



Towards an accurate alignment of the VLBI frame and the future Gaia frame

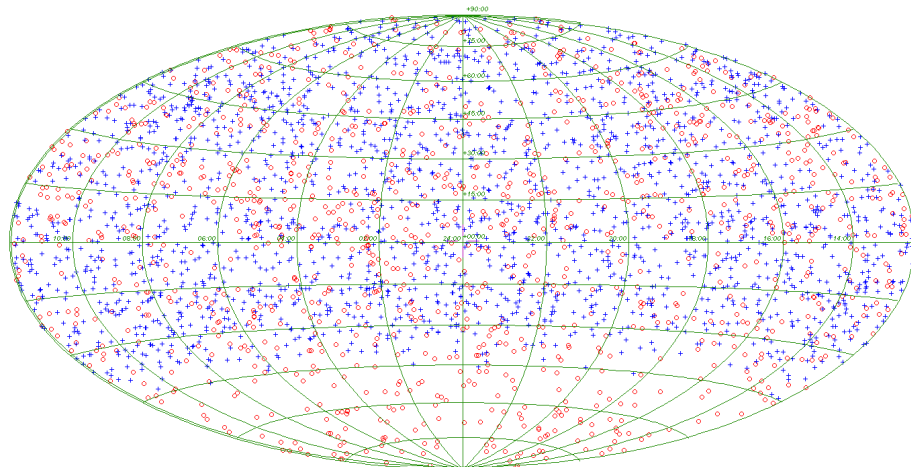
VLBI observations of weak extragalactic radio sources

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Context

By 2020: Two extragalactic celestial reference frames available

VLBI (Radio)



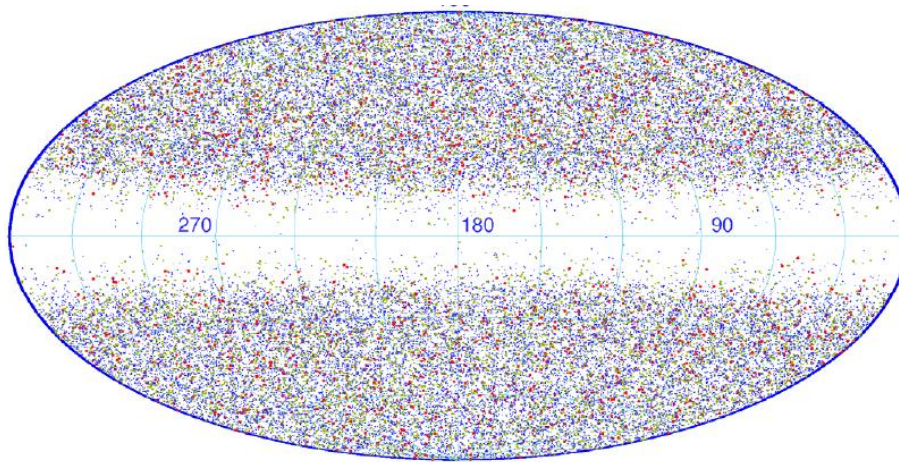
Position accuracy:

1997: ICRF1 – 717 sources – $\sigma \geq 250 \mu\text{as}$

2009: ICRF2 – 3414 sources – $\sigma \geq 60 \mu\text{as}$

2020: ICRF3 ???

Gaia (Optical magnitude ≤ 20)



Anticipated position accuracy:

20 000 QSOs @ $V \leq 18 \rightarrow 16 \mu\text{as} \leq \sigma \leq 70 \mu\text{as}$

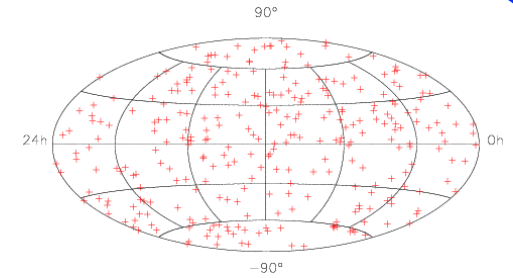
500 000 QSOs @ $V \leq 20 \rightarrow 16 \mu\text{as} \leq \sigma \leq 200 \mu\text{as}$

Lindgren et al. 2008

Linking these 2 frames is important:

- to ensure continuity of the fundamental celestial reference frame
- to register optical & radio positions with the highest accuracy

Gaia-VLBI frames alignment



- **Requirements:**

- ✓ Several hundreds of common sources
- ✓ With a uniform sky coverage
- ✓ Common sources must have:
 - Accurate Gaia position → Optically-bright (mag. ≤ 18 ; *Mignard 2003*)
 - Accurate VLBI position → Good astrometric quality (point-like VLBI structure)

