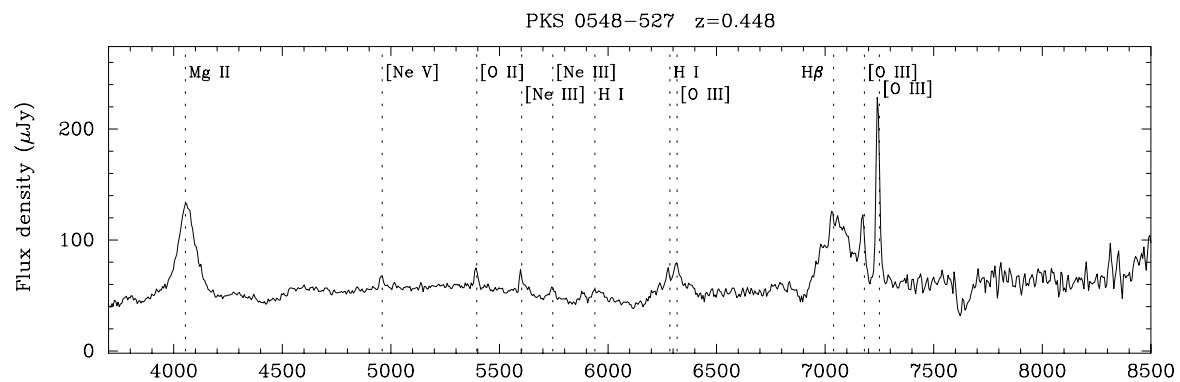
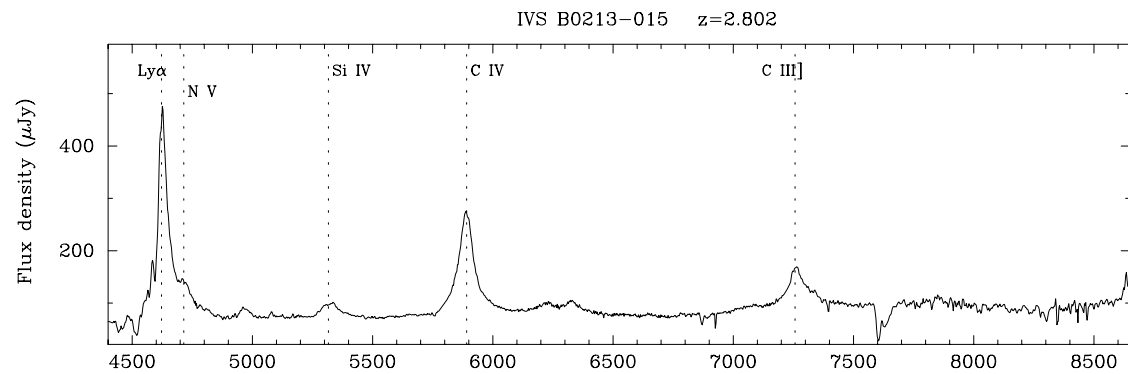
La source ICRF J072153.4+712036 observée avec le télescope TAROT en filter V

CATALOGUE GAIA => QSO'S A LA LIMITE DE LA DETECTION (V=19~20)

SUJETS A DES "TROUS OBSERVATIONNELS"

