Towards an accurate alignment of the VLBI frame with the future Gaia optical frame

G. Bourda, P. Charlot, A. Collioud

Laboratoire d'Astrophysique de Bordeaux

R. Porcas

Max Planck Institut für Radioastronomie

S. Garrington

Jodrell Bank Observatory

The Gaia astrometric mission

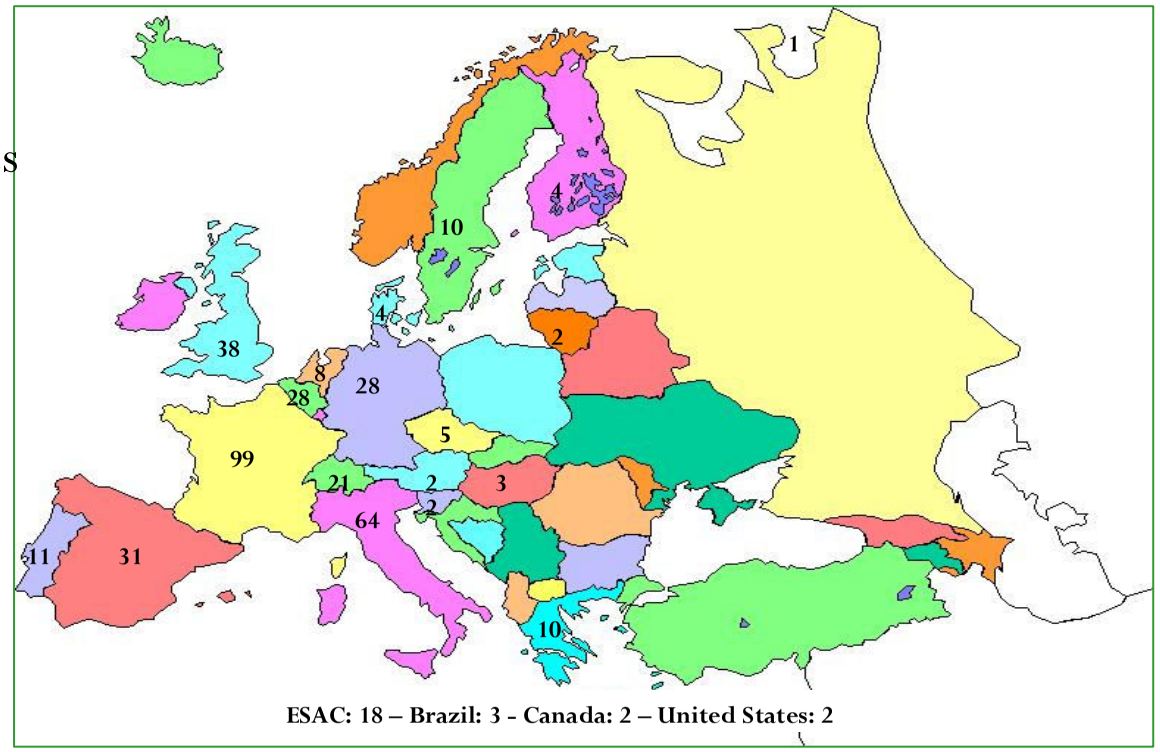
- Gaia will observe 1 billion stars, 500 000 QSOs and 350 000 asteroids
- Astrometric accuracy

V magnitude	6 - 13	14	15	16	17	18	19	20	mag
Parallax	8	13	21	34	55	90	155	275	μas
Proper motion	5	7	11	18	30	50	80	145	μas / an
Position @2015	6	10	16	25	40	70	115	205	μas