- **Current status:**

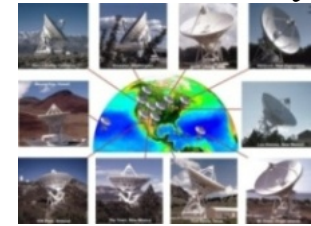
- ✓ ICRF1: 10% of sources suitable = 70 sources (*Bourda et al. 2008*)
- ✓ ICRF2: 6% of sources suitable = 201 sources [*see P. Charlot talk*]

➡ **Need to find new radio sources suitable for accurate Gaia-VLBI alignment**

Our project



*Very Long
Baseline Array*



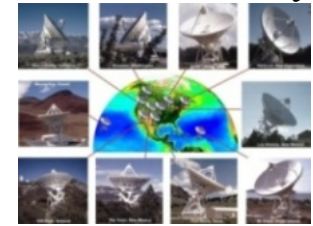
- Idea: New candidates → Weak sources (< 100 mJy)
- Specific VLBI observing program designed (with EVN & VLBA)
- Observing Sample: 447 weak extragalactic radio sources
 - ✓ NVSS catalog (excluding ICRF1 and VCS sources)
 - ✓ Optical magnitude $V \leq 18$
 - ✓ Total flux density (NVSS) ≥ 20 mJy
 - ✓ $\delta \geq -10^\circ$
- Observing Strategy:
 1. VLBI detection (*Bourda et al. 2010, A&A 520, A113*)
 2. Imaging (*Bourda et al. 2011, A&A 526, A102*)
 3. Accurate astrometry (for the most compact sources)

*NRAO VLA Sky Survey
(Condon et al. 1998)*

Our project



*Very Long
Baseline Array*



- Idea: New candidates → Weak sources (< 100 mJy)
- Specific VLBI observing program designed (with EVN & VLBA)

This observing program is part of GBOG
(Ground-Based Observations for Gaia)

Work related in the optical part → Cf. F. Taris talk

- Observing Strategy:
 1. VLBI detection (*Bourda et al. 2010, A&A 520, A113*)
 2. Imaging (*Bourda et al. 2011, A&A 526, A102*)
 3. Accurate astrometry (for the most compact sources)

Step 1: VLBI detection

- Two 48-hour EVN experiments
(S/X @ 1Gbps)

EC025A: June 2007 – 224 sources

EC025B: October 2007 – 223 sources

Weak sources in VLBI

- High sensitivity necessary
- Need large antennas & high recording rate

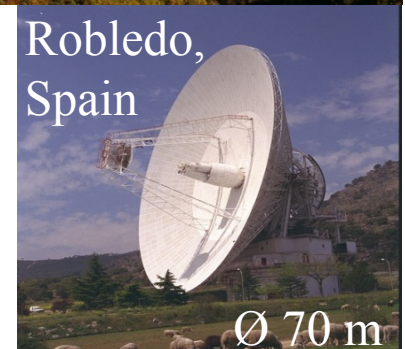
- S/X detection rates:

EC025A ~ 96 %

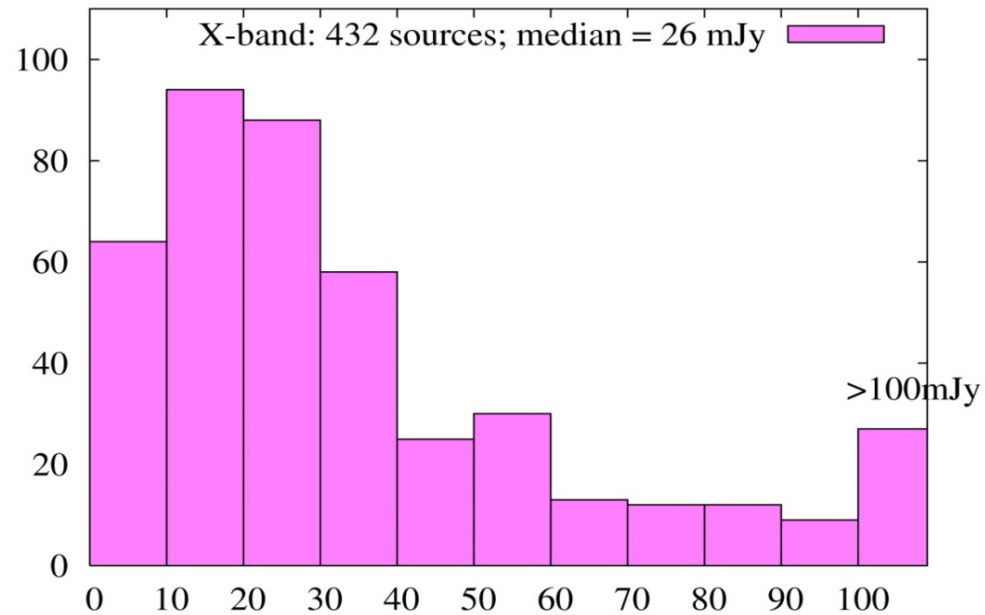
EC025B ~ 82 %

Overall detection rate: ~ 89 %
(398 sources detected)

