BASAL FINANCING PROGRAM
FOR SCIENTIFIC AND TECHNOLOGICAL CENTERS OF EXCELLENCE

ANNUAL PROGRESS REPORT

NAME OF THE CENTER	CODE
CATA: Centro de Astrofísica y Tecnologías Afines	**PFB-06**

GUIDELINES

The report should be written following the format specified hereafter. Once it is completed, it should be sent in printed and in electronic version to the following address:

Programa De Investigación Asociativa
CONICYT

Mailing address: Bernarda Morín 551, tercer piso, Providencia, Santiago
E-mail:
Phone:
For further inquiries contact:

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REPORT PERIOD : 1st Year ☐ 2nd Year 3rd Year X 4th Year ☐

PERIOD COVERED : From January 2010 to January 2011

I. PRESENTATION

NAME OF THE CENTER	CODE
CATA: Centro de Astrofísica y Tecnologías Afines	PFB-06
Name and Signature of the Center Director	E-MAIL
María Teresa Ruiz	
Name and signature of the Executive / Deputy / Co-director	
Guido Garay	
Name and signature of the Manager (if applicable)	
SPONSORING INSTITUTION (if applicable)	
Universidad de Chile	
ASSOCIATED INSTITUTION(S) (if applicable)	
Pontificia Universidad Católica, Universidad de Concepción	
CENTER WEBSITE ADDRESS[1]	
www.cata.cl	

[1] The home page of the website should contain the logo of the Basal Financing Program and of CONICYT.

Research Lines

N°	Title	Objective(s)	Principal Investigator	Other Researchers
1.-	Area 1	Birth and evolution of structures in the Universe	Leopoldo Infante	Barrientos, Bauer, Cuadra, Dunner, Escala, Galaz, Jordán, Lira, Lopez, Motta, Nagar, Padilla, Puzia, Quintana, Reisenegger
	Area 2	Stellar Populations in the Local Universe	Doug Geisler	Borissova, Catelan, Costa, Fellhauer, Gieren, Infante, Jordán, Minniti, Mendez, Pietrzynski, Richtler, Rubio, Zoccali
	Area 3	Distance Scale	Wolfgang Gieren	Costa, Hamuy, Mennickent, Minniti, Pietrzynski
	Area 4	Star Formation	Guido Garay	Bronfman, Casassus, Escala, Mardones, May, Rubio
	Area 5	Extrasolar planets and brown dwarfs	Dante Minniti	Geisler, Gieren, Jordan, Mendez, Pietrzynski, Rojo, Ruiz, Zocalli
	Area 6	Supernovae and Dark Matter	Mario Hamuy	Clocchiatti, Maza, Pignata, Reisenegger
2.-	Area 7	Astronomical Instrumentation	Leonardo Bronfman	Altamirano, Bustos, May, Mena, Nagar, Vanzi
	Area 8	High Performance Astronomical Computing	Alejandro Clocchiatti	Cuadra, Escala, Padilla
	Area 9	Outreach	José Maza	Galaz, Nagar

II. EXECUTIVE SUMMARY OF THE PROGRESS MADE

This section should be written in no more than two pages (Arial 10 or equivalent) and must be in relation to the progress made in the reporting period. This information together with the financial management and the annual indicators are the only ones public of this report, while this project is in function, and can be published on CONICYT's web site and used for other public entities or provided under the Public Service Transparency regulations.

The Centro de Astrofísica y Tecnologías Afines (CATA) is hosted by the Universidad de Chile at its Astronomy Department in Cerro Calán, and has as associated organizations the Astronomy Department of the Pontificia Universidad Católica and the Astronomy Department of the Universidad de Concepción. The main goals of the CATA are to produce a significant increase in the astronomical community working in Chile: researchers, students and specialized engineers, in order to meet, in the best possible way, the challenges posed by the newly available facilities and take advantage of the opportunity for technological developments associated with these foreign investments. One of the goals of CATA is to support Chilean astronomers and engineers to become actively involved in the joint development of new instrumentation, which requires innovation in high technology and computer science. The CATA continues to support and generate the conditions to boost Chilean astrophysics and place it among the world leaders in the area. In what follows we summarize the main achievements during 2010.

New researchers. CATA has brought forth a substantial increase in the number of new researchers at the three associated institutions. During the third year of operation, CATA hired two new astronomers, Rolando Dunner and Thomas Puzia, on a full-time basis. This brings to eleven the total number of new researchers incorporated to the Center. The research interests of Dunner include the study of the large scale structure of the Universe and cosmology, the formation and evolution of clusters and super-clusters of galaxies, studies of the Cosmic Microwave Background, and blind galaxy cluster surveys through the Sunyaev-Zeldovich effect. The research interests of Puzia include the formation and evolution of galaxies, the study of their star cluster systems, chemical evolution and enrichment histories of galaxies, stellar populations and population synthesis models, stellar abundances, hierarchical structure formation and mass assembly of galaxies.

Graduate students. CATA is supporting the formation of human resources in astrophysics in all of the Astronomy programs in the country. The number of graduate astronomy students at the three institutions associated to the Center continues to increase with respect to the average value of the last decade. During 2010 there were thirty nine (39) Ph.D. students in astronomy and twenty nine (29) students in Master's in Astrophysics programs. Most of these students have taken advantage of the Center being granted funds in order to participate in observing runs at the International Observatories in Chile and/or to attend international meetings. In addition the Center has given full fellowships to more than a dozen of graduate students. During 2010, five students obtained Ph.D. degrees and seven students obtained Master degrees. Also more than thirty graduate and undergraduate students were working in individual science projects associated with Key Projects.

Research. The scientific work performed in all six research areas of the CATA during the third year of operation has been considerable and fully in accord with the science goals as formulated in the original proposal. During the January 2010 - December 2010 period, CATA members published one hundred and seventy five (175) papers in refereed journals. The list of refereed (ISI) publications is presented in Table 1.

Collaborations. CATA continues to bring scientists from the three Chilean institutions to work together, particularly in large collaborative projects that are beyond the scope of small research groups. In addition to the Key Projects executed during the last years, which have established strong collaborations within the members of the center, new initiatives have been started to increase multi-institutional collaborations between researchers within the country and abroad in new areas of research. All these projects have been granted considerable amounts of observing time in several telescopes at the International Observatories in Chile. The new initiatives are:

1. Vista Variables in the Via Lactea (PI. Dante Minniti; ESO Large Programme). Public Survey with the VISTA telescope on Paranal, lead by Center members. This near-IR variability survey will scan the Milky Way bulge and an adjacent section of the mid-plane where star formation activity is high.

