MONDAY

Session 1a
Oral, 8:30am–10:00am

1.01 **The Gaia Mission,** *M. Perryman (European Space Agency)*

The talk will outline the overall organisation of the Gaia mission: the role of ESA, the industrial teams, and the scientific community in the project; the organisation, structure, and goals of the scientific working groups; their interaction and influence on the satellite and payload design; the overall project schedule; the organisation and overall approach to the challenges of the data analysis; and the mission data products and their estimated release dates.

1.02 **Overview of the Gaia science objectives,** *F. Mignard (OCA/Cassiopie)*

This talk provides an overview of the science objectives of the Gaia mission. Starting with the expected performances of the three detectors I will show how the combined and repeated information on each source will lead to a major step forward in our current knowledge of stellar and galactic physics, resulting both from the accuracy on individual object but also from the statistical exploitation of the unbiased census over one billion stars. Besides these central topics the talk will also cover the science output from the detection of extra-solar planetary systems, the determination of thousands of stellar masses, the massive impact on Solar System studies and the fundamental physics.

1.03 **Performance of the Gaia mission,** *Lennart Lindegren (Lund Observatory)*

The expected performance of the Gaia mission is outlined. The improvement compared with Hipparcos in the accuracy, number of objects and limiting magnitude is staggering, and the talk focuses on explaining how such a gain can be achieved.

—Coffee Break—

Session 1b
Oral, 10:30am–12:00pm

1.04 **Astrometry with Pan-STARRS and PS1,** *K. Chambers and The Pan-STARRS Team (Institute for Astronomy, UH, Pan-STARRS)*

The Institute for Astronomy at the University of Hawaii is developing a large optical synoptic survey telescope system; the Panoramic Survey Telescope and Rapid Response System. Pan-STARRS will consist of an array of four 1.8m telescopes with very large (7 square degree) field of view, giving it an etendue larger than all existing survey instruments combined. Each telescope will be equipped with a 1 billion pixel CCD camera with low noise and rapid read-out, and the data will be reduced in near real time a to produce both cumulative static sky and difference images, from which transient, moving and variable objects can be detected. Pan-STARRS will be able to scan the entire visible sky to approximately 24th magnitude in less than a week, and this unique combination of sensitivity and cadence will open up many new possibilities in astrometry as well as a wide range of astronomical problems in the Solar System, the Galaxy, and the Cosmos at large.

The Pan-STARRS Telescope No. 1 (PS1) is the prototype telescope for the Pan-STARRS project and is scheduled for first light in January 2006. PS1 is 1.8 meter telescope with a Gigapixel Camera and 7 square degree field of view. Its primary mission will be an astrometric and photometric survey of 3pi steradians to form the intial catalog for Pan-STARRS.

A description of Pan-STARRS, PS1, and the design reference mission for PS1 will be presented including astrometric and photometric requirements and goals.

1.05 **The Pan-STARRS Science Database,** *Jim Heasley (Univ. of Hawaii)*

1.06 **The Discovery Channel Telescope: A Wide-field Telescope in Northern Arizona,** *E. W. Dunham, R. L. Millis, and B. A. Smith (Lowell Observatory)*

—Lunch —

Session 2a
Oral, 1:00pm–3:00pm

2.01 **A Survey of Surveys: Opportunities and Challenges for Astrometry,** *Sidney C. Wolff (National Optical Astronomy Observatory)*

The next decade will witness the commissioning of an unprecedented number of new ground-based telescopes and instruments dedicated to obtaining uniform observations of large areas of the sky. After a brief overview of the characteristics of several of these planned surveys, the 8.4-m Large Synoptic Survey Telescope will be used as a case study to illustrate the kinds of science that can be addressed through astrometry. The design of the LSST and the project status will be described briefly.

2.02 **Science Results Enabled by SDSS Astrometric Observations,** *Zeljko Ivezic (Univ. of Washington), Nick Bond, Jeff Munn, Robert Lupton, Mario Juric, et al.*

We will discuss several results made possible by accurate SDSS astrometric measurements (absolute accuracy better than 100 mas, and relative accuracy of about 20-30 mas for sources not limited by photon statistics) in a large sky area. In particular, we will summarize the SDSS observations of solar system objects, and discuss proper motions obtained by comparing POSS and SDSS astrometric measurements, and by comparing multiple SDSS measurements.

2.03 **CTI II: A Stable, Nonmoving Photometric and Astrometric Survey Telescope,** *John T. McGraw, G. F. Benedict, Mark R. Ackermann, Peter C. Zimmer, Tom Williams, C. J. Wetterer, Eric Golden*

We describe the ongoing design of a telescope and its focal plane mosaic of optical and infrared detectors for a deep, wide-field-of-view multi-bandpass imaging photometric and astrometric survey conducted in the time-delay and integrate mode. We assess the effects of the seeing-blurred PSF, including components introduced by TDI operation. Optical system and detector tradeoffs are determined by considering "sciences drivers" that define requirements on the design. The key scientific programs we consider are: photometric and astrometric investigation of the solar neighborhood, synoptic AGN reverberation analysis, and discovery of targets of opportunity, such as distant supernovae. These programs stress photometric and astrometric precision and stability. The sky survey implemented by the fully-defined telescope will be conducted as part of the AFRL-funded Near Earth Space Surveillance Initiative (NESSI).

2.04 **Results from CTIOPI: Parallaxes, Perturbations, and Pushing Towards SIM,** *Todd Henry, Wei-Chun Jao, John Subasavage (Georgia State University)*

In August 1999 the RECONS team began an aggressive southern parallax program under the auspices of the NOAO Surveys Program. Since February 2003, this program has continued as part of the SMARTS Consortium. The observing is done at the CTIO 0.9m (350+ targets) and 1.5m (57 targets) and concentrates on nearby red, brown, and white dwarf targets.

Here we present our first set of definitive parallaxes and highlight discoveries made during the first five years of the program. The total number of new RECONS sample members — systems within 10 pc for which we have the first reliable trigonometric parallax measurements — currently stands at 22. In addition, several new proper motion companions have been identified, and we are beginning to see evidence of perturbations on a few targets.

Multiple systems with periods less than five years are potential targets for our MASSIF (Masses And Stellar Systems with InterFerometry) Project, a SIM Science Team effort that endeavors to determine the mass-luminosity relation in several clusters and for several special target samples. In particular, new red and brown dwarf binaries, new white dwarfs within 25 pc, and new nearby subdwarfs found via CTIOPI will be examined as possible high-priority targets for SIM.

