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This report covers the period from January 1 to December 31, 2001.

The Instituto de Astronomía (UNAM) has a total number of 85 full time researchers and 55 members of the technical staff in its three locations: Mexico City, Ensenada (Baja California) and Morelia (Michoacán). The institute also operates the OAN (Observatorio Astronómico Nacional) in the San Pedro Mártir mountains in Baja California.

## 1. STAFF

Director : S. Torres-Peimbert

Director of the OAN : J. A. López

Scientific staff : H. Aceves, L. Aguilar, C. Allen, M. Alvarez, S. Ambrocio, A. Arellano Ferro, S.J. Arthur, R. Avila-Reese, V. Avila, S. Ayala, E. Benitez, L. Binette, J. Bohigas, J. Cantó, L. Carigi, L. Carrasco, R. Carrillo, C. Chavarría, P. Colín, M.E. Contreras, R. Costero, F. Cruz, I. Cruz-González, S. Curiel, P. D'Alessio, J. de Diego, D. Dultzin-Hacyan, J. Echevarría, V. Escalante, J. Espresate, J. Fierro, J. Franco, J. Galindo, J. A. García-Barreto, G. García-Segura, A. Gazol, L. Georgiev, Y. Gómez J. González, R.A. González-Lopezlira, W. Henney, H. Hernández Toledo, M.A. Herrera, D. Hiriart, G. Koenigsberger, S. Kurtz W. Lee, S. Lizano, L. Loinard, J.A. López, E. Luna, M. Martos, E. Masciadri, S. Mendoza, R. Michel, A. Moitinho, M.A. Moreno Corral, E. Moreno, V.G. Orlov, D. Page, A. Peimbert, M. Peimbert, M. Peña, J.H. Peña, A. Poveda, A. Porras, A. Raga, M. Reyes-Ruiz, M.G. Richer, L.F. Rodriguez, M. Rosado, M.T. Rozas, R. Ruelas-Mayorga, E. Ruíz, L. Salas, L. Sánchez, F.J. Sánchez-Salcedo, W.J. Schuster, A. Serrano, J. Stepanian, M. Tapia, S. Torres-Peimbert, G. Tovmassian, R. Vázquez, E. Vázquez-Semadeni, H. Velázquez, V.V. Voitsekovich, A. Watson, S. Zharikov

## 2. OBSERVATORIO ASTRONÓMICO NACIONAL

### 2.1 Facilities

The OAN is maintained and operated by the Instituto de Astronomía. The observatory has three telescopes, of 2.1, 1.5, and 0.8 meter diameters. A number of instruments (including CCD imagers, spectrographs, scanning Fabry-Perot interferometer, IR camera + spectrograph + Fabry-Perot, photometers, etc.) are available at the 2.1m and 1.5m telescopes. Several projects for new instruments are in progress.

### 2.2 The Telescopio Infrarrojo Mexicano (TIM)

The TIM infrared/optical telescope is in the planning stage. The TIM will have a 6.5 meter (effective diameter) segmented mirror, and a set of instruments spanning the 0.3 to 20 micron wavelength range. Progress has been made on the design of the telescope itself, and of the dome.

### 2.3 Other instrumental developments

ESOPO, an intermediate resolution spectrograph, is being designed and built for the 2.1-m telescope. An adaptive optics system is also being built for the 2.1-m telescope.

## 3. PARTICIPATION IN OTHER OBSERVATORIES

A joint participation with INAOE that amounts to 5% in the GTC segmented mirror telescope (of 10 m effective diameter, which is being built in the Canary Islands, Spain) has been signed. Furthermore, the Institute is responsible for the design and construction of the Commissioning Camera and participates in the design and construction of the multi-object spectrograph "OSIRIS."

An infrared extension of the low resolution spectrograph on the HET telescope (U. OF Texas) is being designed.

The Institute has continued collaboration with the US National Radio Astronomy Observatory toward the completion of the Extended Very Large Array project and the access by Mexican astronomers to the Atacama Large Millimeter Array.

## 4. COMPUTING FACILITIES

The institute has many workstations (bought using both UNAM and individual research grant funds) as well as a large number of PCs. There are also three recently installed PC clusters (one in each branch of the institute), and an Origin 2000 parallel computer (in Ensenada). Researchers from the institute have access to the vector and parallel supercomputers of the computer center of the UNAM.

## 5. CONFERENCES AND PROCEEDINGS

The "Galaxies: the Third Dimension" conference took place in Cozumel in 3-7 December 2001. This meeting covered a range of topics related to fully and partially ionized plasmas, and was organized with the participation of a group of astronomers from our institute (Aguilar, Franco, Rosado).

The proceedings of the "The Seventh Texas-Mexico Conference on Astrophysics: Flows, Blows, and Glows" conference (which took place in Austin, Texas 6-8 April 2000) were published in *Revista Mexicana de Astronomía y Astrofísica (Serie de Conferencias)*, Vol. 10, marzo 2001, edited by W.H. Lee and Torres-Peimbert.