- Launch: fall 2012
- Preliminary catalog: ~ 2015
- Final catalog: 2018-2020

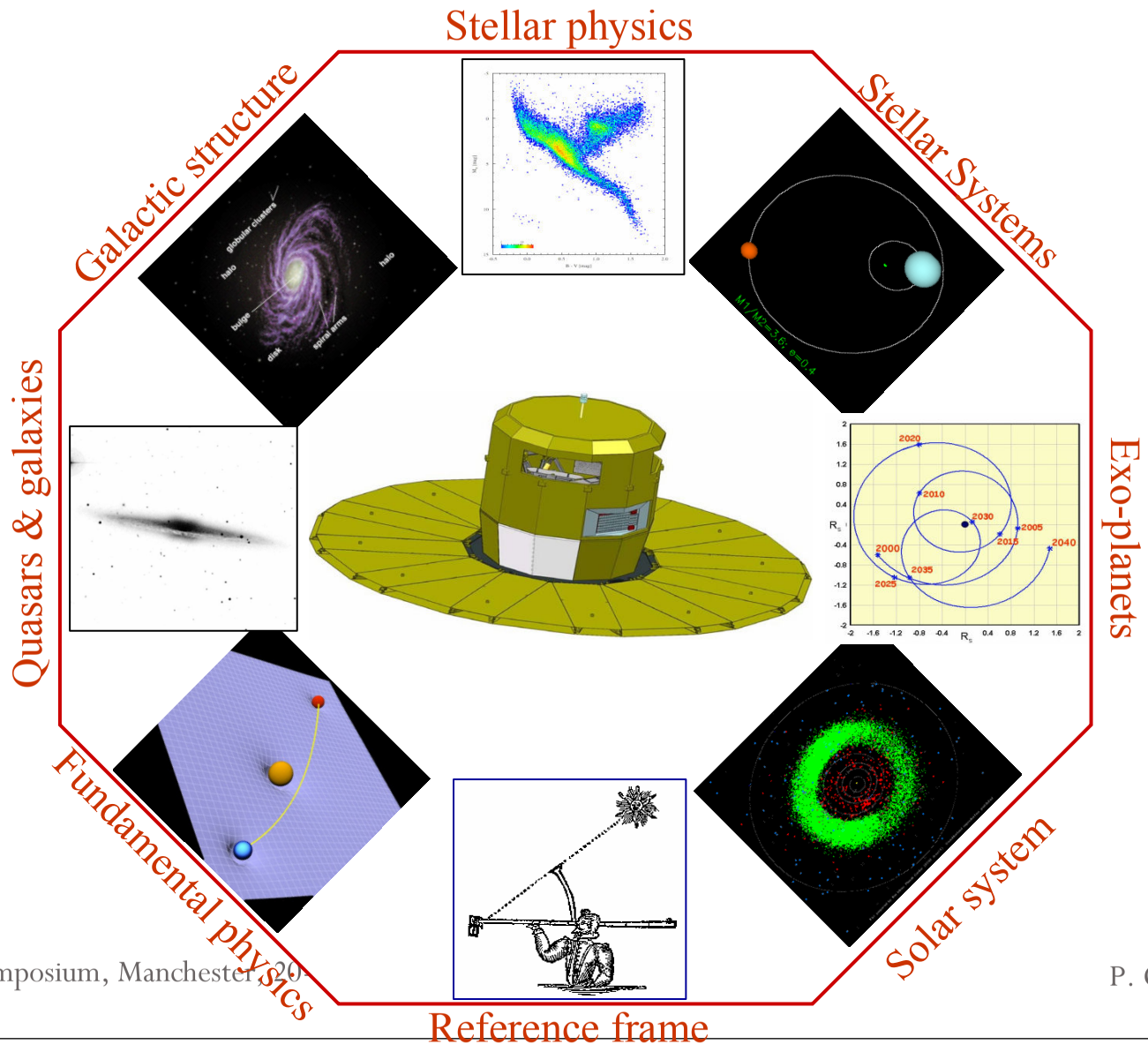
Gaia organization

- Satellite and instruments built by ESA and industry
- Data analysis conducted by the DPAC (Data Processing and Analysis Consortium)
  - 400 members
  - 22 funding agencies in Europe

