

**MegaPrime/MegaCam
and the
Canada-France-Hawaii Telescope
Legacy Survey**

ADASS 2003

**Christian Veillet
Canada-France-Hawaii Telescope**

The Canada-France-Hawaii Telescope Legacy Survey

ADASS 2005

**Christian Veillet
Canada-France-Hawaii Telescope**



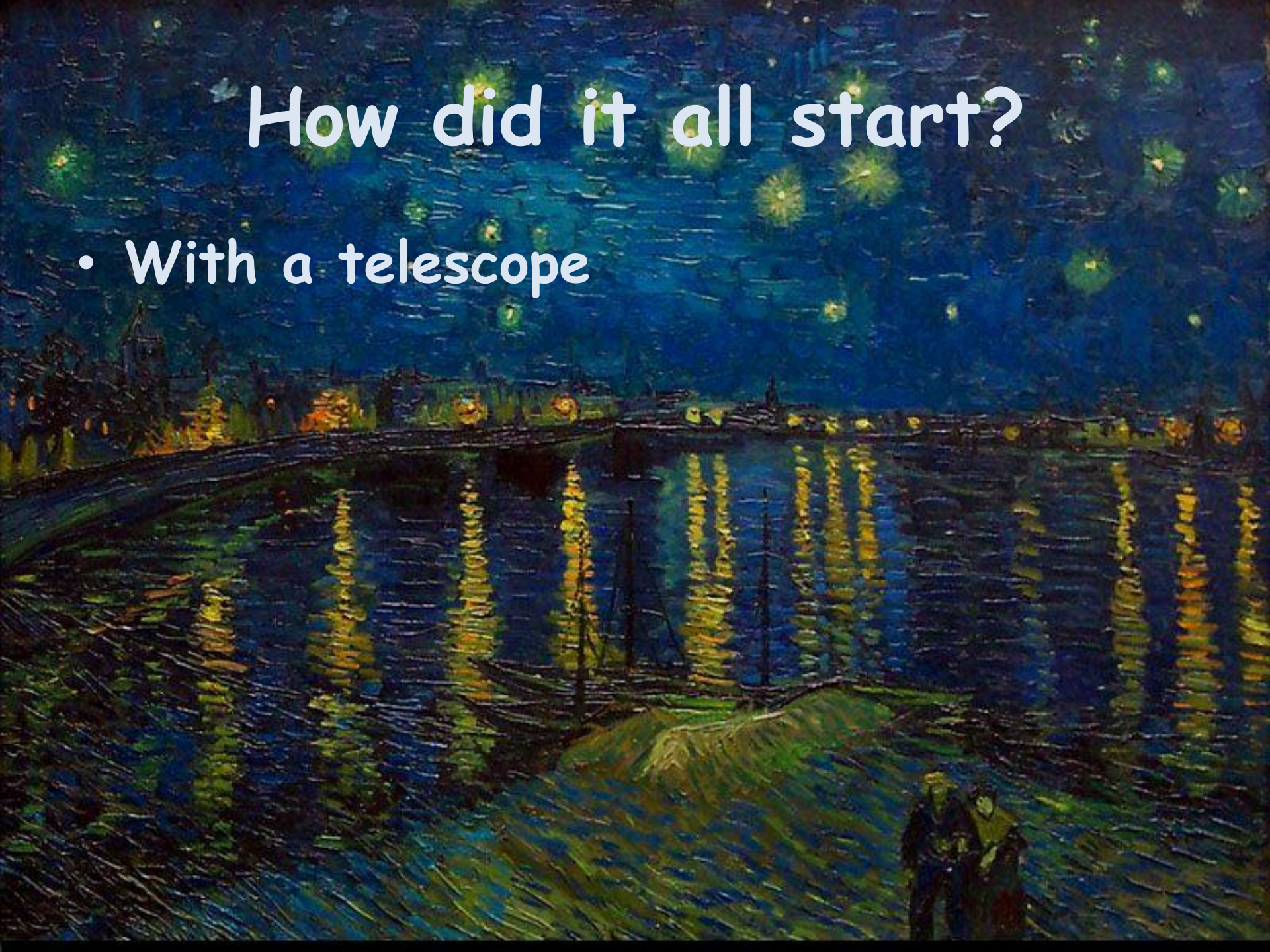
The Canada-France-Hawaii Telescope Legacy Survey: Done!

ADASS 2010

**Christian Veillet
Canada-France-Hawaii Telescope**

How did it all start?

- With a telescope



3.6m - 1st light in 1979



How did it all start?

- With a telescope
- With a new instrument: MegaCam (1997) and a new prime focus environment (MegaPrime)



**Mosaic – 36 (40) CCDs – 2k x 4.6k
1deg x 1deg – 0.18"/pixel – 340 Mpixels**

~ 707 MB

Readout time + overhead: 40s

Point source – 30mn – S/N=5 (mag AB)

