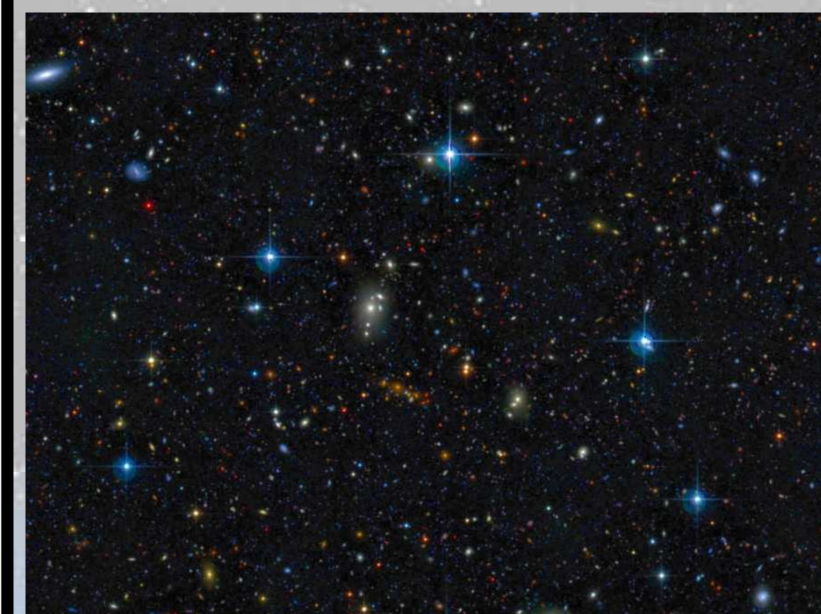
# Canada−France−Hawaii Telescope MegaCam Surveys

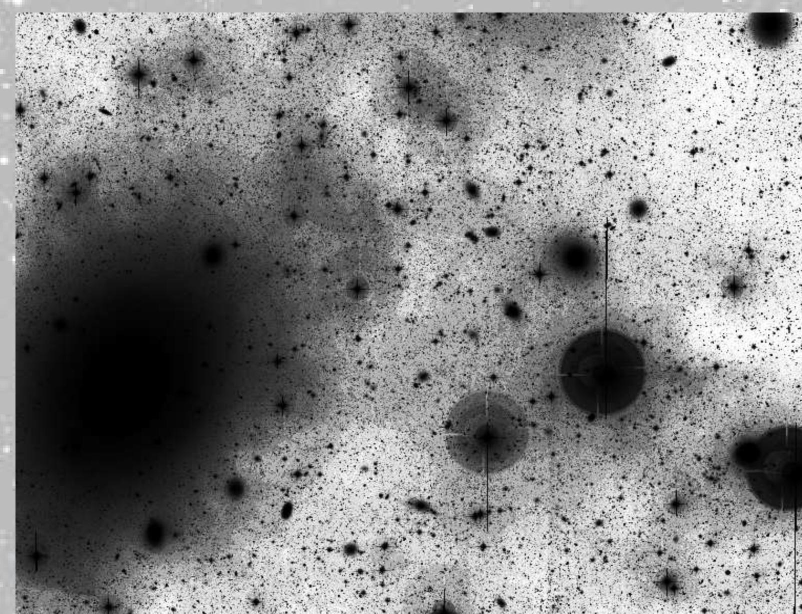
## *History, strategy, and lessons learned*

**Jean−Charles Cuillandre (CFHT)**

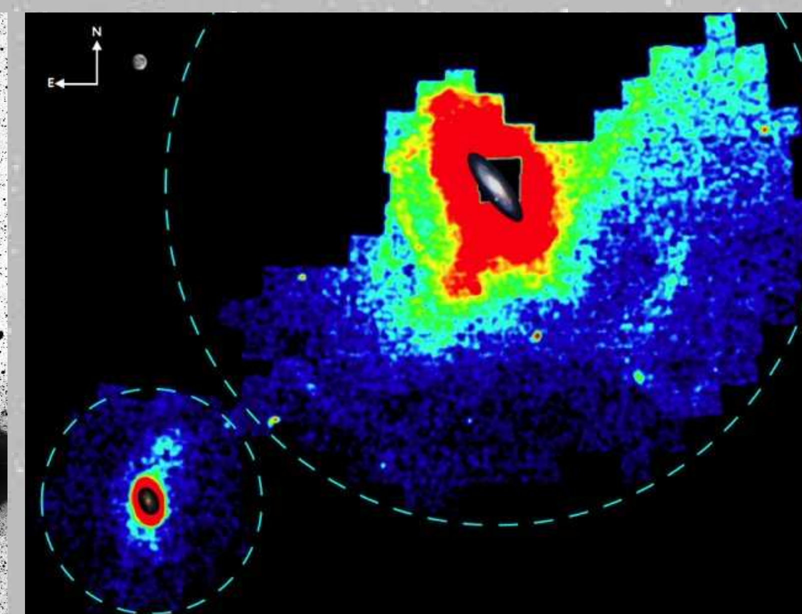
***One Degree Imager Survey Workshop − Yale − October 2009***



**Legacy Survey**
***2003−2009***



**Virgo Survey**
***2009−2012***



**Pan−Andromeda Survey**
***2009−2012***

NATIONAL RESEARCH COUNCIL CANADA
CONSEIL NATIONAL DE RECHERCHES CANADA

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

# CFHT and Scientific Impact: citation metric (2006)

naturenews

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News

## The world's top ten telescopes revealed

**The best observatories ranked by their scientific impact.**

Eric Hand

It doesn't take a big mirror to have a big impact. The Sloan Digital Sky Survey, a project conducted with a modest 2.5-metre-wide telescope in New Mexico, performed the most highly cited science in 2006, according to a new analysis of the top ten 'high impact' astronomical observatories[1].

"It measures how hot the science of the telescope is," says Juan Madrid of McMaster University in Hamilton, Canada, of the top-ten table he has released for most years since 1998. "In a way it measures how good the time-allocation committee is and how good the telescope is. I will also say it measures how good the scientists are."

Also in the top five is another modest telescope — Swift, a satellite that looks for γ-ray bursts — followed by three technological giants of the astronomy world: the Hubble Space Telescope, the four 8-metre telescopes of the European Southern Observatory in Paranal, Chile, and the twin 10-metre Keck telescopes in Hawaii.

The table shows that a telescope's technological advantages can push it to the top of the list, but also operating institution are important. However, some astronomers caution that citations are just one c assess an observatory's value.

HIGH-IMPACT OBSERVATORIES

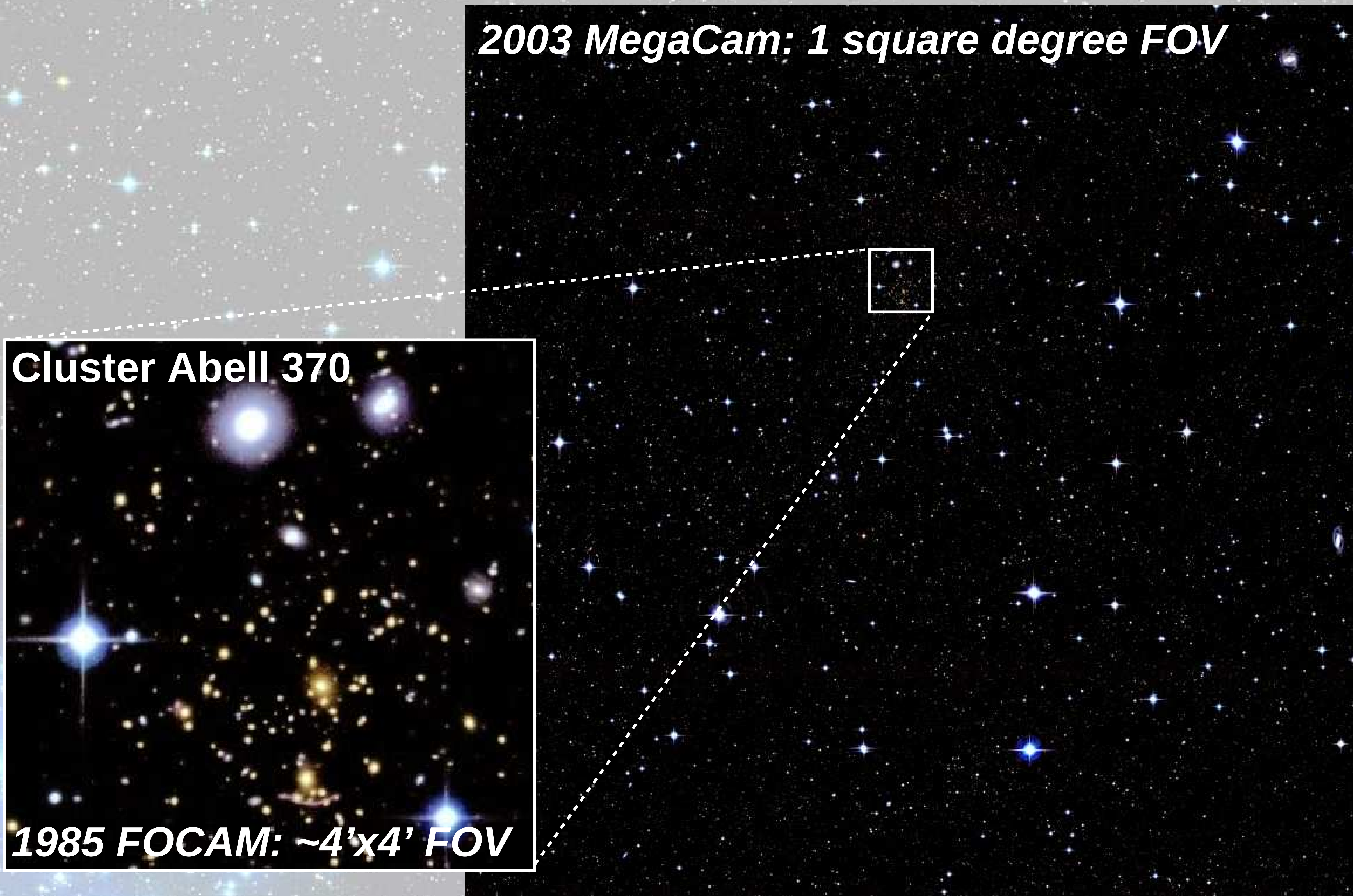
| Rank | Facility | Citations | Participation |
|---|---|---|---|
| 1 | SDSS | 1892 | 14.3% |
| 2 | Swift | 1523 | 11.5% |
| 3 | HST | 1078 | 8.2% |
| 4 | ESO | 813 | 6.1% |
| 5 | Keck | 572 | 4.3% |
| 6 | CFHT | 521 | 3.9% |
| 7 | Spitzer | 469 | 3.5% |
| 8 | Chandra | 381 | 2.9% |
| 9 | Boomerang | 376 | 2.8% |
| 10 | HESS | 297 | 2.2% |

