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ABSTRACT

The Observatorio Astronómico Nacional on the Sierra San Pedro Mártir (OAN-SPM) in Baja California, Mexico is currently undergoing a substantial expansion in its observational infrastructure. The OAN-SPM's three principal telescopes were installed in the 1970s. In 2015, the BOOTES-5 telescope was installed and is now operational (partners: Mexico, Spain, South Korea). In 2011 the construction of the TAOS-II project begun and its three telescopes are now in commissioning (partners: Taiwan, Mexico, USA, Canada). Also undergoing commissioning are the COATLI and DDOTI projects (both: Mexico, USA). Two projects, COLIBRÍ and SAINT-EX are about to begin construction (COLIBRÍ: Mexico, France; SAINT-EX: Switzerland, Mexico, UK). Finally, the Telescopio San Pedro Mártir project is advancing through its design phase (partners: Mexico, USA). All save the TSPM are fully funded, so the OAN-SPM will host 11-12 telescopes by the 2020's, ranging in size from 28cm to 6.5m.

Keywords: observatory, OAN-SPM, telescopes

1. INTRODUCTION

The Observatorio Astronómico Nacional (OAN) as it exists today was established in 1878 by presidential decree. It was first set up in the Castillo de Chapultepec in Mexico City. A few years later, it was moved beyond the then capital to the nearby town of Tacubaya where it remained until the early 1950s. In 1929, when the Universidad Nacional Autónoma de México (UNAM) received its autonomy from the federal government, it was entrusted with maintaining and developing the OAN on behalf of the nation. Long before the OAN's subsequent move to the town of Tonantzintla, near the city of Puebla, the light pollution from Mexico City made astronomical observation in Tacubaya impossible. Although Tonantzintla served as the main observing station of the OAN for only a relatively short time, it was a tremendously productive period. Nonetheless, by the early 1960s it was clear that the OAN needed to establish another research station in a location with dark skies if it was to remain competitive as an observatory. In the mid 1960s, a concerted effort was made to identify the most suitable locations within Mexico considering not only the availability of clear, dark skies, but also the likelihood of their remaining so for decades to come. By 1967, the Sierra de San Pedro Mártir (SPM) in Baja California had been identified as this most suitable location (see Figure 1). That year, work began on the road to the present installations at the OAN-SPM and by 1970 the first permanent building at the site (cabaña roja) and first telescope (1.5m Harold Johnson Telescope) were built. The following year, the second telescope (0.84 m telescope) was brought into operation. By the mid 1970s, plans were afoot to construct the 2.1m telescope, which was inaugurated in 1979 and remains the largest telescope at the OAN-SPM. In 1967, the OAN officially became the Instituto de Astronomía of the UNAM (IA-UNAM) and is the institution that runs the SPM and Tonantzintla stations of the OAN.

The OAN-SPM is located within the Parque Nacional Sierra de San Pedro Mártir (PNSSPM; a national park) as a result of a presidential decree in 1975. The PNSSPM itself had been established by presidential decree

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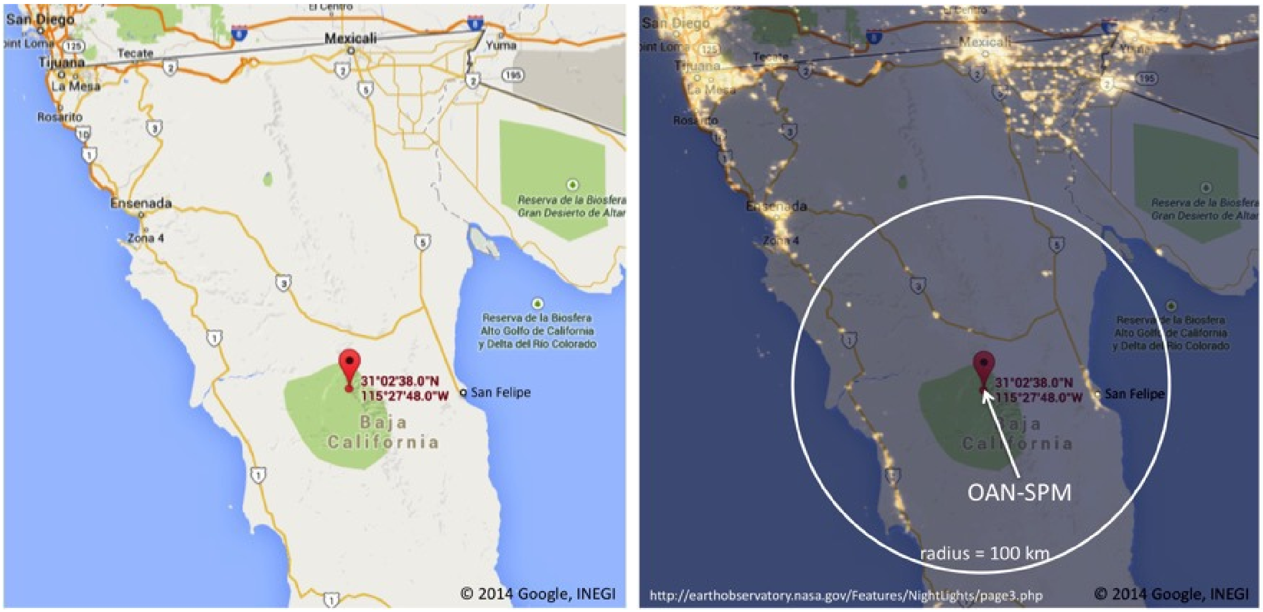

Figure 1. The OAN-SPM is located in northern Baja California on the highest mountain range in the state. As the right panel shows, it is still a dark, isolated location.

in 1947. The OAN-SPM participated in drafting the management plan for the PNSSPM that was published in 2009. This management plan was complemented in 2012 when a perimeter containing 3048 ha surrounding the OAN-SPM were legally reserved for astronomical use through an agreement between the UNAM and the Comisión Nacional de Áreas Naturales Protegidas (CONANP), part of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

International collaborations have long been a part of the OAN-SPM. The first telescope installed at the OAN-SPM was a collaboration between the IA-UNAM and the University of Arizona (UA), motivated largely by Harold L. Johnson. Since then, many projects have been carried out in collaboration with international partners. At present, three operating instruments are hosted at the OAN-SPM as a result of collaborative agreements with the Observatorio Astronomico di Brera (Boller & Chivens spectrograph), the University of Manchester (Manchester Echelle Spectrograph; MES), and a collaboration involving the IA-UNAM, University of California, Arizona State University (ASU), and the NASA Goddard Space Flight Center (Reionization And Transients InfraRed project; RATIR). The BOOTES-5 telescope was installed in 2015 as a collaboration between the IA-UNAM, Spain's Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) through the Instituto de Astrofísica de Andalucía, and the Sungkyunkwan University in South Korea. Two projects are in commissioning: The COATLI project is a collaboration with ASU while the DDOTI project is a collaboration with ASU and University of Maryland. Currently, the IA-UNAM is building a variety of international projects: The TAOS-II project is a collaboration with the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), Harvard's Smithsonian Astrophysical Observatory (SAO), and the Canadian Astronomy Data Centre (CADC) of the National Research Council of Canada (NRC-CNRC). The SAINT-EX project is a collaboration with the University of Bern, the National Center of Competence in Research PlanetS, and the University of Geneva, all from Switzerland, and the United Kingdom's Cambridge University. The COLIBRÍ project is a collaboration with France's Centre National d'Etudes Spatiales, the Centre National de Recherche Scientifique, the Institut de Recherche en Astrophysique et Planetologie, and Aix Marseille Université. Finally, the TSPM project is a collaboration of Mexican institutions, led by IA-UNAM, the Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE) and the Consejo Nacional de Ciencia y Tecnología (CONACyT) in partnership with SAO and UA.