2. The Milky Way Millennium Nucleus (PI. Marcio Catelan). This Nucleus will undertake frontier scientific research on the Milky Way through the ESO Public Survey Vista Variables in the Milky Way, which will include its early history with implications for understanding formation of big galaxies.

3) Protoplanetary disks in ALMA Early Science (PI. Simón Casassus). This project aims at performing ALMA observations of planet-forming systems, in particular on the acquisition of data on circumstellar disks known to be sites of active planet-formation. This will give information about the accreting gas and dust in proto-planetary disks, their physical, chemical, and morphological characteristics, and will form the basis of state-of-the-art theories on planet formation.

4) Solving the puzzle of the Milky Way bulge (PI. Manuela Zocalli; ESO Large Programme). The aim of this Programme is to determine the metallicity distribution and kinematics across a wide area of the Galactic bulge, with the final goal to understand its formation. This survey will allow Center members to investigate the great complexity of the bulge's population, to separate multiple populations and to put constraints on their formation epochs.

The Center has also hosted several scientists from abroad. Their expertise on different astrophysical topics has enhanced the activities of the Center. In addition to the research collaborations with Center members, the visiting scientists have played an important role in the teaching of astrophysics in our Ph.D. programs. CATA is also supporting the hiring of postdoctoral fellows, which are expected to be key elements in establishing strong scientific collaborations between all associated astronomical Institutions. During the third year of operation CATA allowed the hiring of four new Postdoctoral fellows.

Technology. During 2010 CATA continued to play a key role in the development of high technology in Chile. The initiatives in astronomical instrumentation and robotics are moving successfully and as expected in order to achieve their final goals. All these projects are involving professors of electrical engineering and engineering students from the associated institutions. We expect that at the end of the ten year period, CATA will not only be responsible for the production of high technology astronomical products, but also the seed for the development of engineering and industry in the country.

Workshops. During 2010, five International Workshops were organized with the support of CATA:

1) Supercomputing Techniques in Astrophysics. International school, organized by Padilla, held in Santiago was attended by more than 85 researchers and students from Chile and abroad. *2) Araucaria workshop.* Three-day workshop, organized by Gieren, held in Potsdam, Germany focussing on the Araucaria Project, attended by all members of this international collaboration. *3) VVV Survey of the Milky Way.* Workshop, organized by Minniti, held in Viña del Mar, Chile, and attended by 75 VVV Science Team members and their students from all over the world, including scientists from five Chilean Universities.

*4) Star Formation in the Early ALMA years***.** Mini-Workshop, organized by Mardones, held at Cerro Calan, during March 2010. It was attended by more than 50 participants, including Yale and ALMA researchers and faculty and students from the 3 institutions associated to the Center. *5) Star Formation and Galaxies with Early ALMA.* Workshop, organized by Mardones, held at Cerro Calan, during December 2010. It was attended by more than 60 participants from ALMA, Yale, Mexico, Australia and researchers and students from Chilean Universities.

In summary, activities in both the research and development of high technology areas are proceeding intensely in-line with the initial objectives. The large and small projects carried out by Center members are fulfilling one of the Center goals, that is to broaden the research base in each astronomy site within the country, as well as to establish strong collaborations between the member institutions.

III. RESULTS ACHIEVED

3.1.- Considering the objectives established for the period reported, please describe in **6 pages maximum** the most outstanding results achieved in research activities. If these have resulted in publications simply mention the corresponding reference, if patents or other type of products have been generated please indicate so. If there have been unexpected research results include them here and explain whether may be the projections if any.

3.2.- Include any new and possible application of your research results to non-academic domains (public entities, enterprise, other fields or disciplines) and describe when necessary. Indicate the activities performed and its current stage. Use the amount of space necessary.

3.3.- Name activities that have been done to support other national research groups. If these are **new**, name and shortly describe them, if they consist of **continuing** activities just name them. Use the amount of space necessary.

3.4.- Outreach and dissemination activities of the Center and/or synergies with science education must be described here for the reported period and also included as part of the appendices. Printed and digital material related to these activities must be sent with this report but not attached to it.

The scientific contributions from members of the Center for Astrophysics and Associated Technologies during its third year of operation are fully in accord with the science goals as formulated in the original proposal. Research activities in all areas proceeded intensely in-line with the initial science objectives and broadening their scope. A summary of the principal science results obtained during the third year of activities in each of the individual areas of research is presented in what follows.

Area 1. Birth and Evolution of Structures in the Universe (PI. Leopoldo Infante)

Ongoing research projects:

*Clustering of LAEs at z=3.1***.** Project aimed at measuring the clustering properties of Lyman Alpha Emitter (LAE) and Lyman Break Galaxies (LBG) in quasar fields.

Lyman-break Galaxy Redshift Survey at z≈3. Currently the survey contains 2100 galaxy redshifts obtained with VLT VIMOS. The goal is to study luminosity functions, clustering and gas outflows.

*The Chile-ACT Ultradeep Survey (CACTUS***).** Deep mapping of a 30 sq.deg. region of the Atacama Cosmology Telescope southern strip with the goal of probing deeper into the luminosity function of submm galaxies, and to lower the mass limit on the mass function of galaxy clusters.

AGN and low-surface brightness galaxies. Members studied the frequency of AGN activity in LSB galaxies, finding it to be lower than on high surface brightness galaxies.

Low Surface Brightness galaxies (LSBGs). Using the SDSS DR-7, Center members obtained new results on the distribution of LSBGs in the cosmic web, which indicate that these galaxies are located in significant numbers in the outskirts of the voids.

Detection and characterization of galaxy clusters from the Atacama Cosmology Telescope. Center members have made SZ detection and optical imaging confirmation.

Theory and simulations. Continuing work on: (1) Semi-analytic galaxy formation modeling for ALMA; (2) AGN-host galaxy alignments; (3) Pop III stars from gas turbulence at z=11 and (4) Black hole – galaxy connection.

