Joint Discussion 7

POSTERS

Session 1 Theoretical aspects of reference systems (Sergei Klioner, chair)

Frequency shift at the post-post-Minkowskian approximation

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We present here an algorithmic approach of frequency shift's calculations within the post-Minkowskian approximation of General Relativity. As an application of this method, we calculate an explicit formula for this shift up to the second post-Minkowskian order of approximation.

A New Relativistic Time Delay Formula for VLBI

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In this paper, an error is found in the coordinate transformation between BCRS and GCRS in IAU 2000 resolutions. A new coordinate transformation is therefore recalculated and derived, and then a new relativistic VLBI time delay formula is derived, too. Apparently, these new formulae are useful in the future highly-precise astrometry.

Relativistic modeling for high precision space astrometry at post-post Minkowskian approximation.

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One of the main goals of modern astronomy is the realization of reference frames based on a large number of precise observations (radio or optical) of celestial objects. Beside the highly technological capabilities of future space astrometric missions like Gaia, it requires an accurate theoretical description of light propagation taking into account relativistic effects as light deflection and aberration. Almost all studies devoted to relativistic astrometry are based on the solution of the null geodesic differential equations to describe the trajectory of a photon from a celestial object to a moving observer. However, this difficult task can be avoided using the time transfer function's formalism. We present here our last advances in the formulation of an astrometric modeling using this formalism at the post-post-Minkowskian approximation.

Transformative Relation of Kinematical Descriptive Quantities Defined by Different Spatial Referential Frame, Its Property and Application

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Quantitative transformations between corresponding kinetic quantities defined by any two spatial referential frames, whose relative kinematics relations (purely rotational and translational movement) are known, are presented based on necessarily descriptive definitions of the fundamental concepts (instant, time, spatial referential frame that distinguishes from Maths. Coordination, physical point) had being clarified by directly empirical observation with artificially descriptive purpose. Inductive investigation of the transformation reveals that all physical quantities such as charge, temperature, time, volume, length, temporal rate of the quantities and relations like temporal relation between signal source and observer as such are independent to spatial frames transformation except above kinematical quantities transformations, kinematics related dynamics such as Newton' s second law existing only in inertial frames and exchange of kinetic energy of mass being valid only in a selected inertial frame. From above basis, we demonstrate a series of inferences and applications such as phase velocity of light being direct respect to medium (including vacuum) rather than to the frame, using spatial referential frame to describe any measurable field (electric field, magnetic field, gravitational field) and the field' s variation; and have tables to contrast and evaluate all aspects of those hypotheses related with spacetime such as distorted spacetime around massive stellar, four dimension spacetime, gravitational time dilation and non-Euclid geometry with new one. The demonstration strongly suggests all the hypotheses are invalid in capable tested concepts' meaning and relations. The conventional work on frame transformation and its property, hypothesized

by Voigt, Heaviside, Lorentz, Poincare and Einstein a century ago with some mathematical speculation lacking rigorous definition of the fundamental concepts such as instant, time, spatial reference, straight line, plane area, merely good in building up patchwork to do self preferred explanation by making up derivative concepts or accumulating new hypothesis, has disturbed people to describe the physical nature by setting up the sound basis of concept and relations with capable tested method, it' s time to be replaced by empirically effective alternative.

Session 4 Space mission requirements (Nicole Capitaine, and Dafydd Wyn Evans, chairs)

The coincidence of the HCRF with the XPM as necessary step in densification of the optical reference frame.