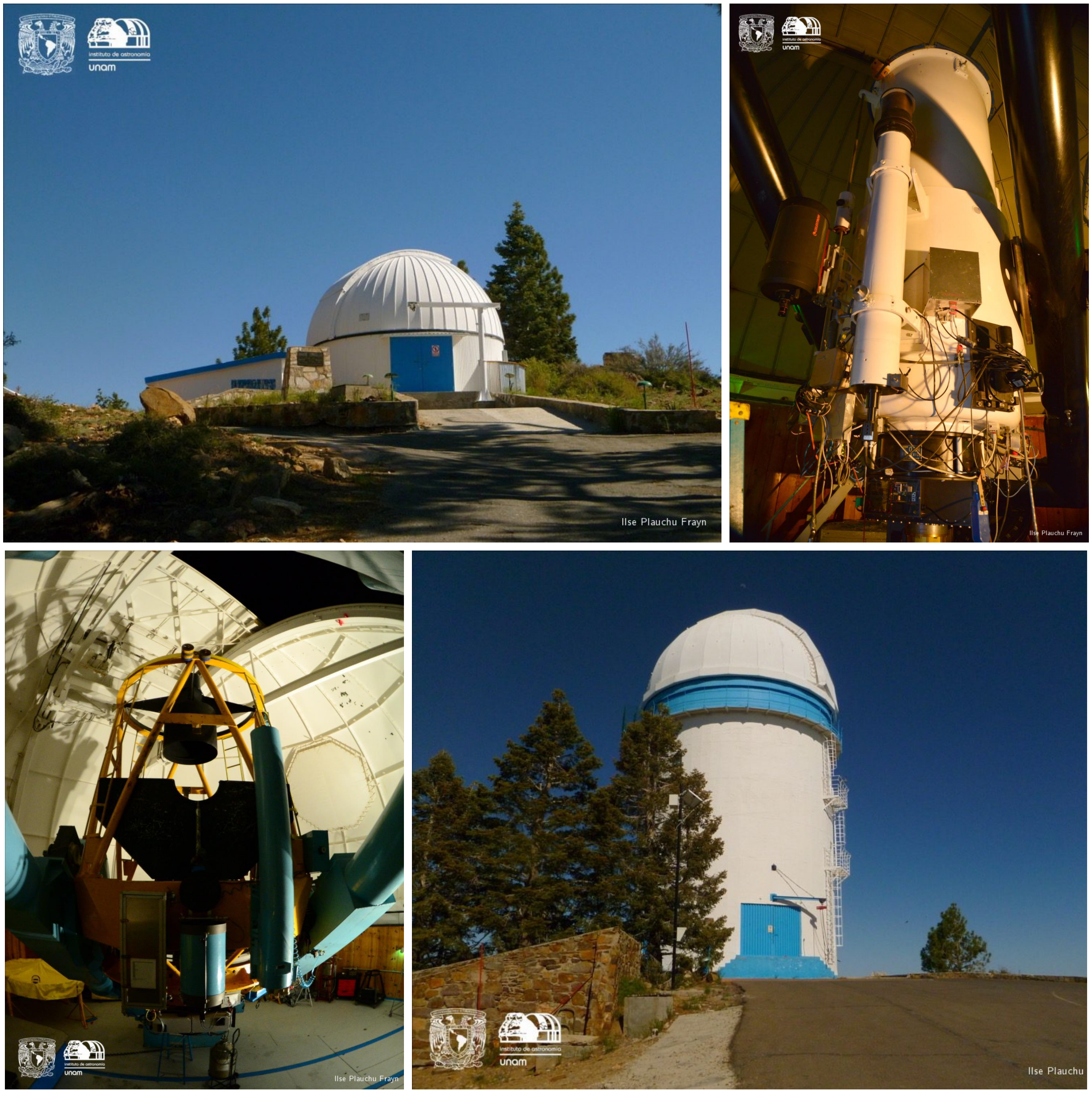

Figure 2. These photos show the Harold Johnson Telescope building, the 0.84m telescope, the 2.1m telescope, and the 2.1m telescope building.

2. ESTABLISHED TELESCOPES

The three oldest telescopes at the OAN-SPM are the 1.5m (Harold Johnson Telescope), 0.84m telescope, and the 2.1m telescope, installed in 1970, 1971, and 1979, respectively. All of these telescopes have been greatly modified over the years, in particular as regards their instrumentation and control.

The 0.84m telescope is mostly dedicated to imaging, polarimetry, and stellar photometry. It is still used in classical mode, with visiting observers operating the telescope and instruments directly. The 1.5m telescope was converted to robotic operation[1] in 2011 to be used with the RATIR instrument.[2] Since then, it has been one of the most productive terrestrial telescopes in following up gamma-ray bursts. The 2.1m telescope, which is also still used in classical mode, is primarily dedicated to spectroscopy, serving three instruments,[3,4] but is also used

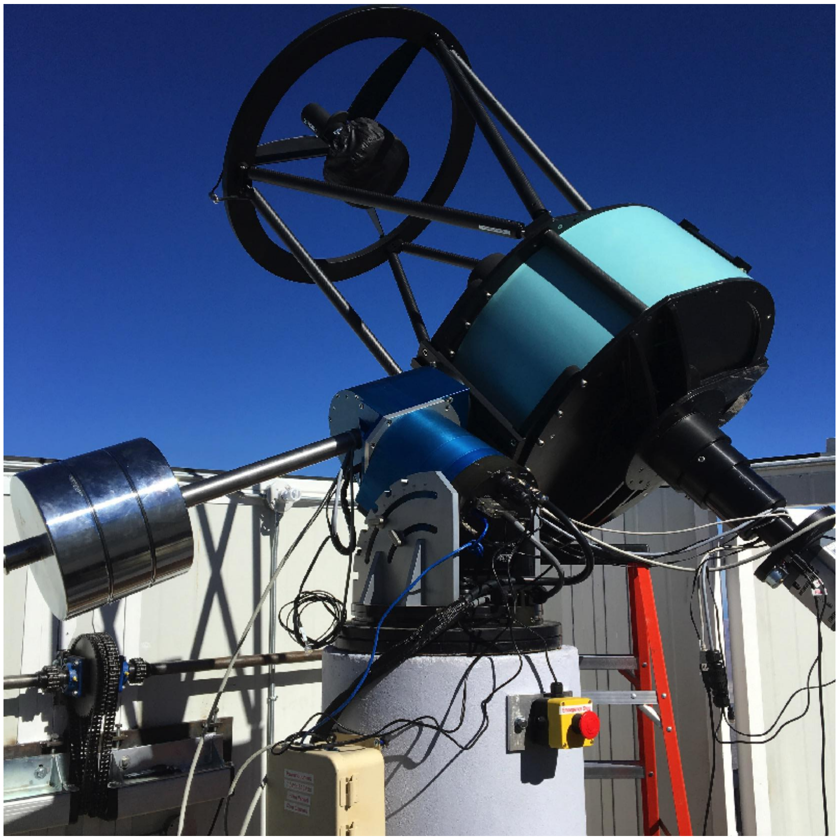

Figure 3. BOOTES-5 telescope optical tube and mount at the second floor of the building. At the background, in the bottom left, can be seen part of the motors and gears to open the North half segment of the dome.

for Fabry-Perot interferometry,[5] and some direct imaging in the visible, near-infrared,[6] and mid-infrared.