—Coffee Break—

Session 2b

Oral, 3:30pm–5:30pm

2.05 **A suitcase full of astrophysics: The MOST microsat and opportunities for low-cost space astronomy,** *Jaymie Matthews (University of British Columbia)*

The MOST (Microvariability & Oscillations of STars) microsatellite, launched in June 2003 aboard a reconditioned Russian ICBM, houses a 15-cm optical telescope and CCD camera. MOST performs photometry of bright stars ($V < 6$) with precisions as low as 1 micromagnitude, to detect subtle acoustic oscillations in stars and reflected light from exoplanetshas. Despite its low inertia (mass = 54 kg; dimensions $60x60x30$ cm), MOST is achieving a pointing accuracy of better than 1 arcsec rms. This kind of stability on such a small platform and other innovative aspects of the MOST mission design may enable cost-effective approaches to other space astronomy applications, from NEO asteroid detection and tracking to perhaps, astrometry. Given the total MOST budget of about USM, it is worth exploring these other possibilities. I'll describe the distinctive aspects of the MOST design and implementation, present some of the scientific results after a year of operation, and discuss the potential and challenge of applying MOST technology to space astrometry.

2.06 **Origins Billion Star Survey,** *Ken Johnston (USNO)*

2.07 **Precision Astrometry with the Space Interferometry Mission,** *Stephen C. Unwin (Jet Propulsion Laboratory, California Institute of Technology)*

Optical interferometry in space offers the prospect of microarcsecond precision astrometry of stars, enabling a wide range of problems in Galactic astronomy, stellar astrophysics, and planet detection and characterization to be addressed. The Space Interferometry Mission (SIM) will be the first space-based long baseline Michelson interferometer designed for precision astrometry, operating in an Earth-trailing solar orbit for a minimum of 5 years.Launch is currently planned for February 2010.

SIM will be a powerful tool for discovering planets around nearby stars, throughdetection of the stellar reflex motion. The astrometric method complements the radial velocity technique which has already yielded many new planets, and has the additional benefit of measuring planetary masses rather than mass lower limits. In a frame defined by nearby reference stars, the single-measurement precision of SIM will be 1 microarcsecond, enabling searches for planets with masses as small as a few Earth masses around the nearest stars. SIM will be able to fully characterize multiple-planet systems which are now known to exist. It will explore the nature and evolution of planetary systems in their full diversity, including age, by including young (0.5-100 Myr) solar-type stars. The mission will also serve as a precursor for future astrophysics missions using interferometers, demonstrating several needed technologies.

SIM will make global astrometric measurements by observing an all-sky grid of reference stars, anchored by observations of distant quasars. Relative to this frame, SIM will deliver positions and parallaxes to 4 microarcsecond accuracy on stars as faint as 20th magnitude. This unprecedented precision will allow stellar masses and luminosities to be measured to accuracies better than 1%, which is currently very hard. By observing samples of stars in the Galactic halo, SIM will probe the gravitational potential of the Galaxy, and trace its past history of interactions with dwarf companions. Finally, SIM will probe some of the most powerful objects in the universe, through astrometry of the structure of the nuclei of active galaxies.

2.08 **Musings about Future Large Telescopes,** *G. W. Van Citters (National Science Foundation)*

Some thoughts and questions about the nature of future large telescope undertakings, from the scientific case to the sociology of our field. The presentation is designed to raise more questions than it answers and to provoke a continuing dialogue with the community. The history and future of astrometry seems a prime example of many of the points we all must consider in the next decade.

Session 3

Posters and Reception, 5:30pm–6:30pm, in the Rotunda

TUESDAY

Session 4a

Oral, 8:30am–10:00am

4.01 **The Current State of Scientific Imagers for Astronomy,** *Michael Lesser (University of Arizona)*

Charge Coupled Devices (CCDs) have been the favorite scientific imaging detector for astronomical use for several decades. Recent progress has been made in developing several new types of CCDs, as well as other imaging devices such as CMOS imagers. We discuss the current state of scientific imagers and their associated technologies. In particular we will describe the current state of (standard) epitaxial CCDs, monolithic and hybridized CMOS imagers, orthogonal transfer devices and arrays, and deep- and fully-depleted detectors.

4.02 **Experience with SDSS; the Promise and Problems of Large Surveys,** *Robert Lupton (Princeton)*

4.03 **Astrometry, the Virtual Observatory, and Astrophysical Data Mining,** *David Schade (Canadian Astronomy Data Centre)*

Cross-identification of sources of flux across instruments, facilities, and across wavelengths and observation times is a fundamental science procedure. Scientific use cases range from interactive sessions where a scientist is trying to identify a few sources by direct examination of images with catalog overlays, through to the provision of services which produce on-the-fly cross-identifications over the network based on user-defined matching criteria. Obviously, astrometry whose quality (random and systematic errors) is well-defined is the basis for the cross-identification although an astrophysics-based rules system becomes increasingly important in complex situations. The construction of datasets and services for the Virtual Observatory or Astrophysical Data Mining applications requires an automated approach to deal with the scale of the problem and requires that estimates of the reliability of the cross-identification in general and the astrometry in particular be delivered along with the results. Although we would like to have knowledge of astrometry errors in hand before we undertake the cross-identification process, our experience with CFHT cameras and WFPC2 data suggests that the process itself will produce a much clearer understanding of the actual errors as a valuable by-product.

—Coffee Break—

Session 4b
Oral, 10:30am–12:00pm

4.04 **The WIYN Speckle Program: HIPPARCOS Binaries and Beyond,** *Elliott Horch (University of Massachusetts Dartmouth), William van Altena (Yale University), Reed Meyer (RIT)*

Since 1997, a program of speckle observations of binary stars has been in operation at the WIYN 3.5-m Telescope at Kitt Peak. In 2001, a new speckle camera called RYTSI, the RIT-Yale Tip-tilt Speckle Imager, was completed and has been used since that time. Since it collects speckle patterns on a bare (unintensified) CCD camera, RYTSI is capable of determining reliable magnitude differences of binary stars in addition to the precise relative astrometry for which speckle imaging is well-known. The WIYN observing program currently consists of follow-up observations of the HIPPARCOS Double Stars and other targets of occasional interest. The benefits of a sustained program for the mass-luminosity relation and detailed stellar evolution calculations, as well as binary statistics, will be discussed.

4.05 **Extraction of Sub-Milliarcsecond Parallaxes from Hipparos Data,** *Bill Heacox (University of Hawaii at Hilo)*

The 200+ Galactic Cepheids observed with Hipparox have a mean observed parallax of 1.01 mill-arcseconds (mas) and a mean standard error of 1.47 mas; 29% have negative observed parallaxes and only 39% of the positive parallaxes are larger than their standard errors. Direct use of such data to infer distances and luminosities is out of the question. But the Cepheid population is both spatially and kinematically constrained, a source of additional information that allows physically meaningful parallax estimates to be derived, even from the compromised Hipparcos data. A Bayesian model of parallaxes and proper motions, employing standard Galactic and extreme Population I kinematics, has been used to resolve the ambiguities inherent in negative and low signal-to-noise ratio parallaxes of 194 well-identified Hipparcos Cepheids. These kinematically inferred parallaxes pass all tests for statistical bias and significance, and effectively remove all formal probabilities of negative parallaxes. The mean (median) inferred parallax among these stars is 0.83 (0.59) mas, with a mean relative error of ¡sigma/pi¿ = 0.45, a substantial improvment over the raw Hipparcos values. These data have been used to calibrate the Galactic Cepheid Period-Luminosity (PL) relation entirely independently of the Magellanic Clouds. The Galactic PL relation is shallower than that inferred for the Large Magellanic Cloud (LMC), a result that is signficant at the 2-sigma level. Application of this Galactic PL relation to the Hubble Key Project calibrating galaxies implies distances that are, on average, about 9% less than those implied by the LMC PL relation, and a resulting Hubble constant estimate that is correspondingly larger. The use of statistical models such as that used here may be of some value in analysis of data from future astrometric observations, including those of anticipated spacecraft missions; whose observing strategies might be devised accordingly

