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

VLBI observations of weak extragalactic radio sources

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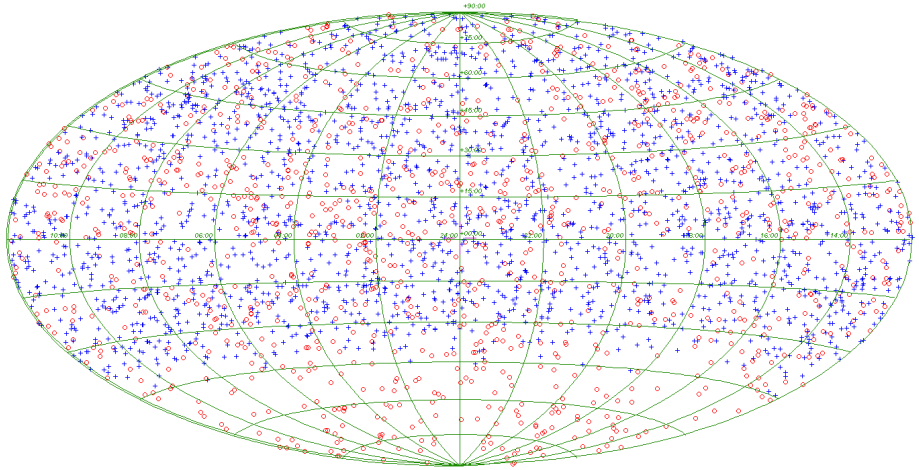
Context

By 2020: Two extragalactic celestial reference frames available

VLBI (Radio)



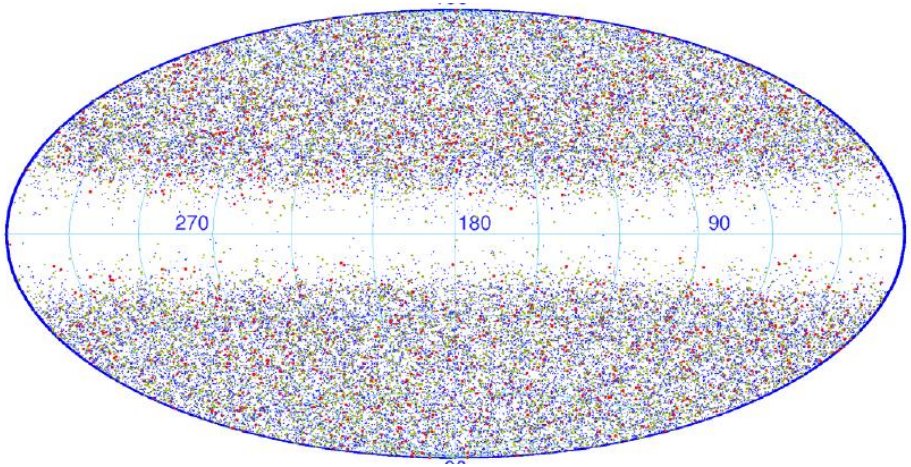
Position accuracy:

1997: ICRF1 – 717 sources – $\sigma \geq 250$ µas

2009: ICRF2 – 3414 sources – $\sigma \geq 60$ µas

2020: ICRF3 ???

Gaia (Optical magnitude ≤ 20)



Anticipated position accuracy:

20 000 QSOs @ V≤18 → 16 µas ≤ σ ≤ 70 µas

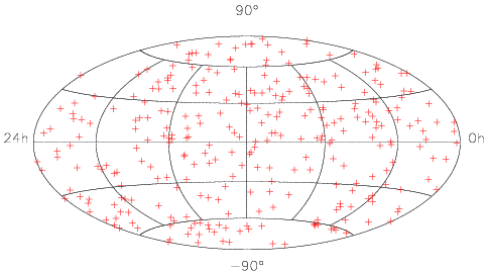
500 000 QSOs @ V≤20 → 16 µas ≤ σ ≤ 200 µas

Lindegren 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*)

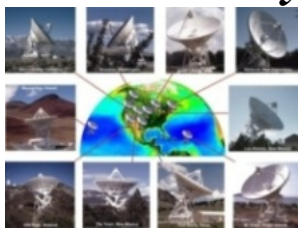
✓ ICRF2: 6% of sources suitable = 201 sources [*see P. Charlot talk*]

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

Our project

EUROPEAN vlbi NETWORK

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 ≤ 18
✓ Total flux density (NVSS) ≥ 20 mJy
✓ δ ≥ -10º