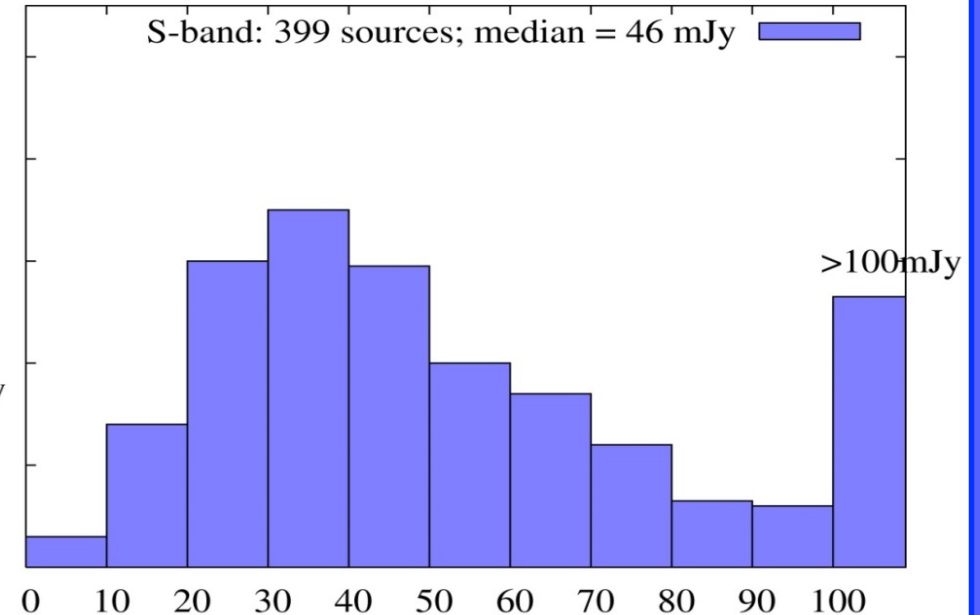
(*Bourda et al. 2010, A&A 520, A113*)



Flux density distribution



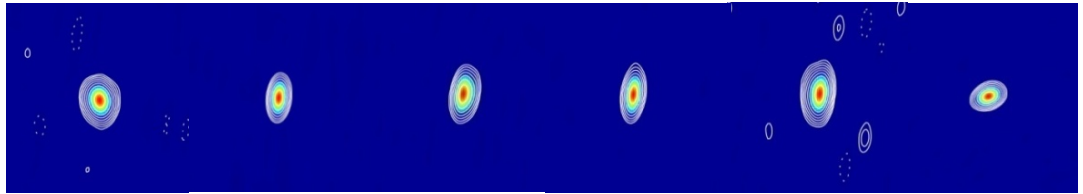
X-band
mean correlated flux density
(mJy)



S-band
mean correlated flux density
(mJy)

