Towards a VLBI catalog of optically-bright extragalactic radio sources

for the alignment of the radio frame with the future Gaia frame

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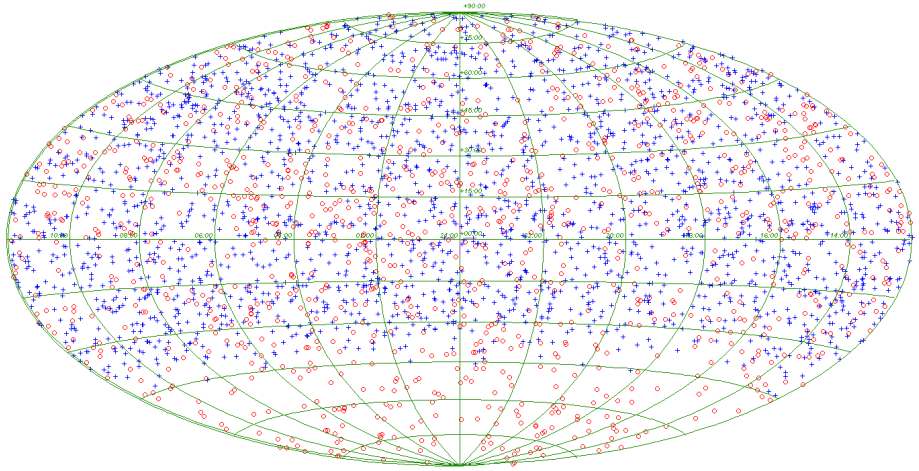
Context

By 2015-2020: Two extragalactic celestial reference frames available

VLBI (Radio)



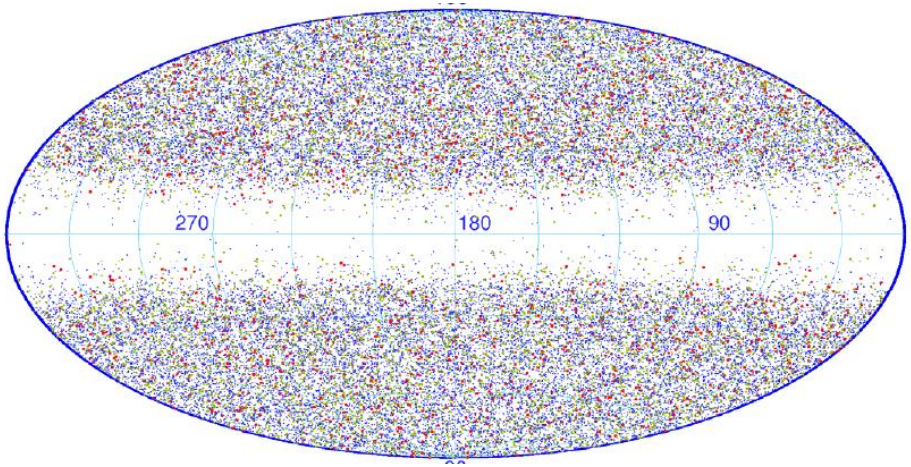
Position accuracy:

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

2009: ICRF2 – 3414 sources – $\sigma \geq 40$ µas

2020: ICRF3 ???

Gaia (Optical magnitude ≤ 20)



Anticipated position accuracy:

2015–2020: ~10 000 – 20 000 QSOs /

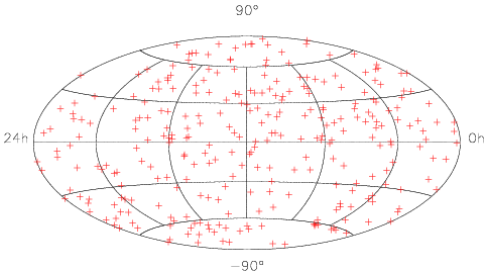
16 µas $\leq \sigma \leq$ 70 µas @ $15 \leq V \leq 18$

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-Radio frames alignment



- **Requirements:**

✓ Several hundreds of common sources

✓ With a uniform sky coverage

✓ Link sources must have:

Accurate Gaia position → Optically-bright (V ≤ 18)

Accurate VLBI position → Good astrometric quality (point-like VLBI structure)