4.06 **The Astrophysical and Technical Aspects of Astrometric Methods on Hubble,** *Douglas Currie (University of Maryland)*

The astrometric analysis of eta Carinae, the associated homunculus, the surrounding ejected debris field and the inner core region with its more recent ejecta has provided both a wide variety of astrophysical results and a study on the use, methods and accuracy of astrometric procedures, both for the "plane of the sky" and for radial velocity or 3D astrometry, on extended or diffuse objects. From an astrophysical point of view, it has revealed the origin, history and 3D structure of the homunculus that was ejected in the Great Eruption of 1842. Additional information on the structure of the homunculus has been provided by the use of the Fabry-Perot with ADONIS on the European Southern Observatory's 3.6 meter telescope at La Silla, Chile. The analysis of the surrounding ejected debris has yielded information on the history of previous eruptions and may yield information as to the physical nature of these earlier eruptions. The interaction of the debris from various eruptions addresses the current state of the circumstellar media. Finally, recent analysis of the inner core region, using both the UVES spectrograph on the ESO's VLT at Paranal, Chile and the WFPC and the HRC/ACS on HST has yielded a definitive determination of the date of the origin of the Weigelt blobs. It should also yield definitive information on the motion of the inner disk. In general, it has yielded a large body of new information and, in addition, it has also greatly constrained theories and conjectures as to the history, structure, origin and evolution of eta Carinae and its ejecta.

On the other hand, eta CAR has also been a very interesting object for the technical development of astrometric methods for use on diffuse objects. It is bright enough to allow multiple observations to understand the reproducibility of the results without a large penalty for telescope time. It is also bright enough to provide sufficient photons in an acceptable exposure time to obtain a very good signal-to-noise ratio so that other error sources may be quantitatively studied. Finally, the nature of the illumination and scattering of the homunculus is such that there is relatively little change in the apparent structure between the visible (for the WFPC and ACS of Hubble) and the infrared observations by ground-based adaptive optics systems. This allows an on-going quantitative evaluation of the performance of the AO systems and their associated image reconstruction programs.

—Lunch —

Session 5a

Oral, 1:00pm–3:00pm

5.01 **Present and Future Astrometric Study of Halo Substructure,** *Steve Majewski (University of Virginia)*

I intend to focus on how future astrometric surveys might be exploited to the study of substructure in the halo deriving from the disruption of satellite systems. The template of the Sagittarius dwarf spheroidal tidal stream will be used for examples of present and future capabilities in the use of proper motions for finding and exploring substructure, and for exploiting tidal streams for a better understanding of the Milky Way.

5.02 **The Future of Astrometric Education,** *William van Altena (Yale University), Magda Stavinschi (Astronomical Institute of the Romanian Academy)*

The future of astronomy, and in particular astrometric research, is very exciting due to the SIM and GAIA astrometric space missions, which will provide 10–20 microarcsecond positions, parallaxes and proper motions for 10^9 stars. Innovative ground based telescopes, such as the LSST, are planned which will provide less precise data for many more stars. The potential for studies of the structure, kinematics and dynamics of our Galaxy as well as for the physical nature of stars and the cosmological distance scale is without equal in the history of astronomy.

Hipparcos and the HST were astrometric successes due only to the dedicated work of specialists in astrometry that fought to optimize and maintain the astrometric characteristics of those satellites and their data pipelines. It is ironic therefore that given this unparalleled treasure trove of data that in two years not one course in astrometry will be taught in the US, leaving all astrometric education to Europe, China and Latin America. Who will ensure the astrometric quality control for the JWT, SIM, GAIA, LSST, to say nothing about the current large ground-based facilities, such as the VLT, Gemini, Keck, NOAO, Magellan, the LBT, etc.?

We propose a renewal of astrometric education in the universities to prepare qualified scientists for these unique opportunities so that the scientific returns from the investment of several billions of dollars will be maximized. The universities, national and international observatories and agencies should acknowledge their responsibility to hire qualified full-time teachers and astrometric scientists to supervise existing and planned astronomical facilities so that quality data will be obtained. The funding agencies are providing outstanding facilities. Will the universities, institutes and observatories assume their responsibilities?

5.03 **Ensuring the Next Generation of Astrometrists,** *Kathy DeGioia Eastwood (Northern Arizona University)*

What does it take to ensure the next generation of astrometrists? Funding for astrometric projects, and a supply of smart, interested people to carry out the work. In this talk I will argue that outreach is fundamental to meeting both of these objectives. I will discuss why outreach matters, and offer tips on how to get started and achieve success.

5.04 **Parallax Park,** *G. Fritz Benedict (McDonald Observatory)*

We present the design concept for an outdoor, bilingual (English/Spanish) exhibit about astronomical distances and finding extrasolar planets. The exhibit will encourage parents to help their children appreciate science, encourage Spanish-speaking audiences to participate in science, and encourage parents and the public to become more informed and supportive of science.

This exhibit will provide visitors with an opportunity to understand how astronomers use parallax to measure the vast distances encountered in astronomy, to see how extrasolar planets are detected and characterized, to understand that stars have differing intrinsic luminosities, and to appreciate the benefits of space missions over ground-based science for parallax investigations.

This exhibit will provide children with an opportunity to participate in an interactive science activity with their family members and/or classmates. We will share our final design with other institutions with similar missions.

—Coffee Break—

Session 5b
Oral, 3:30pm–4:30pm

5.05 **The SDSS, SEGUE, and the halo of the Milky Way,** *Heidi Newberg (Rensselaer Polytechnic Inst.)*

The current status of SEGUE, the extension of SDSS that targets Galactic stars, will be presented, along with new halo results from the SDSS survey.

5.06 **Astrometric Science and the NASA Vision for Exploration,** *Philippe Crane (Universe Division NASA Headquarters)*

NASA has embarked on a major effort to transform the agency to align its management and missions with the President's Vision for Space Exploration. This presentation will discuss how this may effect ongoing projecst snd how it may effect the future. Current missions relevant to astrometry, SIM, Keck Outriggers, Palomar Testbed, and others will be discussed. The prospect for future missions will also be discussed.