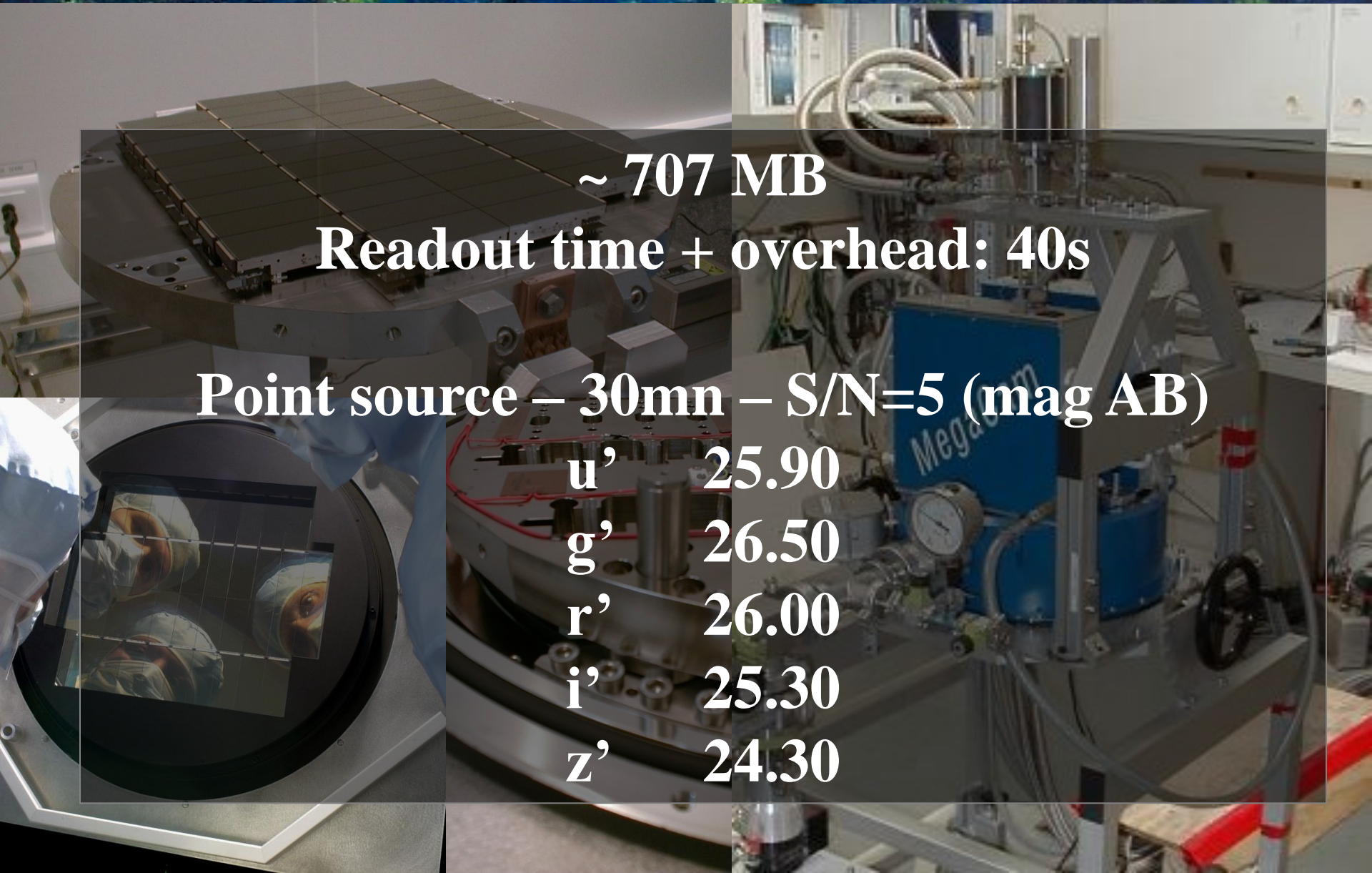
u' 25.90

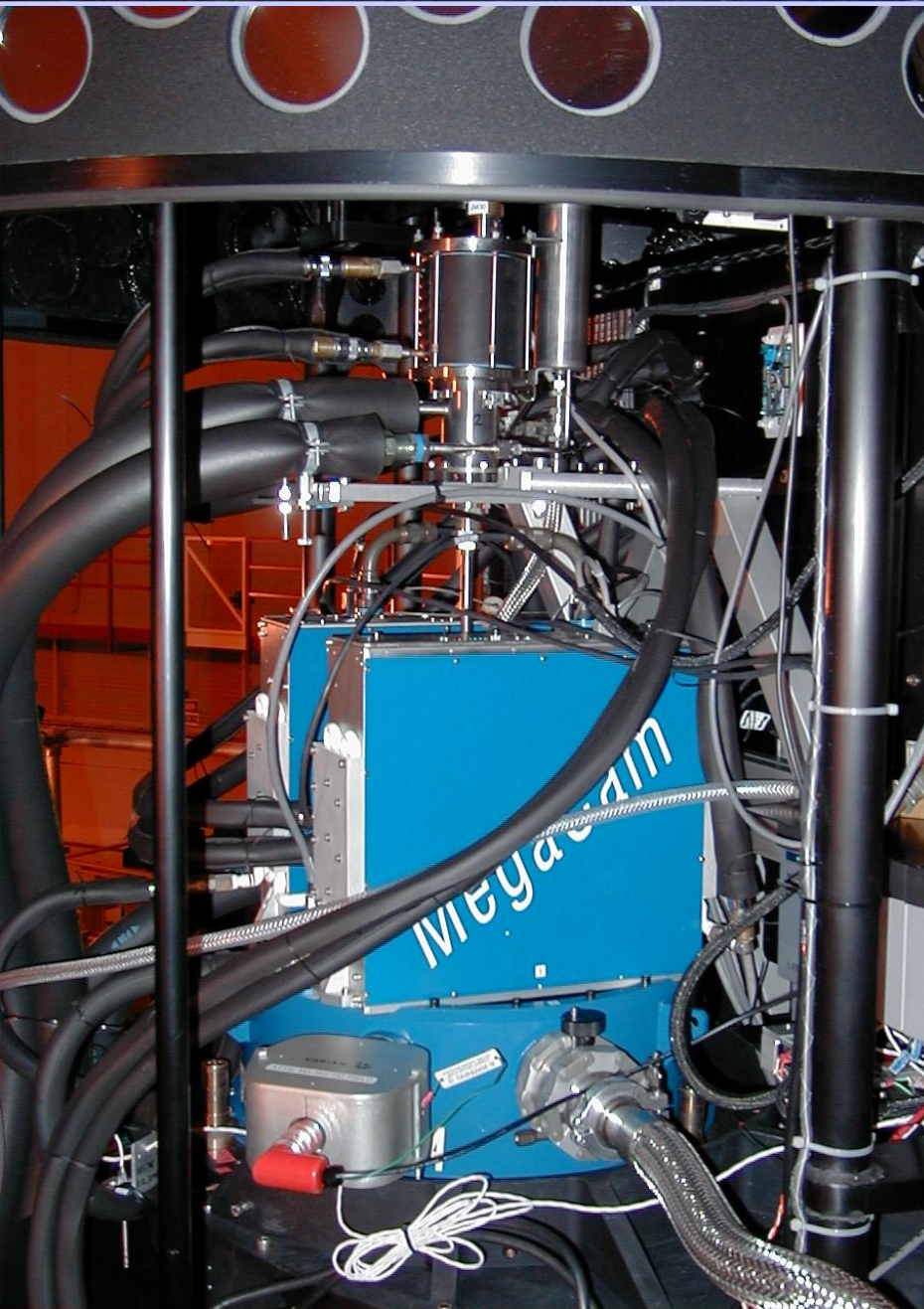
g' 26.50

r' 26.00

i' 25.30

z' 24.30







How did it all start?

- With a telescope
- With a proposed new instrument: MegaCam (1997) and a new prime focus environment (MegaPrime)
... and a string attached:

"MegaCam has to be used for a survey for at least 6 weeks a year"

CFHLS Working Group

- Started its work in 1999
- At first, community driven



Solar system

1. A Megacam ecliptic survey (JJ Kavelaars et al.)
2. Releve d'images au TCFH: proposition pour l'observation d'objets de la ceinture de Kuiper (P. Rousselot et al.)
3. A systematic search for asteroids inside or on the earth's orbit with megaprime (C. Veillet et al)
4. MegaWISP: A systematic search for moving objects in the MegaCam surveys (C. Veillet)

Star formation

1. A deep optical survey of the Taurus and Orion molecular clouds (C. Dougados et al)
2. Mass loss in star forming regions: A complete census of jets and outflows around young stars (F. Menard et al.)

Galactic structure

1. Fonctions de luminosite stellaire, cinematique et histoire de la formation galactique (O. Bienayme)
2. Environmental effects on galactic and extragalactic stellar clusters (G. Bergond et al.)
3. Shallow multi-color survey of fields surrounding all intermediate and high-latitude globular clusters (S. VanDenBergh)
4. A megaprime survey for structure in the halo of the galaxy (G.G. Fahlman)
5. Probing the deep halo (M. De Robertis)
6. Brown dwarf (BDs) and very low mass star (VLMS) (T. Forveille)
7. Brown dwarf luminosity functions in the solar neighbourhood and 2 nearby open clusters and The halo dark matter and the luminosity function of stars at the bottom of the halo and thick disk main sequences (M. Haywood)
8. Recherche de candidats a la matiere noire baryonique dans le halo (A. Robin)

Cosmology (SNe)

1. Detailed study of type Ia supernovae at $z = 0.4-0.8$ (R. Pain et al.)
2. MegaCam observations of high redshift supernovae (C. Pritchert)
3. Very distant lensed SNIa which will allow new constraints to be placed on cosmological models (R. Carlberg)
4. Wolf-Rayet stars in nearby galaxies: Search for pre-supernovae (A. Moffat et al.)

Extra-Galactic

1. Probing the formation of galaxies with extragalactic globular clusters systems (D. Burgarella)
2. The Virgo cluster as a laboratory for galaxy evolution studies (P. Martin et al.)
3. Deep wide-field survey of the Virgo cluster (R. Wainscoat)
4. MegaCam observations of globular clusters in the core of the Virgo cluster (M. West)
5. Wide-field, multi-color (UBVRI) imaging survey of the Coma cluster of galaxies to a limiting magnitude $R \sim 25$ (M. West, A. Mazure)
6. Testing weak-field gravity (M. McCall)
7. Low surface brightness galaxies (A. Bosma et al.)
8. Structure of disk galaxies (A. Bosma et al.)
9. Searching for primeval galaxies at $z \sim 2.5$ and 5 (M. De Robertis)

Large Scale Structures

1. An optical imaging programme for the XMM serendipitous x-ray sky survey (P. Guillot et al.)
2. Megacam survey of clusters of galaxies: a detailed study of cluster history (A. Blanchard et al.)
3. Proposal for a combined MEGACAM/XMM/VIRMOS large scale structure survey (M. Pierre et al)
4. A MegaPrime survey: Mapping the large scale structures and the evolution of galaxies on 100 deg² (O. LeFevre)
5. A MegaPrime ultra deep survey (O. LeFevre)
6. Proposal for a join MEGACAM/XMM/VIRMOS/ARCHEOPS survey on weak lensing (Y. Mellier et al.)
7. A cluster survey in weak lensing (J.G. Bartlett)
8. A deep, wide-field weak lensing survey with Megacam (N. Kaiser et al.)