=> SUIVI NECESSAIRE AU SOL

Etude spectroscopique des sources ICRF/GAIA



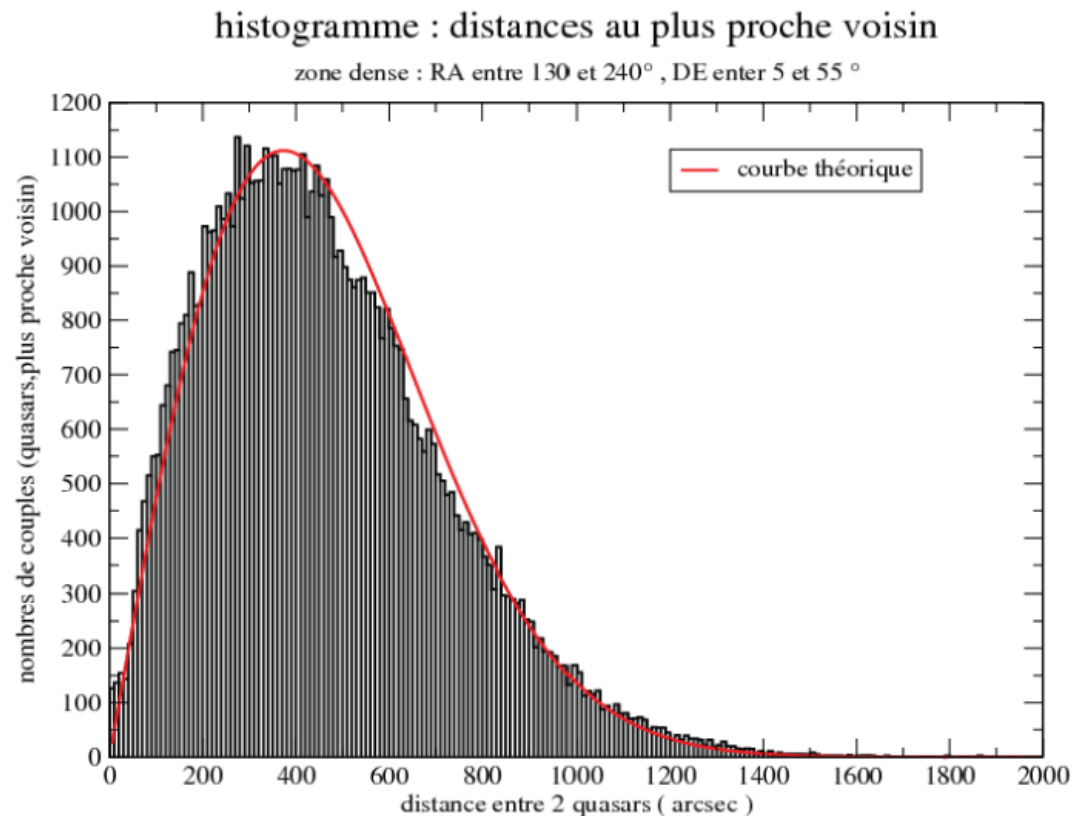
Le problème des quasars doubles

doublons non justifiés (ex. deux catalogues) ?

coïncidences réelles (ligne de visée) $z_1 // z_2$?

vrais couples physiques $z_1 = z_2$?

lentilles gravitationnelles ?