New projects started in 2010:

The LABOCA Survey of Clusters at All Redsfhits (LASCAR). Survey of 870 um emission towards 15 of the most massive galaxy clusters detected by the Atacama Cosmology Telescope.

Spectroscopic follow-up of Quasars behind Clusters.

Black hole spin and AGN feedback.

Lensed cluster masses.
*Galaxies at z>7***.** Collaboration within the CLASH (Cluster Lensing and Supernova survey with Hubble) consortium to follow up galaxies at redshifts larger than 7.
Search of QSO close pairs from the Red-Sequence Cluster Survey 2 and SDSS.
Evolution of the M/L ratio for luminous red galaxies from galaxy-galaxy lenses in the Red-Sequence Cluster Survey 2.

Area 2. Stellar Populations in the Local Universe (PI. Doug Geisler)

Ongoing research projects:
Globular Cluster Systems. Project aimed at undertaking studies of galaxy formation and evolution, dark matter distribution, chemical evolution of globular clusters and galaxies and cluster kinematics.
Stellar Populations in Nearby Galaxies. Project aimed at performing studies of stellar populations in order to understand star cluster formation and evolution as well as chemical evolution and galaxy formation.
*Stellar Populations in the Milky Way***.** Research on stellar population in our Galaxy in order to understand its structure and formation, as well as star cluster formation and evolution.

New projects started in 2010:
*Testing the Universality of the Mass-Metallicity Relationship in Globular Cluster Systems***.** Project aimed at studying a number of galaxies with a range of environments and types to study the mass-metallicity relationship and assess whether or not this is due to self-enrichment of the most massive protoclusters during their formation
*Vista Variables in the Via Lactea (VVV***).** ESO Public Survey with the VISTA telescope on Paranal, lead by Center member D. Minniti. The VVV near-IR variability survey will scan the Milky Way bulge and an adjacent section of the mid-plane where star formation activity is high. The Survey will take 1929 hours of observations with the 4-meter VISTA telescope during five years (2010 − 2014), covering a billion point sources across an area of 520 sq. deg, including 33 known globular clusters and ~ 350 open clusters. The final product will be a deep IR atlas in five passbands (0.9 − 2.5 μm) and a catalogue of more than a million variable point sources. This will enable construction of a 3-D map of the surveyed region using well-understood distance indicators such as RR Lyrae stars, red clump giants, and Cepheids.
Multiple Populations in Globular Clusters. Project aimed at observing stars in a variety of clusters at high spectral resolution in order to derive detailed abundances of many elements to try and build up our knowledge on their complex formation histories and constrain models for its origin.
Creation of a Theory Group.

Area 3. Distance scale (PI. Wolfgang Gieren)

Ongoing research projects:
The Araucaria Project: determining the environmental dependence of stellar distance indicators in optical and near-infrared domains. Stellar distance indicators include Cepheids, RR Lyrae stars, red clump stars, TRGB and blue supergiants via the spectroscopic FGLR introduced and calibrated by Center members.
Calibrating the zero point of the cosmic distance scale with late-type eclipsing binaries in the Magellanic Clouds. The goal is to determine orbital solutions and distances accurate to 2-5% for 30 systems in LMC and SMC.
Testing the universality of the Cepheid period-luminosity relation by applying the infrared surface brightness Baade-Wesselink technique to Milky Way and Magellanic Cloud Cepheids.

New projects started in 2010:
1. Calibrating and using near-infrared photometry of Type-II Cepheids to determine the distances to the Magellanic Clouds.
2. Calibrating the near-infrared H-band magnitude of the red clump as a new and robust distance indicator.

3. Comparing eclipsing binary and Baade-Wesselink distances to Cepheids members in double-lined eclipsing binaries in the LMC. The goal is to have a direct empirical determination of the projection factor used in the BW method, currently constituting its largest systematic uncertainty.
4. Measuring very accurate dynamical masses of classical Cepheids in LMC double-lined eclipsing binaries.
5. Determining Cepheid distances to nearby galaxies containing Type I and II supernovae: a Cepheid calibration of SN peak brightnesses.

Area 4. Star formation (PI. Guido Garay)

Ongoing research projects:
Massive star forming regions. Multi-wavelength studies of luminous massive star forming regions in order to determine the properties of the molecular gas and dust as well as on the stellar content.
Molecular outflows. Studies of high velocity molecular gas towards massive young stellar objects.
*Ionized jets towards high-mass young stellar objects candidates***.** Continuing search of ionized jets, using ATCA, towards massive YSOs. A collimated stellar wind emanating from the most luminous massive protostar yet known was discovered this year.
Infrared Dark Clouds. Project aimed at observing the emission in several molecular lines, using MOPRA, toward a large number of filamentary cold, dense molecular clouds seen in order to better characterize the various stages of high-mass star formation as well as the timescales and physical conditions during the collapse into proto-stellar cores.
H_2 formation in the interstellar medium. Project aimed at producing state-of-the-art models for the regions where H_2 formation is known to occur, and to compare these models with unprecedented H_2 spectra.

New projects started in 2010:
*The Millimetre Astronomy Legacy Team 90 GHz (MALT90) Survey***.** Large international project aimed at observing 16 molecular lines near 90 GHz, using MOPRA, towards 3,000 dense cores in the galactic plane in order to probe their physical conditions, chemical state, and evolutionary states.
APEX Telescope Large Area Survey of the southern Galactic plane (ATLASGAL) - Extension southward to Carina. Extension of the ATLASGAL survey at 870 um toward southern regions of the Galactic plane, to fully cover the most nearby Galactic arm: the Carina arm.
Turbulence in molecular clouds. Project aimed at identifying the source responsible for the intermittency of turbulence seen toward non-star forming region, over scales of parsecs.
Protoplanetary disks. Project aimed at understanding the gas content in protoplanetary disks and finding signs for on-going planet accretion. In particular, a Center member (S. Cassasus) was granted with a Millenium nucleus on "Protoplanetary Disks in ALMA Early Science".

