The ICRF now and in the future

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Outline

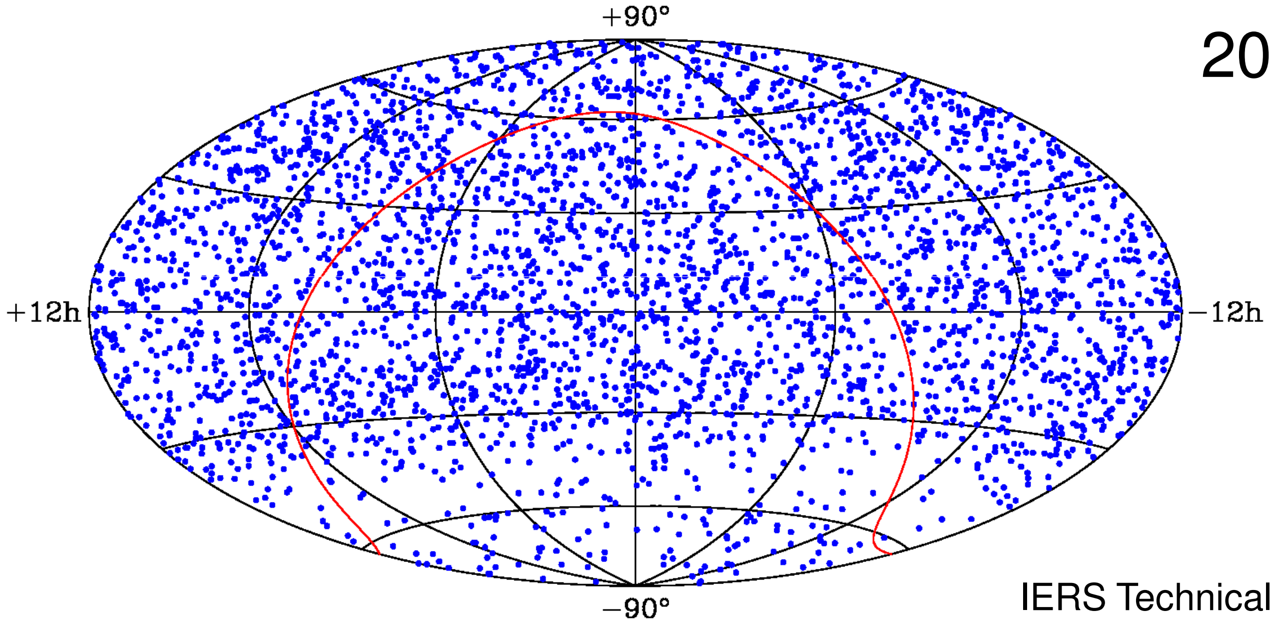
- The current VLBI reference frame: ICRF2
- Future VLBI observational prospects
- Towards the alignment with the future Gaia frame
- Beyond Gaia

The International Celestial Reference Frame: the second realization (ICRF2)