Bourda et al. 2010, A&A 520, A113

Step 2: Imaging

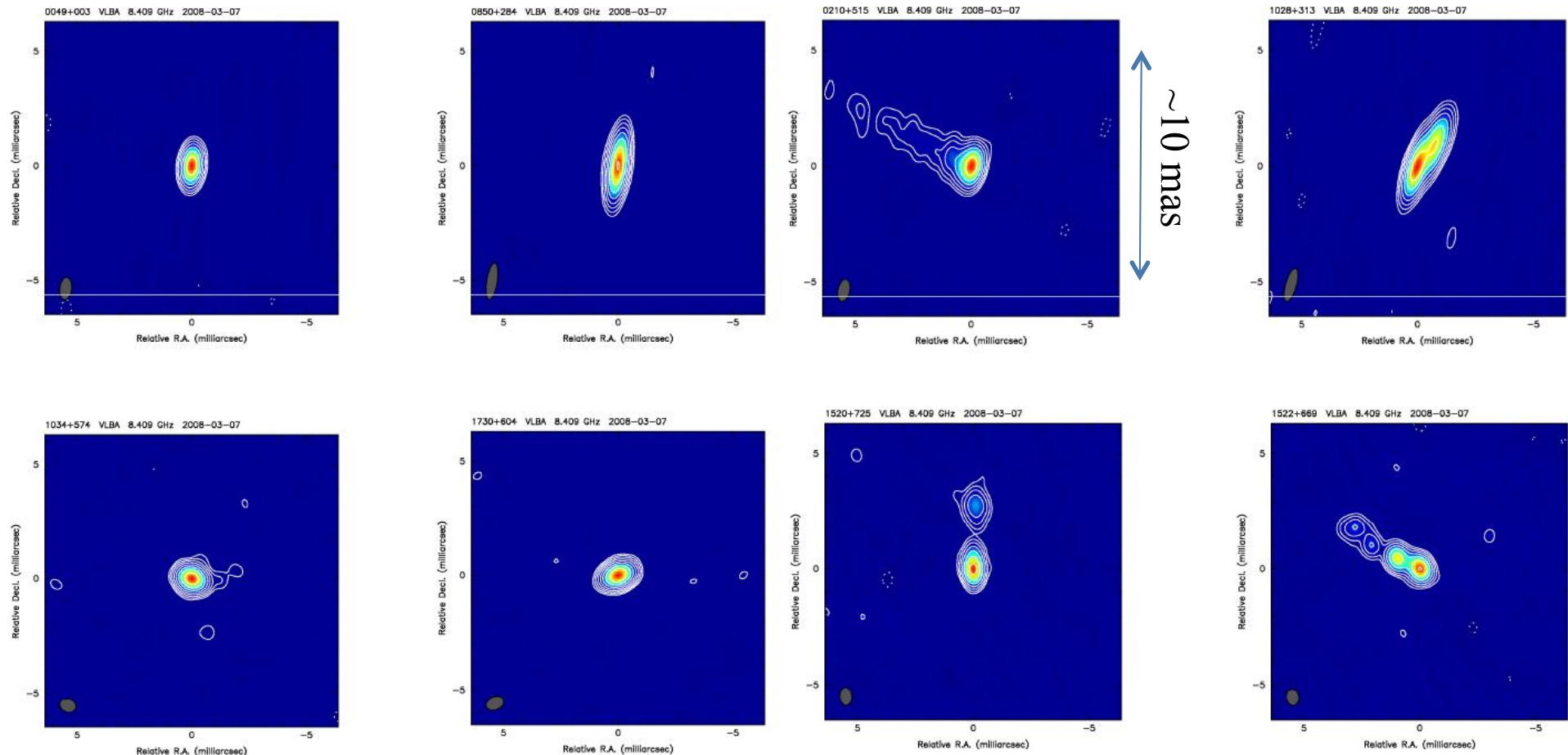


- **Pilot imaging experiment: GC030**
 - ✓ Observations for 25% of the sources previously detected
 - ✓ March 2008 – 48 hours
 - ✓ Global VLBI array (VLBA + EVN)
 - ✓ Standard imaging S/X observations @ 512 Mb/s
- **Results** (*Bourda et al. 2011, A&A 526, A102*)
 - ✓ All 105 sources successfully imaged at both X & S bands
 - ✓ Dynamic range $\sim 1\%$
 - ✓ Flux density consistent within 10% of that measured in previous step

Pilot imaging experiment: Examples of VLBI maps

“Good” sources

“Bad” sources



X-band – 1st contour level @ 1%

VLBI Images in BVID


The Bordeaux VLBI Image Database

Home BVID Database access

Query by : Source name Date Coordinates

For GC030:

105 sources have been found !

=> VLBI image summary (in pdf )

