SCAR AAA 2021

Wednesday 08 September 2021 - Friday 10 September 2021

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CMB Science / 2

Limits on cosmological b-mode polarization from Spider

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Spider is a CMB polarimeter designed for the Antarctic Long Duration Balloon platform. Spider has completed one flight of the two-flight program. In the first flight, Spider has mapped the astrophysical linear polarization over about 10% of the full sky, with significantly greater sensitivity than Planck HFI in the same region. We report limits to the cosmological B-mode polarization that are derived from a subset of these data, corresponding to about 6% of the full sky, and discuss the plans and prospects for the upcoming flight.

Optical Infrared Radio / 3

Progress of Antarctic Survey Telescopes(AST3) project

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The trio Antartica Survey Telescopes(AST3) project is the second generation optical telescopes designed to run on Dome A. The first two telescopes have deployed and operated at Dome A since 2012 and 2015. The third one is now at domestic commissioning stage at Yaoan observatory in Yunnan province, China. This talk will give some details about the latest progress of the project.

Sites and Technologies / 4

A New Seeing Monitor and Profiler for Eureka, on Ellesmere Island

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Although operations at the Polar Environment Atmospheric Research Laboratory (PEARL) nearby Eureka on Ellesmere Island (80 degrees North) have lately been paused, there is renewed interest in the site for astrophysical observations. I will briefly review known PEARL site conditions, and describe the status of a planned compact instrument for characterization of seeing near the ground, of particular interest for continuously observing low-elevation targets.

Talks 2 / 5

Sky brightness evaluation at Concordia Base, Antarctica

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The study of the sky characteristics plays a fundamental role for many astrophysical experiments and on-ground observations. In the field of solar physics, in particular for the observation of the solar corona, it is required to have a very low sky brightness value.
Currently the only place on Earth with the sky characteristics that allow a continuous coronagraphic measurements is at the Mauna Loa Observatory - MLO (Hawaii, ~3400m a.s.l.).
In the following, we show the results obtained as part of the ESCAPE project in Antarctica. In particular, some of the outcome obtained during the XXXIV and XXXV Italian missions in Antarctica at the Concordia Base (Dome C, ~ 3300m a.s.l.) are presented. The local sky brightness was one of the measured quantities. These data were carried out with a coronagraph (AntarctiCor) designed and built for Antarctic environments and able of capturing, at the same time, images with 4 different polarizations.

Optical Infrared Radio / 6

Superb Astronomical Seeing at Dome A

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Following the installation of two DIMMs at Kunlun Station, Dome A in early 2019, we were able to directly measure astronomical seeing through the winter for the first time. At a height of just 8 meters, the seeing was detected as good as 0.13 arcsec. For 31% time, it was free of boundary layer turbulence, and consequently was the free-atmosphere seeing only, with a median of 0.31 arcsec. We also find that the seeing and boundary layer thickness are correlated with local temperature inversion which is monitored by KLAWS, a multi-layer automatic weather station. Then we confirm that the median boundary-layer thickness is about 14 m, while it is 30 m at Dome C. These results further support Dome A to have the best conditions for optical/infrared astronomy.

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The Analysis of the Snow Mechanics and the Survey Telescopes Tower in Dome A

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Abstract:
Located in the highest point of Antarctic ice cap, Dome A has been considered as one of the best astronomical observatory sites in the world. Some survey telescopes is planning to be installed in Dome A. Unlike any other areas, these telescopes have to be settled on the snow ground. In that case, it is very important to analyze the Snow mechanics,and the deformation of the telescope pier

that mostly is truss tower in Dome A. The presentation firstly introduced the analysis of the snow strength and elastic modulus in Dome A. Secondly,the dynamic and statics analysis of the telescope tower and the dome tower will be shown in this presentation. Based on the design of the towers, the snow treatment and strength test method will be introduced at last.
Key words: Dome A; Snow Mechanics; Truss Tower

CMB Science / **8**

CMB spectral distortions from Antarctica with COSMO: performance forecast

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COSMO (COSmic Monopole Observer) is a ground based differential Fourier transform spectrometer, to be operated at Dome-C, Antarctica, which aims at measuring the isotropic y-distortion of the Cosmic Microwave Background (CMB).
The current upper-limit on y is dated back to 1990 by COBE-FIRAS to $|y| < 1.5 \cdot 10^{-5}$.
COSMO will measure the absolute brightness of the sky in the 120-280GHz range in comparison with a reference blackbody calibrator and will monitor and remove the atmospheric emission, with its fluctuations, by performing extremely fast sky dips while scanning the interferogram.
We assess the performance of the instrument via ILC-based simulations: input multi-frequency maps, deprived of the atmospheric contribution after the procedure, include CMB anisotropy, thermal dust as the main Galactic foreground, and the isotropic y-distortion as $y = 1.77 \cdot 10^{-6}$. The ILC machinery returns the Comptonization parameter as $y = (1.82 \pm 0.31) \cdot 10^{-6}$ when a noise realization, limited by the photon noise from the atmosphere and the cryostat window emission, is included.