- 3414 compact extragalactic sources

  5 times more than ICRF1

2009



IERS Technical Note 35

- Noise floor of ~40 µas

  6 times better than ICRF1

- Axis stability of ~10 µas

  2 times better than ICRF1

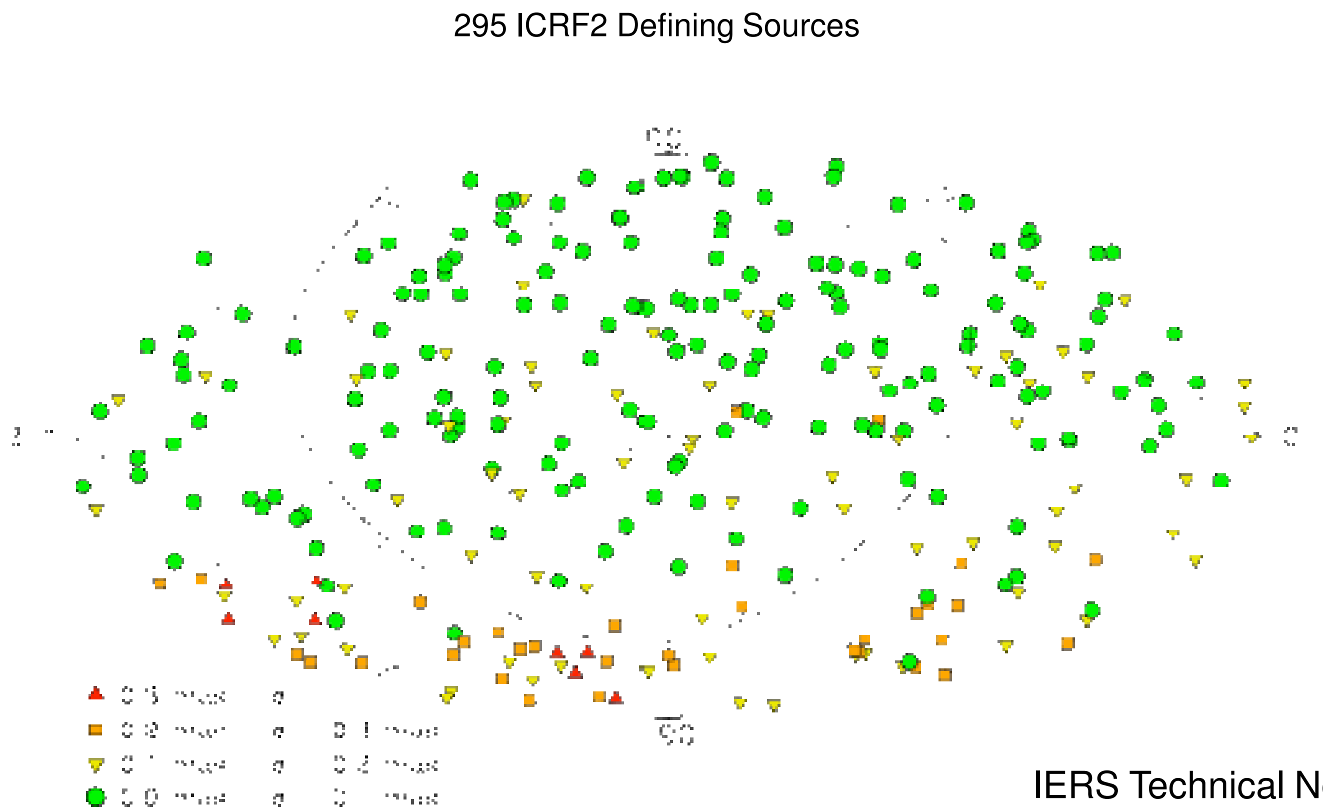
ICRF2: the data

- 30 years (1979-2009) of accumulated VLBI data
  - 6.5 million S/X-band (2.3/8.4 GHz) group delay measurements
  - 4540 IVS (International VLBI Service) type sessions
  - VCS data (Kovalev et al., Petrov et al.) incorporated
  - VLBA contribution: ~28% of all the data used in ICRF2
- Configuration
  - 1448 ICRF2 sources observed in multiple session (295 defining sources)
  - 1966 ICRF2 sources observed in single sessions

IERS Technical Note 35: The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry, Presented on behalf of the IERS / IVS Working Group, A. Fey, D. Gordon and C. Jacobs (eds.). (IERS Technical Note 35) Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, 2009. 204 p.