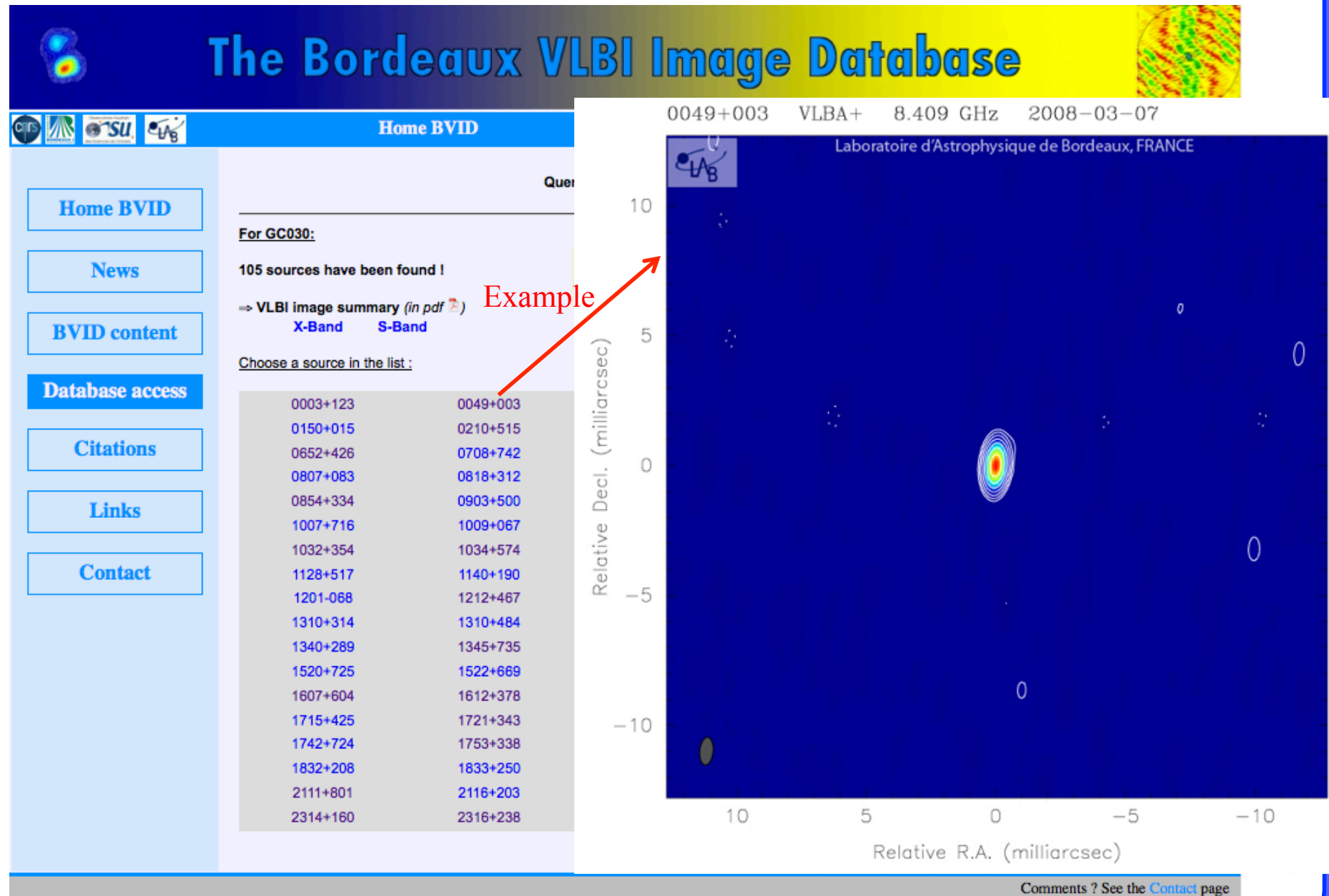
X-Band S-Band

Choose a source in the list :

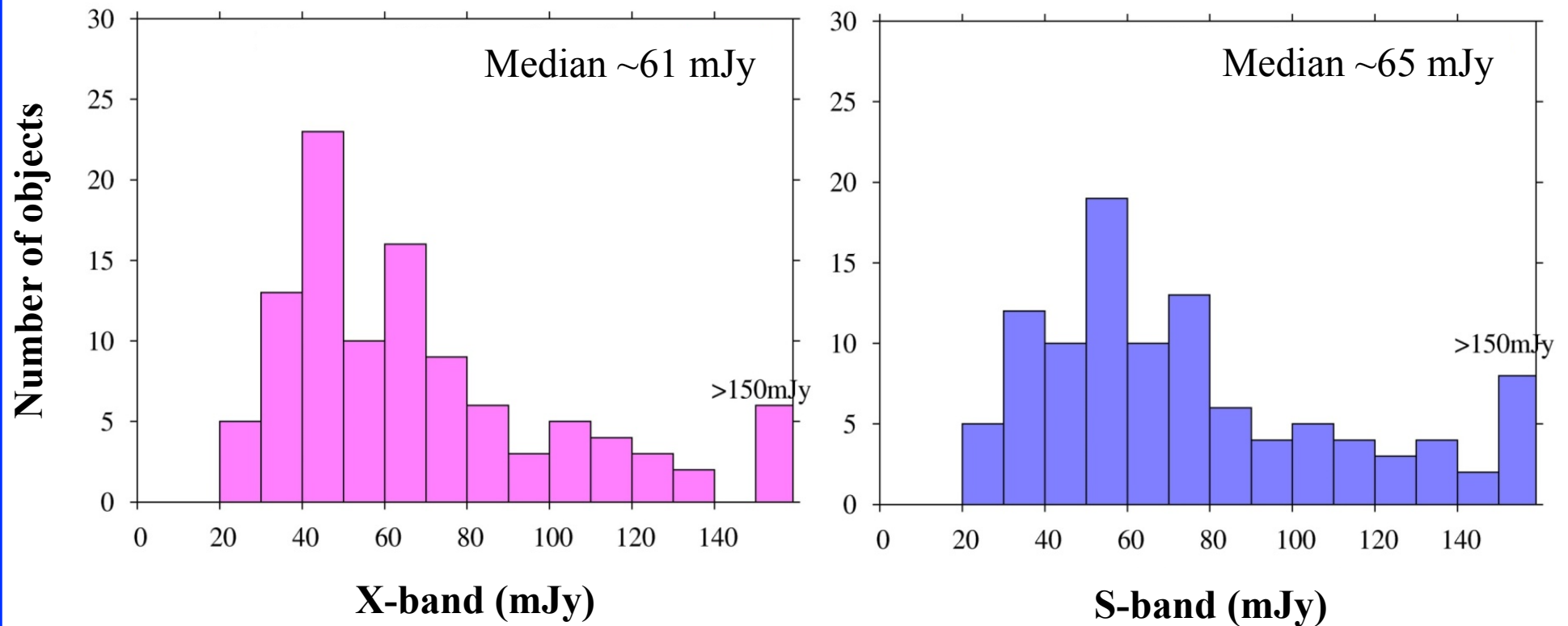
0003+123	0049+003	0107-025	0109+200	0130-083	0145+210
0150+015	0210+515	0446+074	0502+041	0519-074	0651+428
0652+426	0708+742	0741+294	0751+306	0757+477	0806+350
0807+083	0818+312	0821+411	0838+235	0838+456	0850+284
0854+334	0903+500	0907+336	0950+326	0950-084	0952+338
1007+716	1009+067	1009+334	1010+356	1020+292	1028+313
1032+354	1034+574	1040-056	1101+077	1126+237	1127+078
1128+517	1140+190	1141+235	1145+321	1148+592	1201+454
1201-068	1212+467	1228+077	1240+367	1242+574	1307+433
1310+314	1310+484	1312+240	1315+727	1319+006	1338+303
1340+289	1345+735	1411+746	1420+044	1429+249	1518+162
1520+725	1522+669	1535+231	1556+335	1603+699	1607+183
1607+604	1612+378	1618+530	1648+417	1653+198	1714+231
1715+425	1721+343	1722+119	1729+372	1730+604	1741+597
1742+724	1753+338	1759+756	1810+522	1811+317	1818+551
1832+208	1833+250	1838+575	2043+749	2052+239	2057+235
2111+801	2116+203	2128+333	2241+200	2247+381	2300+345
2314+160	2316+238	2322+396			