CMB Science / **9**

Measuring spectral distortions of the CMB: the COSMO experiment

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The COsmic Monopole Observer (COSMO) is a pathfinder, ground-based experiment, designed for the detection of the isotropic y-distortion of the Cosmic Microwave Background (CMB). Deviations from a pure blackbody are expected as an evidence of all the interactions that CMB photons undergo along the thermal history of the Universe. Their observation provides an insight into processes involving CMB photons that took place both before and after recombination.The upper limit on the y-distortion is still the one from the COBE-FIRAS mission ($y < 10^{-5}$) due to the extreme accuracy required for spectral distortions measurements.
COSMO exploits a cryogenic Martin-Puplett Fourier Transform Spectrometer, comparing the radiation collected from the sky to the one from an internal, cryogenic blackbody reference with high emissivity. All the optical elements of the FTS are maintained at a temperature of 2.7 K to minimize instrument emission. The interferogram is obtained modulating the optical path difference (OPD) with cryogenic, frictionless linear motion of one of the two roof-mirrors. The maximum mirror displacement is ± 25 mm, and it is measured with a resolution of 10μm. This provides a spectral resolution around 5 GHz. A flat spinning wedge mirror, at room temperature, allows to perform fast sky dips along 20° diameter circle in the sky while scanning the interferogram. This strategy enables to measure and remove most of the atmospheric emission and its slow fluctuations. Fast detectors are required, so small multi-mode Kinetic Inductance Detectors (KIDs) arrays ($\tau \sim 50\mu$s), operating in the 120-280 GHz range, will equip the two focal planes.
COSMO will operate from the Concordia station, at Dome-C, in Antarctica, arguably the best site on Earth for this kind of measurements.

Talks 2 / 10

Progress Report of Antarctic 30cm submm telescope

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We have developed a 30-cm submm telescope which was designed to be operated in Antarctica (Ishii et al. 2014). We are planning to transport the telescope to Dome Fuji in Antarctic plateau to make a survey of the Galactic plane in CO(J=4-3) and [CI]($^3P_1 - ^3P_0$). [CI]($^3P_1 - ^3P_0$) is a good tracer of diffuse molecular gas, while CO(J=4-3) is a good tracer of warm and dense molecular gas associated with star forming regions. Since the beam size is ~9' which is comparable to that of the Columbia-CfA 1.2m survey in CO(J=1-0), we can make direct comparisons with the lower excitation CO line to investigate the physical condition of molecular gas. We are updating the 500 GHz SIS receiver using state of the art SIS mixer developed by ATC of NAOJ. The mixer enables us to observe the two lines simultaneously. We also have developed an optical pointing system which can be used in summer of Antarctica, that is, daytime. We will apply for general observational research of National Institute of Polar Research of Japan.

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The Greenland Telescope – Thule Extended Operations

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I will report the progress and the status of the Greenland Telescope in Thule, Greenland. The telescope was commissioned in the spring of 2018, and it had since participated in the global VLBI observation campaign in millimeter and submillimeter wavelengths. The GLT has been a partner station in the Even Horizon Telescope since 2018 for the 230 GHz VLBI observation. In 2021, we have also confirmed the fringe detection with ALMA at 345 GHz. Besides the science observations, the operations in Thule allow us to test many new functions, especially those designed to protect the hardware from the harsh cold environment of the GLT before the telescope is deployed to its final destination near the summit of Greenland. The GLT is to achieve two primary scientific goals: To image/study the shadow of the supermassive black hole in M87 [1] and conduct astronomy research in terahertz frequencies. Since the 12-m ALMA North America Prototype Antenna was awarded to our team, the Academia Sinica Institute of Astronomy & Astrophysics (ASIAA) and the Smithsonian Astrophysical Observatory have entirely rebuilt the antenna from the ground up for operation in the extreme arctic conditions of northern Greenland [2]. The Thule site is our first staging area before moving to Greenland's high site, and we have conducted a comprehensive set of technical tests on the telescope in Thule. We have attained the first light at 230 GHz at the end of 2017 and subsequently participated in global VLBI observations at 86 GHz and 230 GHz. While conducting system verifications and some specific science observations, we have explored and studied moving the antenna to its final destination. The final stage of the project will bring the antenna and equipment 1100 km inland to the 3216m summit of the Greenland ice sheet, where the antenna will be reassembled, tested, and commissioned to take advantage of the arid climate and the northern latitude.
Credits:
The Greenland Telescope Project is led by the Academia Sinica Institute of Astronomy and Astrophysics and the Smithsonian Astrophysical Observatory

