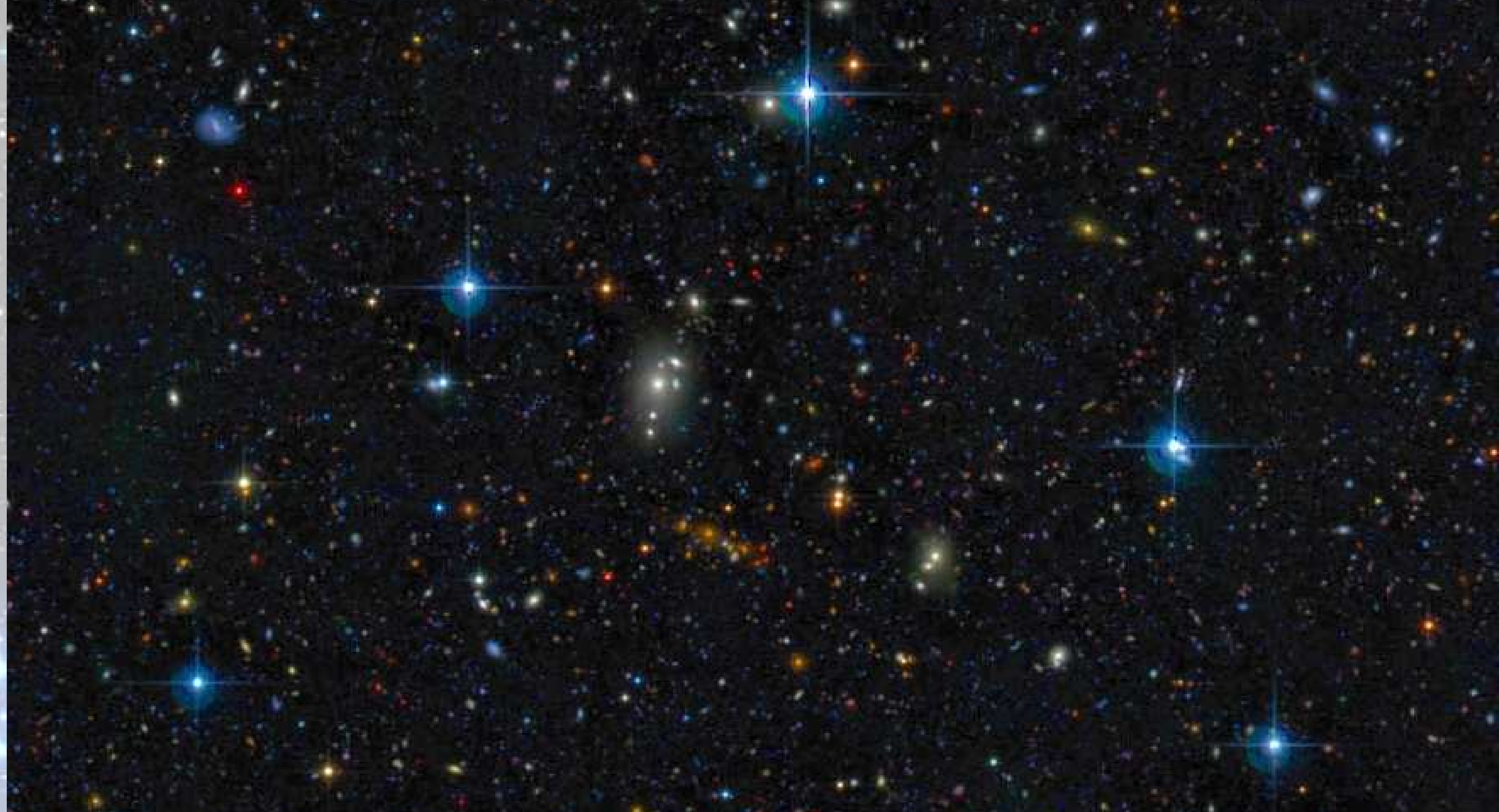
Canada−France−Hawaii Telescope Legacy Survey

History, strategy, and lessons learned

Jean−Charles Cuillandre (CFHT)

CFHTLS Steering Group CFHT representative (and current chairman)



AAS − ODI Session − Pasadena − June 2009

NATIONAL RESEARCH COUNCIL CANADA
CONSEIL NATIONAL DE RECHERCHES CANADA

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cea

CFH

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

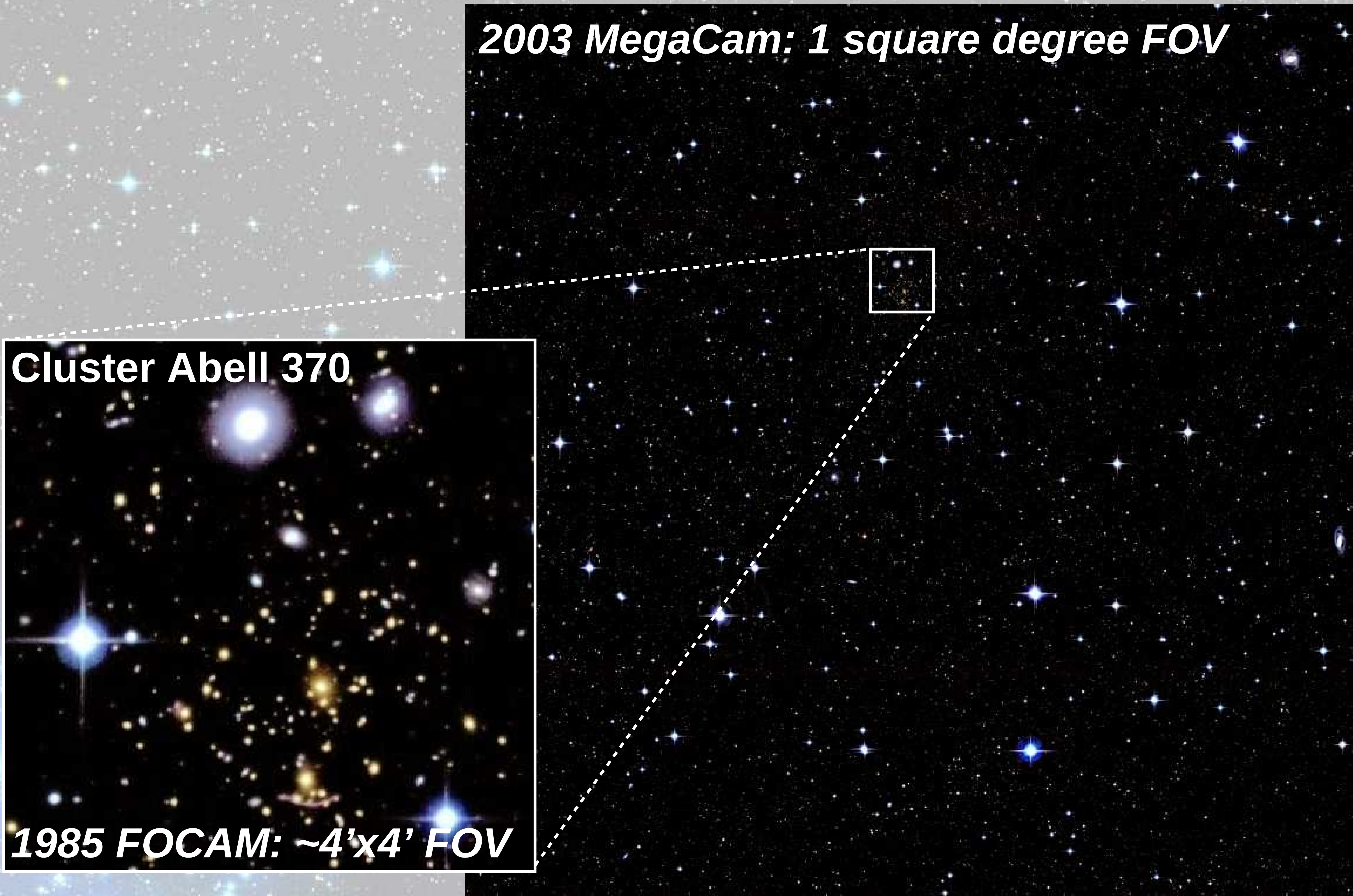
Rank	Facility	Citations	Participation
1	SDSS	1892	14.3%
2	Swift	1523	11.5%
3	HST	1078	8.2%
4	ESO	813	6.1%
5	Keck	572	4.3%
6	CFHT	521	3.9%
7	Spitzer	469	3.5%
8	Chandra	381	2.9%
9	Boomerang	376	2.8%
10	HESS	297	2.2%

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.