Comments ? See the [Contact page](#)

VLBI Images in BVID



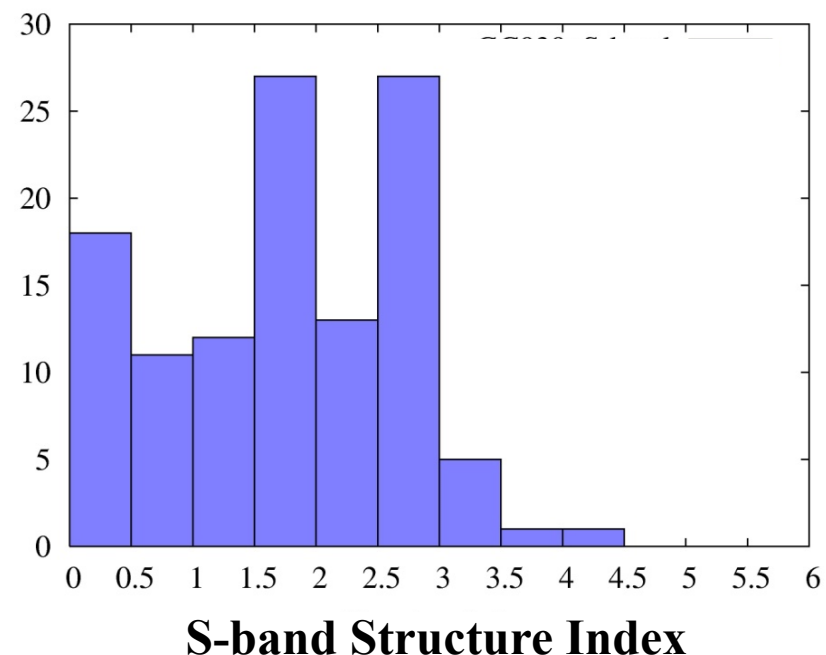
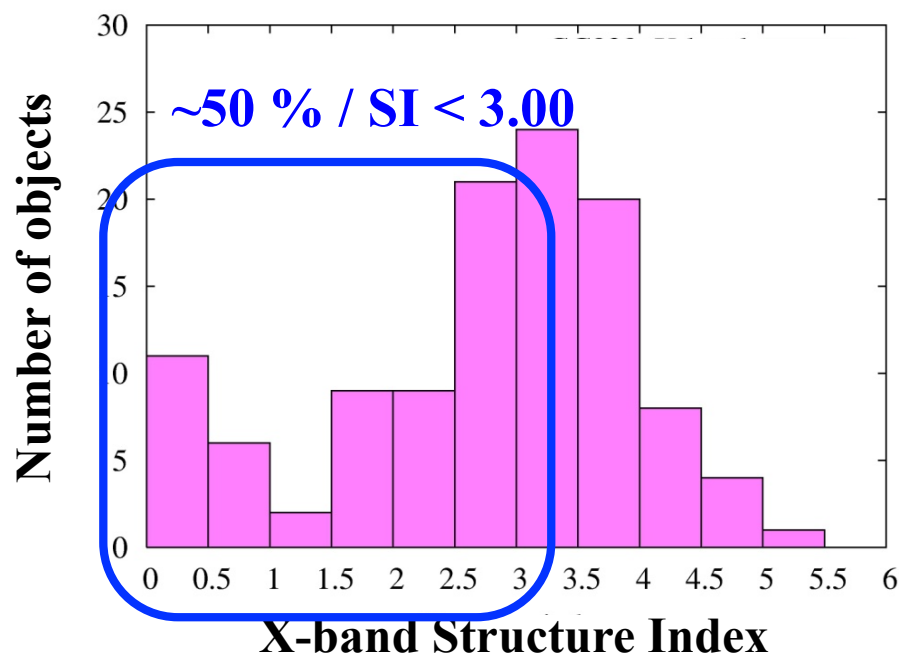
Pilot imaging experiment: Total flux density distribution



