

#### Eder Martioli Laboratório Nacional de Astrofísica - LNA/MCTI

Scientific opportunities arising from the new instruments at Gemini and SOAR, August 7 - 10, 2014, Guarujá - SP, Brazil

## Canada-France Hawaii Telescope

- Telescope: 3.6 m
- Lo 155.472° W La 19.826° N
- Atop of Mauna Kea at 4200 m in Hawaii, USA
- Median seeing ~ 0,7"
- http://www.cfht.hawaii.edu/
- Main partnership: Canada, France, and UH.
   Other partners: Taiwan, Brazil, China, and S. Korea.



# Instruments Available

MegaCam: optical wide field imager
WIRCam: infra-red wide field imager
ESPaDOnS: optical high-resolution spectro-polarimeter

• AOB: infrared imager with AO

# MegaCam

- FoV of I° x I°
- Plate scale 0, 18"/pixel
- 36 CCDs of 2048 x 4612 (340Mp)
- Broad band filters: u, g, r, i, z (SDSS except u)
   Narrow band filters: H-alfa ON, H-alfa OFF, CN, TiO, OIII
- Image stabilization unit and 2 CCDs for guiding/auto-focus







MegaCam 2002 40 CCDs, 20K x 18K champ 1° x 1°





# MegaCam Data

FITS image with 36 extensions of 2k x 4k

CFHT provides pre-reduced data Reduction done with Elixir software: correct instrumental effects, astrometry (1") and photometry

Terapix group from Paris provides additional service for CFHT users upon request: data stacking, fine astrometric calibration, catalog generation. <u>http://terapix.iap.fr</u>



### CFHTLS - Mega-Pipe The archive value



#### Science

Supernovae & Dark Energy Gravitational Lensing & Dark Matter Large Scale Structures Active Galactic Nuclei, Quasars, GRBs, Black Holes Clusters of Galaxies Galaxy Evolution Galaxy Evolution Galaxy Morphology Galaxy Luminosity Function Stellar Populations in the Galaxy Small Bodies in the Solar System

http://www2.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/megapipe/cfhtls/index.html more than 2300 hours over 5 years (an equivalent of 450 nights)



### Science with MegaCam

### Large number of Dark Matter peaks found using Gravitational Lensing



".. Dark Matter is the principal mass component of the Universe making up about 80% of the mass budget .. "

Authors: HuanYuan Shan, Jean-Paul Kneib, Martin Makler, Ludovic van Waerbeke, Eric Jullo

#### SNLS - SuperNova Legacy Survey



CENT Legacy Survey detected and monitored about 1000 supernovae

### Large Programs The Pan-Andromeda Archaeological Survey (PandAS) PI: McConnachie





# Large Programs

#### The Next Generation Virgo Cluster Survey (NGVS) PI: Ferrarese



g < 27.7 mag arcsec-2



PI: Brett Gladman (UBC)

- ~60 km diameter object comprised of rock/ice sharing Uranus' orbit as the first discovered Trojan companion to this planet
  - Remains 10-170 deg ahead of Uranus about L4 point
- QF99 discovered as part of a search for more distant trans-Neptunian objects
- Orbit is stable over timescale of hundreds of thousands of years, unstable over millions of years
  - Certainly not a "primordial" object given the instability of its orbit







# WIRCam





- Plate scale of 0,306"/pix (sampling of 0,15" with microdithering)
- 4 x 2040 x 2040 Hawaii-2RG arrays
- Broad band filters: Y, J, H, Ks Narrow band filters: OH (1.061 & 1.187), CH4 (On/Off), H2 (v=1-0 S1), K-cont, Br gamma
- On-instrument guiding

### WIRCam 4 x Hawaii-2RG







# WIRCam Data

- FITS file with 4 extensions (MEF)
- CFHT provides pre-reduced data
- Pipeline: iiwi-2. I



## The Orion Nebula seen with MegaCam and WIRCam



Color composite made by <u>TERAPIX</u> (Courtesy C. Marmo/Terapix)

## The Ring Nebula (Messier 57)



### WIRCam Science Highlights

#### **Free Floating Planet**

PI: Michael Liu (UH)

