ABSTRACTS QSO Astrophysics, Fundamental physics, and Astrometric Cosmology in the Gaia era 6-9 June 2011

Alberto Vecchiato
OATO/INAF

Putting Einstein to test: astrometric experiments in fundamental physics

In classical Astronomy, the main goal of Astrometry was the determination of an inertial frame of reference, which, in modern language, can be intended as an experiment of fundamental physics. In relativistic physics the concept of an absolute intertial frame of reference cannot hold anymore, nonetheless Astrometry retains its role as an experimental counterpart of fundamental physics. Modern high-precision astrometry, in fact, must be formulated on the theoretical background of relativistic physics and of a relativistic theory of measure. On the other side, it can be used to put to test several topics involved in the quest among the different theories of gravity. This talk will try to give a brief overview on the connections between some of these topics and their formulation as an astrometric experiment.

Alexandre Humberto Andrei
ON/MCT; OATO/INAF; OV/UFRJ; SYRTE/OP

GAIA Initial QSO Catalogue - The Variability and Compactness Indexes

The manifold Gaia scientific output rely on precise astrometry accurate to sub-mas standards. This depends on building a fundamental reference frame formed by pointlike, position stable, and all-sky homogeneous grid points. In one word, quasars. The CU3 Initial Quasar Catalogue Working Package (GIQC WP) was established to beforehand produce one such list, although ultimately the satellite multi-band photometry aided by astrometric monitoring has the potential to pick up a clean sample of quasars. We revise the work of the WP and the current status of the GIQC, presently containing 174,742 objects, divided in 3 categories: defining (the largest one, with 123,880 objects), candidates, and other. The GIQC basic entries are equatorial coordinates, apparent magnitude, and redshift. It additionally has entries for variability and compactness indexes. The definition and determination of the later bring about fundamental aspects of quasar astrophysics and the bearings upon the astrometric stability of the objects, which is paramount to properly grant the status of fiducial grid point.

Andrei Lobanov
Max-Planck-Institut für Radioastronomie, Bonn

Opacity in nuclear regions of AGN: A factor for astrometry, a tool for astrophysics.

Opacity in nuclear regions of radio-loud AGN, resulting from synchrotron self-absorption and external free-free absorption, is both an important astrometric factor and an effective astrophysical tool. The nuclear opacity in AGN leads to dependence of observed positions of radio sources on the frequency of observation (the "core shift" effect). We discuss here several astrophysical and astrometric implications of this effect. The core shift can be used as an effective probe the physical properties of the central regions of AGN. At the same time, the core shift causes offsets between positions of astrometric reference sources measured in the optical and radio domains. As a result, effective alignment of the GAIA Reference Frame and the International Celestial Reference Frame (derived from radio interferometric observations of distant AGN) would require making a proper account of these offsets. The magnitude and the direction of the core shift should therefore be known for the entire sample of objects to be used for the reference frame alignment. As the magnitude of the core shift can vary substantially during flares in AGN, systematic monitoring of the radio flux density and core shifts in the comparison sample are highly desirable for ensuring excellent alignment between the ICRF and GAIA reference frame.

Brigitte Rocca-Volmerange
Institut d'Astrophysique de Paris

AGN and Star formation from powerful radiogalaxies with Gaia

Gaia will observe the most powerful nearby radio galaxies with an exceptionnal astrometric accuracy. Detected through typical huge emission lines (Halpha 6563A plus NII contamination) and continua from ~10^12 M0 early-type galaxies (Rocca-Volmerange et al., 2004), their ~10^9 M0 black hole masses correlate with optical luminosities (Magorrian et al. 1998; Ferrarese & Merritt 2000). Such targets are well suited to addressing the crucial questions of the AGN physics research, with implications for the triggering, fueling, and evolution of the active nucleus in relation with star formation. Moreover the debate on binarity and alignment will be clarified. Gaia observations will be confronted with images from the high spatial resolution surveys of radio galaxies (Tremblay et al, 2009, Allen et al, 2010) and analyzed with the Gaia synthetic library from our evolution code Pégase (Tsalmantza et al, 2006, 2009, 2011) .

