l'Observatoire de Paris — LESIA
Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

國立清華大學物理系
Department of Physics
National Tsing Hua University

l'Observatoire de Paris — GEPI
Galaxies Étoiles Physique et Instrumentation

UltraPhot,
a photometric mode for FLAMES

Françoise Roques
LESIA
Observatoire de Paris

March 9-10, 2009 **ESO Spectroscopic Survey Workshop**

UltraPhot Science :
Variable Objects, Transits, Occultations

Temporal resolution is a relatively unexplored region of the observational parameter space:
CCD cameras =>> frame rate ≤ one frame per minute
Few instruments =>> continuous high-speed observations :

telescope	frame rate Hz
Hale	1000
GHO	7.5
Mayall	24000
Keck II	14
ULTRACAM	**500**
SAAO	1
Gemini South	7
SALT	10
NOT	30

(Dhillon, 2008)

$$t_{dyn} \approx \sqrt{\frac{2R^3}{GM}}$$

ranges from second (white dwarfs) to millisecond (neutron stars and black holes)

UltraPhot allows high speed visible photometry
in three colors
of large number of objects
with frame rate of 100 Hz

UltraPhot Science :
Variable Objects, Transits, Occultations

Potential interested scientific fields are numerous :

- Cataclysmic Variables, accreting white dwarfs
- Black-holes, X-ray binaries
- Stellar occultations (outer solar system)
- Extrasolar Planets Transits
- Pulsars
- Young Stellar Objects

ULTRACAM : ultrafast triple beam camera (Dhillon, Marsh)
87 nights on WHT and 23 nights on VLT - 25 refereed papers - in 4 years

ULTRACAM	UltraPhot
imaging	photometry (3 pts)
1-2 targets	50-100 targets
500 Hz	100 Hz

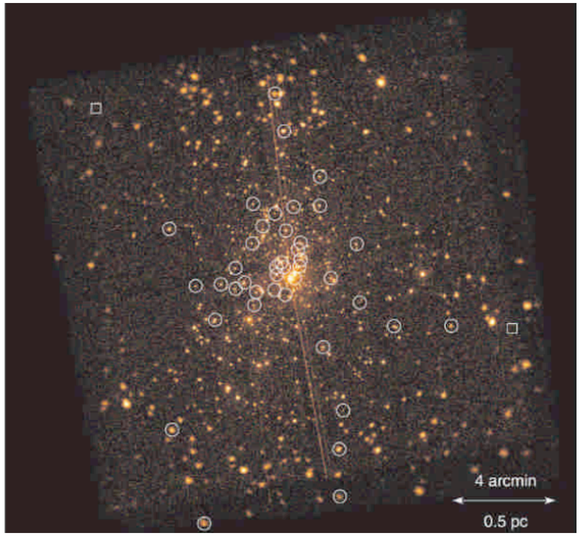
UltraPhot Science- Young Stellar Objects

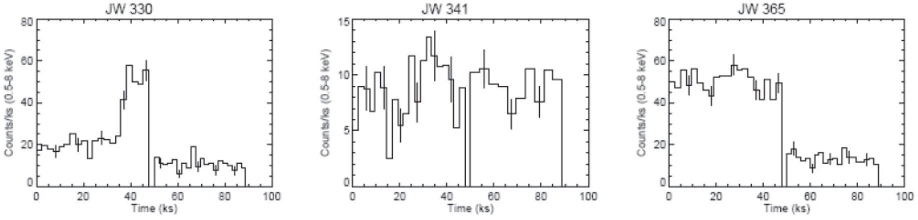
Variability of Young Stellar Objects :

- Rotation, derived from hot spots
- Eclipse/occultation - protoplanets,protoplanetary disks
- Accretion
- Flares