3. BOOTES-5

The robotic telescope BOOTES-5 is the fifth telescope of the international network of robotic telescopes BOOTES for observing transient events of astronomical sources that are observed as soon as possible after they are detected by other terrestrial and space instruments.[7] The BOOTES network provides automated real-time observation to detect transients, such as gamma ray burst events, as well as scheduled observations. These telescopes can make an independent monitoring of the sky for the discovery of comets, meteors, asteroids, variable stars and supernovae, among others.

The BOOTES-5 project is a collaboration between the IA-UNAM, the CSIC, through the Institute of Astrophysics of Andalucía in Spain, and the Sungkyunkwan University in South Korea to install a completely robotic optical telescope at the OAN-SPM.[8] BOOTES-5 provides the opportunity to make continuous observations using coordinated observations with the telescope network in the northern hemisphere:[9] BOOTES-2 in Spain, BOOTES-4 in China, and BOOTES-5 in Mexico. The BOOTES-5 observatory was unveiled and dedicated in the San Pedro Martir Observatory on November 26, 2015. BOOTES-5 was given the name Javier Gorosabel Telescope (JGT) in memory of the Spanish astronomer Javier Gorosabel Urkia.

The BOOTES-5 observatory consists of a 60cm telescope with a field of view of 10 × 10 arcminutes with an plate scale of 0.59 arcseconds/pixel. The BOOTES-5 telescope has a Ritchey–Chretien design with an f/8 beam. The telescope optical tube is composed of ultra-light carbon–fiber struts with an total weight of about 70 kg, which allows the telescope mount to achieve sufficiently fast slewing speeds and accelerations to reach any part

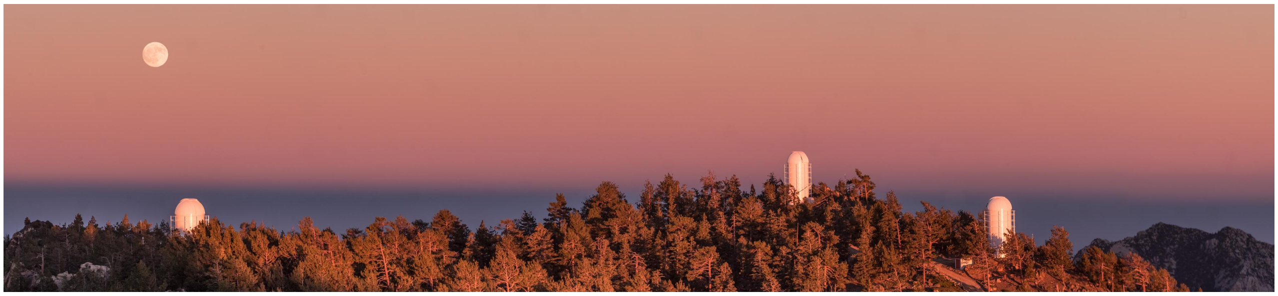

Figure 4. Panoramic view of the TAOS II facilities from the 2m telescope of the OAN-SPM.

of the sky in less than 8 seconds. The telescope has an Astelco NTM-500 mount with a maximum slewing speed of 20°/s. The telescope has an Andor iXon X3 EMCCD 888 camera (1024 × 1024 pixels) and a g′, r′, i′, Z, Y filter set.

The observatory system is managed by RTS2, the second version of the *Remote Telescope System* software[10,11] that can be controlled through a terminal accessible by SSH or by a Web Interface. The weather conditions are determined autonomously by rain, wind, and humidity from which the control system automatically determines when to open or close the dome.

The BOOTES-5 telescope enclosure is a two-storey building constructed of a metallic structure covered with sandwich panel. The building has a dome that opens on the second floor that allows to the telescope to operate in the open air. Underground electric power lines and fiber optic cable were installed to the BOOTES–5 building to provide power and communication services from the 2.1–m telescope building. The building structure is electrically grounded. A lightning rod a few meters away from the building protects the building and equipment. Isolation of the electric power lines between the BOOTES-5 building and the 2.1–m telescope building is provided through isolation transformers. Lightning arrestors are located at both ends of the electric line.

The dome consists of two halves that open/close in a clam shell fashion under the action of electric motors. The dome is 4.9m above ground level. The enclosure has a footprint of 3.3 m × 3.3 m that holds the two dome halves. The two halves were especially designed to be completely open thus allowing the telescope to have access to any part of the sky at any moment.

Figure 3 shows the BOOTES–5 telescope optical tube and mount at the OAN–SPM. The Astelco mount MNT-500 provides high-speed positioning, high–accuracy pointing, and below arc–second precision tracking. From the fabricant specifications, the mount can achieve speeds up to 30°/s and accelerations up to $10^\circ/\mathrm{s}^2$ depending on the optical tube and equipment installed on it. The pointing accuracy is less than 5 arcmin without pointing model and less than 5 arcsec rms with pointing model. Tracking accuracies are better than 2 arcmin per hour without a pointing model and less than 1 arcsec per hour with a pointing model.[12] The mount has air–pressure brakes. The control electronic interface is fully TCI2 complaint and optionally can use the TPL2 network interface.

BOOTES-5 participated in the follow up of the optical counterpart of the detection of the gravitational wave GW170817 observed by the Advanced LIGO and Advanced Virgo detectors.[13]

4. TAOS-II

The Transneptunian Automated Occultation Survey (TAOS II) is an international collaboration between the ASIAA, the IA-UNAM, the SAO, and the CADC, aiming to determine the size and spatial distribution of small Kuiper Belt Objects (KBOs) by observing stellar occultations.