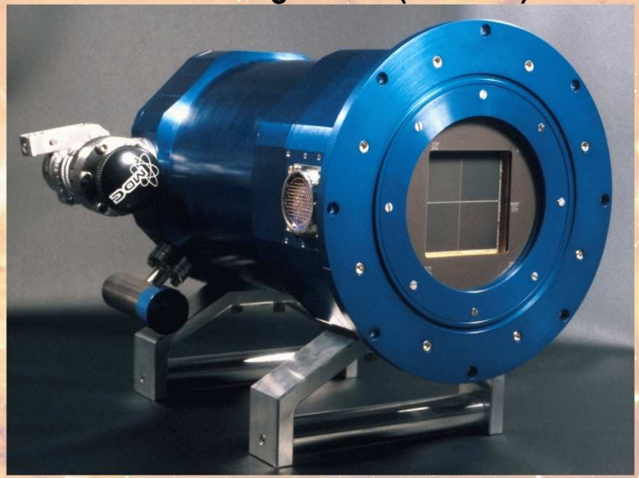
Gravitational lensing: a key science driver for CFHT

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

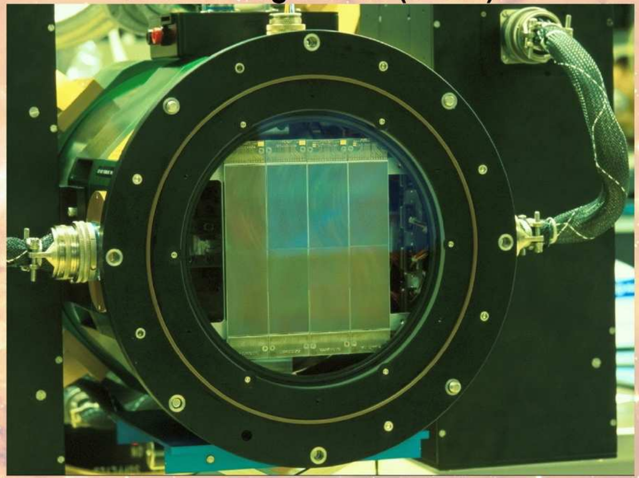


1983–2003: 2 decades to get CFHT full frame digital

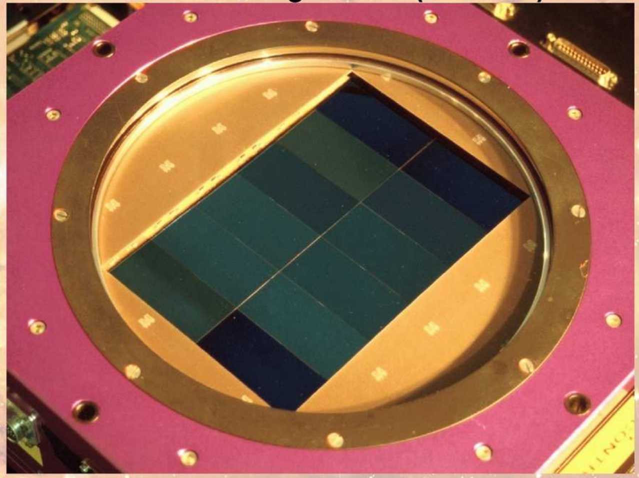
1994: 16 MegaPixels (MOCAM)



1995: 64 MegaPixels (UH8K)



1999: 100 MegaPixels (CFH12K)



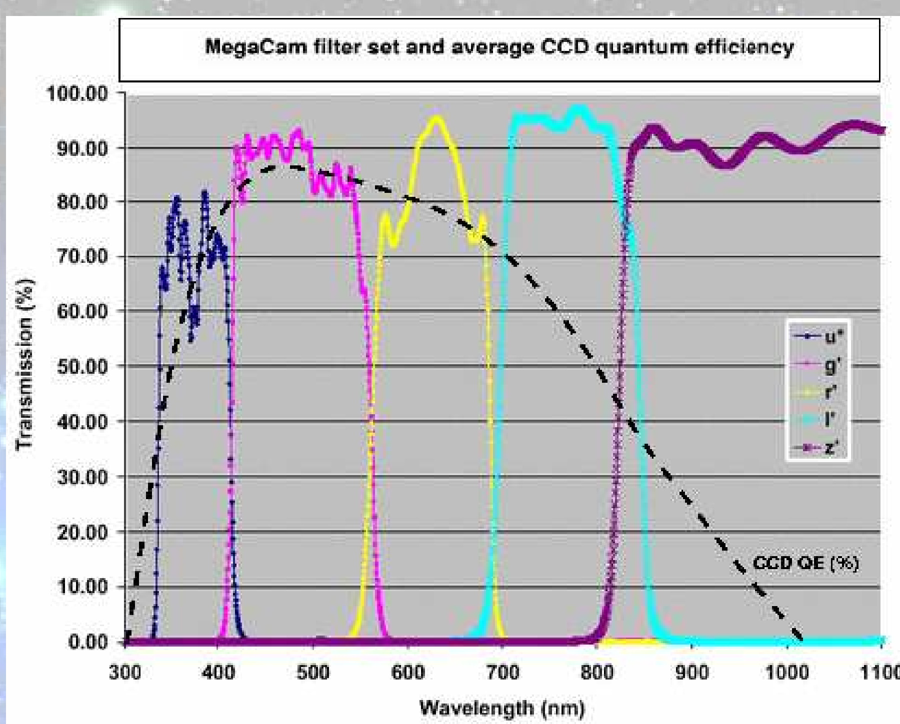
2003: 350 MegaPixels (MegaCam)