Key
SDSS - Sloan Digital Sky Survey
HST – Hubble Space Telescope
ESO – European Southern Observatory
CFHT – Canada France Hawaii Telescope
HESS - High Energy Stereoscopic System

*Madrid, J. P. & Macchetto, D.*

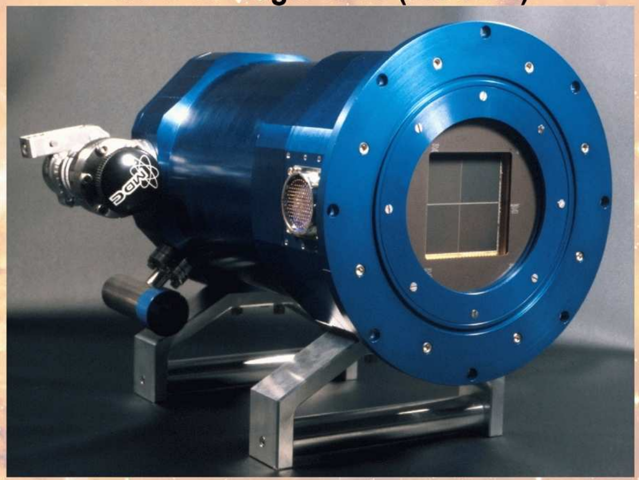
# Gravitational lensing: a key science driver for CFHT

*Discovery of the first giant arc by CFHT in 1985 (Soucail et al.)*

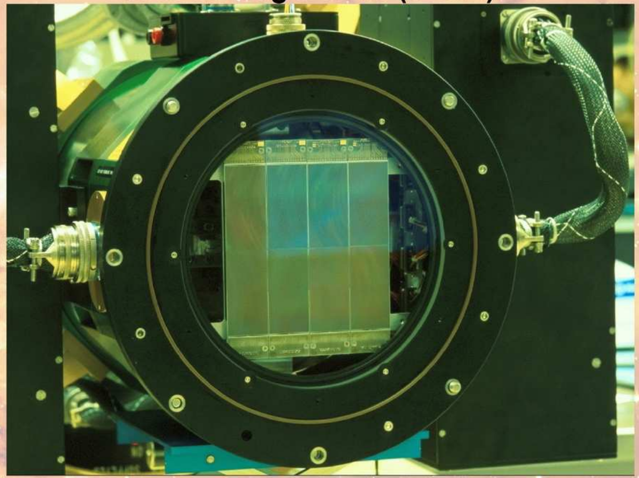


# 1983–2003: 2 decades to get CFHT full frame digital

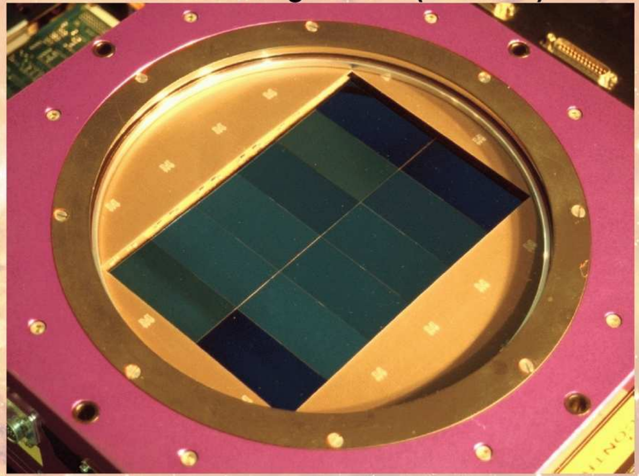
1994: 16 MegaPixels (MOCAM)



1995: 64 MegaPixels (UH8K)



1999: 100 MegaPixels (CFH12K)



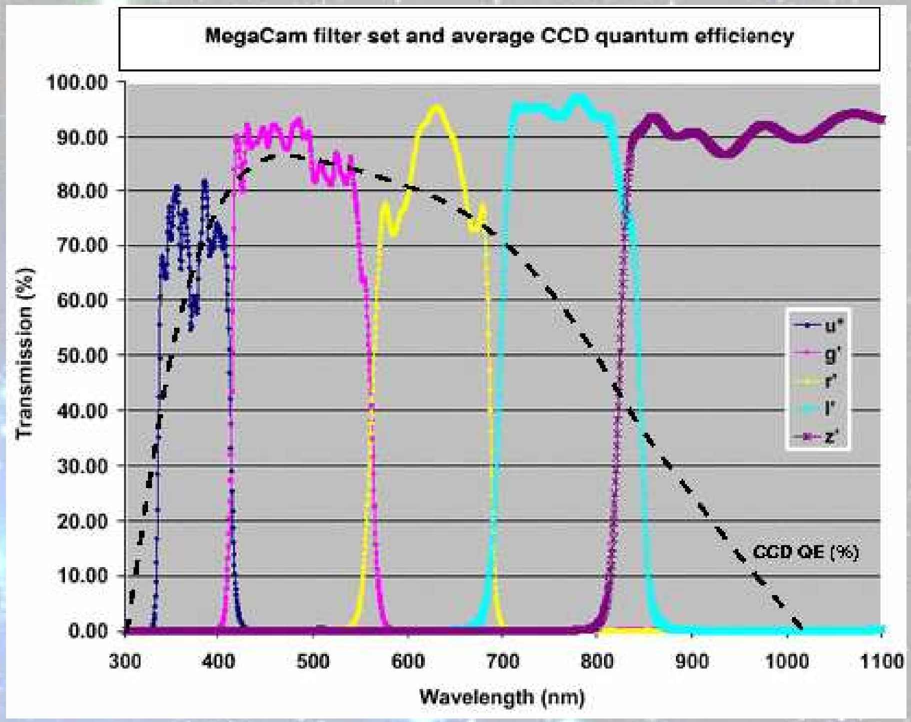
2003: 350 MegaPixels (MegaCam)