Although the size distribution of KBOs has been accurately measured down to diameters of D $\sim$ 25 km,[14–16] a measurement of the size distribution of even smaller objects is needed because it would help constrain models of the dynamical evolution of the Solar System,[17,18] as well as provide important information on the origin of short-period comets.[19] The detection of such objects is difficult because they are extremely faint, with typical magnitudes $r' > 28$ mag, and are thus invisible to surveys using even the largest telescopes. However, a small

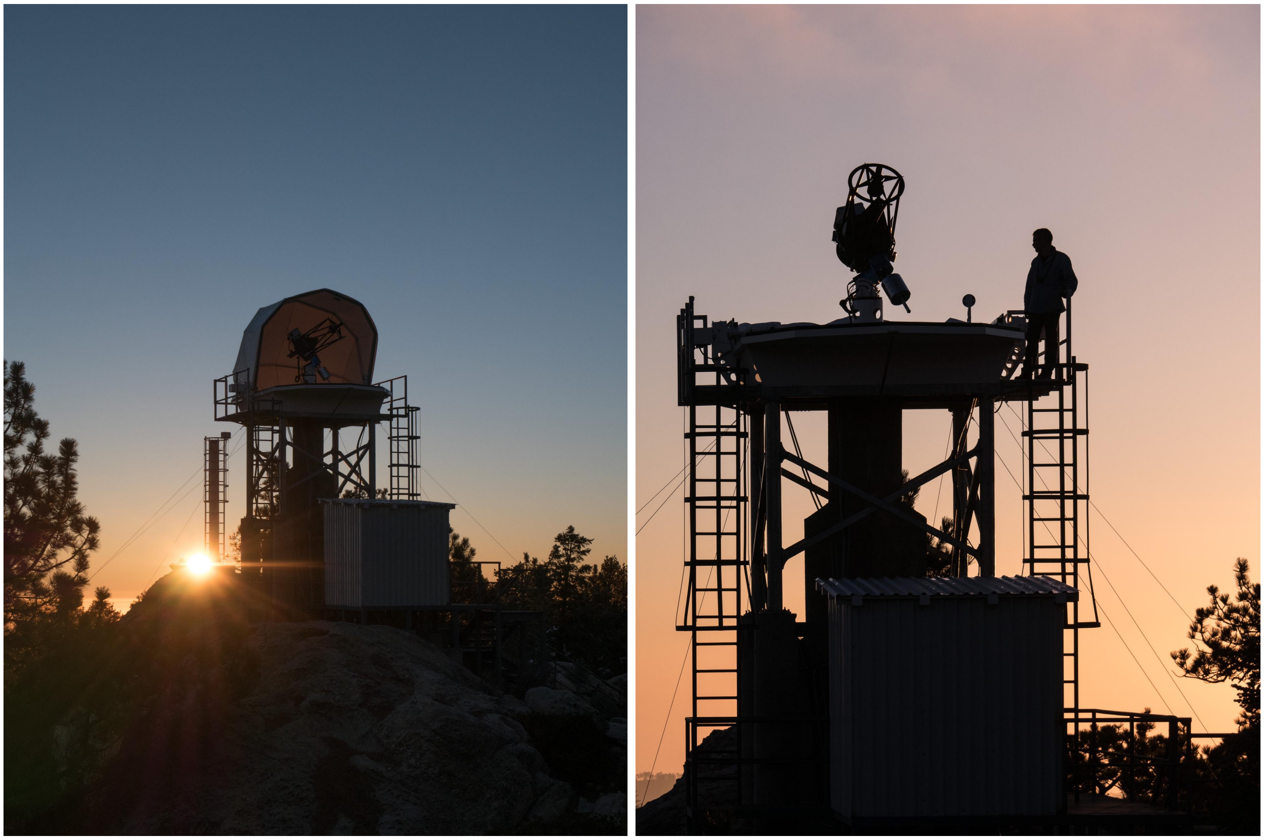

Figure 5. These photos present two views of the COATLI telescope. On the left, only one half of the collapsible dome is open. On the right, both halves are open.

KBO will induce a detectable drop in the measured brightness of a distant star when it passes across the line of sight.[20–22] The goal of the TAOS II project is to detect such occultation events and measure the size distribution of KBOs with diameters $0.5\,\mathrm{km} < D < 30\,\mathrm{km}$.

Such events are very rare ($< 10^{-3}$ events per star per year) and short in duration ($\sim 200\,\mathrm{ms}$), so many stars must be monitored at a high readout cadence in order to detect events. TAOS II will operate three 1.3 meter telescopes at the OAN-SPM. With a 2.3 square degree field of view and a high speed camera comprising a mosaic of CMOS imagers, the survey will monitor 10,000 stars simultaneously with all three telescopes at a readout cadence of 20 Hz.

In addition to the on-site facilities, data storage and processing requirements for the project have lead to the development of a multi-petaByte capacity data center presently under development at the offices of IAUNAM in Ensenada, to be connected to the site via a fiber optic link.

Science cameras consist of a 2×5 array on the focal plane of 4608×1920 pix, back illuminated CMOS detectors ($16\,\mu$m pixels) newly developed by e2v. The devices have been tested having read noise $2.7\,\mathrm{e}^-$, and the dark current is $0.15\,\mathrm{e}^-\,\mathrm{sec}^{-1}$ at -25 C.

Construction at the site began in the fall of 2013 and the survey will begin by the end of 2018. A detailed status report of the project can be found in these proceedings.[23]

5. COATLI

COATLI is a robotic 50-cm telescope and was installed in September 2016. COATLI is a collaboration between the UNAM and Arizona State University. COATLI opens every night that conditions permit and has achieved

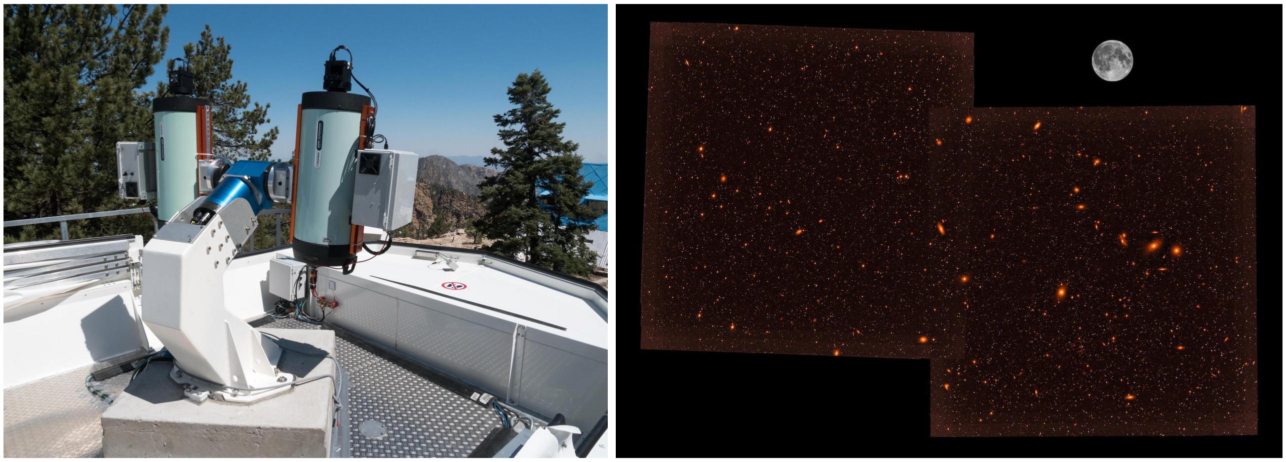

Figure 6. **left photo:** The two DDOTI/OAN tubes at about the time of first light. **right photo:** The first-light image with DDOTI/OAN showing M87 and other galaxies in the Virgo Cluster. This image was taken with two tubes, each with a field of 3.4 degrees to a side. The final imager will have a field that is three times larger. The moon is shown to give an idea of the scale.

excellent reliability. It is currently operating with an interim instrument, a CCD with a field of view of 12.8 8.7 arcmin with BVRIw filters, but our medium-term aim is to install a fast-guiding imager which will provide 0.3 arcsec FWHM images over a field of at least 1 arcmin and coverage of a large fraction of the sky.[24] Figure 5 provides photos of the system.