Christine Ducourant
LAB - Bordeaux Observatory
The extended objects as they will be seen and treated by Gaia
The ESA-Gaia mission, is one of the most ambitious projects of the modern astronomy. The satellite will observe more than one billion of objects, mostly stars, with an astonishing precision. With such a wonderful database it will be possible to understand a lot of our Milky Way behavior. But among the observed objects, there will be 5 to 10 millions of small galaxies observed by the satellite and about 0.5 millions of QSO's. The observation of such objects will have a huge impact on our understanding of the universe. But how these objects will they be processed by Gaia and are we going to recover all the information that they carry? The "Extended Object " component of CU4 has developed methods to extract the morphologic information of all extended objects. This is what we present here.

Donato Bini
Istituto per le Applicazioni del Calcolo "M. Picone" (CNR)
Observers, observables and frames in general relativity: applications to light propagation tracing.
The role of any generic observer family in arbitrary motion on a curved spacetime is clarified in termes of the associated geometrical and physical properties. Applications are then considered in the case of tracing the light propagation.

Fernando de Felice
Department of Physics "G. Galilei", University of Padova
Physical measurements in General Relativity
We first outline the procedures to produce a physical measurement in General Relativity then we discuss a significant example. It was found by the present Author (de Felice F. 1994 Class. Quantum Grav. 11, 1283) that in the space-time of a rotating source, specifically a Kerr black hole, particles moving on spatially circular counter-rotating non-geodesic orbits with radii which can be arbitrarily large, increase their binding energy if one increases the modulus of their angular velocity hence they require a larger acceleration pointing outwards in order to remain on circular orbits at the same radius. This is a new general relativistic effect which has no Newtonian analogue and generalizes a similiar one found to hold nearby a Schwarzchild black hole (Abramowicz M. and Lasota J.OP. 1974 Acta Phys. Pol. B5, 327).

Francois Finet
Université de Liège
Detection of bright multiply imaged quasars by GAIA
Bright multiply imaged quasars offer unique tools to investigate the properties of the Universe as a whole (cosmological parameters), the astrophysical properties of the remote galaxies acting as deflectors (i.e. their mass, extinction law, ...) as well as the structure of the background sources (accretion disk, central engine, etc.). Multiply imaged quasars will represent the most easily identified signature of lensing in GAIA observations. Several thousands of such cases are expected with J <=20. Furthermore, the complete QSO catalog which will be built from the GAIA observations will be very attractive and unique in order to study QSO evolution, large scale structures, intervening absorbers, the inertial frame. The aim of this presentation is to report about a realistic estimate of the expected number of bright multiply imaged quasars that will be detected by GAIA.

Francois Mignard
Observatory of the Côte d'Azur
QSO recognition and observation with Gaia
The ESA space astrometry mission, due for launch in 2013, will survey the sky down to the 20th magnitude with an unprecedented astrometric accuracy of 25 mircoarcsec at 15 mag, carrying out simultaneously multi-epoch photometry and spectroscopy. Although the mission is optimised for stellar observations, the satellite will also repeatedly measure the position of ~ 500,000 quasars in a consistent way, leading to a direct realisation of the primary inertial frame in the visible meeting the ICRS concepts. To achieve this goal one

must first recognize the QSOs from the stars in an automatic and efficient way and then select a clean sample of sources to serve as defining source for the frame. During this talk I will recall the main properties of Gaia astrometry and will report on the current selection approach of the QSOs, primarily photometric. I will conclude with the overall properties of the frame and the limitations of its realisation due to random noise, source instability and to lensing by intervening galaxies.

Francois Mignard
Observatory of the Côte d'Azur
From the Gaia Frame to the ICRF-3
Gaia will produce internally a fully consistent reference frame for its astrometric solution and attitude parameters, referred to a set of well-behaved QSOs. This set and the construction of the frame will meet the principles set up for the ICRS and the Gaia frame is potentially a good candidate for a future version of the ICRF. I will summarise the properties of the Gaia frame in terms of accuracy and precision and open the discussion on how to turn the Gaia frame into an IAU approved ICRF.