New Era in Wide Field Imaging: MegaPrime at CFHT

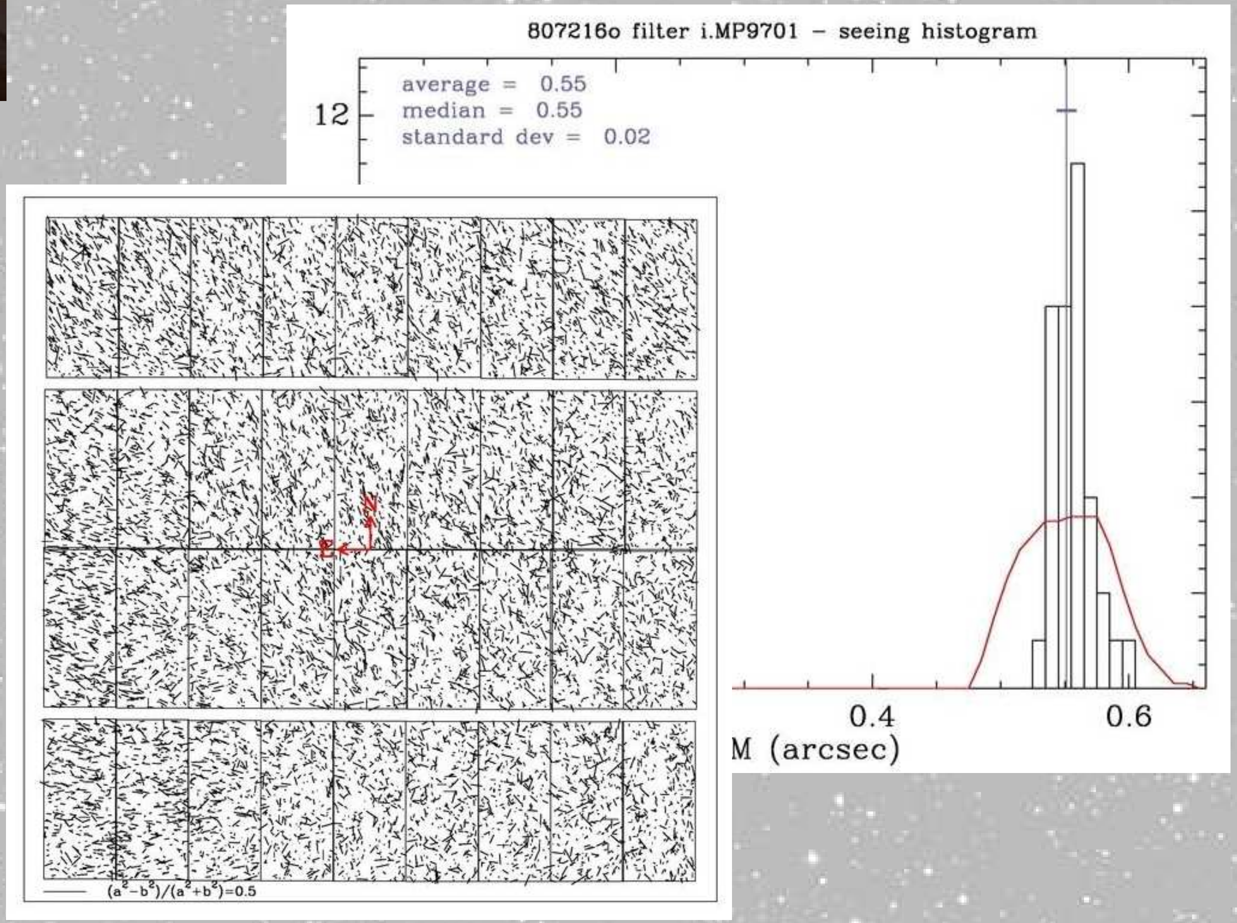
# The instrument: MegaCam on CFHT atop Mauna Kea

MegaPrime on CFHT (3.6m mirror)

MegaCam by CEA : 340 megapixels CCD mosaic




Wavelength coverage: from u−band to z−band

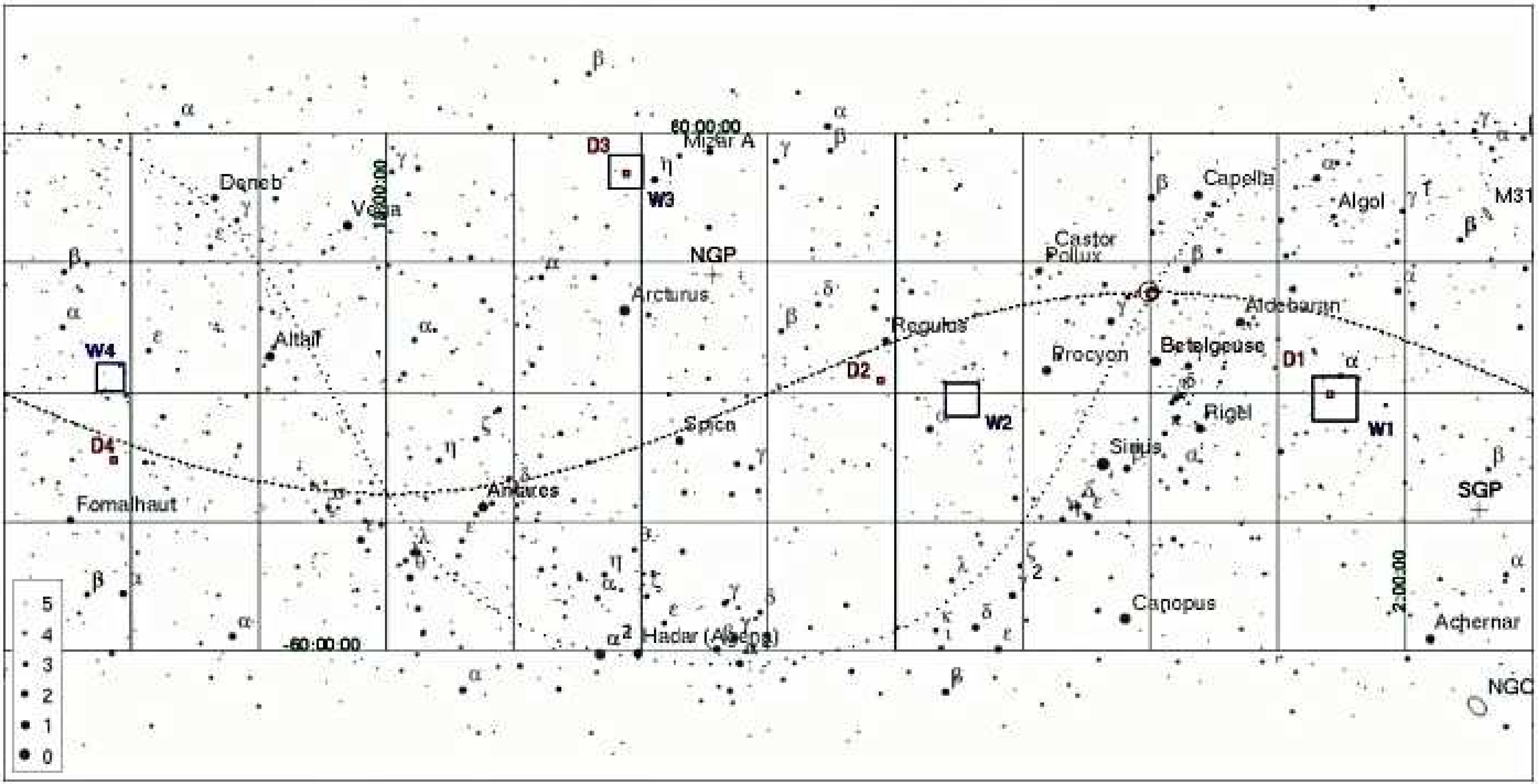



Excellent image quality (uniformity) over 1 sq. deg.

# Origins and evolution of the CFHT Legacy Survey

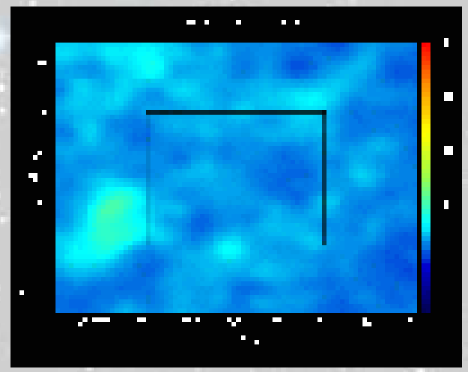
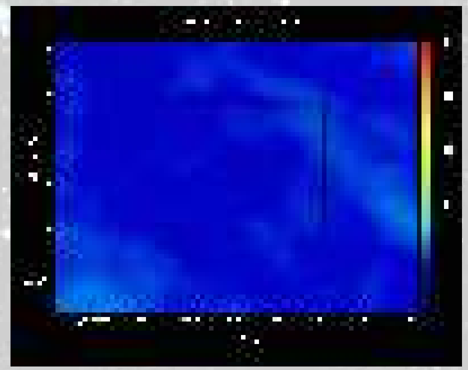
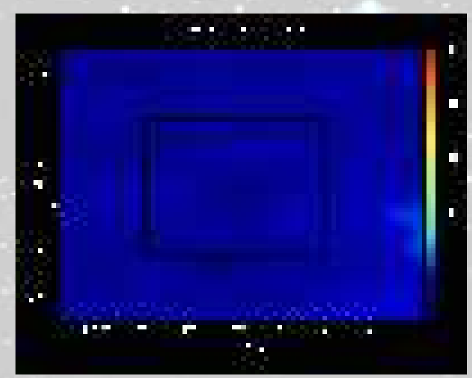
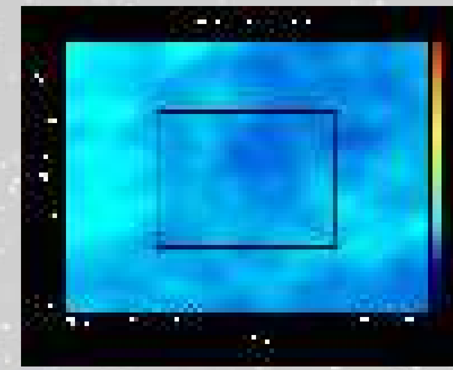
- *1998: CEA offered to build MegaCam and offer it to the entire CFHT scientific community on the condition a major general interest survey is undertaken with it.*
- *1999: CFH12K operational, and with MegaCam and the CFHTLS on the horizon (4 years), an evolution of the CFHT observing process is needed: start of the CFHT's New Observing Process, including Queued Service Observing (QSO).*
- *2000: with the brisk success of the CFH12K across many communities (solar system, stellar physics, nearby Universe, cosmology), resulting with a consistent telescope allocation of 55% over its 4 years lifetime, the call for ideas for the CFHTLS with MegaCam is a success. The French and Canadian agencies allocate 30% of all the telescope time to the survey (they own 85% of the time together).*
- *2001: a science definition group is created, seeking the support of external (of C+F) reviewers. The three core topics adressing the most burning astrophysical questions tailored to make an optimal use of the u to z band sensitivity, the 0.7" median seeing, the 1 sq. degree field, the 3.6m aperture, and the dark skies of Mauna Kea were:*
  - Dark energy study using a large sample (500) of high redshift SNe type Ia (Deep survey)
  - Cosmic shear and cosmological constraints (Wide survey)
  - Origins of the Solar system: Kuiper Belt Objects (Very Wide survey)
  - ...with MANY other science programs enabled: High−z QSOs, brown dwarfs, clustering, etc.
- *2002: CFHTLS green−lighted (500 nights over 5 years) by the CFHT board and C+F agencies after review by the Scientific Advisory Commitee (SAC). Steering Group created (9 members, PI−less), under a continuous review process by the SAC+Board.*

