2015 CFHT Annual Report

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Front and back covers: The spiral galaxy Messier 98, as imaged by CFHT's MegaCam, is shown on the front and back covers together with CFHT atop the upper ridge of Maunakea. This image depicts a huge range in object distances, with face-on spiral galaxies, dwarf galaxies, and bright foreground stars all in the same field.

Director's Message

CFHT's 36th year in operation was marked by the arrival of a new instrument, completion of what may be the largest engineering project in the history of the observatory, release of new and innovative operating modes, a new Telescope Control System, the first fiber link between two major observatories enabling shared instrumentation, regular use of the new dome vent system, fantastic scientific and technical progress with MSE and SPIRou, a myriad of fascinating scientific discoveries, launch of new outreach initiatives, and direct engagement of the most complex and impactful issues Hawaii astronomy has ever faced. 2015 was a busy year…

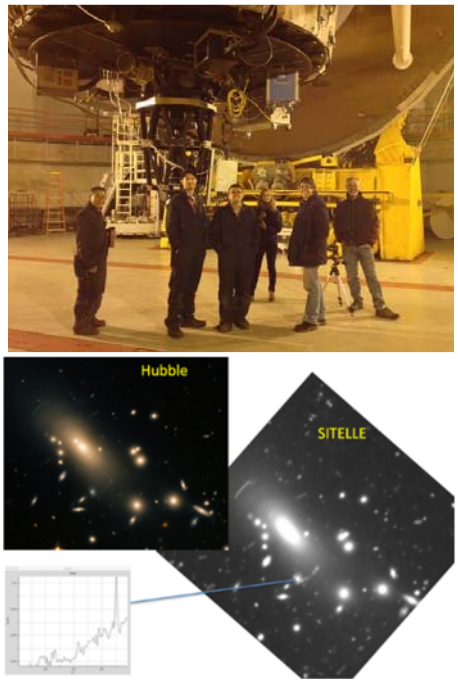

Figure 1 – Top: Members of CFHT's staff after SITELLE was first bolted to the telescope. Bottom: Some of the impressive Science Verification results from SITELLE, in this comparison of an HST image and one from SITELLE of Abell 1413. Of course the power of SITELLE is its ability to yield spectra across its entire field.

Each of these is covered in the pages that follow, but here I take particular note of the delivery of SITELLE. It has been roughly a decade since a new instrument arrived at CFHT and in keeping with "tradition" at CFHT, this instrument is like no other in astronomy. The first facility class imaging FTS working at optical wavelengths at an observatory, made of carbon fiber and housing a metrology system accurate enough for UV interferometry, SITELLE is a technology marvel. When fully unleashed on the sky in 2016 and beyond SITELLE will likely trigger the development of similar instruments on the world's largest telescopes. A collaboration between industry (ABB), academia (Laval University), and an observatory (CFHT), as a lifelong developer of new instrumentation I found the process used to make the instrument as intriguing as the product that emerged. A partnership from its inception, with everyone on the team dedicated to seeing SITELLE become nothing short of a scientific success, the challenges that inevitably occurred when such technology leaps are made were systematically overcome by methodic engineering and a commitment by everyone on the team to not only the project but to each other. I look forward to crafting the 2016 CFHT Annual Report, in which I will highlight some of the first science results from this revolutionary new instrument.

A completely different dimension of 2015 activity erupted to life on Maunakea with the conflict over the construction of TMT, the future of Hawaii astronomy and, given the 50 year legacy of Maunakea Observatory discoveries, the future of 21st century astronomy period. What happened in 2015 to Hawaii astronomy is complex but, through patience and a relentless drive to find lasting solutions, good things can emerge from the conflict. Finding a path forward for not only CFHT but Hawaii astronomy was the focus of a considerable fraction of my attention in 2015 and will likely be so for several years to come, as we work through a dynamic situation, replete with nuances that I do not think anyone has fully grasped.

A remarkable confluence of circumstances led to the challenges now evident in the future of Hawaii astronomy. A resurgence of Hawaiian culture within a young generation that is adept at social media, political circumstances, communication issues, legal battles in multiple courts, sacred sites, all cast in the context of an indigenous people struggling to build a nation, the geographic pinnacle of which is the tallest mountain in the Pacific basin that hosts the world's most scientifically productive observatories

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THE PULSE OF PARADISE

BIG ISLE SCOPES OPEN FOR TOURS

The 8-meter mirror of the Gemini Observatory's telescope was exposed and shown in action Tuesday at a preview of the Kamaaina Observatory Experience atop Mauna Kea on Hawaii Island.

The Mauna Kea community hopes to "inspire a passion for astronomy" among kamaaina

By Timothy Hurley

MAUNA KEA, HAWAII >> The astronomy community in Hawaii has taken its lumps over the past year, from the Native Hawaiian-led rebellion against the Thirty Meter Telescope to the state Supreme Court ruling invalidating the project's construction.

Now the observatory community on Mauna Kea is fighting back. And it begins Saturday.

For the first time in its 50-year history, the world-class telescopes on Hawaii's tallest mountain will be opening their doors to the public for tours.

The aim, according to a news release, is "to inspire a passion for astronomy and an appreciation for the cultural and environmental future of Mauna Kea among Hawaii residents."

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CHANCE OF A LIFETIME

A new program awards Kapolei students time at a powerful Mauna Kea telescope

Figure 2 – Among the many responses to the conflict over the future of Maunakea have been innovative new outreach programs including the Kama'āina Observatory Experience (above) and Maunakea Scholars program (bottom) captured on these Hawaii newspapers front pages.

make this conflict unprecedented. I have been privately approached on many occasions about how these conflicts have been resolved elsewhere in the world, but the layers upon layers of complexity in the Maunakea situation is unique. Daunting though it may feel, CFHT, working with a broad spectrum of community members, the University of Hawaii, the Maunakea Observatories and State officials has constructively engaged the situation. The intent is to create a lasting and inclusive resolution that ensures a future for Hawaii astronomy, grounded in a vision for Maunakea that the people of Hawaii can affectionately embrace. Central to this vision is the need to balance cultural, environmental, and scientific interests in all future planning of Maunakea. Community based stewardship, consistent with the "kuleana" Hawaii Island residents have over the mountain they live upon, is also crucial. Stewardship serves to bridge between the cultural, environmental, and scientific triad that must form the framework of resolution.

In addition to helping bridge perspectives, CFHT, working closely with fellow Maunakea Observatories, has taken a number of steps to deepen the relationship between the observatories and community. This is intended to instill a sense of community ownership, understanding, and pride in the observatories. Innovative programs are emerging that bringing the community into the observatories as partners in our voyage of discovery. The Kama'āina Observatory Experience, which was first announced by President Obama in October 2015 as part of the Astronomy Night event on the South Lawn of the Whitehouse, provides Hawaii residents a comprehensive experience melding Hawaiian culture with the delicate Maunakea ecosystems and the Maunakea Observatories into a single learning experience for the public. These monthly tours have been extremely popular and help promote a balanced vision for Maunakea. Another new initiative is the Maunakea Scholars program which CFHT spearheaded in the fall of 2015. This program culminates in high school students conducting observations on CFHT as part of astronomy research projects they developed. Like the Kama'āina Observatory Experience, the Maunakea Scholars program opens the doors of the observatories in exciting and unprecedented ways, giving the community and students opportunities to see these remarkable facilities up close, talk to their staffs, and actually use them as part of a powerful STEM education experience. Make no mistake about it – 2015 was tumultuous, but conflicts always bring with them opportunities and CFHT will continue to seek them out, build bridges, lay foundations, and find lasting solutions.

Science Report

Maunakea Observatories and NASA Space Telescopes Find Galaxy Cluster with a Vibrant Heart

A multi-national collaboration involving data from Maunakea Observatories and NASA space telescopes helped Tracy Webb from McGill University, Montreal, Canada and her collaborators discover a rare beast of a galaxy cluster whose heart is bursting with new stars. The unexpected find, made with NASA's IRAC/MIPS on Spitzer, WFC3 on HST, SPIRE on Hershell, MOSFIRE on Keck Observatory, WFCam on UKIRT and MegaCam on CFHT, suggests that behemoth galaxies at the cores of these massive clusters can grow significantly by feeding off gas stolen from another galaxy.

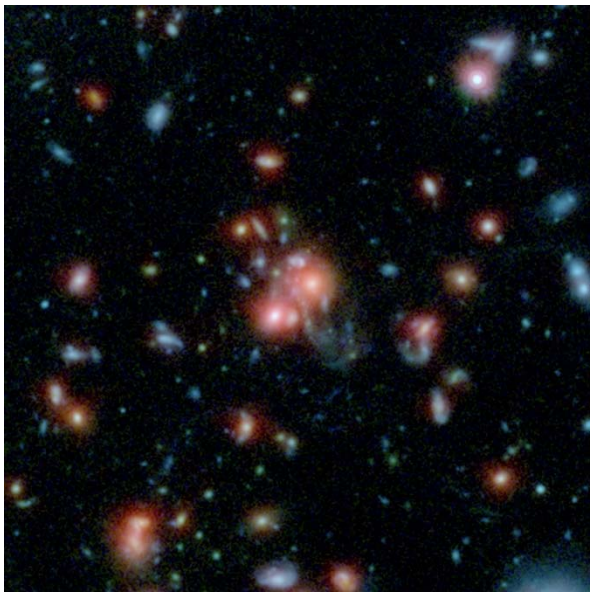


Figure 3 - The massive cluster of galaxies can be seen in this multi-wavelength view from NASA's Hubble and Spitzer space telescopes. At the middle of the picture is the largest, central member of the family of galaxies (upper right red dot of central pair). Unlike other central galaxies in clusters, this one is bursting with the birth of new stars caused by a merger between a smaller galaxy and the giant, central galaxy. The tidal tail can be seen coming out below the larger galaxy. Throughout this region are features called "beads on a string," where gas has clumped to form new stars. The Hubble data in this image shows infrared light at a wavelength of 1 micron in blue, and 1.6 microns in green. The Spitzer data show infrared light of 3.6 microns in red. Image credit: NASA/STScI/ESA/JPL-Caltech/McGill

The cluster in the new study, SpARCS1049+56, has at least 27 galaxy members and a combined mass of nearly $4x10^{14}$ $M_{\odot}$. It is located 4 billion light-years away in the Ursa Major constellation. The object was initially discovered using Spitzer and CFHT and confirmed using MOSFIRE on Keck Observatory.

What makes this cluster unique is its luminous heart of new stars. At the core of the most massive clusters lies an enormous single galaxy which forms stars at a rate of 860 $M_{\odot}$ per year. Follow-up studies with Hubble in visible-light helped confirm the source of the fuel, or gas, for the new stars. Hubble specifically detected features called beads on a string, which are pockets of gas that condense where new stars are forming. Beads on a string are telltale signs of collisions between gas-rich galaxies, a phenomenon known as wet mergers, where "wet" refers to the presence of gas. In these smash-ups, the gas is quickly converted to new stars. Dry mergers, by contrast, occur when galaxies with little gas collide and no new stars are formed.

The new discovery is one of the first known cases of a wet merger at the core of a distant galaxy cluster. Hubble previously discovered another closer galaxy cluster containing a wet merger, but it wasn't forming stars as vigorously.

For more details see the original paper: http://arxiv.org/pdf/1508.04982v1.pdf

Hot Jupiters Courting Baby Stars?

Although first detected 20 years ago, hot Jupiters are still enigmatic bodies. These celestial objects are giant Jupiter-like exoplanets that orbit 20 times closer to their host stars than the Earth does the Sun. Using ESPaDOnS, the MaTYSSE team led by J.-F. Donati (Toulouse, CNRS) and co-authored by CFHT's

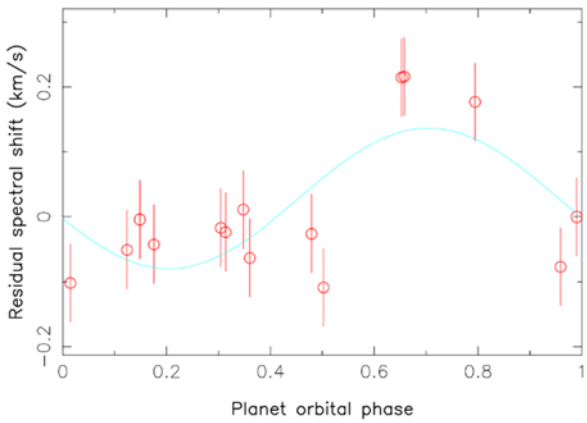


Figure 4 - ESPaDOnS observations of V830 Tau. Once the complicating effects of star spots are removed, the residual shift of the spectrum (red dots and error bars) varies with time with a 6-day period. This spectral motion is compatible with that expected from a 1.4 Jupiter-mass planet orbiting at only 1/15th of an AU. More densely sampled observations are necessary to validate this preliminary result. Image credits: The MaTYSSE collaboration.

resident astronomer Claire Moutou reports the preliminary evidence that a hot Jupiter orbits V830 Tau, a 2-My old star in the Taurus star forming region. This planet, which is yet to be confirmed, has a mass of 1.4 times that of Jupiter, a 6-day orbital period and was unveiled by the gravitational pull it imprints on its stellar host once the stellar activity features are modeled. The discovery of this hot Jupiter could help better understand how planetary systems like (or unlike) the solar system form and evolve into maturity. This could also be the first exoplanet ever revealed by CFHT, a nice introduction to the coming SPIRou planet search survey.

Hot Jupiters form in the outer regions of a protoplanetary disc, then migrate inwards but avoid falling into their host star. This could happen either very early in their lives, when still embedded within their primordial disc or much later, once multiple planets are formed and mutually interact in a rather unstable choreography, with some planets spiraling inward toward their host stars.

The V830 Tau results have provided preliminary evidence supporting the first of these two scenarios. This discovery, published in MNRAS, suggests that hot Jupiters may be extremely young and occur more frequently around very young stars than around mature Sun-like stars.