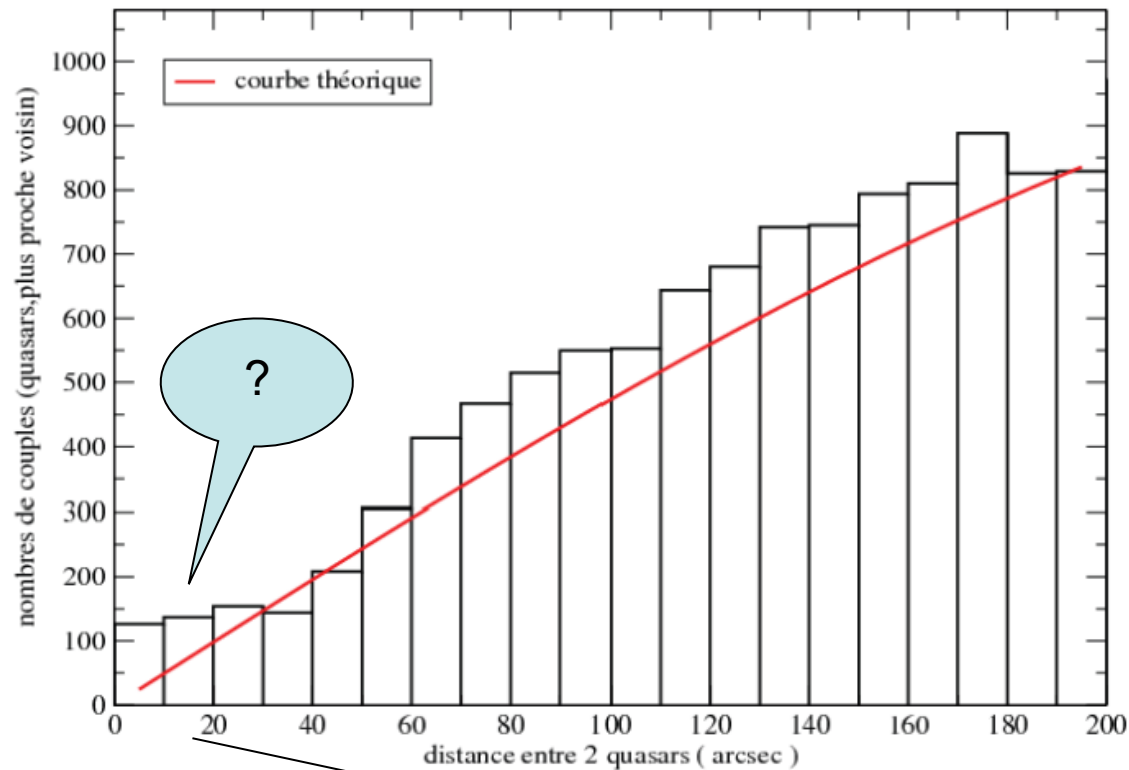


Statistiques % plus proche voisin

(Mignard,2008)

histogramme : distances au plus proche voisin

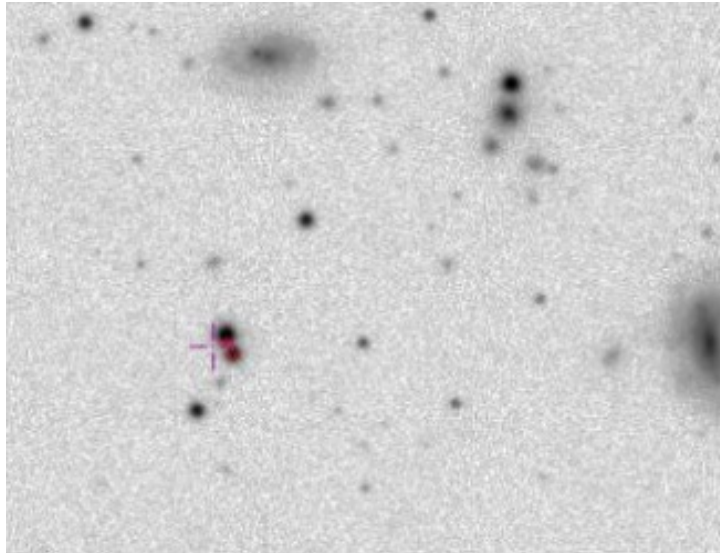
zone dense : RA entre 130 et 240°, DE entre 5 et 55°



DSS images

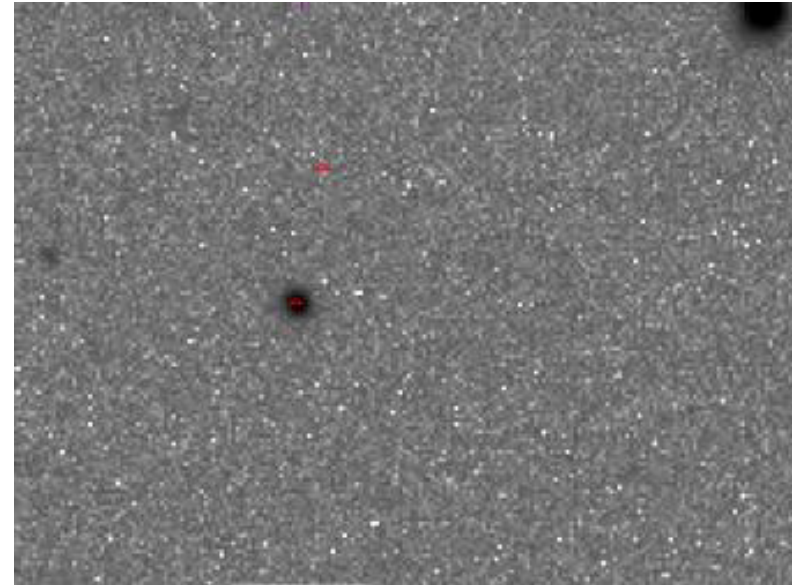
- QSO's coincidents ?
- doublon ?
- vrai couple physique?
- lentille ?

