Astronomy and Earth’s Rotation with GEODESIE

Sébastien Lambert
SYRTE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, LNE
What Science can we make with Astrogeodetic Techniques?

- Answer is *plenty*
- Some examples *within our skills and fields:*
  - Geosciences
    - Link polar motion/LOD to climate
    - Describe Earth’s interior w/ nutation and deformations
  - Astronomy
    - Understand physics of AGN
    - Measure Solar system acceleration, test GR/SME
What I Propose Today

- Give GEODESIE some possible directions in link with Earth’s rotation, reference frames, and one fundamental technique

- Outline
  - VLBI
  - Celestial Frame Issues
  - Earth Rotation Issues
  - Conclusions
VLBI
VLBI

- Initiated in the 1960s to resolve submas-structure of newly discovered quasars (Kellermann and Moran 2001, Clark 2003, Matveenko 2007)
- Sensitive to
  - Radio source position
  - Radio source morphology
  - Earth orientation
  - Earth deformation
  - Atmosphere content
  - Light deflexion
VLBI

- Geodetic mode allows measurements of
  - Telescope positions and velocities
  - Radio source coordinates
  - Telescopes-to-radiosources transformation: Earth orientation parameters
    - Pole coordinates wrt crust (polar motion and rates)
    - Earth rotation angle (UT1)
    - Pole coordinates wrt space (nutation)

- Accuracy < 1 cm
- VGOS deployment + Tahiti
Celestial Frame Issues
Celestial Frame Issues

Network radio sources: ~600 in the 1990s to 4000+ now

ICRF1 Ma et al. 1998 AJ
Stability ~ 0.02 mas
Accuracy ~ 0.04 mas

ICRF2 Fey et al. 2015 AJ

Recent issue: Gaia DR1 (sept. 2017)
Ongoing: ICRF3 (2018)
Celestial Frame Issues

Network radiosources: errors

Difference of new catalogs to ICRF2
Jacobs et al. 2015: evidence of **zonal errors**

Signature of **non-Gaussian correlated errors**
(Gipson 2006; Romero-Wolf et al. 2012; Lambert 2014)

Need better modeling/parameterization of station-dependent parameters
Celestial Frame Issues
Network radio sources: morphology/stability

3C273/VLBA (MOJAVE, Purdue)

2234+282

0923+392

0059+581
Celestial Frame Issues

Network radio sources: core-shift (opacity)

Frequency dependent position shift of VLBI core.
Kovalev et al. 2008

Hot questions:

- Where is the fixed point? (black hole(s))
- How to use multi-$\lambda$ CRFs to retrieve that?
Celestial Frame Issues

Fundamental physics and cosmology: two achievements at SYRTE

First measurement of the Solar system acceleration (Titov, Lambert and Gontier 2011)

First direct estimate of SME parameter in the pure gravity sector (Le Poncin-Lafitte, Hees and Lambert 2016)
Celestial Frame Issues

- Still unsolved questions on 9 March 2017 for which GEODESIE could help
  - Reference frame
    - How to choose the reference sources?
    - How to handle moving sources?
  - Correlated errors
  - Core-shift effect in radio source positions

- Synergies w/ ongoing projects
  - ICRF3 effort
  - Gaia DRs in progress
  - Potential for tests of fundamental physics
Earth Rotation Issues
Earth Rotation Issues

- Earth’s rotation measures integrate the results of a large number of forcing mechanisms
  - Astronomical
  - Climatic
    - Oscillations in atmosphere, oceans...
    - Terrestrial and submarine volcanism
    - Solar forcing
  - Internal
    - Deformability
    - Core rotation

- Our work is traditionally
  - Understanding interaction between solid Earth and forcing mechanisms
  - Validate forcing models
Earth Rotation Issues

Interannual time scales

Example: ENSO forcing, how AGCM explain the observed LOD variations?
Earth Rotation Issues

Multidecadal time scales / climate change issues

Example: the LOD trend as a climate index (Dickey et al. 2011; Tolstoy 2015; Sottili et al. 2015; Zotov et al. 2016; Marcus 2016), or connections between LOD, climate, and other internal and external forcings.
Earth Rotation Issues

- Nutation, LOD, deformations
- Inference of Earth’s internal structure and properties
  - Whole/core/inner core flattening + admittances at CMB/ICB (Mathews et al. 2002; Koot et al. 2008)
  - Multidecadal LOD and torsional oscillations in the core (Holme and de Viron 2013; Buffett et al. 2016)
- Some pending hot questions
  - Contribution of the atmosphere to nutations
  - Excitation mechanism of the FCN
  - Reliability of the estimation of the FICN period
Earth Rotation Issues

Less accurate but useful to constraint long periodic nutations

More accurate after 1995

Available series (Gattano et al. 2017) →
Issues about observation/analysis strategies to optimize the geophysical signal including combination w/ other techniques
Earth Rotation Issues

- Still unsolved questions on 9 March 2017 for which GEODESIE could help
  - Link between climate oscillations and Earth’s rotation
  - Period of the FICN
  - Free modes’ excitation mechanisms

- Synergies w/ ongoing projects
  - ORB (V. Dehant’s Rotanut ERC)
  - SYRTE
    - Y. Ziegler, postdoc – gravi/VLBI
    - I. Nurul Huda – VLBI
Concluding Remarks

- **GEODESIE** is a way to improve reference frames and Earth’s rotation
  - May have a great contribution to CRF
  - May better EOP accuracy

- **GEODESIE** will bring scientific results in
  - Climate branches, as it is primarily designed for!
  - But also possibly in
    - Earth’s deep interior
    - Astronomy and fundamental physics