Pilot imaging experiment: Structure Index

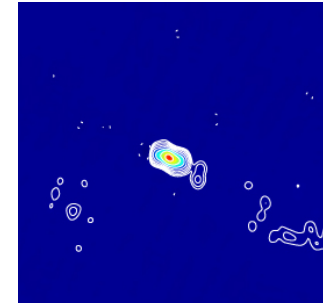
Astrometric quality

- Same criterion as for the selection of ICRF2 "defining" sources (continuous structure index < 3.0)



→ ~50% of sources point-like or with compact structures (i.e. 47 sources)

Next stages



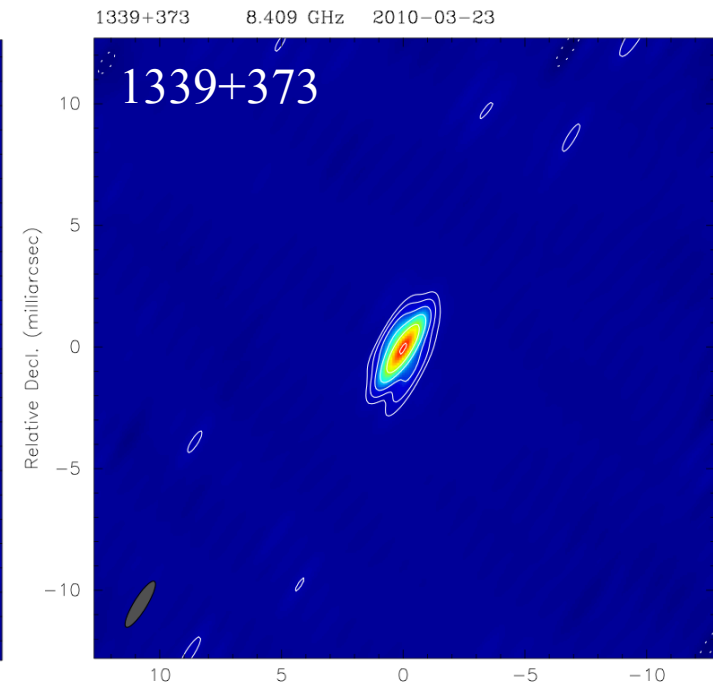
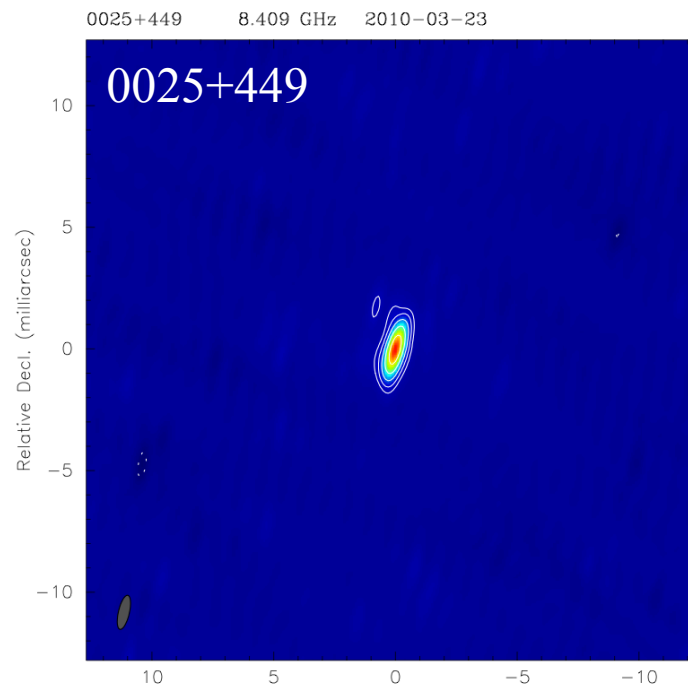
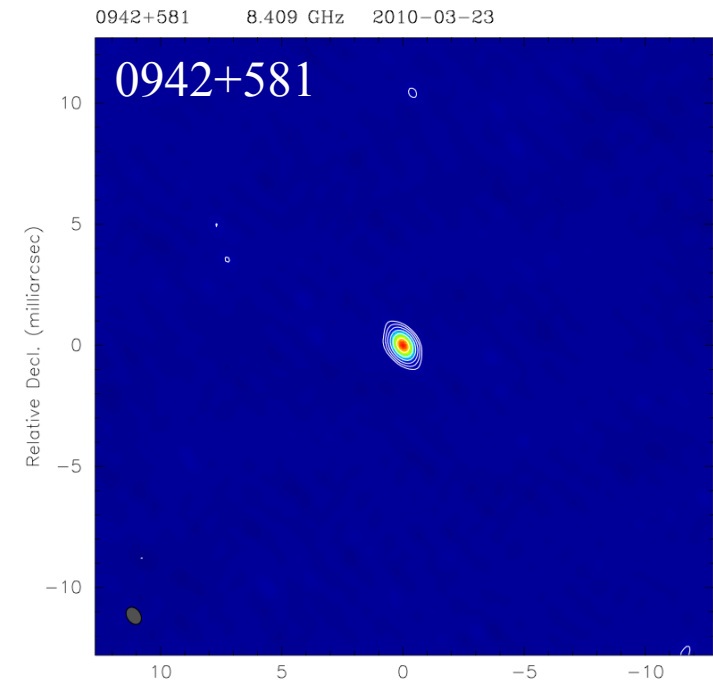
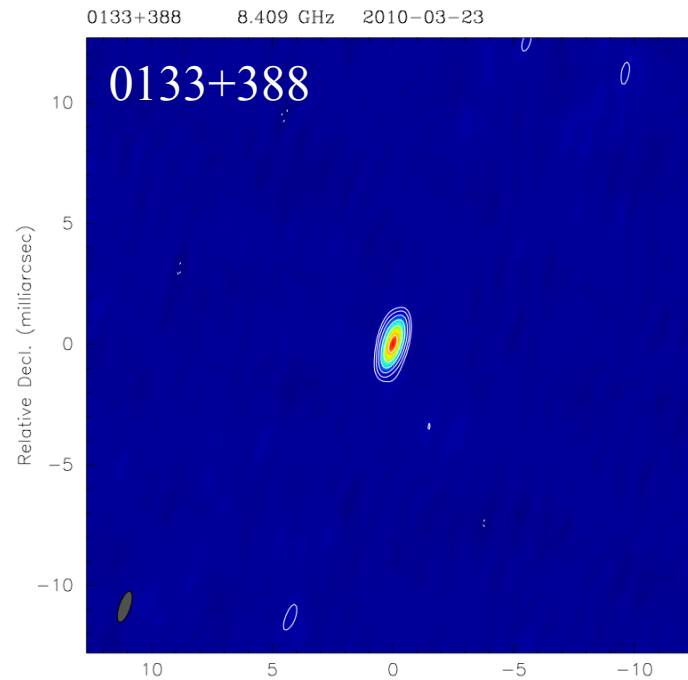
- **VLBI imaging (continued)**
 - ✓ 290 remaining sources
 - ✓ 144-hour EVN/VLBA global observations @ 512 Mbps
 - March 2010: 48-hour → 97 sources
 - November 2010: 58-hour → 118 sources
 - March 2011: 38-hour → 75 sources