Large Scope Survey (near IR)

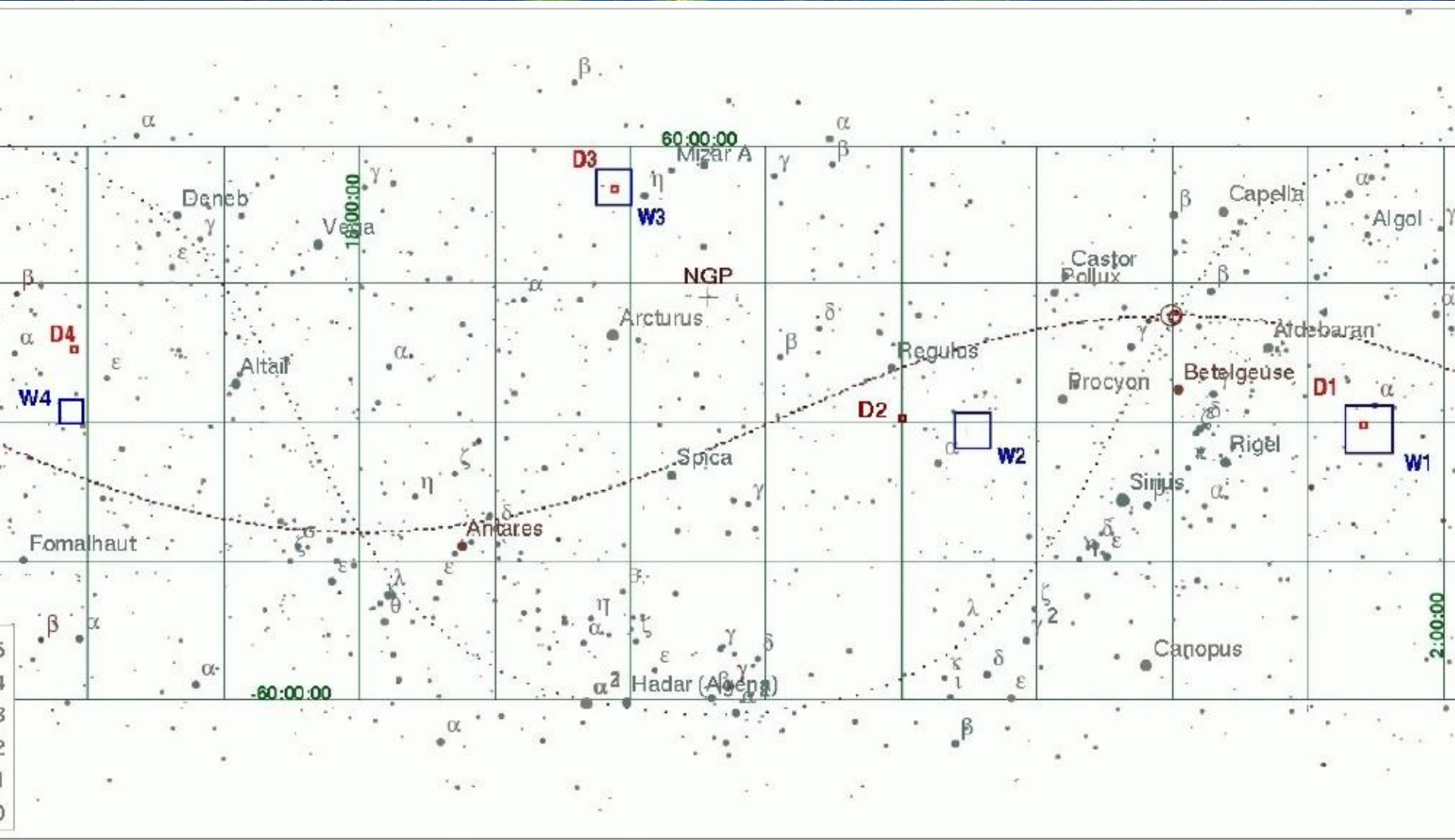
1. A survey with 1um with Megacam (J.G. Cuby)

CFHLS Working Group

- Started its work in 1999
- At first, community driven
- Choices had to be made...
 - Identify key goals
 - Be reasonable!
 - Only C and F ☹ ...

CFHT Legacy Survey

- A joint Canadian and French endeavor
- ~ 500 nights over 5 years
- Three main scientific goals
 - Study of the Kuiper Belt
 - Large scale structures and dark matter (*weak lensing and galaxy distribution*)
 - Equation of state of dark energy (*type Ia SNe*) SNLS (SuperNova LS)
- Strategy is optimized for these goals BUT takes into account other applications



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CFHTLS basic principles

- No PIs... C and F communities own the data, with equal access to all in C & F
- The CFHTLS Steering Group tends to the execution of the survey
- Each component has a coordinator within the Steering Group

Some difficulties...

- Other instruments offered on the telescope (and in high demand)
- MegaCam shared between the CFHTLS and PI programs (with much pressure from PIs!)
- Weather too good in the early 2000s
- Survey to start as soon as MegaCam is available on the sky...
 - IQ issues ☹️
 - One filter lost/replaced

... but not starting from scratch!

- Much experience at CFHT in QSO (queued service observing) with CFH12K
 - Observing
 - In-house data processing
- Good and efficient archiving scheme (CADDC)
- Much experience in data processing at IAP (TERAPIX)
- An eager community 😊

Where are we today?

- Last observations done in early 2009
- Final public release in a couple of weeks
- Already many data available!





The Canadian Astronomy Data Centre

[Register](#)

If you have used CADC facilities for your research, please include the following acknowledgment:

This research used the facilities of the Canadian Astronomy Data Centre

operated by the National Research Council of Canada with the support of the Canadian Space Agency.

[Contact](#)

Target:

All Archives ▾

Search

[Advanced Search](#)



The CFHT Science Data Archive

▼ PI Tools

>Archive

>CFHTLS

>Environment

>Help

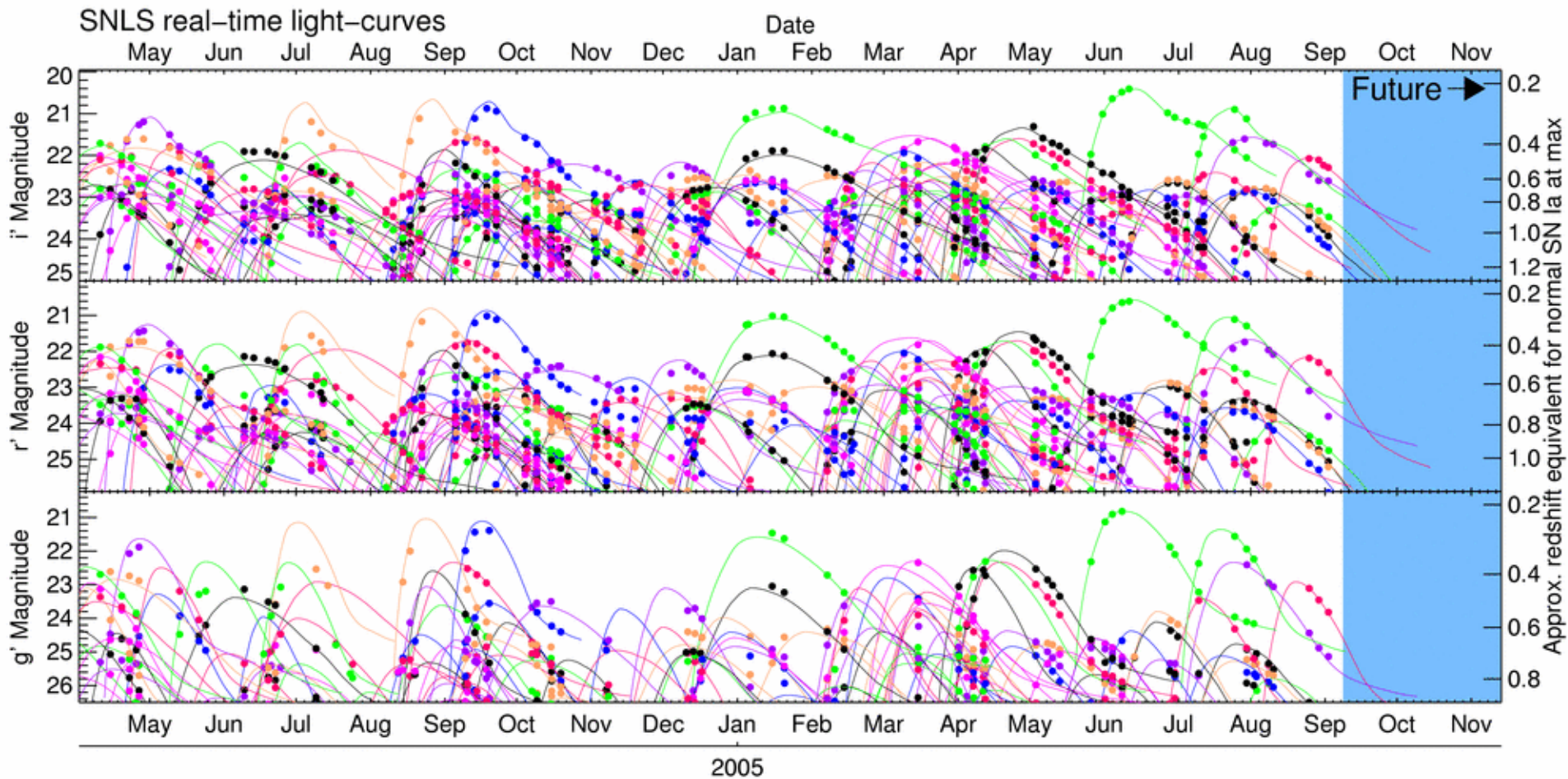
CFHTLS TeraPix T0005 Release

W1	02:18:00	-07:00:00	9×8	8.5×7.5	$u^*, g, r, i/y, z$
W2	08:57:49	-03:19:00	5×5	4.8×4.7	$u^*, g, r, i/y, z$
W3	14:17:54	+54:30:31	7×7	6.7×6.6	$u^*, g, r, i/y, z$
W4	22:13:18	+01:19:00	25	23.3	$u^*, g, r, i/y, z$