François Taris
Observatoire de Paris, France
Optical observations of QSOs for the link of reference systems
G. Bourda et al. (2008, 2011) gave two provisional lists of roughly 100 QSOs to link the future optical Gaia Celestial Reference Frame (GCRF) to the radio International Celestial Reference Frame (ICRF). The goal of our observation program is the monitoring of the optical stability of the faintest sources in the short term (15 days). After the works of Andrei et al. (2008) and Taris et al. (2011) it seems that photometric variations on a monthly basis could be closely related to astrometric variations at the level of some mas. The core of a quasar's optical emission may originate in a small region near the black hole and the accretion disk. It would produce photometric variations on a time base of 15 days. Such astrometric displacement of the centroids of the QSOs (some μas) could have important involvement for the link of the GCRF-ICRF. We will present the first observations obtained with telescopes in Haute Provence Observatory (OHP), Côte d'Azur Observatory (OCA, Tarot telescop) and ESO-Chile (Tarot telescop)

Geraldine Bourda
Laboratoire d'Astrophysique de Bordeaux
Towards an accurate alignment of the VLBI frame and the future Gaia optical frame – VLBI observations of weak extragalactic radio sources: Status and future plans
The space astrometry mission Gaia will construct a dense optical QSO-based celestial reference frame. For consistency between optical and radio positions, it will be important to align the Gaia and VLBI frames with the highest accuracy. However, the number of quasars that are bright in optical wavelength (for the best position with Gaia), that have a compact core (to be detectable on VLBI scales), and that do not exhibit complex structures (to ensure a good astrometric quality), is currently rather limited (Bourda et al. 2008). It was hence realized that the densification of the list of such objects was necessary. Accordingly, we initiated a multi-step VLBI observational project, dedicated to finding additional suitable radio sources for aligning the two frames. The sample consists of ~450 optically-bright weak extragalactic radio sources, which have been selected by cross-correlating optical and radio catalogs. The initial observations, aimed at checking whether these sources are detectable with VLBI, and conducted with the European VLBI Network (EVN) in 2007, showed an excellent ~90% detection rate (Bourda et al. 2010). The second step, dedicated to extract the most point-like sources of the sample, by imaging their VLBI structures, was initiated in 2008. About 25% of the detected targets were observed with the Global VLBI array (EVN+VLBA; Very Long Baseline Array) during a pilot imaging experiment, revealing ~50% of them as point-like sources on VLBI scales (Bourda et al. 2011). The rest of the sources were observed during 3 imaging experiments in March 2010, November 2010 and March 2011. In this paper, we give an overview of the project, we present the results of these imaging campaigns, and we draw future prospects, concerning e.g. the third step (to engage in 2011) dedicated to measuring accurately the VLBI position of the most point-like sources of the sample.

Giuseppe Cimo
Joint Institute for VLBI in Europe
Accurate astrometry for Planetary Radio Interferometry and Doppler Experiments.
The Planetary Radio Interferometry and Doppler Experiment (PRIDE) is a multi-disciplinary enhancement of the scientific suite of current and planned interplanetary missions. The Very Long Baseline Interferometry (VLBI) observations of the Huygens probe during its descent on the surface of Titan is a successful

demonstration of the PRIDE technique. We will present the capabilities of PRIDE to measure accurately the state-vector of spacecraft using VLBI tracking and multi-station Doppler measurements in phase-referencing mode. The larger number of possible phase-reference calibrator with high precision astrometry, which can be achieved with Gaia and a new larger reference frame, is critical for increasing the accuracy of the spacecraft state-vector determination. Highly accurate measurements of the state-vector allow a wide range of studies, ranging from gravimetry and celestial mechanics to fundamental physics studies in our solar system.