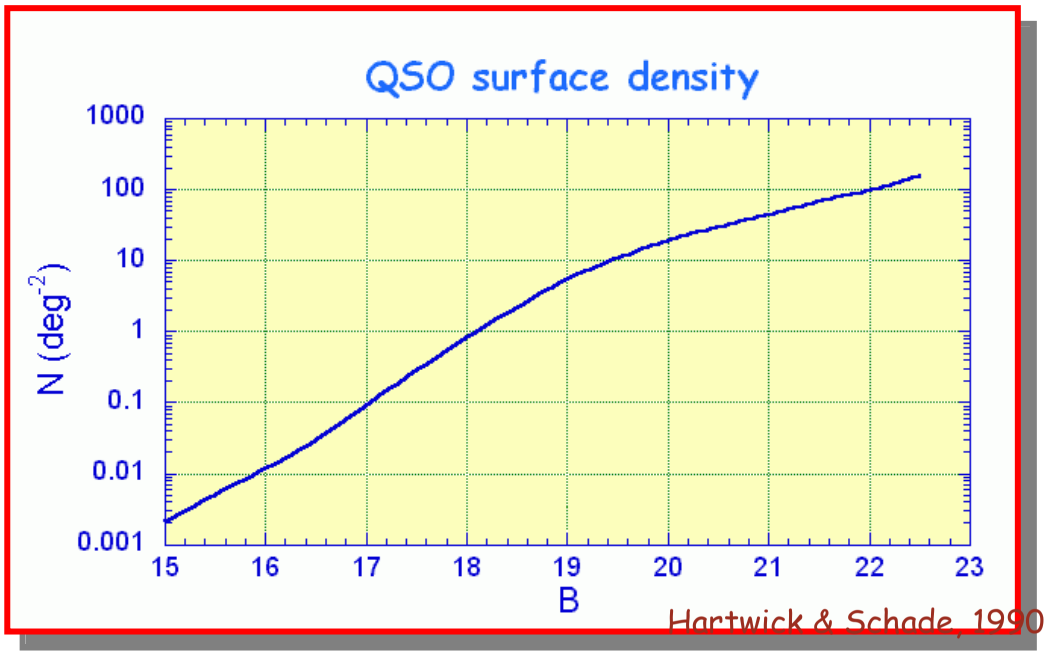


DPAC active members

Which science with Gaia?



QSO Reference Frame



With a flawless selection : GAIA will observe on ~ half of the sky

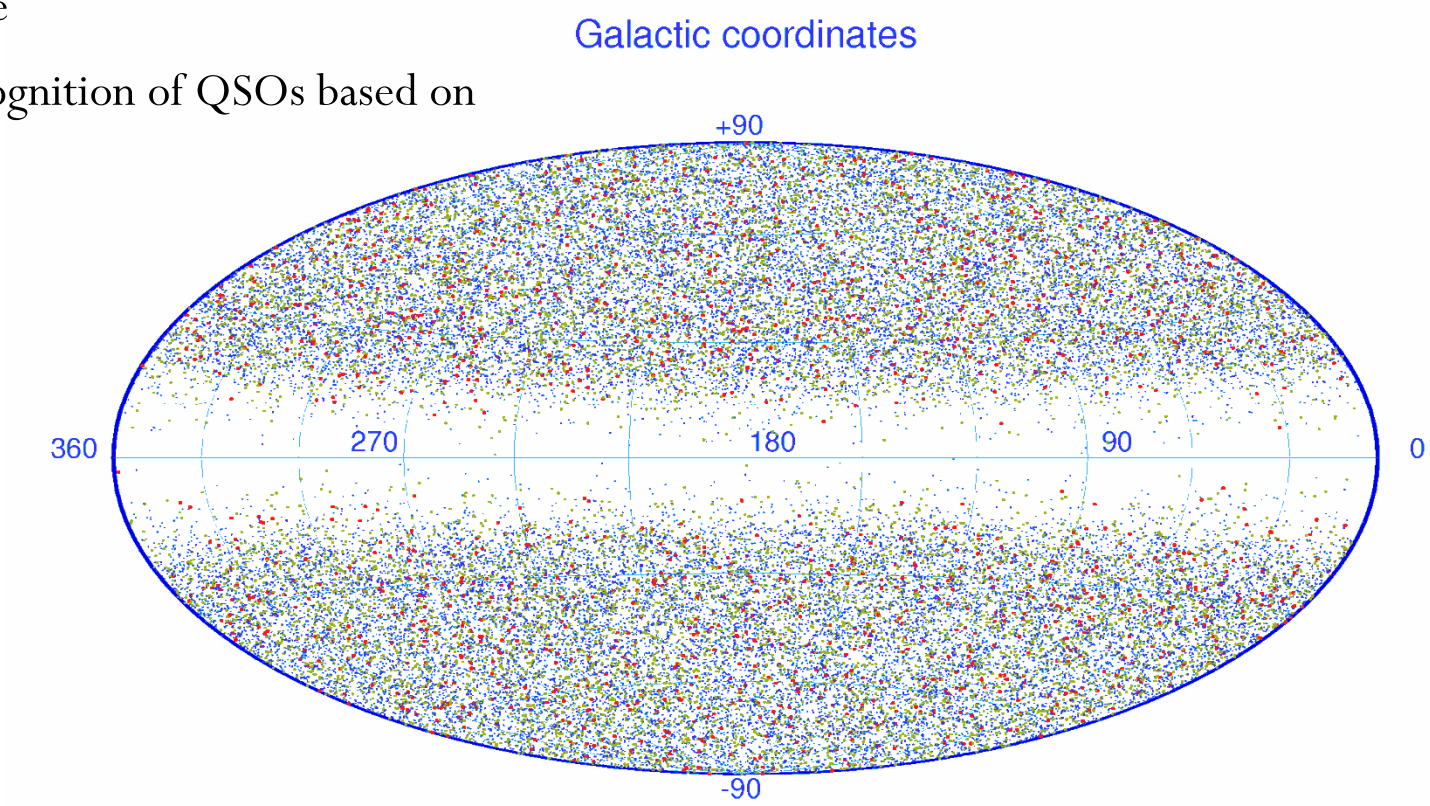
- $B \leq 16$ 200
- $B \leq 18$ 20 000
- $B \leq 20$ 400 000