New Era in Wide Field Imaging: MegaPrime at CFHT

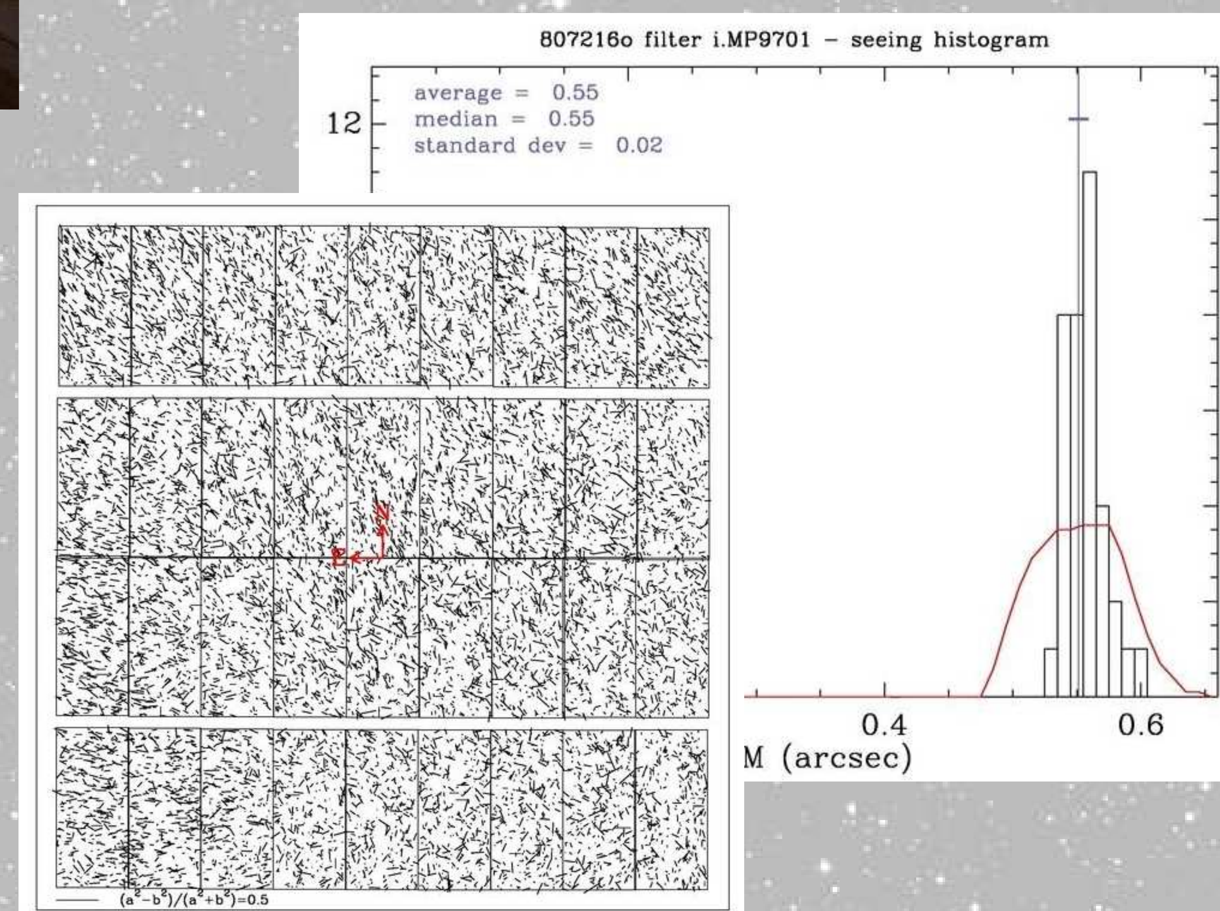
The instrument: MegaCam on CFHT atop Mauna Kea

MegaPrime on CFHT (3.6m mirror)

MegaCam by CEA : 340 megapixels CCD mosaic



Wavelength coverage: from u−band to z−band

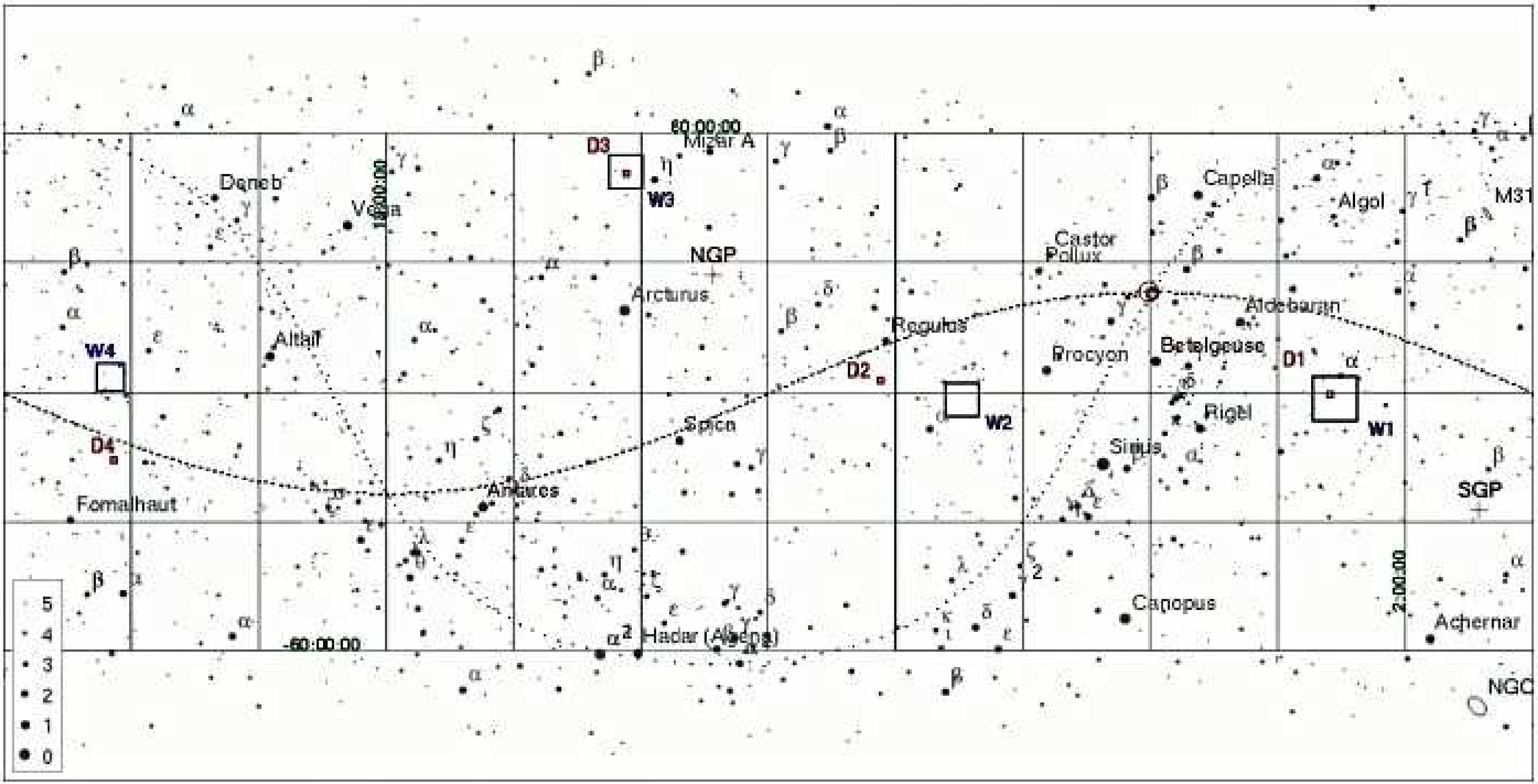


Excellent image quality (uniformity) over 1 sq. deg.

