Calibration and Standardization of Large Surveys and Missions in Astronomy and Astrophysics

Monday 16 April 2012 - Thursday 19 April 2012

Fermilab

Book of Abstracts

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A Balloon-Borne Light Source for Precision Photometric Calibration

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The ability of type Ia supernova surveys to distinguish among the various proposed theories of dark energy is presently limited by the need to reduce systematic photometry errors to significantly less than 1%. In pursuit of this goal, Stubbs and Tonry (2006) have proposed an approach to photometric calibration that deemphasizes celestial standards in favor of using a NIST-calibrated photodiode as the radiometric standard. We have successfully implemented this technique in calibrating instruments and in accounting for molecular extinction in the atmosphere. We report on the design of ALTAIR, a stratospheric balloon-borne instrument intended to directly measure the aerosol component of atmospheric extinction. ALTAIR lofts a calibrated, polychromatic light source well into the stratosphere, which, when observed from the ground with a dispersive imager, directly reveals the transmission function of the atmosphere at selected wavelengths. The light source employs a bank of laser diodes to excite an integrating sphere which precisely maintains the luminosity ratios among colors across all viewing angles. An onboard photodiode with NIST-traceable sensitivity function monitors the source luminosity.

Summary:

The design and construction of a high altitude balloon-born light source for calibrating out the effects of the atmosphere, and providing 1a supernova photometry beyond the 1% level.

Session 3C / **65**

A Path to NIST Calibrated Stars over the Dome of the Sky

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The UNM Measurement Astrophysics group is currently constructing and testing a mobile instrument suite that includes a multi-wavelength backscatter lidar, stellar spectroradiometer and cameras (visible and thermal infrared) that will provide real-time atmospheric transmission metadata in the column of atmosphere through which the supported telescope is observing. The design, operation and calibration of the lidar (the Facility Lidar for Astronomical Measurement of Extinction - FLAME) and spectroradiometer (the Astronomical Extinction SpectroPhotometer - AESoP) are detailed.

The first task of this instrument suite will be to help create a new set of standard stars radiometrically calibrated to NIST standards. Initially this will be done for bright stars across the wavelength range 350nm to 1050nm at 1nm spectral resolution with measurement accuracy better than 1% per spectral resolution element by calibration to NIST silicon detectors.

Because these standard stars will support both ground- and space-based observations, our proposed evolution of calibration begins with suitable bright optical standards and then adds measurements into the infrared. Following optical/infrared calibration of bright stars we plan to calibrate fainter stars, ultimately to V ˜ 18, both in the optical and near infrared.

Session 4C / **54**

ACCESS: Status, Calibration Strategy, and Design Performance

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ACCESS, Absolute Color Calibration Experiment for Standard Stars, is a series of rocket-borne sub-orbital missions and ground-based experiments that will enable improvements in the precision of the astrophysical flux scale through the transfer of absolute laboratory detector standards from the National Institute of Standards and Technology (NIST) to a network of stellar standards with a calibration accuracy of 1% and a spectral resolving power of 500 across the 0.35 to 1.7 micron bandpass of the cross dispersed (m=1-4) echelle spectrograph fed by a 15.5-inch Dall-Kirkham Cassegrain telescope.

The telescope mirrors have received their flight coatings. Flight detectors have been selected. The detector subsystem has undergone vibration testing. Confirmation of initial detector performance and the detailed ground based characterization of the detector will begin in the next few weeks.

Fabrication, integration, and automation of the ground-based calibration subsystem is in progress.

The ACCESS design, calibration strategy, and ground-based integration and test plans will be presented. Launch is expected within the year.

Nasa sounding rocket grant NNX08AI65G and DOE DE-FG02-07ER41506 support this work.

Session 1D / **12**

Addressing the photometric calibration challenge: explicit determination of the instrumental response and atmospheric transmission functions

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I will present an overview of our ongoing efforts to ascertain (through direct measurement) the both instrumental response function and the variable aspects of atmospheric transmission, in the context of surveys such as PanSTARRS and LSST. We have now gained experience with the use of tunable lasers and NIST-calibrated photodiodes to ascertain the instrumental response function from

multiple telescopes, and have obtained interesting results on stray and scattered light. We have also been operating a spectrophotometric sky transmission monitor for PanSTARRS, and I will present initial results from that system. I will close with some thoughts on next steps in this process.

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Amplitude Calibration at Millimeter and Submillimeter Wavelengths

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The goal of amplitude and flux calibration at millimeter and submillimeter wavelengths is to convert the output voltage or counts from a telescope spectrometer into brightness temperature or flux density. Because the adverse effects of instrumental and atmospheric variations of the detected amplitude grow rapidly with frequency, standard calibration procedures used at longer radio wavelengths are generally not directly applicable at millimeter and submillimeter wavelengths. Furthermore, the design specifications of the Atacama Large Millimeter Array (ALMA) require a much higher calibration accuracy than that achieved by conventional techniques. The ALMA amplitude calibration requirements are: relative amplitude calibration of 1%/3% for frequencies less than/greater than or equal to 370 GHz, absolute amplitude calibration of 5% at all frequencies. These amplitude calibration requirements are much more stringent than those obtained at existing millimeter and submillimeter observatories, which are typically no better than 10%. ALMA's scientific capabilities, including the production of high dynamic range (>1000) images, for example, require better than a few percent accuracy in amplitude calibration, and there are many scientific demands for achieving similarly high accuracy in flux calibration as well. In this presentation we will discuss the amplitude calibration system used for ALMA and its plans for attaining the high standard of amplitude calibration accuracy called for by its specifications. In particular we will review the flux calibration sources which have been considered for ALMA and discuss their strengths and weaknesses. We will present some recent studies of K-M giant stars which are a promising class of flux calibration source for ALMA.