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The final version of the XPM catalog contains about 314 million stellar positions and absolute proper motions and covers the whole celestial sphere without gaps in the magnitude range 10m < B < 22m. The analysis of stellar positions and proper motions of the XPM catalog is presented. The coordinate axes, defined by the XPM catalog, were shown to have an ambiguity of rotation relative to the LQAC quasars and ICRF2 sources less than 0.2 mas yr−1. It is concluded that the XPM catalog is the independent realization of the ICRS in the optical and near-infrared wavelengths in the sense of obtaining of proper motions. The absolute proper motions of XPM stars were compared with the similar data from the HCRF modern catalogs. The proper motions of stars in these catalogs were shown to have the appreciable random and systematic errors. From a comparison of absolute proper motions of stars from the XPM catalog with those of the same stars from the PPMXL, UCAC3, Tycho-2 and XC1 catalogs, the equatorial components of the rotation vector of these coordinate systems are determined with respect to the coordinate system specified by positions and proper motions of XPM. These parameters are calculated with the use of about 90 million stars from the UCAC3 catalog and about 300 million stars from the PPMXL catalog. It is shown that the HCRF represented by the Tycho-2, PPMXL, UCAC3 and XC1 catalogs has a significant rotation component $\omega z = (-1.8 \pm 0.16)$ mas yr−1 about the equatorial axis directed to the celestial pole. The result is confirmed by an analysis of the formal proper motions of the extragalactic sources contained in the considered catalogs. The parameters of this residual rotation could be used for combining the catalogs of the HCRF system and the XPM catalog for creation of new optical realization of the ICRS.

The LQAC-2 (Large Quasar Astrometric Catalog, V.2)

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We present the characteristics of the recently up-dated version of the compilation of all the recorded quasars named as LQAC (Large Quasar astrometric Catalog) (Souchay et al.,2012). We emphasize the qualitative and quantitative improvements with respect to the initial version of the catalog, and add some statistical studies relative to sky coverage and nearest neighbours

The Gaia reference frame and the acceleration of the solar system barycenter in the presence of quasar variability

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The relative measurement principle of Gaia results in astrometric parameters (positions and proper motions) which are undetermined with respect to six degrees of freedom in the orientation and rotation of the reference frame. In order to express the final astrometric results in a celestial reference frame which closely matches the ICRS, the orientation and rotation parameters will be estimated from a set of optical quasars, assumed to have zero proper motion, some of which also having well defined positions in the ICRS. Recent observations of AGNs and theoretical studies indicate that variability in the accretion disk and dusty torus surrounding the central black hole can cause photocenter shifts of up to the milliarcsec level. We investigate the statistical impact of expected photocenter variability on the Gaia reference frame based on simulated observations, and discuss some possible strategies to minimize the effect. The solar system' s galactic orbital velocity of about 220 km/s causes an aberration effect of up to 2.5 arcmin, which in itself is unobservable. However, the acceleration of the solar system towards the galactic center causes this aberration to change slowly with time, giving an apparent proper motion of up to 4.5 microarcsec/yr to the quasars. This pattern of proper motions must be solved for while determining the reference frame orientation and rotation parameters. We present an estimate of how well the acceleration vector can be determined based on realistic Gaia simulations.

An Intensive Consideration for the Galactic Coordinate System

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The definition of the Galactic coordinate system (GalCS) in the framework of B1950.0 reference system was announced by the IAU Sub-Commission 33b on behalf of the IAU in 1958.An non-rigorous transformation was adopted by the Hipparcos group to transform the GalCS from the FK4-based B1950.0 system to the FK5-based J2000.0 system or to the International Celestial Reference System (ICRS), however the definition of the GalCS was not updated until now. This may lead to some confusions and misunderstandings when applying of the Galactic coordinates. To establish a GalCS which is directly connected with the ICRS for highly precise observations and data reductions, we re-determine the position of the Galactic plane based on modern large catalogs, such as the near-infrared Two-Micron All-Sky Survey (2MASS) catalog and the SPECFIND v2.0 catalog of radio continuum spectra. The resulting obliquity of the Galactic equator on the ICRS principal plane is about 0.4◦ (2MASS) and 0.6◦ (SPECFIND v2.0) larger than the J2000.0 value, which is widely used in coordinate transformations between the equatorial (α, δ) and the Galactic (l, b). This work also aims to propose a possible definition of the optimal Galactic coordinate system by adopting the ICRS position of the Sgr A* at the Galactic center. For practical applications, we suggest that a revised definition of the GalCS should be required in the near future.

Optical variability and morphology of AGN. Consequences for the future Gaia Celestial Reference Frame.