However, there are two major problems with the telescope and mount that severely impact image quality. (1) The mount frequently shows vibrations with an amplitude of typically 10 arcsec, apparently due to an instability in the mount control system. This problem affects about half of all pointings, apparently randomly. The vibrations appear to be stronger and more common in higher winds. The manufacturer will perform on-site tuning in June 2018, and we hope to resolve this problem. (2) The telescope mirrors were misfigured and deliver 1.4 arcsec FWHM images even in the best conditions. We are awaiting delivery and installation of a second set of mirrors from the manufacturer in fall 2018. Development of the definitive fast-guiding imager has been suspended until these two problems have been satisfactorily resolved and the mount and telescope are shown to be within specification and capable of delivering seeing-limited images.

6. DDOTI

DDOTI/OAN is a robotic wide-field imager and was installed in June 2017. DDOTI/OAN is a collaboration between the UNAM, Arizona State University, and University of Maryland. The DDOTI concept uses multiple comercial 28-cm f/2.2 telescopes on a common mount.[25] The key science goals of DDOTI are the localization of the optical transients associated with relativistic stellar transients – gamma-ray bursts detected by the GBM instrument on the Fermi Gamma-Ray Space Telescope and with gravitational-wave events detected by LIGO and Virgo. These transients typically have positional uncertainties of order 100 square degrees, and so their localization requires a wide-field imager like DDOTI. Figure 6 provides photos of the system.

DDOTI/OAN is in commissioning, and we are still working on solving the last reliability problems with power supply to the CCDs. Two telescopes are installed and the total field is 23 square degrees, but we expect to install another four in summer 2018 and achieve an instantaneous field of 69 square degrees.

7. COLIBRÍ

The COLIBRÍ project will install a robotic 1.3m telescope optimized for rapid follow-up of high-energy transients, prioritizing those observed by the Sino-French mission SVOM,[26] in particular gamma-ray bursts, but also other types of alerts including gravitational wave events. COLIBRÍ is a collaboration between UNAM and CONACyT in Mexico, and CNES, CNRS and Aix-Marseille Université in France. The field of view is matched to the SVOM position accuracy, and will cover 26′. The telescope will have two imagers. One will operate in the visible (DDRAGO-Detectando Destellos de Rayos Gamma en el Óptico), with B,g,r,i,z,y filters and with the goal of mounting two detectors. The second imager will operate in the infrared (CAGIRE-Catching Gamma-ray bursts In the infraREd), with J,H filters using a SOFRADIR detector. The telescope mount will allow for prompt slewing and rapid observations 20 seconds after an alert is received. This configuration will allow for the possibility of observing OIR emission simultaneous with the prompt high-energy emission (for long GRBs), and for the determination of photometric redshifts and the identification of high-z events. As the key program will not require all of the available observing time, other general programs will be carried out as requested by the partners and their respective user communities. Civil work at the site has begun in spring 2018, and the telescope will be commissioned in spring 2020, prior to the launch of SVOM.

8. SAINT-EX

SAINT-EX, which stands for **S**earching **A**nd characteris**IN**g **T**ransiting **EX**oplanets, consists of a fully-robotic, 1-meter telescope at the OAN-SPM, and will be the first dedicated project in Mexico searching for exoplanetary systems and their characterization. SAINT-EX will benefit from the fact that transiting exoplanets orbiting relatively bright stars are one of the only systems that allow for the direct measurement of *both* the planet mass and radius, making them essential observational calibrators for planetary structure models.[27] Fortunately, the most successful technique for detecting exoplanets is the one based on identifying planetary transits in the light curves and with which over 3750 exoplanets, in over 2800 planetary systems, have been discovered to date[*]. Planetary transits occur when a planet eclipses the disk of its host star blocking part of the stellar light.

SAINT-EX has two main science objectives and are described below:

1. *Searching for transiting small, rocky planets around ultra-cool dwarfs*:

   Most planet-searching surveys have targeted solar-type stars (i.e., FGK dwarfs), in part ultimately because we look to provide context for our own Solar System, but also in combination of observational (e.g., more bright targets, stars with a lot of well-defined spectral lines) and astrophysical limitations (e.g., stellar activity). Thus, most of the confirmed planetary systems have been found around FGK dwarfs in close orbits, consequently receiving high amounts of irradiation from their hosts. SAINT-EX will search for planetary systems around the lowest-mass stars, namely ultra-cool dwarfs (i.e., M-dwarfs with spectral types ranging from M5.5 to M9) intending to increase the number of known small, temperate exoplanets and that are well characterized.

   As the recent discovery of the TRAPPIST-1 system[28,29] highlights, ultra-cool dwarfs are excellent targets to search for transiting systems given that: (a) a small planet will show a deeper transit making it more easily detectable when orbiting a smaller star;[30] (b) the probability of transit decreases with increasing orbital period;[31] (c) a planet in a close orbit around an ultra-cool star will receive similar irradiation at a few tenths of an AU than the Earth at 1 AU from the Sun and thus, represents the best chance to currently study Earth-sized exoplanets in their habitable zone,[32] (d) including probing their atmospheres for biosignatures,[33] for example via transmission spectroscopy[34,35] with near future facilities (e.g., JWST);[36] (e) the rotation periods of ultra-cool dwarfs are longer than the orbital periods corresponding to a terrestrial planet in the habitable zone avoiding possible false detections;[37] (f) there is evidence that there are more planets in relatively close orbits ($\lesssim$50 days) around M-dwarfs than around FGK dwarfs,[38] and finally, (g) recent simulations of planet formation via core accretion predict that planets around ultra-cool dwarfs will be mostly Earth-sized.[39]

   The SAINT-EX ultra-cool dwarf sample consists of >250 spectroscopically-confirmed stars, bright enough ($J < 12.5$) and observable only from the North (e.g., from the SUPERBLINK catalog and new observations).[40] In the case, that these planets are found in multi-planetary systems as TRAPPIST-1, transit timing variations will provide constraints on the masses of the planets from the SAINT-EX photometry alone. The photometric precision attainable with SAINT-EX will allow the detection of a Mars-size planet

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[*] From the Extrasolar Planet Encyclopaedia accessed on 14 May 2018 (`http://exoplanet.eu`)