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Report of progress on the instalation of an optical robotic observatory at the argentine base Belgrano II

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Our objective is the development of a robotic optical observatory designed to house a 20" telescope with a low focal ratio of abou f/3. Naturally, this project will take advantage of observing at very high latitudes during the southern night. The scientific objectives will be focused on high brightness point sources with valuable information for various areas of astronomy such as Planetary Sciences or Stellar Astrophysics and also on Planetary and Space Defense through the detection of potentially dangerous objects in the Solar System and space junk . This project is part of the National Antarctic Plan, has passed the environmental impact requirements and was elevated to the Antarctic Treaty countries. In this presentation we will detail the characteristics of the observatory and its fundamental motivations, the current state of development, the difficulties encountered in the process and the missing tasks for completion.

Optical Infrared Radio / 13

The impact of the COVID-19 pandemic on ECRs

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This presentation will broadly cover the impacts of the COVID-19 pandemic on students and early career researchers (ECRs) in the Antarctic and Astronomical fields over the past 1.5 years. I will highlight the obstacles many have faced such as graduation/research delays, as well as some new policies that have been introduced that improve access and collaboration. Finally, I will briefly discuss a *Nature* article published in July 2021 on the wider impact to Polar Researchers.

Optical Infrared Radio:2 / 14

Cryoscope, a technology pathfinder for time domain astronomy in the NIR

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The convergence of many new technologies will soon enable high cadence surveys of the infrared sky for the first time. We describe a pathfinder telescope currently under construction, which will demonstrate imaging over a field of view two orders of magnitude greater than previously achieved in the thermal infrared. The novel optical design not only delivers diffraction limited image quality over larger fields, but its double meniscus corrector serves as the entrance window to a fully cryogenic optical path that assures low thermal background. We describe the window manufacturing and support strategies which allow scaling to apertures larger than a meter, and the various methods to prevent ice precipitation. A new, cheaper, growth process for large format infrared detectors is showing promise of making a 600 megapixel NIR focal plane feasible. High speed direct drive telescope mounts, now commercially available, will be upgraded to provide the vibration isolation necessary to take advantage of the exquisite seeing.

Optical Infrared Radio:2 / 15

Unveiling Our Dynamic Infrared Sky

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Many astronomical events shine the brightest in the infrared due to atomic opacity, self enshrouding, dust extinction, or low temperature. When we saw the first electromagnetic counterpart to gravitational waves from a binary neutron star merger, it was the rapid reddening due to bound-bound opacity and infrared spectral features that confirmed the synthesis of heavy elements by the r-process. Unveiling infrared counterparts to neutron star black hole mergers requires sensitive wide-field infrared surveyors. The best place to build a sensitive infrared surveyor is the Antarctic given the extremely low sky background in the K-dark bandpass. Here, we present a fully cryogenic

Antarctic concept for such a dream infrared surveyor that leverages the lower background, advances in detector technology and progress from pathfinder experiments. A companion talk by Roger Smith will describe the enabling technologies in more detail.

Optical Infrared Radio / 16

A Decade of Astronomy at Dome A

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Astronomy work has been carried out at Dome A for more than ten years. The efforts have greatly advanced our knowledge in understanding the site conditions for astronomical observations, the instrumentation under extreme Antarctica conditions, and the research in time-domain astronomy. A complete review is available in Research in Astronomy and Astrophysics (Shang 2020, RAA, 20, 168). We will highlight the major work and results in this presentation.

Science / 17

Science Overview for the IceCube Neutrino Observatory and Future Gen2

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The IceCube Neutrino Observatory is the largest neutrino telescope in the world and uses clear Antarctic ice to detect neutrinos and cosmic rays over an incredibly wide range of energies. The multifaceted experiment runs with over 99% uptime and has been taking high-quality data for over a decade. In my talk I will give a brief overview of IceCube science including real-time efforts in partnership with multi-messenger observatories, the possible first identification of astrophysical tau neutrinos and the recent result of the detection of W boson (Glashow) resonance at the energy beyond reach of the currently operating and future planned particle accelerators. The next generation detector, IceCube Gen2, is designed to do precision neutrino astronomy at high energies. I will briefly discuss the science gain with Gen2.