The MaTYSSE survey aims at mapping the surfaces of young stars and at looking for the potential presence of hot Jupiters. In the case of V830 Tau, the authors accurately modeled the stellar surface magnetic field and spots in order to remove the complications they introduce in the detection of the much weaker signal that hints at the presence of a giant planet. Although more data are required for a definite detection, this promising first result helps demonstrate that the technique the team devised will be an important tool in answering the question of how hot Jupiters form. SPIRou will offer vastly superior performance in this area thanks to its operation at near infrared wavelengths (where young stars are much brighter) and superb stability, allowing a much deeper understanding of this long-standing problem in exoplanet research.

Additional information can be found here: http://arxiv.org/abs/1509.02110

Faint Galaxies in the Virgo Cluster

During the first days of the 2015 CASCA meeting in Hamilton, Canada, a press release was issued, summarizing very interesting observations of the Virgo cluster by the NGVS team. The survey has discovered hundreds of new galaxies, most being extremely faint "dwarf" galaxies, objects hundreds of thousands of times less massive than our own galaxy, the Milky Way, and amongst the faintest galaxies known in the Universe. The Virgo cluster appears to be home to far more of these faint systems than the Local Group, suggesting that galaxy formation on small scales may be more complicated than previously thought, and that the Local Group may not be a typical “corner” of the universe.

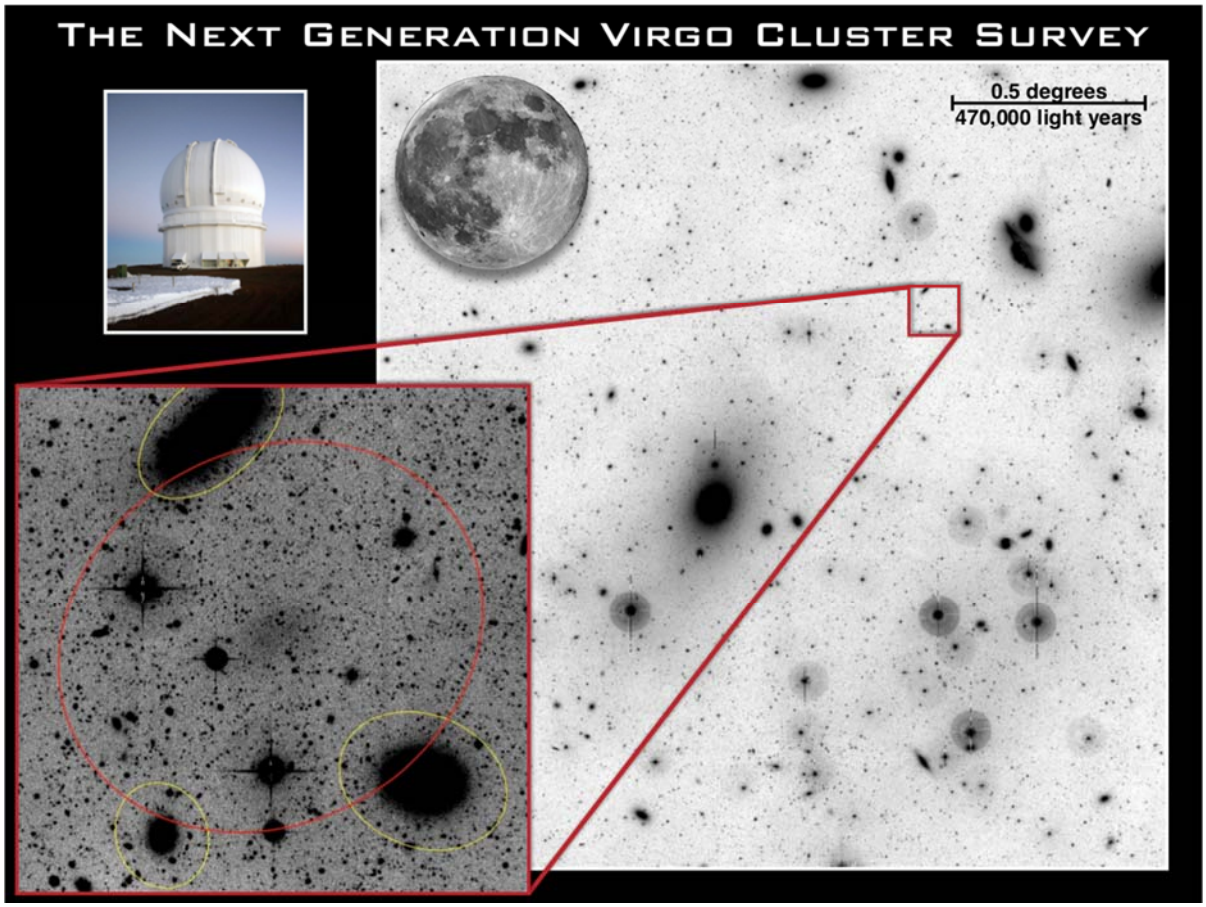


Figure 5 – Example of a Low Surface Brightness Galaxy in the Virgo cluster. These galaxies are very hard to detect and the LSB mode on MegaCam enabled the possibility of such detections. Figure courtesy of Laura Ferrarese.

Taking advantage of MegaCam's wide angle coverage, the NGVS team was able to observe the Virgo cluster in its entirety, covering an area of the sky equivalent to over 400 full moons, at a depth and resolution that significantly exceeds that of any existing survey of the cluster. The resulting mosaic, comprising nearly 40 billion pixels, is the deepest, widest contiguous field ever seen in such detail.

To exploit the full power of the data, Laura Ferrarese, Lauren McArthur and Patrick Cote of the National Research Council of Canada developed a sophisticated data analysis technique that allowed them to discover many times more galaxies than were known previously, including some of the faintest and most diffuse objects ever detected. Virgo contains dozens of bright galaxies and thousands of fainter ones. In the Local Group, the current theories of galaxy formation suggest there should be hundreds or thousands of dwarf galaxies, but fewer than 100 have been detected, leading to the well-known missing satellites problem. Clusters such as Virgo were known to be rich hunting grounds for dwarfs, but only recently has the NGVS team made it possible to set firm constraints on their numbers.

To understand the implications of these new discoveries, Jonathan Grossauer and James Taylor at the University of Waterloo ran computer simulations of clusters like Virgo, to see how many bound concentrations of dark matter they should contain now. Comparing the numbers and masses of dark matter clumps to the population of galaxies discovered by the NGVS, they find a very simple pattern, where the ratio of stellar to dark matter mass changes slowly from the smallest to the largest galaxies. It

seems that in Virgo, there could be a simple relationship between dark matter mass and galaxy brightness, valid over a factor of 100,000 in stellar mass

Mysterious, Massive, Magnetic Stars

A Canadian PhD student has discovered a unique object – two massive stars with magnetic fields in a binary system. Matt Shultz of Queen's University in Canada, along with collaborators from the BinaMIcS large program, found the system – Epsilon Lupi – and published the new result in Monthly Notices of the Royal Astronomical Society.

Around 1/3 of the stars in our Galaxy are thought to be in multiple systems, where two or more stars orbit around a common center of mass. They are invaluable for astronomers, because through orbital measurements it is possible to measure the masses of individual stars. Connecting this data with their luminosities leads to a deeper understanding of stellar evolution.

Epsilon Lupi is the fourth brightest star system in the southern constellation of Lupus. This binary system is about 500 light years away and includes blue stars each 7 to 8 solar masses with a combined luminosity about 6000 times that of our sun. Astronomers have known for many years that Epsilon Lupi is a binary system, but had no idea that the two giant stars had magnetic fields. In cool stars, such as our Sun, magnetic fields are generated by dynamos powered by strong convection in the outer layers of the star, where hot material rises, cools and falls inward. However, there is essentially no convection in the envelopes of massive stars, so there is no support for a magnetic dynamo. Nevertheless, approximately 10% of massive stars have strong magnetic fields.

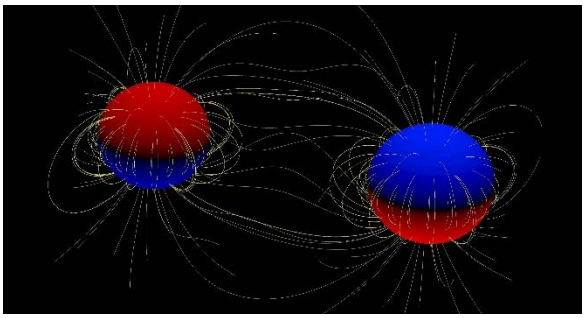


Figure 6 - The polarity of the star's surface magnetic field, north or south, is indicated by red and blue respectively. Yellow lines indicate the magnetic field lines running from the stellar surfaces. Credit: Visualisation courtesy of Volkmar Holzwarth, KIS, Freiburg.

Two explanations have been proposed for their origin, both variants on the idea of a so-called "fossil" magnetic field - a field generated at some point in the star's past and then locked into the star's surface. The first hypothesis is that the magnetic field is generated while the star is being formed; the second is that the magnetic field originates in dynamos driven by the violent mixing of material when two already-formed stars in a close binary merge. The latter scenario seems unlikely to account for a doubly magnetic massive binary since two separate mergers would be required. However, it doesn't change the basic finding of the BinaMIcS collaboration: fewer than 2% of massive stars in close binaries have magnetic fields, and nobody knows why.

The research shows the strengths of the magnetic fields are similar in the two stars, however their magnetic axes are anti-aligned, with the south magnetic pole of one star pointing in approximately the same direction as the north pole of the other. It may even be that the two stars share a single magnetic field. The stars are close enough that their magnetospheres are likely to be interacting throughout their orbital period. This means that their magnetic fields may act like a giant brake, slowing down the stars as they orbit each other. As a result, in the long term, the two stars could be spiraling closer together.

For more information see: http://arxiv.org/pdf/1507.05084.pdf

First Discovery of a Magnetic delta Scuti Star

Coralie Neiner from the Laboratory for Space Studies and Astrophysics Instrumentation, LESIA (CNRS / Observatoire de Paris / UPMC / Université Paris Diderot) and Patricia Lampens (Royal Observatory of Belgium) discovered the first magnetic delta Scuti star through spectropolarimetric observations at CFHT. Delta Scuti stars are pulsating stars some of which show signatures attributed to a second type of pulsation. This discovery shows that the secondary pulsation is actually the signature of a magnetic field. This has important implications for understanding the interiors of stars.

Two types of pulsating stars exist among stars with a mass between 1.5 and 2.5 solar masses: delta Scuti stars and gamma Dor stars. Theory tells us that stars with a temperature between 6900 and 7400 degrees Kelvin may have both types of pulsations. These are called "hybrid stars". However, NASA's Kepler satellite has detected a large number of hybrid stars at different temperatures. The existence of these hybrid stars on a larger temperature range is controversial as it challenges our understanding of pulsating delta Scuti and gamma Dor stars.

To help resolve this mystery Coralie Neiner from LESIA(CNRS / Observatoire de Paris / UPMC / Université Paris Diderot) and Patricia Lampens (Royal Observatory of Belgium) explored the physical phenomena that might mimic the signatures of gamma Dor pulsations in delta Scuti stars, making them only appear as hybrids when they were really not. One explanation could be the presence of a magnetic field that would produce spots on the surface of the star. When the star rotates, the passage of the spot in front of the observer would mimic the signature of gamma Dor type of pulsation. However, no magnetic field has ever been observed in a delta Scuti star.

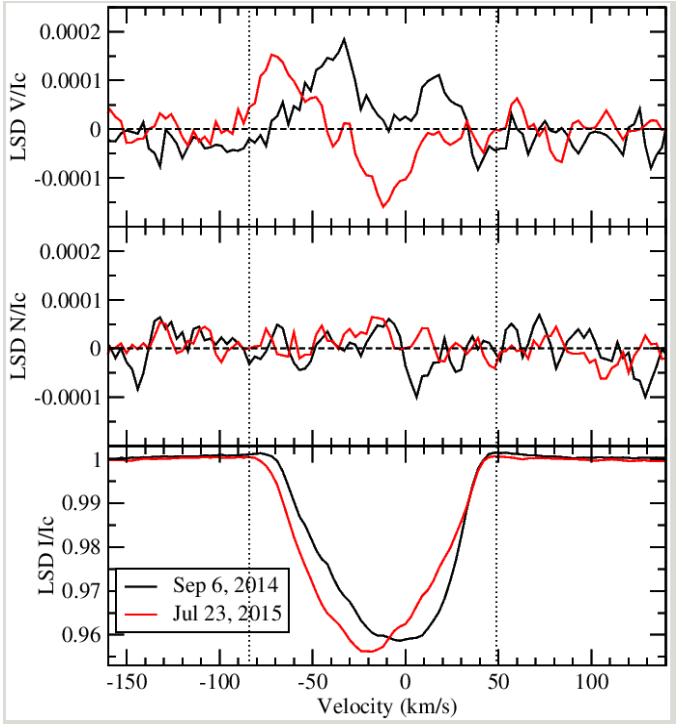


Figure 7 - Measuring the magnetic field (top), test pollution measurement (middle), and average profile of HD188774 spectral lines at two different dates (bottom). The nonzero visible signature in the upper panel shows that the star is magnetic. © Neiner et al. 2015, MNRAS.

Through spectropolarimetric observations at CFHT, they looked for the presence of a magnetic field in a putative hybrid Kepler star: HD188774. They discovered that this star is actually a magnetic delta Scuti star and that the signature of this magnetic field is confused with the signature of gamma Dor type pulsations. HD188774 is thus not a true hybrid, but the first known magnetic delta Scuti star. It is likely that many other stars thought to be hybrids among Kepler stars are actually magnetic delta Scuti stars, which would resolve the controversy between theoretical predictions and Kepler's observations. This discovery brings new insight into the interpretation of the Kepler observations, and the physics of stellar interiors.

Additional information can be found here:
http://mnrasl.oxfordjournals.org/lookup/doi/10.1093/mnrasl/slv130

Engineering Report

SITELLE

Certainly one of the 2015 highlights at CFHT was the arrival of the new imaging Fourier Transform Spectrometer, SITELLE. Developed as a collaboration between ABB, Laval University, and CFHT, this unique and powerful instrument is the first facility class visible light imaging FTS used in astronomy. With a ~10 arcmin field of view, SITELLE generates a spectrum at each point in its field with resolutions up to R~5000 depending on source brightness and scan parameters. This type of spectroscopy is attuned to emission line work, due to the nature of noise propagation in FT spectroscopy. Importantly, SITELLE operates down to UV wavelengths, yielding important astrophysical information on high energy emission lines in complex star formation regions. This capability is also a testament to the exceptional metrology system incorporated in SITELLE, since interferometry at UV wavelengths requires exceptional scan mirror positional accuracy.