- **Current status:**

✓ ICRF1: 10% of ICRF1 sources suitable (*Bourda et al., 2008*)

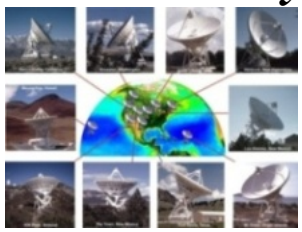
✓ ICRF2: < 50% of *defining* sources with a proper optical counterpart

➡ Need to find new radio sources suitable for 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 ICRF and VCS sources)
✓ Optical magnitude V ≤ 18
✓ Total flux density (NVSS) ≥ 20 mJy
✓ δ ≥ -10°

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

- Observing Strategy:

1. VLBI detection (*Bourda et al., 2010a; A&A published online*)
2. Imaging (*Bourda et al., 2010b; A&A accepted*)
3. Accurate astrometry (for the most point-like sources)

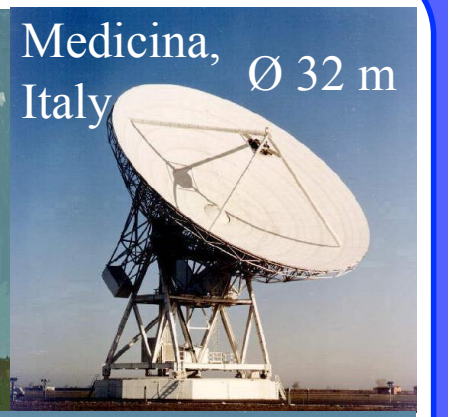
Step 1: VLBI detection

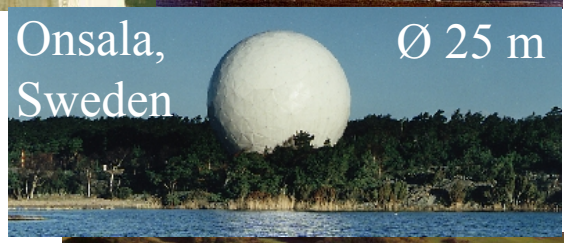
- Two 48-hours experiments
  (S/X dual-frequency geodetic style @ 1Gb/s)
  EC025A: June 2007 – 224 sources
  EC025B: October 2007 – 223 sources

Weak sources in VLBI

➡ High sensitivity necessary

➡ Need large antennas & high recording rate

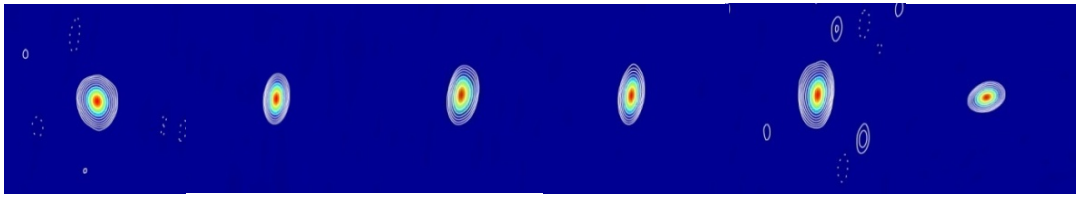




- S/X detection rates:
  EC025A ~ 94 %
  EC025B ~ 82 %

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

Step 2: Imaging



- **Pilot imaging experiment**

✓ Observations for 25% of the sources previously detected

✓ March 2008 – 48 hours

✓ Global VLBI array (VLBA + EVN)