Origins and evolution of the CFHT Legacy Survey

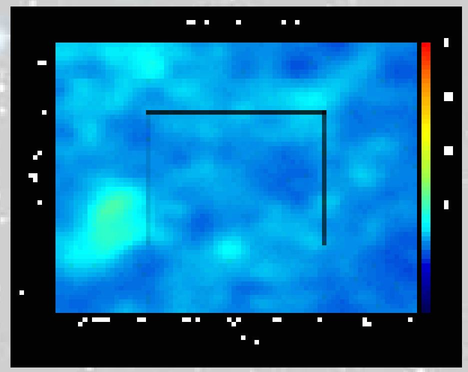
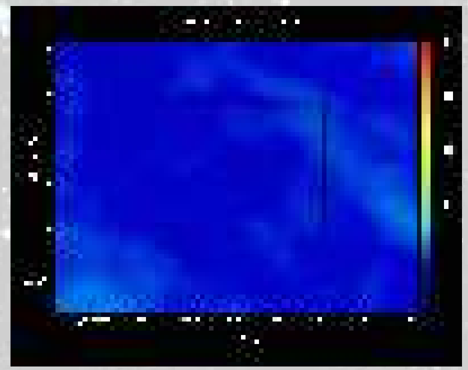
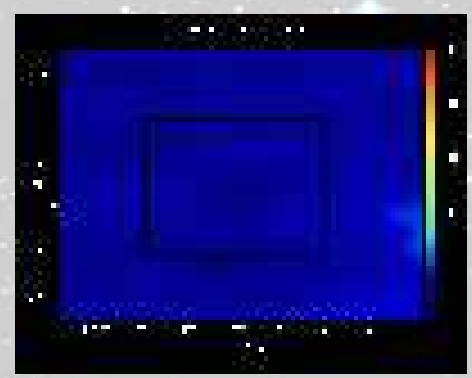
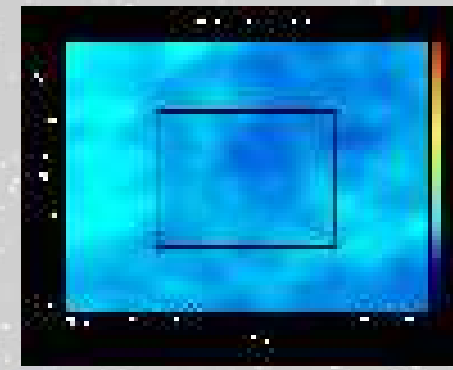
- *1998: CEA offered to build MegaCam and offer it to the entire CFHT scientific community on the condition a major general interest survey is undertaken with it.*
- *1999: CFH12K operational, and with MegaCam and the CFHTLS on the horizon (4 years), an evolution of the CFHT observing process is needed: 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

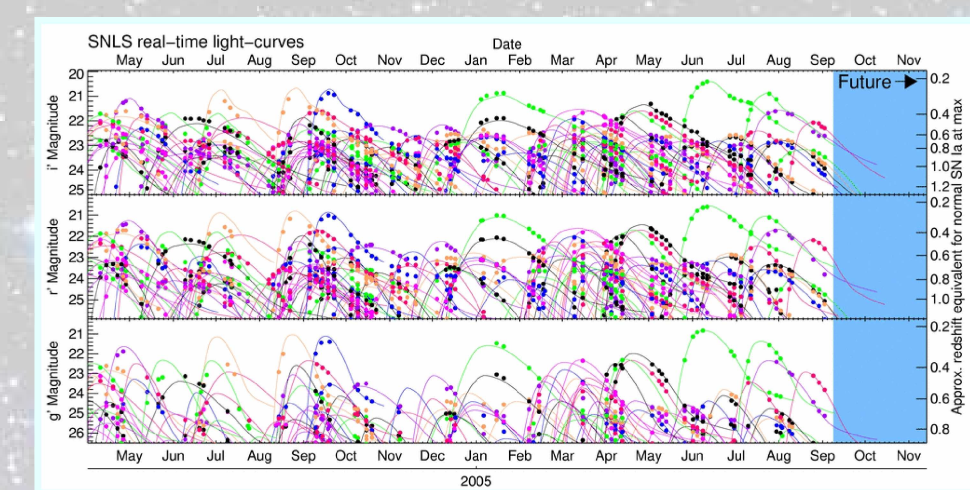


Survey	Area (sq. deg.)	Location	u*	g'	r'	i'	z'
Deep	4	D1/2/3/4	28.7	28.9	28.5	28.4	27.0
Wide	170	W1/2/3/4	26.4	26.6	25.9	25.5	24.8
Very Wide	410	On ecliptic		25.5	25.0	24.4	

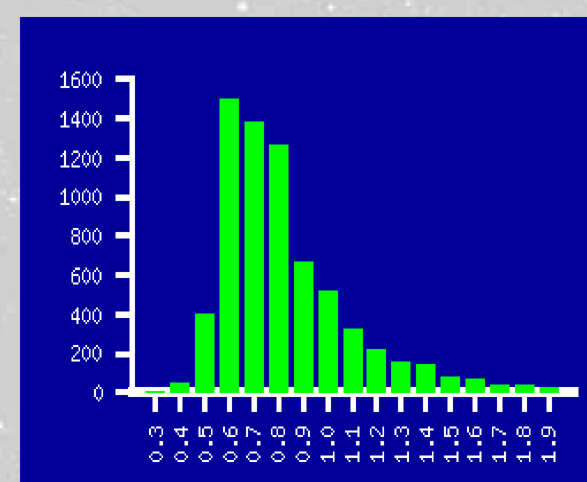
The Deep Survey – Completed integration

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"

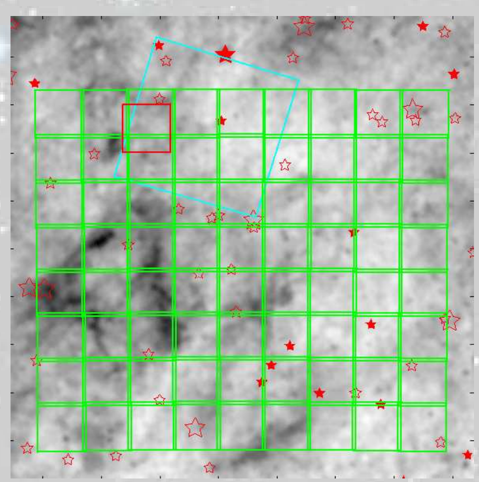
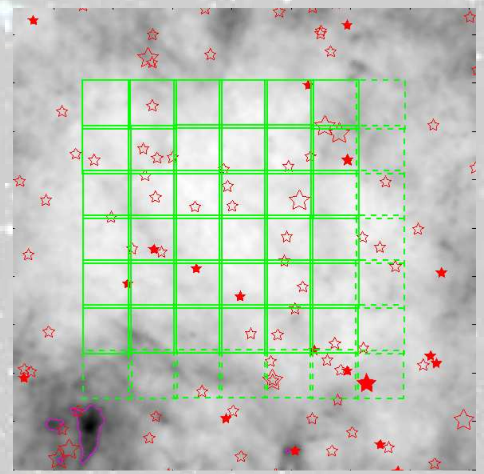
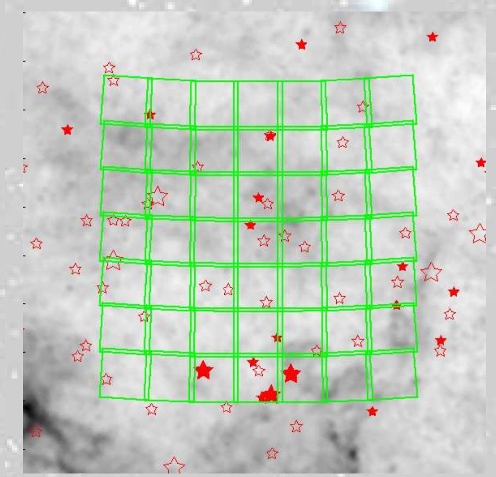
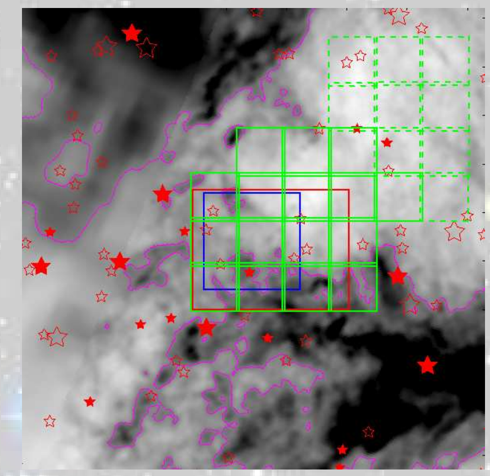