Filter	Mean number of exposures	Mean exposure time [s]	Mean limiting magnitude [MegaCam AB system]	Mean seeing ["]
u^*	5	3000	25.34	0.850
g	5	2500	25.47	0.780
r	4	2000	24.82	0.720
i/y	7	4300	24.48	0.640
z	6	3600	23.60	0.680

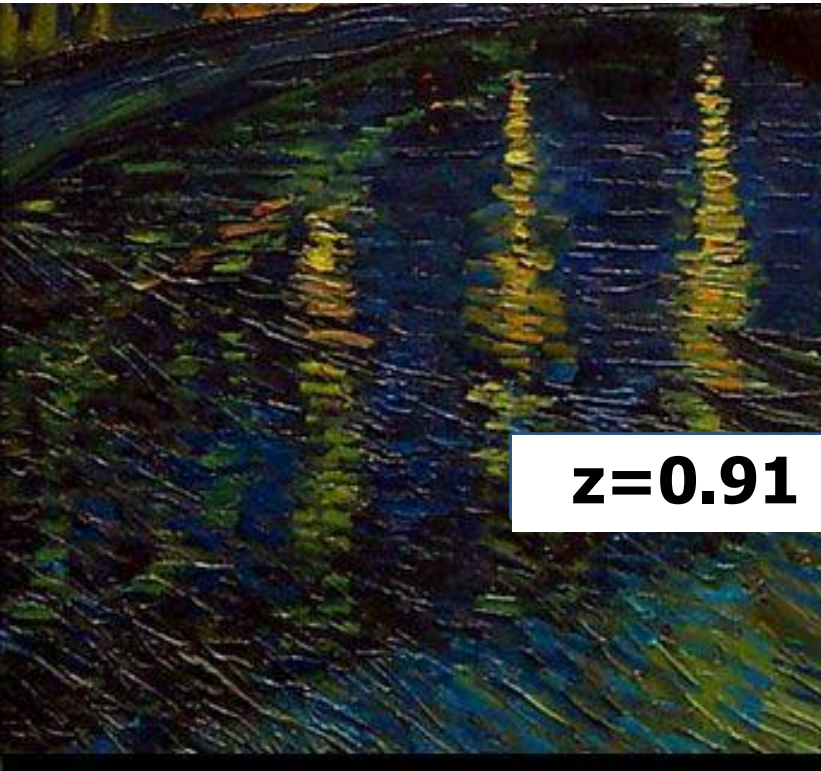
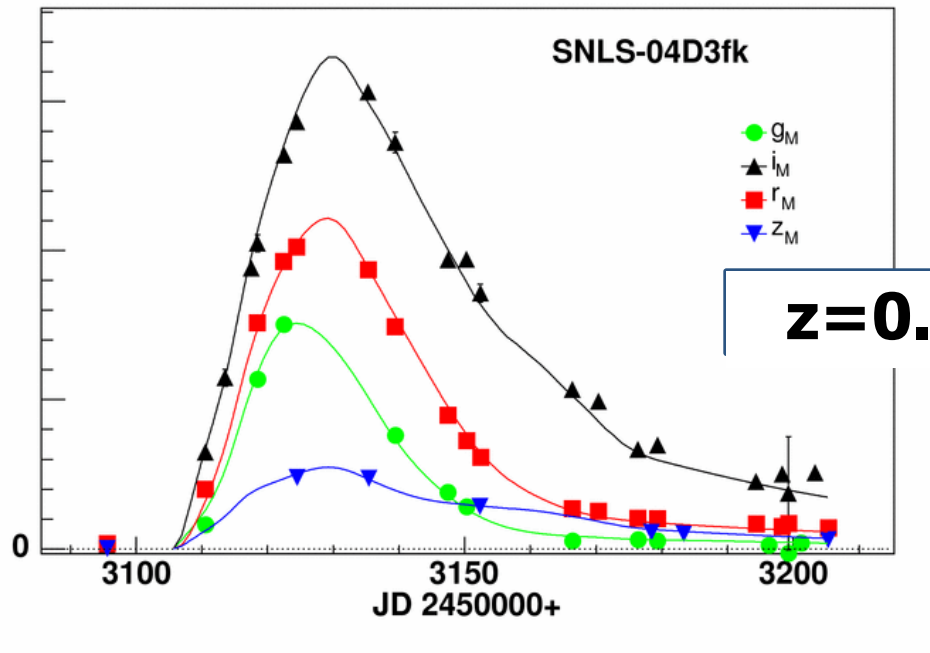
Field	Parameter	u^*	g	r	i	y	z
D1-25	Nb images	34	115	159	164	69	162
	Exp. time [s]	22443	27233	50411	79052	27724	58331
	Seeing ["]	0.74	0.68	0.64	0.63	0.58	0.58
	80% Compl. (stellar)	26.22 ±0.10	25.94 ±0.10	25.40 ±0.10	25.10 ±0.10	25.00 ±0.10	24.59 ±0.10
	80% Compl. (extended)	25.52 ±0.10	25.29 ±0.10	24.68 ±0.10	24.32 ±0.10	24.28 ±0.10	23.83 ±0.10
	Int. astrom. err.	(0.010",0.009")	(0.011",0.010")	(0.010",0.008")	(0.013",0.010")	(0.012",0.011")	(0.010",0.008")
	Ext. astrom. err.	(0.25",0.22")	(0.26",0.24")	(0.26",0.24")	(0.25",0.24")	(0.27",0.25")	(0.26",0.24")
	Mag. int. err. [mag.]	0.03	0.02	0.02	0.02	0.02	0.03
25% best seeing	u^*	g	r	i	z		
80% Comp. (stellar)	26.1	26.0	25.4	25.0	24.5		
Seeing (")	0.75	0.69	0.64	0.61	0.58		
Int. astrom. err.	(0.009",0.009")	(0.009",0.009")	(0.010",0.009")	(0.009",0.010")	(0.009",0.010")	(0.009",0.010")	(0.009",0.010")
Ext. astrom. err.	(0.21",0.21")	(0.23",0.22")	(0.22",0.23")	(0.21",0.22")	(0.23",0.23")	(0.21",0.22")	
Mag. int. err. [mag.]	0.03	0.02	0.02	0.02	0.02	0.03	
CFHTLS-SDSS $\langle \delta_m \rangle$ [mag.]	+0.059	+0.024	+0.017	+0.026	+0.020	+0.022	
85% best seeing	u^*	g	r	i	z		
80% Comp. (stellar)	26.1	26.1	25.5	25.3	24.9		
Seeing (")	0.88	0.82	0.75	0.70	0.68		
Int. astrom. err.	(0.008",0.007")	(0.037",0.029")	(0.032",0.027")	(0.034",0.026")	(0.028",0.024")	(0.052",0.045")	
Ext. astrom. err.	(0.24",0.24")	(0.25",0.25")	(0.25",0.25")	(0.25",0.25")	(0.27",0.26")	(0.25",0.25")	
Mag. int. err. [mag.]	0.03	0.02	0.02	0.02	0.02	0.04	
CFHTLS-SDSS $\langle \delta_m \rangle$ [mag.]	+0.049	+0.020	+0.016	+0.023	+0.018	+0.006	
D4-25	Nb images	35	114	140	157	49	168
	Exp. time [s]	23103	27862	46448	73330	19883	60490
	Seeing ["]	0.77	0.71	0.61	0.58	0.60	0.57
	80% Compl. (stellar)	25.99 ±0.10	25.92 ±0.10	25.41 ±0.10	25.11 ±0.10	24.98 ±0.10	24.55 ±0.10
	80% Compl. (extended)	25.37 ±0.10	25.26 ±0.10	24.65 ±0.10	24.31 ±0.10	24.22 ±0.10	23.76 ±0.10
	Int. astrom. err.	(0.046",0.039")	(0.087",0.075")	(0.069",0.070")	(0.083",0.056")	(0.083",0.056")	(0.068",0.068")
	Ext. astrom. err.	(0.22",0.21")	(0.23",0.22")	(0.23",0.22")	(0.22",0.21")	(0.24",0.22")	(0.22",0.21")
	Mag. int. err. [mag.]	0.04	0.02	0.02	0.02	0.02	0.03