Area 5. Extrasolar Planets and Brown Dwarfs (PI. Dante Minniti)

Ongoing research projects:
The HAT South Project. This search for extrasolar planetary transits started producing the first southern hemisphere candidates that are being followed up.
Optical photometry Monitoring of Transiting Exoplanets for Transit Timing Variations. Members have completed a study of OGLE-TR-111b, and are analyzing other transits.
*Search for planets in M67 using HARPS***.** Continuing search of planets, using HARPS, in this cluster of similar age and metallicity as the Sun.
The Magellan Planet Search. This radial velocity search for planets yield five new discoveries during 2010. Center members are now finishing up a study of the HK chromospheric activity of a large sample of stars and improving the precision of M-dwarf radial velocity observations.
Ultrafast infrared photometry of planetary transits. A new method for photometry of extrasolar planetary transits, based on ultrafast near-IR observations, will allow the detection of extrasolar planetary transits down to a few millimagnitudes.
*Characterization of Extrasolar Planets atmosphere***.** Project aimed at detecting Thermal emission and/or Transmission Spectra of selected transiting candidates.

*The WFC3 Galactic Bulge Treasury Program***.** As follow up of previous HST survey for exoplanetary transits in the bulge, members have obtained metallicity estimates for the stellar population and exoplanet hosts.
CHEPS: The Calan-Hertfordshire Extrasolar Planets Survey. On-going planet search project carried out using the CORALIE and HARPS instruments on La Silla.

New projects started in 2010:
*Brown dwarf birthrate from UKIDSS BDs***.** Project aimed at taking spectra, using XSHOOTER at the VLT, of a sample of ~300 brown dwarf candidates in the L-T transition region to constrain the birthrate for brown dwarfs.
Search for nearby BDs in the VVV Survey data. The VISTA Variables in the Via Lactea is a treasure for the search of high proper motion objects, specially faint red objects like nearby BDs.
Spectral synthesis analysis of main sequence and subgiant stars using FEROS optical spectroscopy. The goal is to apply a new method for abundance analysis of Sun-like stars to a large sample of stars to analyse them for future planet search and analysis of abundance trends in the galaxy.

Area 6. Supernovae and Dark Energy. (PI. Mario Hamuy)

Ongoing research projects:
Supernova Search (CHASE). Continuing search using the PROMPT telescopes to discover nearby supernovae. In 2010, 36 supernovae were reported in Central Bureau Electronic Telegrams.
*Spectroscopic and Photometric follow-up of CHASE supernovae***.** Center members continued the photometric follow-up of selected CHASE supernovae using the PROMPT telescopes. The spectroscopic follow-up of the youngest CHASE supernovae was done with the VLT, Gemini, SOAR, and Magellan telescopes.
Determination of Extragalactic Distances. Center members perfected the techniques for distance determination using Type Ia and Type II supernovae**.**
*The physics of supernovae***.** Center members have published papers on supernova asymmetries from spectropolarimetry, on supernova progenitors, on supernova off-center explosions, on stripped-envelope supernovae, and on a relativistic supernova.

Area 7. Astronomical instrumentation (PI. Leonardo Bronfman)

The main goal of this area is to build a prototype receiver for the lowest frequency band of ALMA, covering the 31.3 - 45 GHz range. The major activities during 2010 are the following:
Receiver General Specifications. In a joint effort with HIA (Canada) and ASIAA (Taiwan), the document “Band 1 Cartridge Technical Specifications” was completed.
Cryogenic test set-ups. The NAOJ Cryogenics system was completed and tested. Four temperature sensors were installed and put to operation. The CBI receiver is being reassembled as a cryogenic test station for components. Temperature monitor and sensors were mounted for use, as well as the Helium compressor, Helium pipelines and water cooling pipelines.
Prototype design. After various iterations, the final components layout was defined. The mechanical drawings were reviewed and a final detailed design of the cartridge produced. To build the blank cartridge, G-10CR polymer material was acquired for thermal separation between the cold plates. Construction begins in 2011.
Optics System. A theoretical analysis of the quasi optical beam propagation for the Band 1 system was achieved. The lens was designed and a first prototype was machined at the University of Koln. The work on the anechoic chamber was finalized and high quality data of the horn performance were produced. Major improvements were achieved in the calibration of the Orthomodal Transducer (OMT) test measurements, and a new version of the OMT was designed using the data obtained.
*Low Noise Amplifiers (LNA***).** A review of the specifications for Band 1 LNAs and some proposed technologies were compiled and presented. To develop the capabilities for amplifiers fabrication, the first version of an LNA, based on a commercial MMIC, was built in 2009. During 2010 important changes in the design and fabrication process were introduced, largely improving the overall

performance. Gold plating of the chassis and transitions was introduced, more suitable components selected, and a compact design achieved. Our abilities now more mature, work started to focus in the fabrication of amplifiers based on single HEMT transistors (MICs). Two new students started work in 2010, one in the fabrication of amplifiers based on commercial transistors, the other in characterization of high quality Cryo-3 transistors obtained from Caltech.
*Test set-up for receiver cartridge***.** The coming stage of the project consists of assembling the Band 1 prototype and test it to measure its performance. A test set-up to measure the prototype receiver noise temperature and beam patter, at cryogenic conditions, was designed, and will be built in 2011.

New projects and unanticipated outcomes.

Construction of the RF test source for ALMA Band 5. Our laboratory is involved in a collaboration with several European partners, including GARD (Group for Advanced Receiver Development, Sweden) and RAL (Rutherford Appleton Laboratory, UK), for the assembly, integration, and verification of 6 receivers for the Band 5 of ALMA (186-211 GHz). While our original participation was focused on the training of Chilean engineers, the development of laboratory facilities allowed us to build at home the radio frequency RF test source to be used at RAL for measuring the beam pattern of the receivers. Principal parts of the source, like the high precision waveguide probe, were machined in our laboratory. This is the highest frequency emitter ever built in a Chilean laboratory.

Side-band separating mixer for ALMA Band 9. In a new collaboration with the Netherlands Institute for Space Research (SRON), we designed and successfully fabricated in our laboratory the central element for a new sideband-separating receiver working at the frequency range of 600-720 GHz corresponding to Band 9 of ALMA. The element is part of an already working prototype; future receivers, based on this prototype, will eventually replace the double-sideband receivers currently being fabricated at SRON and delivered to ALMA. The circuitry has transversal dimensions of few hundred microns with smaller details reaching dimensions of around 20 to 50 microns, implying a great fabrication challenge. A second block was delivered later in the year, this time made out of bronze for comparing the machining ability w/r to copper. In this regard, copper has proven to be preferable for machining. Moreover, after gold plating, both blocks have demonstrated similar results.