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The Gaia catalogue will contain 500 000 QSOs with very accurate optical coordinates, at level of some tens to some hundreds of micro-arcsecond. From these targets a core sample will be chosen, formed by those with the most precise positions, to define the Gaia Fundamental Reference Frame. It will be at the basis of an optical reference frame (provisionally, the GCRF) more accurate than the current version of the (radio) ICRF. At the same time due care must be taken when choosing the core picks because quasars do are also known by their flux variability, on time scales that may span from hours up to years. We will review some of the potential astrophysical processes that could induce these variations in the corresponding emission regions and we will present light curves that were obtained by small robotic telescopes during more than 1.5 years. We will also present high resolution images obtained at ground based optical telescopes together with the morphological analysis of the targets. Finally we will conclude by the presentation of an optical image database currently under construction in the frame of the ICRS-pc.

Reconsidering the International Celestial Reference System based on the effect of the secular aberration

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The acceleration vector of the known Solar System barycenter has been determined with high accuracy using VLBI observations, with not only a significant Galactic centric component but also the vertical acceleration perpendicular to the Galactic plane. The secular aberration drift, which results from this notable acceleration, causes all of the observing radio sources apparent proper motions of up to 5 micro-arc-seconds per year. Moreover, since the middle epochs of observations of the radio sources in the northern hemisphere are mostly previous to those in the south hemisphere about couple of years, these systematic variations may make a tiny rotation exist in the defining sources of the ICRF2. And based on these factors, the next-generation International Celestial Reference System with considering this effect will be put forward for high-precision astrometric and geodetic applications. The results of this effect and the suggestion of the next-generation ICRF will be reported in this talk.

VLBI Application for time and frequency transfer, and comparison with other techniques

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NICT is the institute of keeping Japanese national time standard JST, and has been developing next generation optical frequency standards. For comparison of these primary frequency standards with those of other institutes, long distance frequency transfer is required. We are investigating VLBI application for of long distance frequency transfer. In this paper, we present a comparison result between VLBI and other techniques for frequency transfer.

Observations of ERS which are visible in optical domain using 2 m telescope

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During 2011 we observed the extragalactic radio sources (ERS), which are visible in the optical domain, from ICRF2 list using the Rozhen 2 m (Bulgaria) telescope with CCD camera. It is of importance to compare the ERS optical and radio positions (VLBI ones) and to search for a relation between optical and radio reference frames. We used the CCD VersArray 1300B (1340x1300 pixels, the pixel size is 20x20 mkm). The reduction and preliminary results of observed ERS are presented here.

Radio-optical reference frame offsets from CTIO and UCAC4 data

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CTIO 0.9m observations of ICRF counterparts were re-reduced with reference stars observed by the USNO CCD astrograph at the same epoch, applying UCAC4-type reductions and systematic error corrections. Significant offsets between these optical and the ICRF radio positions are found for a number of sources and possible explanations are investigated.

Assessment of stochastic errors of radio source position catalogues

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Investigation of the stochastic errors of the radio source position catalogues derived from Very Long Baseline Interferometry (VLBI) observations plays an important role in deriving of the Celestial Reference Frame. A value of these errors is a good indicator of the quality of the catalogue. Moreover, since the each VLBI-based source positions catalogue is computed in a global solution, together with station position catalogue and Earth rotation parameters, a large value of errors in source positions may indicate that other result are also not very good. Another important application is using stochastic errors for determination of the weights of the input catalogues during computation of combined catalogue. To solve these tasks, we have to use the realistic stochastic errors of catalogues which may be quite different of formal uncertainties reported in the catalogue. In this presentation, we overview several known methods for stochastic errors assessment, and present some our new developments in this field. Results obtained in this study were used during construction of new Pulkovo combined catalogues PUL(2012)C01 and PUL(2012)C02.