Simulations of Gaia catalog

(Slezak and Mignard 2008)

Galactic absorption included in the visible range

Automatic recognition of QSOs based on photometry

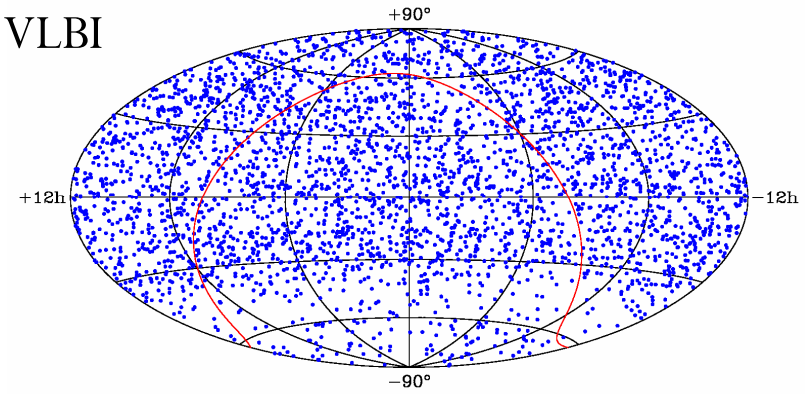


● G < 18 ● 18< G < 19 ● 19< G < 20

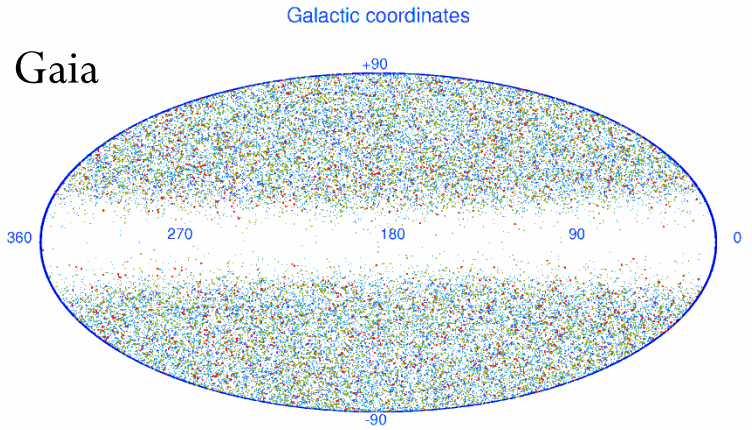
Reference frames in the next decade

By 2015-2020, two extragalactic celestial reference frames will be available

VLBI



Gaia



Position accuracy:

1998: ICRF1 – 717 sources – $\sigma \geq 250$ μas

2010: ICRF2 – 3414 sources – $\sigma \geq 40$ μas

2015-2020: ICRF3 ???