SNLS - Rolling search

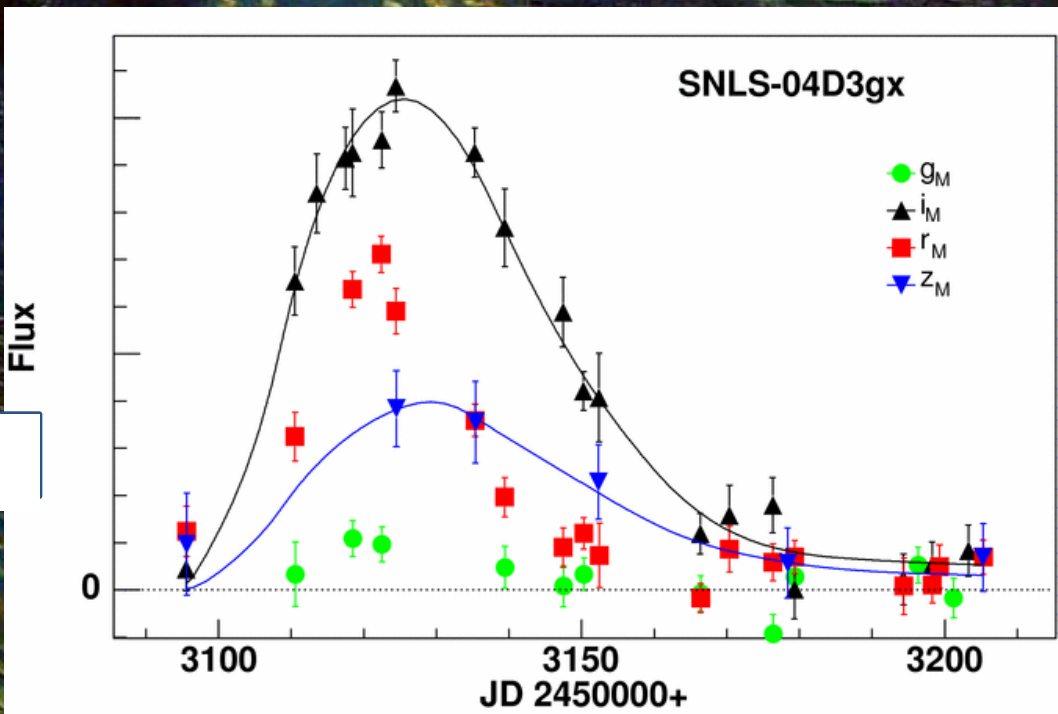


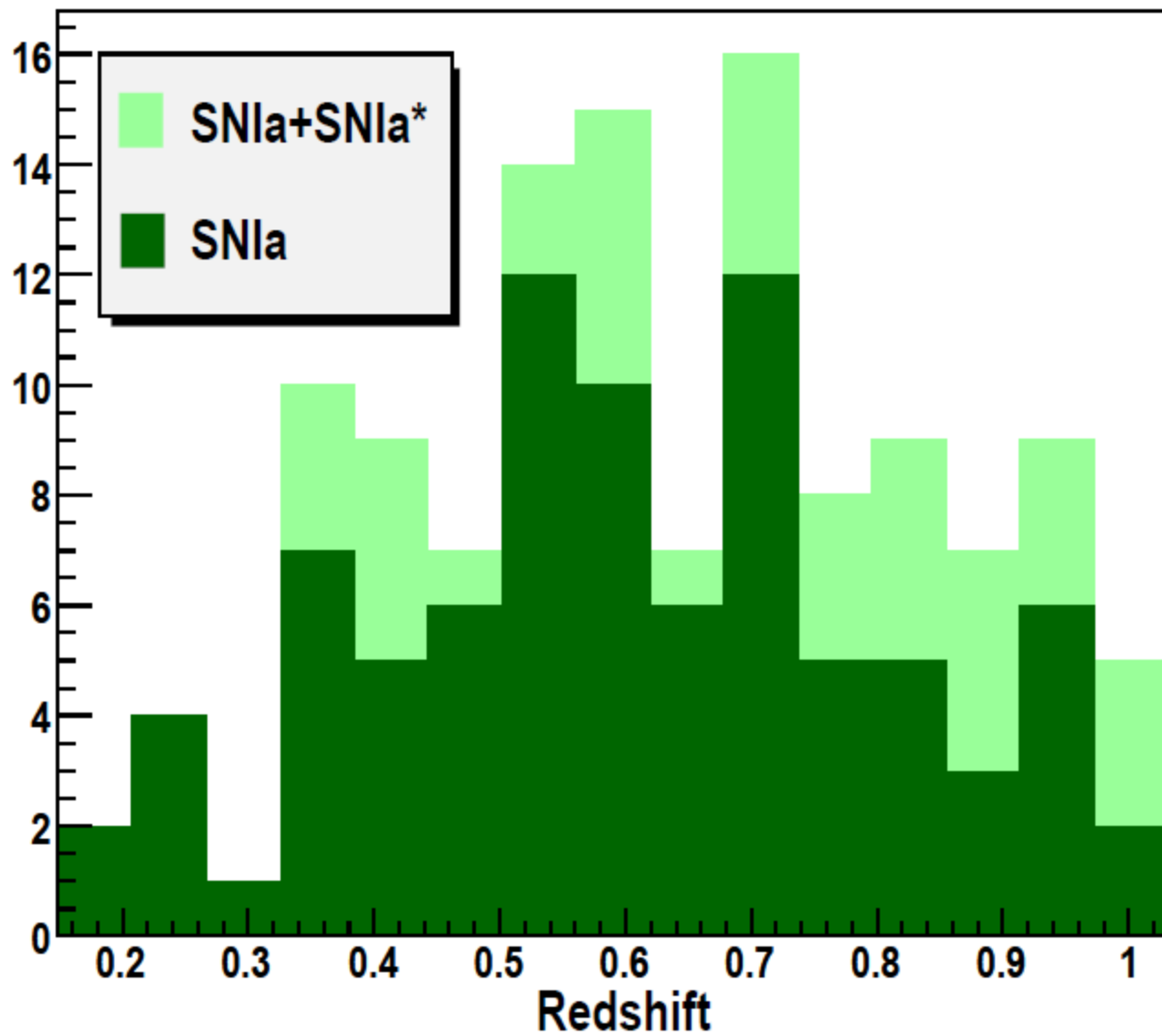
(this shows real-time Elixir photometry only)