Yebes, Spain – Ø 40 m

March 2010
imaging
experiment:
Examples of
VLBI maps

~ 10 mas



Summary and Future prospects

Step 1

VLBI
detection



Step 2

VLBI
imaging



Step 3

VLBI
Astrometry

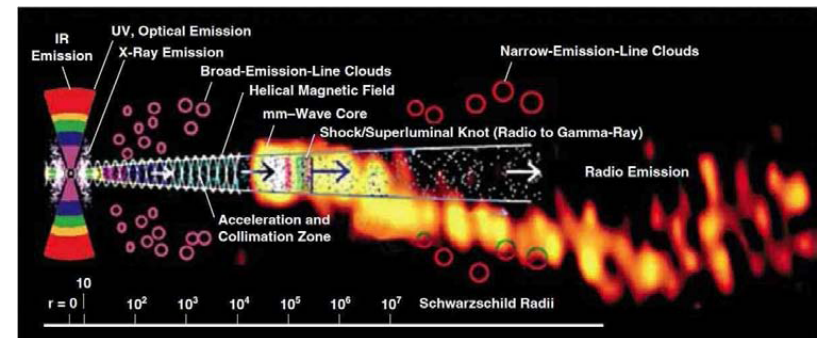


- To finish this program:

- ✓ Carry out global astrometry (on the most compact sources)
- ✓ Positions wanted to better than $<100 \mu\text{s}$
- ✓ First proposal during the year 2011

- In the “near” future:

- ✓ Cover southern hemisphere
- ✓ Astrophysics: Issues of core shifts
- ✓ Ultimately the Gaia *link* sources could/should be part of the ICRF3 to be constructed by 2020



Thanks for your attention ...



Thanks to GREAT for travel support !!