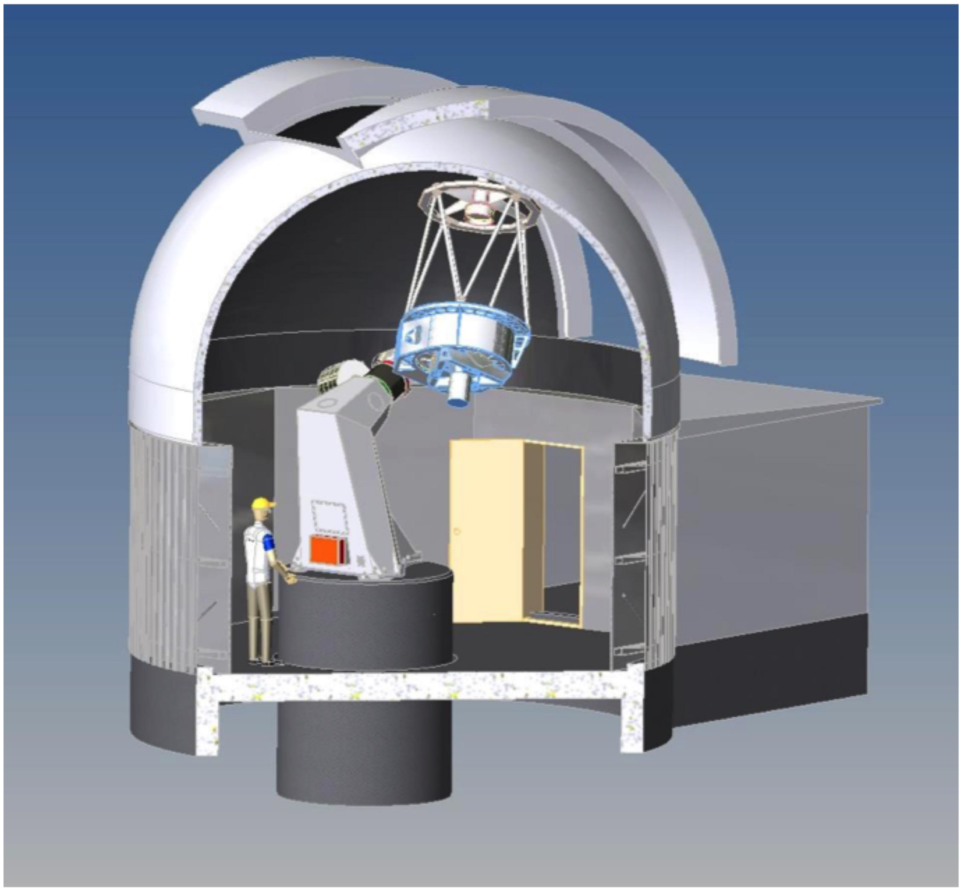

Figure 7. Ilustration of the SAINT-EX Facility provided by ASTELCO

around the brightest ultra-cool dwarfs. Given the success rate of the TRAPPIST survey of ultra-cool dwarfs which searched 50 stars and detected one system with 7 Earth-size planets, we expect SAINT-EX to discover a few 10s of exoplanets out of the sample of ultra-cool dwarfs only observable from the North.

2. *Optimizing CHEOPS observations in the search for transits of RV-discovered planets*:

   CHEOPS (CHaracterising ExOPlanet Satellite) is the next transiting planet mission by the European Space Agency that is scheduled to be ready to launch in 2018[†]. CHEOPS will have unique capabilities to explore known exoplanets at visible wavelengths, unmatched by other existing and near-future facilities. CHEOPS's precise, space photometry will enable science goals that go beyond the mass–radius relationship,[41] such as probing the atmospheres of exoplanets by directly measuring albedoes and orbital phase-curves potentially providing 1 and 2D reflection maps.[34, 42] One of CHEOPS main goals is to search for the transits of exoplanets that have been discovered via radial velocities. Finding the transit of RV planets provides a measure of the planetary radius and of the orbital inclination, consequently the actual planet mass and its bulk density can be derived. The mass derived from the amplitude of the RV curve depends on the inclination of the orbit (i.e., $m_{\rm pl} \sin i$) given that the RVs measure the projection in the line of sight of the movement of the star around the system's center of mass. Thus, in the case where the orbital inclination is unknown (e.g., planets for which the transit has not been observed), the measured massed from the RV curve is actually the minimum possible planet mass.

[†] CHEOPS ESA website accessed on 14 may 2018: http://sci.esa.int/jump.cfm?oid=58971

> Taking into account the finite duration of the CHEOPS space mission (3–5 years) and the stringent constraints on target visibility due to the orbit of the satellite, CHEOPS will be heavily oversubscribed. Its target list will consist of hundreds of planetary systems, coming from current and near-future RV and photometric surveys (e.g., HARPS planet search, TESS, NGTS, etc.), where most of them will be (mini-)Neptunes.[43] The most interesting objects, because fewer have been detected and well characterized, are smaller and/or less massive planets and those in longer period orbits. However, in both of these cases the ephemeris of the transit is more uncertain, extending the window during which the transit is expected to occur. Searching for transits for these interesting targets only with CHEOPS will be very expensive in observing time. Thus, SAINT-EX will be the only robotic facility capable of monitoring the transit window of planets with Super-Earth radii or larger orbiting relatively bright stars (V=6–11 mag), and available to the CHEOPS consortium in the Northern hemisphere. The vetting of these targets with SAINT-EX will provide the exact time at which CHEOPS should observe the transit, minimizing the satellite's observing time necessary to obtain the same science result and allowing more observing time to exploit CHEOPS's unique capabilities, searching for additional small, transiting planets in known systems, Earth-size planets orbiting bright stars, occultations, and phase-curves, which cannot be done from the ground.

SAINT-EX is unique from the closest competitors looking for transiting planets around M-dwarfs in the Northern Hemisphere, namely MEarth,[44] APACHE,[45] PAIRITEL,[46] and TRAPPIST-N.[47] MEarth and APACHE consist of 16" ($\sim$40 cm) telescopes and are not able to probe down to Earth-size planets;[48] the sample of ultra-cool dwarfs is not within reach for such a small apperture. PAIRITEL is a robotic 1.3m telescope with a NICMOS-3 infrared detector, and due to instrumental systematics, the precision of the photometry is limited to $\sim$1%. Thus, despite a large observing campaign targeting 13 ultra-cool dwarfs, only a limit on planets larger than 3 $R_\oplus$ could be determined.[46] TRAPPIST-N is the only to have proven its ability to detect Earth-size planets around the brightest ultra-cool stars. However, these represent only the 10-15% of the entire ultra-cool dwarf sample observable with SAINT-EX. Furthermore, the next transiting planet space missions, NASA TESS[49] and ESA CHEOPS, will not be able to search for small planets orbiting ultra-cool dwarfs because of their small apertures (10 and 30 cm, respectively) and because their detectors are not optimized for redder wavelengths.

8.1 Description of the SAINT-EX facility

The SAINT-EX facility will be composed of a 1-meter F/8 Ritchey-Chretien telescope installed on a high-performance equatorial mount with no meridian flipover 20°(shown in Fig. 7), based on SPECULOOS[50] currently under finalizing their installation at Paranal, Chile. SAINT-EX operations will be entirely remote, having automated dome functions, weather monitoring and observations. The instrumentation will consist on a back-illuminated, deep-depleted Andor Ikon 2k×2k camera, optimized to reach high efficiency between 400 to 900 nm with a diffraction-limited field of view of 20 sq-arcmin. These new generation of detectors have been installed on the NGTS telescopes since 2014,[51] and have since matured, ironing out initial defects and have demostrated an unprecedented photometric precision. A filter wheel with broad-band Sloan u'g'r'i'z' filters and narrow-band comet filters will be utilized. The building will consist of a circular structure on which the a $\sim$6m dome will be installed, joined to a 6m×2m control room.