Anticipated position accuracy:

2015-2020:

20000 QSOs @ V ≤ 18 → 16 μas ≤ σ ≤ 70 μas

500000 QSOs @ V ≤ 20 → σ ≤ 200 μas

Linking the two frames is important

- to ensure continuity of the reference frame
- to register optical and radio positions with the highest accuracy

ICRF-Gaia frame alignment

Alignment must be based on several hundreds of common sources

Link sources must have:

- accurate Gaia positions ➔ magnitude V ≤ 18
- accurate VLBI positions ➔ good astrometric quality (no structure)

Current situation:

- ICRF1: only 10% of ICRF1 sources suitable (Bourda et al. 2008)
- ICRF2: < 50% of *defining* sources with a proper optical counterpart

➡ Need to find new radio sources suitable for determining accurately the link

EVN/Global VLBI specific program designed to find such sources

➡

Overview of VLBI observing program

Source sample

- 447 targets selected from the NVSS (excluding ICRF and VCS sources)
- Optical magnitude $V \leq 18$
- Total flux density (NVSS) ≥ 20 mJy
- $\delta \geq -10^{o}$

Observing Strategy

1. VLBI detection
2. Imaging
3. Accurate astrometry (for the most compact sources)

Step 1: VLBI detection

- Two 48-hour EVN experiments (S/X @ 1Gbps)
  - EC025A: 224 sources observed in June 2007
  - EC025B: 223 sources observed in October 2007

- 4 or 5-station network
  - Effelsberg (100m), Medicina (32m), Noto (32m), Onsala (25m)

  + Robledo (70m) for EC025B

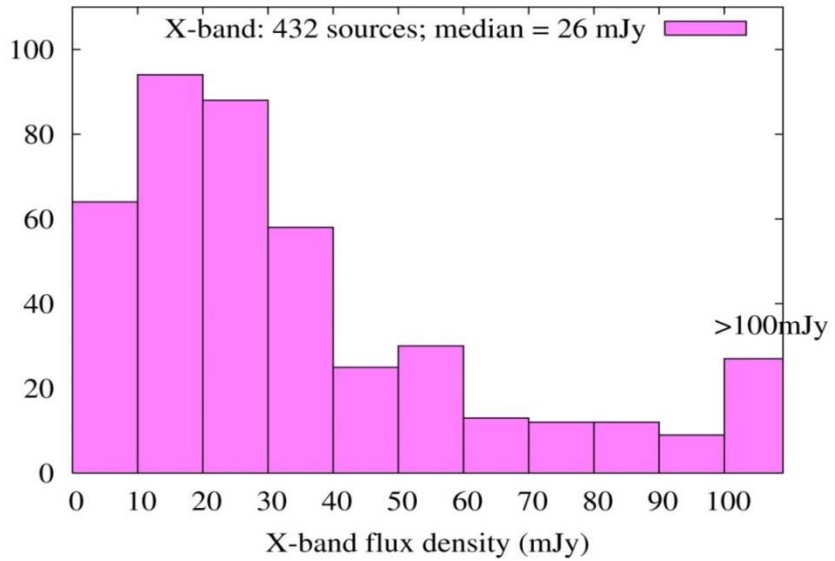
- S and X detection rates
  - EC025A: 96%
  - EC025B: 82%