Session 2C / **52**

An Absolute Flux Density Scale from 1 to 50 GHz

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In order to address deficiencies in the flux density scale used in most radio astronomy observations (Baars et al. 1977), we have carried out observations of the so-called "secondary calibrators" from that paper over the past 28 years with the Very Large Array. To establish an absolute flux density scale from 1 to 50 GHz, we use the emission from Mars at frequencies above 5 GHz, and the Baars scale from 1 to 5 GHz. The model for the emission from Mars (Rudy et al. 1988) has been modified to reconcile it with recent WMAP observations (Weiland et al. 2011).

Fourteen sources have been monitored by this program, including the extragalactic sources 3C48, 3C123, 3C138, 3C147, 3C196, 3C286, and 3C295, the planetary nebulae NGC7027 and NGC6572, the evolved star MWC349, and the planets Venus, Mars, Uranus and Neptune, at ten frequency bands spanning the range from 74 MHz to 50 GHz. Three sources – 3C196, 3C286, and 3C295 are shown to be non-variable over the monitoring period to an accuracy of 1%, and we will present polynomial expressions, accurate to ~1% at most bands, for their spectral flux density from 1 to 50 GHz. The observations of the planets other than Mars have been used to modify existing models for their emission, which can take into account time-variability of viewing geometry. These models are of potential use not only for calibration of high-resolution interferometers like the VLA and ALMA, but also for space observatories like Herschel.

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Assessing SDSS spectroscopy via kinematics

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A statistical-parallax analysis of the sample of Chen at al. (2010), which the authors purport to consist mostly of red horizontal-branch stars selected based on SEGUE spectroscopy, shows that the luminosities of the stars of this sample are overestimated, on average, by ˜2 mag in terms of absolute magnitude. This result implies that the sample actually consists mostly of main-sequence and turnoff stars and might be only slightly contaminated by horizontal-branch objects. Hence SDSS surface gravities in the temperature range of RHB stars appear not to allow proper separation of highly and moderately evolved stars, in contrast to the situation with blue horizontal-branch stars identified by Xue et al. (2008) whose absolute magnitudes are found to be consistent with their classification.

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Assessing the photometric calibration of the ASAS survey

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We compare bona fide ncalibrated mean (VI)C magnitudes of several thousand stars found in the CCD frames taken during our photometric observations of Cepheids and RR Lyrae type stars at the South African Astronomical Observatory with the corresponding mean (VI)C magnitudes measured in the course of the ASAS survey to assess the quality of ASAS photometry and derive the appropriate transformation equations.

Session 2D / **18**

Calibrating the PAU Survey's 46 Filters

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The Physics of the Accelerating Universe (PAU) Survey, being carried out by several Spanish institutions, will image an area of 100-200 square degrees in 6 broad and 40 narrow band optical filters. The narrow band filters will each cover 100 Angstroms, with the set spanning 4500-8500 Angstroms. The broad band set will consist of standard ugriZy filters. The team is building a camera (PAUCam) which will be installed in the 4 meter William Herschel Telescope at La Palma in 2013. PAUCam's focal plane holds 18 CCDs; the 46 filters are arranged in a jukebox-like system of filter trays inside the cryostat, such that one filter typically covers one CCD. The narrow band filters will provide low-resolution (R˜50) photometric "spectra" for all objects observed in the survey, which will reach a depth of ˜24 mag in the broad bands and ˜22.5 mag (AB) in the narrow bands. Such precision will allow for galaxy photometric redshift errors of 0.0035(1+z), which will facilitate the measurement of cosmological parameters with precision comparable to much larger spectroscopic and photometric surveys. Accurate photometric calibration of the PAU data is vital to the survey's science goals, and is not straightforward due to the large and unusual filter set. We describe the photometric calibration strategy for the PAU Survey, and the tools we are developing to test the calibration quality.

Session 3C / **42**

Calibration and inter-calibration of the SNLS and SDSS-II supernova survey

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With around 1 thousand type-Ia supernovae populating the Hubble diagram, the uncertainty of the photometric calibration of the survey now limits the precision of the cosmological parameters. We first

present the method used to establish a uniform photometric response of the MegaCam instrument from CFHT used for SNLS. We then present a joint effort of the SNLS and SDSS collaborations to merge the photometric calibration of the two largest supernova surveys to date. Main products are a direct cross-calibration between the two surveys with a precision reaching 0.5%, a better understanding of the survey uniformity, and an improved absolute calibration with a redundant anchoring to the HST white dwarf system. We describe the method, dataset and results and discuss the remaining limitations and their origin.

Session 2C / **58**

Calibration of the Atacama Large Millimeter Array (ALMA)

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Signal calibration at millimeter and submillimeter wavelengths requires the correction of amplitude and phase irregularities at several levels in an observatory system. Measurement calibration of the Atacama Large Millimeter Array (ALMA) requires that the signal amplitude, phase, and polarization be monitored for stability and purity. Instrumental bandpass, antenna positioning, antenna location, antenna and electronic delay, detector system optics, and antenna primary beam response also require regular monitoring and correction. Accuracy and repeatability requirements for each type of instrumental and science measurement calibration are driven by the ALMA science requirements. In this presentation I will give an overview of the ALMA calibration system and will discuss the methods and techniques used to effect calibration of the ALMA observatory system and scientific measurements.