✓ S/X observations @ 512 Mb/s

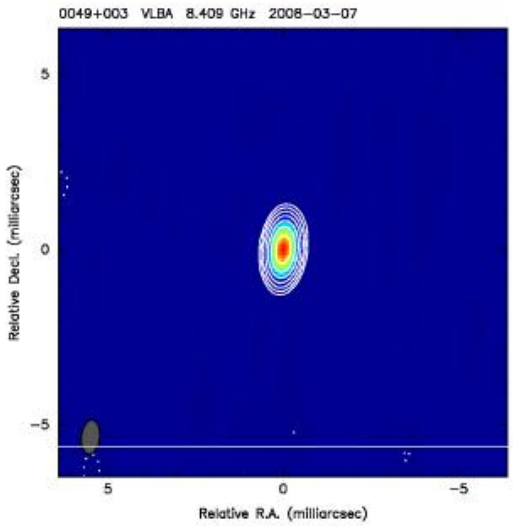
- **Results**

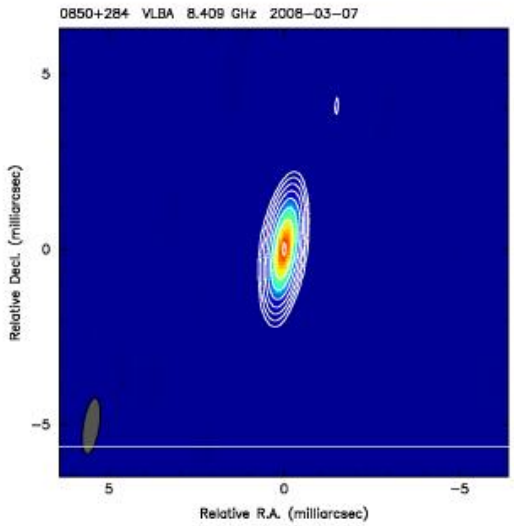
✓ All 105 sources successfully imaged at both X & S bands

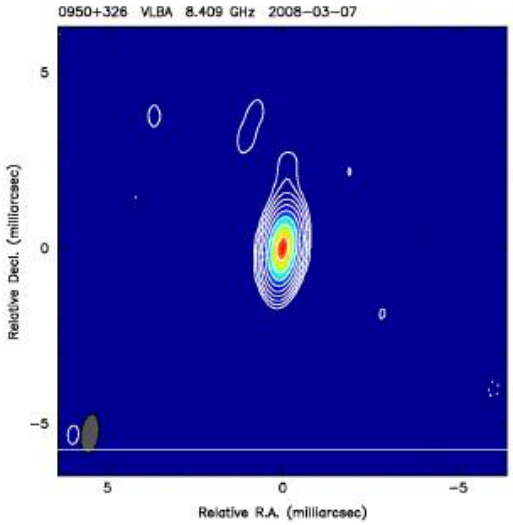
✓ Total flux density & Structure Index determined for each source

→ **~50% point-like sources** (47 sources)