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

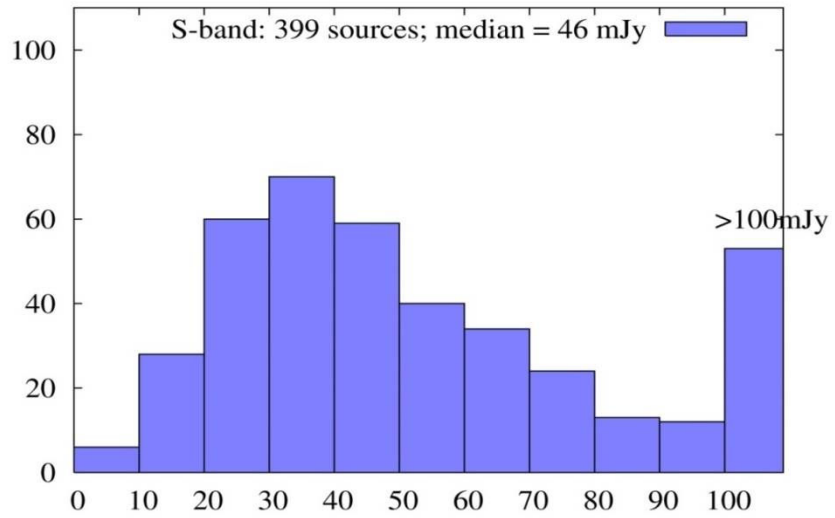
(Bourda et al. 2010a)

Flux density distribution

X-band (mJy)



S-band (mJy)



All flux densities are the mean correlated flux densities over all baselines

Step 2: imaging

Pilot imaging experiment:

- 105 sources (out of 398 detected in step 1)
- Global VLBI array (EVN+VLBA)
- March 2008 – 48 hours
- Dual-frequency S/X @ 512 Mbps
- Standard imaging