Ian Browne
JBCA, University of Manchester
Searching for offset AGN; kicked black holes, binary black holes, gravitational lensing.
There are several reasons why the centroid of radio emission may be offset from centroid of optical emission in a galaxy. All will be a nuisance to those wishing to tie frames together but nevertheless may point to interesting astrophysics. I will concentrate on what one might learn from studying relatively nearby, passive, early-type galaxies with detectable compact radio emission and which are bright enough to be measured by Gaia. Big radio-optical displacements would be expected in those rare cases that the galaxy is lensing some background source. More interesting are cases where the radio emission pinpoints a black hole and the optical emission gives the centroid of the stellar emission. Here the displacement could arise from one member of a binary black hole system or from a black hole that has received a kick after a binary black hole merger. I will discuss the practicalities of a possible programme to search for such displacements in SDSS-selected galaxies using a combination of e-MERLIN and Gaia astrometry.

Ioana Sotuela
UCM-UAM/MDSCC-INSA
The contribution of X/Ka-band VLBI to multi-wavelength studies of the Celestial Frame – Poster
We report the results of VLBI astrometry using the Deep Space Network at X/Ka-band (8.4/32 GHz) for over 450 quasars with current precisions of 200-300 µas. The leading components of the error budget have been identified and a program is underway to reduce position errors by factor of 2 to 3. More than 300 of our sources should also be detectable by Gaia (V< 20 mag). A covariance study using the existing X/Ka radio data and simulated Gaia uncertainties for the 300+ objects shows that a frame tie could be made with a precision of 10-15 µas (1-sigma) for each of the three rotation parameters with the potential for 5 µas precision if our error budget reduction plan succeeds. The characterization of frequency dependent systematic errors from extended source morphology and core shift should benefit greatly from adding X/Ka-band measurements to existing and planned S/X-band measurements thus helping to constrain astrophysical models of the frequency dependence of photocenter positions.

Jacques Roland
IAP
Determination of the characteristics of the BBH system using VLBI observations
VLBI observations shows that VLBI jets precess. We explain the precession of VLBI jets by a binary system of supermassive black holes (BBH system). From VLBI observations it is possible to determine the characteristics of the BBH system. We will present the method to solve the problem and show the results obtained for some sources.

Jean Souchay
SYRTE, Observatoire de Paris
The LQAC (Large Quasar Astrometric Catalogue) : principle and construction"
In its up-date version the LQAC will contain the quasi totality of recorded quasars with all the information related to them (redshift,photometry, radio-flux, absolute magnitudes) and the a priori most accurate determination of their coordinates with respect to the ICRF. We explain the main characteristics of the LQAC and its importance in the scope of the GAIA mission.

Jorge Páramos
Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico
Testing a non-minimal coupling between matter and curvature and beyond
One of the most interesting and current phenomenological extensions of General Relativty is the so-called f(R) class of theories; a natural generalization of this includes an explicit non-minimal coupling between

matter and curvature. In this talk, I review the main characteristics of this model, as well as its applicability and compatibility with observables in a wide range of contexts --- including astrophysics, dark matter, cosmology and inflation.

Kenneth Johnston
Institution US Naval Observatory
Stability of QSO Astrometric Positions
The ultimate stability of the positions of QSO measured with the VLBA and VERA telescopes will be discussed in detail. A series of observations of four QSOs located within 2 degrees of one another were made o precisely determine their relative positions. These observations were conducted over a year and a half. The positional stability, the structure and variability of the sources will be described in detail. The implications of limitations of precision astrometry from ground based observations for astrophysics, and geodesy will also be discussed.