#### A free floating planet, originally discovered by Pan-STARRS1 and followed up at CFHT for astrometric measurements (Mike Liu et al., 2013)

- Follow up observations completed at IRTF, Gemini, UKIRT, CFHT
- CFHT/WIRCAM precision astrometry(~4 mas error) used to measure distance and therefore pin down luminosity
- Excellent "case study" in young planets given lack of interference from a bright host star

#### Planet vitals -

- **\*** Age: ~12 million yrs
- Distance: 80 ly
- Mass: 6 M<sub>1</sub>
- Member of β-pic cluster





#### **CFHT** Astrometry



## Large Program:TETrEs



 Thermal Emission of Transiting Exoplanets (TETrEs): Probing the Diversity of Hot Jupiter Atmospheres with Multi-Wavelength Precision Photometry Pl: Jayawardhana



## WIRCam Staring Mode photometry

Photometric precision ~0.02%



Croll et al. 2010

AOB: The CFHT Adaptive Optics Bonnette (only offered in classical mode)



- IR imager with AO
- CCD HAWAII IR 2K x 2K pixels. 0.03 or 0.06 arcsec/pixel
- FoV of ~1.5 arcmin
- Input/Output F ratios 8 / 19.6
- For seeing~0.65", AOB provides Strehl ratios of 0.27 in J, 0.41 in H, and 0.56 in K.
- Strehl ratio is attenuated in 50% for guiding stars of J>14.3, H>15.0, and K>15.7.



# ESPaDOnS

- High resolution spectro-polarimeter
- Coverage: 370 nm a 1050 nm
- 3 modes:
  (1) Star-only R=80K
  (2) Star+Sky R=65K
  (3) Polar R=65K Stokes V, U, Q
- RV precision ~ 150 m/s
- Lim V < 17 mag
- Max. exptime = 2400 s





# ESPaDOnS Data

- 2k x 4k single extension FITS image
- Reduction Software: Upena/Libre-Esprit or OPERA
- Extracted ID wavelength-calibrated spectra

#### Raw Data

#### Reduced Data





# ESPaDOnS Science

- Magnetic Protostars and Planets (MaPP)
   PI: Donati
- Magnetism in Massive Stars (MiMeS) PI:Wade





Donati, J.-F., et al. 2006, MNRAS.

\* CUTOVENUS STUDYING EARTH'S TWIN









#### **Venus Express**





homas

Objective : Monitor the instantaneous variations of cloud top winds (z ~70km)

Method : Doppler shift of solar Frauhofer lines in light scattered by cloud particles in motion - data used to constrain global circulation models

First evidence of a meridional flow at cloud tops observed from Earth



Manual guiding using ESPaDOnS' guide camera allowed monitoring of instantaneous cloud top winds ( $z \sim 70$ km) at ESPaDOnS' spatial resolution of 1.6 arcsec projected on Venus EUTOVENUS STUDYING EARTH'S TWIN





Rapid variations of wind velocity reflect strong dependency with latitude and local time



Ground-based measurements overlap analysis based on a different technique using VIRTIS-M on ESA's Venus Express.

## ESPaDOnS Science Highlights

#### Fingerprinting the formation of giant planets



Difference in chemical composition between the stars 16 Cyg A and 16 Cyg B, versus the condensation temperature of the elements in the proto-planetary nebula.

Maia, M. T., Meléndez, J., and Ramírez, I. Marcelo Tucci Maia et al. 2014 ApJ 790 L25

# CFHT Proposals

#### Deadline to submit proposals for 2015A: Sep 21 2014

Northstar (Phase I): <u>http://www.cfht.hawaii.edu/en/science/Proposals/</u>

# New instrumentation

- MegaCam new filter set
- SITELE optical michelson spectral imager with FoV~12'
- GRACES (Gemini not CFHT!)
- SPIRou high resolution infrared spectropolarimeter - VR precision of ~ 1 m/s (under construction)

## MegaCam New Filters

\*All 10 filters on order now from a pair of companies

Two companies chosen to "spread risk" and match unique expertise with technical challenges of filters (u-band filter is non-trivial to make)