Spin-off to other universities; Beam pattern measuring setup and transfer to UTFSM. A near field beam pattern measuring system, to test the receiver optics, was designed and assembled in our laboratory. The original value of USD 150.000, quoted from an external company, was reduced to USD 30.000, through complementary funding by ALMA-CONICYT, by purchasing the needed components and integrating them into our own innovative setup. The control software, a complex automation problem, was developed as an Engineering title memoir. The know-how acquired was subsequently transferred to the Telecommunication Department of UTFSM, who plan to build a similar system. In retribution, using their expertise, they are designing for us a Fresnel Zone plate lens, as an alternative for the ALMA Band 1 lens, that could critically reduce the contribution from the optics to the receiver noise.

Spin-off to national industry; Gold Plating of the Low Noise Amplifier mount. Physical mounting in a chassis affects the noise and the gain for the Low Noise Amplifiers (LNA). During 2010 a second version of the LNA was produced, improving the gain and noise, by gold plating the chassis and the wave-guide transition. The gold plating was done by local industry and required joint work with our team to achieve optimal thickness of the gold layer, producing transfer of technology to the industry, which may be used in several other fields.

Area 8. High Performance Computing (PI. Alejandro Clochiatti)

Hardware. The Geryon computer cluster is now composed of 64 nodes with 128 CPU Intel Xeon E5405 Quad Cores running at 2.00 GHz (this makes up a total of 512 cores). Static memory has been expanded to 1 TB RAM. The data disk boasts 45 TB and we are currently purchasing 20 TB more. Nodes connect through a 1000 Mbps ethernet. We ran a 64 bits Linux operating system.

Software development tools include Intel FORTRAN and C compilers, a Sun Grid Engine queue system and the standard GNU tools. Further tools are being purchased in order to make the system friendlier to users of the Computing Science Department and, in general, users outside the astronomy community. The computer room was improved by installing noise reducing layers in walls and ceiling, as well as special sound proof door. The system was upgraded with support from different grants, other than Basal, and there are further plans to make it more powerful. By mid 2010, the system administration opened the system to the Chilean community. After a technical evaluation of proposals and convergence to a sustainable plan of usage, access is granted. A web page was created (geryon.astro.puc.cl/usage) were users can check in real time the status of their accounts as well as the statistics of the general use of the machine.

Software and Usage. Researchers, postdocs and students of two of the associated institutions of CATA (PUC and U. de Chile), have made extensive use of Geryon. The cluster has been continuously used as a support for research and teaching. Three PhD dissertations, which involved critical steps ran in the cluster, were finished. In what follows we mention the main works carried out by Center members and their students.

1. Parallelization of the Princeton-Goddard-PUC stellar evolution code, carrying out extensive computations in Geryon to explore a wide range of parameters space, including metallicity and helium abundance. They produced one of the most extensive databases of stellar evolutionary tracks and isochrones for old stellar systems, which are now being used in extensive comparisons with the empirical data, including the Hubble Space Telescope Advanced Camera for Surveys Treasury Program of Galactic Globular Clusters and the Vista Variables in the Vía Láctea (VVV) ESO Public Survey of the Galactic bulge and inner disk.
2. Galaxy profile fitting for a sample of five million galaxies observed by the 1000 square degree Red Cluster Sequence Survey. The process, aimed at cataloguing galaxy morphology, involves model convolution with the observed PSF and a Chi2 minimizing algorithm. 50 processors of Geryon were simultaneously committed for about a week in order to perform this task.
3. Studies of the formation of the first structures in the universe using cosmological simulations. They followed the collapse of dark matter halos from redshifts 100 up to 11, including cooling by 21 species of molecules in non-equilibrium, and identified turbulent regions, likely to be primordial cluster and star formation regions, as the suitable birth place of Pop. III stars. This work required the full capacity of Geryon during several weeks.
4. Semi-analytic model extensions, including line emission for low and high redshift galaxies. In particular they have: (1) undertaken numerical simulations and perfected algorithms to identify large-scale structures in them and to study their role in galaxy formation; (2) analyzed the evolution of large-scale structure in the Universe and its relation with the assembly bias superimposing model semi-analytic galaxies over very large numerical simulations; (3) investigated measurable effects of cosmology based on halo catalogues extracted from numerical simulations.

Area 9. Outreach (PI. José Maza)

The Center continues to support the involvement of its members in Education and Public Outreach. In what follows we mention the main activities carried out during 2010.

1. Project Carina. The Center purchased three portable telescopes, two reflectors of 8 inches and a refractor of 4 inches of aperture, to be used for *star parties* at different public schools in the neighborhoods of Santiago. The observations are complemented with lectures about the solar system and stellar evolution. An assistant astronomer with lots of experience with telescopes was hired to operate the telescopes. A total of 30 parties at 13 public schools have been delivered.
2. *Training of science teachers in astronomy.* A High school science teacher was hired to analyze basic school and high school science curriculum relative to astronomy and to prepare material with the appropriate content. The first training of teachers was carried out at Cerro Calán Observatory. Fifty teachers from all over the country, from Arica to Punta Arenas, received lectures, practical sessions, observing sessions and a large quantity of material including a special booklet.

3. Astronomia Educativa 2.0. Our CATA Journalist, David Azócar, created and is the leader of the facebook group "Astronomia Educativa 2.0" where science teachers, particularly those that attended the workshop, are participating and sharing experiences.

4. Radiotelescope. The Center supported the installation in Cerro Calan of a 1.2 mm-wave telescope that will be used to introduce radioastronomy to visitors by observing molecular clouds in the Galaxy, where stars form.

Networking.

During 2010, there was considerable interaction with research and researchers of all areas of the Center. Thirty three (33) percent of the papers published during the third year have two or more Center members as co-authors. In what follows we summarize the way in which the different programs of the Center interact.