http://www.iers.org/nn_11216/IERS/EN/Publications/TechnicalNotes/tn35.html

The 295 ICRF2 defining sources

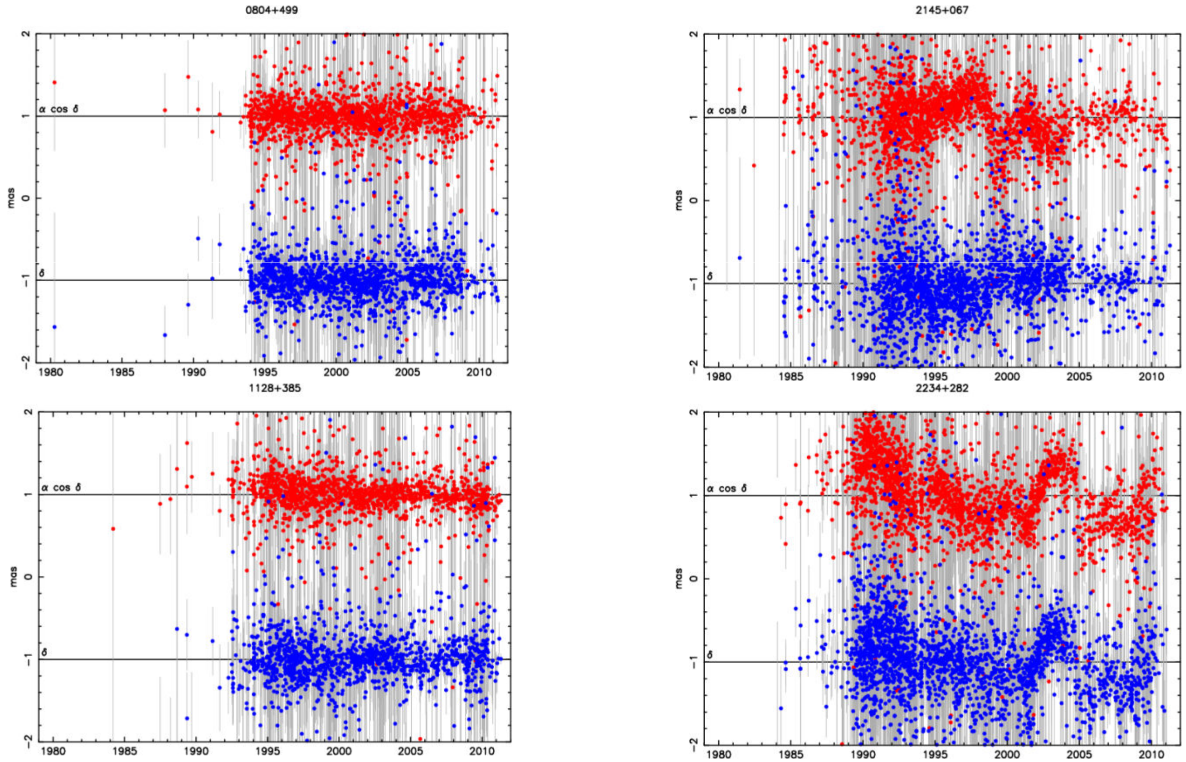


IERS Technical Note 35

Selecting defining sources

1. Source position stability

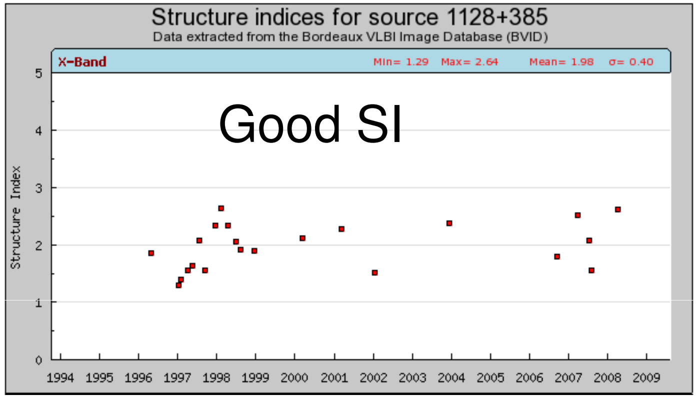
stable | unstable

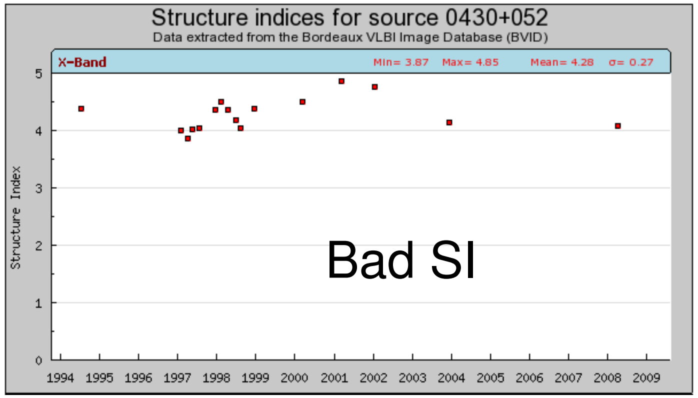


Credit: S. Lambert (Paris Observatory)