NRAO VLA Sky Survey
(Condon et al. 1998)

- 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)

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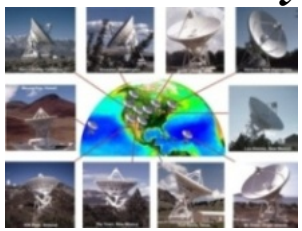

- Idea: New candidates → Weak sources (< 100 mJy)
- Specific VLBI observing program designed (with EVN & VLBA)

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*)
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Step 1: VLBI detection

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

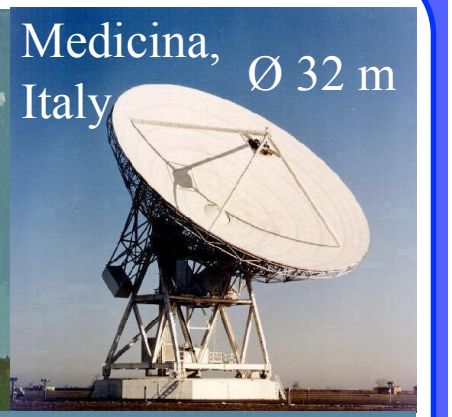
  EC025A: June 2007 – 224 sources

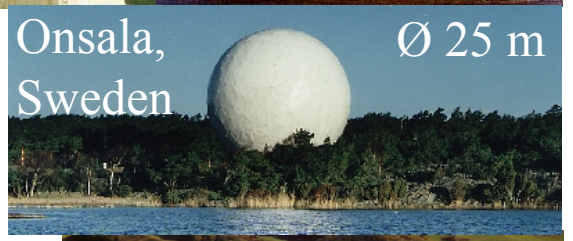
  EC025B: October 2007 – 223 sources

Weak sources in VLBI

⇒ High sensitivity necessary

⇒ Need large antennas & high recording rate





- S/X detection rates:

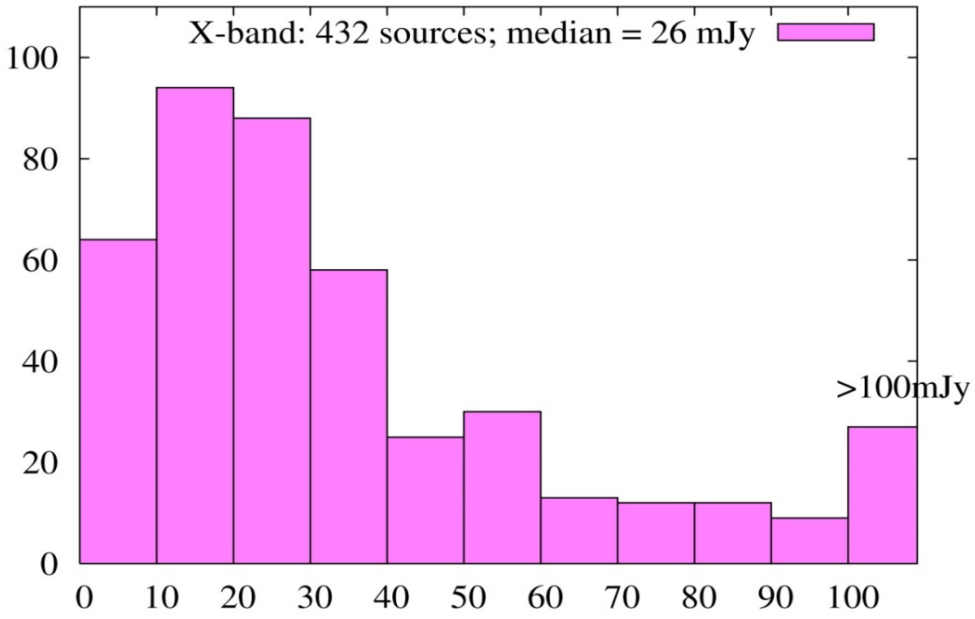
  EC025A ~ 96 %

  EC025B ~ 82 %

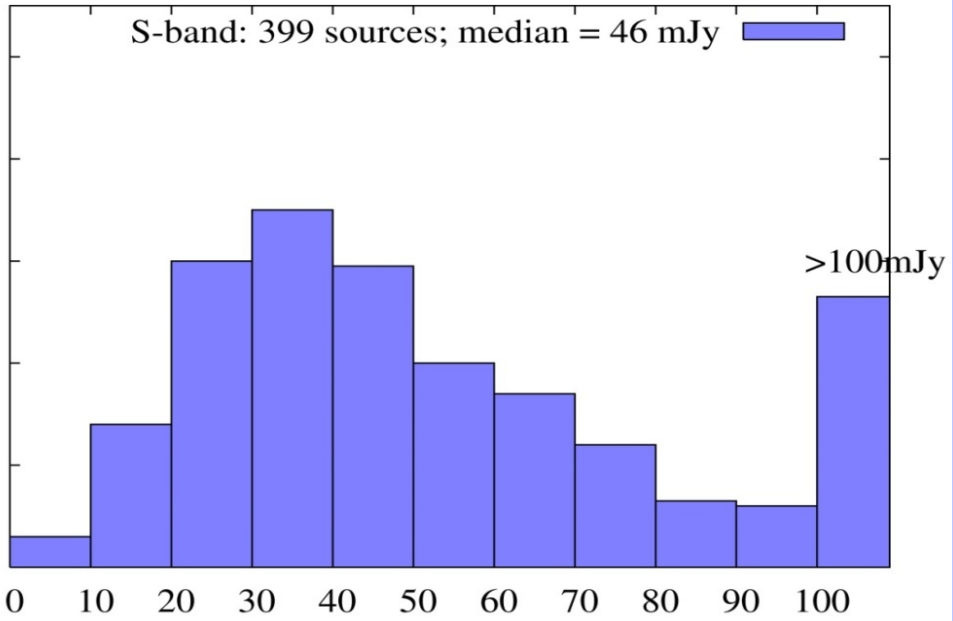
  Overall detection rate: ~ **89 %** (398 sources detected)

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

Flux density distribution



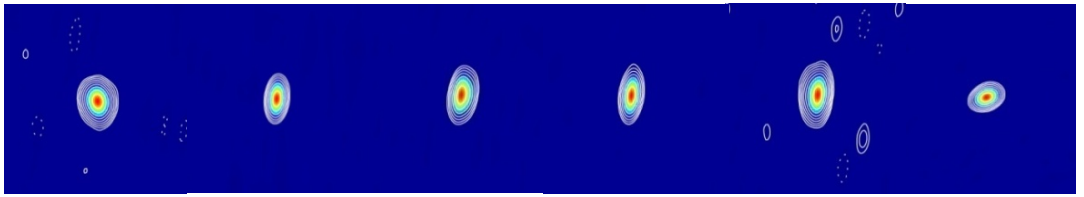
X-band
mean correlated flux density
(mJy)