SITELLE was first installed on the telescope on 6 June 2015 for a 3 night run to verify basic interferometer functionality during different instrument attitudes, image quality, and overall system throughput. The next observing run was completed in August which yielded valuable performance information including on-sky Modulation Efficiency which was found to be ~80% near Zero Path Difference (ZPD) and remained excellent over ~3/4 of the total scan range. QSO software tools, including the reduction pipeline, worked as expected. Image quality was found to be fine except in the upper ~20% of the field of view. Extensive testing and analysis has not resolved this problem, which will be the focus of more engineering effort in 2016. Improvements in achieving improved modulation efficiency uniformity across the field is also underway. In any case, SITELLE has been a great success and was released for general use starting in 2016A.

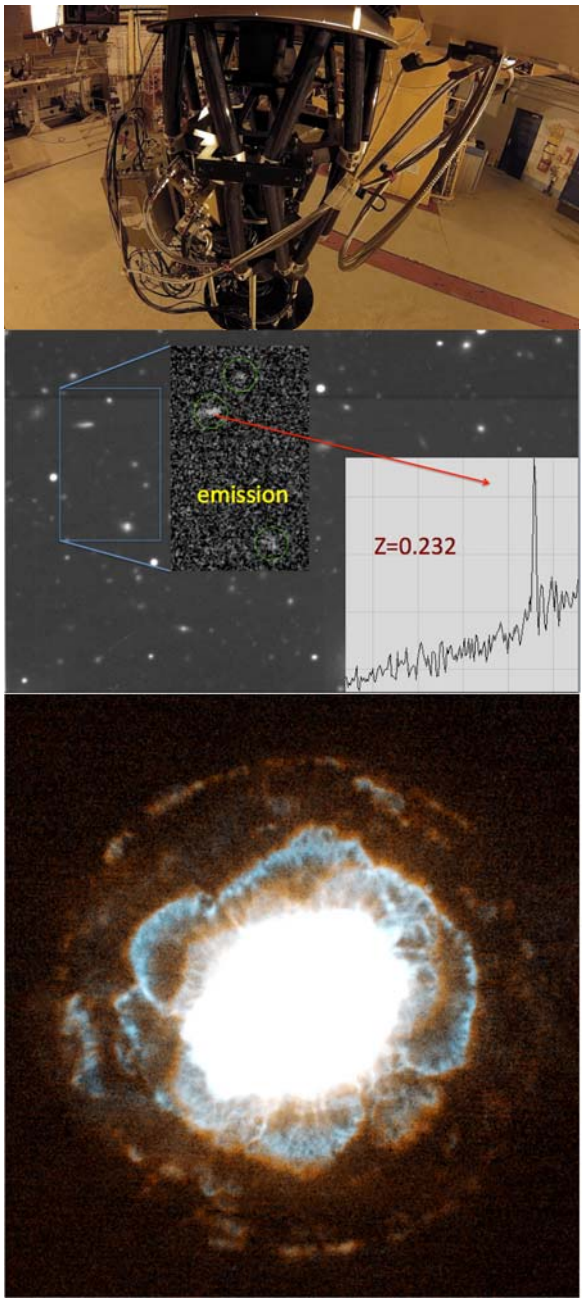


Figure 8 – Top: SITELLE seen mounted at the Cassegrain focus of CFHT. Middle, an example of emission line spectroscopy on a fairly faint distant galaxy in the cluster Abell 2261. The [OII] line at 3727 Å has been redshifted to 4590 Å. Bottom: A composite image of M57, with blue corresponding to [NII] (6584 Å) flux and red to Hα flux.

SPIRou

Overall excellent progress was made by SPIRou's international development team in what may be termed the most technologically challenging instrument ever built for CFHT and one that when completed will be unique worldwide. SPIRou is an R~70,000 spectropolarimeter that can record YJHK spectra in a single shot thanks to its crossed dispersed optomechanical design and use of the largest near infrared array under development – Teledyne's H4RG. SPIRou will be the first fiber fed spectrometer that operates through the K-band in astronomy thanks to the use of ultrapure fluoride fibers that couple the Cassegrain assembly housing a NIR guider, polarizing elements, cold stop, etc. to the large bench mounted echelle spectrometer that will be in the third floor Coude room (next to ESPaDOnS). The instrument is being designed to operate with exceptional (~1 mK) temperature stability and vibrationally damped to permit a velocity sensitivity of ~1 m/s. As such SPIRou will be capable of detected terrestrial class exoplanets around nearby M stars – a facet of exoplanet research that is relatively young given the need to push to near infrared wavelengths to pursue such observations. SPIRou will be highly synergistic with TESS – NASA's forthcoming satellite that is being design to detect exoplanets around nearby stars.

Figure 9 – Above: the lower and upper parts of SPIRou's Cassegrain assembly are shown. Below: The large cryostat that will house SPIRou's spectrometer is shown.

Among the challenges of building SPIRou is the detector technology needed for its focal plane. The H4RG-15 program at Teledyne made good progress in 2015, substantially driven by the University of Hawaii's NSF funded development program at Teledyne. CFHT is also working closely with the University of Montreal and GL Scientific to procure and mount the H4RG detector made by Teledyne into a focal plane assembly, together with the required ASIC and cabling needed for data and control signals.

In June, a SPIRou Mid-Term Review (MTR) was held in Toulouse by an external panel focused mainly on readiness of the project to enter the MAIT (Manufacture, Assembly, Integration, and Testing) phase of the project. SPIRou was deemed to be on track and progressing well.

Most long lead-time items have been ordered and many have been received. The structure for the Cassegrain unit has been delivered to Toulouse and is currently being populated. Subsystem validation tests are scheduled for February, 2016. At NRC-H in Victoria, the cryostat has been delivered and will undergo extensive tests. Initial, warm, vacuum hold time tests indicate that the vacuum vessel leak rate is well within specification. The cryostat is currently being populated with its internal structure using dummy optics for tests of the thermal stability of the optical bench prior to delivery to Toulouse.

Victoria is also responsible for mounting the majority of the optics in SPIRou. Production of the mounts is underway and testing with dummy optics will take place prior to installation of the real optics. The

cryostat and mounted optics are scheduled to be sent to Toulouse in early 2016 for final optical alignment.

SPIRou's transmissive camera optics are being procured by U. Laval in conjunction with U. Montreal, with CFHT providing the funding. Montreal is also responsible, in collaboration with Laval, for designing and building the optical barrels for these lenses and mounting the lenses once they arrive. The optics are nearly complete and should be sent to the coating facility in December. They should be delivered to U. Montreal by early 2016.

The grating has been delivered to NRC-H from Newport-Richardson and is the subject of wavefront error measurements before and after cooling at NRC-H.

Optical fiber manufacture by Le Verre Fluore is progressing well and is still on schedule. The short Cassegrain unit fiber and termination are finished and within specification while the short spectrograph fiber link and the long fibers from the telescope to the 3rd floor coude room remain under development.

The calibration unit is progressing well though the precision RV source (thermally stabilized Fabry-Perot) was delayed. It is currently scheduled to be integrated with the rest of the calibration unit at OHP in January 2016.

The guide camera is working well at CFHT and a second unit has been procured by ASIAA to be sent to Toulouse for integration in the Cassegrain unit. Work is underway to identify a computer that meets the stringent processing and space requirements in the Cassegrain assembly. Finally, an amended ITAR Technical Assistance Agreement (TAA) was submitted to the US State Department. Once approved it will allow direct communications between all SPIRou parties registered in that TAA, greatly simplifying communications across the already geographically dispersed team.

MegaCam

After the arrival of 10 new larger and higher throughput filters for MegaCam in 2014, an additional ultrawide band filter was procured and made available starting 2015B. This filter is optimized for delivering maximum point source sensitivity and spans the gri band passes. Manufactured by Materion, like most of the other recently acquired filters, its throughput averages 90-95% across its exceptionally broad bandpass.

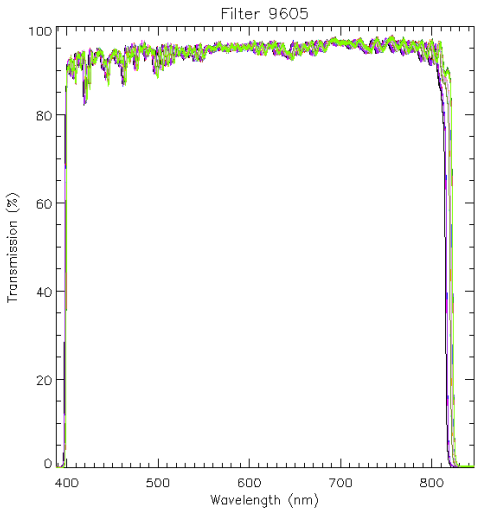


Figure 10 – The bandpass for the new gri ultra-wide band filter for MegaCam that was released for use in 2015 is shown.

An additional benefit to all of the new MegaCam filters is that they transmit light to all 40 CCDs, instead of just the 36 inner CCDs used throughout MegaCam's lifetime. This additional ~10% areal coverage, combined with the significantly higher throughput of the advanced multilayer filters now used with MegaCam, will be extremely valuable in future time-intensive surveys.

Other work dedicated to improving CFHT's workhorse instrument included tests in the lab in Waimea to increase the readout speed of MegaCam's 40 CCDs. Work started

with a study of the DSP code to understand the timing of the clocking signals and electronics. As a result, the analogue-to-digital converters (ADCs) on a spare readout board have been upgraded to a faster version and the detector controller code was modified to take advantage of the faster sample rate by reducing the pixel conversion time. Readout speed was increased from 333 k samples/sec to 500 k samples/sec. Preliminary tests show a gain of about 4.0 seconds in read time, from a baseline of 35.6 sec to 31.6 sec.

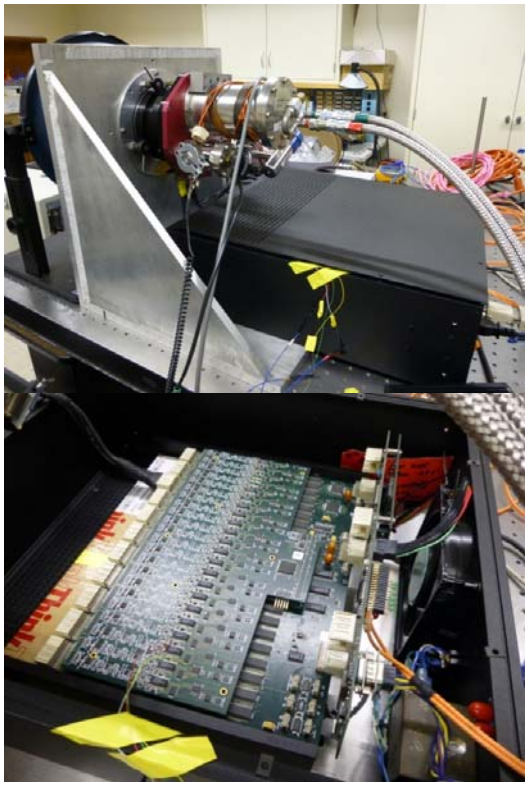


Figure 11 – The MegaCam test bed used to identify and implement ways to speed up the readout of the instrument, as another form of efficiency gain for this venerable instrument, is shown.

Other work on MegaCam in 2015 was unplanned and required considerable troubleshooting to resolve. When it became clear through periodic MegaCam throughput measurements that the camera's throughput was significantly degrading, an extensive investigation led to the discovery that the front anti-reflective (AR) coating on MegaCam's first element in its wide field corrector had deteriorated, leading to a large amount of scattered light. This was not immediately obvious through normal inspection but became very clear when this lens was removed from its cell and backlit, revealing the complete deterioration of this AR coating. Normally the procedure to replace a coating is to polish it off and recoat – an expensive and lengthy procedure that would have left CFHT's most popular instrument off-line for many months. Instead, a mild acid wash was used to dissolve the remaining coating from this front surface. This was possible because (fortuitously) the glass used in this lens is highly impervious to acid etching. Instead of many months a few days of effort went into removing the AR coating. It was not replaced because the throughput loss attributable to this one AR surface along the entire optical train is negligible and it is unlikely to create any ghost images given the geometry of the corrector and focal plane.

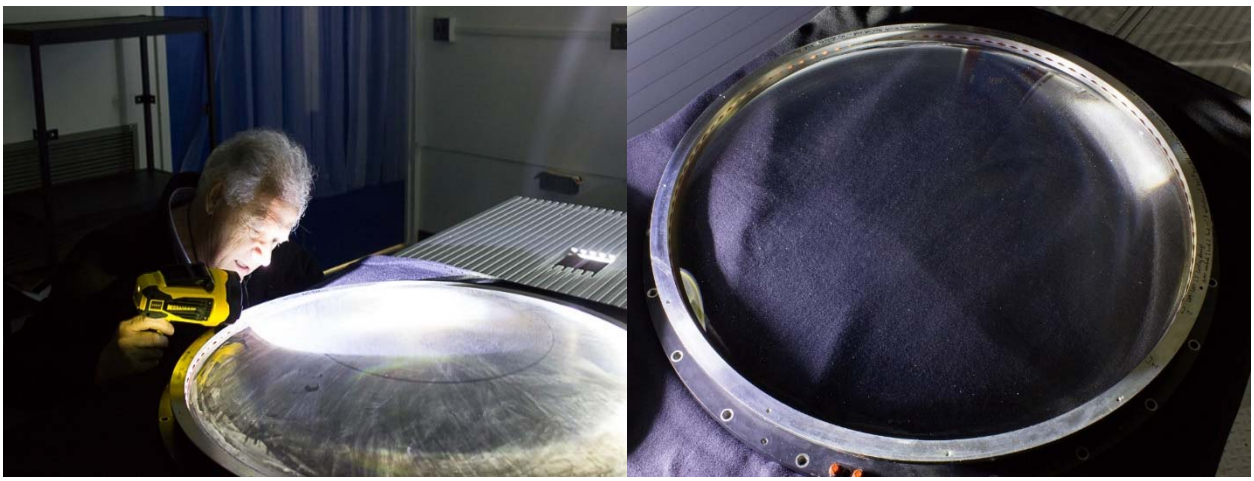


Figure 12 – Left, Director of Engineering Derrick Salmon inspects a heavily pitted AO coating on a MegaCam lens. Right, that same lens after the AR coating was removed through the use of a mild acid wash.