Substrates delivered to filter vendors and we anticipate first filter to arrive this summer, all filters to arrive by end of 2014

# Broad band filters



# Narrow band filters



# Sitelle

#### Imaging Fourier Transform Spectrometer

#### Imaging Fourier Transform Spectrometer

- \* Based on SpIOMM (Mont Mégantic) but with improved transmission and modulation efficiency at short wavelengths
- Intended to study the structure and kinematics of emission line sources (nebulae, galaxies, clusters)



- Wavelength range: ~350-970 nm; resolution >6.4 cm<sup>-1</sup>
- Field of view: 11x11 arcmin
  - Square FOV uses 2048 x 2048 pixel CCD (0.32" per pixel)

Filter wheel supports up to 5 optical filters to determine band pass of each scan Built-in calibration sources



#### One spectrum for every pixel!



Laurie Rousseau-Nepton NGC 5055, SpIOMM (Observatoire du Mont Mégantic)

# Science with Sitelle

#### http://www.craq-astro.ca/sitelle/talk.php







# Gemini Remote Access to CFHT ESPaDOnS Spectrograph

# Design Overview





## The pipeline







Source: A-N Chene et al. SPIE 2014 paper





## GRACES module on ESPaDOnS



## The Slicer Bench



# The slices

#### 4 slices I fiber

# 2 slices 2 fibers







# CCD Characteristics

Read mode	Read time (s)	Read noise (e <sup>-</sup> )	Gain (e <sup>-</sup> per ADU)
Fast	32	4.7	1.6
Normal	38	4.2	1.3
Slow	60	2.9	1.2

## GRACES vs. ESPaDOnS

Instrument Configuration	ESPaDOnS		GRACES	
Mode	star	star/sky	star	star/sky
focal ratio	f/8	£/8	f/16	f/16
number of slices	6	3	4	2
number of fibers	1	2	1	2
fiber size (µm)	100	100	165	165
fiber length (m)	36	36	270	270
resolution	80,000	65 <b>,</b> 000	55 <b>,</b> 000	33,000
aperture size (arcsec)	1.6	1.6	1.2	1.2

#### **Optical Transmission Changes**



## **GRACES** Operation

• ESPaDOnS will be available for Gemini whenever it is not being used by CFHT for either observations, maintenance, or other servicing periods.

• CFHT night time usage will be scheduled in blocks of time on a semester basis, though the maintenance needs of the instrument may occur at any time.

# Data Format



Source: A-N Chene et al. SPIE 2014 paper

## The 2 modes

Star-only: 1 fiber, 4 slices

Star+Sky: 2 fiber, 2 slices

![](_page_60_Figure_3.jpeg)

Star-only: 1 fiber, 4 slices

Star+Sky: 2 fiber, 2 slices

![](_page_60_Figure_6.jpeg)

#### GRACES First Light Tests (May 6, 2014)

![](_page_61_Figure_1.jpeg)

#### GRACES First Light Tests (May 6, 2014)

![](_page_62_Figure_1.jpeg)

![](_page_62_Figure_2.jpeg)

## Wavelength Calibration

![](_page_63_Figure_1.jpeg)

## Spectral Resolution

0.0

Wavelength [nm]

0.0

Wavelength [nm]

![](_page_64_Figure_1.jpeg)

Source: A-N Chene et al. SPIE 2014 paper

# Sensitivity

![](_page_65_Figure_1.jpeg)

Source: A-N Chene et al. SPIE 2014 paper

![](_page_65_Figure_3.jpeg)

![](_page_65_Figure_4.jpeg)

# Performance

![](_page_66_Figure_1.jpeg)

Source: A-N Chene et al. SPIE 2014 paper

# Conclusion

Experimental phase is complete with great success.

Performances comparable to other instruments on 6-10m telescopes.

# Important Notes

Possibile call for System Verification programs during 2014B - stay tuned!

GRACES is an experiment and a future decision about providing GRACES to the community depends on a long term agreement to share this facility between CFHT and Gemini.

The Instrument Scientist for GRACES is André-Nicolas Chené. Gemini staff who also supports GRACES include Vinicius Placco

![](_page_69_Picture_0.jpeg)