

From Gaia frame to ICRF-3?









- Celestial reference frames
- ICRS/ICRF
- The Gaia-CRF
- From Gaia-CRF to ICRF-3



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- Reference system based on the FK4
 - dynamical system
 - 1500 stars, accuracy of 0."1
 - based on principles more than 200 years old
- The Carte du Ciel officially terminated in 1970 (started in 1887)
 - But publication of AC 2000.2 in 2001: main source of first epoch for PM inTycho-2.
- Start of CCD observations
- Solar system distances with radar
- Satellite and lunar laser ranging operational







- 1988 Creation of IERS
- 1988 Definition of the IERS Celestial Reference System (ICRS) and frame (ICRF)
 - Reference system kinematically defined realized by the positions of a set of extragalactic objects determined with the VLBI technique
 - International coordination with IAU
 - Radio observations used as the most accurate VLBI observations in dedicated sessions
 - the choice of radio was motivated by practical considerations
- 1990 Studies of the link to other systems and frames, FK5 and HIPPARCOS particularly







- IAU Working Group tasked to select EG sources
- 1995 sub-group of IAU WGRF tasked to construct CRF
- 1997 sub-group work completed CRF solution finished
- ICRF adopted by IAU at Kyoto General Assembly
- 1997 IAU Working Group on ICRS created
- 1998 ICRF replaces FK5 as fundamental frame
- 1999 ICRF Ext.1 completed
- 2000 IAU Working Group on ICRS renewed
- ICRS Product Center formed
- 2004 ICRF Ext.2
- 2009 ICRF-2 approved by IAU in Rio







- Kinematical system with basic assumption :
 - the most distant sources exhibit no global rotation
 - globally at rest with respect to CMB
 - QSOs have no sizeable transverse motion
 - Origin : should be the solar system barycentre
- Pole : should be close to the J2000 celestial pole
 - must be within the uncertainty of the FK5 pole
- Origin of right ascension : should be consistent with the FK5 equinox
 - uncertainty of 80 mas
- Realisation : from a set of stable QSOs
 - Observational technique determined at any time by the state of the art







- International coordination with IAU
- Radio observations have been used as the most accurate
- VLBI observations in dedicated sessions
 - most of the VLBI network is used for geodetic purposes
- 1.6 million observations collected over ~ 15 years
- global treatment for a set of sources
 - final subset based on the most stable and best observed
- 608 sources selected for ICRF-1
 - 212 defining sources used to determine the system
 - 294 candidate sources whose quality is still questioned
 - 102 additional sources for densification







- Primary frame in radio wavelength
 - comparable to Standards in Weights & Measures
 - no ageing effect (in principle)
- Practical access in the visible done with secondary realisations
 - most important was the HCRF (Hipparcos CRF)
 - secondary frame tied to radio frame (orientation and rotation)
 - densified with fainter stars with Tycho-2, UCAC, 2MASS ..
 - These frames degrade with time due to proper motion limited accuracy
 - they must be updated with new observations (eg: URAT)
 - nano-Jasmine, JMAPS or the HTPM project with Gaia could rejuvenate the HCRF with better proper motions

















Accuracy ~ 1 mas





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Accuracy ~ 0.2 to 2 mas



defining (295)
VLBI (923)

• VLBA Calib. (2197)



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- The Gaia-CRF (*) will consist of :
 - Defining sources
 - the clean subset of QSOs used to fix the frame
 - A larger set of secondary QSOs
 - The Gaia-SRF (for stellar reference frame)
 - About one billion stars with proper motions
 - easy access thanks to its density
 - will degrade with time

(*) GCRF : too close to Geocentric Celestial Reference Frame







- Global astrometry with full sky coverage
 - 1 billion stars
 - 500,000 QSOs expected to G = 20
 - 20,000 to G = 18
 - The solution is brought to ICRS paradigm
 - QSOs have no global motion beyond the cosmic acceleration pattern
- The Gaia Celestial Reference Frame (Gaia-CRF) will become a standard
 - all the positions and proper motions will be referred to the Gaia-CRF
 - solar system object astrometry will be given in this frame
 - density will be large with 25,000 stars/deg²







Degradation with time due to proper motion uncertainty









- Gaia will provide simultaneously :
 - ▶ a realisation of a primary frame with the bright QSOs
 - ▶ a dense optical version to G = 20, degrading very slowly
- But when published by the Gaia community this will just be a consistent solution of the Gaia data processing
 - will supersede immediately any other optical celestial frames
 - many works will refer to the Gaia-CRF
- BUT ...
- neither IAU or IERS are involved in this process















- Gaia-CRF must be compatible with ICRF-2
 - within the uncertainty of the latter
- Rotation: done automatically with a much larger number of QSOs
- Orientation: must be done explicitly with an alignment procedure
 - ▶ same pole, same origin → G. Bourda talk
- Assessment of the optical-radio offsets
- Then the final realisation must be perfectly documented
- An IERS or IAU WG involving Gaia DPAC and international external experts should be formed
 - competence in radio and visible physics of QSOs
 - Finally an IAU resolution should follow to turn the GCRF into ICRF-3

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- The radio ICRF is not associated to an epoch
 - defining QSOs have fixed celestial coordinates
 - they are not epoch dependant
 - the define axis direction 'for ever'
 - time is no involved in the process
- A stellar reference frame is defined at a particular epoch
 - defining stars coordinates come with their proper motion
 - the PMs are part of the fundamental catalogue
 - each star comes with a particular PM and its uncertainty
 - with N stars, there are 2N parameters needed
 - the system degrades due to the limited uncertainty of the PMs
 - accuracy in position and annual PM are similar







- What about the Gaia-CRF
 - QSOs have a systematic proper motion of ~ 4 muas/yr
 - But these are not individual PM, but the result of a systematic pattern
 - only 3 parameters are required to maintain the system
 - the accuracy should be close to 0.5 muas/yr
 - Individual positions of the primary sources will have an accuracy of ~ 80 muas
 - degradation will be very very slow
- Therefore : the Gaia-CRF will have an epoch attached to it
 - but it has very different meaning as for a stellar reference frame
- How to avoid it: take the origin at the galactic centre !
 - this is for the future \rightarrow see Kopeikin talk