Source structure and VLBI position instabilities

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Most of the extragalactic radio sources that materialize the International Celestial Reference Frame (ICRF) exhibit spatially-extended structures on milliarcsecond scales which limit the accuracy of the source positions estimated from Very Long Baseline Interferometry (VLBI) data. These structures when varying with time may also lead to instabilities in the source positions. Structural variations are generally due to ejection of material from the VLBI core in a recurrent although unpredictable manner.

Based on the available VLBI astrometric data and source images, we compare position instabilities and structural variations and conclude about the level of correlation between the two phenomena.

1821-7167: Sensitivity studies of HEO Mars orbiters using perturbation theory

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The sensitivity of the Mars orbiters to the Mars gravity field is usually evaluated and quantified in terms of the magnitude and frequency of their position and velocity perturbations. This information, in consort with the coverage and accuracy of the tracking data, provides insight into the strengths and weakness of each orbiter when treated as a sensor of the Mars gravity field. Kaula's linear theory is often used for such kind of sensitivity study in the orbital motion, but usually effective only for orbits of low eccentricity. In Kaula's linear theory, the eccentricity function is related to the Hansen coefficients. The definition of the Hansen coefficients is a sum of terms, which include factorials and binomial coefficients. This formulation is not numerically stable at higher eccentricity, and direct application of Kaula's solution to the high eccentricity orbits poses some difficulty. In the case of the high eccentricity, Gooding and King-Hele (1989) replaced Kaula's formula by an integral formula. Considering computation time and numerical instability, the integral formula is limited when indices reach high values. A modification of classical formula of the Hansen coefficients (Wnuk, 1997) is thus presented in this study. It's an efficient method for the calculation of the eccentricity function and it is numerically stable for high eccentricity and for high indices. In this study, we use linear orbital theory to analysis MEX and the Chinese first Mars mission, YH-1, to calculate the contribution of Mars gravity field to the amplitudes of all the orbital perturbations, including the radial, along-track and cross-track positional or velocity perturbations. This information can help to estimate how accurately the different coefficients of the gravity field model can be determined, and help to understand how the tracking data from those spacecrafts can be combined in a Mars gravity solution

Global solution of the pulsar clock model and the earth ecliptic position based on millisecond pulsar timing

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Barycentric ephemeris position of the Earth is largely influenced by the error parameters of outer planets, the calculated position cannot be reached accurately using a dynamics-related method. Pulsar timing is able to calculate the Earth SSB position directly for the first time on the basis of pulsar' s space-time reference. It is well-known and obvious that the pulsar clock model at SSB should be dealt prior to calculating the position of the Earth. However, the position of the SSB is generally obtained from a dynamic ephemeris and is relatively poor, if using an ephemeris to build a model of pulsar clock, and considering that the model is sensitive to the position of SSB. As a result, the precision of the Earth SSB position calculated by pulsar timing will be influenced by the SSB error. We present another way to solve the Earth position and the pulsar clock model globally, so the correction of the Earth SSB position is equivalent to the combined effect of the outer planets errors, and the pulsar clock model can be accurately determined. Due to a radio telescope is unable to observe several pulsars at the same second, we select observation data of every epoch as timing 4 to 5 pulsars within 24 hours, then deal with the data of different time, and solve the pulse integer ambiguity. Afterwards, the Earth position in BCRS and the pulsar clock model at SSB can be calculated according to the data of pulse arrival time.

Asteroids Dynamic Site - AstDyS

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The AstDyS online information service (http://hamilton.dm.unipi.it/astdys/) contains data on numbered and multi-opposition asteroids, including orbital elements, their uncertainty, proper elements, ephemerides with uncertainty, and more. AstDyS also provides additional scientific output computed from the raw observational data. This value added currently includes: more accurate orbits computed with advanced dynamical and observational error models; their uncertainty, as expressed by the covariance matrix formalism; ephemerides computed on request for each observer, with uncertainty; mean and proper orbital elements (for this output, AstDyS is the primary source worldwide); statistical quality control, providing a rigorous observational error model. All this is available with a sophisticated web interface, providing multiple search functions and online computations as well as complete orbital and residual files. There are several ways in which the AstDyS service could be expanded and improved in the next future, like the explicit classification of asteroids into asteroid families, the classification of resonant asteroids, and an updated self-consistent population model (to be used, e.g., for survey simulations). The IAU Division I endorsed

the proposal for AstDyS to become an IAU (permanent) service, which would include the IAU supervision of the AstDyS system, keeping under control the quality of the work and the continuous update under conditions of scientific competition.