Figure 13 – Bearings retrofit into the MecaCam filter frames now provide a near-zero friction mechanism, leading to more reliable and safer filter exchanges.

Finally, another major in-house upgrade for MegaCam in 2015 was the design and installation of new filter jukebox fault sensors and filter frames. This project was launched after anomalous filter movement in 2014 led to repeated troubleshooting of the filter exchange mechanism and the possibility of filter damage if not addressed in a robust manner. New sensors coupled with reversing the orientation of the filter frame locking tab to their original design orientation prevented a repeat of the problem. In addition all filter frames had four low profile precision roller bearings mounted their sides. The new bearings eliminated problematic metal-to-metal sliding contact between the filter rails and frames. A mock-up and a lab fixture with an upgraded jukebox camera rail system including channels for the rollers was successfully tested several thousand times over a wide range of simulated telescope orientations. With the concurrence of CEA the new system was installed in MegaCam during the annual maintenance in October, 2015 and has performed well ever since.

GRACES

Gemini Remote Access to ESPaDOnS (GRACES) is now operational. The first of its kind in the world, this novel technology allows the sharing of fiber based instrumentation between observatories, yielding important new capabilities at a fraction of the cost and time needed to develop such instrumentation from scratch.

The bulk of 2015 work at CFHT on GRACES was to modify the ESPaDOnS housing needed to accommodate GRACES as a regularly supported instrument. A new outer thermal enclosure (provided by Gemini) was installed in August, providing excellent thermal stability as well as more convenient walk-in access to the instrument for maintenance or when the fiber injection system is switched between CFHT and Gemini fibers. Final optical adjustments were made soon after the installation of this enclosure to optimize throughput and make GRACES available to Gemini whenever ESPaDOnS is not being used at CFHT. Time is offered on Gemini back to CFHT's community through this program at the rate of 3 nights on Gemini for every 20 nights GRACES is used by Gemini. Through this program CFHT's community will have access to instrumentation at either Gemini telescope. This time will be "banked" and used in the form of ~1 week mini-queues, likely executed by a CFHT staff astronomer on behalf of CFHT users.

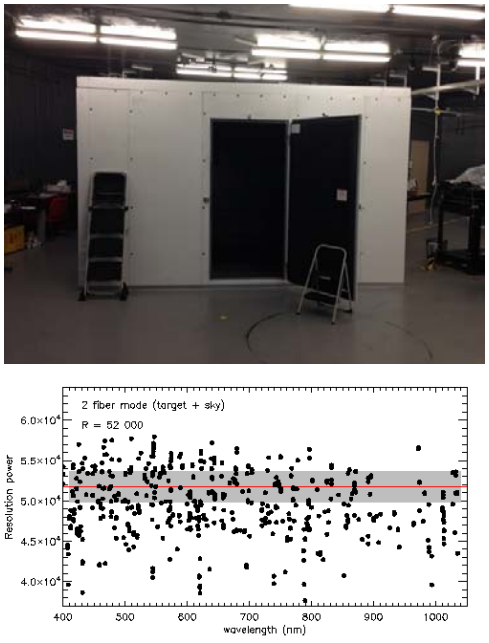


Figure 14 – Above is the new thermal enclosure (provided by Gemini) to house the ESPaDOnS bench spectrograph. Bottom is the measured spectral resolution of GRACES in the star+sky mode – R>50,000 was the design goal.

Having demonstrated the success of this technology, it is hoped that more fiber-fed instrumentation can be shared across the summit of Maunakea. This brings the Maunakea Observatories into closer collaboration, both in terms of jointly developing new capabilities and sharing access to

Figure 15 – New dome vents suffered premature paint peeling (left) under high wind conditions. Working closely with the manufacturer this was addressed through the installation of replacement vent slats (right). Extensive environmental testing of the new slats gives confidence that they will weather much longer than the original ones.

facilities that enable even more extensive research opportunities across an even more diverse international community.

Facilities Development

After the lengthy shutdown in 2012 from the catastrophic dome shutter drive failures, an extensive multi-year program to rebuild this massive assembly was completed. This included the removal, refurbishment, and replacement of all 8 drive units. In addition all twenty six upper rollers on the twelve shutter panels were rebuilt and reinstalled with new bearings, races, and pins. Relatively minor additional work remains with the replacement of the open/close limit switches and adding a redundant limit switch for the close and open positions. The Herculean effort needed to rebuild this crucial system is a real testament to the engineering team at CFHT that worked tirelessly under difficult summit conditions to troubleshoot and rebuild the shutter drive system.

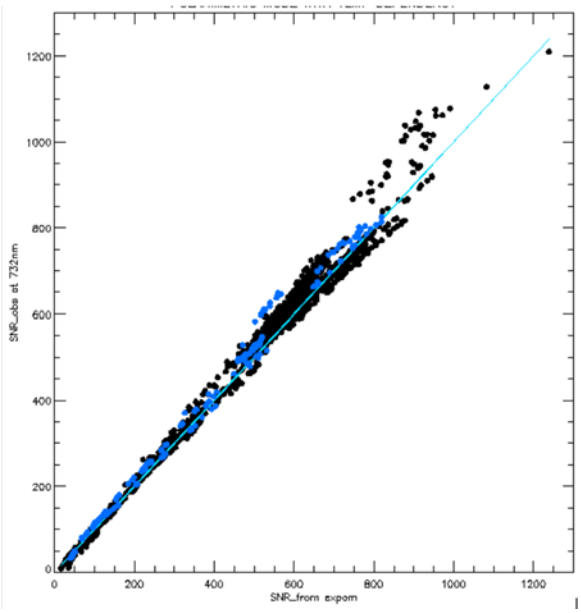


Figure 16 – This plot of predicted SNR from the ESPaDOnS exposure meter vs. actual SNR measured at the detector bodes well for offering the new SNR mode for ESPaDOnS.

In parallel with that effort, all of the slats on the new vents were replaced by the manufacturer after a processing error with the original slats led to the premature peeling of paint from their surfaces. To avoid a repeat, the manufacturer, working closely with CFHT, performed extensive and harsh environmental tests on the new slats with an improved paint formulation. By the end of 2015 the vents once again looked “good as new”.

CFHT’s QSO system is always being upgraded to provide even greater observing efficiencies or innovations in observing techniques. One of the most exciting new modes being developed is “SNR QSO”. In this mode observations consisting of multiple integrations are accumulated until the desired SNR is reached. This is a more natural means of defining the completion of observations, which generally are preprogrammed as a certain integration time under assumed conditions, often

yielding an "overshoot" in SNR to ensure data meet user requirements. SNR QSO is now regularly offered with MegaCam and is under development for ESPaDOnS. For the former, on-the-fly SNR measurements are made after each integration to determine a trend and the final integration in a sequence is dynamically adjusted to extrapolate the integration needed to reach the required SNR. Like all new filters with increased bandpass, larger filters allowing use of 4 more CCDs in the MegaCam focal plane, and speeding up the MegaCam array controller, adopting SNR QSO for MegaCam effectively increases the amount of observing time available for all users. Include the impressive improvement in image quality achieved with the new dome vents and these improvements add up to impressive system efficiency gains that feed into the increasing use of Large Programs at CFHT starting in 2017A.

Another major engineering upgrade that was completed in 2015 was the new Telescope Control System or TCS. The new TCS hardware was released for operation in March 2015, along with pointing models for ESPaDOnS, MegaCam, WIRCam and SITELLE. The telescope speeds in both axes have been kept the same as the old system. However, target to target acquisition times are about 25-50% faster when slewing due to improved servo settling times. Dither patterns with large offsets no longer require switching encoders from incremental to absolute, a limitation of the old TCS electronics. Offsets now complete slightly more quickly. Tracking error is about the same but may be improved by further servo tuning.

Other facilities upgrades include a new method for scaling WIRCam master-flats, resulting in the same zero point (ZP) for each detector. Previously a separate ZP for each detector was published – while this is still the case now the ZP for each detector is the same. In addition CFHT released a new method for non-linearity correction that utilizes a per-pixel characterization and correction as opposed to a mean correction for each detector. Two new filters were also purchased for WIRCam including a new CO filter (provided by NAOC) and a new W filter.

Work to improve the Exposure Time Calculator (ETC) software continues for existing instruments as well as developing an ETC for SITELLE. All ETC's can now compute exposure time and/or signal-to-noise (in either direction) to facilitate SNR-mode observing strategies. WIRCam and MegaCam now support the use of Sersic profiles for extended sources in place of simple "field galaxy" and "nearby galaxy" modes. The chromatic transmission profile of the ESPaDOnS ETC was updated to give more accurate results for cool stars. Providing similar base functionality across ETC's is intended to simplify their use and provide common planning tools across multiple instruments.

A number of changes were made in 2015 in the way preventive maintenance is handled at CFHT. Development of a modern preventative maintenance software system for the observatory staff was started in the spring of 2015 after a review of commercial systems which were deemed too unwieldy for use by a small staff. A software solution using mobile devices is being developed that will enhance the way tasks are scheduled and maintenance activity is recorded. The project moved through the scoping and design process earlier in the year. A full rollout of the new system is expected in 2016.

Beyond more robust logging of repairs and maintence for internal use, CFHT now provides an "Observatory Event Log" for the user community intended to provide succinct information about technical changes or problems so CFHT's user community has a record of such events and can track them over time. That new log iss accessible through http://www.cfht.hawaii.edu/en/science/.

MSE Report

MSE continued to progress well in 2015 on the three main fronts of science, engineering, and partnership development.

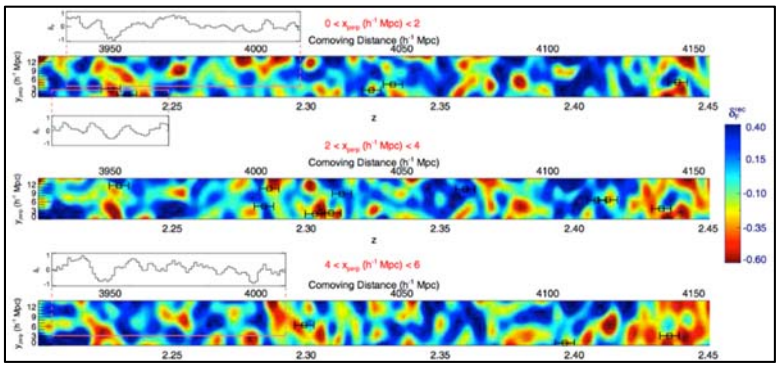


Figure 17 - Tomographic reconstruction of 3D Lyα forest absorption in COSMOS field using LRIS data from Lee et al. (2014), shown projected over three slices along the R.A. direction.

A major science achievement was the formal delivery by Project Scientist Alan McConnachie of an MSE Science Requirements Document (SRD). While this document very succinctly describes in 24 short statements the guiding requirements for the project, it comes to us only after an extensive partnership-wide effort to study the observational niche for MSE science and ultimately to understand and distill the performance needed to address MSE's role: measuring the composition and dynamics of the faint Universe. Many of MSE's 86 member international science team met for three fascinating days at Waikoloa at the annual MSE science meeting and used that occasion to review the science cases and SRD in the context of the three science themes: a) Deconstructing the Galaxy, b) Galaxies across Cosmic Time, c) Illuminating the Dark Universe.

With the SRD in hand, the project's international engineering staff members were able to move ahead in developing a baseline architecture and top level technical requirements for the project. To do so required a series of design evaluations against the SRD, and decisions taken, to end up with the complete decomposition and system level description. Some of the more interesting and challenging design areas included developing an instrument development strategy and concepts capable of delivering our unique requirements for a resolutions spanning 2000 to 40,000 with a focal plane multiplexing from 1000 to 3200 and with complete fill factor in each case. The Project Office also solicited and extensively evaluated different telescope configurations, receiving proposals from Australia, Canada, and China, ultimately choosing a 11.25 m diameter prime focus layout. From there, our colleagues at Anglo Australian Observatory (AAO) detailed a Wide-Field Corrector / Atmospheric Dispersion Corrector design that met the needs of MSE – needs that were as challenging in optical performance as they were in the manufacturability of the very large pieces of glass that would be required. We received some help from Dynamic Structures Limited in Canada to develop concepts for a geometrically complete MSE telescope structure and Calotte enclosure layout, and also to provide structural design support to CFHT staff (Bauman and Szeto) who re-designed the CFHT facility building to meet the new needs of MSE. Meanwhile,

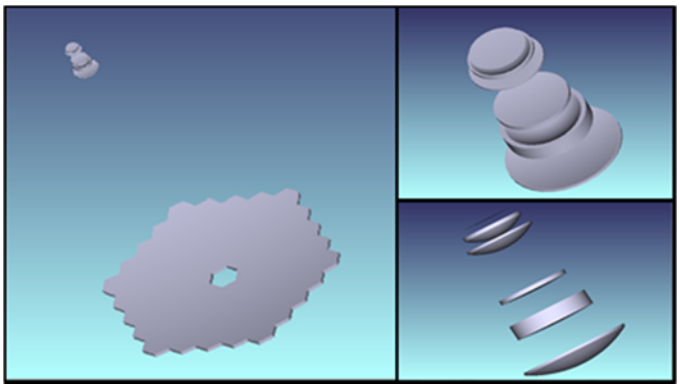


Figure 18 – MSE optical design.

our lead System Engineer at GEPI, France (Mignon) and System Scientist (Flagey) spent the latter part of the year working the key system issues such as throughput budgets, injection efficiency, image quality budgets and inter-spectra contamination. As the year drew to a close, the MSE baseline configuration includes a 11.25 m, 60 segment telescope within a Calotte enclosure, and illuminating a 3200 fiber positioner at prime focus through a 5 element corrector. The fiber positioner feeds two separate fiber bundles; one bundle terminating at four banks of low-moderate resolution spectrographs on Nasmyth-like telescope platforms, and the second bundle terminating at the three banks of high resolution spectrographs in the Coude room. The fifth (observing) floor of the CFHT facility building will be completely removed and a new observing floor established at about the fourth level; the labs and working space currently within the lower four floors will be reconfigured to control heat flow during nighttime operations.