- Interaction between researchers of Areas 2 and 3 provided many valuable insights on how different distance indicators are affected by age and metallicity. For example, as a byproduct of the blue supergiant distance work, researchers of Areas 2 and 3 measured the first chemical abundance gradient in a disk galaxy beyond the Local Group. The interaction between these two groups will increase very dramatically with the onset of the VVV project especially after the intense variability study commences, which will provide distances to a huge number of RR Lyrae and Cepheids in the Galaxy and provide extremely precise distances to the Galactic center, a large number of open and globular star clusters, the Sagittarius dwarf galaxy, the size of the Bulge, etc. During 2010, a postdoc shared between these two areas, as well as between Universidad de Concepcion and Universidad de Valparaiso, began a two-year position funded in part by the Center.
- Members of Area 3 and Area 6 started a new common program to provide Cepheid calibrations of supernova peak brightnesses, particularly to improve the calibration of the Expanding Photosphere Method for SN II. In a future stage of Area 3 work (re-determination of the Hubble constant once our programs have yielded a set of improved tools, and distances to nearby galaxies allowing calibration of secondary methods) they expect to increase collaboration with Center members working in projects belonging to Area 1.
- The VVV survey is also initiating increasing collaboration between researchers of Areas 2 and 5 as the database will provide a huge database relevant to both Groups. There has been fruitful interaction of researchers in these areas taking advantage of the similar techniques (e.g. precision photometry, optical spectroscopy) they use.
- Inter-institutional collaborations have also increased. One example of these is CHEPS: The Calan-Hertfordshire Extrasolar Planets Survey, which is led by Jenkins at UCH, that includes collaborative efforts from PUC members. Another example is the on going project of characterisation of extrasolar planetary transit candidates, which involves scientists from PUC, UCH and UCon. In addition, often graduate students have committees that include BASAL members from different institutions.

IV. PROJECT MANAGEMENT

4.1 Advisory Committee

Please include copy of the minutes resulting from the reported period meetings. Give a brief summary of the main decisions taken.

4.2 Changes in research personnel

Indicate any changes in the Staff of Principal Investigators and other Investigators as compared to the original Development Plan.

4.3. Changes or adjustments in the Center organization that affect the objectives of the Development Plan.

In case these have occurred over the reported period please modify the organizational flowchart.

4.4. Indicate the most significant activities (according to your perspective) oriented to establish links with other partners that generate important projections for the Center in aspects such as financial investments, international cooperation, training of students, etc.

4.1 In what follows we provide answers and/or information concerning the main suggestions and recommendations raised by the referees.

- We have now filled in the report ''Section V. Lessons learned'' providing information on the problems encountered and what has been learned.

- We have now indicated in ''Section III. Results achieved'' the synergies across the different research lines. Collaborations between members of different areas are increasing steadily with time. It is fair to say, however, that the "interface" between astronomy and engineering is nowadays scarce, but it is expected to increase naturally when the final product is delivered. For instance, a handful of Ph.D. thesis could be finished this year as the computer cluster was ready for operation.

- A handful of reports related to astronomical instrumentation have been published during the last two years:

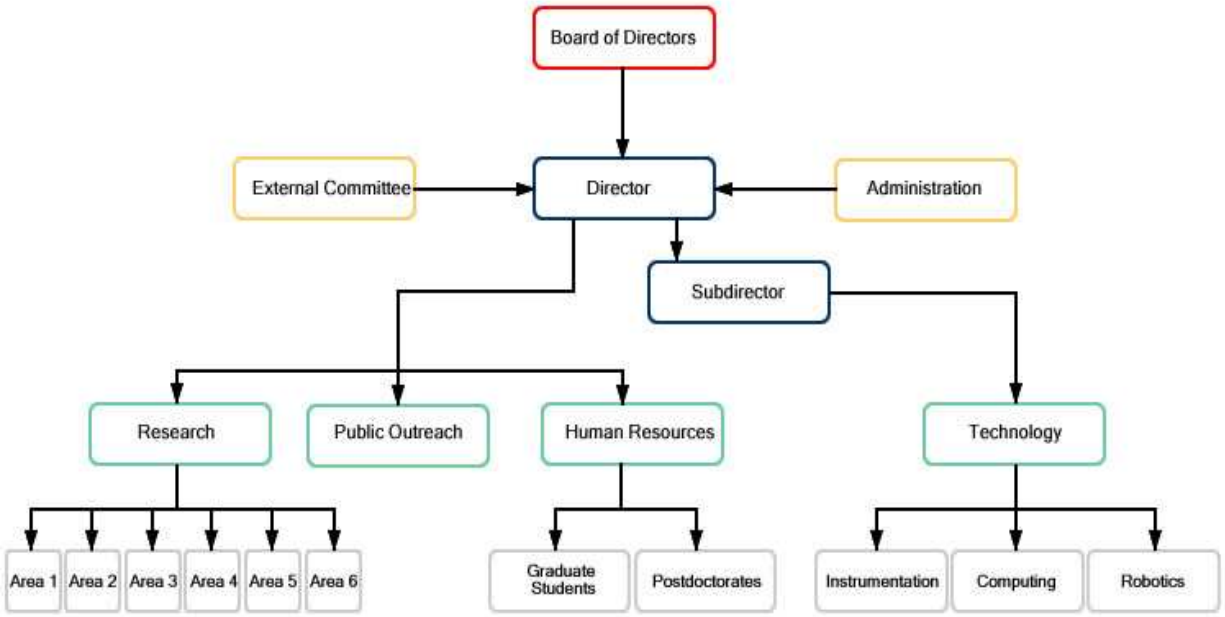
1. *Analysis of the Amplification System of ALMA Band 1*. SPIE Conference in Astronomical Telescopes and Instrumentation July 2010, San Diego California. N. Reyes, C. Jarufe, F. P. Mena, J. Pizarro, L. Bronfman, and J. May.
2. *Design of a heterodyne receiver for Band 1 of ALMA*. Proceedings of the 20th International Symposium on Space Terahertz Technology, Charlottesville, April 20-22, 2009. N. Reyes, P. Zorzi, F.P. Mena, C. Granet, E. Michael, and L.Bronfman.
3. *Performance Comparison of Corrugated and Smooth-Walled Spline-Profile 31.3-45 GHz Horns for ALMA.* 4th European Conference on Antennas and Propagation, EuCAP 2010. 12-16 April 2010, Barcelona, Spain. Granet C. , Mena, P., Zorzi, P., Davis, I.M., Kot, J.S., and Pope, G.
4. *Revisiting the ALMA Band 1 Optics Design.* 21st International Symposium on Space Terahertz Technology, ISTT March 2010. University of Oxford, UK. P. Zorzi, D. Henke, S. Claude, P. Mena, L. Bronfman, and J. May.
5. *Construction of a heterodyne receiver for Band 1 of ALMA.* 21st ISTT March 2010. University of Oxford, UK. N. Reyes, P. Zorzi, C. Jarufe, P. Altamirano, F. P. Mena, J. Pizarro, L. Bronfman, J. May, C. Granet, and E. Michael.
6. *Implementing a Modular 650 GHz Sideband-Separating Mixer* . 21st International Symposium on Space Terahertz Technology, ISTT 2010. 23rd - 25th March 2010, University of Oxford, UK. R. Hesper, A.M. Baryshev, G. Gerlofsma, F.P. Mena, T. Zijlstra, M.C. Spaans,