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

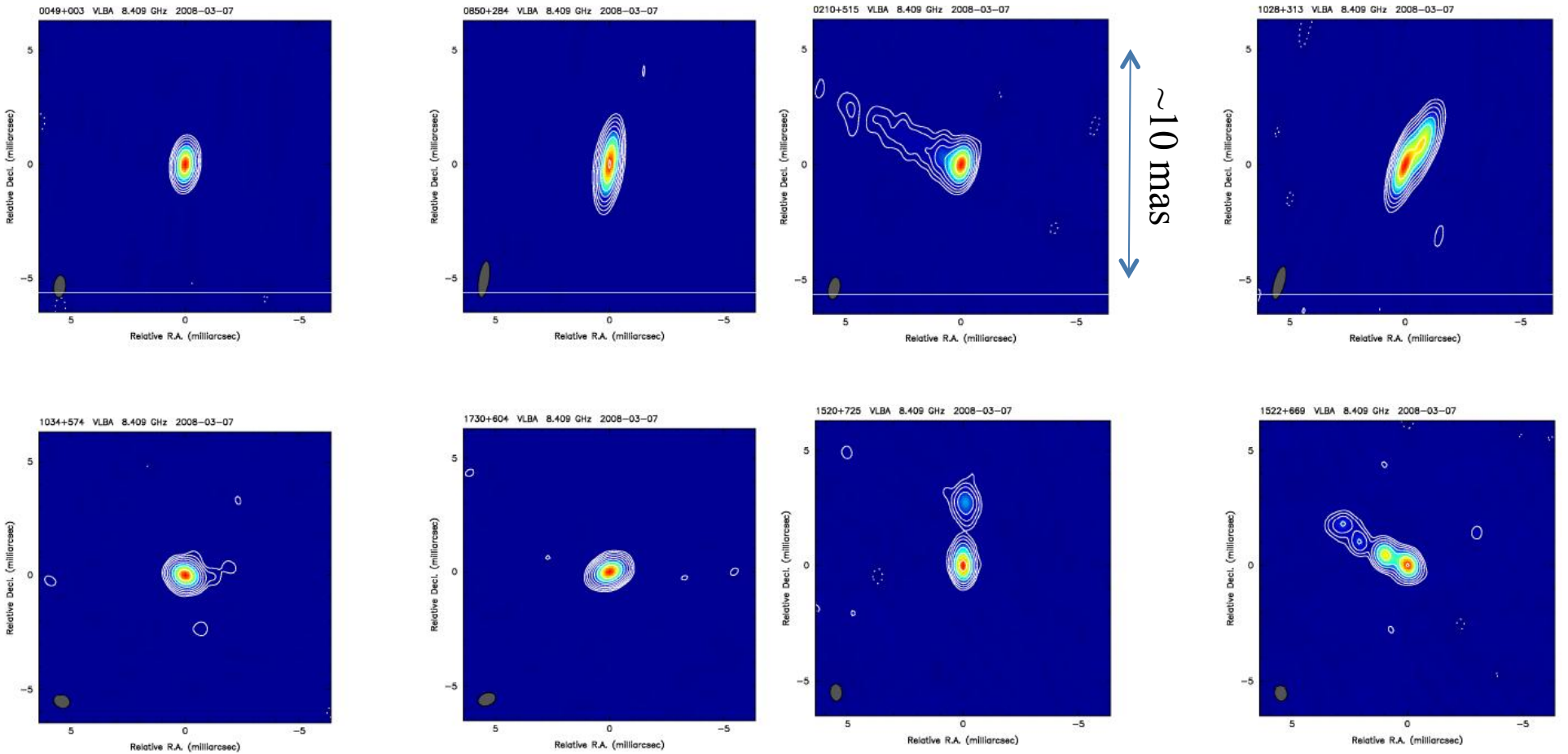
✓ Dynamic range ~1%

✓ Flux density consistent within 10% of