Science / 18

The radio detection of neutrinos in polar ice

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The low expected flux of cosmic neutrinos drives the need for neutrino experiments with large exposures and lower thresholds. Radio experiments can achieve such large exposures by taking advantage of the coherent broadband radio emission resulting from ultra-high-energy (E>10^16 eV) neutrino interactions. In this talk, I will review the status of existing Antarctic radio experiments and discuss the new Radio Neutrino Observatory in Greenland (RNO-G), which completed the first season of

detector installation in the summer of 2021. The outlook for the IceCube-Gen2 radio array will also be briefly presented.

Talks 2 / **19**

Response Functions of a Semi-Leaded Neutron Monitor from Latitude Surveys during 2018 - 2020

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We have developed a mobile neutron monitor ("Changvan") with three neutron counters to investigate cosmic ray spectral variations via ship-borne latitude surveys. Because Earth's magnetic field excludes cosmic rays below the local geomagnetic cutoff rigidity, which depends on magnetic latitude, the count rate due to atmospheric neutrons from cosmic ray showers vs. cutoff rigidity (i.e., the response function) is directly related to the cosmic ray spectrum. Repeated measurements with the same detector over different solar cycle phases can provide precise information about cosmic ray spectral variations. The Changvan uses the NM64 design, except that the central counter lacks the lead producer, so we call this a "semi-leaded" neutron monitor. The Changvan was operated on two voyages on the Chinese icebreaker "Xue Long" between Shanghai and Antarctica during 2018 – 2020, from which we have measured the response function of each counter. We present a preliminary comparison of response functions from Monte Carlo simulation and Changvan measurements. We find that the leaded/unleaded count rate ratio is sensitive to the cutoff rigidity, and the maximum difference between simulated and experimental ratios was less than 8%. This leads to a promising spectral indicator that could be used to determine the spectral index of relativistic solar ions or Galactic cosmic rays with a single detector. The research is supported in part by Thailand Science Research and Innovation via Research Team Promotion Grant RTA6280002.

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Cosmic Ray Flux Correlation between McMurdo and Jang Bogo Stations

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A neutron monitor is a large ground-based detector responding to the flux of cosmic ray particles in space by measuring atmospheric secondary neutrons. Any ground-based detector is sensitive to cosmic rays from a certain range of directions in space. In particular, a particle arriving from a specific sky direction with a specific rigidity (momentum per unit charge) was necessarily moving in a certain direction in space, called the asymptotic direction outside the geomagnetic field. McMurdo and Jang Bogo neutron monitor stations are Antarctic stations with similar geomagnetic latitude but slightly different geomagnetic longitude. From December 2015 to October 2016, we had transferred six of the eighteen neutron counters from McMurdo to Jang Bogo, with full transfer to Jang Bogo completed in December 2017. We present an analysis of the correlation of the cosmic ray flux between the McMurdo and Jang Bogo stations, during the time when both were operating, with ten-second time resolution. Although highly correlated, there are significant differences, including systematic time lags, in the data from the two stations. Since McMurdo observes a similar asymptotic direction to Jang Bogo with a time delay of approximately 13 minutes, the joint observations reveal structure in the interplanetary cosmic ray density at a unique distance and angular scales. The research is supported in part by TA/RA scholarship (active recruitment) of Chiang Mai University and Thailand Science Research and Innovation via Research Team Promotion Grant RTA6280002.

Talks 2 / 21

RESOURCE Radio Sciences Research on AntarCtic AtmosphEre

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We report the establishment of a Programme Planning Group for developing a SCAR (Scientific Committee on Antarctic Research) Scientific Research Programme (SRP) entitled "Radio Sciences Research on AntarCtic AtmosphEre" (RESOURCE). The proposed SRP aims to gather the communities that investigate the polar atmosphere, with particular reference to Antarctica but with a bi-polar perspective, by means of radio probes into a common shared initiative. The scope is to improve the current understanding of the Antarctic atmosphere by sharing the expertise and the experience achieved by several scientific teams in the world, thus facilitating the advancement in the field and avoiding any duplication of activities already in action. SCAR is the best platform to create the necessary environment to assess the actual current understanding and to address the efforts to fill the gaps. The radio techniques enabled by ground and satellite-based sensors have proved to be very effective when probing the lower, middle and upper atmosphere. In parallel, several scientific communities using radio techniques spent significant efforts to remove (what they consider) "atmospheric noise" to extract the desired information from their measurements (as in the case of geodesy). However, these communities do not sufficiently interact. The RESOURCE SRP aims to take advantage of the experience of the SCAR Expert Group GRAPE (GNSS Research and Application for Polar Environment). The proposed SCAR scientific programme RESOURCE will build upon this important legacy by enhancing interactions between the scientists who measure and utilise the entire radio spectrum, either as an auxiliary or principal observation, to study the atmosphere, the ionosphere, the ocean, the solid earth and outer space as well as ancillary measurements such as from magnetometers which provide supporting data on the solar-terrestrial relationship. Moving from the radio probing of the atmosphere, the proposed SRP aims to encompass the ICESTAR (past SCAR SRP) heritage to fill the current gap of SRPs dedicated to the study of the atmosphere, the