Goal : flares frequency with mass/age - disks accretion rates…

A possible target : Orion Nebula Cluster : 2000 stars in a 8’ radius sphere





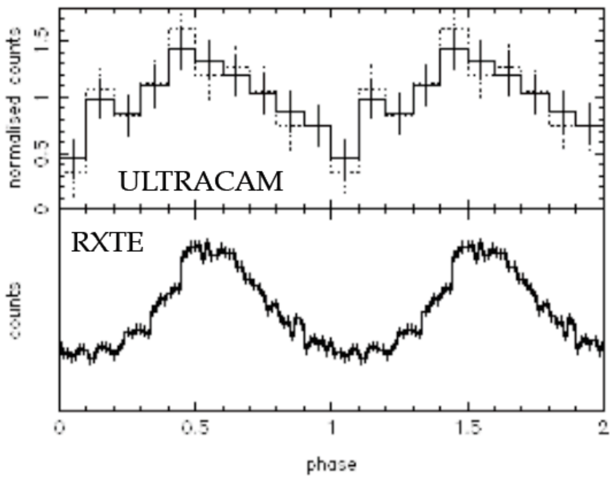
Feigelson et al, 2002

Neutron stars, black holes in X-ray binaries

Variability of compact binaries :
• orbital period
•Super orbital period (precession)
•Pulsation
•Quasi-Periodic-Oscillations

Dynamical time scale:
seconds (white dwarfs) - milliseconds (black holes)

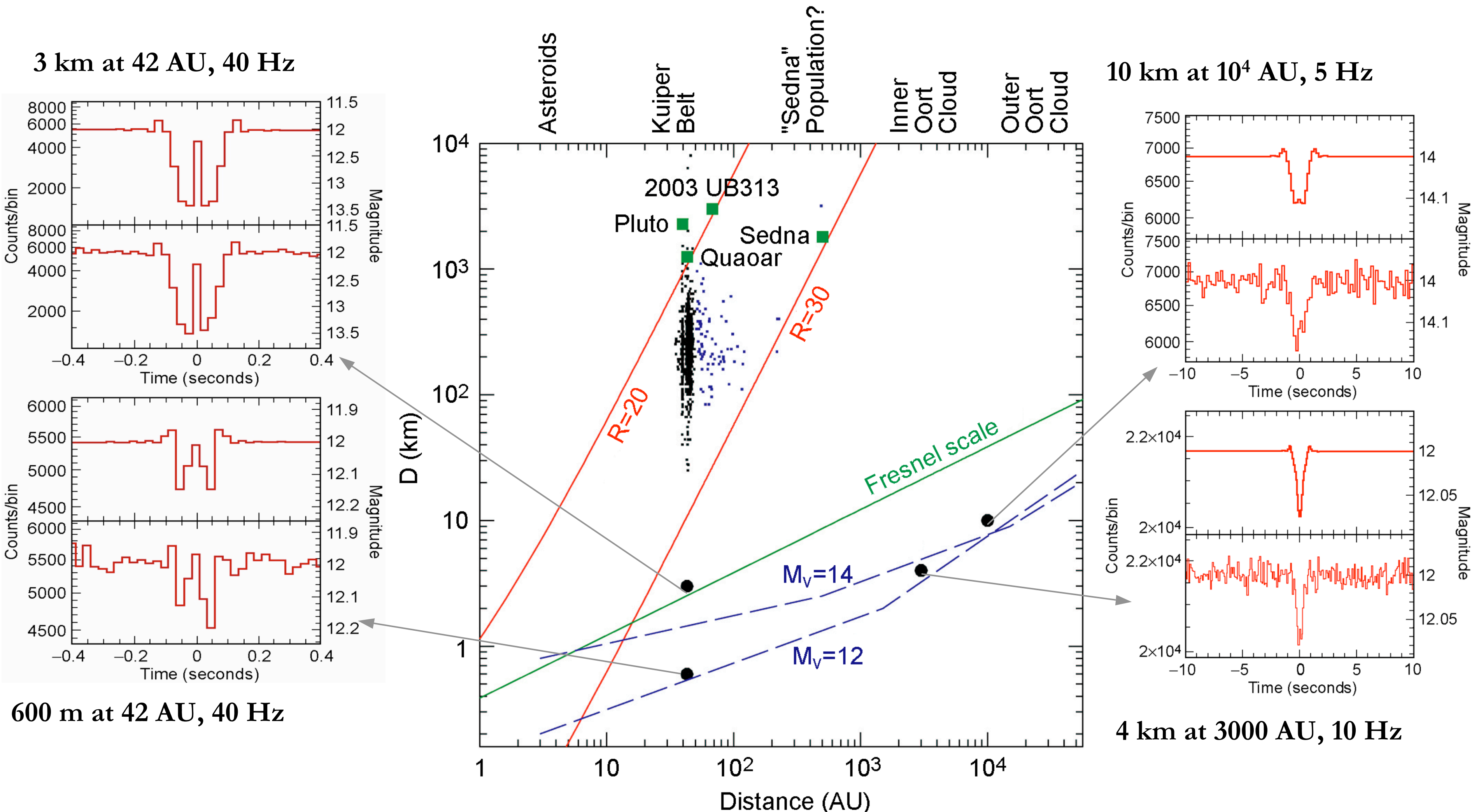
Echo-tomography : time delay between X and optic :UltraPhot-ASTROSAT (launched in 2009)