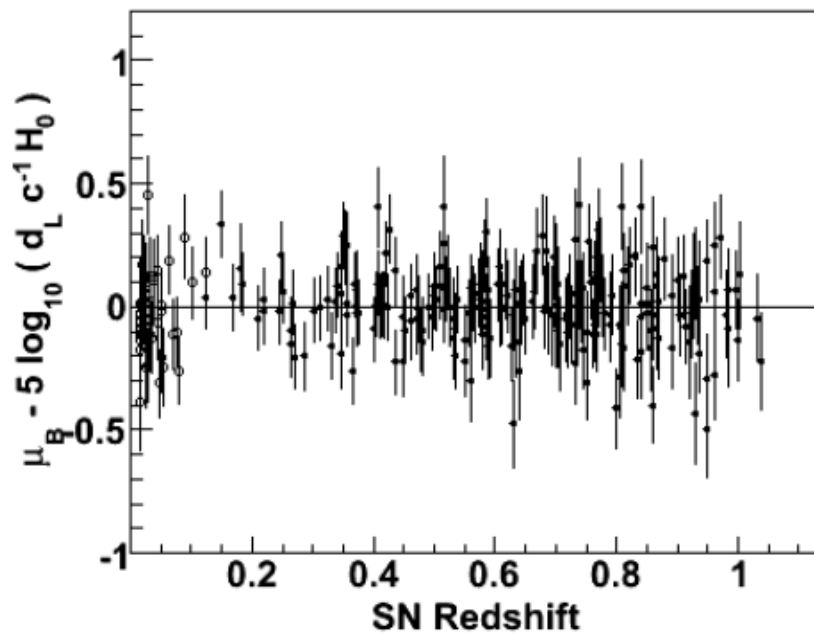
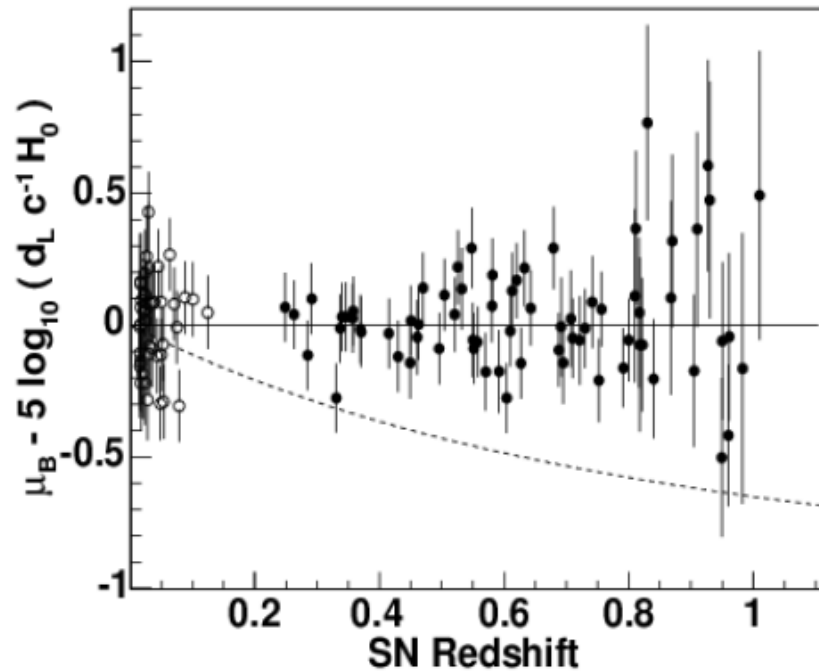
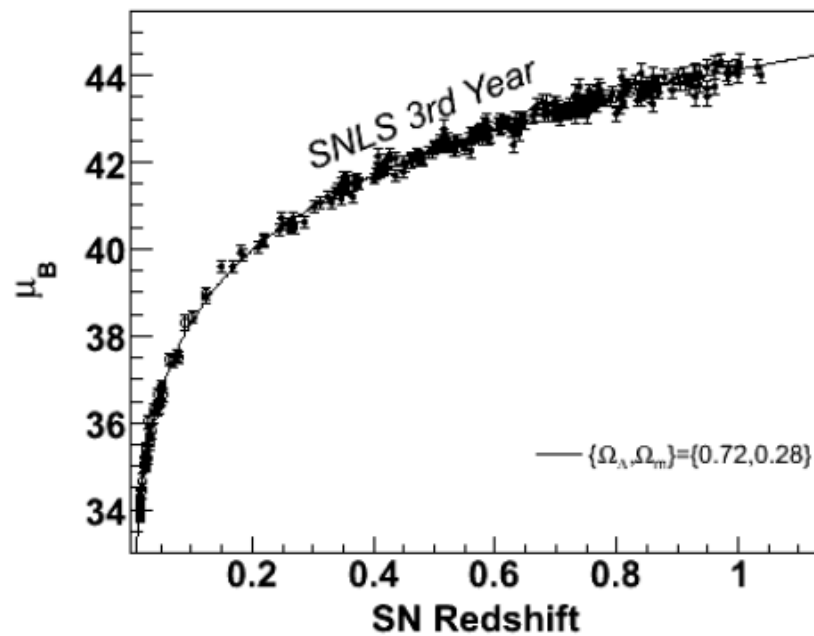
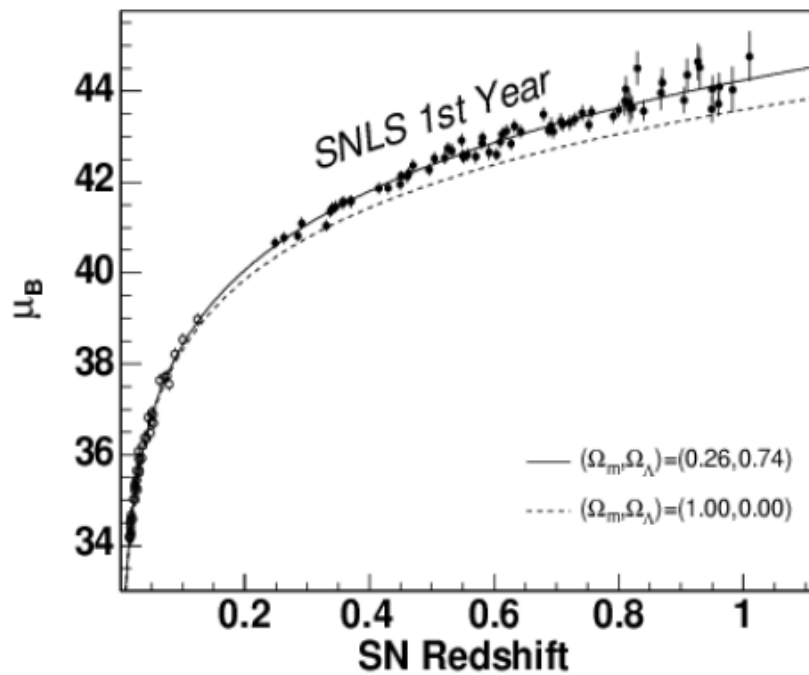
Flux



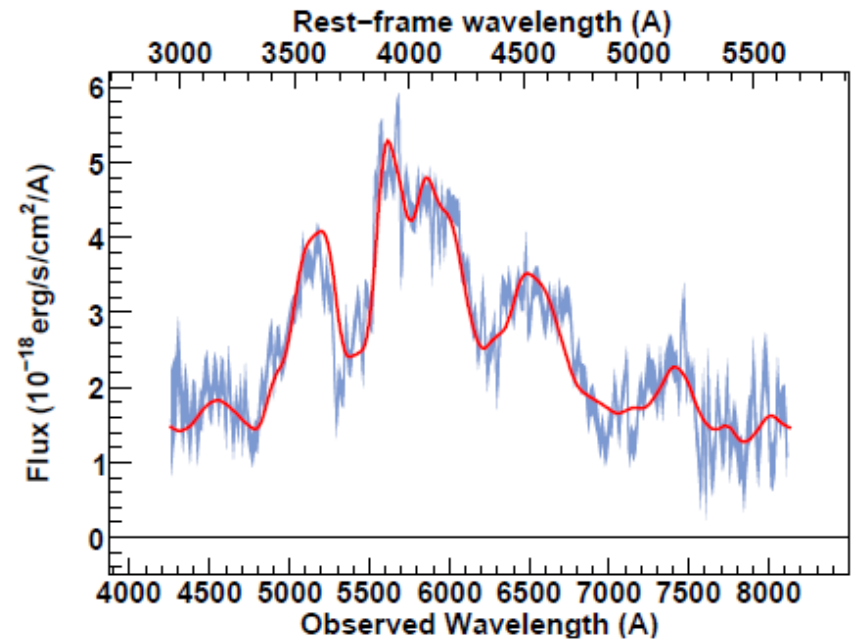
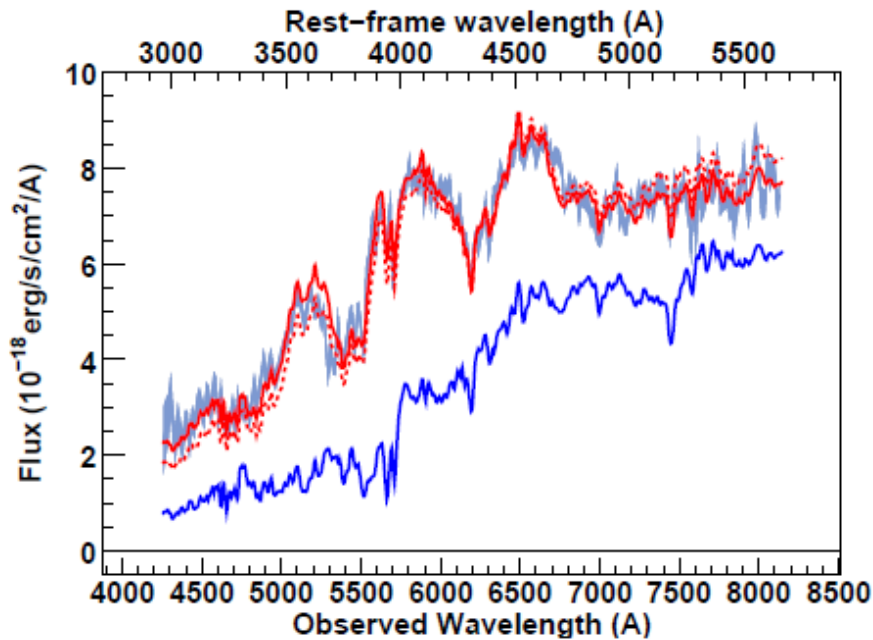
$z=0.91$