Session 3B / **17**

Calibration of the Bright Sky with APASS

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The AAVSO Photometric All-Sky Survey (APASS) has been underway for over a year. This survey will calibrate the entire sky from 10<V<17 in five filters: Johnson B and V, and Sloan g',r' and i'. Each area of the sky is visited four times during the course of the survey, with two visits at one field center and two visits at a field located center-to-corner from the first so as to have maximum overlap. For bright stars, the photometric accuracy will 0.02mag, and the astrometric accuracy will be 100mas. We have made five data releases to date, covering about 90 percent of the sky with a minimum of two visits. Users can access the current catalog at http://www.aavso.org/apass. The survey will be completed in about two years.

Session 2A / **22**

Calibration of the Far-infrared and Sub-millimetre Instruments of the Herschel Space Observatory

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The Herschel Space Observatory has the largest aperture of any space telescope, with a primary mirror of 3.5 metres in diameter. The telescope is radiatively cooled to below 90K, allowing it to be used for far-infrared and sub-millmetre observation. It has three cryogenically cooled focal plane instruments that cover the wavelength range of 55 to 670 microns. These allow broad-band photometry at 6 wavelengths at 70, 100, 160, 250, 350 and 500 microns using two types of bolometers as well as spectroscopic capabilities at various resolutions up to ˜10ˆ{7} using grating, FTS and heterodyne (AOS and autocorrelation) spectrometers. The observatory provides a centralized coordination of calibration and cross-calibration for all instrument modes through a steering group. In this presentation we concentrate on the calibrators and the modeling of calibrators used for the flux calibration of the photometers and instrument cross-calibration. The linearity and stability of the bolometer responses enables very accurate and repeatable photometry. Further improvements are discussed and examples of the science capabilities and results provided.

Summary:

Overview of the overall calibration and performance of the far-infrared instruments on the Herschel Space Observatory.

Session 4C / **68**

Calibration plan for J-PAS and J-PLUS surveys.

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J-PAS survey consists of an 8000 square degree photometric sky survey with a set of 52 narrow-band and 2 broad-band filters. The main goal is to produce a photo-redshift catalog of ˜15 millions red, early-type galaxies with a precision σ(z)˜0.003(1+z) to measure the Baryonic Acoustic Oscillation (BAO).Such precision requires specific care in the photometric calibration survey. This contribution presents the calibration protocol developed at ceFca for the J-PAS data and to be applied from its first day. An auxiliary telescope 80 cm telescope will perform an initial survey, J-PLUS, available one year before J-PAS, to create a set of flux calibrated stars in all J-PAS fields. Seven reference stars were already chosen to calibrate in flux the J-PLUS survey. J-PLUS 12-filter system was also specifically optimized to retrieve stellar parameters, T, log(g), [Fe/H], through the fitting of flux calibrated models. J-PLUS will be used as the standard network of flux calibrated stars to create synthetic spectro-photometry for J-PAS 56-filter system and to achieve the 2% photometric precision required for BAO measurements.

Session 4A / **55**

Calibration strategy for the SkyMapper Survey

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Skymapper is a survey of the sky south of the equator in 6 bands, u,v,g,r,i,z. SkyMapper's griz bands are similar to those of SDSS while the u band is similar to Stroemgren u, and the v band is similar to DDO 38. It will be conducted over 5 years commencing in late 2012. The first year will concentrate on a shallow coverage (g=8 to 18 mag) of the whole area in photometric weather to provide standard photometry for the deep survey. The system will be calibrated to the AB photometric system using a grid of 9 new STIS spectrophotometric standards, six placed at 4 hour intervals in RA, one circumpolar star and two equatorial stars. We will also obtain new STIS spectrophotometry for 6 northern secondary SDSU standards, to tie the northern and southern surveys together. The spectrophotometric precision will aim to be within 1%, similar to the best of the Calspec fundamental calibrators. The spectrophotometry will be conducted in collaboration with Bohlin, Deustua, Heap and colleagues to ensure that the high precision requirement is achieved.

Summary:

New STIS spectrophotometry, to better than 1%, will be obtained for 15 stars to calibrate the northern and southern surveys. Our goal is to tie photometry in both hemisphere to an absolute spectrophotometric system - This would serve the basis of SkyMapper's photometric system, and is the basis of the calibrations necessary to undertake supernova cosmology experiment to a high degree of precision. Currently, uncertainties in the overall calibration of SN to the fundamental standards is the largest single source of systematic uncertainty in the SN experiments. These data would be used for current SNLS/SDSSII work, as well as SkyMapper, and DECCAM, and eventually LSST calibration.

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Cloud Computing with Context Cameras

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We summarize plans to monitor, calibrate and validate photometric observations with our autonomous, robotic network of 2m, 1m and 40cm telescopes. These are sited globally to optimize our ability to observe time-variable sources.
Wide field "context" cameras aligned with our network telescopes cycle through BVriz filters spanning our optical range every ˜2 minutes, measuring instantaneous throughput (transparency) against Tycho and (occasionally) primary standards. Similar "flash" measurements are made for all science images, but matched against fewer standards in our telescope fields of ˜0.5 degrees.

Summary:

Comprehensive transparency measurements (cf. SkyProbe) can be used to inform and calibrate our data, to characterize, monitor and inter-compare our sites and equipment, and to select photometric periods when traditional calibrations of Target against Standard fields can be optimally and automatically performed.
We summarize our attention to system bandpass measurements including atmosphere, mirrors, filters and detectors, modeled and measured calibrations of our system bandpasses against UBVRI and ugriz standard systems, our attention to baffling and flat-fielding for optimal instrument signature removal,

and preliminary results from our test facility in CA.