Session 6
Posters, 4:30pm–5:30pm, in the Rotunda

—Conference Banquet - Museum of Northern Arizona—

WEDNESDAY

Session 7a
Oral, 8:30am–10:00am

7.01 **Exoplanets: New Parameter Space,** *Geoff Marcy (UC Berkeley), R.P.Butler, D.A.Fischer, S.S. Vogt*

The 140 known exoplanets span two orders of magnitude in mass, from 10 Jupiter-Masses to 15 Earth-Masses, increasing in numbers toward smaller masses. About 7% of FGK stars harbor Jupiter and Saturn-sized planets within 3 AU. Most known exoplanets orbit beyond 1 AU, and multiple planets are common, many residing in resonances. Planets correlate strongly with the metallicity of the host star. Roughly 10 known planets induce an astrometric wobble of 1 mas, the detection of which would constrain sin i to provide unambiguous planet masses. To date, only Gliese 876 has such an astrometric constraint by HST/FGS (Benedict et al. 2002). With astrometric precision of 0.05 mas, over half of the known planets could be detected, a clear goal for GAIA and SIM. Precision of a few microarcsec permits detection of nearly all known exoplanets, and would determine co-planarity of multi-planet systems. Microarcsec precision opens an unexplored realm of exoplanets: Earth–Mass planets orbiting beyond 0.1 AU, inaccessible to the Doppler method. Two concerns for microarcsec planet detection are the identification of stable reference stars and the confusion from multiple planets around each star.

7.02 **Minor Planets detection and astrometry with CCD frames,** *Alvaro Lopez Garcia (Astronomical Observatory, Valencia Univ.)*

Minor Planets astrometry at Valencia Observatory is carried on since 2001 using CCD frames. Software for CCD field automatic measure has been developed. Sidereal and differential tracking objects can be analyzed.

On the other hand, modern telescopes with robotic operation allow to carry on standard survey programs for detection of variable objects on stellar or galactic fields.

Algorithms for individual and 'mosaic' fields comparison has been developed, allowing the search and detection of objects with different positions or brightness (new asteroids, novae and variable stars) on standard or crowded stellar fields (galaxies and clusters).

7.03 **Asteroid Astrometry,** *Edward Bowell (Lowell Observatory)*

Asteroid astrometry has had a rich history, is enjoying a vibrant present, and promises an outstanding future. I'll give some examples of applications of asteroid astrometry drawn from a variety of astronomical endeavors.

Asteroid astrometry underlies orbit and ephemeris computation. Studies of orbits and their distribution have in the past been used to determine the astronomical unit, the equator and equinox, planetary masses, delineate asteroid families, and enable long-term dynamical studies of the solar system. At present, a number of near-Earth asteroid search programs are providing large numbers of asteroid positions, mostly of relatively poor astrometric accuracy, though sufficient that close to 100,000 asteroids have been numbered. Work is flourishing on asteroid shapes from occultation studies, and asteroid mass determination from asteroid-asteroid encounter perturbations. Over the last decade and more, Doppler/delay radar observations, mostly of NEAs, have complemented optical astrometry, and have recently enabled an elegant investigation of the Yarkovsky effect.

Large all-sky surevy telescopes, such as Pan-STARRS, DCT, and, eventually, LSST, will accelerate the rate of asteroid observation by two orders of magnitude. Within the next decade, good orbits should be secured for 10,000 KBOs, several million main-belt asteroids, and tens of thousands of NEAs. Most of the groundbased telescopic observations will be accurate to about 30 mas. That accuracy will be surpassed by three orders of magnitude when the astrometric satellite GAIA is realized. GAIA's astrometric and photometric data will enable new fields of asteroid study: multi-parameter modeling of asteroids' shapes, light-scattering properties, and rotation; detection and orbital characterization of binary asteroids; greatly improved determinations of asteroid masses, sizes, and densities; and a means of testing general relativity. I speculate that classical methods of orbit computation will become obsolete and will be replaced by the equivalence between astrometric observations and orbital-element probability den sity.

—Coffee Break—

Session 7b
Oral, 10:30am–12:00pm

7.04 **Astrometry with PRIMA/VLTI,** *Sabine Reffert (nee Frink) (Sterrewacht Leiden), Saskia Hekker, Johny Setiawan, Ralf Launhardt, Damien Segransan, Andreas Quirrenbach, Didier Queloz, Thomas Henning*

ESO's PRIMA (Phase-Referenced Imaging and Micro-arcsecond Astrometry) facility at the VLT Interferometer on Cerro Paranal in Chile is expected to be fully operational in only a few years from now. With PRIMA/VLTI, it will then be possible to perform relative astrometry with an accuracy of the order of 10 microarcseconds over angles of about 10 arcseconds. The main science driver for this astrometric capability is a systematic search for extrasolar planets around nearby stars.

7.05 **The challenge of astrometric planet searches - How to find stable reference stars,** *Ralf Launhardt (Max Planck Institute for Astronomy, Heidelberg), J. Setiawan, S. Reffert, D. Segransan, S. Hekker, B. Tubbs, Th. Henning, D. Queloz, A. Quirrenbach*

Precise astrometry is a powerful tool to detect and characterize extrasolar planets, very complementary to radial velocity surveys. In particular, the radial velocity method is restricted to certain types of stars and leaves the inclination angle of the orbit (sin i) undetermined, thus providing only a lower limit to the mass of the planets. Astrometry has a different detection bias, favoring planets in large orbits versus the short-period orbits preferentially detected by the radial-velocity technique. Moreover, astrometry measures two components (right ascension and declination) of the stellar reflex motion versus the single radial component that is observable spectroscopically. To play a significant role, an astrometric accuracy of order 10 microarcsec is needed, which is beyond the performance of current instrumentation (including HST). However, differential astrometry relies on phase reference stars. Target and reference star pairs have to fulfil tight requirements on separation, brightness, distance, physical stellar parameters, and, in particular, on astrometric stability. In preparation of a ground-based astrometric planet search program with PRIMA at the ESO-VLTI, we systematically explore the detection domain for this method, investigate the effects of various astrophysical factors that potentially affect the detection of an astrometric signal due to an orbiting planet, and derive a preparatory observing strategy. Some of our results may also be applicable for other, e.g., space-based astrometric planet searches like the SIM program.

7.06 **PRIMA astrometry operations and software,** *Eric J. Bakker (Leiden Observatory), Bob Tubbs, Andreas Quirrenbach, Walter Jaffe, Rudolf Le Poole, Sabine Frink, Jeroen de Jong et al.*

A search for extrasolar planets using the ESO VLTI PRIMA facility will become feasible in 2007. An astrometric accuracy of 10 micro-arcseconds will allow us to detect sub-Uranus mass planets ($M_Uranus = 14.5M_Earth$) around the most nearby stars, as well as to conduct a planet search around stars of different ages. Most of the PRIMA hardware subsystems are currently being developed by industry. At the same time a scientific Consortium has formed that will deliver the differential delay lines and astrometric software for PRIMA to ESO.