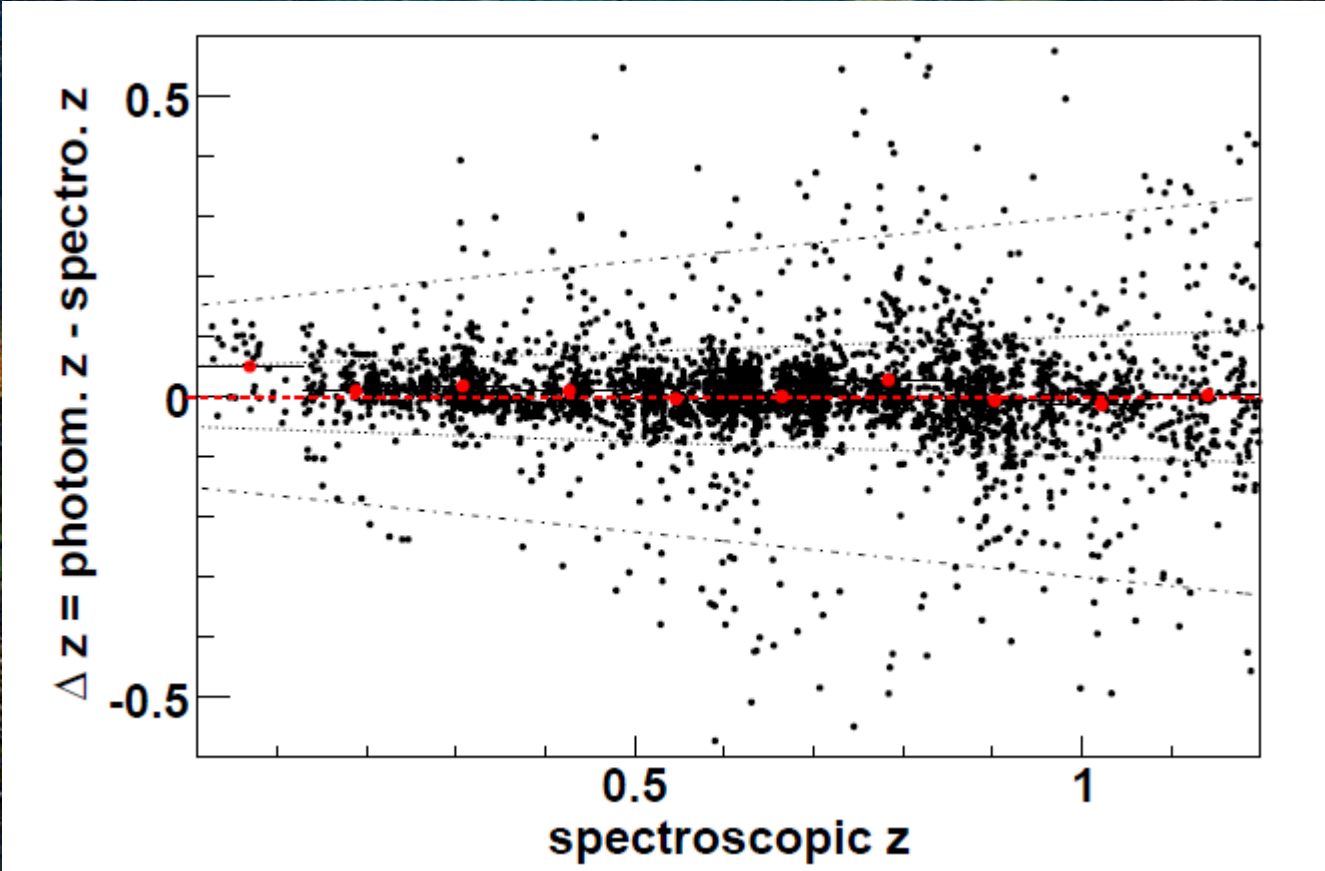


On the way, a lot of work done pushing data processing to its limits...



More observing time spent on 6/10m class telescopes (VLT, Gemini, Keck, Magellan)

Parameter	CMB	CMB+Lens	CMB+SN	CMB+Lens+SN	CMB+Lens+SN+sys
Ω_b	$0.045^{+0.020}_{-0.016}$	$0.041^{+0.016}_{-0.008}$	$0.0433^{+0.0028}_{-0.0026}$	$0.0432^{+0.0026}_{-0.0023}$	0.0428 ± 0.0029
Ω_m	$0.262^{+0.099}_{-0.093}$	$0.242^{+0.092}_{-0.048}$	$0.257^{+0.025}_{-0.023}$	$0.253^{+0.018}_{-0.016}$	$0.251^{+0.023}_{-0.018}$
τ	0.087 ± 0.016	$0.086^{+0.016}_{-0.017}$	$0.088^{+0.019}_{-0.016}$	$0.088^{+0.019}_{-0.015}$	0.088 ± 0.017
w	$-1.08^{+0.39}_{-0.53}$	$-1.09^{+0.24}_{-0.22}$	$-1.025^{+0.071}_{-0.072}$	$-1.010^{+0.059}_{-0.060}$	$-1.021^{+0.079}_{-0.081}$
n_s	$0.963^{+0.019}_{-0.014}$	$0.961^{+0.014}_{-0.016}$	0.962 ± 0.015	$0.963^{+0.015}_{-0.014}$	$0.963^{+0.014}_{-0.015}$
$10^9 \Delta_R^2$	$2.43^{+0.13}_{-0.14}$	$2.418^{+0.083}_{-0.110}$	$2.43^{+0.12}_{-0.11}$	$2.414^{+0.098}_{-0.092}$	2.41 ± 0.11
h	$0.74^{+0.18}_{-0.12}$	$0.754^{+0.096}_{-0.089}$	$0.719^{+0.025}_{-0.022}$	$0.720^{+0.023}_{-0.021}$	$0.723^{+0.027}_{-0.025}$
σ_8	$0.82^{+0.14}_{-0.15}$	$0.819^{+0.061}_{-0.069}$	$0.807^{+0.044}_{-0.046}$	$0.795^{+0.030}_{-0.027}$	$0.798^{+0.037}_{-0.044}$






3D-Matched-Filter Galaxy Cluster Finder I: Selection Functions and CFHTLS Deep Clusters

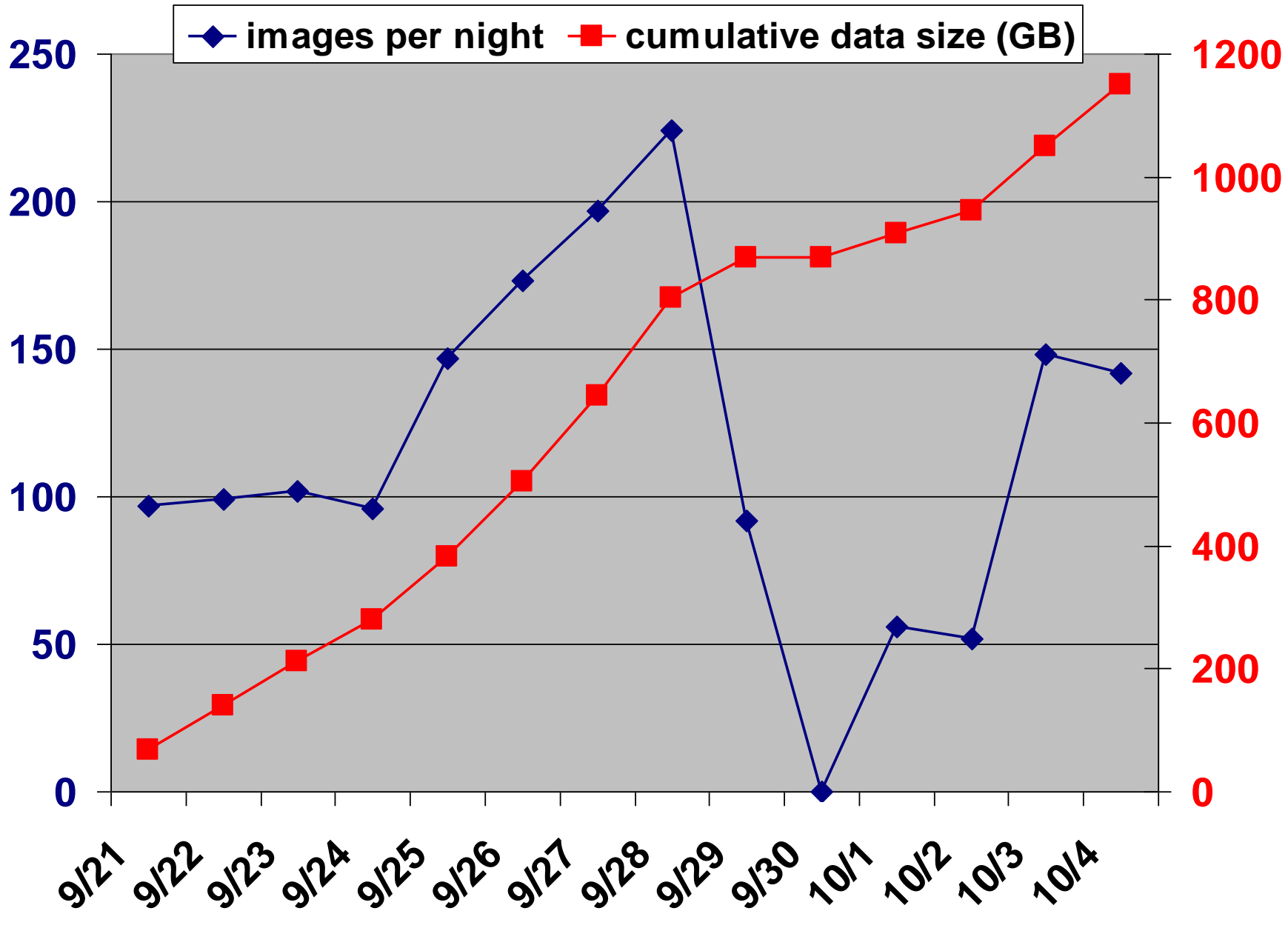
M. Milkeraitis^{1*}, L. Van Waerbeke¹, C. Heymans², H. Hildebrandt³,
J. P. Dietrich^{4,5,6}, T. Erben⁷