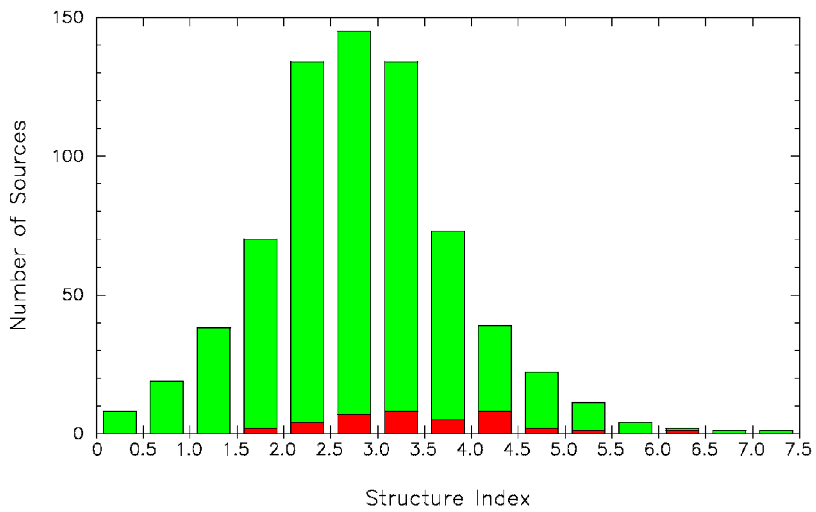
Selecting defining sources

2. Source structure index (SI)

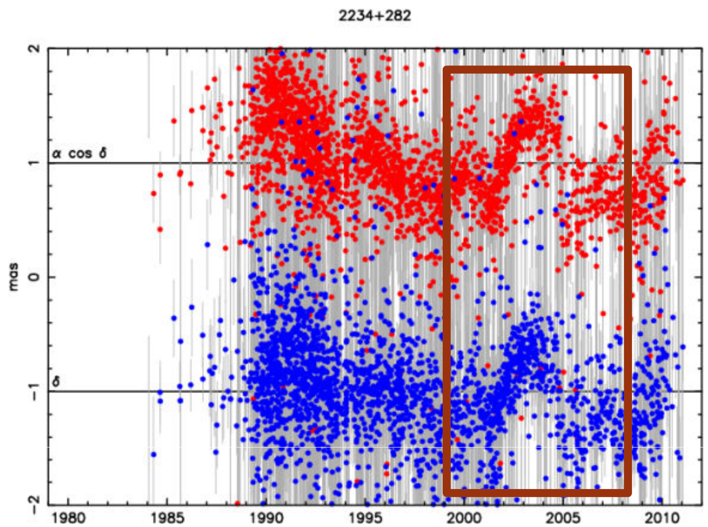




Distribution of SI for 701 sources

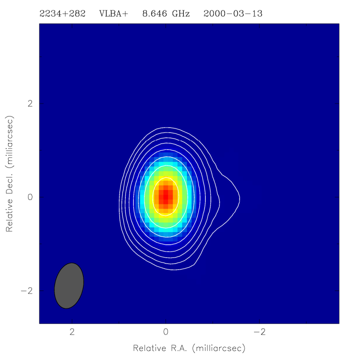


Source structure evolution

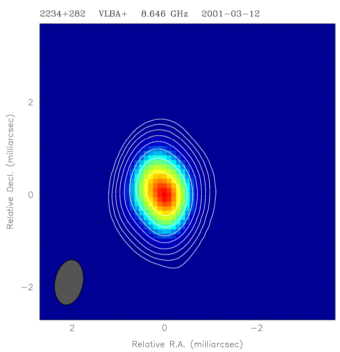


Correlation between source position instabilities and source structure evolution

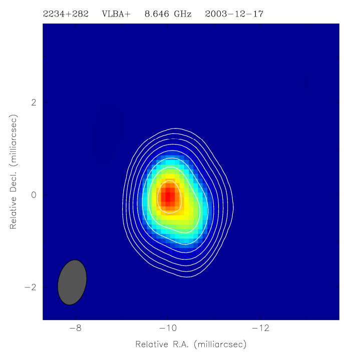
2000



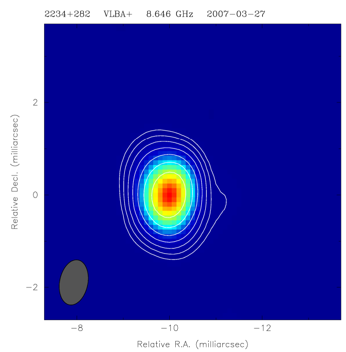
2001



2003



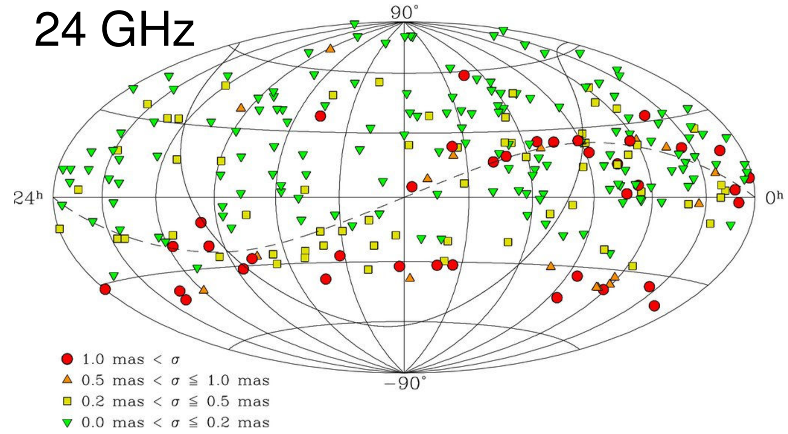
2007



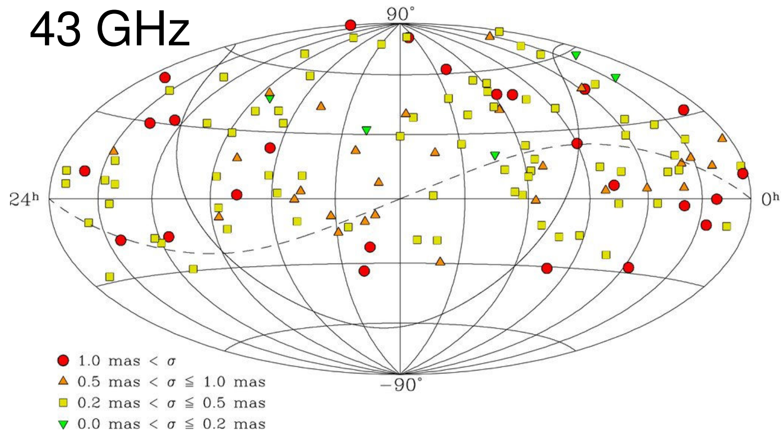
Bordeaux VLBI Image Database (BVID)

Extension of ICRF to higher frequencies

- K band (24 GHz)
  12 VLBA sessions
  278 sources



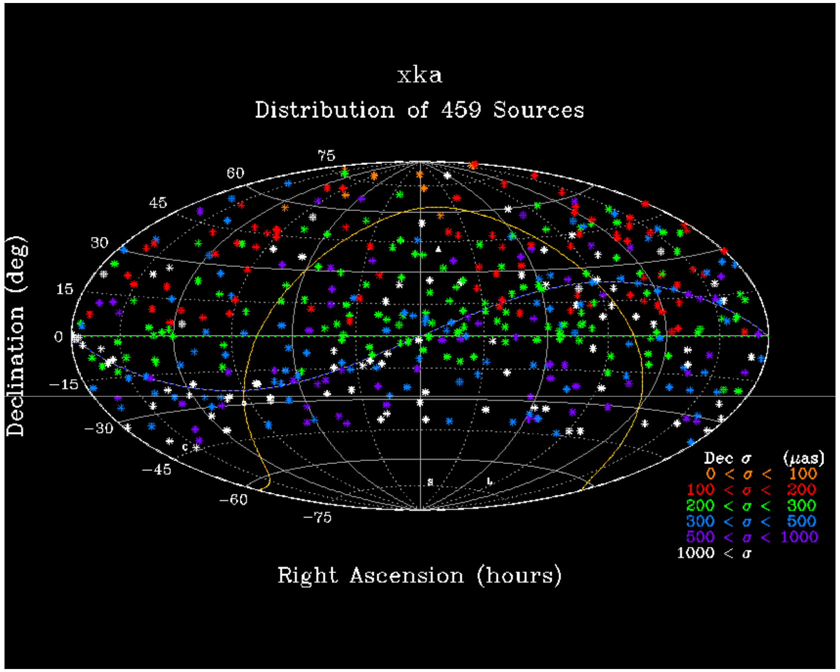
- Q band (43 GHz)
  5 VLBA sessions
  131 sources



Lanyi et al. (2010), Charlot et al. (2010)

Extension of ICRF to higher frequencies

- X/Ka band (8.4/32 GHz)
  50 DSN sessions
  459 sources

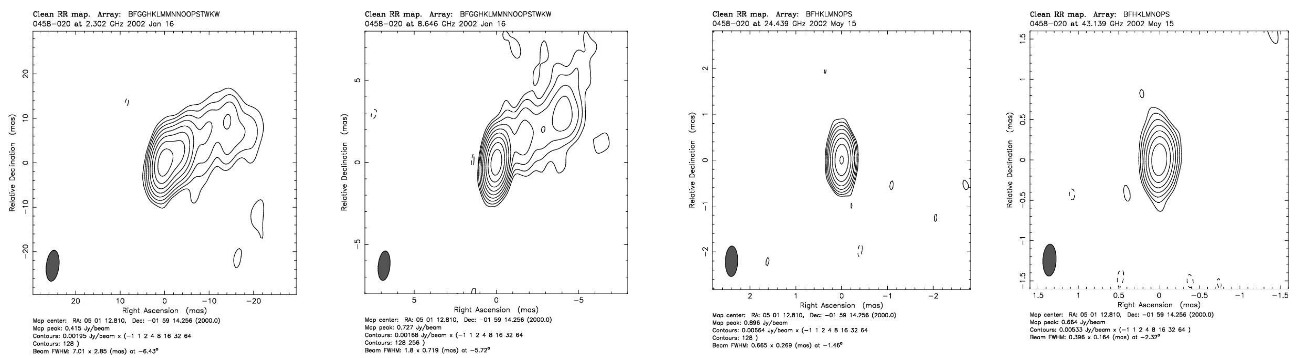


32 GHz

Jacobs et al. (2011)
See also poster by Sotuela et al.