In this paper we describe the planned efforts by the Consortium related to the PRIMA astrometry operations and software". These PRIMA astrometry observation preparation tools" and the PRIMA a astrometry data reduction tools". We describe how all these components fit together in an overall approach to the flow of knowledge within the project. First by quantifying the fundamental limits of the VLTI infrastructure and the targets under study. Followed by elimination or suppression of the errors through either a hardware change to the system, software control of the system, or a proper calibration and observation strategy.

The ultimate goal is being able to calibrate all PRIMA astrometric data acquired over the full lifetime of PRIMA (5 to 10 years) to a uniform accuracy of 10 micro-arcseconds. This will allow identification of long-term trends in the astrometric parameters due to planetary companions around nearby stars and to determine the distances and proper motions for the selected targets.

—Lunch —

Session 8a
Oral, 1:00pm–3:00pm

8.01 **The 8.4m Large Synoptic Survey Telescope: The process from science to engineering concepts,** *Chuck F. Claver (NOAO)*

8.02 **Color Induced Displacement binaries in SDSS,** *Dimitri Pourbaix (FNRS, IAA Universite Libre de Bruxelles)*

The Sloan Digital Sky Survey offers the first coherent multi-wavelength astrometric programme. Measuring the position at different wavelengths makes it possible identify binaries with similar brightness but very distinct colors, the so-called Color Induced Displacement binaries. I will present the results obtained with the 3rd public data release and characterize briefly the spectral type of the stars involved.

8.03 **Science Alert System for Gaia and Similar All-Sky Space Missions,** *Piotr Popowski (MPA, Garching)*

I use the example of the Gaia astrometric mission to discuss the implementation of Science Alert System in a future all-sky observational program of large magnitude. Gaia will observe 1 billion stars distributed over the entire sky down to a magnitude V = 20. Such an ambitious goal will not allow Gaia to be a pointed mission. The Gaia satellite will scan the sky according to a predefined spin and precession, and the time of the next visit will be determined by the technical setup of the satellite rather than a real time decision of astronomers interested in a certain celestial object. As a result, Gaia will find a huge number of fascinating objects which it will not be able to follow or classify. An essential ingredient of the project is how to deal with those discoveries and alert the international astrophysical community about their occurrence in an efficient manner. I discuss several ways to enhance the science alert system. I stress the role of pre-launch variability surveys and post-lunch follow-up facilities in boosting the scientific return of any Gaia-type mission.

8.04 **Stellar Dynamics at the Galactic Center with a Next Generation Large Telescope,** *Nevin Weinberg (Caltech), Milos Milosavljevic (Caltech), Andrea Ghez (UCLA)*

We discuss physical experiments achievable via the infrared monitoringof stellar dynamics in the neighborhood of the massive black hole at the Galactic center with a Next Generation Large Telescope (NGLT). Given the likely observational capabilities of an NGLT and what is currently known about the stellar environment at the Galactic Center, we synthesize plausible samples of stellar orbits around the black hole. We use the Markov Chain Monte Carlo method to evaluate the constraints that the monitoring of these orbits place on the matter content near the black hole. We find that if the astrometric resolution of an NGLT is at least 0.5 mas and the extended matter distribution enclosed by the orbits at 0.01 pc has a mass greater than 1000 Msun, it will produce measurable deviations from Keplerian motion. We also estimate the constraints that will be placed on the black hole's mass and on the distance to the Galactic Center, and find that both will be measured to better than 0.1% for 0.5 mas astrometric resolution. The lowest-order relativistic effects, such as the prograde precession, will be detectable with an NGLT. Higher-order effects, including frame dragging due to black hole spin, requires an astrometric precision of at least 0.05 mas, or the favorable discovery of a compact, highly eccentric orbit. Finally, we calculate the rate at which monitored stars experience detectable strong and weak encounters with background stars. The encounters probe the mass function of stellar remnants that accumulate near the black hole. We find that 10 such encounters should be detected by an NGLT with 0.5 mas astrometric resolution over a ten year period.

—Coffee Break—

Session 8b
Oral, 3:30pm–5:30pm

8.05 **Radio Astrometry: Present Status and Future,** *Edward Fomalont (National Radio Astronomy Observatory)*

Very Long Baseline Interferometry has led in the development of astrometric precision over the last ten years. The International Celestial Reference Frame (ICRF) is defined by a set of 212 quasars whose positions are known to 0.25 milliarcsec accuracy and define the celestial reference frame to 20 microarcsec stability. In the next five years, the ICRF will become more accurate by: reunifying it with the terrestrial reference frame and the the earth orientation parameters; including optical observations and spacecraft navigation; improving the quality and distribution of suitable radio sources; decreasing the effects of source structure evolution; incorporating thousands of additional radio sources as secondary calibrators; observing at higher radio frequencies; utilizing new methods to reduce the ionospheric and tropospheric contamination. Relative astrometry, which determines the motion of individual objects, uses phase-referencing to reach sub-milliarcsec level. With the use of several calibrators, astrometric precision of 10 microarcsec has been obtained. With large telescopes, accurate positions of sources as weak as 50 micro-Jy can be measured. More long-term improvements in radio astrometric accuracy will come from the improved reliability of water vapor radiometers to decrease the effects of the troposphere, with multi-telescope space-VLBI projects with increased resolution and little propagation effects, and from the square-kilometer array which will have the sensitivity and flexibility to reach the one microarcsec level.

8.06 **General Relativistic Effects in High-Precision Astrometry,** *Toshio Fukishima (National Astronomal Observatory of Japan)*

The general relativistic effects will be regarded as the noise to be reduced if the astrometry itself is the target. While they can be thought as the signal to be detected if one want to investigate the gravitational physics. In any sense, they are unique in the sense that they are color-independent, and therefore, their detection is possible only through its variation or difference. I review some recent articles which have discussed the effects in the high-precision (micro arcsecond level) astrometry. The covered topics will be (1) the definition of four-dimensional spacetime coordinate systems, (2) the four-dimensional coordinate transformation among them, (3) the time ephemerides and the conversion fo units, (4) the geodesic rotation and its application to the Earth well known as the geodesic precession, (5) the basic equation of light propagation in a curved spacetime, (6) the analytical and numerical approach to solve them, (7) the equation of light time posed as its boundary-value problem, (8) the formulas of light bending and Shapiro delay as its approximate solution, (9) the discussion of various effects in light bending, and (10) the dynamical effects mainly consisting of the well-known secular advance of pericenter.

8.07 **Changes in Reference Systems and Time,** *P. Kenneth Seidelmann (University of Virginia)*

The International Celestial Reference System (ICRS) has been introduced as recommended by the International Astronomical Union (IAU). This is a fixed reference system that is epoch independent. This is based on Earth kinematics rather than the solar system dynamics. It is implemented by a reference frame, the International Celestial Reference Frame (ICRF), determined from distant radio sources, that are not moving. The optical implementation is based on those Hipparcos Catalog stars, which do not have known problems.