Session 5 Future requirements for planetary ephemerides (George Kaplan, Chair)

A linear operator method to compute the rotational modes of asymmetric 3D Earth by vector spherical harmonics

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Generalized spherical harmonics (GSH) are usually applied on the problems where the Earth model is elliptical and elastic stress tensor is involved in, as stress tensor can't be represented in vector spherical harmonics. However, the divergence of the tensor and a vector dot-product with the tensor are only needed on computation rotation modes of the Earth which can be written in the vector spherical harmonics. We extend the equations on the spherical Earth to asymmetric 3D model by means of linear operator method. This method doesn't use the complicated generalized spherical harmonics nor Wigner 3-j symbol. As a validation of this method, the practical calculation of rotational modes of 3D Earth will be made and discussed.

A preliminary study of the relationship between gravity change and plumb line variation on ground in case of anomalous mass underground

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The relation between the gravity changes and the plumb line variations on ground, in case of the presentation of an anomalous mass underground is studied theoretically, formulas are figured out, including the one which describes the relation between the gravity change and the plumb line variation in a more simple way. In a simulation the actual precision of the obtained result is estimated, while the gravity data of the West Yunnan gravity network, China is also used for the same purpose at the same time. Additionally, by taking use data of this network (32 batches during 1985-1998), we analyzed the obtained results of plumb line variation determined at certain sites, and found the similar phenomena which have been reported previously for the Northern China area.

A study of discovered non-tidal vertical variations in China

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Tidal vertical variations have been removed in astrometric observations, but the non-tidal ones remain unknown and have never been considered in astrometry until now. In order to make clear whether they are negligible or not, the problem has been studied. Remarkable non-tidal vertical variations have been discovered in Northern China and West Yunnan, which have been studied, including their magnitude, characteristic and interpretation, and found that they should not have been neglected in the past long time. Since they have never been considered and removed in an astrometric observation, we should keep in mind that they are still there, as well as their influence in the results and publications based on these observations. An estimate of these influences on certain astronomical topic is also given in the paper.

Excitations of length-of-day variations determined from GPS, SLR and GRACE

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In the past decades, excitation of the length-of-day (LOD) variations has been investigated from climatological/hydrological assimilation systems and models of the general circulation of the ocean. However, quantitative assessment and understanding of the contributions to the LOD remains unclear due mainly to the lack of direct global observations. In this paper, the total Earth's surface fluids mass excitations to the LOD at seasonal and intraseasonal time scales are investigated from the JPL Estimating Circulation and Climate of the Ocean (ECCO) model, the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis and the European Center for Medium-Range Weather Forecasts (ECMWF) Re-analysis (ERA)-Interim, GPS mass displacement, SLR and GRACE, respectively. Results show that the GRACE, GPS+GRACE and SLR better explain the geodetic residual LOD excitations than the models at annual and semi-annual time scales. For less

than 1-year time scales, GPS and GRACE are worse to explain the geodetic residuals, while SLR agrees better with the geodetic residuals. However, the combining GRACE with GPS or SLR are better than GRACE alone in explaining the geodetic residuals at intraseasonal time scales.

IAU SOFA Software

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SOFA (Standards Of Fundamental Astronomy) software is a resource for astronomers, provided via IAU Division 1. The library contains the latest (IAU approved) algorithms for Earth attitude - precession, nutation, Earth rotation angle, sidereal time. Does your software use time? Need to convert between, for example UTC, UT1, or TT? Then SOFA has all you need. Using SOFA you can convert between FK5 and Hipparcos positions, between geodetic and geocentric coordinates, as well as conversions between the BCRS (ICRS) or J2000.0 and both the celestial and terrestrial reference systems. All routines, Fortran or ANSI C, are available as source code or as part of a library. Visit our website at http://www.iausofa.org/ to find out more and download what you need.