Session 1B / **26**

Comments on Optical Photometry and the Generation of Standard Stars

Author: Arlo Landolt[1]

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Comments will be made on situations encountered in the process of observational optical photometry and the establishing of standard star sequences.

Session 4D / **34**

Conference Wrapup

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Posters / **15**

DA-Type White Dwarfs: Soft X-ray Standards for the Calibration of X-ray Instruments

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Thermal soft X-ray emission is detected from many hot hydrogen-rich white dwarfs (spectral type DA) with an effective temperature in excess of 20 000 K. Most of the objects with effective temperatures < 40 000 K have virtually pure hydrogen atmospheres while the majority of the hotter ones emit X-ray fluxes lower than predicted by hydrogen model atmospheres and therefore must contain heavier elements as absorbers.

Although such objects have a relatively soft X-ray spectrum, they are invaluable for the calibration of X-ray instruments. The hydrogen-rich DA-type white dwarfs HZ 43 A and Sirius B with effective temperatures of 51 100 K and 24 900 K, respectively, were used to establish soft X-ray standards: A cross-calibration between the Chandra LETG+HRC-S, the EUVE spectrometer, and the ROSAT PSPC was successfully performed.

The DA-type white dwarf HZ43 A provides, thus, an ideal calibration target for space-borne X-ray missions that cover the soft X-ray range.

Session 1D / **21**

DECal: A Spectrophotometric Calibration System For DECam.

Author: Jennifer L. Marshall[1]

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DECal is a new spectrophotometric calibration system for the CTIO Blanco 4 meter telescope. It is currently being installed as part of the Dark Energy Survey. The system uses a tunable light source to measure the wavelength-dependent instrumental response function of the total telescope+instrument in the range 300<λ<1100nm. The calibration will be performed regularly to monitor changes in telescope throughput during the 5 year Dark Energy Survey project. DECal consists of a monochromator-based tunable light source that is projected on a Lambertian flat field screen using a broadband "line to spot" fiber bundle and an engineered diffuser. Several calibrated photodiodes positioned along the beam monitor the telescope throughput as a function of wavelength. DECal has a peak output power of 2 mW, equivalent to a flux of approximately 800 photons/s/pixel on DECam.

Session 2B / **51**

Defining High-Energy Calibration Standards: IACHEC (International Astronomical Consortium for High-Energy Calibration)

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The International Astronomical Consortium for High-Energy Calibration (IACHEC) aims to provide standards for high energy calibration and supervise cross-calibration between different X-ray and Gamma-ray observatories. This goal is reached through Working Groups, involving around 40 astronomers worldwide. In these Groups, IACHEC members co-operate to define calibration standards and procedures. Their scope is primarily a practical one: a set of astronomical sources, data and results (eventually published in refereed journals) will be the outcome of a co-ordinated and standardized analysis of reference sources ("high-energy standard candles"). We briefly describe here just two of the many studies undertaken by the IACHEC; a cross-calibration analysis of O and Ne line fluxes from the thermal SNR 1E0102.2-7219, and at higher energies a comparison study of a sample of cluster temperatures and fluxes. A more detailed picture of the activities of the IACHEC is available via the information portal at http://web.mit.edu/iachec/.

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Earth's Atmosphere and Climate

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Earth's Atmosphere and Climate

Author: Bruce Wielicki[1]

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TBD (Invited Talk)

Session 2B / **50**

Effect of Calibration Errors on Cosmological Parameter Estimates

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Imperfect calibration of galaxy surveys due to either astrophysical or instrumental effects leads to biases in measuring galaxy clustering. These systematics in turn affect cosmological parameter measurements. More interestingly (and disturbingly), the spatially varying calibration errors also generically lead to violations of statistical isotropy of the galaxy clustering signal. Here I present preliminary results from ongoing work to estimate the effect of calibration errors with arbitrary spatial dependence on the cosmological parameter constraints. Using results from a recently developed end-to-end pipeline to study the effects of calibration errors, I illustrate biases on dark energy and non-Gaussianity parameters using some specific calibration error examples, and outline requirements on the calibration so that it does not lead to appreciable biases in the cosmological parameters.

Session 3C / **7**

Experience with SDSS SN Calibration

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Experience with the SDSS calibration applied to SDSS SN will be described.

Session 4C / **48**

From Hubble's NGSL to Absolute Fluxes

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Hubble's Next Generation Spectral Library (NGSL) consists of R˜1000 spectra of 374 stars of assorted temperature, gravity, and metallicity. Each spectrum covers the wavelength range, 0.18-1.00 μ. The library can be viewed and/or downloaded from the website, http://archive.stsci.edu/prepds/stisngsl/. Stars in the NGSL are now being used as absolute flux standards at ground-based observatories. However, the uncertainty in the absolute flux is about 2%, which does not meet the requirements of dark-energy surveys. We are therefore developing an observing procedure that should yield fluxes with uncertainties less than 1% and will take part in an HST proposal to observe about 15 stars using this new procedure.

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GAIA Calibration

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Session 3A / **30**

High-Precision Wavelength Calibration

Author: Ronald Holzwarth[1]

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Session 1C / **64**

How the Evil Atmosphere Affects Ground-based Astronomy, and How to Correct for It

Author: John McGraw[1]

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Earth's atmosphere is a wavelength-, direction-, and time-dependent turbid medium through which all ground-based telescopes observe. Transmission through the atmosphere is a significant source of systematic radiometric error which can best be obviated by direct, real-time measurements of the column of atmosphere through which a telescope is observing. Using weather and imaging radiometric data we describe and demonstrate the effects that the atmosphere has on wide-field imaging radiometric surveys. We assess the wavelength, angular and time scales on which these absorption and scattering effects operate and estimate the resulting loss of radiometric precision.