Since most observations are made from the surface of the Earth, which has many motions, it is still necessary to use a moving, time dependent reference frame. There is a new precession-nutation model, IAU 2000A, with sub-milliarcsecond accuracies. Based on the new precession-nutation model, the Celestial Intermediate Pole (CIP) has been introduced to replace the Celestial Ephemeris Pole. A new fiducial point the Celestial Intermediate Origin (CIO) based on the non-rotating origin has been introduced, as a possible replacement for the equinox. Since observations now permit the determination of sub-daily periodic motions in the Earth's pole, arbitrarily all periodic motions with periods less than two days are considered polar motion.

Some additional changes are the introduction of geodesic precession and nutation in the precession-nutation model, the detection of free core nutation, although that is only represented in observational data and not included in the precession-nutation model.

Significantly, there is a proposal to redefine UTC such that there would no longer be leap seconds, but only leap hours. This means that the difference between UTC and UT1 would grow continuously and software and applications would require the introduction of both UTC and UT1 as separate quantities.

There are continuing discussions concerning the definitions and terminology for the some aspects of the new system.

8.08 **The URAT Project,** *Norbert Zacharias (USNO / AD)*

The U.S. Naval Observatory Robotic Astrometric Telescope (URAT) is designed for an automated all-sky survey to provide accurate positions, proper motions and parallaxes on the 10 mas level and below with a limiting magnitude of about R=21. The goal is to extend the optical reference frame beyond the UCAC (USNO CCD Astrograph Catalog) 16th magnitude and provide a direct tie to the defining ICRF extragalactic sources. Access to bright stars (up to 3rd magnitude) is part of the mission. This project will serve DoD needs, provide an accessible, accurate reference frame for other projects like LSST and PanSTARRS, and will have an impact in galactic kinematics studies in the pre-GAIA era.

Optical design studies for the 0.85m aperture, f=3.6m astrometric telescope with a 3 degree diameter field of view are in the final stages. Blanks for the optics will be ordered by end of 2004. The detector development (single chip > 10k by 10k) is under way with an accepted SBIR topic. See also poster paper about URAT optics by Laux & Zacharias.

POSTERS

Sessions 3 and 6, in the Rotunda

1. **Astrometry with ground based CCD Wide Field Imagers,** *Luigi Bedin (ESO - Garching)*

We show the astrometric potential of the Wide Field Imager mounted at the focus of the MPG-ESO 2.2m Telescope. Currently we are able to place a well exoposed star with a precision of 4 mas/frame (under 1" seeing conditions). We present here preliminary results.

2. **Parallaxes with Hubble Space Telescope - How and Why We Do It,** *G. Fritz Benedict (McDonald Observatory), Barbara E. McArthur*

Obtaining absolute parallaxes with Hubble Space Telescope is sort of like making sausage; a lot goes into it, some parts prettier than others. We have established a process whereby ANY information relevant to the final parallax result can be used. The impact of this information is weighted fairly by how well it is known. As an example we describe how we obtained an absolute parallax for three stars in the Pleiades, a somewhat contentious issue, given the discrepancies between the 800 lb (and extremely valuable!) gorilla of Astrometry (HIPPARCOS) and everybody else. For this result we included previously measure proper motions, multi-color photometry, and luminosity class estimates derived from reduced proper motion diagrams. Additionally we constrained the parallax differences among the three Pleiades members by limiting the depth of the cluster. This depth was based on the angular size of the Pleiades and an assumption of spherical symmetry. We find pi(abs) $=7.43 \pm 0.17$milliseconds of arc, in excellent agreement with distances obtained through main sequence fitting.

Other principals in this work included Dave Soderblom (STScI), P.I., Ed Nelan (STScI), and Burt Jones (Lick Obs.) We gratefully acknowledge support from STScI, through grant GO-08335.

3. **Small body occultation predictions,** *Amanda S. Bosh (Boston University), James L. Elliot (MIT)*

Occultations by small bodies require accurate predictions for the purpose of allowing observers to navigate into the shadow path to the extent they are able, either by proposing at the appropriate fixed large telescope, or by navigating an airborne observatory (SOFIA) or portable telescopes into the path. Larger telescopes are important for predictions of events such as occultations by Kuiper Belt objects. We will discuss various aspects of occultation predictions, including field size, limiting magnitude, and astrometric reference networks.

4. **Absolute Proper Motion of the Sagittarius Dwarf Galaxy and of the Outer Regions of the Milky Way Bulge from the Southern Proper Motion Catalog 3,** *Dana I. Dinescu (Yale University), Terrence M. Girard, William F. van Altena and Carlos E. Lopez*

We have determined the absolute proper motion of the Sagittarius dwarf spheroidal galaxy (Sgr) from the Southern Proper Motion Catalog 3, by selecting red giant candidates from the Two Micron All Sky Survey. We obtain $\mu_l \cos b = -2.35 \pm 0.20$ and $\mu_b = 2.07 \pm 0.20 mas/yr$.

Using the same procedure, we also determine the absolute proper motion of the bulge in the region of the sky that overlaps with Sgr. For the bulge, we obtain $\mu_l \cos b = -5.86 \pm 0.14$ and $\mu_b = -0.59 \pm 0.14 mas/yr$, at $l = 7.6°$ and $b = -21.2°$. The absolute proper motions are on the International Celestial Reference System via Hipparcos Catalog stars.

5. **Radiation Damage to Candidate Space Astrometry CCDs: Current Status of USNO Activities,** *Bryan Dorland (US Naval Observatory, Astrometry Dept.)*

I report on the current status of radiation testing and simulation for CCDs for use in future space astrometry missions. CCDs from both Semiconductor Technology Associates (STA) and e2v technology have been irradiated with high energy protons at U.C. Davis' Crocker Nuclear Lab at fluence levels equivalent to five years on-orbit. I describe the subsequent Charge Transfer Inefficiency, Noise, and Dark Current testing, radiation damage mitigation effectiveness, and discuss impacts on future space astrometry missions.

6. **Astrometry With Adaptive Optics,** *Michael Fitzgerald (University of California, Berkeley)*

An overview of advantages, problems, and error sources associated with relative astrometric measurements using Adaptive Optics.

7. **Space Astrometry in the Next Decade,** *Ralph Gaume (US Naval Observatory, Astrometry Dept.)*

Following on the highly successful Hipparcos space astrometry mission of the early 1990s, a number of space astrometry missions have been proposed and planned for the next decade, including DIVA, FAME, Gaia, SIM, AMEX-SMEX, JASMINE, AMEX-MIDEX and OBSS. We will review the astrometric capabilities and status of each of these proposed/planned space astrometry missions.

8. **Transverse Velocity Distribution of the Thick Disk from SPM 3 Proper Motions,** *T. M. Girard (Yale University), V. I. Korchagin, D. I. Dinescu, W. F. van Altena, C. E. Lopez, D. G. Monet)*

Proper motions from the SPM 3 Catalog have been combined with 2MASS near-infrared photometry for a photometrically selected sample of 1200 red giants at the South Galactic Pole. The U,V velocity distribution as a function of distance from the Galactic Plane (z) is well-determined out to its volume-completeness limit of z=3 kpc, i.e., to several scale heights of the Thick Disk.