# CFHTLS completed in Feb.09, 2400 hr of valid data

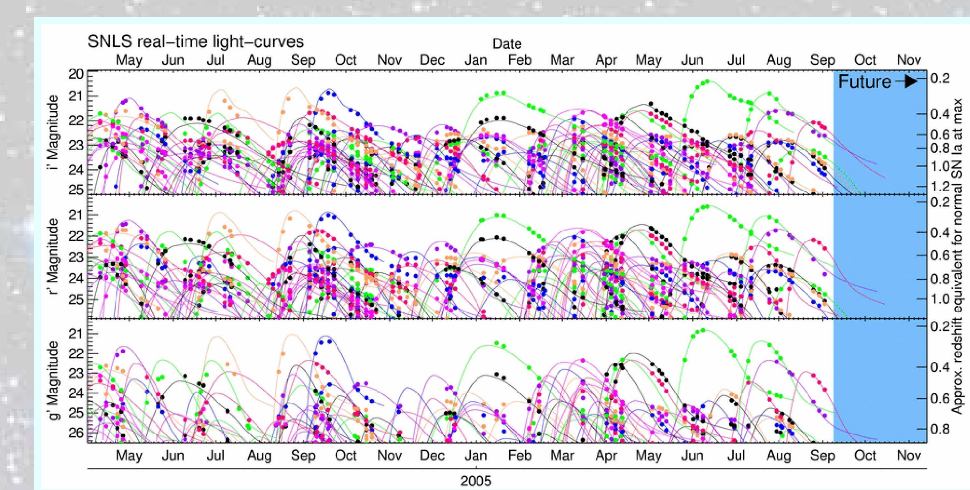



| Survey | Area (sq. deg.) | Location | u* | g’ | r’ | i’ | z’ |
|---|---|---|---|---|---|---|---|
| Deep | 4 | D1/2/3/4 | 28.7 | 28.9 | 28.5 | 28.4 | 27.0 |
| Wide | 170 | W1/2/3/4 | 26.4 | 26.6 | 25.9 | 25.5 | 24.8 |
| Very Wide | 410 | On ecliptic | | 25.5 | 25.0 | 24.4 | |

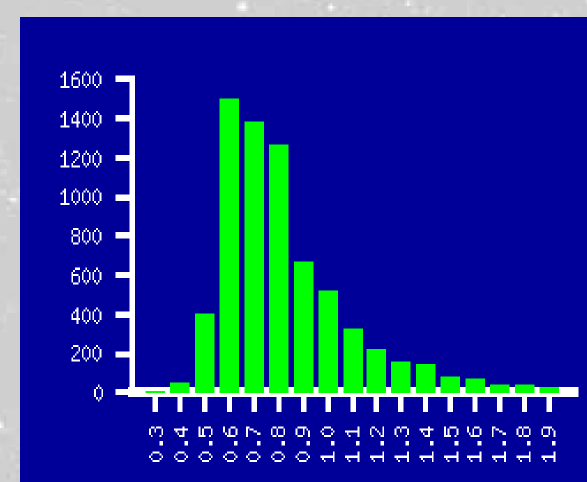
# The Deep Survey – Completed integration

| Field | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| RA/DEC | 02:26/−04:30 | 10:00/02:12 | 14:17/+52:30 | 22:15/−17:44 |
| Overlap | in W1 | On COSMOS field | in W3 | LBQS2212−17 |
| Dust |  |  |  |  |
| Int. | 289 hr. | 252 hr. | 285 hr. | 270 hr. |

| Filter | Fraction | Mean IQ |
|---|---|---|
| u* | 9% | 0.91" |
| g' | 10% | 0.88" |
| r' | 20% | 0.79" |
| i' | 40% | 0.76" |
| z' | 21% | 0.75" |

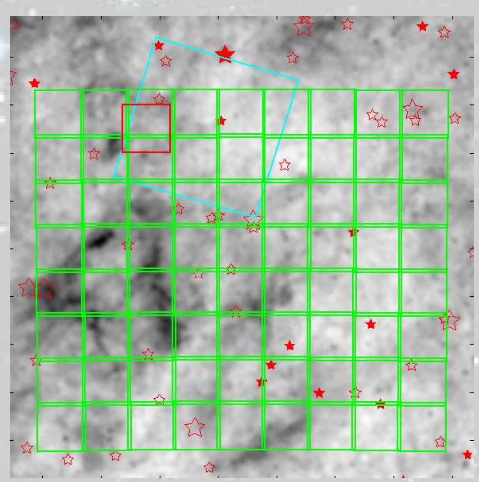
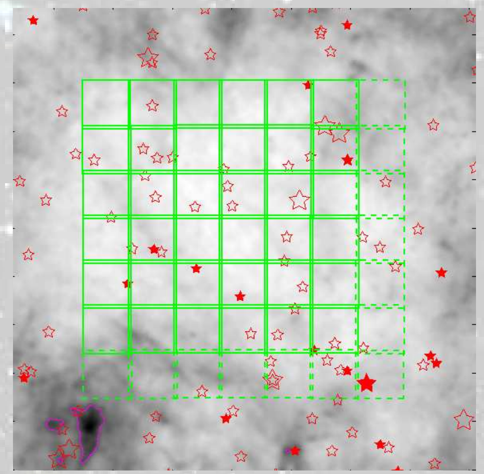
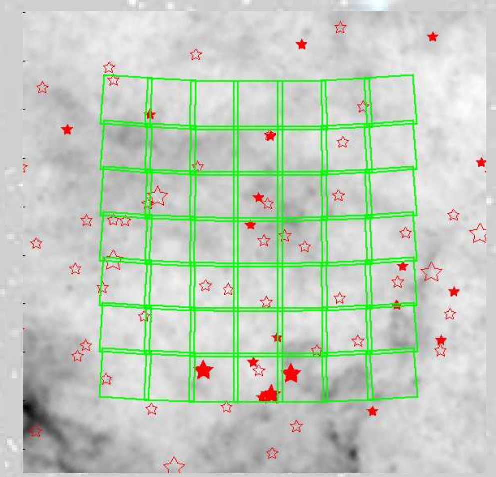
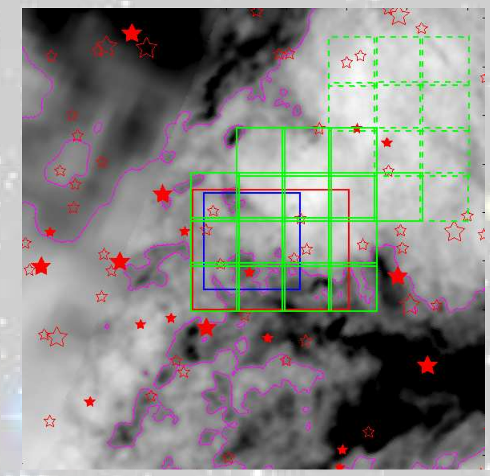