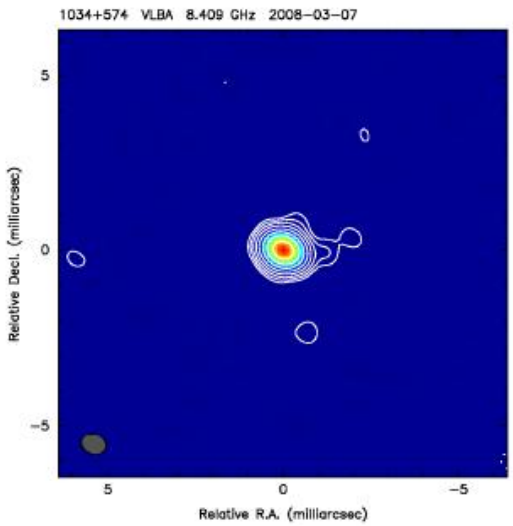
Some very good link sources

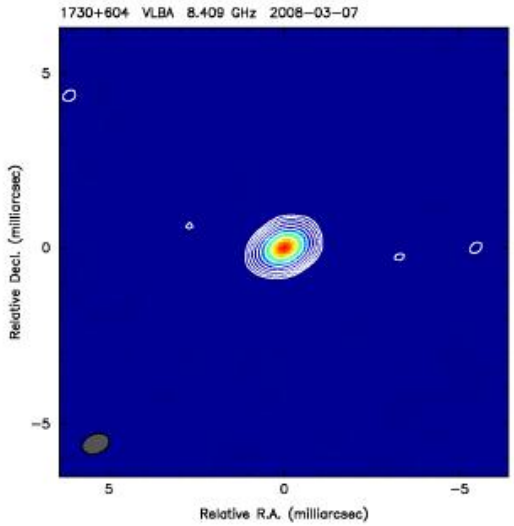




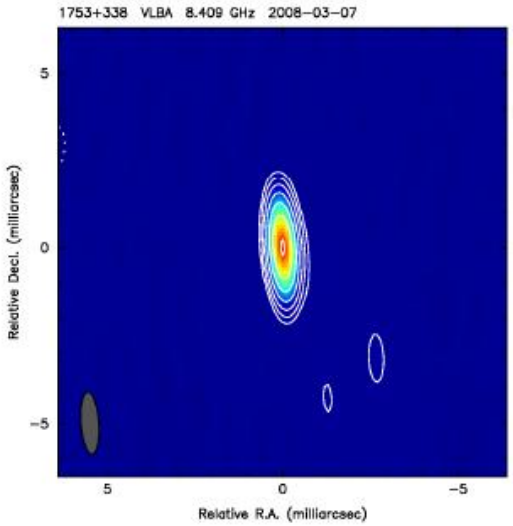


X-band −1st contour level @ 1%

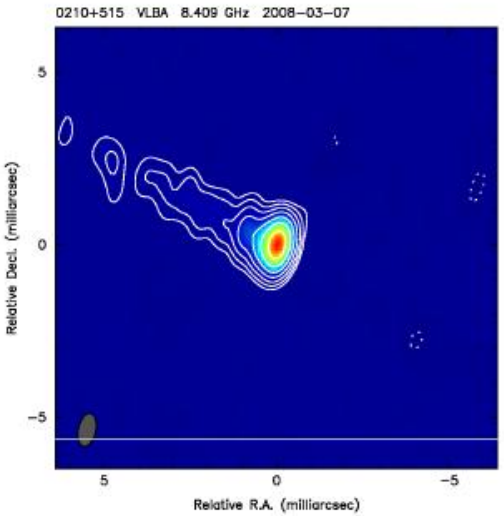