SNLS’ SNe Ia light curve tracking



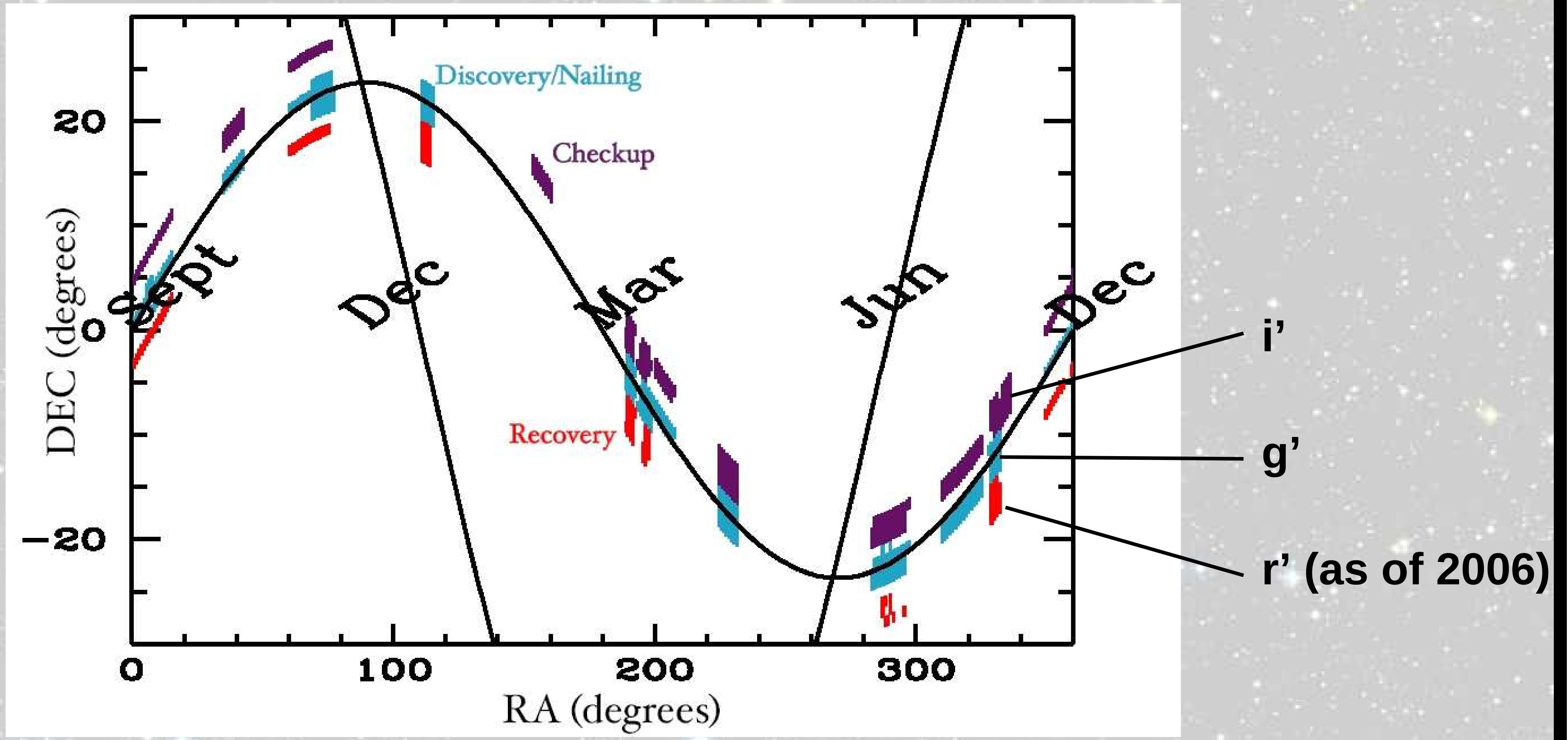
i’ FWHM

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

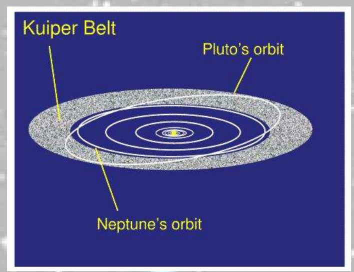


Filter	g'	r'	i'
Integration	47 hr.	75 hr.	70 hr.
Fraction	24%	40%	36%
Mean IQ	0.90"	0.80"	0.80"

Sky Coverage: 410 sq. deg. ...

Science with the CFHT Legacy Survey

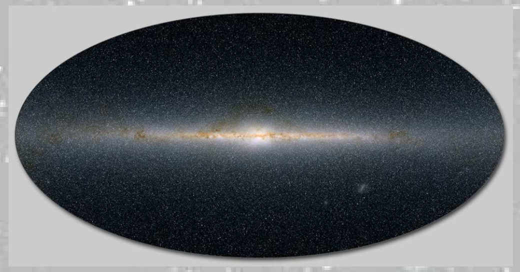
Solar System



Very Wide

- The Kuiper Belt
- Asteroids

The Galaxy



Very Wide / Wide / Deep

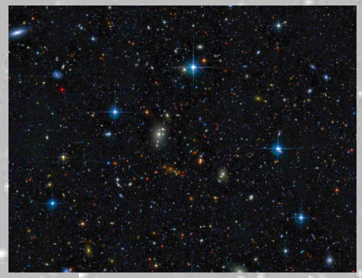
- Stellar Populations
- Brown Dwarfs
- Low Mass Stars
- White Dwarfs
- Dynamics
- Variability

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

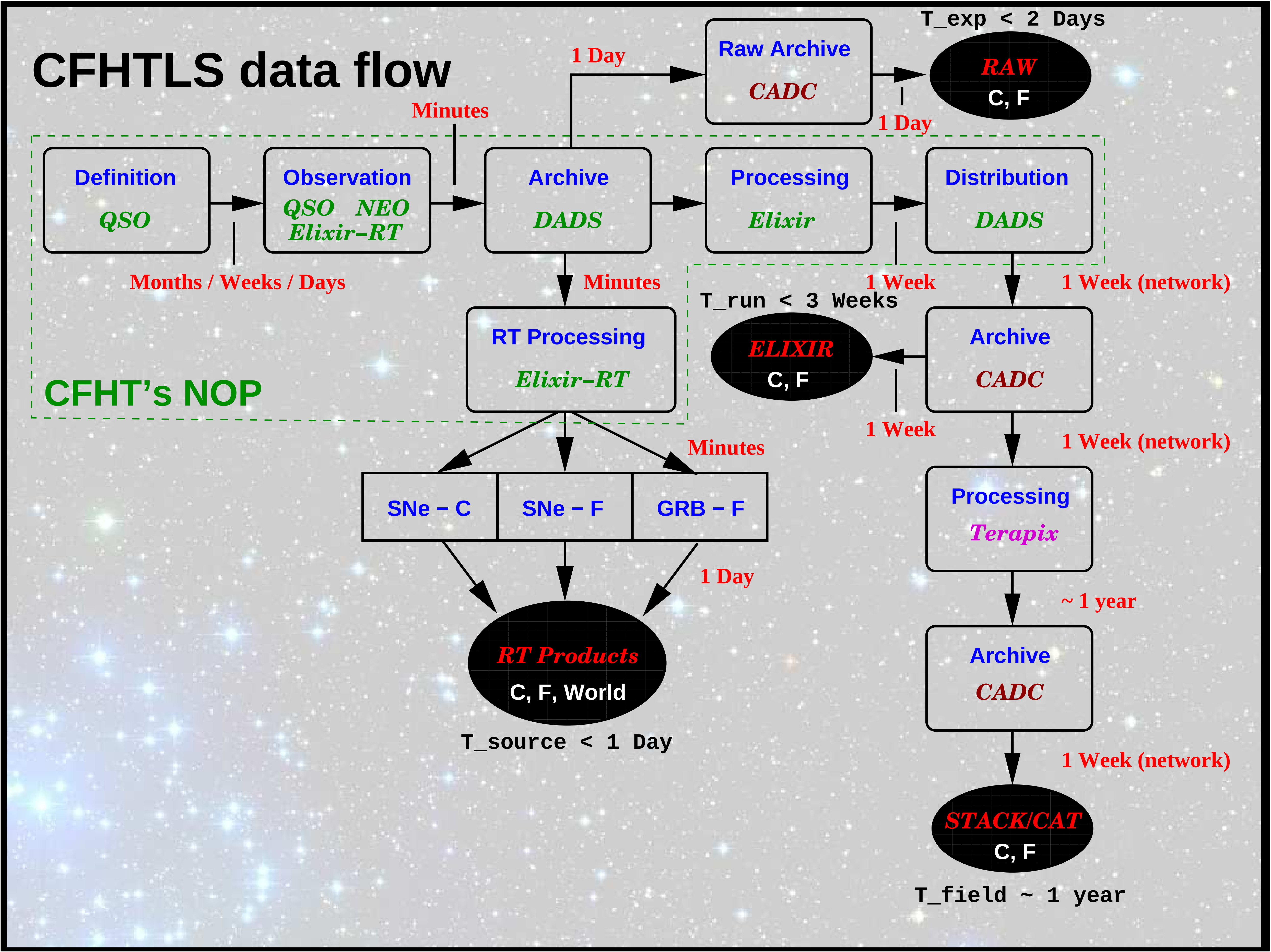
Yearly publication rate:

2005: 4

2006: 19

2007: 25

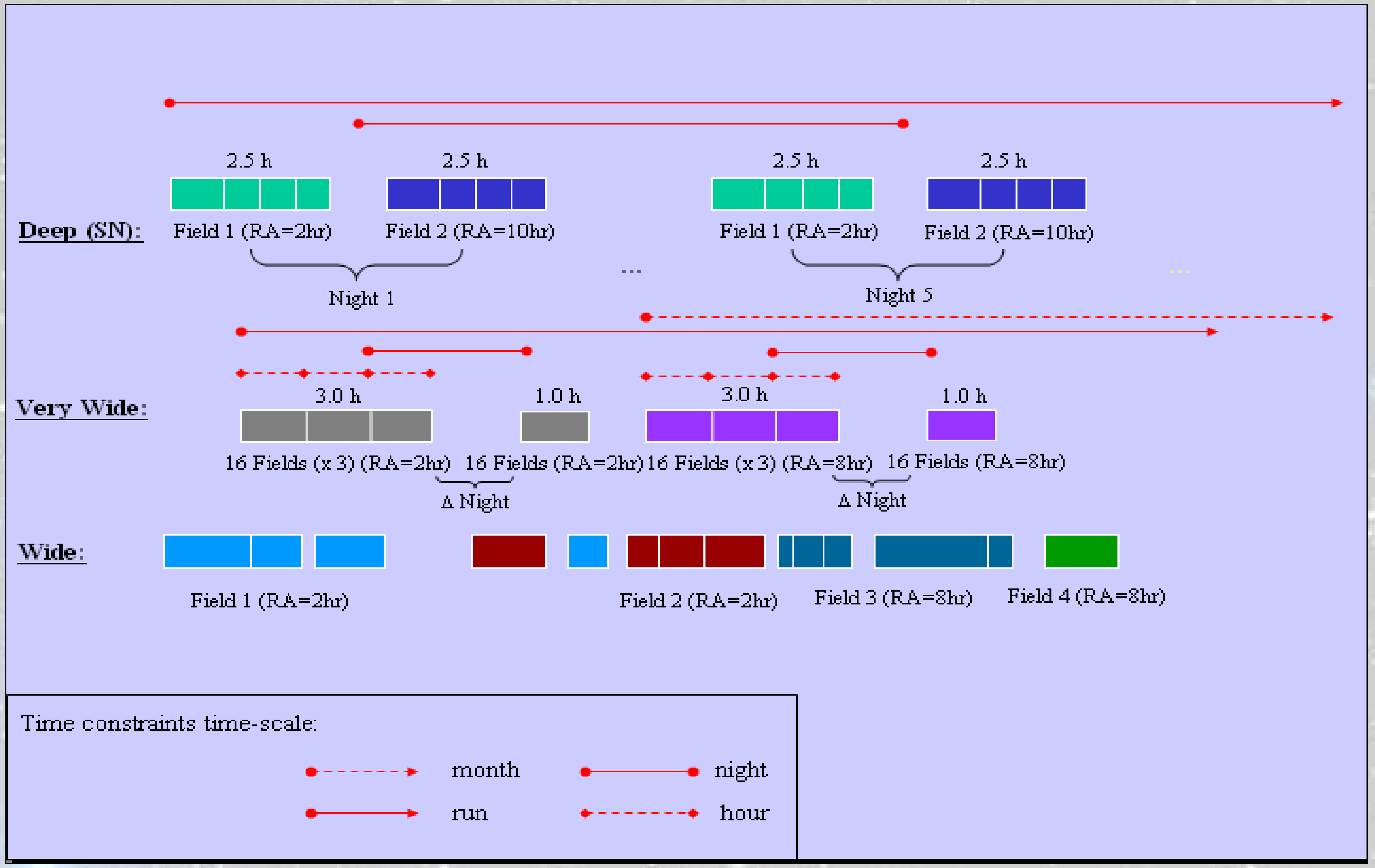
2008: 19



CFHTLS data flow
Definition
QSO
Observation
QSO NEO
Elixir–RT
Months / Weeks / Days
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)
T_run < 3 Weeks
RT Processing
Elixir–RT
ELIXIR
C, F
Archive
CADC
CFHT's NOP
1 Week
1 Week (network)
Minutes
SNe – C
SNe – F
GRB – F
Processing
Terapix
1 Day
~ 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 CFHTLS seen by Queued Service Observing