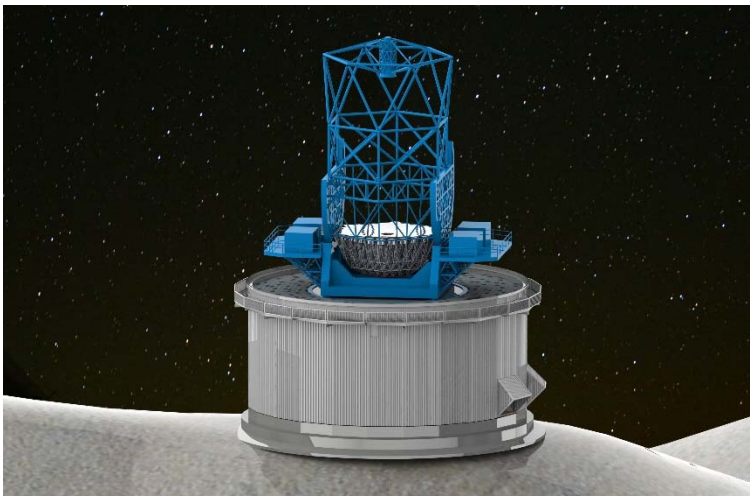


Figure 19 - MSE telescope atop CFHT facility building.

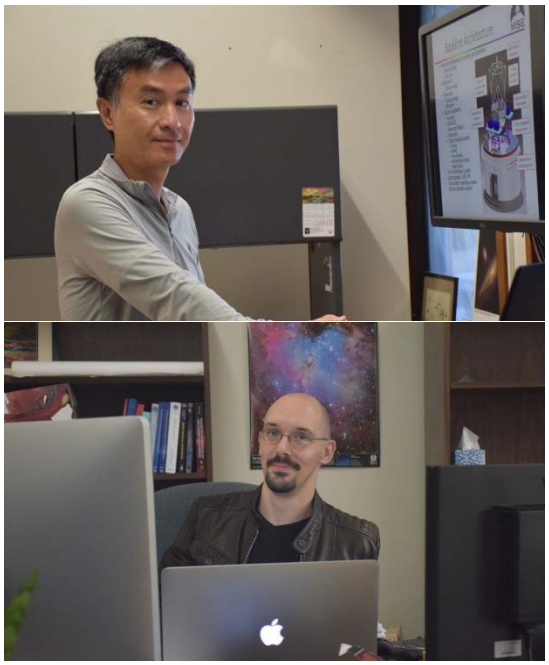


Figure 20 - Kei Szeto (top) and Nicolas Flagey (lower).

Engineering team members from CFHT, Australia, Canada, China, France and Spain working on aspects of the design met together twice in the year: the Vernal MSE Engineering Workshop hosted graciously by our Chinese colleagues in Nanjing, and the Autumnal meeting hosted by Observatoire de Paris.

Two significant enhancements to the MSE partnership occurred in 2015. In the spring, two members of AAO with extensive experience in fiber multiobject spectroscopy instrumentation (Gillingham and Saunders) joined the engineering team, and in the autumn, Spain, represented by Consejo Superior de Investigaciones Científicas (CSIC) formally joined the design phase partnership. Spain brings expertise in particular in advanced fiber positioners and segmented mirror telescopes. At this time, the MSE partnership for the design phase comprises Canada, France, Hawaii, Australia, China, India and Spain.

Within the project office itself, the year saw two new members of the Project Office take up positions in Waimea. Kei Szeto joined the project as our Project Engineer, and Nicolas Flagey accepted the post of MSE System Scientist.

Administration Report

Overview

CFHT bid farewell to longstanding Director of Finance and Administration (DFA) DeeDee Warren during 2015. DeeDee retired to California and was only the second person to have that role at CFHT Corp. since the inception of the corporation, performing a myriad of tasks during her tenure ranging from overall financial management to handling the administrative aspect of ITAR compliance at CFHT. She was replaced with Sheri Christopher, who joins CFHT from the University of Hawaii – Hilo, where she led the UH-H Office of Research Services grant compliance program on Hawaii Island. Sheri brings strong credentials to the DFA position, having served a similar role at Imiloa, and a number of high-level administrative roles on the US mainland including Teledyne, Arthur Anderson LLP, Countrywide Financial Corp., and the Mississippi State University. Sheri overlapped with DeeDee by ~6 weeks for cross-training in CFHT's administrative systems and some reassignments were made with her appointment to spread DeeDee's responsibilities over a larger group. Specifically Steve Bauman is now responsible for shop and exterior facilities management, while the safety program now falls under Derrick Salmon. Given her strong background in government compliance Sheri will retain responsibility for ITAR administration, working closely with Derrick Salmon who remains the ITAR lead for technical matters. Sheri is already looking into several possibilities for improving CFHT's business systems, bringing fresh insights to help the group function more effectively.

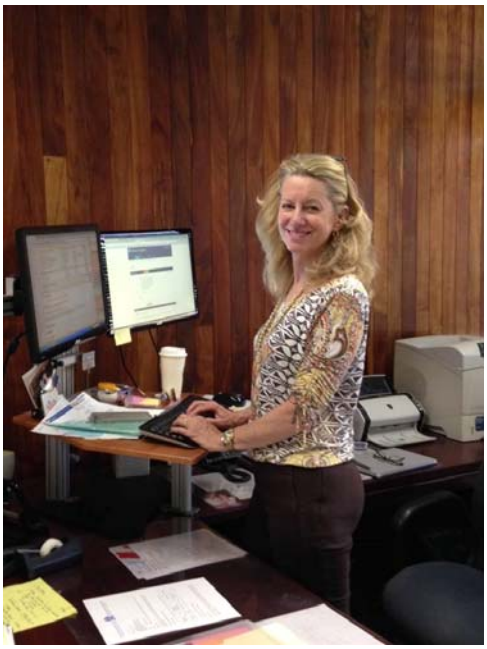


Figure 21 – DeeDee Warren, seen here in her office on her last day at CFHT, retired after a lengthy and incredibly productive tenure as CFHT's Director of Finance and Administration.

Agency Contributions (US$)	
NRC	3,211,145
CNRS	3,211,145
UH	744,610
Total	7,166,900

Table 1 – Contributions from each partner in CFHT Corp. are listed.

Summary of 2015 Finances

Table 1 list contributions from the three founding partners in CFHT. Once again no increase in contributions was made over the prior year, but on-going efficiency gains and careful attention to expenditures led to a balanced budget. Under collaborative agreements with CFHT, the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) of Taiwan, the Brazilian Ministry of Science, Technology and Innovation (MSTI), the National Astronomical Observatory of China (NAOC), and the Korean Astronomy and Space Science Institute (KASI) remitted $523,500, $192,000, $615,750 and $66,000, respectively, as reimbursement for costs associated with their use of the Corporation's facilities. The collaborative agreement with KASI ended in 2015A. CFHT continues to seek opportunities to partner with East Asia Observatory as a means of collaborating

Operating Fund Expenditures (US$)	
Maunakea facility and operations	395,745
Base facility and operations	308,808
Services	322,470
Maunakea Support Services	88,865
Management & General	428,155
Staffing	5,259,750
Outreach	59,070
Instrumentation	64,735
Science	78,409
Transfer to Reserve	160,893
Total	7,166,900

Table 2 - Operating expenditures are broken down into various cost categories.

under a single umbrella agreement with China, Taiwan, S. Korea, and Japan. The agreement with Brazil's MSTI was also not renewed but efforts remain underway to restart that in the future. Other sources of funds included $8,833 from mid-level facility use credits, $13,861 from distribution of educational materials, $1,509 in staffing cost reimbursements related to work done for other Maunakea facilities, and $21,513 in earned interest. From the operating fund, 2015 expenditures were allocated to the areas listed in Table 2.

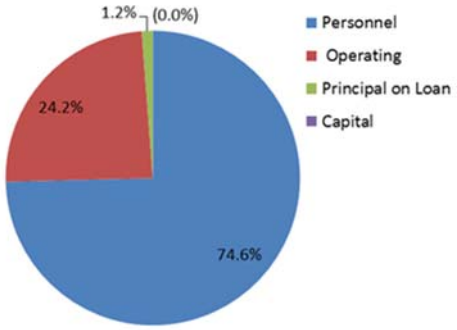


Figure 22 – A graphical representation of CFHT's costs in 2015, which were dominated by operating and personal costs. This chart does not include instrument development funds.

Building Renovations and Administration Activities

Roger Wood, with the assistance of Joe Fehly, completed several fairly large building maintenance projects in 2015. Roger and Joe replaced the floor in the electronics lab in the Waimea headquarters and also added a plastic curtain wall in the computer room, enabling the use of ambient air to cool the computer room, which is expected to lead to a significant reduction in electricity costs. They also completed the replacement of large areas of rotten wood siding and window frames around the building, finishing everything off with a fresh coat of paint. Combined with projects from previous years which included major interior remodeling, improvement in lighting throughout the office, a complete makeover for the front lobby area, etc., the work of Roger and Joe really helped renew the office for everyone's enjoyment.

Figure 23 – The work of CFHT's administrative team is never done and touches upon essentially every aspect of CFHT's operations, ranging from new landscaping in the inner courtyards of the office (above) to new vehicles for the fleet which are crucial to sustain operations distributed between Waimea and the summit of Maunakea.

Several landscaping projects were also undertaken to refresh the grounds' appearance. The dead shrubs and plants near the front doors were replaced with newly landscaped beds and the two interior courtyards of CFHT's headquarters also received much needed landscaping. The small interior courtyard was cleaned out by CFHT staff as a volunteer project during the summer months – a project that DeeDee Warren spearheaded. In the cleared out courtyard, native hapu'u fern and anthurium plants were added to help beautify the CFHT grounds.

CFHT hosted a meeting of the Audit Committee (AC) 14-15 May in Waimea. Given that many of the AC members were new this represented a good opportunity to introduce CFHT's mission, operations, and financial systems to the group. The review included concurrent discussion with management and the Independent Auditor. The AC agreed that there appeared to be no material weaknesses in internal control and no notable problems discovered

during the audit. Based on this review, the AC recommended to the Board that the audited financial statements for the year ending 31 December 2014 be approved. The AC also reviewed the IRS Form 990 (Return of Organization Exempt From Income Tax) and reconciled it to the audited financial statements.

The AC considered the appointment of the external auditor for the ensuing three-year period beginning with the audit for the year ending 31 December 2015, and recommended that the Board approve the appointment of KKDLY LLC to provide audit services for fiscal years ending 2015-2017. Overall the meeting was a great success.

Staff Safety

During the year, two injuries occurred. These happened to occur to the same person but are unrelated. On one occasion, an intern fainted while at the observatory, for a few seconds, constituting a loss of consciousness that gets recorded automatically based on OSHA record keeping rules. Second, at a later date the intern got a laceration of the left hand while handling some shelving at the summit. While this was a relatively minor injury, she was taken to the emergency room and given medical treatment beyond first aid (stiches), making it a recordable under OSHA rules. We also hired a new Safety Specialist in April of 2015, who is working closely with observatory staff to improve safety on the summit.

	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
Injuries	2	2	0	0	1	0	0	0	1	0
Illnesses	0	0	0	0	0	0	0	0	0	0
Lost work days	0	10.5	0	0	1	0	0	0	1	0

Table 3 – A decade of top-level statistics pertaining to safety are listed above.

Arrivals and Departures

During 2015 we said farewell to 3 departing staff members and welcomed 6 new members to CFHT's 'ohana, yielding a net increase in our staff size by the end of the year. Departures included some of the most seasoned people on our staff while new arrivals included MSE Project Office staff members, a new Safety Specialist, and Director of Finance and Administration. As we do each year, below we first pay tribute to those who left CFHT in 2015, then wish a fond aloha to the new members of our staff.

Farewell

DeeDee Warren

DeeDee joined CFHT in February 1991 to work as an Accountant, and in January 2003, was appointed as Director of Finance and Administration to replace Claude Berthoud after his retirement. During her 24-year career with CFHT, DeeDee's many contributions included overseeing the refurbishment of our headquarters, the creation of an export controls compliance program and the creation of an award-winning safety program. DeeDee retired on July 2, 2015 and moved with her husband Bob to live in Palm Desert, California. Her contributions to CFHT are as numerous as they are exceptional and she will always be part of the CFHT legacy.

Adam Draginda

Adam joined CFHT in June 2006 and was a highly regarded member of the astronomy staff as a Remote Observer. Adam made significant contributions to the development of custom software tools used to optimize observing. He was extremely gifted in computer science and was generous with his expertise to make CFHT a better observatory from a science operations perspective. In January 2015, Adam left CFHT after his wife accepted a position in California.

Larry Roberts

Larry Roberts joined CFHT in August 2006 as an Electrician and was responsible for electrical work at both our headquarters and the observatory. Larry's dedication showed in his timely and accurate completion of tasks assigned to him and his success in handling any emergency situation that he was called upon to help resolve, such as the unexpected dome shutter failure. Larry's mid-western sense of humor and affable personality made him a valuable member of CFHT's 'ohana. In December 2015, Larry relocated back to the mainland to be closer to family, at the "expense" of experiencing colder winters!

Welcome

Cameron Whipper

Cameron Wipper, a 2013 graduate of UH-Hilo's undergraduate Astronomy program, joined CFHT on June 1, 2015. Prior to joining CFHT, Cameron has already spent time working and volunteering in a variety of positions at the Maunakea Observatories and related facilities, including the Caltech Submillimeter Observatory, the Smithsonian Astrophysical Observatory Submillimeter Array, the Joint Astronomy Centre, Gemini North Observatory, Subaru, the 'Imiloa Astronomy Center of Hawai'i and the Mauna Kea Visitor Information Station. Cameron's personal interests and hobbies include traveling, stargazing, attending concerts, camping, hiking, boating, playing basketball and reading.