upper atmosphere and the solar-terrestrial relationship. Additionally, RESOURCE is designed to support the SERSE SRP, as a continuation of the experience matured within the GRAPE EG, and the AAA EG to facilitate the interaction between researchers in the fields of Astronomy, Astrophysics, Atmosphere and Ionosphere. RESOURCE outcomes are relevant for global change studies, contributing to the investigation of the coupling between the neutral and ionized atmosphere and supporting a correct evaluation of the atmospheric impact on the measurements of geophysical parameters.
RESOURCE aspires to pursue three main scientific objectives:
1. To monitor the polar atmosphere;
2. To investigate the polar atmosphere;
3. To support the sciences interested in removing the atmospheric contribution from their observations or mitigating the negative impact of atmospheric contributions to their observations.

Science / **22**

Cosmic Ray Intensity and Spectral Changes during 27-day Variations Compared with Heliospheric Parameters Using Time-Delay Measurements from Antarctic Neutron Monitor Stations

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Neutron monitors (NMs) are ground-based detectors of the secondary particles produced in atmospheric cascades from primary cosmic rays. Using neutron time-delay data from neutron monitors (NMs), we can extract the leader fraction, L, of neutron counts that do not follow a previous neutron count in the same counter tube due to the cosmic ray shower. L is the inverse of the neutron multiplicity and serves as a proxy of the cosmic ray spectral index over the rigidity range of the NM response function. We present a comparative analysis of L from four Antarctic NM stations outfitted with special electronics to collect neutron time-delay distributions: South Pole (SP), McMurdo (MC), Jang Bogo (JB) and Mawson (MA). To first order L varies in concert with the count rate C, reflecting unrolling of the GeV-range Galactic cosmic ray (GCR) spectrum as part of solar modulation during the declining phase of solar cycle 24 and during solar minimum. We use wavelet analysis to study the periodicity of L, the count rate C, and heliospheric parameters to consider their relationship with the 27-day variations. Variation in C was much more variable over 27 days due to high-speed solar wind streams (HSSs) and corotating interaction regions (CIRs), also in strong combination with the higher harmonics, while L usually had a very weak variation. Near the solar minimum of 2019-2020, we observed essentially no 27-day variation in C. In contrast, during 2015-2016, near solar maximum, the 27-day variation in L and C was much stronger and fluctuating. Our results indicate weak GeV-range GCR spectral variation due to HSSs and CIRs, relative to the flux variation, in contrast with the strong observed spectral variation due to solar modulation. We acknowledge logistical support from Australia's Antarctic Program and support from the National Astronomical Research Institute of Thailand, grant RTA6280002 from Thailand Science Research and Innovation, and US NSF Office of Polar Programs Award No. 1341312.

Optical Infrared Radio:2 / 23

Observing transiting exoplanets in colors with ASTEP+

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The ASTEP telescope has begun since 2019 an active program to confirm and monitor long-period transiting exoplanets. Its unique localisation at the Concordia station, Antarctica, allows the observation of targets difficult to observe from other latitudes, in particular when close to the celestial South pole or for long-duration transits. This is ideal to follow-up TESS exoplanetary candidates (in majority near the poles) but also for the preparation of JWST and ARIEL as this corresponds to their continuous viewing zones. By following-up exoplanet candidates found by the NASA TESS mission, ASTEP has enabled the confirmation of exciting exoplanets, including the observations of transits lasting more than 8 hours (a first from the ground) and the participation to the discovery of the temperate Neptune-size exoplanet TOI-1231 b. At the end of 2021, a new camera box will be installed, enabling simultaneous observations in two colors. This effectively new instrument, ASTEP+, will thus have the capability to efficiently separate false positive from bona fide exoplanets, in addition to a much increased sensitivity. I will discuss the perspectives of this evolution.

Talks 2 / 24

The micrometeorite flux at Dome C (Antarctica) with the CONCORDIA collection

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The flux of extraterrestrial material on Earth is dominated by sub-millimeter particles, however the mass distribution and absolute value of this cosmic dust flux at the Earth surface is still uncertain due to the difficulty to monitor both the collection efficiency and the exposure parameter (*i.e.* the area-time product in m^2.yr). Thanks to the exceptional conditions encountered in central Antarctic regions, we recently succeeded to measure there the micrometeorite flux down to 30 µm (Rojas et al., 2021).