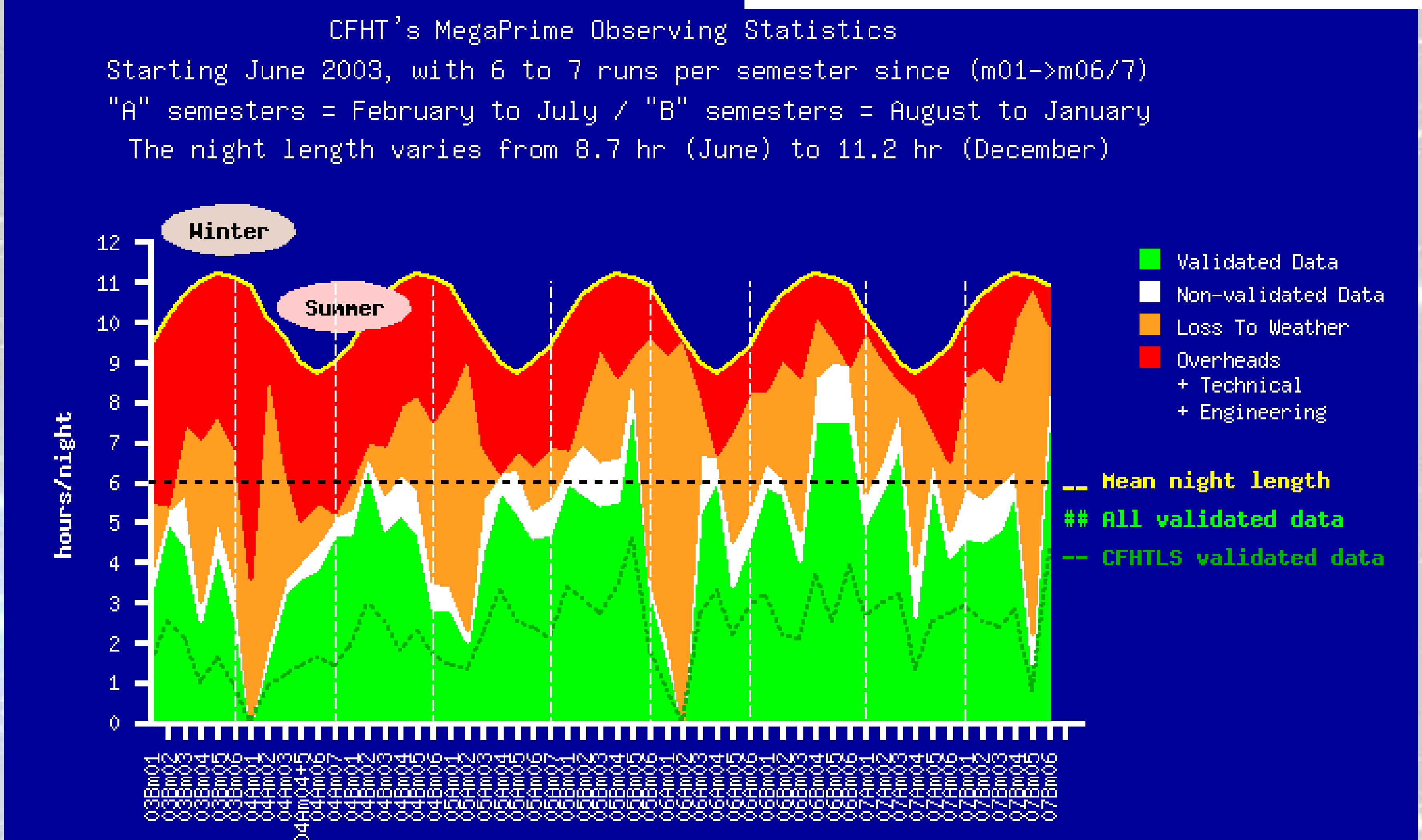
- √ ***Time critical observations on a large-scale***
  - ***SNe fields every 4 nights, 2 fields per run***
  - ***Each Very Wide patch has 5 time constraints***
- √ ***Balancing Agency Time***
  - ***PI programs (50%) versus CFHTLS (50% or "49" nights at best per semester)***
- √ ***Balancing time share 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

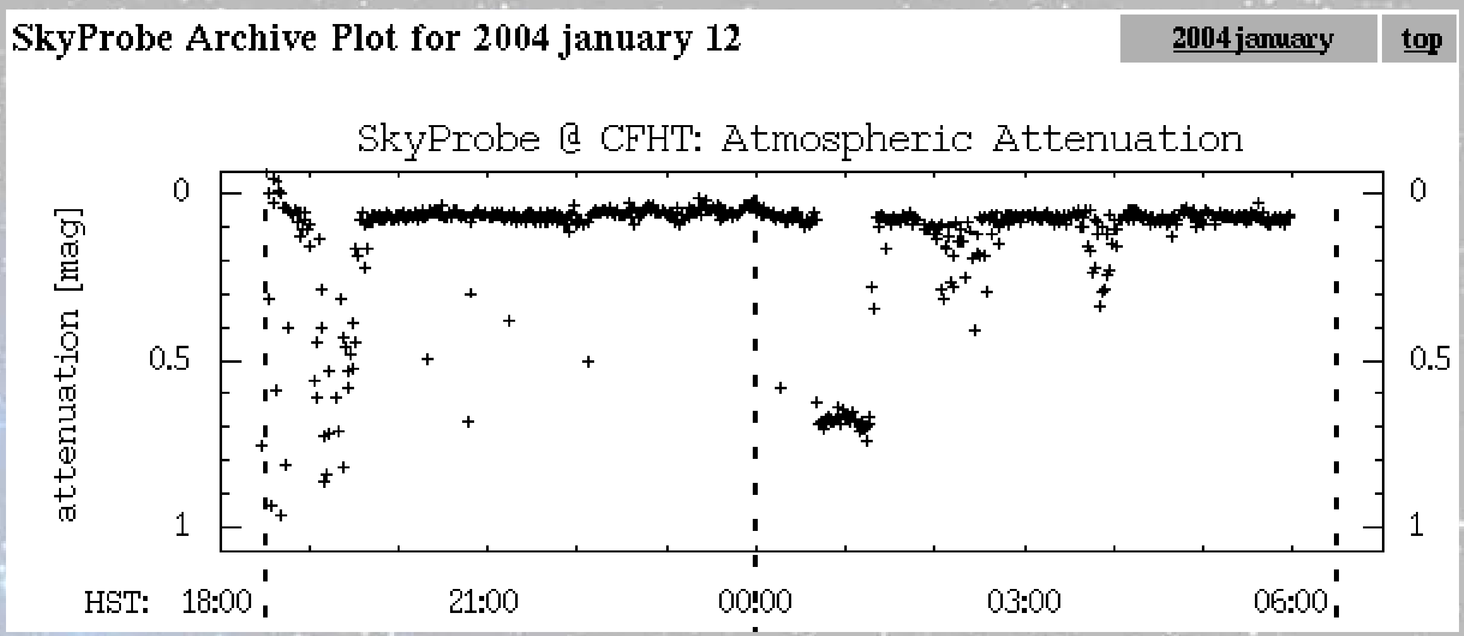
... plus a 6 months extension with top priority to get the core CFHTLS completed.