Kirill Sokolovsky
Max Planck Institut for Radio Astronomy, Bonn, Germany
A VLBA survey of opacity-driven positional shifts in AGN
The effect of a frequency dependent shift of the apparent position of the brightness peak in radio-loud AGN (known as the "core shift") has important astrophysical and astrometric applications. In order to achieve a broader understanding of this effect and the physics behind it, we have used the NRAO's Very Long Baseline Array (VLBA) to image 20 pre-selected compact extragalactic radio sources simultaneously at nine frequencies in the 1.4-15.4 GHz range (with all these objects being potential candidates for performing the radio-optical reference frame alignment). The core position at each frequency was measured by referencing it to a bright, optically thin feature in the jet. A significant core shift has been successfully measured in each of the twenty sources observed. The median value of the core shift was found to be 1.21 mas if measured between 1.4 and 15.4 GHz, and 0.24 mas between 5.0 and 15.4 GHz. The dependence of the core position on frequency is found to be consistent with the theoretical predictions for a purely synchrotron self-absorbed conical jet in equipartition. These results argue that systematic measurements of the core-shift in a broader sample of radio-loud AGN would increase substantially the accuracy of the radio-optical reference frame alignment.

Mariateresa Crosta
INAF-Osservatorio Astronomico di Torino
Physics and Coordinates in competition in highly accurate measurements
Advancement in astronomical observations and technical instrumentation requires coding light propagation at high level of precision; this could open a new detection window of many subtle relativistic effects suffered by light while it is propagating and recorded in the physical measurements. Light propagation and its subsequent detection should indeed be conceived in a fully relativistic context, in order to interpret the results of the observations in accordance with the geometrical environment affecting light propagation itself. This talk aims to present examples showing how keeping the physical aspects of the problem guarantees consistency of the measured physical effects to the intrinsic accuracy of space-time.

Mario Gai
Institution Osservatorio Astronomico di Torino (OATo) - Istituto Nazionale di Astrofisica (INAF), Italy
Gravitation Astrometric Measurement Experiment
GAME (Gravitation Astrometric Measurement Experiment) is a mission concept taking advantage of astronomical techniques, in particular inherited from Gaia, for high precision measurements of interest to Fundamental Physics, and in particular the γ and β parameter of the Parameterized Post-Newtonian formulation of gravitation theories extending the General Relativity. A space based telescope, looking close to the Solar limb thanks to coronagraphic techniques, may implement astrometric measurements similar to those performed in the solar eclipse of 1919, when Dyson, Eddington and Davidson measured for the first time the gravitational bending of light. Also, it will be possible to perform a high precision determination of Mercury's perihelion precession, implementing in the same experiment two of the classical tests on General Relativity. Simulations show that the final accuracy of GAME can reach the 10^{-8} level on γ and the 10^{-5} level on β within the framework of a medium class space mission. GAME may provide crucial contributions to our understanding of gravity physics, cosmology and the Universe evolution at a fundamental level. The experimental evidence of an accelerated expansion of the Universe is interpreted as a long range perturbation of the gravity field of the visible matter, generated

by the so-called Dark Energy, in addition to the measurements, at different scale length, explained with non-barionic Dark Matter (e.g. galaxy rotation curves). However, such observations might be explained with a modified version of General Relativity, e.g. in which the curvature invariant is no longer constant as in Einstein's equations, i.e. the gravity theories. This scenario might totally suppress the need for Dark Matter and Dark Energy. A 10-8 level determination of □ will provide stringent constraints on acceptable theories. The GAME principle is based on the differential astrometric signature on the positions of stars and planets. The instrument concept ensures rejection of the systematic errors to within a factor 2 of the photon noise limit. The experiment concept is described in the context of measurement requirements, instrument outline and mission profile.

Mario Lattanzi
INAF-Osservatorio Astronomico di Torino
Astrometric Cosmology
The accurate measurement of the motions of stars in our Galaxy can provide access to the cosmological signatures in the disk and halo, while astrometric experiments from within our Solar System can uniquely probe possible deviations from GR. This talk will introduce to the fact that astrometry has the potential to become a major player in the field of local cosmology. For example, the uniqueness offered by accurate absolute kinematics at the scale of the Milky Way is the ability to account in situ for the predictions of the cold dark matter model, in the case of the halo, and eventually map out the distribution of dark matter or other formation mechanisms required to explain signatures recently identified in the old component of the thick disk. Final notes will dwell on to what extent Gaia can fulfill the expectations of astrometric cosmology and on what must instead be left to future specifically designed astrometric experiments.