During the last 2 decades, we performed several field trips at Dome C to recover micrometeorites by melting and sieving large volume of ultra-clean snow using a dedicated protocol (IPEV program #1120, Duprat et al. (2010); Duprat et al. (2007)). The CONCORDIA station is operated by the French and Italian polar institutes (IPEV and PNRA) at Dome C (Antarctica). The regular precipitation rate

and the exceptional cleanliness of the snow at Dome C allow a unique control on both the exposure parameter and the collection efficiency, mandatory to derive the micrometeorite flux.

The thorough inspection of the filters for many years allowed us to recover thousands of particles. Each one was individually imaged by Secondary Electron Microscopy and its bulk composition was determined by Energy-Dispersive X-ray spectra. Micrometeorites were classified in two main types: the unmelted micrometeorites (uMM) that went through the atmosphere without melting and the cosmic spherules (CSs) that have totally melted during the atmospheric entry. Based on the inferred size/mass distribution, we derived the statistical uncertainties expected for collections with exposure parameters ranging from 0.1 up to 10^5 m^2.yr. Within the 30-350 µm diameter range, we measured mass fluxes of 3.0 µg.m^{-2}.yr^{-1} for uMMs and 5.6 µg.m^{-2}.yr^{-1} for CSs. Extrapolated to the global flux of particles in the 12-700 µm diameter range, the corresponding annual mass flux of extraterrestrial dust at Earth surface is 5,200 tons.yr^{-1} (1,600 and 3,600 tons.yr^{-1} of uMMs and CSs, respectively). The flux of altered and unaltered carbon carried by heated and un-heated particles at Earth surface is estimated to range from 20 to 100 tons.yr^{-1}. The results obtained in this study allow to put constraints on the origin of the micrometeorite mass flux (Plane, 2012).

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CMB Science / **25**

CMB spectral distortions measurements at Dome-C: the antenna system of COSMO

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In this work I present the design and forecasted performance of the multimoded feed-horns system of the COSmic Monopole Observer (COSMO). COSMO is a pathfinder experiment that aims at measuring the isotropic y-type spectral distortion of the Cosmic Microwave Background from Dome-C, Antarctica. The current upper limit on the y-distortion is $< 10^{-5}$ (COBE-FIRAS and TRIS).

COSMO exploits a cryogenic Martin-Puplett Fourier Transform Spectrometer to measure the difference in brightness between the radiation collected from the sky and from an internal, cryogenic reference blackbody. To reduce the atmospheric contribution, fast sky-dips at varying elevation are performed through a spinning wedge mirror while the interferogram is scanned by fast, low-noise Kinetic Inductance detectors.

The radiation is coupled to the detectors by two arrays of nine smooth-walled feed-horns working in the $120-180$ GHz and $210-300$ GHz range, respectively. The feed-horns are multimoded to provide a greater throughput and a higher signal-to-noise level than a traditional single-mode receiver, thus increasing the instrumental sensitivity without extending the focal plane.

The antenna design is a trade-off between the multimode requirement on the antenna waveguide, the mechanical constraint on the antenna aperture and the optimization of the antenna directivity within the cryostat aperture window. The arrays are obtained by superimposing aluminum plates made with CNC milling, which is a relatively fast and low-cost manufacturing technique.

Optical Infrared Radio / **26**

Advantage of Space Debris Observation in Antarctica

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Increasing space debris has seriously threatened the safety of spacecraft of various countries. The Pole regions are the most densely distributed regions of Low-Earth orbit space debris, and are ideal sites for observing LEO space debris. Investigating Antarctica as a window to the skies for satellite traffic management has been identified as an important goal for Antarctic Astronomy in the proposal of ASTRO Sciences to SCAR. For the first step, we systematically evaluated the performance of space debris observation at Kunlun Station in Antarctica by revisiting archived data taken in polar night, yielding high detection capability and efficiency in comparison with and numerical simulations. In this year, we plan to deploy small telescope array and carry on small scale survey of space debris as further experiment at Zhongshan Station in Antarctica. In this talk, we will also report the preliminary results of site testing taken at Taishan Station, which is almost in halfway from Zhongshan to Kunlun Station, and the development of logistics in CHINARE.