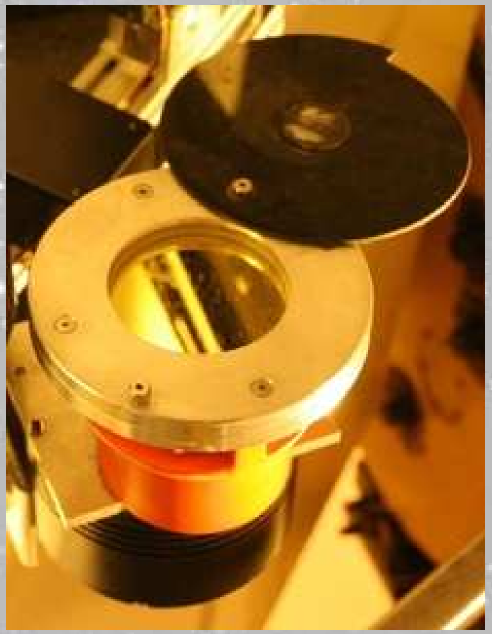
Flexibility = Salvation

Observing flexibility & Environment monitoring

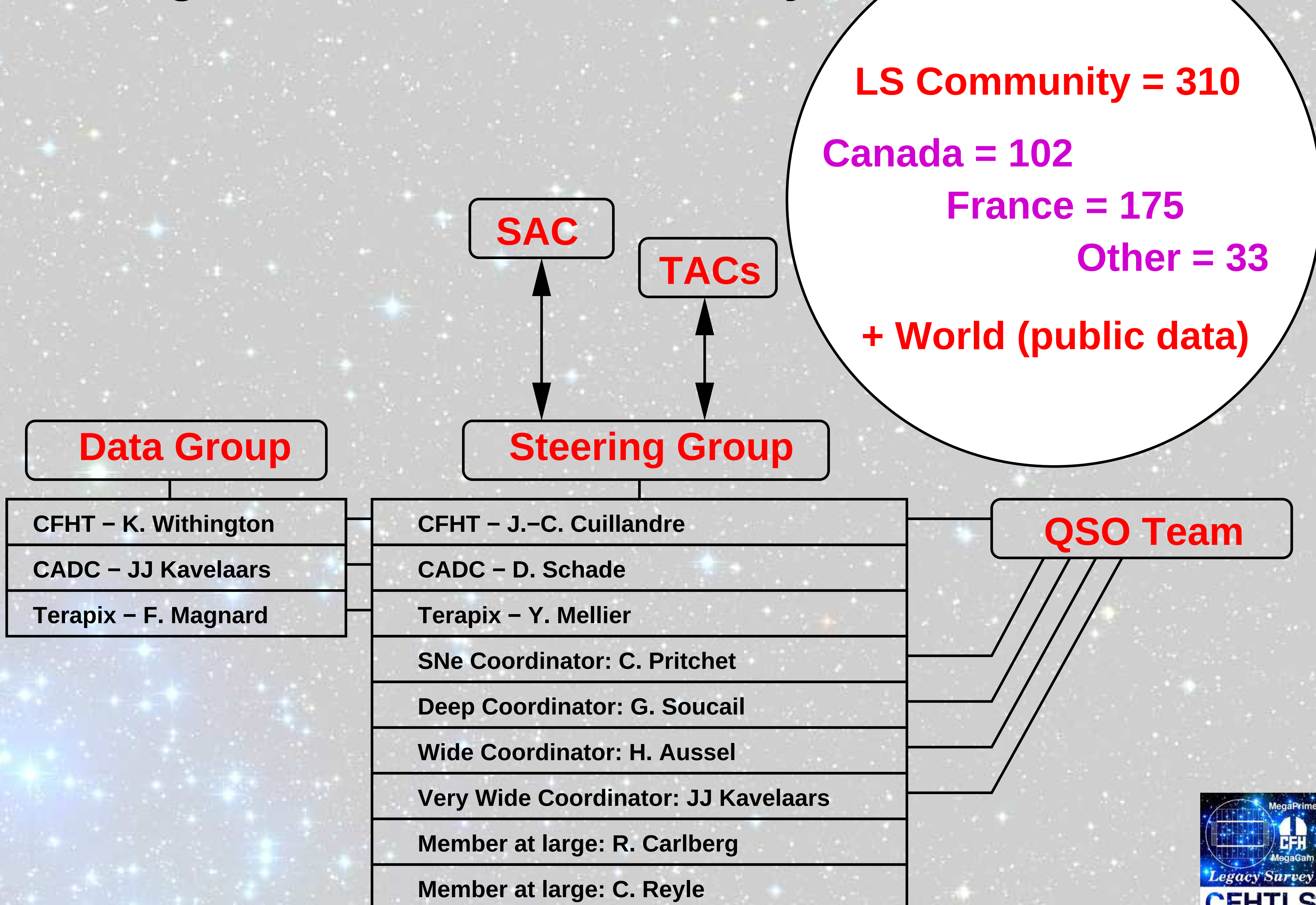
QSO's validation rate is high (80% for the entire CFHTLS − 26,000 exposures) because non adequate conditions are tracked down very quickly through real−time tracking of the key parameters for direct imaging:

- **Image quality** — **Elixir Real Time**
- **Sky background** — **Elixir Real Time**
- **Airmass** — **Telescope Control System**
- **Filter** — **Instrument control**
- **Sky transparency** — **SkyProbe (Elixir)**





Serving the CFHTLS Community



Keys to the success of the CFHT Legacy Survey

- *The survey was community driven, with key core science topics while tailored to provide a high quality data set for a broader usage, as well as legacy value.*
- *Not a blind allocation: though it came with its burdens, the constant oversighting process by various groups ensured the proper success of the project.*
- *Users first! Constant quality service to please the scientists: Observations (QSO), Processing (Elixir, Terapix), Distribution (DADS, CADC).*
- *Human factor: the CFHT QSO team was very flexible and motivated to make it work! There always was a "can do" attitude in a group of dedicated people.*
- *Stable staff: knowledge of the system and programs is key. Staff turnover at CFHT is very low, no change in the observing staff (4) over the 6 years of the survey.*
- *Focused science teams with funding over the whole survey (e.g. SNLS)*
- *Stable and steady data delivery. Interaction with the community on processing.*
- *Terapix and CADC: evolution upon users' needs. Plus followed the technical computing advances which move faster than today's cameras pixel count.*
- *We had two years before the survey started to tweak the tools and procedures.*
- *CFHTLS is not over: data collection is complete, but in depth calibration and global release to the world still pending (large fraction is already public)*
- *It worked so well, we are doing it again: Andromeda and Virgo surveys (2008−2012)*

Future of Wide−Field Imaging at CFHT: ‘IMAKA

‘IMAKA (scenic view in Hawaiian) − 2015

One square degree imager delivering 0.2" to 0.3" in the visible

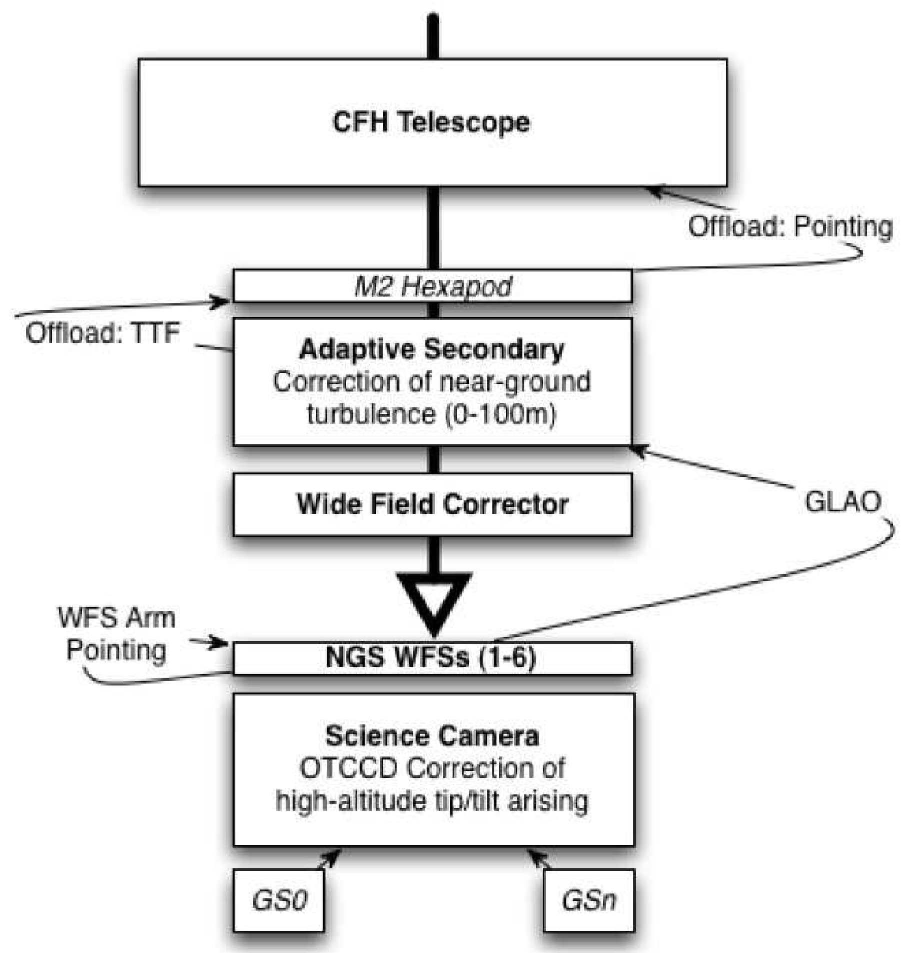


Figure 1: Block diagram of `IMAKA/CFHT. The key components of CFHT and `IMAKA are the telescope primary, adaptive secondary, wide field correcting optics, facility wavefront sensing unit, and science camera.