We further demonstrate application of a suite of facility-class small instruments that supports wide-area observations by monitoring in real-time the column of atmosphere through which the survey telescope is observing. This instrument suite includes a lidar, a spectroradiometer and optical/infrared cameras.

We assert that application of atmospheric metadata provided by this instrument suite corrects for a significant fraction of systematic errors currently limiting radiometric precision, and provides a major step towards measurements that are provably dominated by random noise, ultimately at the fundamental photon shot noise limit.

Session 4C / **70**

Improvements to the absolute photometric calibration of IRAC

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We have made several significant improvements to the final cryogenic calibration of the IRAC instrument aboard the Spitzer Space Telescope. The final calibration uses the ensemble of calibration data collected over the five-plus years of the cryogenic mission and includes knowledge obtained on intrinsic photometric variations. Photometric variation with location on the array and phase of stellar centroid with respect to pixel center have been characterized and corrected for. The stability of the instrument and large amount of calibration data available permit correction of these effects to better than a percent. The uncertainty in the final calibration is dominated by the uncertainty in calibrating the fundamental photometric calibrators used to provide the zero point of the IRAC photometric system. Planned observations of the calibrators Sirius and 109 Vir will be discussed as well as the current results of several cross-calibration experiments with WISE and HST. This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech

Session 1A / **36**

Logistics

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Session 3B / **71**

Lyra mission: establishing a standard system for stellar photometry

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One of the most important tasks of the Lyra mission is to create a dense all-sky grid of high-precision photometric standards.
The total number of standards should be on the order of several million, and to achieve this goal, more than 300 million stars will be measured in the course of the mission.
The system must contain standards in all ranges of magnitudes from the brightest stars down to 16th magnitude. The low random error will be achieved by providing sufficient signal strength in all passbands and using highly accurate and stable detecting equipment. The random error of measured magnitudes is expected to be 0m.001 – 0m.003 and about 0m.01 for stars brighter than 14th magnitude and fainter stars, respectively.
The system must be free from systematic errors, which are to be minimized by careful ground-based calibration and by maintaining this calibration throughout the mission using an earlier developed method of check measurements.
Standard stars should be non-variable and allow unambiguous transformation of their magnitudes into any other photometric system with passbands in the optical range. Throughout the mission, each program star is to be measured, on average, 100 times in 10 photometric bands, allowing stars exhibiting no variations greater than 0m.001 – 0m.003 to be selected using the correlation method of variability detection (Baltic Astronomy, v.12, p.629, 2003). Photometric data in 10 passbands will make it possible to confidently choose stars whose spectral energy distributions allowi their magnitudes to be transformed from the Lyra system into other photometric systems.

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Model-Atmosphere Spectra of Spectrophotometric Standard Stars - Access via the Virtual Observatory Service TheoSSA

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The German Astrophysical Virtual Observatory (GAVO) provides the registered Virtual Observatory (VO) service TheoSSA (Theoretical Stellar Spectra Access, http://dc.g-vo.org/theossa). It is dedicated to the easy access of VO users to theoretical stellar spectral energy distributions, calculated with any model-atmosphere code.

We show examples for TheoSSA in operation.

Session 1A / **9**

Monitoring atmospheric water vapour at ESO's Paranal observatory

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Monitoring the actual atmospheric conditions under which observations are being conducted is a key task of any ground-based observatory. At ESO's La Silla Paranal observatory parameters like seeing, extinction and coherence time are regularly measured and the observed values are routinely used to make real-time scheduling decisions for service mode based on user-provided constraints. This effort ensures that the astronomical observations - combined with proper instrumental calibration – meet their science objective and hence optimizes the output of the observatory. For survey work which usually consists of service mode observations and for which homogeneity of the output data is crucial such monitoring of atmospheric conditions is all the more important. Precipitable Water Vapour (PWV) is one of the main, and variable, sources of opacity in the Earth's atmosphere at infrared wavelengths. In late 2011 a Low Humidity and Temperature Profiling microwave radiometer (LHATPRO) by Radiometer Physics GmbH (RPG) has been permanently deployed at ESO's Paranal site providing accurate measurements of the column of PWV in real-time. The unit measures several channels across the strong H2O emission line at 183 GHz, optimized for the low levels of PWV on Paranal (median ˜2.5 mm). The radiometer has been commissioned and validated across the range 0.5 - 9 mm demonstrating an accuracy of better than 0.1 mm by comparison with 22 balloon-borne radiosondes and other instruments. We'll preset an overview of the instrument, its performance and operations as well as its integration in the Paranal database for environmental parameters.

Summary:

A water vapour radiometer operating at 183 GHz has been deployed at ESO's Paranal observatory site for high precision real-time monitoring of the atmospheric water vapour content. We'll preset an overview of the instrument, its performance and operations as well as its integration in the Paranal database for environmental parameters. We'll also highlight the value of such an instrument for large surveys in terms of homogeneity of data products.

Session 4C / **11**

Panchromatic Calibration of Astronomical Observations with State-of-the-Art White Dwarf Model Atmospheres

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Theoretical spectral energy distributions (SEDs) of white dwarfs provide a powerful tool for cross-calibration and sensitivity control of instruments from the far infrared to the X-ray energy range.

Such SEDs can be calculated from fully metal-line blanketed non-LTE model-atmospheres that are e.g. computed by the Tübingen Non-LTE Model-Atmosphere Package (TMAP) that has arrived at a high level of sophistication. TMAP were successfully employed for the reliable spectral analysis of many hot, compact post-AGB stars.