Optical Infrared Radio:2 / **27**

Rare Transits Observed by ASTEP from Antarctica

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The Transiting Exoplanet Survey Satellite was launched in 2018 to search the sky for planetary candidates. Of the 870+ southern planetary candidates from TESS currently awaiting confirmation, roughly 10% have transit durations longer than five hours; a further third of these have orbital periods longer than 20 days. Systems like these could fall into the sparsely populated parameter space of long-period gas giants; but long transits that happen infrequently present an observational challenge from the ground. Not so for ASTEP, a 40cm telescope installed at Dome C in Antarctica. ASTEP's proximity to the South Pole means that it enjoys outstanding photometric conditions, as well exceptional phase coverage due to uninterrupted observing during the Austral Winter. In this talk I will share some results from ASTEP's first seasons of SG1 observing, including uninterrupted 10 hour-long transits, TTV monitoring, and the first ever ground-based transit of a circumbinary planet. I will also show that ASTEP has the potential to make a significant contribution to ephemeris refinement for upcoming missions such as JWST and Ariel.

Sites and Technologies / **28**

Wind turbines for the high Antarctic plateau

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At the University of New South Wales we are designing a wind turbine for the conditions found at China's Kunlun Station at Dome A in Antarctica. While Dome A is the least windy place on Earth, renewable energy from the wind is still possible and has many advantages over the diesel engines that are typically used: for example, wind energy reduces the need to transport and store fuel while reducing pollution and lowering maintenance requirements. Our baseline design is a horizontal axis wind turbine with three 6m long fixed-pitch blades and a 21m monopole tower. A 10kW alternator is driven directly from the hub. We anticipate a yearly average power of 1kW. Both the tower and blades will be made of carbon fibre due to its excellent structural properties even at low temperature. All components must be chosen to work at low temperature and optimised for the low wind speeds that are found at Dome A. We are also considering ease of construction, installation, and maintenance.

Science / **29**

The IceCube Surface Array Enhancement - A comprehensive overview of the planned cosmic-ray surface detector at the South Pole

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The IceCube Neutrino Observatory is a Cherenkov light detector located deep in the Antarctic ice. A cosmic-ray detector at the surface, named IceTop, composed of Ice-Cherenkov tanks complements the in-ice detector. A Surface Array Enhancement for the IceCube Neutrino Observatory is planned to be deployed in the near future at the South Pole. It will consist of 32 hybrid stations positioned within the current IceTop footprint. Each station of the surface enhancement has one central hybrid DAQ connecting 8 scintillator panels and 3 radio antennas, all elevated to avoid snow coverage. The surface enhancement will considerably increase the detection sensitivity to air showers in the

~100 TeV to EeV primary energy range, mitigate the effects of snow accumulation on the existing IceTop tanks, and be the first step of a future large-scale surface array of IceCube-Gen2 using the same technology. The DAQ and its related components are designed to be easily integrated into the already existing computing, timing, and communication infrastructure of IceCube. In January 2020, a complete prototype station comprising 8 scintillator panels and 3 antennas was deployed and is continuously operating. In this talk, we will try to give a comprehensive view of the development, deployment, and maintenance of a remotely accessible detector and will present some results of the first cosmic-ray induced air-showers detected by the prototype station. We will conclude with an outlook on the scientific prospects of the IceCube-Gen2 surface array whose design builds on the successful experience with the prototype station and extends the planned surface enhancement of IceTop.

CMB Science / 30

Instrumentation and Polar Infrastructure Development Supporting the BICEP Array Telescope

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Measurement of the polarized Cosmic Microwave Background (CMB) over the past few decades has enabled precision probes of the evolutionary history, composition, and dynamics of the primordial Universe. Next-generation CMB experiments will extend this scientific reach, allowing for tests of the inflationary theory of the early Universe, driven through constraints on the tensor-scalar ratio "r" via the search for primordial B-mode polarization. The BICEP Array telescope program is targeting observation of B-modes at large angular scales, building on constraints already placed by the BICEP/Keck program. BICEP Array comprises four BICEP3-class receivers which will operate in conjunction with BICEP3 at 30/40, 95, 150, and 220/270 GHz. The 30/40 GHz receiver was deployed to the Amundsen-Scott South Pole Station during the 2019-2020 Austral summer. With all receivers deployed, BICEP Array will measure primordial gravitational waves to a precision of $\sigma(r)$ between 0.002 and 0.004 after a full three years of observations, with over 30,000 detectors on the sky. This talk will provide an overview of the instrumentation design of the BICEP Array telescope, and infrastructure in development that will enable a sustainable future for BICEP Array and next-generation CMB science at the South Pole.

Optical Infrared Radio:2 / 31

The One-meter Polar Large Telescope (PLT) prototype for Concordia

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Following the ANGISS 2.5m off-axis telescope project, presented at the AAA-2015 conference, we propose to build a 1m prototype for 2.5m PLT. Such an optical design is based on a common 2.5m off-axis primary mirror delivering two science cases modes: (1) two mirror corrector optimized to a wide FOV (1Deg) for IR survey and (2) one mirror corrector optimized for a narrow FOV for direct

exoplanet detection. This 1-m proof-of-concept prototype will access and validate the off-axis PLT technical feasibility and IPEV logistics for larger telescope.