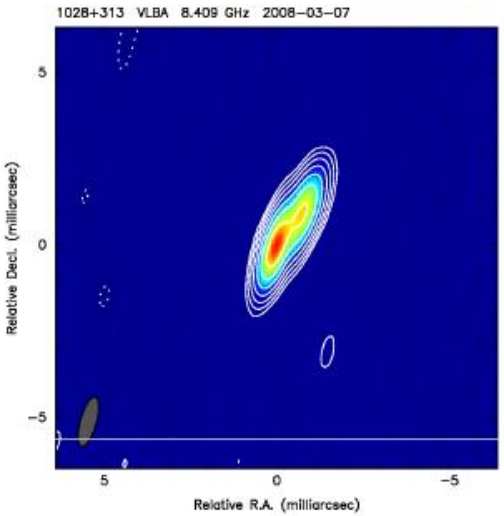


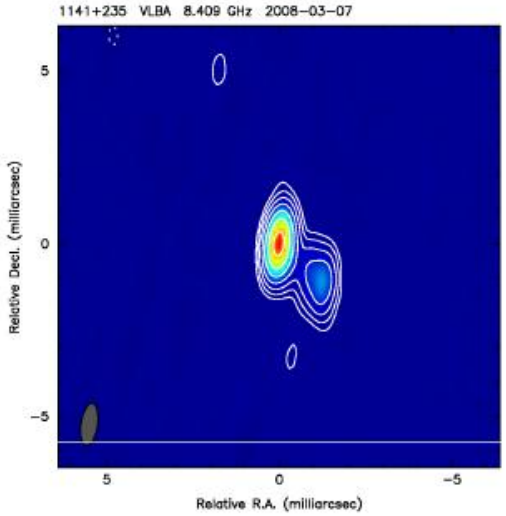
~10 mas



but also some not so good link sources…







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