Matteo Luca Ruggiero
Department of Physics, Politecnico di Torino
Using ring laser systems to measure gravitomagnetic effects on Earth
We investigate the possibility of detecting the draggin of the reference frame of a laboratory fixed on the Earth surface, by means of a ring laser: in particular, the dragging effect shows up as small (post-Newtonian or generalized gravitomagnetic) perturbations of the Sagnac effect induced by the diurnal rotation of the laboratory. We define the space-time metric in the local reference frame of the laboratory and, then, we discuss the impact of the various perturbations in view of the fact that, nowadays, large scale square ring laser systems are approaching a sensitivity of 1x10^-11 rad/s/sqrt(Hz). Eventually, after focusing on the role of VLBI in such measurements, we discuss some geometrical configurations which seem appropriate to detect the effect.

Norbert Bartel
York University
VLBI astrometry for probing astrophysics, celestial reference frames, and general relativity
Very-long-baseline interferometry allows measurements of relative positions and parallaxes of celestial objects with accuracies of 10 microarcseconds, and proper motions of 10 microarcseconds per year. Examples are given showing how this capability can be used for the study of astrophysical properties of core-jet sources in active galactic nuclei, the stability of the extragalactic reference frame, and tests of general relativity. Possible implications for Gaia are discussed.

Orfeu Bertolami
Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto
Underlying principles of our current theories

Orfeu Bertolami
Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto
What if ... General Relativity is not the Theory?

Patrick Charlot
Laboratoire d'Astrophysique de Bordeaux
The ICRF now and the future

Paulo Freire
Max-Planck-Institut fuer Radioastronomie, Bonn, Germany
GAIA and Millisecond Pulsars
In this talk, we review some of the scientific gains of GAIA astrometric measurements of the white dwarf and other stellar companions to millisecond pulsars. These include a much improved frame tie between the JPL solar system ephemeris and the GAIA reference frame, improved, less covariant timing models for millisecond pulsars, the possibility of independent neutron star mass measurements and in at least one case, the possibility of an extremely precise new strong-field test of general relativity.

Pierre Teyssandier
Dept SYRTE/CNRS-UMR8630, Observatoire de Paris
New methods for calculating the propagation direction of light in static, spherically symmetric space-times
We give a survey of the new methods we are currently developing for determining the propagation direction of light in static spherically symmetric space-times when the emitter and the observer are both located at a finite distance. One of these procedures leads to simple calculations at any post-Newtonian order. The problems encountered in the geometric interpretation of the results are discussed in detail up to and including the order (GM/c2)3 for the Schwarzschild space-time.

Richard Porcas
Max-Planck-Institut fuer Radioastronomie, Bonn, Germany
Issues of radio and optical reference-frame alignment

Salvatore Capozziello
Dipartimento di Scienze Fisiche, Universita' di Napoli "Federico II"
Dark Energy and Dark Matter as Curvature Effects
Extended theories of gravity have recently attracted a lot of interest as alternative candidates to explain the observed cosmic acceleration, the flatness of the rotation curves of spiral galaxies, the gravitational potential of galaxy clusters, and other relevant astrophysical phenomena. Very likely, what we call “dark matter” and “dark energy” are nothing else but signals of the breakdown of General Relativity at large scales and could be interpreted as a sort of “curvature effects”. Furthermore, PPN-parameters deduced from Solar System experiments and strong field astrophysical phenomena (compact objects, magnetars and neutron stars) do not exclude the possibility that such theories could give other observable effects. We review these results giving the basic ingredients of such an approach.