Optical Infrared Radio / **32**

China's Kunlun Station is an extraordinarily good site for deep infrared surveys

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At any infrared/THz wavelength longer than about 2.3 microns, China's Kunlun Station in Antarctica has very possibly the darkest sky and best conditions - seeing, cloud coverage, atmospheric stability, transparency - of any site on Earth. This directly translates into dramatic improvements in survey speed and depth. In the near-infrared, the Kdark region just longward of 2.3 microns is particularly favourable, with flux from the night sky and telescope being factors of around 50 times less that temperate-latitude observatories. The Nanjing Institute of Astronomical Optics and Technology has an Antarctic-rated 0.5m telescope ready to go, the Australian Astronomical Observatory is building the camera cryostat, the UK Astronomical Technology Centre is integrating the detector system, and the University of New South Wales is designing the support electronics and power supplies. Together, these contributions form the Kunlun Infrared Sky Survey, which will explore new regions of parameter space and act as a pathfinder for even more ambitious projects that can be undertaken nowhere else on Earth.

Science / **33**

Technical Advances towards the IceCube-Gen2 Neutrino Observatory

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IceCube-Gen2 is a planned extension of the IceCube Neutrino Observatory at the geographic South Pole. Gen2 is optimized to search for sources of astrophysical neutrinos from TeV to EeV energies. IceCube-Gen2 builds on a successful decade of scientific observations with IceCube. The observatory will utilize optical sensor modules integrated into the deep ultra-clear Antarctic ice for the detection of Cherenkov light from neutrino interactions, surface detectors on the ice for the detection of cosmic-ray air showers, and an extended radio array for sensing of ultra-high-energy neutrinos. The presentation will review future IceCube technologies and infrastructure. Technologies for the construction and operations of the Gen2 detector will be described, with a particular emphasis on sustainability and resource optimization.

Talks 2 / **34**

A proxy for decadal solar cycles from AD 1600 to 1900 based on nitrate concentrations in a Dome Fuji (Antarctica) ice core

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Ice cores yield information about astronomical phenomena as well as information about climate changes of the past. We applied time-series analyses to variations in nitrate ion concentrations in one segment of an ice core drilled at the Dome Fuji station in East Antarctica, corresponding to the historical period from AD 1600 to 1900. Our analyses revealed clear evidence of periodicities of ~ 11 years, ~ 22 years, and ~ 90 years, comparable to the 11-year Schwabe, 22-year Hale, and to the ~ 90-year Gleissburg solar cycles, respectively. Our result thereby shows for the first time that nitrate ion variations in an ice core can certainly be used as a proxy for past solar activity on a decadal time scale. This finding may be attributed to the advantage of precipitation environment of the Dome Fuji site. Furthermore, we found an 11-year periodicity in the nitrate ion variations even during AD 1645 – 1715, the period of the grand Maunder minimum when sunspots were almost not observed. Although our evidence for an 11-year periodicity during the Maunder minimum is less strong statistically than that for the periods from AD 1600 to 1645 and from AD 1715 to 1900, the discovery of the 11-year periodicity during the Maunder minimum was unexpected. This discovery may indicate that an 11-year periodicity existed in solar UV radiation even during the Maunder minimum and reconfirms the observation that the solar dynamo retains cyclic behavior even during grand solar minima, as suggested by studies of 10Be content in ice cores.

Science / **35**

Update on the IceCube Upgrade Project

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The IceCube Neutrino Observatory at the South Pole is the leading facility worldwide for scientific exploration in the field of neutrino astrophysics. A more densely instrumented infill array, IceCube DeepCore, was added during construction to lower IceCube's energy threshold where it could exploit the massive volume of exceptionally clear ice at the bottom of IceCube to enable competetive measurements of neutrino oscillation parameters. More than ten years after the last IceCube string was deployed, the IceCube Collaboration has embarked on a further Upgrade to the detector consisting of seven more strings of advanced photodetectors to infill DeepCore, with sensitivity greater than current and near future experiments to detect hints of new physics beyond the best model of elementary particles that has stood for over a half a century. Exploiting the opportunity provided by a restart of deep-ice drilling at the site, new calibration devices will accompany this instrumentation and will provide data for better modeling of the optics of the deep glacial ice. Incomplete current knowledge of the ice introduces systematics in IceCube that limit its precision for neutrino astrophysics. Improved ice models can be fed back into reprocessing more than a decade and a half of archived data to provide neutrino skymaps and other data products with significantly improved resolution.

Optical Infrared Radio:2 / **36**

Report from the French Polar Institute

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