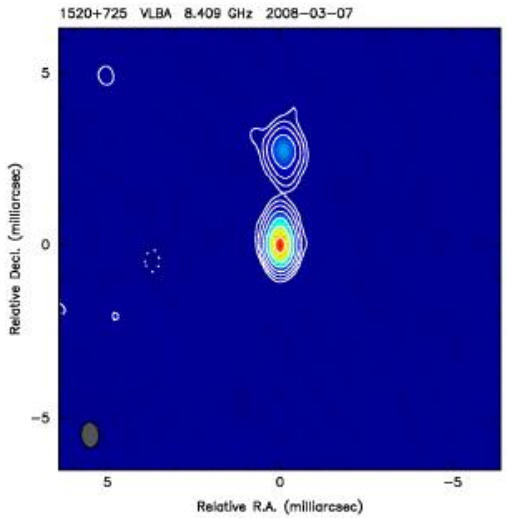
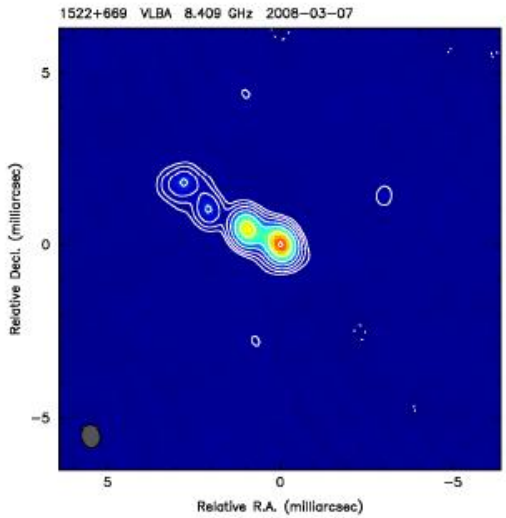
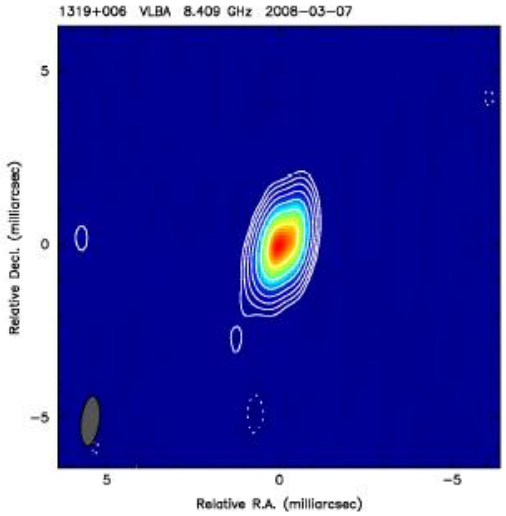
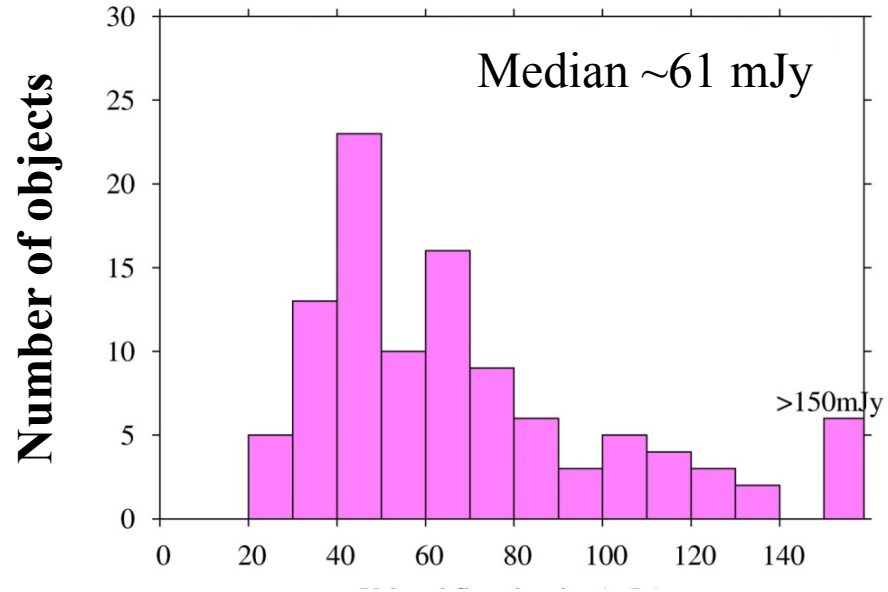
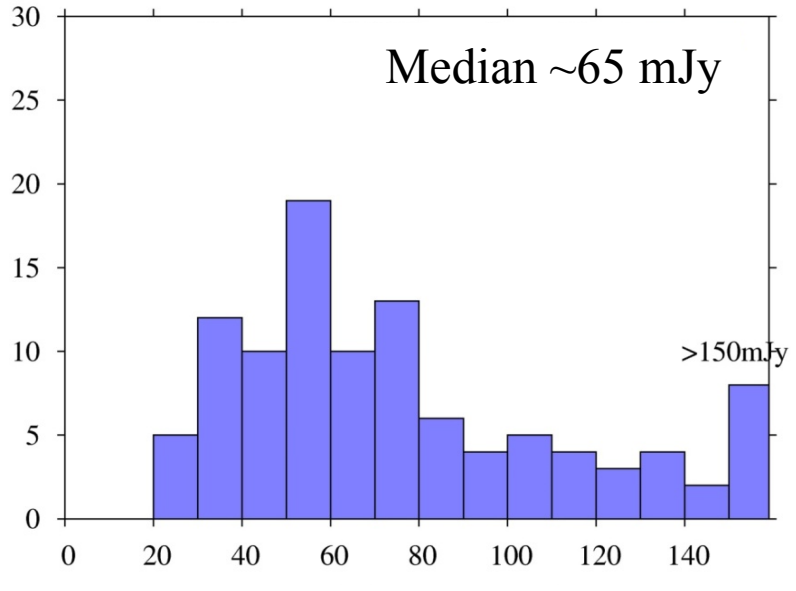