High-frequency vs 8.4 GHz

- High-frequency positions agree with S/X results at 300 μas level
  - consistent with estimated core shift of < 0.1 mas (cf. Lobanov talk)
- Motivations for high-frequency ICRF
  - Sources more compact => reduced structure effects

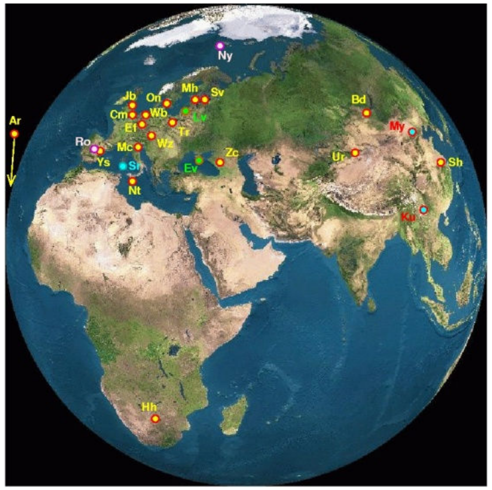


2.3 GHz　　8.4 GHz　　24 GHz　　43 GHz

  - VLBI core closer to central engine

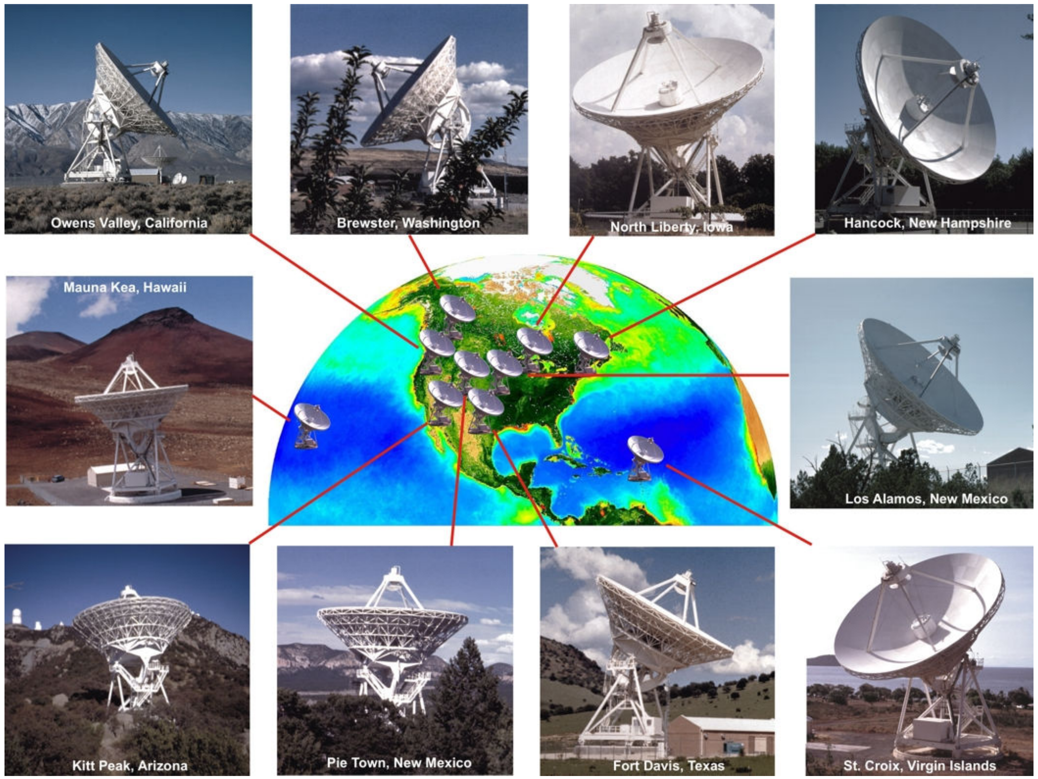
VLBI prospects: EVN

- Recent additions: Yebes 40m, 3 x 32m in Russia
- Upcoming large antennas: Sardinia 64m, Shanghai new 65m; most of these can reach 22 GHz
- Higher recording rates:1 Gb/s → 2 Gb/s ?