High-quality stellar spectra obtained over a wide energy range establish a data base with a large number of spectral lines of many successive ions of different species. Their analysis allows to determine effective temperatures, surface gravities, and element abundances of individual (pre-)white dwarfs with very small error ranges.

We present applications of TMAP SEDs for spectral analyses of hot, compact stars in the parameter range from (pre-) white dwarfs to neutron stars and demonstrate the improvement of flux calibration using white-dwarf SEDs that are e.g. available via registered services in the Virtual Observatory.

Summary:

Theoretical spectral energy distributions of white dwarfs provide a powerful tool for cross-calibration and sensitivity control of instruments from the far infrared to the X-ray energy range.

Session 2D / **8**

Photometric Calibration Strategy of the Dark Energy Survey

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The Dark Energy Survey (DES) is a 5000 sq deg grizY imaging survey to be conducted using a 3 sq deg (2.2deg-diameter) wide-field mosaic camera (the DECam) on the CTIO Blanco 4-m telescope. The DECam is currently in the process of installation and commissioning on the Blanco, with DES operations expected in the second half of 2012. The primary scientific goal of the DES is to constrain dark energy cosmological parameters via four complementary probes: galaxy cluster counting, weak lensing, galaxy angular correlations, and Type Ia supernovae, supported by precision photometric redshifts. Here, we present the general photometric calibration plans for the DES, including a discussion of standard stars and field-to-field calibrations.

Session 4B / **69**

Photometric Calibration for the Large Synoptic Survey Telescope (LSST)

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The Large Synoptic Survey Telescope (LSST) is a next-generation optical astronomy survey facility currently under development. First light is anticipated in 2018, with survey operations officially beginning around 2021. The primary science drivers for the LSST are to understand the nature of dark energy and dark matter, to inventory the small bodies of the solar system (including Potentially Hazardous Asteroids), to explore the transient and variable optical sky, and to map the Milky Way and Local Volume. To simultaneously meet these science goals while providing a rich data set for other astronomical science, LSST will image the entire visible sky (about 18,000 square degrees) every few nights for ten years, across multiple bandpasses (ugrizy) using a 9.6 square degree camera mounted on a 8.4-m telescope.

The photometric requirements for LSST include 5 mmag photometric repeatability (relative measurements, of the same star), 10 mmag photometric uniformity across the sky (relative measurements, between any two stars) and 5 mmag band-to-band calibration. We will meet these requirements using a combination of an auxiliary telescope with spectrograph to measure the atmospheric transmission curve, a tunable laser and NIST-calibrated photodiode to measure the system hardware throughput, and leveraging the hundreds of repeat observations of bright stars in each field to compensate for variable cloud extinction. We will discuss this calibration plan and our simulation results to date.

Session 2C / **63**

Photometric calibration of the Kilo Degree Survey (KiDS)

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The Kilo Degree Survey will cover 1500 sq.deg. in Sloan u, g, r, and i using the OmegaCAM camera on the VST, at ESO Paranal. It is an ESO Public Survey that started October 15, 2011. Its main science driver is dark matter and energy from weak lensing analysis. Photometric calibration of OmegaCAM is based on the combination of (i) a very stable dome calibration unit, (ii) 3 times per night observations of a polar field and (iii) SA fields. A dedicated program until summer 2012 will establish OmegaCAM secondary standards in SA fields. KiDS photometric calibration makes also use of ATLAS, a contemporaneous ESO Public Survey on OmegaCAM. KiDS will be combined with its near-infrared sister survey VIKING (in ZYJHK). Together they will deliver on order 1e8 photometric redshifts out to median z=0.8. KiDS-VIKING is planned as input for Euclid. This is ESA's recently approved optical and near-infrared 15000 sq.deg. survey mission from space.

Session 2D / **41**

PreCam a step towards the Photometric Calibration of the Dark Energy Survey

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The Dark Energy Survey (DES) will be taking the next step in probing the Dark Energy and understanding of the physics of cosmic acceleration. A step towards the photometric calibration of DES, is to have a quick, bright survey in the DES footprint (PreCam), using a prototype of Dark Energy Camera (DECam) CCDs and DES filter set. The objective of PreCam Survey is to create a network of calibrated DES grizy standard stars that will be used for DES nightly calibrations to improve the DES global relative calibrations. We describe the first year of PreCam observation, results and nightly calibration.

Session 2D / **57**

PreCam, the Precursor to the Dark Energy Camera: Instrumentation and First Results

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The Dark Energy Survey (DES) is designed to measure with unprecedented accuracy the time-independent and time-dependent parameters of the Dark Energy Equation of State. Utiliziing the Dark Energy

Camera (DECam), DES will scan 1/4 of the southern hemisphere in order to detect millions of faint galaxies and thousands of supernovae.
In order to measure the brightnesses of these objects accurately, the DECam must be calibrated with standard stars throughout the DES footprint. PreCam, the precursor to the DECam, has already observed millions of stars, and will provide the needed photometric accuracy for a catalogue of standard stars prior to DEcam's first light, thus saving the DES as much as 10% of its scheduled observing time. We describe the PreCam instrument design, construction, and first year of operation, along with some preliminary results that will be incorporated into the PreCam Standard Star Catalog.