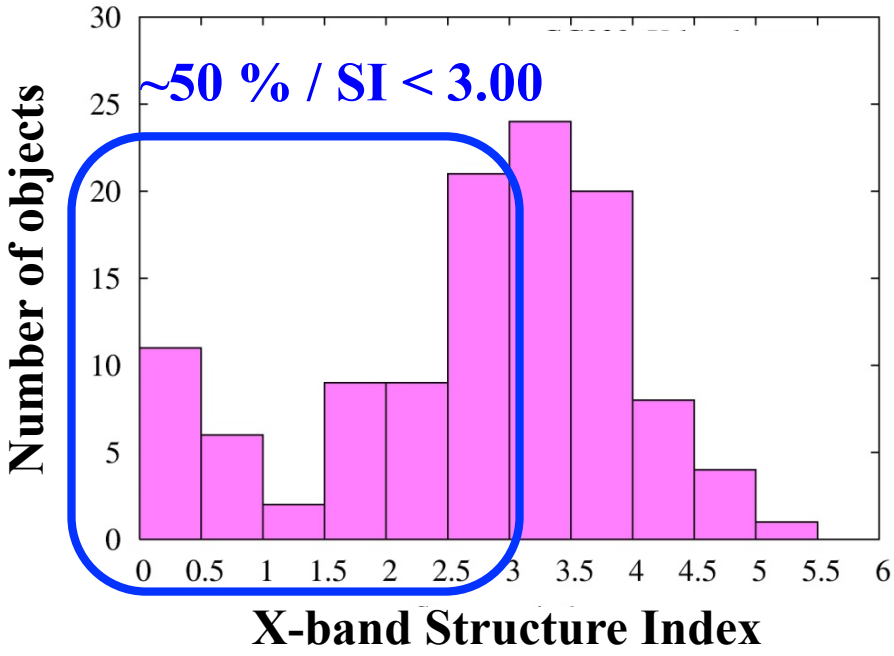


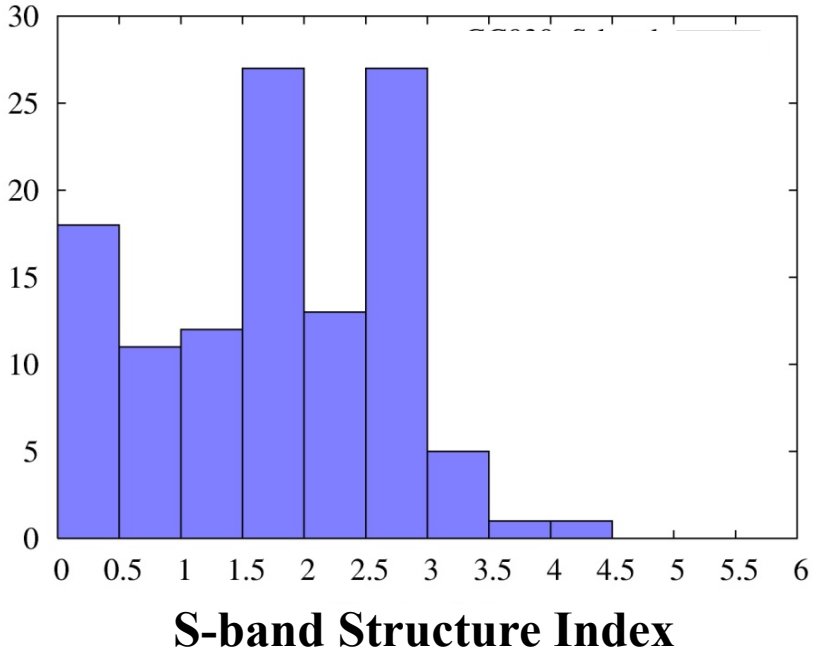
~10 mas



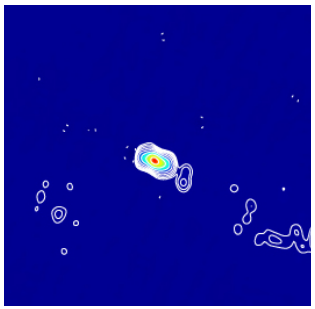

Median ~61 mJy
Number of objects
>150mJy
X-band Total flux density (mJy)

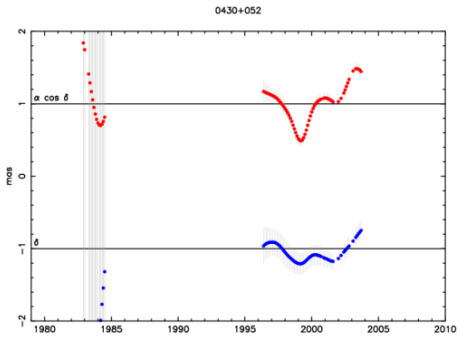

Median ~65 mJy
>150mJy
S-band Total flux density (mJy)


~50 % / SI < 3.00
Number of objects
X-band Structure Index


S-band Structure Index

Next stages





- **VLBI imaging follow up**

✓ 293 remaining sources

✓ Proposal submitted in October 2009 − 144 hours

✓ Accepted (3 sessions) → **March 2010 + October 2010 + ?**

- **Astrometry**

✓ Carry out global astrometry on the most compact sources (200 ?)

✓ Positions wanted to better than <100 μas

✓ First proposal during the year 2011

Progress status & plans for the near future

Detection

Imaging

Astrometry

June & October 2007

March 2008 +
March & October 2010 + ?

2011/2012

Step1
447 sources observed
96-hrs
EVN

398 sources detected

Step2
398 sources will be observed
144-hrs
EVN+VLBA

105 sources observed (25%) &
Maps determined for all of them
→ ~50% point-like

Step3
~200 sources?

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398 sources will be observed
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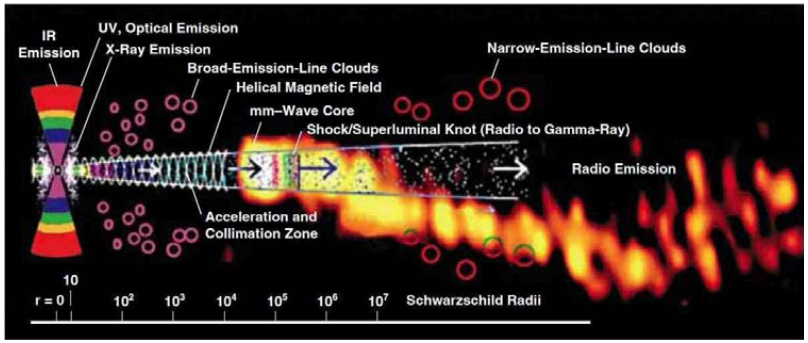
Step3
~200 sources?

- In the future:
  - ✓ Cover southern hemisphere
  - ✓ Astrophysics: Issues of core shifts



Thanks for your attention …