→ Higher sensitivity → weaker sources → densification

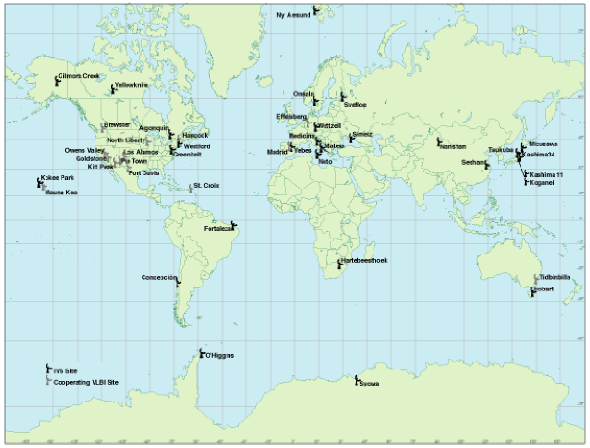
VLBI prospects: VLBA

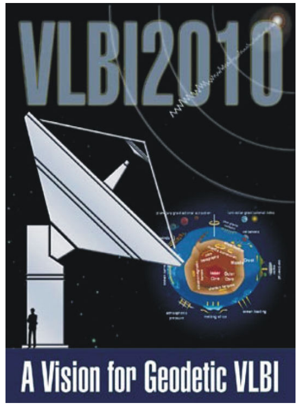


- Higher recording rates: 512 Mb/s → 4 Gb/s

VLBI prospects: IVS

- IVS is planning to move to a new system based on
  - small (10-12m) fast-moving antennas
  - broad continuous frequency range: 2-15 GHz, up to 32 GHz?
- 10-100 times more observations per day
  - Increase precision
  - Can re-observe ICRF (defining sources) everyday.



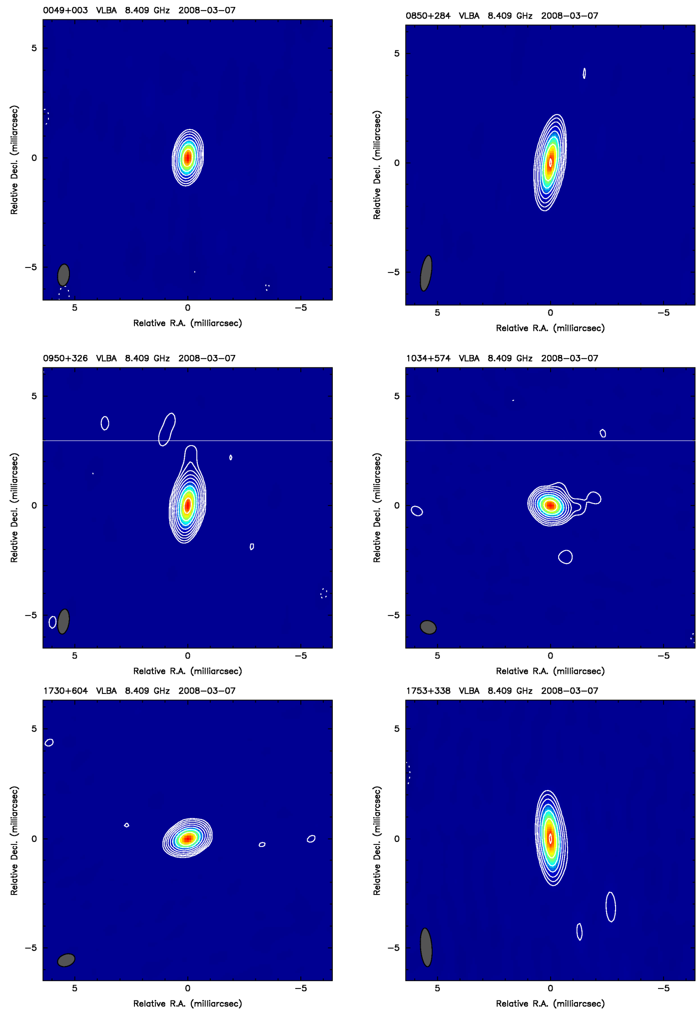


VLBI prospects: others

- DSN (Deep Space Network)
  - Three sites: California, Spain, Australia
  - Will gradually move from 2.3/8.4 GHz to 8.4/32 GHz in the next 5 years
  - A fraction of the time available using 70m-70m antenna pair for very weak (mJy) sources.
- KVN (Korean VLBI Network)
  - 3 antennas built
  - High-frequency network: 22, 43, 86, 129 GHz
  - See poster by T. Jung
- Needs more southern hemisphere antennas

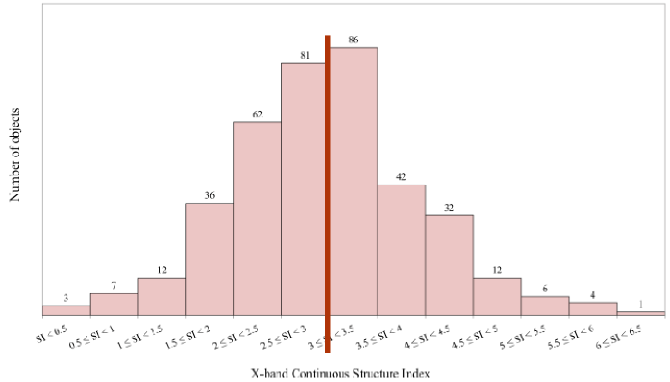
Aligning the ICRF and Gaia frame

- Next ICRF to be focused on the Gaia alignment
- Required source properties:
  - ➢ Optically bright (magnitude < 18)
  - ➢ Strong enough in the radio to be detectable with VLBI arrays
  - ➢ No extended VLBI emission
- Identify several hundreds of sources with such properties