Session 1D / **13**

Precision Photometry via Man-made Light Sources, for Optical and for Microwave Astronomy

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Understanding the properties of dark energy via SNIa will require unprecedented photometric precision. Laboratory and solar photometry and radiometry regularly achieve precisions on the order of parts in ten thousand, but photometric calibration for non-solar astronomy presently remains stuck at the percent or greater level. We discuss our project to erase this discrepancy, and our steps toward achieving laboratory-level photometric precision for surveys late this decade. In particular, I will show observations of the balloon-borne light source we are presently testing, in
addition to previous work with a present calibrated source in low-Earth orbit. Our technique is additionally applicable to microwave astronomy. Observation of gravitational waves in the polarized CMB will similarly require unprecedented polarimetric and radiometric precision, and I will briefly discuss our plans for a calibrated microwave source payload as well.

Session 3C / **45**

SI-Traceable Calibrations of Celestial Objects

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I will discuss NIST's effort to create a catalog of SI-traceable spectrophotometric standard stars. Our work builds on advances in optical metrology and atmospheric monitoring made since the previous set of ground-based calibrations were done roughly thirty years ago. NIST's state-of-the art standards at visible wavelengths are now detector-based rather than source-based. I will explain how we calibrate the detector-based standards in the laboratory, how we maintain their calibration in the field, and what their advantages are. I will briefly explain our atmospheric monitoring program, which will be discussed in greater detail by other speakers, and present some preliminary results. My discussion will be in the context of NIST's institutional perspective on calibrations, maintaining SI-traceability, and reporting uncertainties. If time permits, I will outline other NIST activities in support of astronomy.

Session 3C / **46**

SNDice: a Calibration System designed for Wide Field Imagers

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Dark Energy studies with type Ia supernovae set very tight constraints on the photometric calibration of the imagers used to detect the supernovae and follow them up. Among the key challenges is the measurement of the shape and normalization of the instrumental throughput. In particular, it is absolutely vital to control the flux intercalibration of the imager passbands.

The DICE system was developed by members of the Supernova Legacy Survey (SNLS) collaboration, building upon the lessons learnt working with the MegaCam imager. It consists in a very stable light source, placed in the telescope enclosure, and generating compact, conical beams, yielding an almost flat illumination of the imager focal plane. The calibration light is generated by narrow spectrum LEDs selected to cover the entire wavelength range of the imager. It is monitored in real time by control photodiodes.

In this talk, we present the SNDice concept and discuss the main points of the data analysis. Prior to installation, the apparatus was calibrated on a spectrophotometric test bench using a photodiode calibrated at NIST as a primary standard and taking into account any thermal drift of the system. We report on the stability of the light source and the accuracy of this calibration. The calibration frames taken with MegaCam encode a tremendous amount of information, on the focal plane and the telescope optics. In particular, they are polluted by ghosts generated within the telescope optics. We discuss techniques to separate, with a simple simulation, the direct light from the stray light, and constrain the imager passbands.

Session 4D / **73**

SkyProbe: Real-Time Precision Monitoring, in the Optical, of the Absolute Atmospheric Absorption on the Telescope's Science and Calibration Fields

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Mauna Kea is known for its pristine seeing conditions, but sky transparency can be an issue for science operations since some 25% of the observable nights are not photometric, mostly due to high-altitude cirrus. Since 2001, the original single-channel SkyProbe on the Canada-France-Hawaii Telescope has gathered one V-band exposure every minute during each observing night using a small CCD camera with a very wide field of view (35 sq. deg.) encompassing the region pointed by the telescope for science operations, and exposures long enough (40 seconds) to capture at least 100 stars of Hipparcos' Tycho catalog at high galactic latitudes (and up to 600 stars at low galactic latitudes). A key advantage of SkyProbe over direct thermal infrared imaging detection of clouds, is its capacity to derive an accurate absolute measurement, within a few percents, of the true atmospheric absorption by clouds affecting the data being gathered by the telescope's main science instrument. This system has proven crucial for decision making in the CFHT queued service observing (QSO) representing today the majority of the telescope time: science exposures taken in non-photometric conditions are

automatically registered a new observation later on at 1/10th of the original exposure time per pointing in the observed filters in photometric conditions to ensure a proper final absolute photometric calibration. Photometric standards are observed only when conditions are reported stable by SkyProbe. The new dual color system (simultaneous B&V bands) will allow a better characterization of the sky properties atop Mauna Kea and will enable a better detection of the thinner cirrus (absorption down to 0.02 mag., i.e. 2%). SkyProbe is operated within the Elixir pipeline, a collection of tools used for handling the CFHT CCD mosaics (CFH12K and MegaCam), from data pre-processing to astrometric and photometric calibration.

Session 4B / **61**

Spectrophotometry in Space: HST/WFC3 a case study

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TBD

Session 1B / **14**

Standardization and calibration in the variability time domain

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This talk presents a discussion of new and archival photometric measurements of several stars with complex spectral features, in particular the most massive stars (LBV and B[e] single and binary supergiants, WR stars, etc.). The data outline significant systematic differences between all involved systems of photometric measurement. The conclusion of this study is that objects that slowly change magnitude and color are most difficult objects to standardize, especially when data covering years or decades are applied. Sky surveys, with their short lifetimes, are particularly prone to systematic effects.

Session 3A / **47**

The CALIFA survey

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The Calar Alto Legacy Integral Field spectroscopy Area (CALIFA) survey is the largest integral field spectroscopy survey to date. Its goal is to obtain optical 3D spectroscopy data over the entire optical wavelength range for a representative sample of 600 galaxies over a period of 3-4 years. As a legacy survey the data will become public and is suited to address a wide range of different fundamental issues in galaxy evolution. A proper spectrophotometric and astrometric calibration of such a huge data-set is a challenging task given the complex nature of integral field data. Error propagation is also essential for many science applications and needs to be done carefully. I will present the current schemes applied for calibrating the CALIFA data and how we even want to improve in the future.