SNLS' SNe Ia light curve tracking



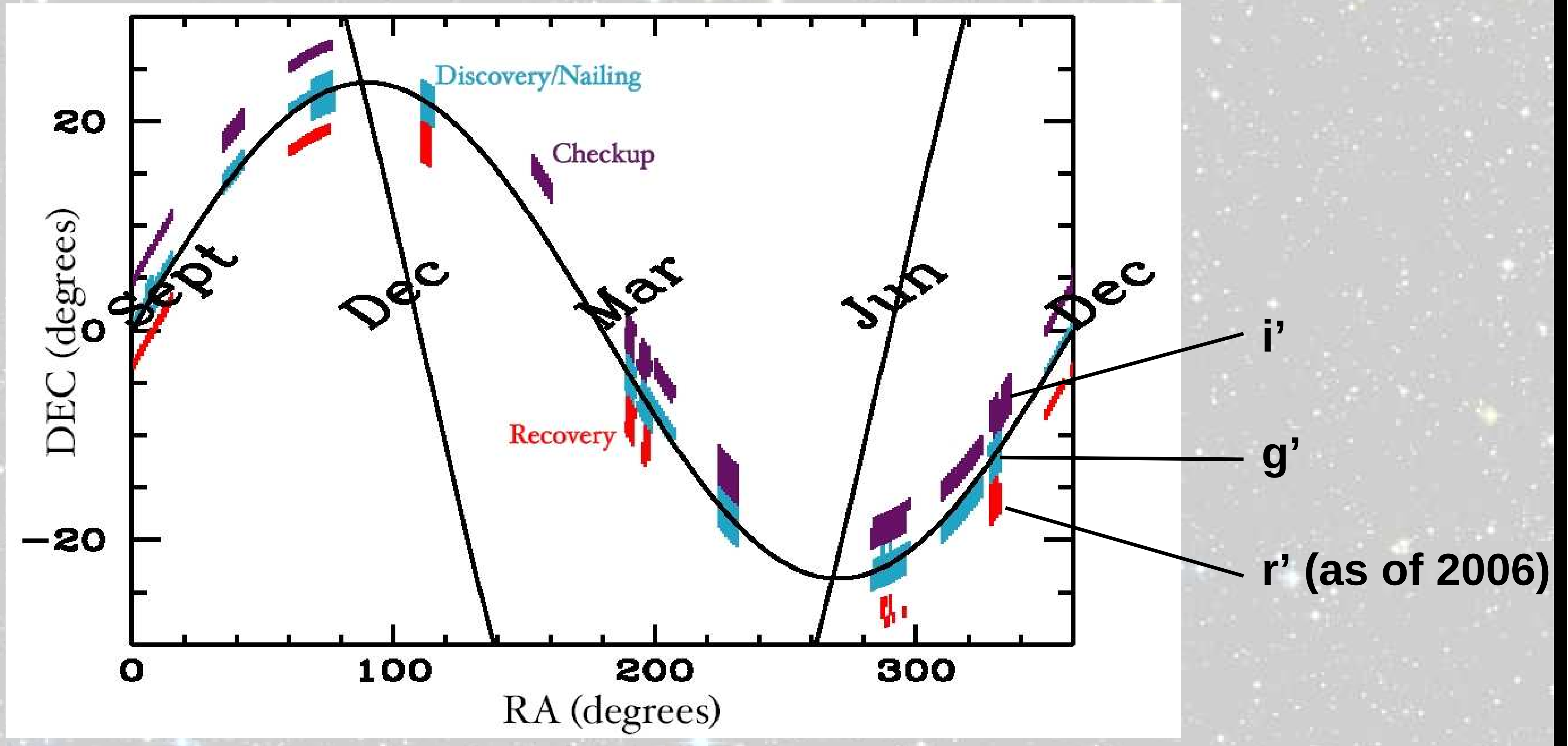

i' FWHM

# The Wide Survey – Completed integration

| Field | W1 – 8x9 sq.deg. | W2 – 5x5 sq.deg. | W3 – 7x7 sq.deg. | W4 – 5x5 sq.deg. |
|---|---|---|---|---|
| RA/DEC | 02:18/−07:00 | 08:54/−04:15 | 14:17/+54:30 | 22:13/+01:19 |
| Overlap | XMM LSS | | Groth Strip | VVDS&UKIDSS |
| Dust |  |  |  |  |
| Int. | 361 hr. | 139 hr. | 242 hr. | 126 hr. |

| Filter | u* | g’ | r’ | i’ | z’ |
|---|---|---|---|---|---|
| Fraction | 17% | 16% | 17% | 28% | 22% |
| Mean IQ | 0.90" | 0.88" | 0.76" | 0.67" | 0.72" |

# The Very Wide Survey – Completed integration

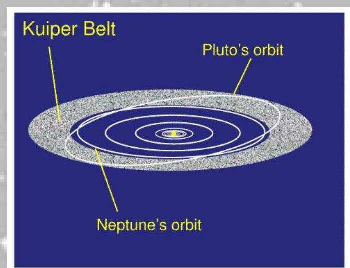



| Filter | g’ | r’ | i’ |
|---|---|---|---|
| Integration | 47 hr. | 75 hr. | 70 hr. |
| Fraction | 24% | 40% | 36% |
| Mean IQ | 0.90" | 0.80" | 0.80" |

Sky Coverage: 410 sq. deg. ...

# Science with the CFHT Legacy Survey

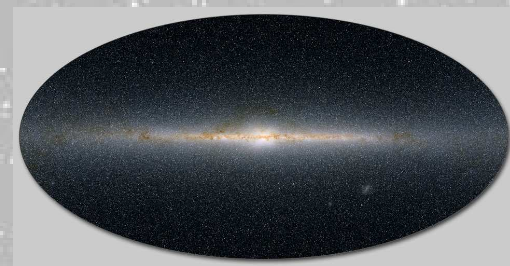
## Solar System




***Very Wide***

- The Kuiper Belt
- Asteroids

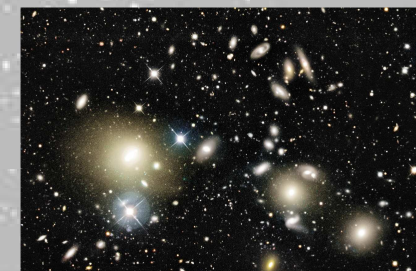
## The Galaxy



***Very Wide / Wide / Deep***

- Stellar Populations
- Brown Dwarfs
- Low Mass Stars
- White Dwarfs
- Dynamics
- Variability

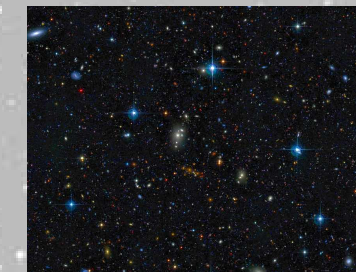
## Galaxies & Clusters



***Wide / Deep***

- Redshift Distribution
- Evolution
- Clusters
- Morphology
- Clustering
- Weak Lensing
- Star Formation
- Luminosity Function
- Environment
- AGNs

## Cosmology



***Very Wide / Wide / Deep***

- Dark Energy
- Cosmic Shear
- Strong Lensing
- Large Scale Struct.
- Supernovae
- GRBs
- QSOs

# The 5 most cited CFHTLS publications

## Article, citations, CFHTLS component, and title (as of June 2009):

| | | | |
|---|---|---|---|
| Astier et al. 2006 | 987 | SNLS | The Supernova Legacy Survey: Measurement of Omega_M, Omega_Lambda and w from the First Year Data Set |
| Hoekstra et al. 2006 | 128 | Wide | First cosmic shear results from the Canada–France–Hawaii Telescope Wide Synoptic Legacy Survey |
| Ilbert et al. 2006 | 121 | Deep | Accurate photometric redshifts for the CFHT Legacy Survey calibrated using the VIMOS VLT Deep Survey |
| Sullivan et al. 2006 | 109 | SNLS | Rates and Properties of Type Ia Supernovae as a Function of Mass and Star Formation in Their Host Galaxies |
| Semboloni et al. 2006 | 74 | Deep | Cosmic Shear Analysis with CFHTLS Deep data |