The proceedings of the "IX Latin American Regional Meeting of the International Astronomical Union" that took place on Tonantzintla, Puebla, November 1998 were published in *Revista Mexicana de Astronomía y Astrofísica (Serie de Conferencias)*, Vol. 11, June 2001, edited by Aguilar y Carramiñana (INAOE).

## 6. SCIENTIFIC HIGHLIGHTS

### 6.1 Interstellar Medium

#### 6.1.1 Planetary Nebulae

The first detection of water in a PN was achieved by Gómez and collaborators in Spain. Water appears to be present not only near the PN nucleus but also in two diametrically opposed regions, at 5000 AU from the nucleus. A magnetic field of a few milligauss was also detected by Gómez and collaborators in the circumstellar toroid surrounding the progenitor star, as required by magnetic models for PN shaping. Magnetohydrodynamical simulations were performed by García-Segura, López and Franco for the case where a cyclic inversion of polarity takes place in a magnetized stellar wind and the results were applied to the problem of concentric arcs found by HST in some PN. Also from HST observations, M. Peña and S. Medina's work showed that the nebular shells are strongly affected by stellar wind, and that the deposition of mechanical energy accelerates the expansion. Steffen and López explored an alternative explanation to the formation of filaments in PNe via a mechanism based on the development of stagnation knots from mildly collimated winds. Tovmassian discovered the planetary nebula PN G135.9+55.9 which is the most oxygen poor planetary known.

#### 6.1.2 HII regions

The escape fraction of ionizing photons is determined by M. Peimbert for the extragalactic HII region NGC 346. The effects of collisional excitation of the Balmer lines in hot HII regions were analyzed by A. Peimbert and collaborators. A morphological, photometric and spectroscopic study of the giant HII region NGC 3603 and its associated molecular cloud was completed by M. Tapia. Franco and Dyson (U. Leeds) wrote a review of theory and observations of HII regions for the new Encyclopedia of Astronomy and Astrophysics published by the Institute of Physics of the United Kingdom. Henney has studied the ionized photoevaporation flows and microjets from the Orion proplyds via HST STIS NUV spectroscopy, radio interferometry and theoretical modelling.

#### 6.1.3 Herbig-Haro objects

R. Avila detected the exciting sources of several Herbig-Haro objects using the VLA. Herbig-Haro jets from orbiting sources and jet outflow within a photoionized nebulae were modelled by Masciadri. Salas and Cruz-González carried out a detailed study of the H<sub>2</sub> kinematics in several outflows and found a flux vs. velocity relation.

#### 6.1.4 SN Remnants

Time-dependent calculations of the photoionized region produced by a supernova remnant blast wave were produced by Arthur.

#### 6.1.5 Radiative transfer

Watson and Henney published details of an efficient Monte-Carlo algorithm for a restricted class of scattering problems in radiation transfer.

#### 6.1.6 Molecular clouds and star formation

Curiel, Cantó, L.F. Rodriguez and Torrelles (IAA) made the surprising discovery of a water bubble (spherical structure) near the young stellar object CEPA/HW2 using the VLBA, which they interpret as being caused by an HII region being turned on.

A multi-fractal study of ISM turbulence was carried out by Vázquez-Semadeni and Chicana in order to understand the physical properties characterized by the multifractal spectrum. Vázquez-Semadeni, Pichardo and collaborators numerically verified the predictions of a theory by Lazarian and Pogosyan for the modification of the emissivity power spectrum in spectroscopic observations dictated by the statistics of the velocity field.

Rosado completed a kinematic study of the molecular and ionized gas in Orion and in S187. Salas, Cruz-Gonzalez and Rosado completed the kinematic study of molecular hydrogen in S187 and HH 211. Detections of very high levels of double deuteration was reported by Loinard in star-forming regions. Porras, Cruz-González and Salas found an index of  $-1$  for the IMF of 40 open clusters in the Perseus Arm.

#### 6.1.7 Accretion disks and stellar winds

Solutions of the thermal and ionization structure of X-ray emitting winds were explored by Lizano and coworkers. Kurtz found clear evidence of an accretion disk surrounding a massive star. A study of the observational impact of dust grain growth within an accretion disk was carried out by D'Alessio.

#### 6.1.8 ISM in galaxies

Loinard modelled the dynamic behavior of molecular gas in the internal regions of M31 and confirmed the triaxiality of its bulge. Martos, Franco and collaborators in Spain (IAA) detected a corrugation in the velocity of the gas entering into the spiral arms in NGC 5427. This corrugation pattern is associated to the interaction of the gas with the spiral wave, creating a hydraulic jump. Sánchez-Salcedo, Gazol, Vázquez-Semadeni and Scalo numerically studied the formation of clouds by thermal instability and the multiphase nature of the ISM, concluding that a significant fraction of the ISM gas should be found in the thermally unstable temperature range. Espresate, Cantó and Franco found a new way of determining the distances of high velocity clouds within the Galactic halo. Ávila-Reese and Vázquez-Semadeni explored the turbulent dissipation efficiency in the ISM by means of MHD simulations and applied the results to models of galaxy formation.