Session 2A / **59**

The Flux Calibration of Gaia

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I will describe the ESA's Gaia astrometric mission and its scientific potential, briefly reporting on the science performances. Then I will focus on the flux calibration model and on the ongoing ground-based campaign started to build the Gaia spectrophotometric standard stars grid, which requires approximately 200 stars, calibrated to a few percent with respect to Vega, and covering different spectral types.

Posters / **60**

The Gaia-ESO survey astrophysical calibration

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The GES is a wide field spectroscopic survey recently started with the FLAMES@VLT in Cerro Paranal. It will produce radial velocities more accurate than Gaia's for faint stars (down to V˜18), and astrophysical parameters and abundances for ˜100000 stars, belonging to all Galactic populations. 300 nights were assigned in 5 years (with the last year subject to approval after a detailed report). In particular, to connect with other ongoing and planned spectroscopic surveys, a detailed calibration program is planned, including well known clusters, Gaia benchmark stars, and special equatorial fields designed for wide field/multifiber spectrographs.

Session 4A / **56**

The International Celestial Reference Frame System (ICRS)

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The definition of a precise inertial reference frame is fundamental to the determination of the location and motion of objects in the sky (astrometry) and features on the earth (geodesy). Since most observing instruments are on the earth surface or in earth orbit, the earth rotation, motion and crustal distortions add considerable complexity to the determination of astrometric and geodetic parameters.

After the discovery in the 1960's of quasars—bright radio compact objects in the center of giant galaxies that are less than one-millarcsecond (mas) (5 nanoradian) in angular size and exceedingly distant (>10**21 km)—astronomers realized that these objects could form the backbone of the nearly quasi-reference system that was more accurate than previous systems.

The majority of the radio data comes from Very Long Baseline Interferometry (VLBI) that has mas-resolution, and has been incorporated with Global Positioning Satellite (GPS) and Laser ranging technologies. The ICRS is the name of the overall system dealing with the data collection, its analysis and interpretation, and is described here. Nearly forty years of data collecting and its analysis have produced a quasi-inertial reference frame that is stable in direction to about 0.02 mas, positions of thousands of radio sources that are accurate to 0.05 mas, earth orientation accuracy to 0.1 mas, earth rotation accuracy of 0.01 msec, polar motion accuracy of < 1cm, and position/motion of radio telescopes to an accuracy of a about 3 mm per year. The major limitations to the ICRF accuracy are the tropospheric and ionospheric refraction, and the variable structure of the radio emission from quasars.

Session 1A / **44**

The Science of Calibration

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The Science of Calibration

What are the most demanding science drivers for calibration? The answer to this question depends on whether we are referring to absolute calibration, differential calibration, or some variant in between. Our published data, even after calibration, retain some imprint of the instrumentation used to obtain them, yet science should not need to care about such artifacts. In this talk I will take a broad look at the calibration of astronomical data and particularly those that have been generated by or will soon be generated by large surveys, and the requirements on calibration that need to be met if we are to extract the maximal science possible.

Session 1C / **53**

Using GPS to Measure NIR Extinction By Water Vapor

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Absorption by water vapor in Earth's atmosphere is a major impediment to ground-based astronomical measurements in the near infrared (NIR). The problem is exacerbated by the fact that the concentration of water vapor in the troposphere is highly variable, and can change on very short timescales. While differential photometric techniques can partially compensate for this, precise NIR photometry of objects with highly-structured spectral energy distributions remains a challenge. Detailed modeling of water vapor absorption is also crucial for high-resolution NIR spectroscopy. A Global Positioning System (GPS) receiver can be used to estimate the total zenith water column in real time. I will show that data from a GPS receiver can be used to generate theoretical atmospheric transmission templates that can be useful for correcting astronomical spectra for telluric absorption and also for improving the precision of broad-band NIR differential photometry of cool stars.

Session 1A / **23**

Welcome

Session 1C / **20**

aTmcam: A Simple Atmosphere Transmission Monitoring Camera For Sub One Percent Photometric Precision

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Traditional color and airmass corrections can achieve ˜1% precision in photometric observing conditions. A major limiting factor is the variability in atmospheric throughput, which changes on timescales of less than a night. We present preliminary results for a system to monitor the throughput of the atmosphere, which should enable photometric precision when coupled to more traditional techniques of less than 1% in photometric conditions. The system, aTmCam, consists of a set of imagers each with a narrow-band filter that monitors the brightness of suitable standard stars. Each narrowband filter is selected to monitor a different aspect of the atmospheric transmission, including the amount of precipitable water, aerosol optical depth, etc. We present performance modeling results and comparison of narrowband photometric measurements with spectroscopic measurements of the atmosphere; we show that the narrowband imaging approach can predict the throughput of the atmosphere to better than ˜10% across a broad wavelength range.

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"Lyra", a high-precision multicolor photometric stellar survey onboard the ISS

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Sternberg Astronomical Institute of Moscow State University is currently developing the “Lyra” space mission with the aim to conduct a multicolor photometric all-sky survey of stars from 3m to 16-17m onboard the ISS and produce a high-precision photometric catalog of stellar standards. The photometric accuracy of the catalog is expected to be 0.001-0.003m for stars brighter than 12m and 0.01m for fainter stars down to a limiting magnitude of 17m. A total of ˜300 million stars are to be observed over five years in 10 bands spanning the 200 to 900-1000 nm interval and in one broad panchromatic band, with on average 100 measurements per object. The expected launch date is between the end of 2015 and mid 2016.

We describe the implementation of the mission, the expected results, as well as possible ways of ca