**Yearly publication rate:**

2005: 4

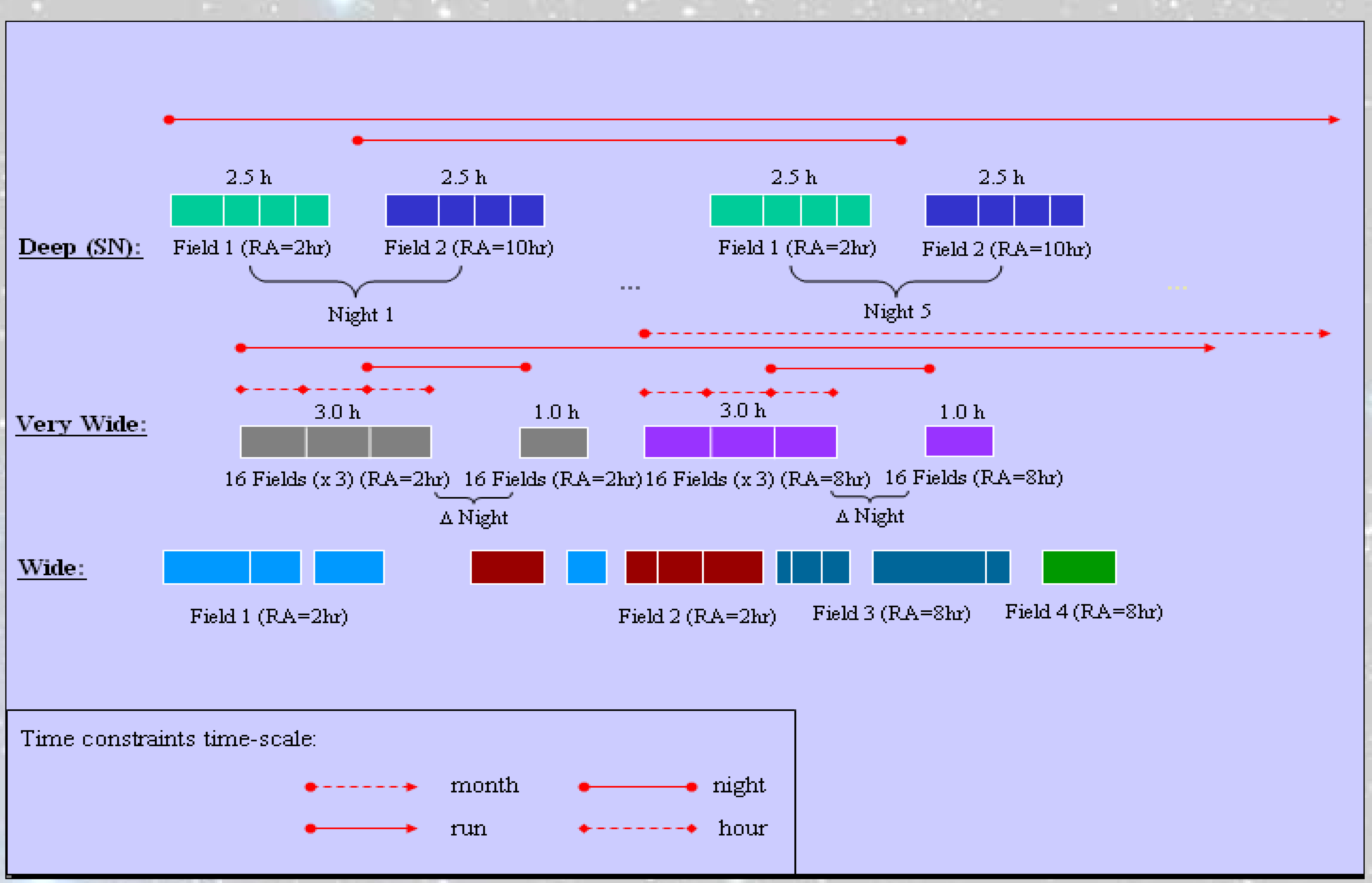
2006: 19

2007: 25

2008: 19

# The CFHTLS seen by Queued Service Observing

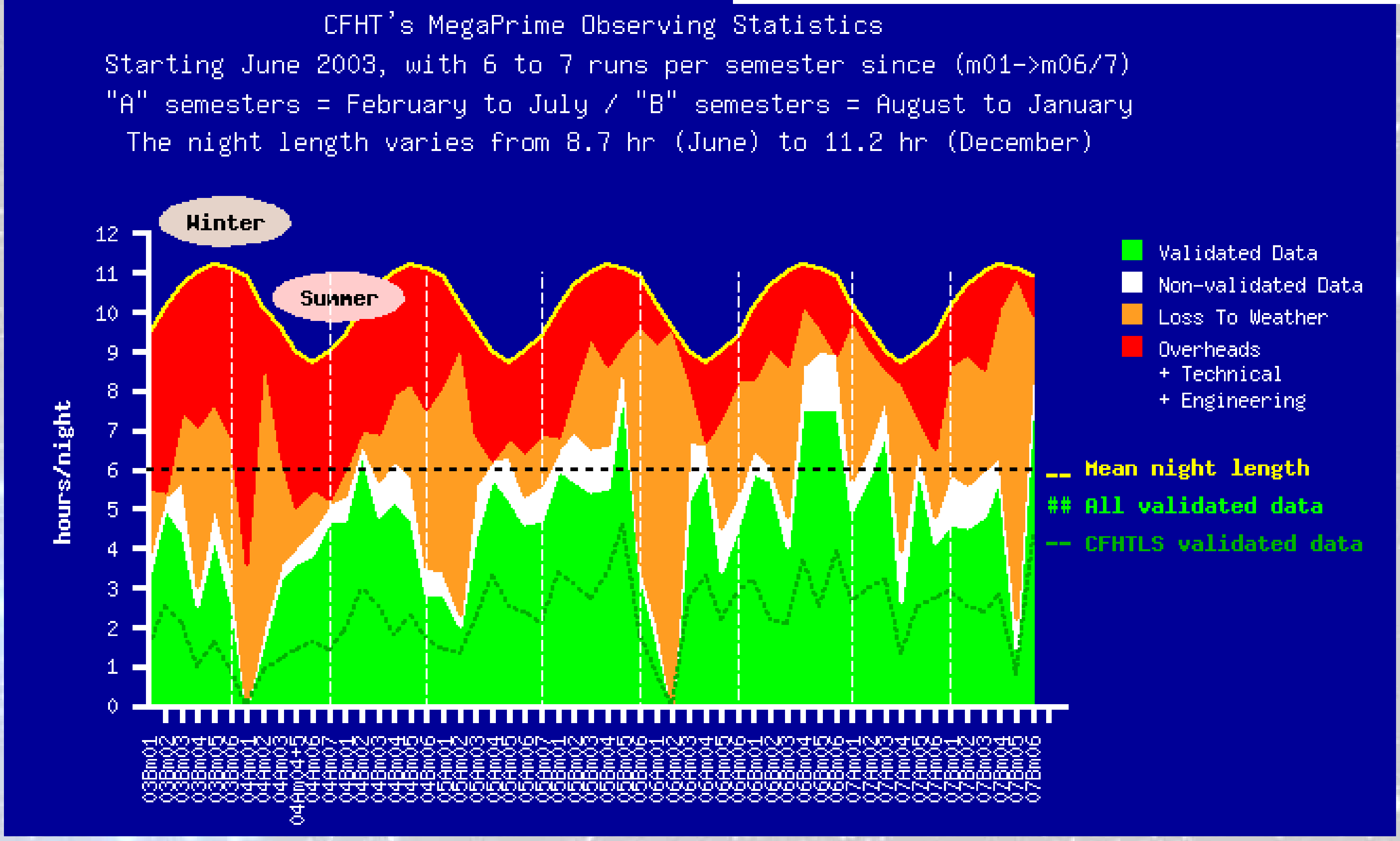
- √ ***Time critical observations on a large-scale***
  - ***SNe fields every 4 nights, 2 fields per run***
  - ***Each Very Wide patch has 5 time constraints***
- √ ***Balancing Agency Time***
  - ***PI programs (50%) versus CFHTLS (50% or "49" nights at best per semester)***
- √ ***Balancing time share between CFHTLS programs***
  - ***Deep (44%), Wide (34%), Very Wide (22%)***
- √ ***Example of conflicts just with the CFHTLS:***




- √ ***Time constraints are a real challenge, require planning, understanding of programs and priorities, and constant attention to the general balance.***

# The real world: weather and technical downtime

| Period | Runs | Nights | Validation | CFHTLS | Unvalidated | Weather | Overheads | Night Length |
|---|---|---|---|---|---|---|---|---|
| All | 55 | 16.5 | 4.5 | 50% | 0.8 | 2.5 | 28% | 10.1 |
| 03B | 6 | 16.8 | 3.7 | 43% | 0.7 | 2.3 | 48% | 10.6 |
| 04A | 6 | 18.7 | 2.8 | 39% | 0.4 | 2.6 | 36% | 9.5 |
| 04B | 6 | 19.0 | 4.8 | 46% | 0.8 | 1.7 | 38% | 10.6 |
| 05A | 7 | 16.4 | 4.2 | 52% | 0.8 | 2.3 | 32% | 9.5 |
| 05B | 6 | 16.3 | 5.7 | 56% | 0.8 | 2.1 | 26% | 10.8 |
| 06A | 6 | 15.8 | 3.5 | 57% | 0.7 | 4.0 | 18% | 9.3 |
| 06B | 6 | 16.8 | 6.4 | 46% | 1.0 | 1.8 | 20% | 10.8 |
| 07A | 6 | 14.3 | 5.1 | 50% | 0.8 | 2.3 | 15% | 9.3 |
| 07B | 6 | 14.2 | 4.9 | 53% | 1.0 | 3.7 | 18% | 10.8 |