Sándor Frey
Satellite Geodetic Observatory, Institute of Geodesy, Cartography and Remote Sensin, Budapeste
Radio-optical outliers - a case study with ICRF2 and SDSS
With Gaia, a sensitive and extremely accurate space-based optical astrometry mission, it will become possible to directly link the radio and optical reference frames using a large number of common objects for the first time. For the best-quality link, it is important to know the level of spatial coincidence between the quasars' optical positions, and the radio positions determined by Very Long Baseline Interferometry (VLBI) observations. The accuracy of the radio-optical reference frame link will depend on selecting the most suitable common reference objects. On the other hand, the 'outliers', for which the positions are significantly offset at the two different electromagnetic wavebands, may well be of astrophysical interest. Here we present a case study to compare the radio positions of more than one thousand active galactic nuclei common in the most recent 2nd realisation of the International Celestial Reference Frame (ICRF2) and in the Sloan Digital Sky Survey Data Release 7 (SDSS DR7) catalogue. Compared to the radio ICRF2, the SDSS provides almost two orders of magnitude less accurate astrometric data in the optical. However, its sky coverage and faint magnitude limit allow us to directly relate the positions of a large sample of radio sources (quasars or galaxies). This way we provide an independent check of the overall accuracy of the SDSS positions and confirm that the astrometric calibration of the latest Data Release 8 (DR8) is poorer than that of the DR7. We find several sources for which the optical and radio brightness peaks are apparently not coincident at least at the 3-sigma level of SDSS DR7 positional accuracy and discuss the possible causes.

Sonia Antón
CICGE-FCUP
Photocenter variability and AGN components

Taehyun Jung
Korea Astronomy Space science Institute (KASI)
Korean VLBI Network (KVN) and its recent activities – Poster
The Korean VLBI Network (KVN) consists of three radio telescopes in Seoul (Yonsei Univ.), Ulsan (Ulsan Univ.) and Jeju (Tamna Univ.) with a maximum baseline length of 480 km. In order to calibrate the tropospheric phase errors using multi-frequency phase referencing, the KVN introduced a simultaneous multi-frequency receiver system, which enable to observe all four bands (22, 43, 86, and 129 GHz) simultaneously. Here, we introduce the progress of the KVN system and several projects related to astrometry and KVN calibrator survey.

Ummi Abbas
INAF - Osservatorio Astronomico di Torino
The halo of the Milky Way

Valeri Makarov
US Naval Observatory, Naval Research Lab
Quasometry, Its Use and Purpose
The future astrometric surveys, capitalizing on the vastly improved throughput and dynamic range of modern instruments and detectors, will accomplish something that has been a mere dream of astrometrists for decades: measuring the relative position of optically faint quasars and bright stars at the same time. This opens the possibility of constructing truly inertial and externally accurate reference frames by means of optical astrometry. We demonstrate how the propagation of zonal errors of systematic or accidental origin can be accurately determined even for huge astrometric solutions, and the benefits of anchoring the measurements to extremely distant objects can be computed for various cut-off magnitudes, configurations and single measurement precision of such objects. These advances are not going to be easy. Quasars are by no means ideal objects for astrometry. Various complications have to be dealt with, e.g., 1) optical variability, 2) extended structures, 3) apparent motion due to binarity, gravitational lensing or jets. A relatively small set of about 100 carefully selected reference quasars can go a long way in improving the astrometric value of a space mission, if they are sufficiently bright, stable, fairly uniformly distributed on the sky, and are prime sources in the ICRF. We present an ongoing program at the USNO to construct a “precious set” of optical quasars with the required properties and to enhance the ICRF with new sources in the areas where known, well-observed quasars are scarce.

Yassine Damerdji
Institut d'Astrophysique et de Géophysique de Liège
The QSO classifier in Gaia
We will present the current status of the quasar classifier package (QSOC) in Gaia CU8. After describing the learning data preparation procedures, we will focus on the astrophysical parameter determination and present the used algorithms in QSOC. Finally, we will discuss the current performances of the QSO classifier applied to synthetic and semi-synthetic data.

Sergei Klioner
Lohrmann Observatory, Technische Universitaet Dresden
Astronomical relativistic reference systems and their application for astrometry
Theoretical foundations of the relativistic model for high-accuracy astrometric observations are overviewed. After a brief discussion of the underlying astronomical relativistic reference systems used in the model, the structure of the model is given and its main components are elucidated.

Sergei Kopeikin
University of Missouri-Columbia
Astrometric reference frames in the solar system and beyond.