Jake Braden

After working a rotational schedule in Alaska at Udelhoven Oilfield System Services, spending roughly half his time in Hawaii, Jake came to work at CFHT in April 2015 and is now able to spend all of his time in Hawaii. Jake comes to us with 6 years of experience in industrial hygiene and safety primarily on the North Slope of Alaska. Jake earned a BS in Biological Sciences with a Minor in Math from the University of Alaska Anchorage, and an MS in Environmental & Occupational Exposure Sciences from the University of Washington. Jake's many interests during his spare time include working out, cycling, mountain biking, and ocean sports.

Sheri Christopher

Sheri joined CFHT on May 26, 2015 as the Director of Finance and Administration, taking the place of CFHT's longstanding DFA, DeeDee Warren, who retired on July 2nd. Sheri was born and raised on the Big Island in Hilo and attended Waiakea district public schools, graduating from Waiakea High. She moved to the mainland to attend college, earning both a B.A. and M.A from UCLA. For the last two decades, Sheri has worked in various business roles on the mainland and moved back to the Big Isle in 2009 for family reasons. Since returning to Hawaii, Sheri has worked as the Business Manager for the 'Imiloa Astronomy Center of Hawai'i, and as the Compliance Officer for the UH System's Office of Research Services. Sheri and her husband Tim have two young daughters, Sophie and Madeline, who both attend Parker School in Waimea.

Nicolas Flagey

Dr. Nicolas Flagey joined CFHT as our MSE Systems Scientist on September 14, 2015. Nicolas received his PhD in Astrophysics from University Paris IX, and has worked as a Post-doctoral Scholar at the Infrared Processing & Analysis Center in the Spitzer Science Center and at the CalTech Jet Propulsion Lab. He also served as a Post-doctoral fellow at UH's Institute for Astronomy and was a Volunteer Astronomer at CFHT from January 2014. Nicolas' interests are in the study of dust and gas in the interstellar medium, infrared observations, data reduction and analysis, observatory and instrument support, teaching, and mentoring.

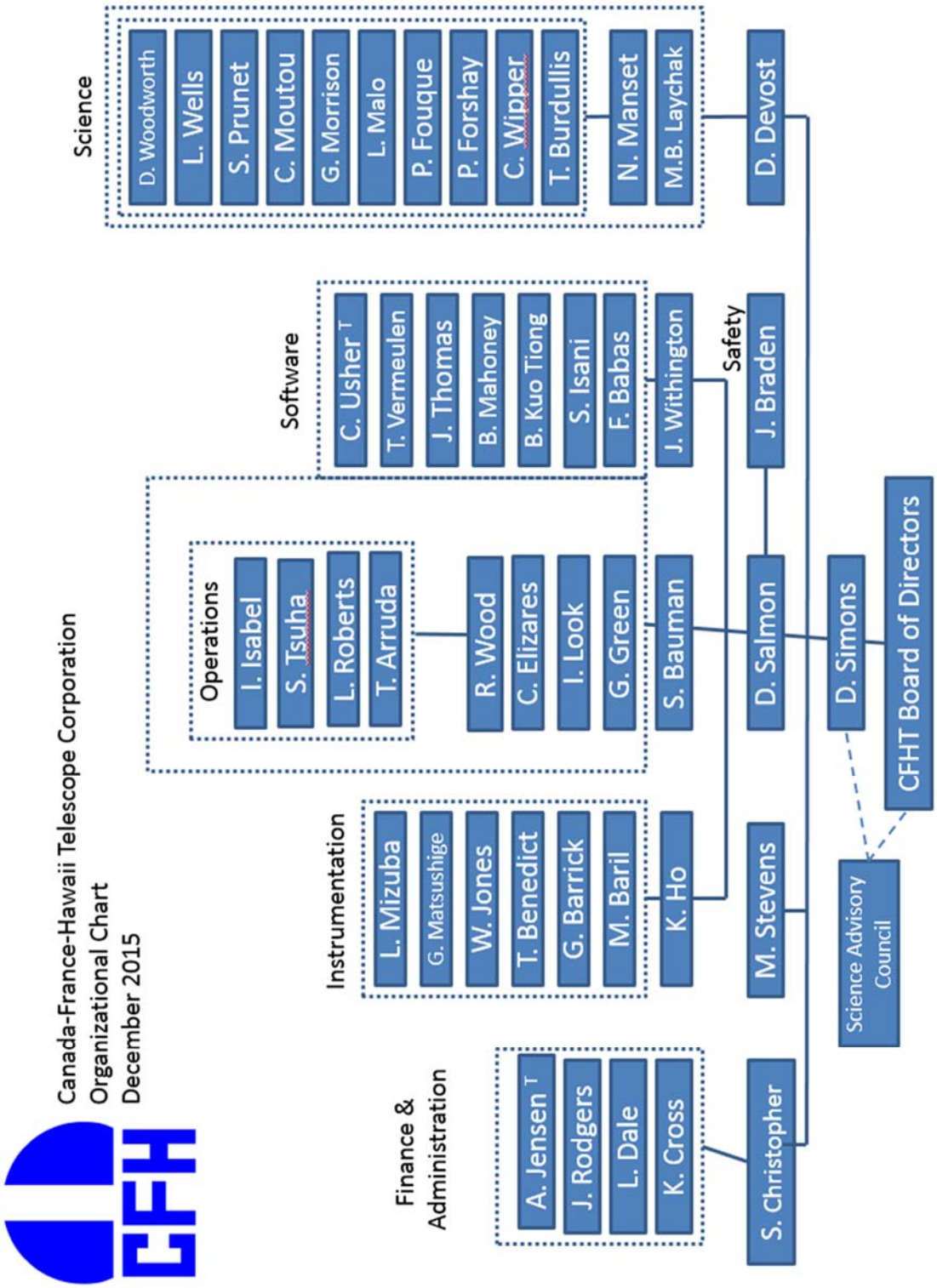
Kei Szeto

Kei joined CFHT as the MSE Engineer from NRC-Herzberg where he acquired over two decades of engineering and project management experience in the development of instrumentation and observatory facilities for astronomy. Kei was responsible for the next generation CFHT technical feasibility study, which is the forerunner of the MSE project. Kei also led the conceptual design of the telescope structure, final design of the enclosure and NFIRAOS, the first-light facility adaptive optics system for the Thirty Meter Telescope project. His instrumentation work included design and delivery of the Gemini Multi-Object Spectrographs and Altair, the facility adaptive optics system for Gemini-North. Kei is joined by his wife Barbara. They are excited to relocate to Hawai'i and have been spending their free time exploring the Big Island.

Seizan Tsuha

On April 14, 2015, Seizan Tsuha joined CFHT as a Mechanical Technician. Seizan joined us from Maunakea Support Services (MKSS), where he was working as a heavy equipment operator and truck driver. Prior to MKSS, Seizen also worked at the Hilo Home Depot in a Pro Contractor Sales position, and at the Hawaii Tribune Herald as an Assistant Press Foreman.

Organization Chart



Staff List

Name	Position	Name	Position
Arruda, Tyson	Mechanical Technician	Mahoney, Billy	Database Specialist
Babas, Ferdinand	System Administrator	Malo, Lison	Resident Astronomer
Baril, Marc	Instrument Engineer	Manset, Nadine	Resident Astronomer
Barrick, Gregory	Optical Engineer	Matsushige, Grant	Sr. Instrument Specialist
Bauman, Steven	Operations Mgr/Mechanical Eng	Mizuba, Les	Instrument Specialist
Benedict, Tom	Instrument Specialist	Morrison, Glenn	Resident Astronomer
Braden, Jake	Safety Specialist	Moutou, Claire	Resident Astronomer
Burdullis, Todd	QSO Operations Specialist	Prunet, Simon	Resident Astronomer
Christopher, Sheri	Director of Finance and Admin.	Rodgers, Jane	Finance Manager
Dale, Laurie	Administrative Specialist	Salmon, Derrick	Director of Engineering
Devost, Daniel	Director of Science Operations	Szeto, Kei	MSE Project Engineer
Elizares, Casey	Summit Operations Manager	Simons, Doug	Executive Director
Flagey, Nicolas	MSE Systems Scientist	Stevens, Mercédes	Assistant to the Exec Director
Forshay, Peter	Remote Observer	Thomas, Jim	Computer Software Engineer
Fouque, Pascal	Resident Astronomer	Tsuha, Seizan	Mechanical Technician
Green, Greg	Mech Designer/Instrument Maker	Usher, Christopher	Software Programmer
Ho, Kevin	Instrument Manager	Vermeulen, Tom	System Programmer
Isabel, Ilima	Custodian	Wells, Lisa	Remote Observer
Isani, Sidik	Software Engineer	Whipper, Cameron	Remote Observer
Jones, Windell	Instrument Engineer	Withington, Kanoa	Software Manager
Kuo Tiong, Blaise	Systems Administrator	Wood, Roger	Automotive Mechanic
Laychak, Mary Beth	Outreach Program Manager	Woodworth, David	Remote Observer
Look, Ivan	Mechanical Design Engineer		

Outreach Report

2015 was the first full year of CFHT's revamped outreach program. Due to unforeseen protests on Maunakea, the year was challenging, but created opportunities to expand our outreach efforts.

Our approach for outreach at CFHT is threefold – (1) showcase the staff, science and instrumentation of CFHT, (2) engage, excite and inspire Big Island keiki and their families and (3) expand CFHT's outreach presence in our partner countries. In 2015 we laid solid groundwork on all three and plan to build on that base in 2016.

Outreach in Canada

CFHT's outreach program manager Mary Beth Laychak now writes a column in the bi-monthly Royal Canadian Astronomical Society's journal, entitled CFHT Chronicles. The CFHT Chronicles debuted in the June 2015 journal. The column focuses on all aspects of CFHT; instrumentation, staff and science. CFHT also plans to publish twice a year in Société des Astronomes Amateurs du Québec. Our strategy with the columns is to make the work of CFHT relatable to the predominately amateur astronomy community readership and cultivate a sense of connection with CFHT. We use a similar model locally by working closely with the West Hawaii Astronomy Club. Members often volunteer at large events like the Solar System Walk and the Star Party. In time, we plan to use the column to create a network of interested contacts across Canada.

Mary Beth also worked closely with Julie Buldac-Duval at Discover the Universe. With support from Rob Cockcroft at McMasters University and the LOC, a workshop was organized for local Hamilton teachers as part of the CASCA meeting. The workshop was free for participants and focused on hands-on activities they can use in their classrooms. The twelve participants ranged from astronomy specific teachers to life science teachers teaching physics and astronomy. CFHT sponsored lunch for the teachers and we invited local grad students, CFHT astronomers, members of the local RASC and other CASCA participants to lunch. The discussion was very positive. Each teacher left with a full set of materials donated by the Perimeter Institute and instructions on how to do the activities covered in the workshop. We plan to conduct a similar workshop during the 2016 CASCA meeting, but we will begin our planning and recruitment earlier to maximize the number of participants.

Figure 24 – The CASCA teachers workshop co-sponsored and organized by CFHT.

Director of Science Operations Daniel Devost actively participates in educational videoconferences with Canadian schools. We are a lesson partner with Exploring By the Seat of Your Pants. A teacher in Guelph, Ontario runs Exploring by the Seat of Your Pants and aims to "connect classrooms to science, adventure and conservation". As a lesson partner, CFHT participates in webcasted Google Hangout talks that are then archived and available to teachers on the Exploring website.

For the first time, CFHT traveled to an international outreach festival, participating in the Eureka! Festival in Montreal in June. CFHT conducted a workshop on spectroscopy for 200 students plus their

families (we estimate ~400 people). 108,000 people attended the festival and while we did not interact with all of them, CFHT was featured in the marketing - appearing on the website listing of workshop participants and participating organizations.

Figure 25 – CFHT Resident Astronomer Lison Malo at the Eureka! Festival in Montreal.

In September, Mary Beth visited Victoria to speak at the last public event of the summer at Dominion Astrophysical Observatory. She gave an overview of CFHT before turning more specifically to CFHT's outreach efforts in all our constituent countries with a special emphasis on Canada. Approximately 100 people attended out of the 409 attending the entire event. Meetings were also held with Friends of DAO and we discussed CFHT's involvement in their plans for the Centre of the Universe.

In 2016 CFHT plans to continue the efforts listed above, but with emphasis on expanding the reach of the programs. One lesson from 2015 is that for the time being we are best suited to plugging into an already existing network of teachers, such as Discover the Universe or Exploring by the Seat of Your Pants. We plan to further develop CFHT's outreach website to include teacher resources like lesson reviews, links to activities and CFHT generated content. Putting these resources online along with our menu of talks is the first step towards recruiting educators ourselves.

Outreach in France

2015 marked the first time that CFHT attempted large-scale outreach in France. We worked with Pascal Petit and Natalie Webb as members of the SF2A LOC to create a CFHT photo display at the meeting in the main conference hall. The Light Beyond the Bulb (LBTB) program, part of the International Year of Light, inspired the display. The display contained eight images; four from the LBTB catalog and four from CFHT's image collection. CFHT was the sole organization with image representation at the meeting. After the meeting, the images moved to the museum at the Pic du Midi Observatory. Remi Cabanac and CFHT installed the display where ~67,000 visitors will have the opportunity to view the images annually. With the success of this display, we will follow this model for future CFHT visits to France. For next year's SF2A meeting in Lyon and the CFHT's user's meeting in Nice, we will work with the organizing committees ahead of time to install a display at the meetings with the intention that post meeting, the display will be donated to a local organization affiliated with astronomy.

Figure 26 – The large extensible banners CFHT brought to the SF2A conference in France.

We also plan to use the SF2A and CFHT user's meeting to establish a network of French astronomers (ideally but not limited to CFHT users) interested in outreach. We plan on

proposing an outreach session at the SF2A meeting with the goal of connecting with institutions and individuals already working on local outreach. Much of our success in Canada this year arose from plugging into existing networks, which we would like to establish in France.