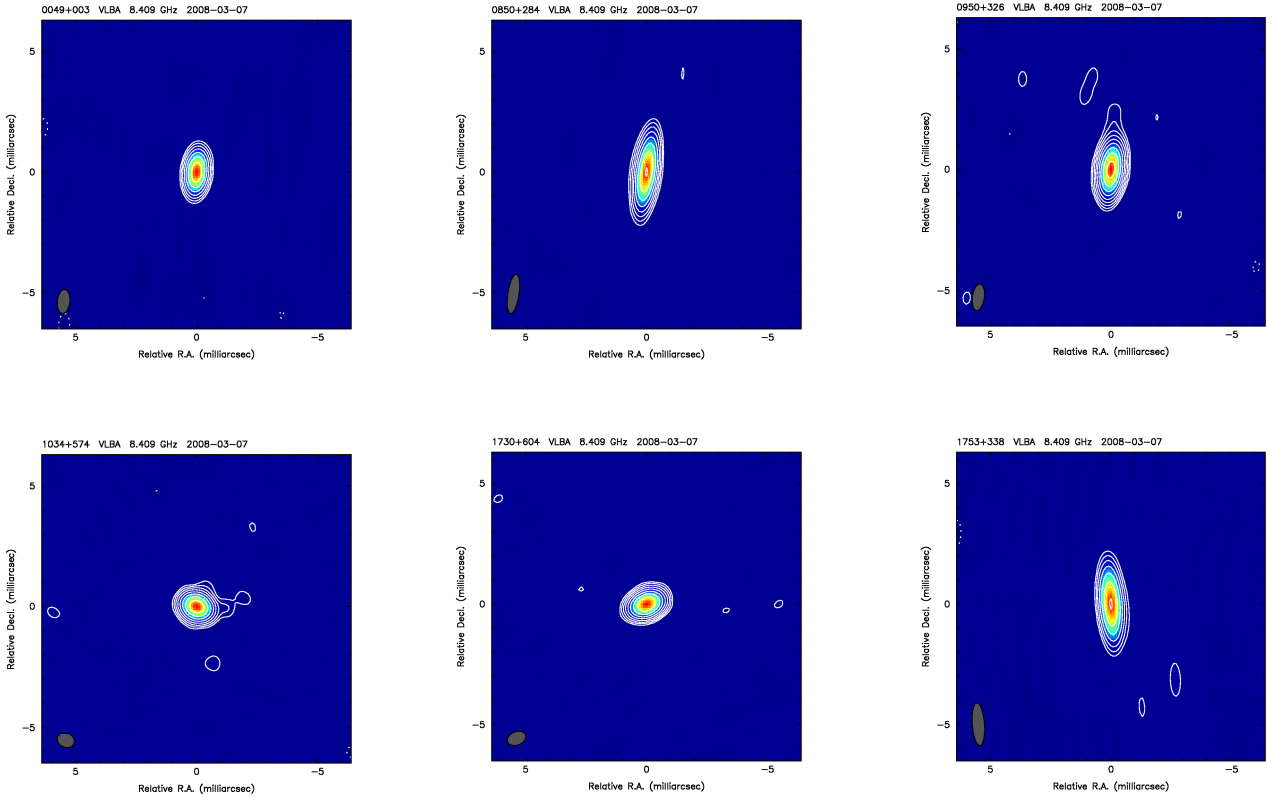
Results

- All 105 sources successfully imaged at both X + S bands
- Dynamic range: ~ 1%
- Flux density consistent within 10% of that measured in EC025A/B

(Bourda et al. 2010b)

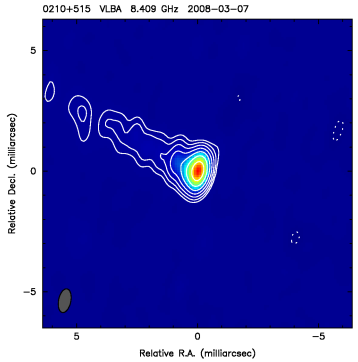
X-band images (1)

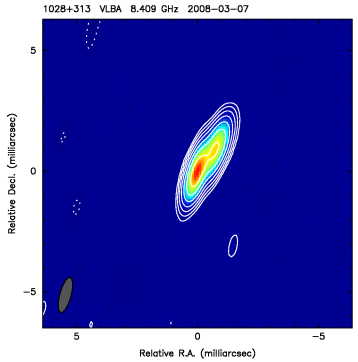
Some very good link sources

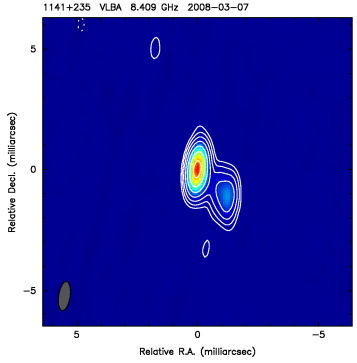


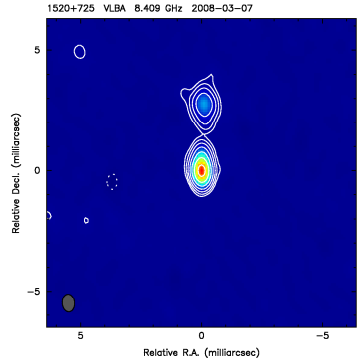
X-band images (2)