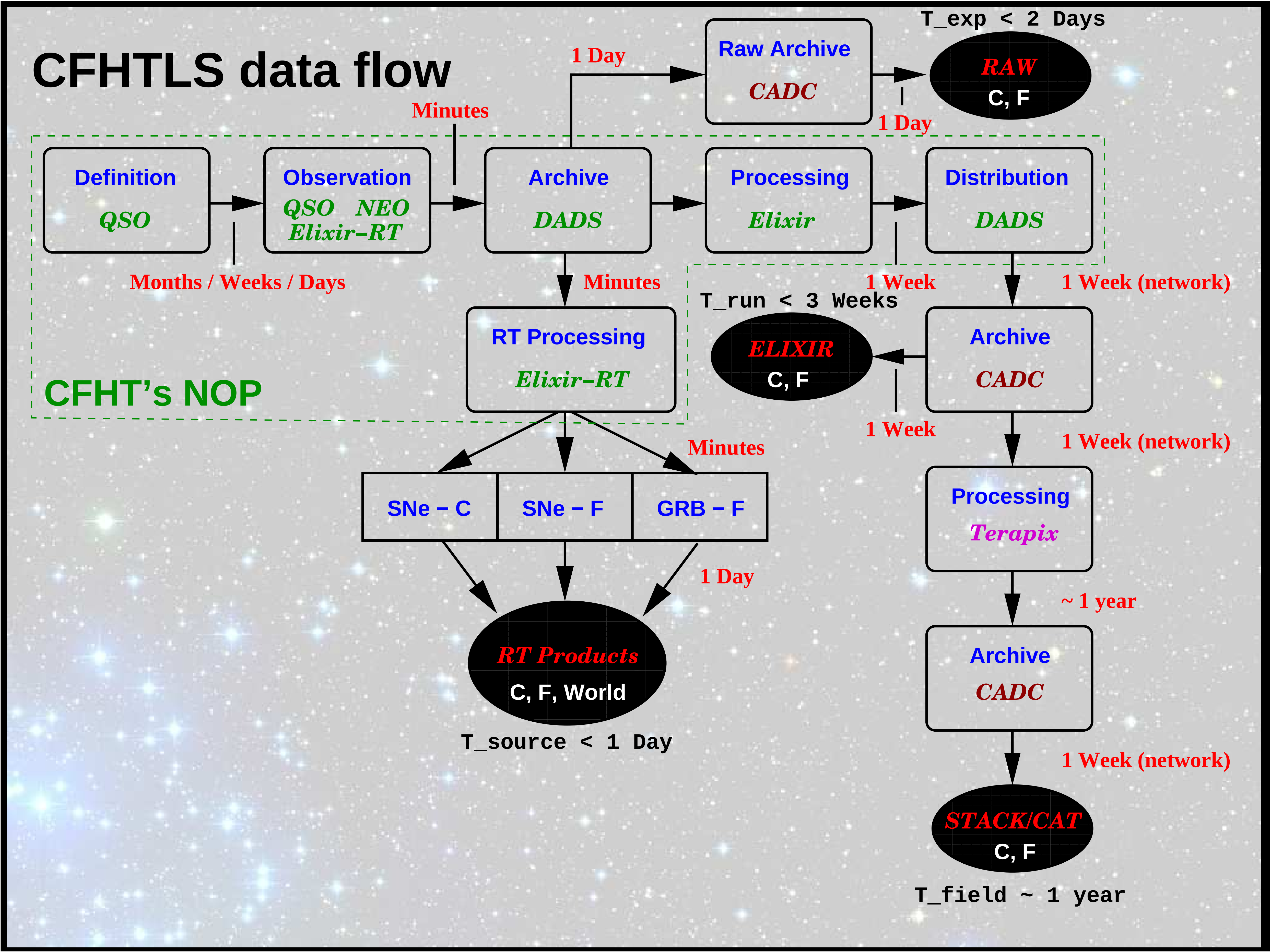

Mid–term review advanced to May 2005

- Priority to core science (SNLS, Cosmic Shear)
- Wide cut to u/2 & z/2
- Very Wide ramped down

... and addition of the W4 field

... plus a 6 months extension with top priority to get the core CFHTLS completed.