that measured in previous step

Pilot imaging experiment: Examples of VLBI maps

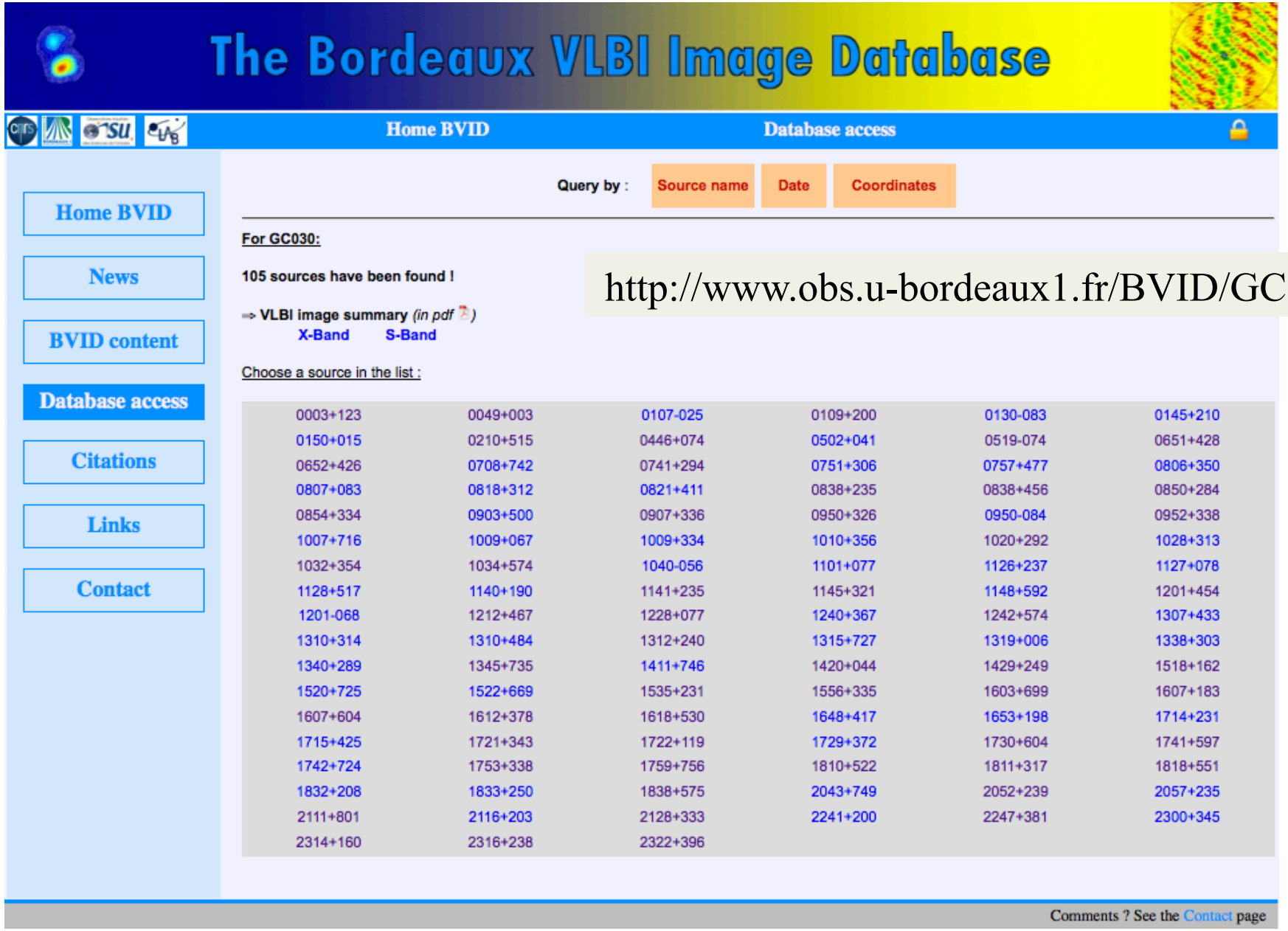
"Good" sources

"Bad" sources