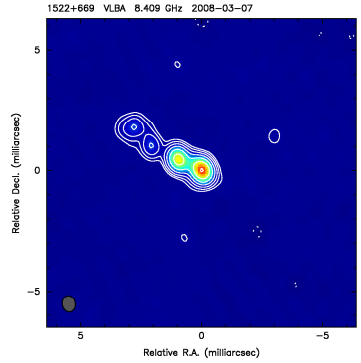
but also some not so good link sources…

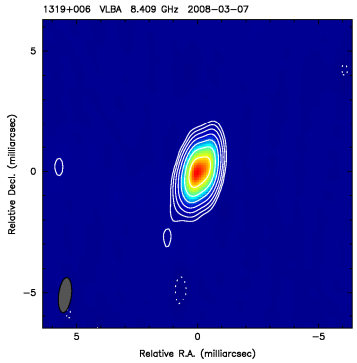






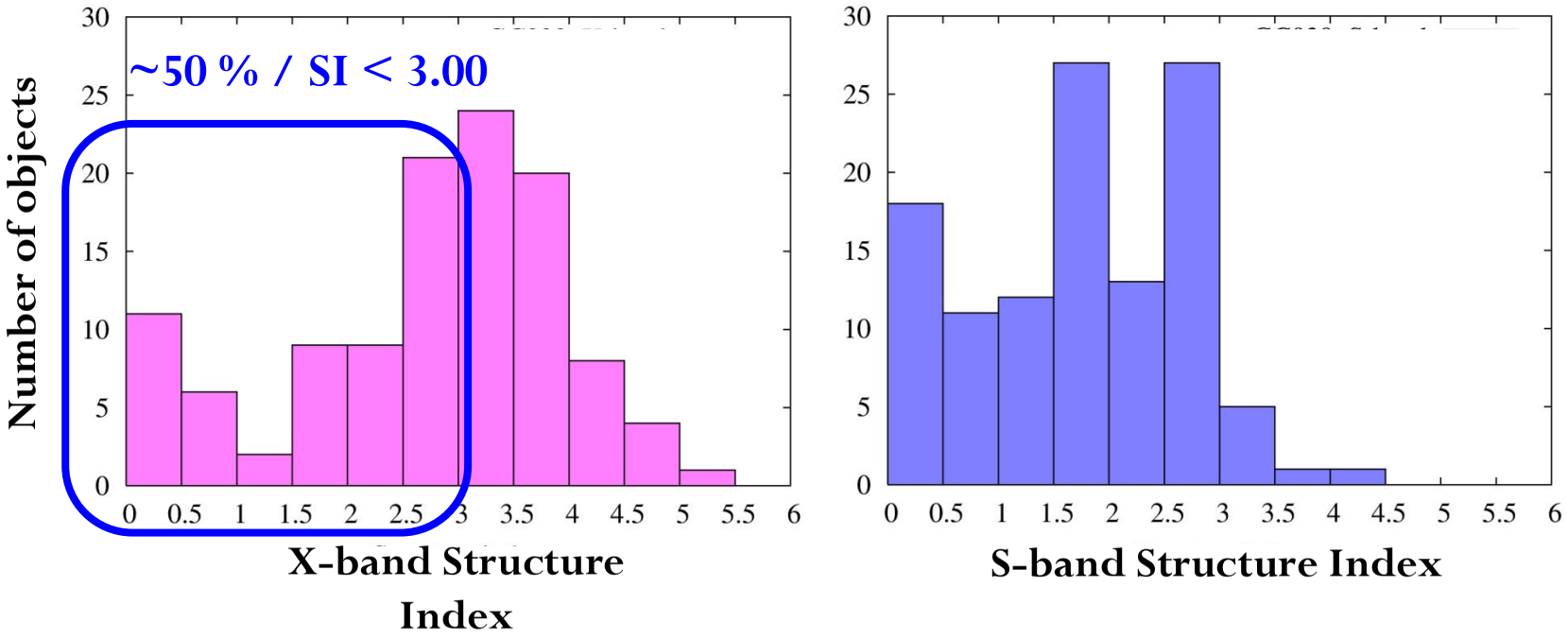






Astrometric suitability

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



➡ About 50% of sources point-like or with compact structure

Next stages

- VLBI imaging (continued)

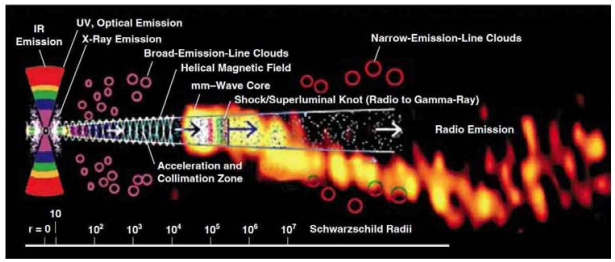
  Observing time approved for the 293 remaining sources

  → 97 sources observed in March 2010

  → 196 sources to be observed in October 2010 + ?

- Astrometry (2011 →)
  - do astrometry on the (200?) most compact sources
  - position wanted to better than <100 μas

- Additional plans
  - cover southern hemisphere
  - ctudy core shift issues



Summary

Step1

447 sources observed

96 hours EVN

398 sources detected

Step2

398 sources to be observed

192 hours EVN+VLBA

105 sources imaged (25%)

→ ~50% point-like

Step3

~200 sources?