Galaxy cluster searches by photometric redshifts in the CFHTLS



C. Adami¹, F. Durret^{2,3}, C. Benoist⁴, J. Coupon^{2,3}, A. Mazure¹, B. Meneux⁵, O. Ilbert¹, J. Blaizot⁶, S. Arnouts⁷,
A. Cappi⁸, B. Garilli⁹, L. Guennou¹, V. LeBrun¹, O. LeFèvre¹, S. Maurogordato⁴, H.J. McCracken^{2,3}, Y. Mellier^{2,3},
E. Slezak⁴, L. Tresse¹, and M.P. Ulmer¹⁰





We just got two new hosts a few months ago with ~30TB each, and that was all we needed to store the raw and processed data for the entire survey. A far cry from anything we could have imagined back in 2003.

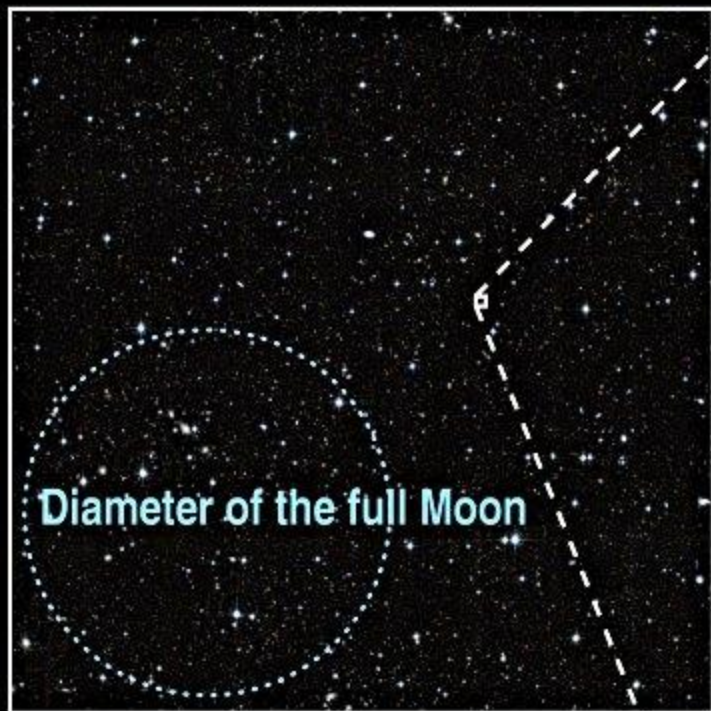
I remember when Megacam first came and you couldn't even buy a rackmount computer that would hold ATA hard drives so we sawed and drilled Dell desktops to jam 11 drives in each of them. Then we had those big wooden shelves built to hold them all. It wasn't all that long ago but each of these new machines has as much storage as the entire megacam cluster originally had. I'm glad we didn't wait for it to get easier though, we just retired the last of the Dell boxes after seven years of round-the-clock megacam data processing; that's a good head-start.

**max 40MBytes par seconde CFHT -> Terapix,
min 10 MB/sec**

Conclusion

- Field selection critical (if not whole-sky!)
- Collaborating/competing teams a real bonus
- HEP-connection in France a plus
- Legacy value very important, but costly and not necessarily fun... Worth the price though!
- Already tens of publications, some with extremely high impact, some from the archive!
- Huge impact on PI programs...
- Still not easy on a multi-purpose multi-user telescope

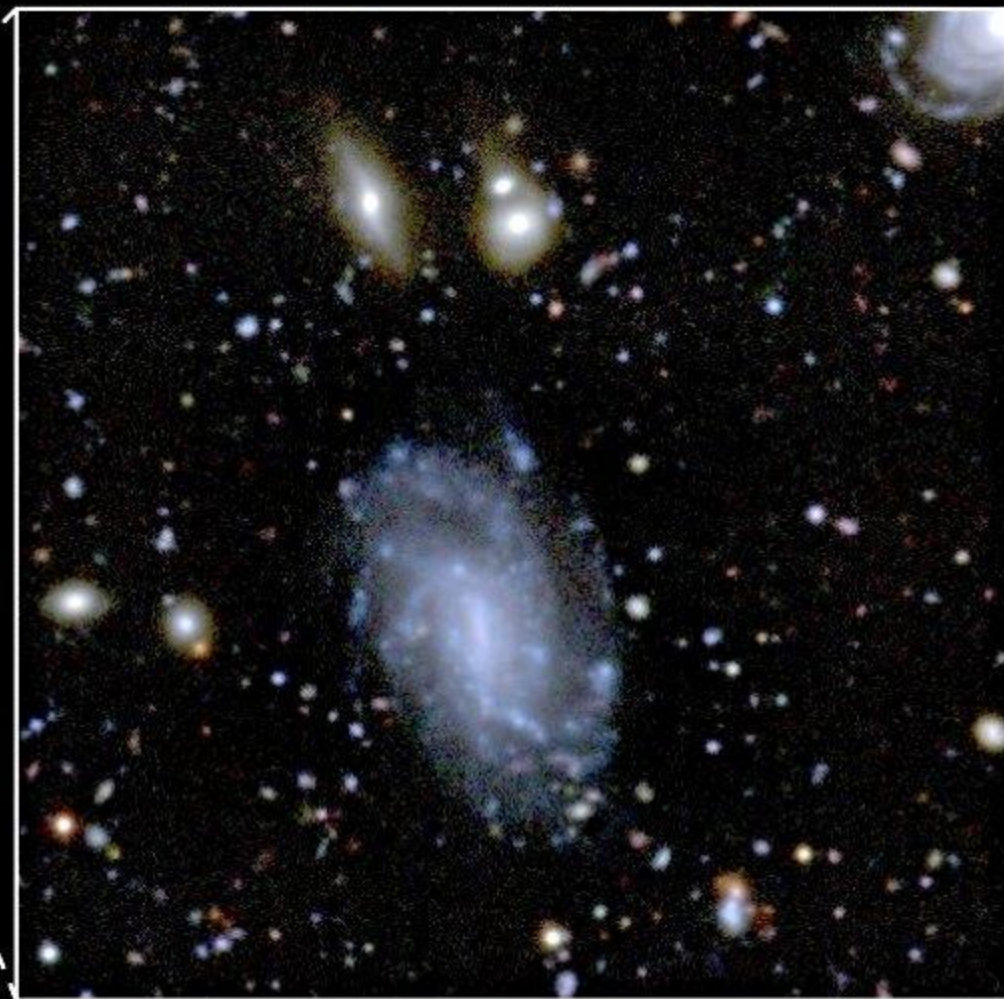
19242 pixels



Diameter of the full Moon

19242 pixels

CFHTLS Deep Field #1
One square degree field of view
500,000 galaxies
Image by CFHT & Terapix





MegaPrime Image Quality