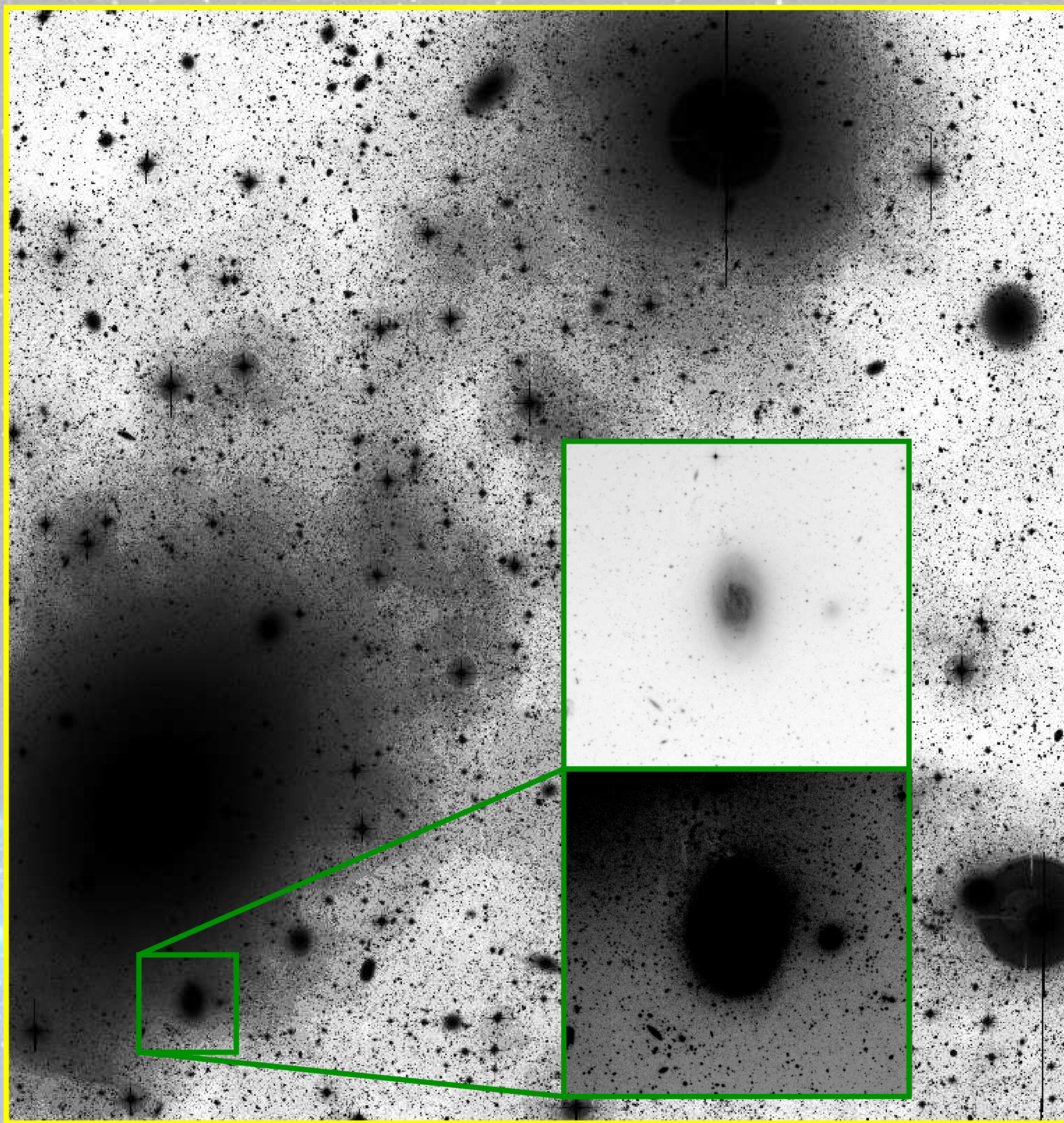
**Flexibility = Salvation**

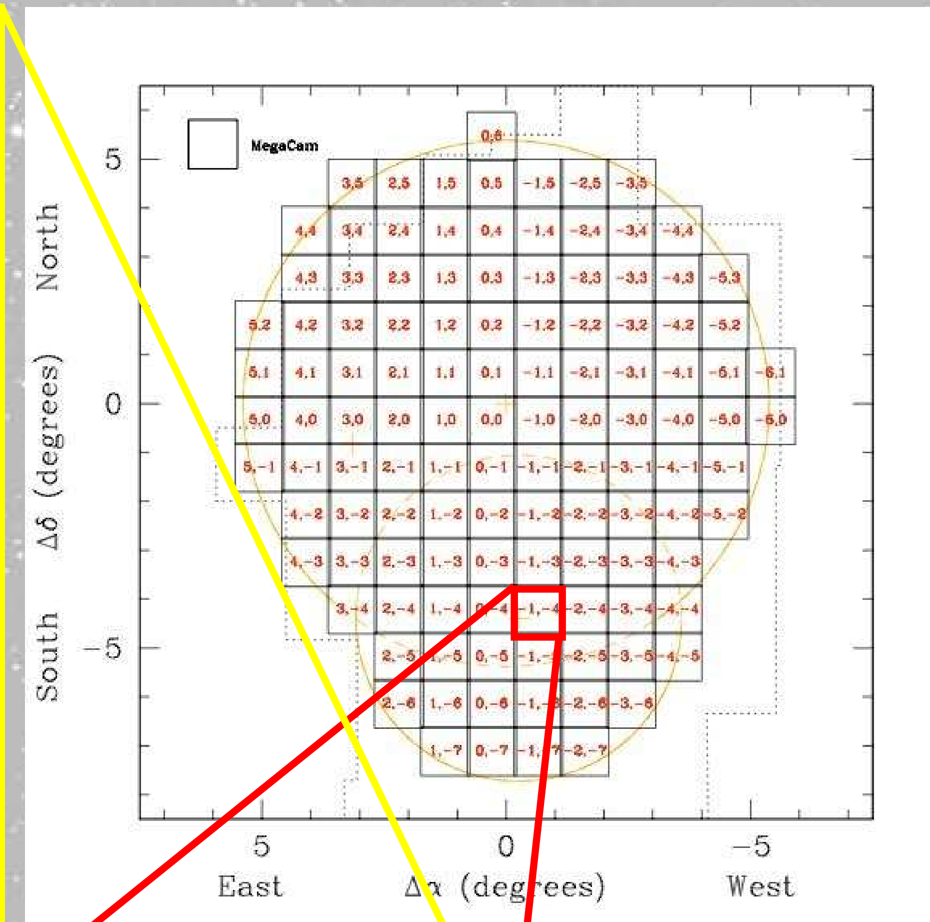


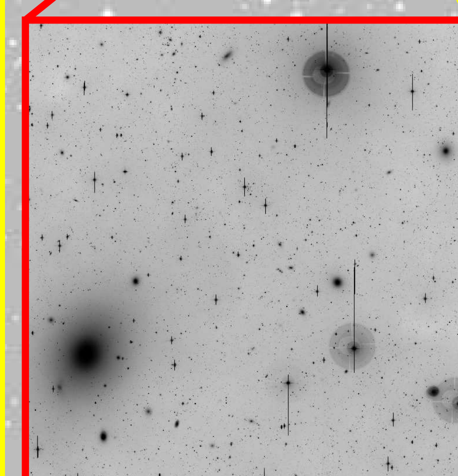
CFHTLS data flow
Definition
QSO
Months / Weeks / Days
Observation
QSO NEO
Elixir–RT
Minutes
Archive
DADS
1 Day
Raw Archive
CADC
T_exp < 2 Days
RAW
C, F
1 Day
Processing
Elixir
Distribution
DADS
Minutes
1 Week
1 Week (network)
RT Processing
Elixir–RT
CFHT's NOP
T_run < 3 Weeks
ELIXIR
C, F
Archive
CADC
1 Week
1 Week (network)
Minutes
SNe – C
SNe – F
GRB – F
1 Day
Processing
Terapix
~ 1 year
RT Products
C, F, World
T_source < 1 Day
Archive
CADC
1 Week (network)
STACK/CAT
C, F
T_field ~ 1 year

# The Next Generation Virgo Survey

## 700 hours over 3 years (2009−12) to cover 104 sq. deg. in u*g’r’i’z’



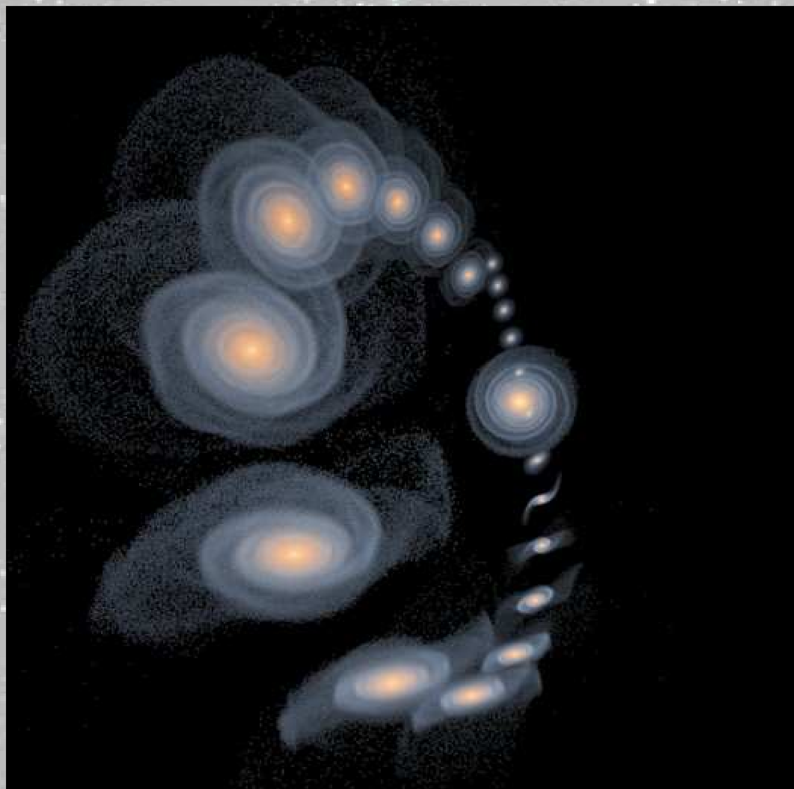


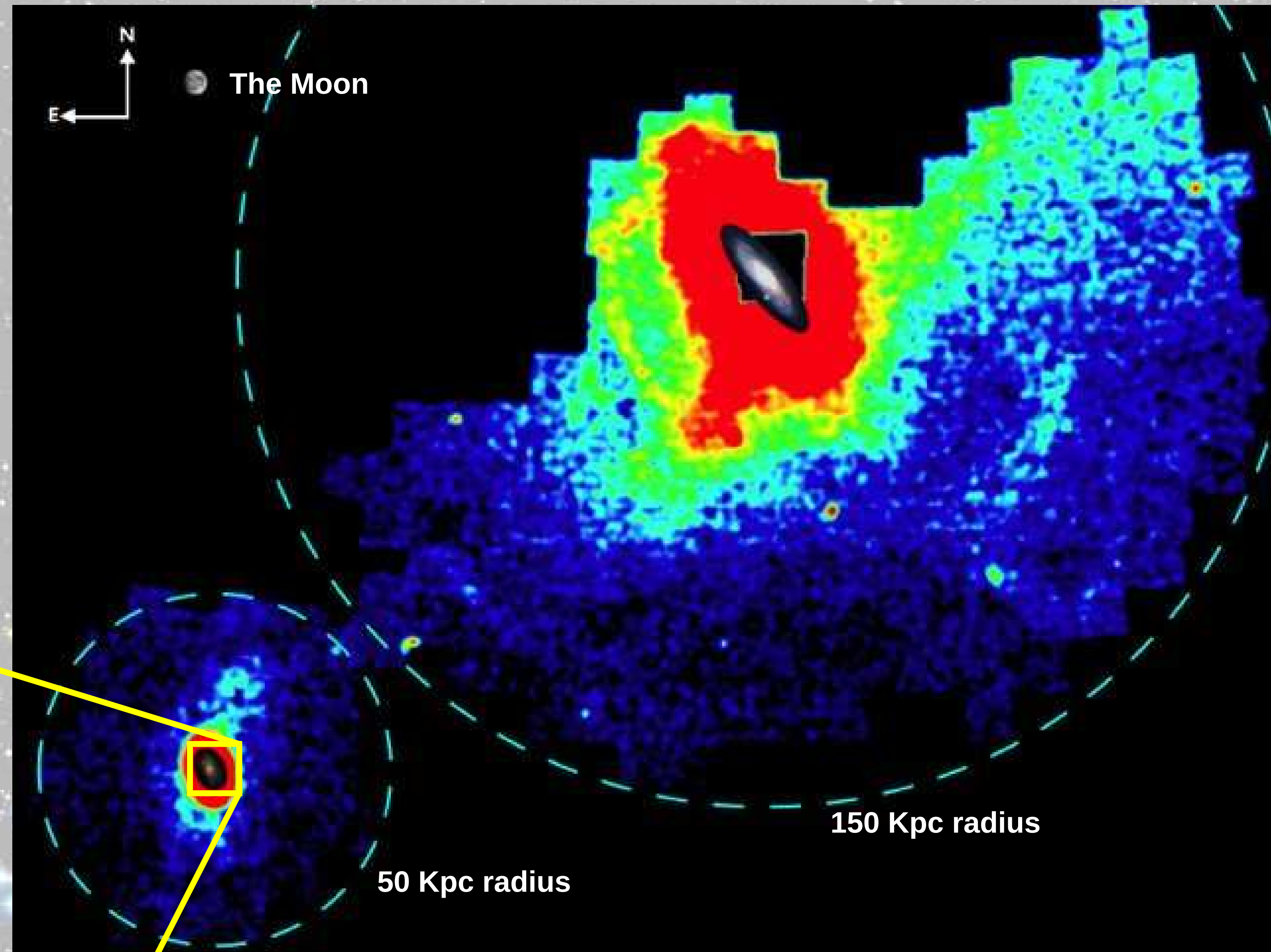



**Messier 49 field (1 sq. deg.)**

# The Pan−Andromeda Survey

## 450 hours over 5 years (2007−12) to cover 350 sq. deg. in g’ and i’






**Depth: g=25.5 i=24.5**

**Detects surface brightness ~32 mag/sq.arcsec**

**Messier 33 field (1 sq. deg.)**