Naval Observatory Vector Astrometry Software (NOVAS) Version 3.1: Fortran, C, and Python Editions

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The Naval Observatory Vector Astrometry Software (NOVAS) is a source-code library that provides common astrometric quantities and transformations to high precision. The library can supply, in one or two subroutine or function calls, the instantaneous celestial position of any star or planet in a variety of coordinate systems. NOVAS also provides access to all of the building blocks that go into such computations. NOVAS is used for a wide variety of applications, including the U.S. portions of The Astronomical Almanac and a number of telescope control systems. NOVAS uses IAU recommended models for Earth orientation, including the IAU 2006 precession theory, the IAU 2000A and 2000B nutation series, and diurnal rotation based on the celestial and terrestrial intermediate origins. Equinox-based quantities, such as sidereal time, are also supported. NOVAS Earth orientation calculations match those from SOFA at the sub-microarcsecond level for comparable transformations. NOVAS algorithms for aberration and gravitational light deflection are equivalent, at the microarcsecond level, to those inherent in the current consensus VLBI delay algorithm. NOVAS can be easily connected to the JPL planetary/lunar ephemerides (e.g., DE405), and connections to IMCCE and IAA planetary ephemerides are planned. NOVAS Version 3.1 introduces a Python edition alongside the Fortran and C editions. The Python edition uses the computational code from the C edition and currently mimics the function calls of the C edition. Future versions will expand the functionality of the Python edition to exploit the object-oriented features of Python. In the Version 3.1 C edition, the ephemeris-access functions have been revised for use on 64-bit systems and for improved performance in general. NOVAS source code, auxiliary files, and documentation are available from the USNO website (http://aa.usno.navy.mil/software/novas/novas_info.php).

Nutation determination using the Global Positioning System

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VLBI observation of extragalactic radio sources is the only technique that allows high accuracy determination of nutation on a regular basis. However, this is limited to periods of nutation greater than about 30 days due to the current resolution of VLBI estimation. It is therefore important to use another technique to improve nutation at shorter periods. It has been shown by Rothacher et al. (1999) and Weber & Rothacher (2001) that GPS is a potential technique for the determination of the short period terms of nutation. The method, which is based on the estimation of nutation rates with respect to an a priori model, is limited to nutation terms in the higher frequency range (with periods up to about 21 days) due to deficiencies in the modeling of the satellite orbits. The high accuracy and high time resolution of the GPS observations that are now achieved give us the possibility to estimate the nutation variations with respect to the IAU2000A nutation, with an expected precision of 10 microarcseconds (μas). The purpose of our study is to use recent GPS observations obtained by 140 IGS stations (IGS08 Core Reference Frame sites

included) to estimate the short period nutations. Two methods are applied: one is to investigate the retrograde diurnal term of polar motion with nutation fixed to the IAU 2006/2000 precession-nutation, using CNES/GRGS software GINS/DYNAMO at Observatoire de Paris; another one is to investigate the nutation time derivative, with polar motion fixed, using Bernese GPS software at University of Technology in Vienna. In this poster, we report on our preliminary results with data set covering a period of 3 years (2009-2011), with appropriate time resolutions and on the comparison between the two approaches.

Progress in SLR - GPS co-location at San Juan (Argentina) station

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From February, 2006, performing a Cooperation Agreement with National Astronomical Observatories of China (NAOC) of the Chinese Academy of Sciences (CAS), Observatorio Astronómico Félix Aguilar (OAFA) of Universidad Nacional de San Juan (UNSJ) is operating a SLR System (ILRS 7406 Station). From the beginning of 2012 a GPS Aztech – Micro Z CGRS is operative at the same place, which made the SLR-GPS co-location possible. The prior objective is to reach co-location between both techniques, so the Station became of 1st order in ITRF net. For that we study and adopt an appropriate strategy to select and place Survey Control Points that ensures higher precision in determination of 3D vectors between the selected reference points. Afterwards we perform translocation tasks of receptor and antenna checking that the GPS verifies builder standards. Then we design and compensate survey control network, by means of software of our own draught. We expect to obtain definitive local ties with precision better than 3 mm, as suggested by IERS for co-located stations. There are very few stations with co-located spatial techniques in the Southern Hemisphere, so it is of great importance to have one in Argentina for improve our participation in IERS on the new realizations of ITRF from now on.