It is now technically possible to reach a precision of 100 parts per million (ppm) on the depth of a planetary transit around a bright star (V = 6 mag) with a ground-based 1-m telescope equipped with the new generation back-illuminated, deep-depleted CCDs, as SAINT-EX will have. Before the development of these detectors, this level of precision in the time-series photometry with a 1-m telescope over the entirety of the duration of a transit of an exoplanet around a main-sequence dwarf star (i.e., from tens of minutes to several hours) was only possible from space.[52] However, SAINT-EX is motivated by the detection of transits of small exoplanets orbiting bright stars from the ground with larger telescopes. The transit of 55 Cnc e, an RV-discovered planet with a 2 $R_\oplus$ around a 0.95 $R_\odot$ star (V=6mag), was detected with the NOT (2.56m) at a 10-σ significance, corresponding to a photometric precision of 40 ppm over 90 min limited by scintillation noise.[53] The photometric precision of these new cameras was tested with the TRAPPIST 0.6m telescope with a V=6.3 star, which resulted in a photometric precision of 100ppm over 30 min. Scaling these tests to the SAINT-EX 1-m apperture with a similar detector would result in a detection of the 55 Cnc e transit with a 4-σ significance. With the installation of SAINT-EX that will begin construction this year (see §8.1 for the description of the facility), the project aims to support upcoming space missions by optimizing their target list, and to discover and characterize transiting exoplanets around ultra-cool stars. SAINT-EX will be the first and currently the only facility in México, and one of a handful in the world, that will be able to reach the required precision in the transit light curves enabling the detection of small rocky exoplanets.

The location of the SAINT-EX facility is key, and the Observatorio Astronómico Nacional at San Pedro Mártir, in Baja California, México and operated by the Instituto de Astronomía at UNAM, more than fulfills the requirements for the project. Firstly, CHEOPS will observe targets in the both the Northern and Southern celestial hemispheres, and thus, a location close to the equator allows for maximum coverage. Southern targets (down to -20° in declination) will have a 4 hour visibility window above an airmass of 2, as required for precise photometry, and the whole ecliptic can be covered throughout the year to search for transits. In longitude, SPM is critical to avoid duplicating existing facilities (e.g., Warwick 1m telescope in La Palma at a 7h shift in longitude and Euler 1m telescope in La Silla at a 3h shift), and allowing the observation of a given transit window continuously. Most importantly, SPM has exquisite astroclimatic conditions,[54, 55] allowing for good stability of the PSF, and minimal disruptions due to weather.

SAINT-EX has been named in honor of Antoine de Saint-Exupéry ("Saint-Ex") who was a famous writer, poet and aviator. He defended a society based on respect for humandkind, cultural diversity, cooperation, commitment and individual responsability.

9. TSPM

The Telescopio San Pedro Mártir (TSPM) project intends to construct a 6.5m telescope to be installed at the OAN-SPM.[56, 57] The project is an association of Mexican institutions, led by the IA-UNAM, INAOE, and CONACyT in partnership with the SAO and the UA. Most of the funding for the design and planning activities that have taken place so far has been provided by CONACYT. Figure 8 presents views of the enclosure and support building while Figure 9 provides details of the telescope's optical design and structure.

The Magellan telescopes in Las Campanas, Chile inspire the telescope's mechanical design. However, the primary mirror cell will be completely compatible with the Multiple Mirror Telescope's (MMT) Cassegrain focus. The TSPM will also include Nasmyth focal stations slightly farther from the primary than at the Magellan telescopes to allow a wider field of view. The enclosure design borrows elements from the Magellan telescopes (Las Campanas, Chile), but incorporating the needs of the particular site that will be used at the OAN-SPM. The primary mirror will be polished at the Steward Observatory's Richard F. Carris Mirror Lab to the same nominal specification as the MMT and the Magellan telescopes. The telescope will initially use the f/5 Cassegrain secondary currently at the Magellan II Clay telescope.[58] The first light instruments are likely to be the Megacam[59] and MMIRS[60] instruments, currently at the Magellan II and MMT telescopes, respectively.

Once completed, it is planned to operate the TSPM in collaboration with the UA and SAO. Jointly, the MMT and TSPM will form a binational astrophysical observatory serving astronomers from all partner institutions, with each site focusing upon its strengths. The TSPM, thanks to its wide field imaging capability, and subsequently its potential spectroscopic and polarimetric capabilities, will allow state-of-the-art research on planetary, Galactic and extragalactic astronomy, variable sky studies, and large-scale surveys. TSPM will be complementary not only to the MMT for large scale, high-impact programs, but also to multi-frequency collaborations that could exploit current Mexican facilities, such as the Gran Telescopio Milimétrico Alfonso Serrano (GTM) and the High-Altitude Water Cherenkov Gamma-Ray Observatory (HAWC). The TSPM will also represent an excellent follow-up complement for the extremely large telescopes that will begin operation after 2020, the Large Synoptic Survey Telescope, and the James Webb Space Telescope.

The TSPM's high level requirements stipulate that it shall be suitable for general science projects, and so should have similar flexibility to other facilities of this type (MMT, Magellan, Keck, Gemini, VLT, and GTC). The TSPM's optical design reflects this, providing seven focal stations (Figure 9). It will have a field of view of up to 1° at the f/5 Cassegrain and f/5 Nasmyth focal stations.