While in Toulouse for the SF2A meeting, CFHT met with Anthony and Sylvie Etcheverry from Observatoire Midi-Pyrénées to discuss future outreach for SPIRou. The efforts are still in the planning stages, but CFHT will contribute towards the team's goal of exhibition and experiments and other educational materials. We will continue to work with Sylvie and her team on SPIRou related projects.

CFHT Resident Astronomer Claire Moutou was featured in the exoplanet episode of the upcoming television series "Sur Les Routes De La Science". The series follows two science journalists, Emilie Martin and Marie-Pier Elie as they travel the world meeting scientists working on "science's biggest questions". The film crew traveled to Hawaii in August for several days of filming on Maunakea including two days at CFHT. The show is anticipated to premier in France in 2016.

In 2016, we plan to continue the efforts listed above, but with emphasis on creating new networks into the French community. We would like to work to target French amateur astronomers. As mentioned above, one lesson from Canada is that for the time being we are best suited to plugging into an already existing network of teachers. We plan to further develop CFHT's outreach website to include teacher resources like lesson reviews, links to activities and CFHT generated content. With the addition of new materials, we will work towards translating them, along with our current materials into French. We have a draft of our CFHT brochure in French that will be ready before the User's Meeting in May 2016.

Outreach in Hawaii

CFHT's outreach efforts in Hawaii transformed throughout the year and expanded into new territories. For the first time, the Maunakea Observatories are working with a public relations firm, Bennet Group, who has also been retained by CFHT to work on MSE and other issues.

Outreach Festivals:

CFHT participated in an assortment of community events: Onizuka Day in January, Astro Day and Innovator's Fair in May, Family Science Day at Imiloa, Family Science Night at Kealakehe Elementary School and Healthy Keiki Fest. In each instance, our booth featured hands on activities designed to explain who we are and what we do. The Innovator's Fair booth was particularly popular. We brought a 3D printer, which was a crowd favorite and our displays were visited by ~3600 people.

We made a concerted effort to emphasize the diversity of job options at the observatories. We created career sheets that feature each of the groups at CFHT. The front side gives general information about the group - the type of jobs, skills needed, educational requirements and general description. The back page profiles a CFHT staff member and their specific position. For the astronomy group, we have two, one profiling Lison Malo as a staff astronomer and the other profiling Lisa Wells as a remote observer. The career sheets are available on our website and are distributed at local schools and career fairs.

Local Students

Building off our work at career fairs, we are expanding our internship program. Currently, CFHT astronomers have visiting graduate students over the summer. In the summer of 2015, we had four astronomy grad students plus another physics student working with Marc Baril on SITELLE. We also had two Akamai interns - undergraduate students from Hawaii working with our instrumentation and

operations group. In spring 2016 CFHT will have an astronomy intern from the University of Hawaii at Hilo working to create an online resource guide for teachers. We are also discussing finding a business or marketing intern to help devise a tracking, distribution and inventory system for CFHT calendars.

As part of CFHT's effort to reach local school students, we have several projects in the works with Big Island and Hawaii schools. In early 2015, CFHT met with the superintendent of West Hawaii Schools, Art Souza. He was interested in the idea of Journey Through the Universe, indicating participation would be left to the individual principals. Dr. Souza proposed that CFHT join his Hokupa'a project (Hokupa'a is Polaris in Hawaiian) as a community partner for a local school. We partnered with Honoka'a Intermediate and High School and are working with students, teachers, and parents. Currently, we are working with the group to create after school programming.

CFHT met with the STEM coordinator for North Hawaii and the Honoka'a Elementary School principal over the summer. Both are in favor of expanding Journey Through the Universe to Honoka'a in 2016. By the end of the year, we plan to meet with the elementary and intermediate/high school principals again and begin preparations for a pilot North Hawaii Journey program in March 2016.

CFHT continues to provide support for local k-12 students working on science fair projects. We offer judges, mentors and prizes to students and local science fairs. The East Hawaii Science Fair continues to be the largest science fair on island, but West Hawaii resumed their science fair for the first time in several years. One local student and her mentor, an astronomer from Gemini, requested and were granted discretionary time from CFHT for her project. Moving forward, we will create a small database on our website with CFHT archival data appropriate for students to use for science fair projects along with suggested science fair topics. This database will be accessible to students worldwide and we will translate the page into French.

At the high school level, CFHT and Gemini partnered to create the "Maunakea Scholars" program, an opportunity for local high school students to work with astronomy mentors on archival Gemini images before proposing their own projects using CFHT. Mentors from Gemini, CFHT and IFA volunteered to work with three classrooms of students, one from Kapolei on Oahu and two from Waiakea in Hilo, teaching the students the science behind the pretty pictures and guiding them towards appropriate topics for their proposals. Each class will receive one hour of telescope time, awarded by a mini CFHT TAC. The project is in its pilot stages and we currently face some challenges, primarily from the lack of technology at the local high schools. The Maunakea Scholars program is one of the key programs we hope to expand in the next few years. Before doing so, we will need to demonstrate that the program is successful, which we anticipate by the end of the 2015/16 school year. We also hope to encourage other observatories to donate telescope time.

In summary, between classroom visits, k-12 career fairs, science fairs and portable planetarium shows, we visited with ~2000 local students this year.

Community Events

CFHT sponsored two major community events this year, the Waimea Solar System Walk in October and the Winter Star Party in December. The Solar System Walk was organized in conjunction with Keck Observatory and focused on the contributions the Maunakea Observatories have made towards our understanding of the solar system. Each booth featured a hands-on activity and MKO discovery. In addition to CFHT and Keck staff, booths were staffed by representatives from UH, the Onizuka Center, Big Kahuna Meteories, Gemini, the Visitor's Information Station and members of the West Hawaii

Astronomy Club. Participating keiki received free passes to Imiloa Astronomy Center in Hilo while adults received discounted passes. We worked with students from Honoka'a intermediate and high schools prior to the walk and they acted as student helpers at each booth. Roughly 200 people participated in the walk, which received coverage on the state television news broadcasts and in Big Island newspapers.

Starting in 2016, eight of the Maunakea Observatories, Imiloa and University of Hawaii will begin hosting the Kama'aina Observatory Experience summit tours. Twenty-four Kama'aina (Hawaii residents) will tour two observatories a month complete with lunch at HP, environmental and cultural briefings. A Visitor Information Station and Imiloa staff member with observatory personal at the summit guides each tour. The participants will take home a Galileoscope and tripod, educational postcards from the Office of Maunakea Management and Hawaiian starlines poster. CFHT plays an active role in the organization and coordination of the tours which are co-sponsored by a grant received by Imiloa with the media plan funded by the Moore Foundation. President Obama announced the tours at the White House Astronomy Night in October.

CFHT continues to host summit tours for visiting astronomers and graduate students, local charities and educational groups. We have escorted an estimated 150 people to the summit this year, including a French film crew (see above), a BBC film crew for the show "Stargazing Live" with Brian Cox and several print journalists. We are planning a tour for a group of Canadian graduate students along with Stephan Courteau for May 2016.

Social Media

The CFHT FaceBook page grew from ~225 fans in December 2014 to ~740 fans in November 2015. Posts are made daily Monday-Friday and focus on good news coming out of CFHT with emphasis on the staff, science, instrumentation and outreach. The vast majority of posts are CFHT generated or specific content. Occasionally we post about other Maunakea Observatories or international friends.

CFHT joined Twitter in August 2015. The debut of the page coincided with the IAU meeting. The content is more astronomy focused since many of our PIs are on Twitter. For example, the OSSOS team has a dynamic Twitter account and often interacts with the CFHT account by tweeting updates and discoveries. Since August we have ~110 followers on Twitter.

In June, CFHT re-launched Hoku, our online newsletter for educators. Hoku is now a blog, updated roughly two times a month that focuses on general astronomy. Recent postings include a November sky report, layperson explanation of the Mars water discovery and information on SITELLE. CFHT also started a Vimeo page where we share videos about CFHT staff and instrumentation.

One of the major issues facing the observatories is a set of common misperceptions. After the April protests, the Maunakea Observatories pulled together and hired a strategic communications firm, the Bennet Group (BG). For the first time, the Maunakea Observatories have a collective logo (seen on the next page) to use for jointly sponsored activities.

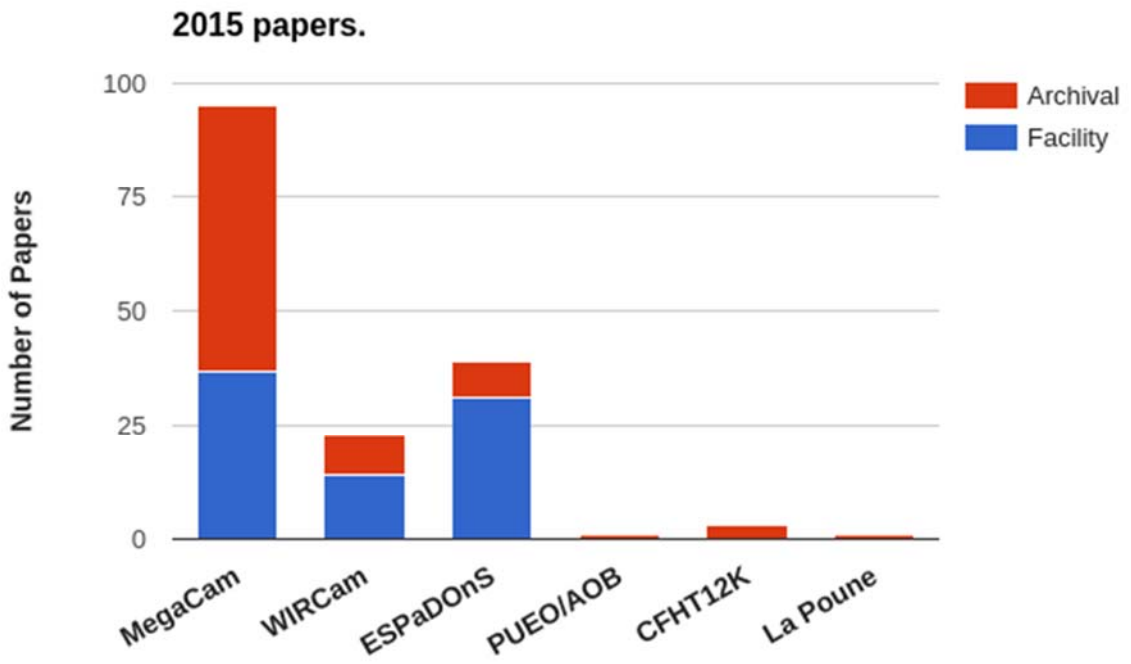
To counteract these misperceptions and others, we created three fact sheets to better inform the public about the observatories. The Maunakea Astronomy Outreach Committee (MKAOC) instituted a crisis communications working group to deal with issues surrounding the protests, particularly when TMT construction was attempted. The working group sprang into action with the June restart and had a plan in place based on lessons learned for the anticipated November restart. BG created talking

points, worked with designated MKO spokespeople, and worked with media. CFHT staff worked closely with BG on the development of all materials.

CFHT also hosted the initial community forum on the Maunakea situation in April at the Honoka'a People's Theater. Doug Simons and representatives from the Maunakea Hui shared their visions for the future of Maunakea. Approximately 200 people attended live with another ~600 attending via the web and an additional 670 viewings on the web. CFHT staff, specifically Doug, have spoken and written about the Maunakea situation extensively in 2015. Working with BG ensures that we publicize our efforts much greater than before and reach audiences statewide. Local papers are more receptive to astronomy and observatory related stories. We hope the increased publicity demonstrates that the observatories are proud members of the community and committed to the work we do here.

2015 Publications Including CFHT Data

The 2015 list of CFHT refereed papers is presented below. Overall, 81 facility papers were published during this period and 70 archival papers, leading to a total of 151 papers published in 2015. The figure below shows the number of papers per instrument.



Facility papers (81)

MegaCam (37)

Morrison C. B., Hildebrandt H. 2015 Mitigating systematic errors in angular correlation function measurements from wide field surveys MNRAS 454 3121

Harnois-Déraps J., et al. 2015 Testing modified gravity with cosmic shear MNRAS 454 2722

Schrabback T., et al. 2015 CFHTLenS: weak lensing constraints on the ellipticity of galaxy-scale matter haloes and the galaxy-halo misalignment MNRAS 454 1432

Du W., et al. 2015 Mass-Concentration Relation of Clusters of Galaxies from CFHTLenS ApJ 814 120

Kuntz A. 2015 Cross-correlation of CFHTLenS galaxy catalogue and Planck CMB lensing using the halo model prescription A&A 584 A53

Hsieh H. H., Sheppard S. S. 2015 The reactivation of main-belt Comet 324P/La Sagra (P/2010 R2) MNRAS 454 L81

Head J. T. C. G., Lucey J. R., Hudson M. J. 2015 Beyond Sérsic + exponential disc morphologies in the Coma Cluster MNRAS 453 3729

Sharon K., et al. 2015 A Multi-wavelength Mass Analysis of RCS2 J232727.6-020437, A ˜3 × 10¹⁵ M_⊙ Galaxy Cluster at z = 0.7 ApJ 814 21

Durret F., et al. 2015 Ophiuchus: An optical view of a very massive cluster of galaxies hidden behind the Milky Way ⋆ A&A 583 A124

O'Mill A. L., et al. 2015 Structure and dynamics of the supercluster of galaxies SC0028-0005 MNRAS 453 868

Liu C., et al. 2015 The Most Massive Ultra-compact Dwarf Galaxy in the Virgo Cluster ApJ 812 L2

Foltz R., et al. 2015 Evidence for the Universality of Properties of Red-sequence Galaxies in X-Ray- and Red-Sequence-Selected Clusters at z ~ 1 ApJ 812 138

Liu C., et al. 2015 The Next Generation Virgo Cluster Survey. X. Properties of Ultra-compact Dwarfs in the M87, M49, and M60 Regions. ApJ 812 34

Goto T., et al. 2015 Evolution of mid-infrared galaxy luminosity functions from the entire AKARI NEP deep field with new CFHT photometry MNRAS 452 1684

Curtin C., et al. 2015 Exploring the Role of Globular Cluster Specific Frequency on the Nova Rates in Three Virgo Elliptical Galaxies ApJ 811 34