Vérification des paires de QSO's



Vrai couple physique de quasars ($z_1 = z_2$)

159



Doublon

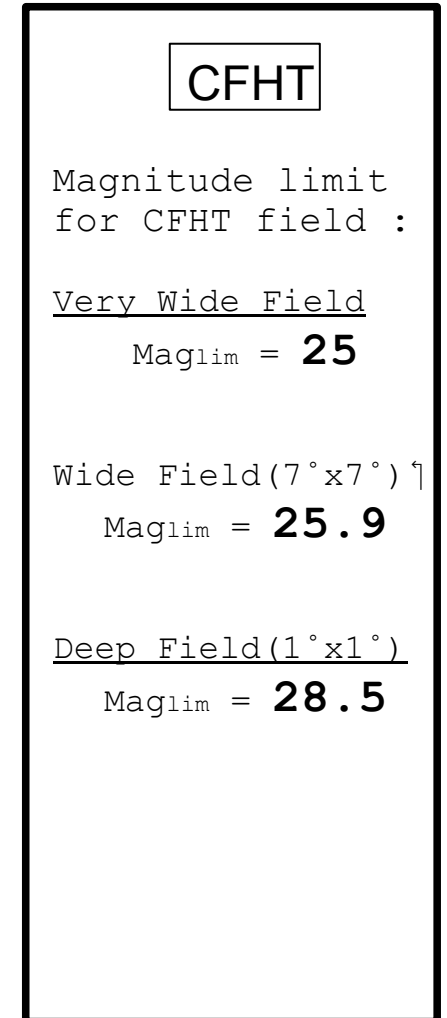
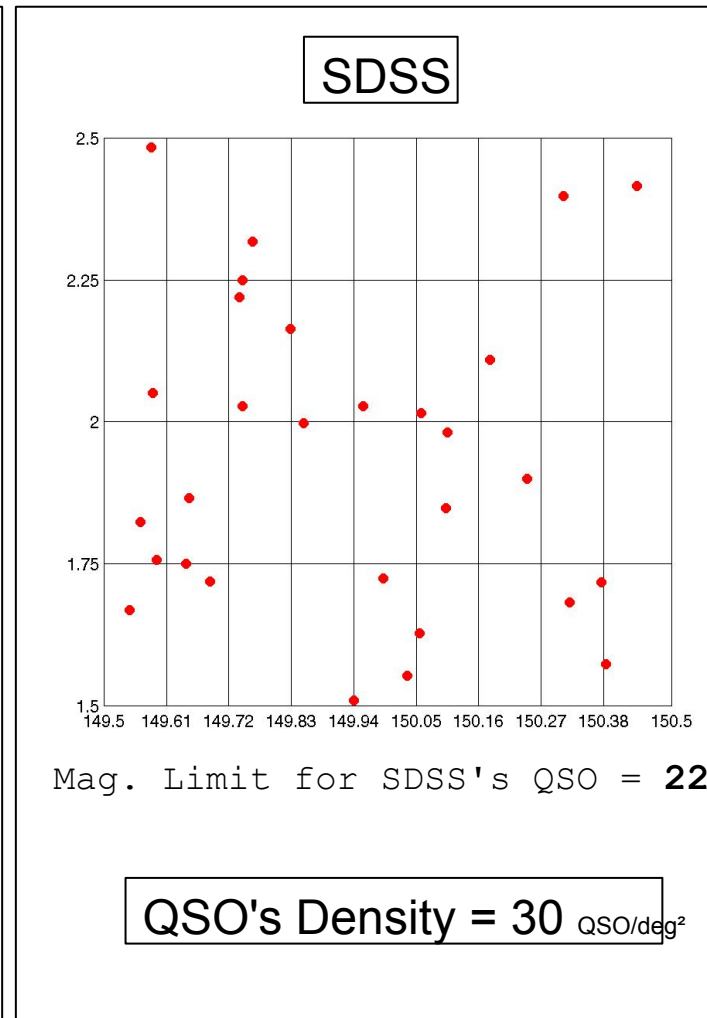
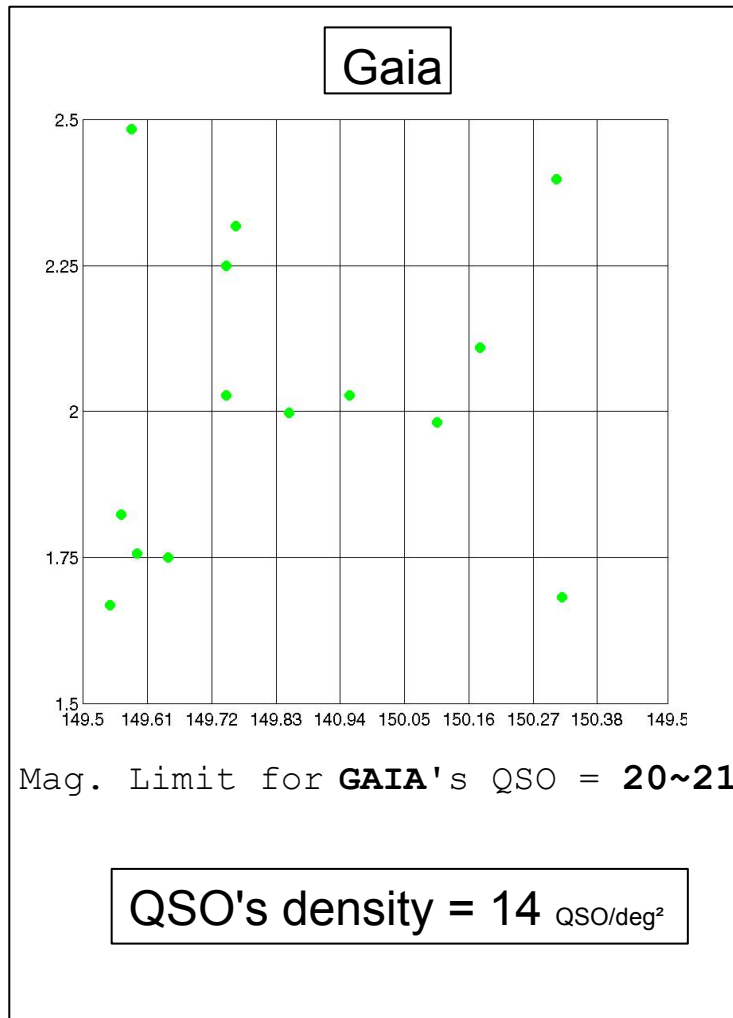
35

GAIA : RESOUDRE LA PROBLEMATIQUE DES COUPLES DE QSO's

=> DATA MINING, OBSERVATIONS AD-HOC

Réduction astrométrique des QSO's non GAIA

CFHT : Field "Deep2"



Les challenges à relever avec les données GAIA % quasars

- Validation du catalogue **GAIA** quasars (CU9) % **LQAC**
incohérences ? complétude ? densité surfacique ?
- Système de Référence Primaire optique, lien ICRF2-3
quels quasars choisir pour raccordement ?
- Offsets radio VLBI-optique (astrométrie, astrophysique)
observations spécifiques (LESIA, LUTH)
- Traitement des « quasars doubles »
doublons ? lentilles ? vrais couples physiques ?(LUTH)
- Variabilité photométrique (programmes au sol)
suivi tél. robotiques TAROT, alertes OHP,Pic (IMCCE)
- Astrométrie optimisée des QSO's $V > 20$
réduction astrométrique optimisée (GEPI)