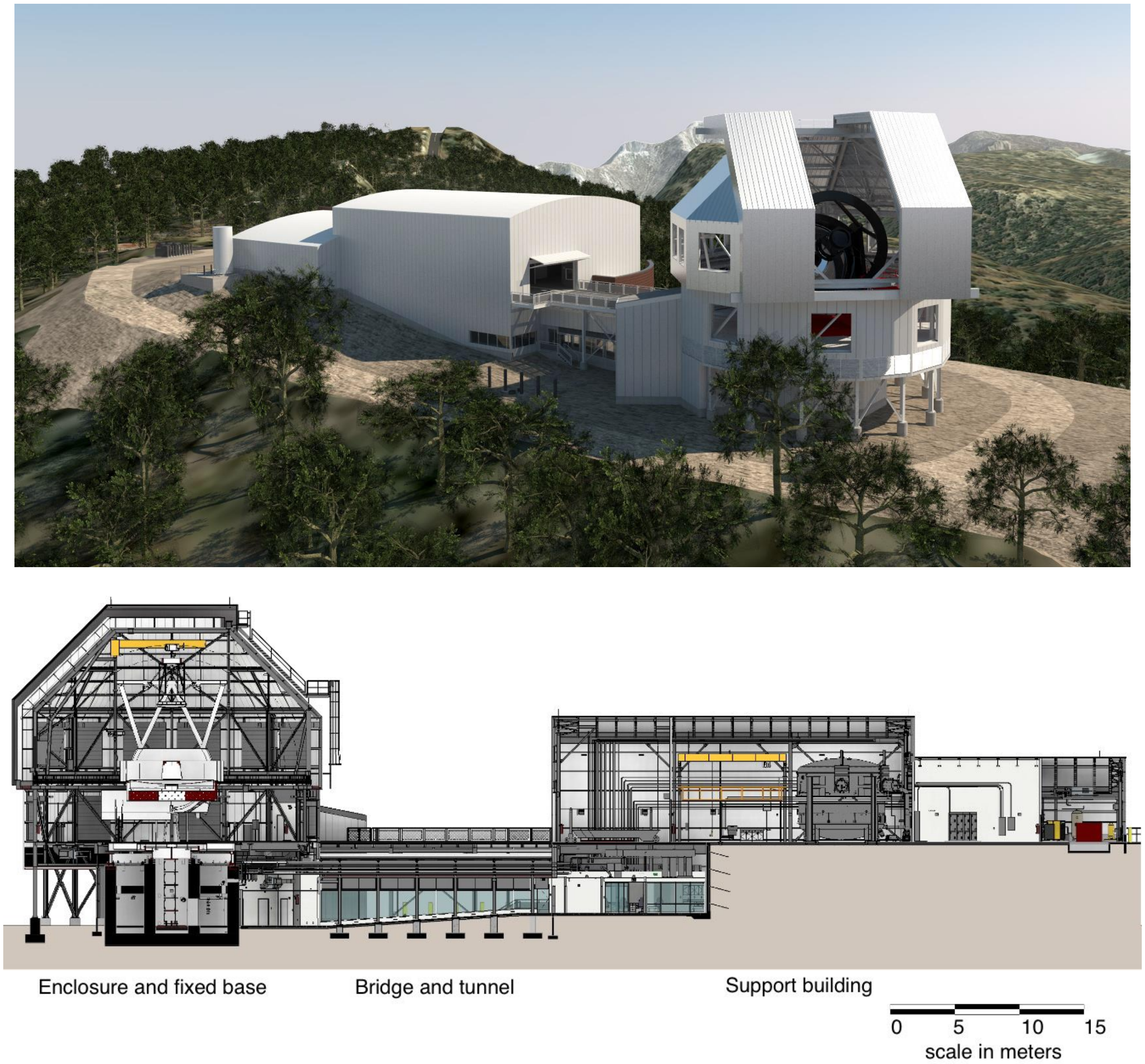

Figure 8. **top:** This rendering of the TSPM project, seen from the north-west, presents the layout of the project. **bottom:** This diagram presents a profile view of the telescope within the enclosure, the bridge that connects the enclosure to the support building, and various parts of the support building. All instrument and telescope maintenance activities occur on the upper level of the enclosure and support building. The telescope will be operated from a control room on the lower level of the support building.

10. SUMMARY

The OAN-SPM is currently undergoing a substantial expansion in its observational infrastructure. The IA-UNAM has the responsibility for the development of the OAN-SPM on behalf of all astronomers in Mexico. In 2015, the BOOTES-5 telescope was installed and is now operational. It is a collaboration between the IA-UNAM, the CSIC (Spain), through the Instituto de Astrofísica de Andalucía, and Sungkyunkwan University (South Korea). In 2011 the construction of the TAOS-II project began and its three telescopes are now in commissioning, the result of a collaboration between ASIAA (Taiwan), the IA-UNAM, the SAO (USA), and the CADC (Canada). Also undergoing commissioning are the COATLI and DDOTI projects. COATLI is an initiative of the IA-UNAM and Arizona State University while DDOTI is a the result of a collaboration between

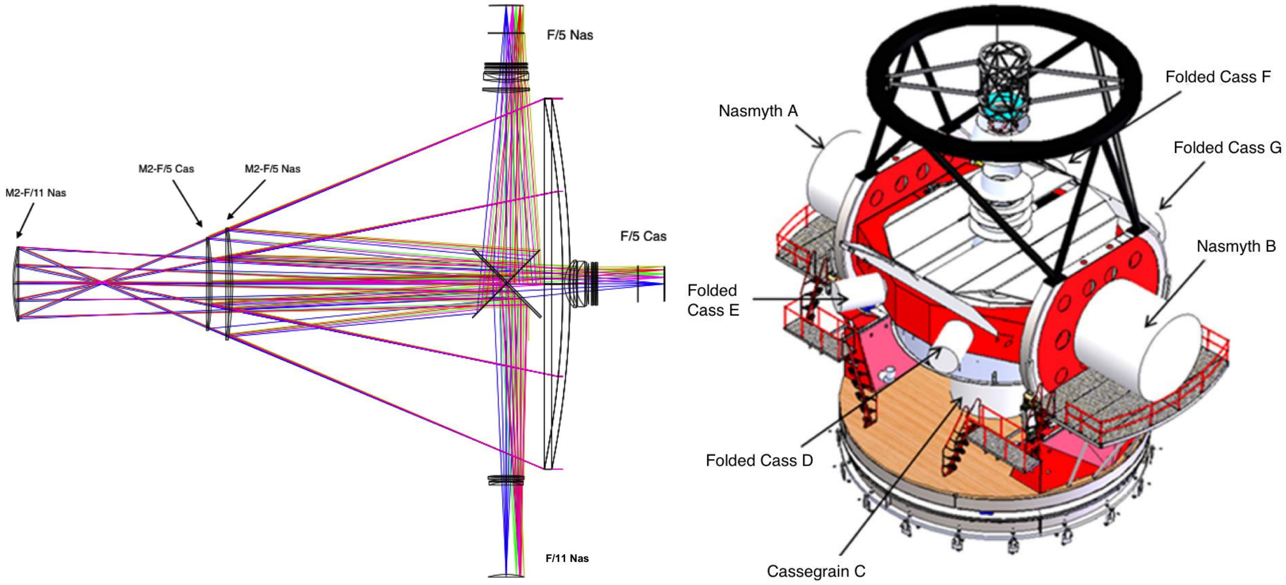

Figure 9. **left:** The optical design contemplates three configurations. The "Day 1" configuration is f/5 Cassegrain, functionally equivalent to the MMT. In addition, two extreme configurations are contemplated: The f/5 Nasmyth configuration has an important impact upon the telescope design[61] while the f/11 Gregorian Nasmyth configuration affects the size of the telescope enclosure.[62] **right:** The many focal stations of the TSPM's design are motivated by its intention to be a flexible, general science instrument.

the IA-UNAM, Arizona State University, and University of Maryland. Two projects, COLIBRÍ and SAINT-EX are about to begin construction. COLIBRÍ is a collaboration between the IA-UNAM and France's Aix-Marseille Université, the Centre National d'Études Spatiales, and the Centre National de Recherche Scientifique while SAINT-EX is a collaboration of the University of Bern, the University of Geneva, and NCCR PlanetS from Switzerland, Cambridge University (UK), and the IA-UNAM. Finally, the Telescopio San Pedro Mártir project is advancing through its design phase. The TSPM is backed by partners in Mexico, lead by the INAOE, IA-UNAM, and CONACyT in collaboration with the SAO and UA. All save the TSPM are fully funded, so the OAN-SPM will host 11-12 telescopes by the 2020's, ranging in size from 28 cm to 6.5 m.

The objective of these different projects is to modernize, diversify, and extend the observational infrastructure at the OAN-SPM. The OAN-SPM has long been known to be an excellent site for optical and near infrared observations, a fact confirmed by various recent international projects.[56] The projects currently starting, in commissioning, or about to begin construction all look to take advantage of the large number of clear nights, good image quality, accessibility to the Northern sky and part of the Southern ($\delta > -40°$), the low humidity throughout the year, and that SPM is separated in longitude from similar Observatories providing complementary coverage of the night sky. A power and fiber optic line are being installed to the site in order to increase the available energy, bandwidth, and reliability of these services, and is scheduled for completion in 2020.

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