- Concerning financial aspects, we note that this report is not designed for the accounting of the finances. Of course financial clarity is a must, but that is done through a different channel. In any case, the problems encountered by one of the referees arose from the fact that the entries in the tables in M$ do not mean million $ but just thousands $ (the M stand for the spanish word Miles which means Thousands).

4.2 There has been no changes in the staff of Principal Investigators.

4.3. Very little progress has been made in the Area of High Performance Computing concerning the handling of large data basis, their transfer and storage. This Area is certainly not fulfilling the initial goals and we are critically reviewing their impact, as well as changes and/or adjustements.

Organizational Flowchart of the Center



Director : María Teresa Ruiz G.

Sub-Director : Guido Garay B.

External Committee: Mark Phillips (Chair), Lars Nyman, Rainer Mauersberger, Tom Wilson

Administration: Administrators: Erika Rojas and Patricia Monroy
Secretary: Mariela Fajardo

Research : L. Infante. P.I. Area 1
D. Geisler P.I. Area 2
W. Gieren P.I. Area 3
G. Garay P.I. Area 4
D. Minniti P.I. Area 5
M. Hamuy P.I. Area 6

Human Resources : D. Minniti . – G. Garay – W. Gieren

Technology : L. Bronfman P.I. Instrumentation
A. Clocchiatti P.I. Computing
M. Hamuy P.I. Robotics

Public Outreach : José Maza

LESSONS LEARNED (If apply)

The following section should provide information on difficulties encountered in the execution of the Development Plan either within the Center, between CONICYT and the Center, or/and the sponsoring and participating institution(s), researchers or any other combination of participants and activities considered.
Any feedback that you consider is important for the Program is appreciated.

Include a summary that indicates how mid-term and previous reviews recommendations have been considered in the present period.
Do not extend further than 3 pages.

In the following we describe some of the difficulties and lessons learned in executing the Development plan. They are mainly concentrated in the area of Astronomical Instrumentation, which is the new area of development undertaken by CATA in technology.

A. Construction of a prototype receiver for Band 1 of ALMA.

General problems and lessons learned.

1. Lack of appropriate level in the overall information among members of the group, with subsequent loss of efficiency and coordination. Stimulate communication between members of the group.

2. Several iterations in the design and construction work, without proper registering. This implies the loss of know how in the event of rotation of the laboratory members. Create a proper system of reports.

3. The nature of the project forces the members to carry on a diversity of jobs, what is good for general training, but limiting the efficiency. Need to have more technical permanent personnel.

4. Any failure in our high precision equipment means a long delay, since diagnosis and repairs are to be processed abroad. Increase the efficiency of order process

Specific difficulties encountered during the year.

1. During 2010 a test setup for room temperature noise characterization of amplifiers was built. Our mm-wave laboratory does not own a spectrum analyzer, so one was loaned by DIE in a short term basis. Lack of a permanent spectrum analyzer is becoming a problem, and all efforts are being done to fund one.

2. Setting up of a cryogenic noise measurement system started in 2010. Mostly due to shortage of qualified manpower, the goal has not been reached. Reassignment of personnel is taking place in 2011, so it is expected to complete this work and have cryogenic measurements as soon as possible.

3. A cryogenic isolator is needed between the LNA and the mixer, for a low insertion loss (better than 0.3dB) over the band, further, the isolator should be small. Modified compact isolators were purchased from Channel Microwave; after several iterations, it is clear that the insertion loss values cannot be achieved over the complete Band 1. A new specification for the edges of the band (31-33GHz, 43-45 GHz) was accepted and the delivering of the units delayed from December 2010 to June 2011.

B. Robotic Telescope

During 2010 several parts of the 50 cm robotic telescope were installed: (1) the optical tube, including its control box, environmental sensors and control for the focuser; (2) the camera and filter wheel, and (3) the telescope control software. The telescope accomplished its first light during Nov 2010 and obtained its first scientific result, the confirmation of a supernova candidate, a few days afterwards. In achieving this milestone, several difficulties were encountered.

1. Delays from multiple manufacturing. The dome, designed by us with the goal of performing adequately under conditions of extreme snow loads, was built from parts made by four Chilean companies: Istria,Vignola, He Fiberglass and Elastoplastic. The building process required a close interaction between all the participants causing an unexpected delay. In order to improve the design of certain components it was necessary to test them implying
slow iterations between all the manufacturers. Now we have learnt that this is normally the case for the prototyping process. As the iterative prototyping proceeded, the manufacturers had to modify their assumptions and their associated costs, which implied unforseen costs which we had to cover.

2. Delays due to competition with the mining industry. Some manufacturers decided to stop working in our project for periods of weeks at critical moments when mining companies would present them with new orders. Companies will prefer to pay a fine rather than losing an opportunity with the mining industry, which needs to be acknowledged in the planning of another project like this, including legally binding agreements. Since the installation of the dome required the hiring with anticipation of teams of people, trucks, a crane, special equipment and the purchase of numerous components, the delays suffered during the construction phase also delayed the installation phase and increased the costs.

3. Maintenance and design problems. Some companies found it difficult to offer maintenance due to the difficult location of the project, which also meant that some design problems were not solved satisfactorily. For example, the rubber seals that protect the telescope from the rain, wind and snow were difficult to install. After the installation it became clear that their design was not satisfactory, with big leaks apparent in many sections of the dome. Given the urgency of other steps during the installation procedure it was decided to fill the observed leaks with a polyurethane foam that will probably need replacement before the coming winter. There were also coordination problems with the electronic control of the telescope. In order to meet projected deadlines we bypassed the company Vignola and modified the electronic control system provided by them, purchasing a different programmable logic controller.