The stars are found to be distributed exponentially in the z direction with a scale height of about 780 pc, consistent with previous determinations of the Thick-Disk scale height. The U,V velocities are consistent with disk-like motion. The U-component is roughly constant with z, reflecting the peculiar velocity of the Sun. A considerable velocity shear is seen in the mean V-velocity that grows linearly with z. The dispersions in both U and V also show a nearly linear increase as a function of z.

The shear in the V-component is a consequence of the combined disk/halo gravitational potential as it changes with distance from the Galactic plane, together with the increase in the dynamic pressure that results from the growing velocity dispersion. We find that the measured velocity and velocity-dispersion profiles are inconsistent with a Plummer model and with a simple, spherically symmetric, pseudo-isothermal model of the halo potential.

9. **Progress in Parallaxes at USNO,** *Hugh Harris (US Naval Observatory)*

The accuracy of trigonometric parallaxes from the U.S. Naval Observatory has continued to improve. An optical CCD camera is used regularly on the 61-inch telescope. It produces parallaxes with typical errors of ±.5 mas, and can reach ±.3 mas with some effort. The program provides distances, absolute magnitudes, and tangential velocities accurate to a few percent for many white dwarfs and low-luminosity red dwarfs and brown dwarfs. Other classes of special interest being observed are planetary nebulae, cataclysmic variables, dwarf novae, and dwarf carbon stars. Some stars show residual perturbations from a close companion, and the astrometric orbital solutions indicate a brown dwarf or (in a few cases) a possible planetary companion. In addition, a near-IR InSb camera is used for parallaxes of very red L and T brown dwarfs. We discuss the relationship of USNO and other programs, and the prospects for further progress.

10. **Where are the stellar road runners – beep beep – in the sky?,** *Wei-Chun Jao (Georgia State University), Todd Henry, John Subasavage, Thom Beaulieu*

Selecting high proper motion stars is one of the best starting points to search for nearby stars. Therefore, the complete charactarization (photometry, spectroscopy and astrometry) of these high proper motion stars (μ greater than 1 arcsec per year) is essential. We present the current status of this project. 4 stars are the new RECONS samples within 10 pc and 22 stars are within the Nstar 25 pc horizon. New subdwarfs/extreme-subdwarfs are determined not only through the astrometry efforts but the spectroscopic observations. In addition, we also have identified the first two M subdwarf/white dwarf binaries located on the new territory in the HR diagram.

11. **ACS/HRC Astrometry for polarizer filters: to fit or to map?,** *Vera Kozhurina–Platais (STScI), John Biretta*

The Hubble Space Telescope's ACS/HRC camera is optimized for a high resolution (27 mas/pix) allowing us to reach a sub-mas regime in differential astrometry. Here we consider the ACS/HRC astrometric properties through polarizer filters, in case if one would like to compare polarized and non-polarized images of the same target. The geometric distortion of polarizer filters not only has the low- and high-frequency components, as found by Anderson and King for wide-band filters, but also shows a complicated anisotropic structure, tightly correlated with the polarization angle. Thus, instead of a polynomial model, the mapping technique was used in differential mode to correct for distortion, which at the maximum reaches 15 mas. As a result, the post-correction residuals show only a 0.8 mas scatter. At the moment, the ACS/HRC is the only existing imaging instrument capable to deliver sub-mas astrometry in various filters from a single observation, although in a very small field-of-view.

12. **Astrometry with the James Webb Space Telescope,** *Ed Nelan (Space Telescope Science Institute)*

The James Webb Space Telescope (JWST) is an infrared optimized observatory to be launched in late 2011. The short wavelength arm (0.6 to 2.5 microns) of the Near Infrared Camera (NIRCam) will have 32 mas pixels. Combined with the telescope's 6.5 meter segmented primary mirror, NIRCam images will have an angular resolution similar to what is achieved by the Advanced Camera for Surveys (ACS) on HST. Thus, JWST will have the potential for astrometric performance similar to that achieved with HST imaging. Using archived data from HST observations to provide first epoch positions, JWST will be the observatory of choice for measuring the tranverse motions of stars within globular clusters and other crowded fields. JWST can also provide parallaxes for nearby objects too faint (neutron stars, L-dwarfs, e.g.) for SIM and GAIA. However, the most important application of JWST/NIRCam astrometry will be the routine measurement, with a required accuracy of 4 milliseconds of arc, of the position of field stars relative to newly discovered, astrophysically interesting objects. This is needed for precise placement of these objects in JWST's near infrared multiple object spectrograh (NIRSpec) for followup studies.

13. **Astrometric Binaries in the Age of the Next Generation of Telescopes,** *Rob Olling (US Naval Observatory & USRA)*

We analyze several catalogs of known visual and spectroscopic binaries and conclude that a large number of binaries is missing in current catalogs. Samples of the best studied (nearby and bright) stars indicate that the true binary fraction may be as high as 95%.

We estimate the effects of binarity on the error budget of various past and future astrometry missions. The effects tend to be large.

Starting with a sample of Hipparcos stars with parallaxes measured to better than 10% and the period distribution of Duquennoy & Mayor (1991), we generate a fake star catalog that should be fairly representative for stars in the Solar neighborhood. We estimate the masses of the systems based on the observed B-V color, where we apply corrections based on the sample of measured stellar masses in the 6th Catalog of Visual binary orbits. With the periods and masses assigned, we derive the orbital size for all stars in our sample. Positions are derived for these orbits, where the sampling periods and intervals roughly correspond to the Tycho-2, Hipparcos, SIM, GAIA and OBSS mission durations and sampling rates. The scatter incurred as a result of these orbital motions are significant and will contribute to the error budgets. A preliminary analysis indicates that 45% of Tycho-2 stars, 30% of Hipparcos stars and 95% of SIM, GAIA and OBSS stars are/will be significantly affected (assuming a true binary fraction of 100%). Ground-based observing programs will be mostly affected when the observing programs last decades or more, and/or the single measurement accuracies drop below 10 mas.

14. **Are these observations really necessary ?,** *Patricia Lampens (Koninklijke Sterrenwacht van Belgïe)*

In this presentation I will draw the attention to some bright, double and multiple visual systems with interesting, long-period orbits currently lacking high-quality astrometric data. When - for any good reason - a thorough study of these is being undertaken, the importance of of the coverage of the critical phases in the orbit and of follow-up observations should once more be stressed. I will present arguments for resuming astrometric observations of these apparently very classical systems.