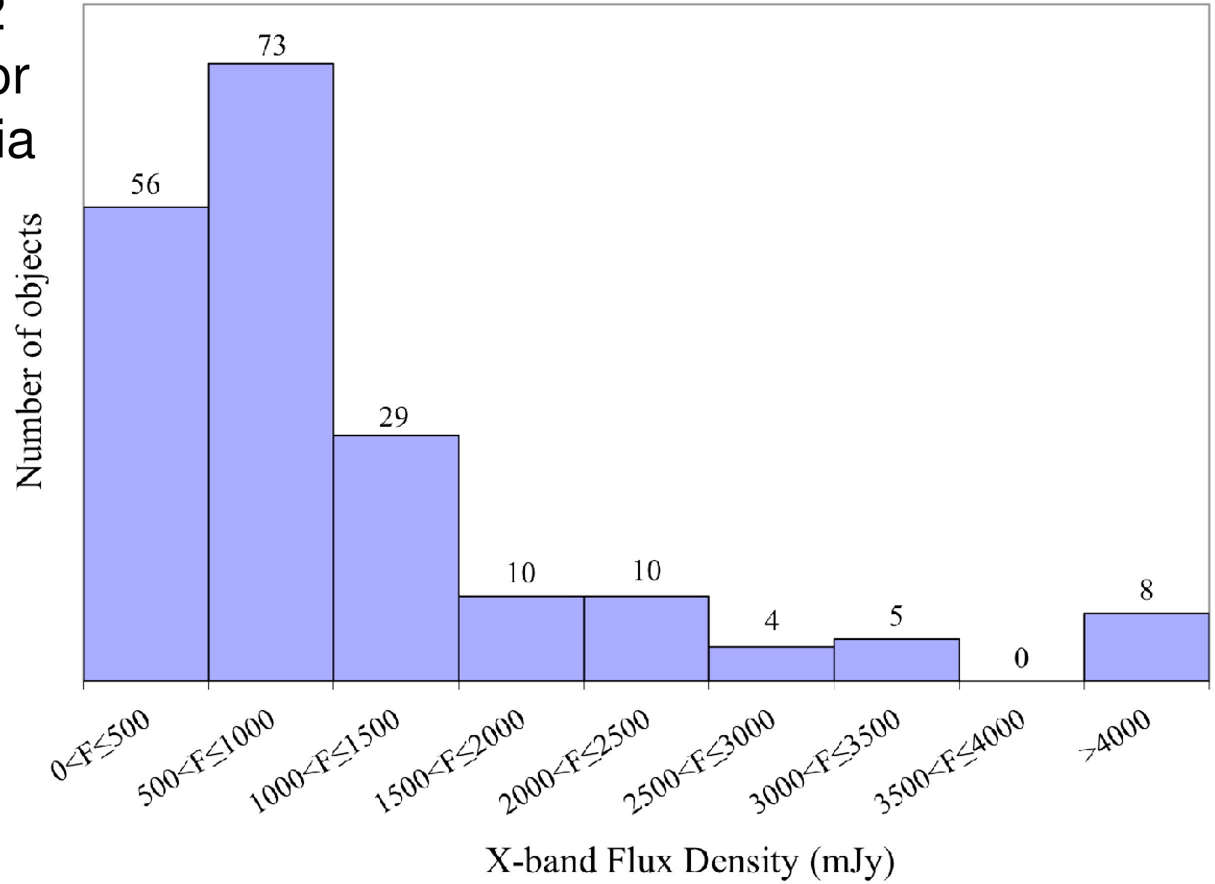
Current status

- 70 suitable sources found in ICRF (Bourda et al. 2008)
- VLBI observations of 398 candidate sources in progress (see next talk)
- ICRF2 examined for suitable sources
  - 1128 sources with V or R or I < 18 from LQAC
  - Of these 201 have an appropriate structure index (< 3.0)
  - 108 sources common to K band (8.4 GHz) catalog
  - 139 sources common to Ka band (32 GHz) catalog