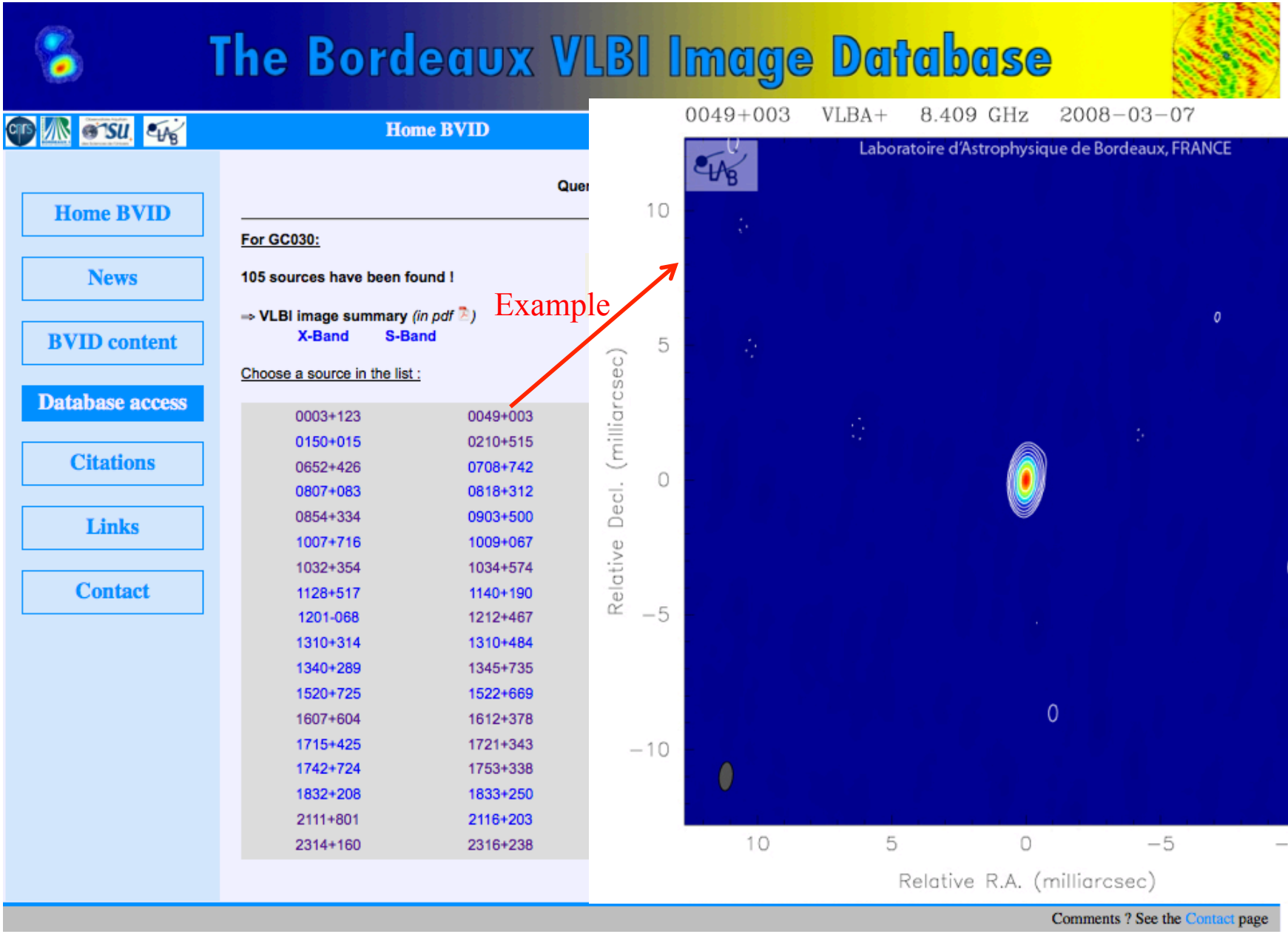
X-band −1st contour level @ 1%

VLBI Images in BVID

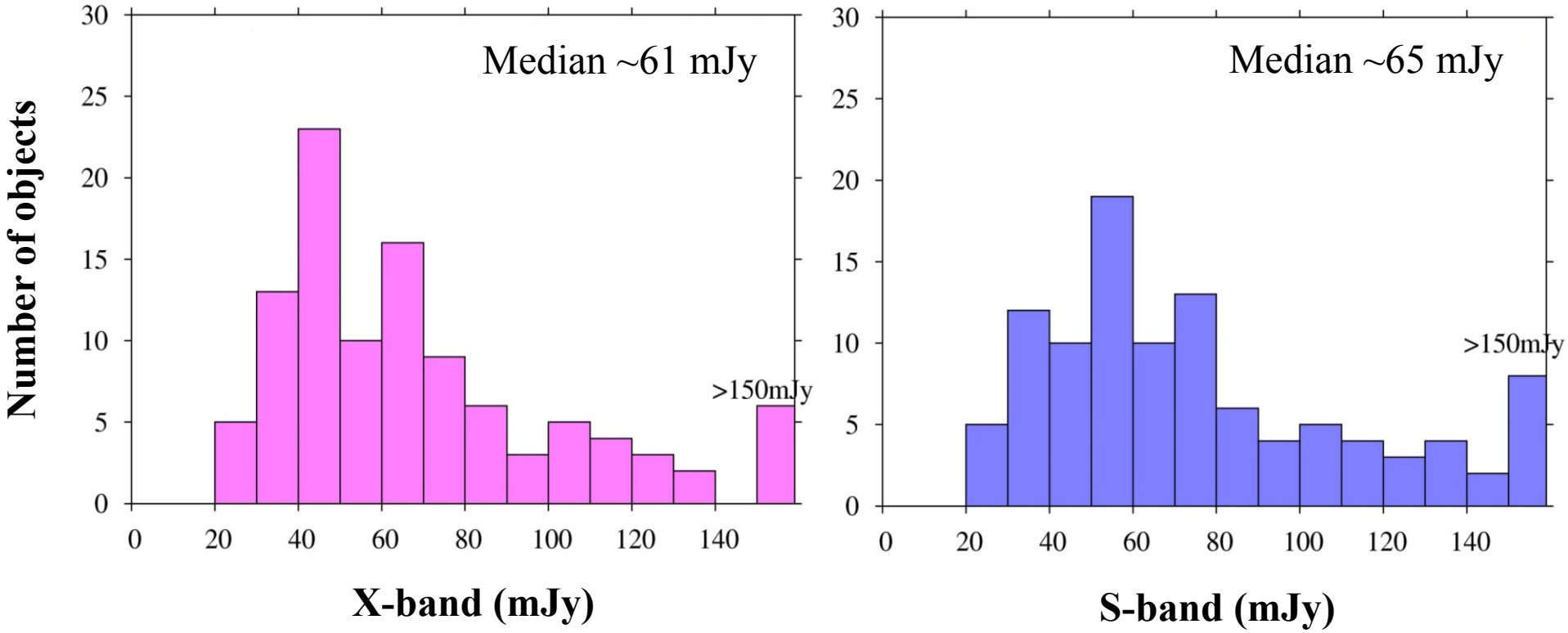