4. Equipment problems. The optical system did not achieve the resolution specified by the manufacturers (AstroTech). The optical tube was recently collimated with the help of an astrophotographer in order to try to reverse this problem, but it is now believed that the thermal inertia of the mirror is what stops us from achieving the design specifications. We ask the manufacturers to add new fans that could make the temperature equilibration of the mirrors faster. The CCD camera we purchased is a grade 1 CCD, which should have very few bad pixels on it. However, we detected the presence of a very big cluster of bad pixels at the center of the CCD frame. Thus, the camera did not even meet the design specifications of the lower quality models offered. This was recognized by the manufacturer, Finger Lakes Instrumentation Inc., and the CCD was replaced at the beginning of 2011.

VI. PERFORMANCE INDICATORS

The following section is a summary of the information provided in the previous sections.
Please complete the base line and the data for the reported period. When it does not correspond, indicate not applicable with N/A.

DEVELOPMENT AREAS	INDICATORS	BASE LINE(*)	REPORTED PERIOD	
			Basal Financing Funds(+)	Other Sources
GENERAL	Number of Principal Investigators	**10**	**10**	
	Female Gender (%) of Principal Investigators	**10%**	**10%**	
	Number of other Investigators	**15**	**32**	
	Female Gender (%) of other Investigators	**15%**	**10%**	
SCIENTIFIC EXCELLENCE	Number of ISI publications	**70**	**175**	
	Number of non ISI publications	**40**	**74**	
	Number of citations in ISI Journals	**280**	**1185**	
	Percentage of publications Co-authored with national/international researchers from other institutions	**80%**	**98%**	
	Percentage of publications Co-authored with researchers of the Center	**20%**	**33%**	
	Average number of citations per article	**4**	**7**	
	Number of international exchange networks			
	Number of national presentations/conferences	**8**	**43**	
	Number of international presentations/conferences	**25**	**51**	
TRAINING OF HUMAN RESOURCES	Number of undergraduate students			
	Number of female (%) undergraduate students			
	Number of completed undergraduate theses			
	Number of Master students	**24**	**18**	**11**
	Number of female (%) Master students	**33%**	**21%**	
	Number of completed master theses	**4**	**7**	
	Number of Ph.D. students	**22**	**27**	**12**
	Number of female (%) Ph.D. students	**33%**	**33%**	
	Number of completed Ph.D. theses	**2**	**5**	
	Number of posdocs working in the Center	**18**	**14**	**17**
	Number of female posdocs(%) working in the Center	**16%**	**19%**	
	Number of stays/visits from students or researchers from other Centers or projects (national and international)	**15**	**8**	**15**
	Number of stays/visits to other institutions by students or researchers of the Center	**20**	**13**	**12**

DEVELOPMENT AREAS	INDICATORS	BASE LINE(*)	REPORTED PERIOD	
			Basal Financing Funds(+)	Other Sources
TECHNOLOGICAL TRANSFER AND LINKAGE WITH OTHER SECTORS OF CHILEAN ECONOMY AND SOCIETY	Number of patent applications	**0**	**0**	
	Number of patents granted	**0**	**0**	
	Number of licenses and/or Technology Transfer Agreements applied and/or granted	**0**	**0**	
	Number of spin-offs companies rising from the Center	**0**	**0**	
	Number of doctorates and postdoctorates inserted in the Industry	**0**	**0**	
	Number of participations in instances of public policy definition (consulting councils, advisory committees).	**0**	**0**	
	Number of participations in other relevant institutions	**0**	**0**	
	Amount and % of the Center´s income from private sector companies (in cash and in kind (non cash) contributions can be considered).	**0**	**0**	
	Amount and % of the Center´s income from other non-government sources (in cash and in kind (non cash) contributions can be considered).	**0**	**0**	
SUPPORT TO OTHER RESEARCH GROUPS	Percentage of ISI publications co-authored with national researchers (from other institutions).	**2%**	**4%**	
	Percentage of theses co-tutored with national researchers from other institutions.	**0**	**0**	
	% of equipment available to researchers who are not part of the Center.	**0%**	**15%**	
OUTREACH ACTIVITIES	Number of outreach and/or extension activities.	**10**	**20**	
	Total number of people attending to outreach and/or extension activities.	**1000**	**2000**	
	Number of times the project appears in mass media.	**0**	**6**	
	Number of documents, reports, proceedings resulting from outreach/extramural events or activities.			
OTHERS				

(*) Base line is the average indicator from the last 3 years before the application (presented in the Application Form).

(+) Including resources from the Basal Financing Program and resources from other significant and stable public sources, such as: FONDAP, Institutes and Groups of the Millennium Scientific Initiative (ICM) and Regional Center Associations in Science and Technology, Team Research Projects in Science and Technology.

FINANCIAL STATEMENT

FUNDS OBTAINED

Please indicate the funds obtained in the reported period using the following table:

MAIN FUNDING		In cash(M$)	In kind (M$)
Main Public Funding - Significant and Stable			
CONICYT	Basal Funding	690000	
	FONDAP	600000	
	ANILLOS		
	Regional Centers		
MSI	Millennium Institutes		
	Millennium Nuclei	295820	
COUNTERPART FUNDING			
Other Public Competition Funds			
CONICYT	FONDECYT	532356	
	FONDEF		
	INTERNATIONAL COOPERATION		
CORFO	CORFO - INNOVA		
Other sources (FIA, FIP, etc.)-you may add rows	*Name of the agency that delivers the grant*		
Private Sources - National or International Non-Profit or For-Profit Organizations			
National Sources			
Corporations	*Name of the institution*		
Non-profit Org.	*Name of the institution*		
Other, (insert rows)	*Name of the institution*		
International Sources			
Corporations	*Name of the institution*		
Non-profit Org.	*ALMA*	122721	
	GEMINI	107020	
	ESO	174800	
	European Union	38000	
Other, insert rows	*Name of the institution*		
Contributions from the Sponsoring Entity			
	Name of the institution		

PRODUCTS

All products resulting from this reported period must be included in the appendices provided for that effect. (The appendices already have the information that you provided in your previous report). Among the most important are: publications and patents, scientific events (congresses, courses, conferences, workshops and/or symposia); theses finished; public policy events and private sector events among others.