Nie J. D., et al. 2015 An Extended View of the Pisces Overdensity from the SCUSS Survey ApJ 810 153

Cañameras R., et al. 2015 Planck's dusty GEMS: The brightest gravitationally lensed galaxies discovered with the Planck all-sky survey A&A 581 A105

Venuti L., et al. 2015 UV variability and accretion dynamics in the young open cluster NGC 2264 A&A 581 A66

Soucail G., et al. 2015 The matter distribution in z ~ 0.5 redshift clusters of galaxies. II. The link between dark and visible matter A&A 581 A31

Wolk M., Carron J., Szapudi I. 2015 Unveiling the cosmological information beyond linear scales: forecasts for sufficient statistics MNRAS 451 1682

Webb T., et al. 2015 An Extreme Starburst in the Core of a Rich Galaxy Cluster at z = 1.7 ApJ 809 173

Di Cecco A., et al. 2015 On the Absolute Age of the Metal-rich Globular M71 (NGC 6838). I. Optical Photometry AJ 150 51

Grossauer J., et al. 2015 The Next Generation Virgo Cluster Survey. IX. Estimating the Efficiency of Galaxy Formation on the Lowest-mass Scales ApJ 807 88

Graham M. L., et al. 2015 Confirmation of Hostless Type Ia Supernovae Using Hubble Space Telescope Imaging ApJ 807 83

Stroe A., et al. 2015 The rise and fall of star formation in z ˜ 0.2 merging galaxy clusters MNRAS 450 646

Grier C. J., et al. 2015 The Sloan Digital Sky Survey Reverberation Mapping Project: Rapid CIV Broad Absorption Line Variability ApJ 806 111

Dawson W. A., et al. 2015 MC²: Galaxy Imaging and Redshift Analysis of the Merging Cluster CIZA J2242.8+5301 ApJ 805 143

Dalessandro E., et al. 2015 Evidence of tidal distortions and mass-loss from the old open cluster NGC 6791 MNRAS 449 1811

Hoekstra H., et al. 2015 The Canadian Cluster Comparison Project: detailed study of systematics and updated weak lensing masses MNRAS 449 685

Carballo-Bello J. A., et al. 2015 A Megacam Survey of Outer Halo Satellites. IV. Two Foreground Populations Possibly Associated with the Monoceros Substructure in the Direction of NGC 2419 and Koposov 2 ApJ 805 51

McGinnis P. T., et al. 2015 CSI 2264: Probing the inner disks of AA Tauri-like systems in NGC 2264 A&A 577 A11

Li J., Jewitt D. 2015 Disappearance of Comet C/2010 X1 (Elenin): Gone With a Whimper, Not a Bang AJ 149 133

Jee M. J., et al. 2015 MC ²: Constraining the Dark Matter Distribution of the Violent Merging Galaxy Cluster CIZA J2242.8+5301 by Piercing through the Milky Way ApJ 802 46

Martinet N., et al. 2015 The evolution of the cluster optical galaxy luminosity function between z = 0.4 and 0.9 in the DAFT/FADA survey A&A 575 A116

Wegner G. A., Chu D. S., Hwang H. S. 2015 The double galaxy cluster Abell 2465 - II. Star formation in the cluster MNRAS 447 1126

Duc P.-A., et al. 2015 The ATLAS^{3D} project - XXIX. The new look of early-type galaxies and surrounding fields disclosed by extremely deep optical images MNRAS 446 120

Shen Y., et al. 2015 The Sloan Digital Sky Survey Reverberation Mapping Project: Technical Overview ApJS 216 4

WIRCam (14)

Foltz R., et al. 2015 Evidence for the Universality of Properties of Red-sequence Galaxies in X-Ray- and Red-Sequence-Selected Clusters at z ~ 1 ApJ 812 138

Liu C., et al. 2015 The Next Generation Virgo Cluster Survey. X. Properties of Ultra-compact Dwarfs in the M87, M49, and M60 Regions. ApJ 812 34

Chiang P., Chen W. P. 2015 Discovery of Young Methane Dwarfs in the Rho Ophiuchi L 1688 Dark Cloud ApJ 811 L16

Goto T., et al. 2015 Evolution of mid-infrared galaxy luminosity functions from the entire AKARI NEP deep field with new CFHT photometry MNRAS 452 1684

Cañameras R., et al. 2015 Planck's dusty GEMS: The brightest gravitationally lensed galaxies discovered with the Planck all-sky survey A&A 581 A105

Sobral D., et al. 2015 CF-HiZELS, an ˜10 deg² emission-line survey with spectroscopic follow-up: Hα, [O III] + Hβ and [O II] luminosity functions at z = 0.8, 1.4 and 2.2 MNRAS 451 2303

Zhang M., et al. 2015 A Deep Near-infrared Survey toward the Aquila Molecular Cloud. I. Molecular Hydrogen Outflows ApJS 219 21

Navarete F., et al. 2015 A survey of extended H₂ emission from massive YSOs MNRAS 450 4364

Chun S.-H., et al. 2015 Near-infrared photometric properties of asymptotic giant branch stars in the dwarf irregular galaxy IC 1613 A&A 578 A51

Dupuy T. J., et al. 2015 The Mass-Luminosity Relation in the L/T Transition: Individual Dynamical Masses for the New J-band Flux Reversal Binary SDSSJ105213.51+442255.7AB ApJ 805 56

Rajan A., et al. 2015 The brown dwarf atmosphere monitoring (BAM) project - II. Multi-epoch monitoring of extremely cool brown dwarfs MNRAS 448 3775

Chiang P., et al. 2015 Searching for T dwarfs in the ρ Oph dark cloud L 1688 MNRAS 448 522

Croll B., et al. 2015 Near-infrared Thermal Emission Detections of a Number of Hot Jupiters and the Systematics of Ground-based Near-infrared Photometry ApJ 802 28

Martinet N., et al. 2015 The evolution of the cluster optical galaxy luminosity function between z = 0.4 and 0.9 in the DAFT/FADA survey A&A 575 A116

ESPaDOnS (31)

Jofré E., et al. 2015 KIC 9821622: An interesting lithium-rich giant in the Kepler field A&A 584 L3

Siqueira-Mello C., et al. 2015 High-resolution abundance analysis of HD 140283 A&A 584 A86

Neiner C., Lampens P. 2015 First discovery of a magnetic field in a main-sequence δ Scuti star: the Kepler star HD 188774 MNRAS 454 L86

Shultz M., et al. 2015 Detection of magnetic fields in both B-type components of the ε Lupi system: a new constraint on the origin of fossil fields? MNRAS 454 L1

See V., et al. 2015 The energy budget of stellar magnetic fields MNRAS 453 4301

LeBlanc F., et al. 2015 Project VeSElkA: results of abundance analysis I - HD 71030, HD 95608, HD 116235 and HD 186568 MNRAS 453 3766

Donati J.-F., et al. 2015 Magnetic activity and hot Jupiters of young Suns: the weak-line T Tauri stars V819 Tau and V830 Tau MNRAS 453 3706

Silvester J., Kochukhov O., Wade G. A. 2015 The magnetic field topology and chemical abundance distributions of the Ap star HD 32633 MNRAS 453 2163

Walker G. A. H., et al. 2015 Identification of More Interstellar C₆₀⁺ Bands ApJ 812 L8

Khalack V. R., LeBlanc F. 2015 Project VeSElkA: Vertical Stratification of Element Abundances in CP stars AASP 5 3

Sikora J., et al. 2015 Confirming HD 23478 as a new magnetic B star hosting an Hα-bright centrifugal magnetosphere MNRAS 451 1928

Miroshnichenko A. S., et al. 2015 Toward Understanding the B[e] Phenomenon: V. Nature and Spectral Variations of the MWC 728 Binary System. ApJ 809 129

Landstreet J. D., et al. 2015 A novel and sensitive method for measuring very weak magnetic fields of DA white dwarfs. A search for a magnetic field at the 250 G level in 40 Eridani B A&A 580 A120

Bailey J. D., Landstreet J. D. 2015 The remarkably unremarkable global abundance variations of the magnetic Bp star HD 133652 A&A 580 A81

See V., et al. 2015 Time-scales of close-in exoplanet radio emission variability MNRAS 450 4323

Khalack V., LeBlanc F. 2015 Project VeSElkA: Analysis of Balmer Line Profiles of Slowly Rotating Chemically Peculiar Stars AJ 150 2

Martin R. P., et al. 2015 Oxygen, α-element and iron abundance distributions in the inner part of the Galactic thin disc MNRAS 449 4071

Shultz M., et al. 2015 The magnetic field and spectral variability of the He-weak star HR 2949 MNRAS 449 3945

Bowler B. P., et al. 2015 Planets Around Low-mass Stars (PALMS). V. Age-dating Low-mass Companions to Members and Interlopers of Young Moving Groups ApJ 806 62

Rosén L., Kochukhov O., Wade G. A. 2015 First Zeeman Doppler Imaging of a Cool Star Using all Four Stokes Parameters ApJ 805 169

Martins F., et al. 2015 Surface abundances of ON stars A&A 578 A109

Moritani Y., et al. 2015 Probing the Nature of the TeV γ-Ray Binary HESS J0632+057 by Monitoring Be Disk Variability ApJ 804 L32

Wade G. A., et al. 2015 Rotation, spectral variability, magnetic geometry and magnetosphere of the Of?p star CPD -28° 2561 MNRAS 447 2551

Bailey J. D., Grunhut J., Landstreet J. D. 2015 A comprehensive analysis of the magnetic standard star HD 94660: Host of a massive compact companion? A&A 575 A115

Martins F., et al. 2015 The MiMeS survey of magnetism in massive stars: CNO surface abundances of Galactic O stars A&A 575 A34

Yakunin I., et al. 2015 The surface magnetic field and chemical abundance distributions of the B2V helium-strong star HD 184927 MNRAS 447 1418

Rucinski S. M. 2015 Time Sequence Spectroscopy of AW UMa. The 518 nm Mg i Triplet Region Analyzed With Broadening Functions AJ 149 49

Yan F., et al. 2015 The centre-to-limb variations of solar Fraunhofer lines imprinted upon lunar eclipse spectra. Implications for exoplanet transit observations A&A 574 A94

Aurière M., et al. 2015 The magnetic fields at the surface of active single G-K giants A&A 574 A90

Sabin L., Wade G. A., Lèbre A. 2015 First detection of surface magnetic fields in post-AGB stars: the cases of U Monocerotis and R Scuti MNRAS 446 1988

Pereyra A., Rodrigues C. V., Martioli E. 2015 Measuring the continuum polarization with ESPaDOnS A&A 573 A133

Archival Papers (70)

MegaCam (58) Eckert D., et al. 2015 Warm-hot baryons comprise 5-10 per cent of filaments in the cosmic web Natur 528 105

Agnello A., et al. 2015 Discovery of two gravitationally lensed quasars in the Dark Energy Survey MNRAS 454 1260

Rebull L. M., et al. 2015 YSOVAR: Mid-infrared Variability in NGC 1333 AJ 150 175

Gerbrandt S. A. N., McConnachie A. W., Irwin M. 2015 The red extended structure of IC 10, the nearest blue compact galaxy MNRAS 454 1000

Ishikawa S., et al. 2015 The very wide-field gzK galaxy survey - I. Details of the clustering properties of star-forming galaxies at z ˜ 2 MNRAS 454 205

Kim M., et al. 2015 An Off-nucleus Nonstellar Black Hole in the Seyfert Galaxy NGC 5252 ApJ 814 8

Kim Y., et al. 2015 Discovery of a Faint Quasar at z ˜ 6 and Implications for Cosmic Reionization ApJ 813 L35

Hui M.-T., et al. 2015 Gone in a Blaze of Glory: The Demise of Comet C/2015 D1 (SOHO) ApJ 813 73

Stroe A., Sobral D. 2015 A large narrow-band Hα survey at z˜ 0.2: the bright end of the luminosity function, cosmic variance and clustering across cosmic time MNRAS 453 242

Cooke J., O'Meara J. M. 2015 A New Constraint on the Physical Nature of Damped Lyman Alpha Systems ApJ 812 L27

Bowler R. A. A., et al. 2015 The galaxy luminosity function at z ⍰ 6 and evidence for rapid evolution in the bright end from z ⍰ 7 to 5 MNRAS 452 1817

Finet F., et al. 2015 Predicted multiply imaged X-ray AGNs in the XXL survey MNRAS 452 1480

Geach J. E., et al. 2015 The Red Radio Ring: a gravitationally lensed hyperluminous infrared radio galaxy at z = 2.553 discovered through the citizen science project SPACE WARPS MNRAS 452 502

Collett T. E. 2015 The Population of Galaxy-Galaxy Strong Lenses in Forthcoming Optical Imaging Surveys ApJ 811 20

Bouché N., et al. 2015 GalPak^{3D}: A Bayesian Parametric Tool for Extracting Morphokinematics of Galaxies from 3D Data AJ 150 92

González-Gaitán S., et al. 2015 The rise-time of Type II supernovae MNRAS 451 2212

Aird J., et al. 2015 The evolution of the X-ray luminosity functions of unabsorbed and absorbed AGNs out to z˜ 5 MNRAS 451 1892

Polshaw J., et al. 2015 A supernova distance to the anchor galaxy NGC 4258 A&A 580 L15

Matthee J., et al. 2015 Identification of the brightest Lyα emitters at z = 6.6: implications for the evolution of the luminosity function in the reionization era MNRAS 451 400

Liu X., et al. 2015 Cosmological constraints from weak lensing peak statistics with Canada-France-Hawaii Telescope Stripe 82 Survey MNRAS 450 2888

Bonfini P., Dullo B. T., Graham A. W. 2015 Too Big to Be Real? No Depleted Core in Holm 15A ApJ 807 136

Bender R., et al. 2015 Structure and Formation of cD Galaxies: NGC 6166 in ABELL 2199 ApJ 807 56

Viaene S., et al. 2015 NGC 4370: a case study for testing our ability to infer dust distribution and mass in nearby galaxies A&A 579 A103

Pila-Díez B., et al. 2015 A skewer survey of the Galactic halo from deep CFHT and INT images A&A 579 A38

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