http://www.obs.u-bordeaux1.fr/BVID/GC030

VLBI Images in BVID



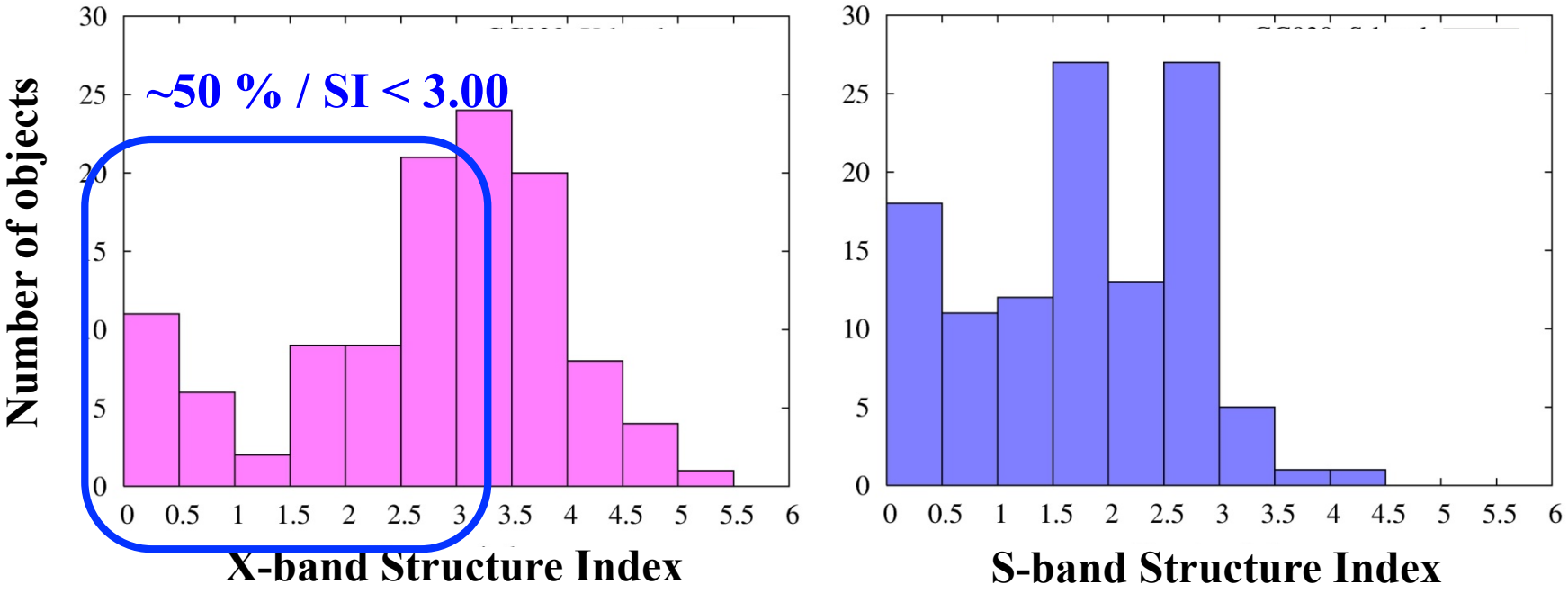
Pilot imaging experiment: Total flux density distribution