Russian astronomical software

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Institute of Applied Astronomy of RAS has published “The Astronomical Yearbook”(AY) with 1921, “The Nautical Astronomical Yearbook” (NAY) with 1930, “The Nautical Astronomical Almanac”’biennial (NAA-2) with 2001. The new IAU2006/2000 precession-nutation models, and the FK6/HIPPARCOS stellar catalogues were used in these editions. Ephemeris editions are based on the domestic EPM2004 (IAA RAS) theory of movement of planets, Sun and Moon. The electronic versions are developed for two editions. The important stage of work is creation of “The Personal Astronomical Yearbook”’(PersAY). The system gives ample opportunities to the user to put and to solve tasks of calculation of ephemerides for any moment in various time scales, and for any location of the observer on a terrestrial surface. Also in PersAY it is possible to calculate by means of DE405/LE405 theory to make comparison with others ephemeris editions. The time interval of validity of the system makes 2010-2015. Besides system of the removed access the ``Navigator’ ’was developed. It intended to solve some the navigating tasks described in NAA-2. The system is accessible on a site http://shturman.ipa.nw.ru/ (in Russian). In electronic systems as in AY the same reduce theories and the theory of movement of planets, the Sun, the Moon are used. All calculations are work out on the basis of the multifunctional software system ERA.

SLR and GPS spatial techniques in ITRF. Argentine results

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Along the late 30 years spatial geodetic techniques enable us to measure horizontal and vertical deformations of the Earth's surface with a very high precision. Performing this task we made Satellite Laser Ranging (SLR), and Global Positioning System (GPS) observations in South America ILRS 7406 Station placed at Observatorio Astronómico Félix Aguilar (OAFA) in San Juan, Argentina, accomplishing a Cooperation Agreement between CAS-NAOC and OAFA–UNSJ. Trough LAGEOS II Satellite observations we obtain rectangular coordinates of San Juan ILRS Station in the Terrestrial Reference Frame (ITR 2000), standing out that Argentine Station data were included in the late arrangements ITRF given by International Earth Rotation and Reference System Service (IERS). Spatial and temporary variations of the epoch 2010 – 2011 were evaluated finding out remarkable displacements, of about a half meter, related with seismic events on the region. We confirm these deformations by means of GPS determinations referred to Permanent GPS Station placed nearby the SLR Station.

Reference selenocentric net

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The catalogues based on mission "Apollo" and reference nets of the west lunar hemisphere made by missions "Zond 5", "Zond 8" cover small part of the Moon surface (zone from -20 to +40 degrees by latitude). Three ALSEP stations were used to transform "Apollo" topographic coordinates. Transformation mean-square errors are less than 80 meters and measurement's errors are about 60 meters. On this account positions inaccuracy near and between ALSEP stations are less 150 meters. The offset from place of the location ALSEP enlarges the supposed mistake is more than 300 m and this is a major part of the lunar surface. Catalogues of the mission "Apollo" realize quasidynamic coordinate system. Distribution reference nets DMA/A 15, NOS/USGS and DMA/603 mission "Apollo" on visible side of the Moon didn't bring in appreciable results. Only KSC-1162 realizes dynamic coordinate system and covers zone from -70 to +70 degrees by latitude. The reference selenodetic net KSC-1162 was made in the dynamic coordinate system. Analysis KSC-1162 catalogue shows it corresponds to an essential requirements. It has enough reference points to cover main areas of the lunar visible side. Reference points accuracy for plan coordinates is ± 40 meters and it is ± 80 in height. The purposes of investigation are increasing concentration accuracy and expansion of selenodetic control system based on optimal coordinate transformations. At present the best method of the expansion selenodetic reference net wide lunar area is the use of coordinate's transformation matrix. Constituents of matrix and displacement vectors can be obtained by transform available general points in KSC-1162 and transformable in its system catalogues. As a result was obtained summary reference net by expansion KSC-1162 selenodetic system using 12 cosmic and ground selenodesic catalogues. In the future we plan to bind to the KSC-1162 catalogue reference coordinate system data topocentric modern space missions in which there are visually identify the lunar objects