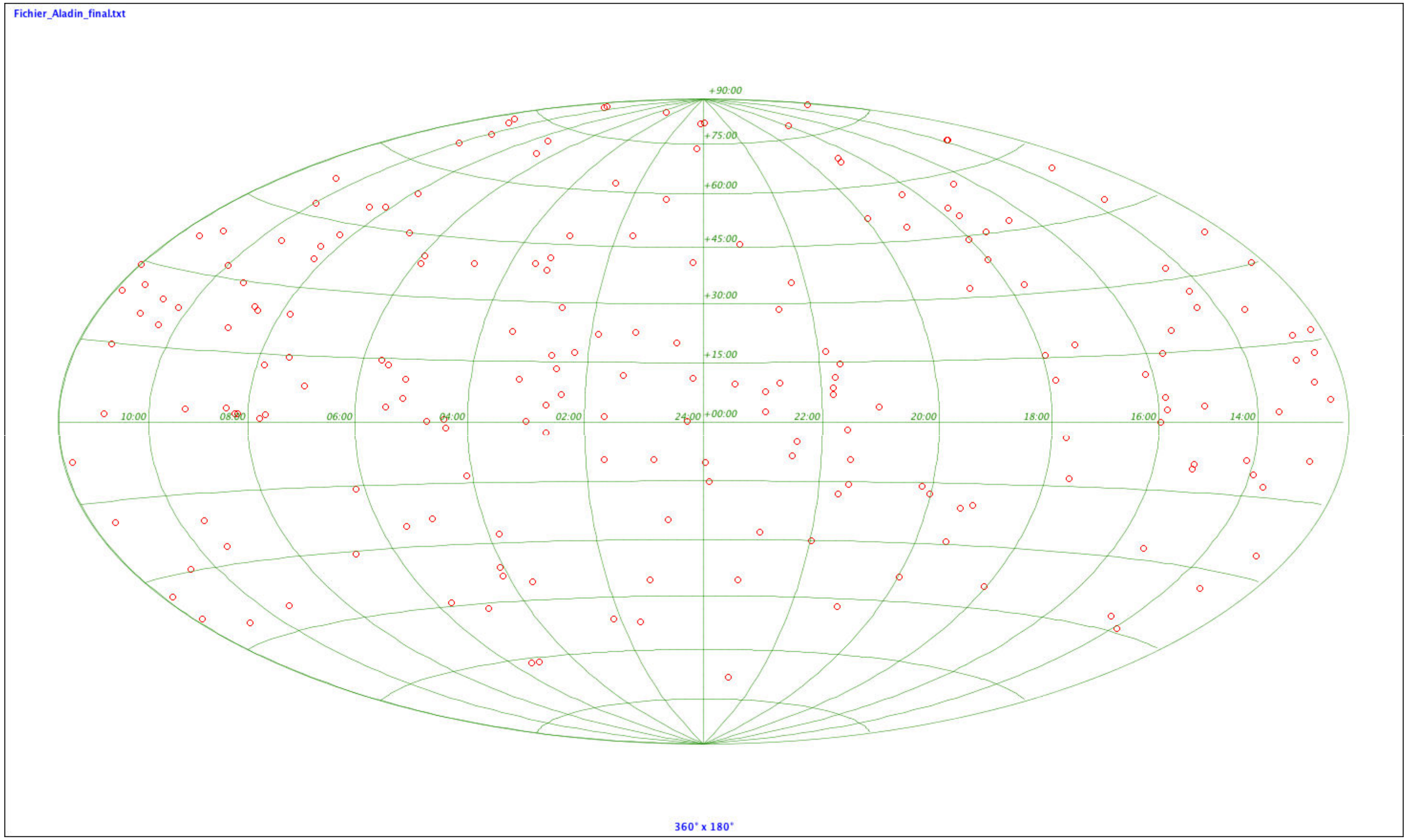


Flux density distribution

201 current ICRF2 sources suitable for alignment with Gaia frame



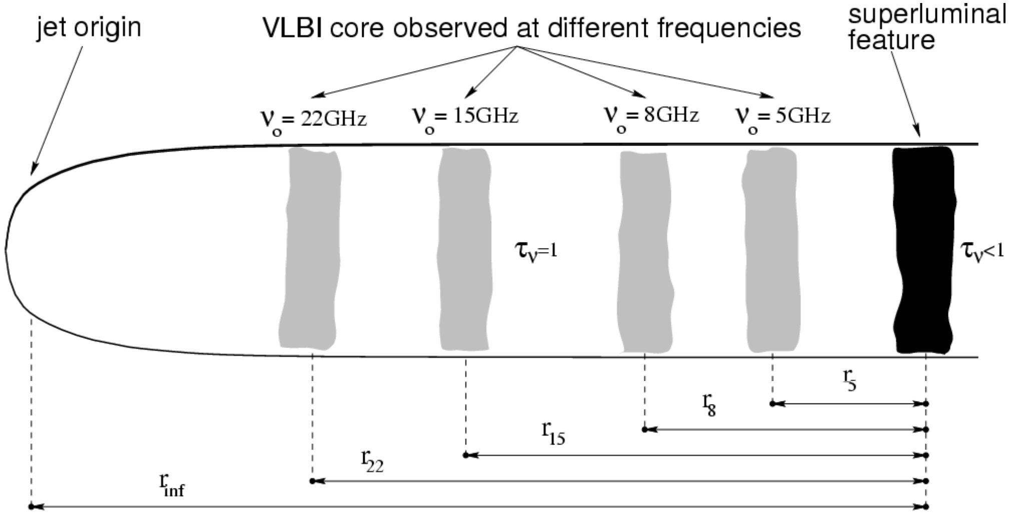
Sky distribution



201 current ICRF2 sources suitable for alignment with Gaia frame

Issues in the ICRF/Gaia frame alignment

- Optical variability
- Optical structure
- Core shifts



Credit: A. Lobanov

→ invest in source quality (both radio and optical)

→ Needs sample larger than actually required because a fraction of the candidates is likely to be rejected in future stages due to impredictable quasar physical behavior

VLBI observational plans

- Finalize source sample for the alignment
- Measure source positions before Gaia launch (for those not yet known precisely-enough)
- Monitor sources during the Gaia mission
  - Use Gaia scanning law to plan VLBI observations
  - Control VLBI position stability and accuracy
  - Make images to control structure
- Observing networks
  - IVS for the stronger sources
  - EVN/VLBA/DSN for the weaker sources
  - Higher frequency (32 GHz) observations to reduce core shifts?

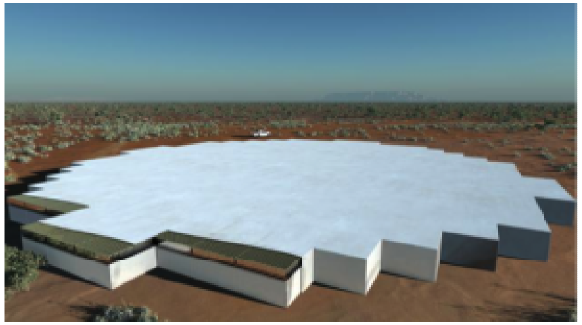
Beyond the ICRF/Gaia frame alignment…

- One will be able to compare the VLBI and Gaia positions to within their error bars (< 100 μas) for any detected celestial object

- Measure relative location of radio and optical emission
  - Probe AGN geometry
  - … but also for stellar objects

Beyond 2020…: SKA

- Will have nanoJy sensitivity
- Site: Australia/New Zealand or South Africa (to be decided in 2012)
- Requirements for astrometry
  - Must have long baselines (>= 5000 km)
  - Must reach 10 GHz frequency at least
- If so, SKA may be able to build the radio counterpart of Gaia



Conclusion

- ICRF2 is a big step forward compared to ICRF
- VLBI observational trends
  - Weaker sources ➔ densification of the frame
  - Higher frequencies: 22 GHz, 32 GHz,…
- Next stage is to properly align the ICRF and the future Gaia frame
  - Need carefully-selected set of sources to achieve the highest accuracy
- SKA may be able to build the radio counterpart of the Gaia frame in the long-term (2020-2030)