Pilot imaging experiment: Structure Index

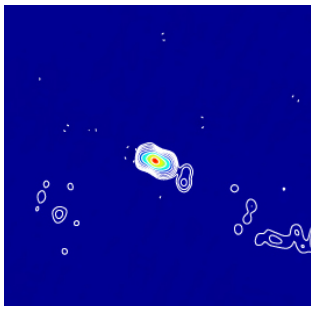
Astrometric quality

- 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)**

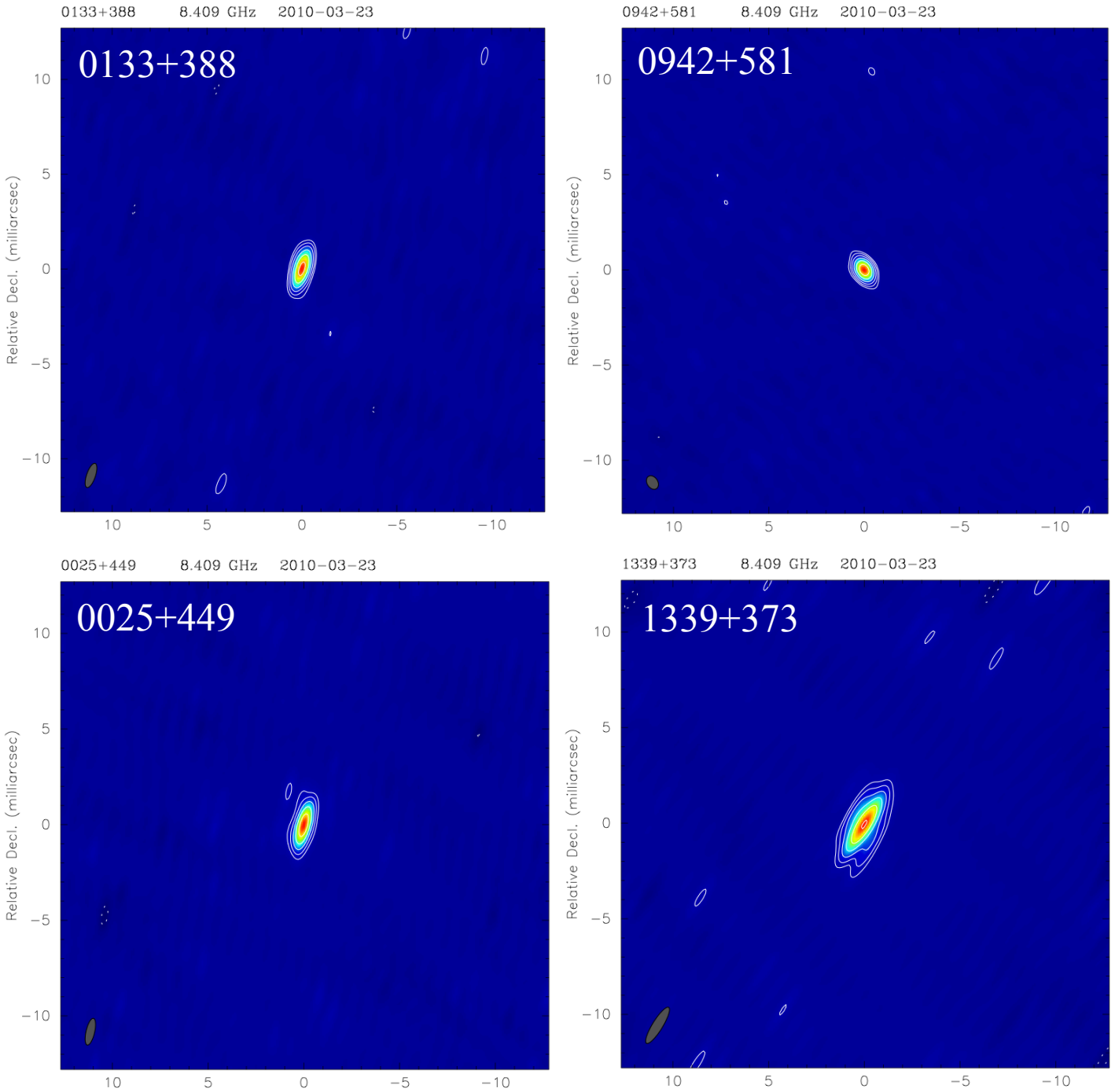
✓ 290 remaining sources

✓ 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

March 2010 imaging experiment:

Examples of VLBI maps



Summary and Future prospects

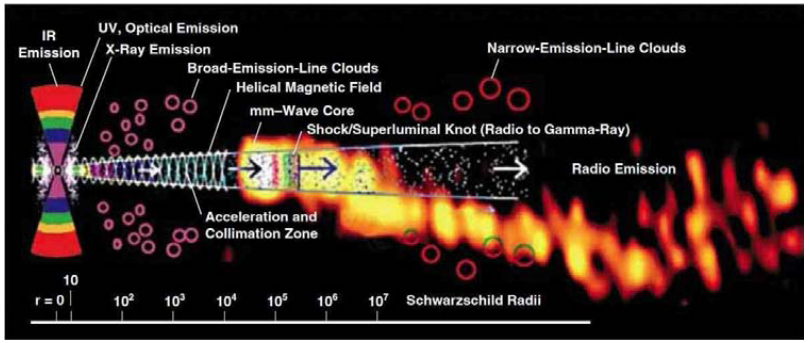
Step 1	Step 2	Step 3
VLBI detection ☑	VLBI imaging ☑…	VLBI Astrometry ☐

- To finish this program:

✓ Carry out global astrometry (on the most compact sources)

✓ Positions wanted to better than <100 μas

✓ 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 !!