The geopotential computed from global crustal models

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The geopotential of the interior Earth is generally computed from the hydrostatic equilibrium hypothesis. There are several global crustal models from which we can calculate the geopotential without considered the hydrostatic equilibrium hypothesis. So we discuss the possibility of this situation and find a few of problems that should be noticed.

The interior structure of the Earth constrained from gravity field data and the generalized theory of the figure of the Earth

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The classical studies of equilibrium figures of the Earth usually start from Clairaut equation (or Darwin-de Sitter theory and etc.) and one dimensional Earth model like PREM. Considering the topographic existence of the crust and its gravitational effects on the equi-potential figures interior the Earth, a new generalized theory of the figure of the Earth to third-order accuracy was developed recently (Liu & Huang, 2008; Huang & Liu, 2012), in which, both the direct and indirect contribution of the anti-symmetric crust layer are included, thus, all the non-zero order and odd degree terms, up to degree/order of six, are included in the spherical harmonic expression of the figures. Furthermore, space-borne global gravity field observations have provided an integrated information of the mass distribution inside the Earth and will also constrain the figures interior the Earth. Related consideration and attempts to integrate such constraint into the generalized theory of the figure of the Earth will be discussed in this presentation.

The new expansion of annual aberration into trigonometric series

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The Earth' s instantaneous velocity vector with respect to the center of mass of the solar system, needed for the precise reduction of annual aberration, is expanded into a trigonometric series using planetary theory VSOP2000 for the heliocentric motion of the planets. The vector components are given in the International Celestial Reference System (ICRS). The heliocentric motion of the Earth-Moon barycenter, the motion of the sun around the barycenter of the solar system, and the motion of the Earth around the barycenter of the Earth-Moon system are discussed. The accuracy achieved by the expansion, estimated by comparison with integrated velocity vectors, is sufficient even for the most precise astrometrical reductions. Possible inclusion of the procedure for annual aberration into the SOFA package will be discussed.

New role of astrometry technique in sciences and technologies

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Abstract Ground astrometry optical techniques have played an important role in modern astronomical history, especially in the field of star catalog composing, Earth orientation parameters (EOP) determination and geodesy. The number of astrometric instruments attained a peak in the years of 1960-1975, while hundred instruments over the world were being operated routinely. Since space techniques had taken over the job in 1980's, they were withdrawing rapidly, down to only a few for the moment. Since years it has been asked: what is the future for this technique? Actually, the question has already been answered by a statement of the IAU Commission 19 resolution in 1991: "modern astrometric observations provide a unique set of data sensitive to variations in the deflection of the vertical". In response to the call of the resolution: "to investigate the possibility of deriving long-term variations in the deflection of the vertical within the reference frame provided by HIPPARCOS "we have been working ever since. One of the main difficulties that we are confronting is the lacking of data, since most of the instruments are no more working when the space technique was really able to provide all the information needed in a treatment in which all the factors, other than the variations in the deflection of the vertical (or Plumb Line Variations, PLV, as below) itself, may be removed completely in an observation. Fortunately, there are usable gravimetry data in China with which the PLV in certain regions of China is able to be calculated, although they are not in the sense of directly observed, and thus able to be studied in practice. The PLVs in China, including their magnitude, characteristic, interpretation, as well as their special function in studying underground matter changes, which are related to earthquakes, underground water storage et al., have been studied. A summary of these works is presented here, hoping that one will keep in mind that all the astrometry results published in the past has not yet been freed from the PLV mentioned here, but at the same time, understanding that the special function of this technique in "looking" into the ground is going to make it a new role in sciences and technologies.