## 6.2 Stellar and Planetary Astronomy

### 6.2.1 WR stars, T Tauri stars and binaries

Arrellano carried out a variability study of T Tauri stars while Moreno-Corral finds new stars of WTT type in well

known star formation regions. Contreras finds evidence that the emission lines and infrared excess in H Ae/Be stars take place within an accretion disk.

### 6.2.2 *The Sun*

Galindo studied with a magnetohydrodynamic model the stability of a solar protuberance submerged in a vertical field.

### 6.2.3 *Old stars and post-AGBs*

Arellano analyzed the spectra of Li-rich and C-rich post-AGB stars.

### 6.2.4 *Variable or active stars*

Tovmassian continued search and study of Cataclysmic Variables from the lists of ROSAT sources. Chavarría, de Lara and Moreno-Corral prepared an extensive catalog containing uvby $\beta$  photometry of stars active in the X-rays.

### 6.2.5 *Planetary dynamics*

Poveda and Galindo studied the generation of electrical currents in particles of planetary rings while crossing the planets magnetic field, as well as the associated orbital decay. Numerical models of protoplanetary disks by Reyes-Ruiz indicate that they are unlikely to form shells. A binary system was discovered in a bipolar protoplanetary by Gómez and L.F. Rodriguez.

### 6.2.6 *Open clusters*

J.H. Peña combined CCD acquisition techniques with multi-band photometer observations of open cluster variable stars. Moitinho began new UBVRI measurements of 50 open clusters. An extensive study of Tr 37 was performed by Contreras who analyzed the photometry of 94 intermediate mass stars.

### 6.2.7 *Compact objects*

Modelling of the hydrodynamics and the gravitational waves produced by binary compact systems was performed by W.H. Lee. One combination considered was that of a quark matter object orbiting a black hole. Page studied the thermal evolution of strange quark stars with a surface made of bare quark matter.

## 6.3 *Galactic and Extragalactic Astronomy*

### 6.3.1 *Chemical composition and evolution*

Carigi, Hernández and collaborators modelled the chemical evolution of four spheroidal dwarf galaxies and concluded that they underwent 1–2 episodes of rapid star formation, by combining direct inferences based on CMD analysis and a thermodynamic modelling of the gas in the dark matter potential of the observed dSphs.

### 6.3.2 *Structure of galaxies*

Color-magnitude diagrams of the irregular IC1613 were constructed by Rosado, which are being tied out with the dynamics of the superbubble. A detailed study with the VLA at 3.6 cm and 20 cm of the barred spiral NGC 3367 was

performed by García-Barreto. Richer confirmed that IC10 is a dwarf starburst galaxy and showed that Hickson 31 is in a very advanced stage of fusion. Gonzalez-Lopezlira has developed a method to measure total extinction through disk galaxies, from colors and counts of background field galaxies, without a priori assumptions about the reddening law and spatial distribution of the obscuring dust. A detailed analysis of the HII kinematics in NGC 7479 was performed by Rozas using rotation curves and angular momentum and residual velocity maps. A quantitative relation between the HII regions and the diffuse gas was established by Rozas in three spiral galaxies.

### 6.3.3 *Galactic dynamics*

Orbits of old stars in the galactic halo were computed by Allen and compared with data from 40 halo stars. Poveda, Allen and Herrera studied the distribution of binary separation as a function of age. Moreno and Martos developed a new 3D model of spiral arms in the Galaxy and in barred galaxies. Martos, Pichardo, Moreno and Espresate studied non-linear and chaotic processes using the above 3D model for the arms. Hernández-Toledo has assembled low resolution spectroscopic data and infrared images of a set of binary and triple galactic systems.

### 6.3.4 *Active galaxies*

Dultzin-Hacyan and Krongold completed their comparative study of the environment of active galaxies. Dultzin-Hacyan and Marziani explored the correlation space of optical and UV lines with the soft X-ray index of AGN. A study of the effect of intergalactic absorption on the quasar energy distribution was carried out by Binette. Hydrodynamical simulations by Mendoza determined the largest angle under which internal shocks develop when a radio-galaxy jet is deflected. For 13 SBS nearby AGNs, color isophotal maps were constructed by Stepanian with the aim of investigating the morphological differences between different types of AGNs and testing whether the particular type of active nucleus is related to any property of the host galaxy.

## 6.4 *Cosmology*

Hernández and Ávila-Reese compared models of star formation history near the Sun to that inferred from observations. Hernández studied the relative number of low mass stars that the cosmological model predicts for the Galactic halo. A study of the viability of the Warm Dark Matter model has been performed by Ávila-Reese, Colín and Firmani. An observational inference of the cross-section parameter in a Self-Interacting Dark Matter cosmology has been performed by Firmani, Hernández-Toledo and Ávila-Reese.

## 6.5 *Site Testing*

Masciadri proposed a new calibration technique for the atmospheric model which simulates the turbulence in a region surrounding a telescope. R. Avila studied the wave-front outer scale at San Pedro Mártir and found that it compares favorably to that of the major observational sites in the world.

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**The publication list includes all papers published in refereed journals between January and December 2001.**

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