15. **Estimating Secular Parallaxes for Young Solar-Type Stars in the FEPS Spitzer Legacy Surveys: The Benefits of Astrometry for "Origins" Science,** *Eric Mamajek (Harvard-Smithsonian Center for Astrophysics)*

The "Formation and Evolution of Planetary Systems" (FEPS) Spitzer Legacy Science program seeks to investigate the evolution of dusty circumstellar disks around solar-type stars between the ages of 3 Myr and 3 Gyr. The FEPS proposal required a large number of young, solar-type stars in nearly equally-filled, logarithmically-spaced, age bins. Well-characterized "post-T Tauri" stars with ages ~3 Myr-100 Myr are rare in the literature, especially those with measured distances (via membership to a cluster/association or trigonometric parallax), and those that were still available to Legacy teams after early target selection by the Guaranteed Time Observers (GTOs). Out of necessity, many FEPS targets were drawn from spectroscopic surveys of X-ray stars in the ROSAT All-Sky Survey (RASS), for which little was known, and fiducial age estimates were made by virtue of Li abundances and activity. Here I describe efforts to further characterize the FEPS RASS population using astrometry. Proper motions (along with radial velocity data) can be used to test whether some young "field" stars actually belong to clusters and associations (e.g. Pleiades, Cas-Tau) with known ages. For young stars without obvious cluster membership, we can estimate their distances using secular parallax. If a star is spectroscopically confirmed to be more Li-rich than the Pleiades (so inferred to be <100 Myr-old), we can estimate a secular parallax using both the star's proper motion, and an empirical velocity ellipsoid model appropriate for stars in this age range. This technique primarily exploits (1) the observation that nearby, <100-Myr-old stars have coherent space motions with a small velocity dispersion (of order ~5 km/s), and (2) the recent arrival of new astrometric catalogs (e.g. Tycho-2, UCAC, USNO-B) which provide accurate proper motions for ever fainter stars. Accurate proper motions can help in constraining that most difficult of stellar parameters, age, and directly benefit the scientific output of "Origins"-themed investigations like the FEPS Spitzer Legacy survey.

16. **The Double-Lined Spectroscopic Binary Haro 1-14c,** *L. Prato (Lowell Observatory), M. Simon (SUNY Stony Brook)*

We report detection of the low-mass secondary in the spectroscopic binary Haro 1-14c in the Ophiuchus star forming region. The secondary/primary mass ratio is 0.310 ± 0.014. With an estimated photometric primary mass of $1.2 M_s un$, the secondary mass is about $0.4 M_s un$ and the projected semi-major axis is approximately 1.5 AU. The system is well-suited for astrometric mapping of its orbit with the current generation of ground-based IR interferometers. This could yield precision values of the system's component masses and distance.

17. **Astrometric Detection of Low Mass Companions with STEPSc,** *Steven Pravdo (Jet Propulsion Laboratory, Caltech), S. Shaklan*

The Stellar Planet Survey (STEPS) is an ongoing astrometric search for giant planets and brown dwarfs around a sample of 32 M dwarfs. We have discovered several low-mass companions two of which have been confirmed with imaging observations. We present herein the STEPS method for centroiding that enables our 1 milliarcsecond relative astrometry. As an example of the results, we briefly describe the discovery of GJ 164B, a low-mass companion that, based on its mass, colors, and spectral properties, has spectral type M6-8 V.

18. **Target selection for planet detection,** *Johny Setiawan (MPIfA)*

19. **43 GHz SiO Masers and Astrometry with VERA in the Galactic Center,** *Loránt O. Sjouwerman (National Radio Astronomy Observatory), Maria Messineo, Harm J. Habing (Sterrewacht Leiden)*

We present Very Large Array (VLA) observations of 43 GHz SiO ($J = 1 \rightarrow 0,\ v = 2$ and $v = 1$) maser emission in a sub-sample of late-type stars in the Inner Galaxy selected on their relatively strong (> 0.5 Jy) 86 GHz SiO masers, and located within $2.5°$ of the galactic center. Furthermore we combine these results with a summary of previous surveys for 43 GHz SiO masers in the galactic center and comment on their use as calibrators for the Japanese "VLBI Exploration of Radio Astrometry" (VERA) network, which is intended to perform sub-milli-arcsecond astrometry in the Galaxy and the galactic center.

20. **Photometric and Astrometric Precision,** *Vladimir Strelnitski (Maria Mitchell Observatory)*

21. **Radial Velocities and Space Motions,** *Arthur Upgren (Yale & Wesleyan Univ.)*

22. **Image Centering,** *Bill van Altena (Yale)*

23. **Astrometry with the OPTIC camera at WIYN,** *Kathy Vieira (Yale University), William van Altena and Terry Girard*

The OPTIC Camera (Orthogonal Parallel Transfer Imaging Camera) installed at the WIYN telescope, consists of two 2Kx4K chips and is able to do orthogonal transfer shifting, that can be used to remove image motion. We study the astrometric precision of OPTIC, and analyze the form and variation of the PSF function along the chips. A preliminary internal reduction of 130 frames of the open cluster NGC188, taken with Johnson-V and Gunn-i filters, produces a single positional accuracy of 0.02 arcseconds. Therefore, we expect to achieve a milliarsecond precision afterperforming a more complete reduction and by combining several frames.

24. **Radio-Optical Reference Frame Link: First results using dedicated astrograph reference stars,** *Marion I. Zacharias (USRA / USNO), Norbert Zacharias (USNO)*

The radio-optical reference frame link program at USNO is part of the UCAC (USNO CCD Astrograph Catalog) project. Between 1998 and 2004 deep CCD images around optical counterparts were observed during over 20 runs at Cerro Tololo and Kitt Peak. Contemporaneously to the deep frames dedicated wide-field CCD frames were taken with the astrograph on the same fields. Data from these special observing did not enter the UCAC2 public catalog. For the first time some of these dedicated astrograph observations are reduced now to provide a reference star catalog for the June 2001 KPNO 2.1m deep frames. Results from the first 2 nights of that run are presented. The astrograph frames are reduced with Tycho-2 stars to give positions on the Hipparcos system for reference star to about R=16.5. From 10 to over 150 such reference stars are available for each of the 10 arcmin wide deep field. The mean standard error of the deep frame reductions is about 25 mas. Positions for 15 optical counterparts are provided. Optical minus radio position differences are on the 10 to 20 mas level for the mean of about 6 deep frames per field.

25. **URAT optical design options and astrometric performance, ,** *Norbert Zacharias (USNO / AD) and Uwe Laux (Landessternwarte Tautenburg, Germany)*

The U.S. Naval Observatory Robotic Astrometric Telescope (URAT) is designed for an automated all-sky survey to provide accurate positions, proper motions and parallaxes on the 10 mas level and below. URAT-type project and telescope was originally envisioned by the late professor Christian de Vegt in the late 1980's, then intended for use with photographic plates.

Here 3 variations on the Richter-Slevogt design are investigated. The systems feature circular symmetric pupils without spider constructions, small optical distortions, highly symmetric images and nearly no color errors in a 3 degree diameter field of view. The most likely design to be built consists of 2 full-size (0.85 m aperture, f=3.6 m) lenses, a primary and secondary mirror, a flat filter and a concave lens as dewar window. Only 2 surfaces (1 lens, secondary mirror) are aspheric. The design is diffraction limited and optimized for astrometry.