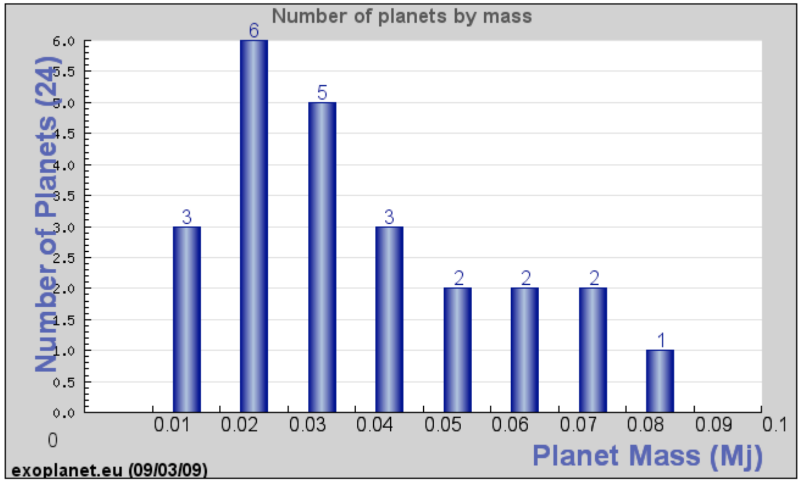
Dhillon et al. 2009

UltraPhot Science - Outer solar system - Stellar occultations

(NASA: Whipple - Canadian-Space-Agency : microsatellite)



March 9-10, 2009 ESO Spectroscopic Survey Workshop Nihei et al., 2007, Roques et al., 2008

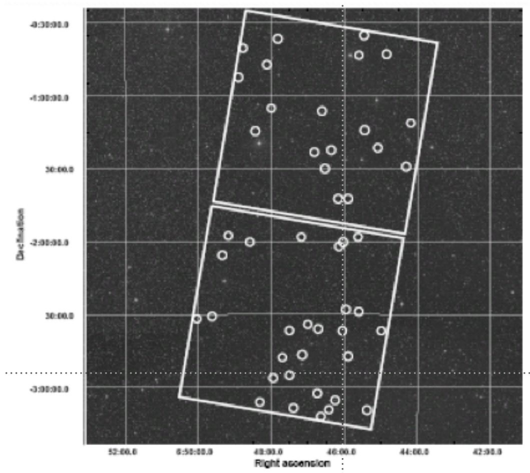


<u>Transit Timing Variations :</u> changes in the parameters of the transits.
Timing accuracy of *6 seconds par epoch* (Steffen et al. 2007)
Multiple planetary systems: => 5 M_{moon} (Algol et al. 2005)
Exomoon => 0.44$M_{\oplus}$ (Kipping et al., 2008)

<u>Transits Research :</u> Earth-like planet are detectable. Fast photometry avoids red noise

<u>Corot targets monitoring :</u> hundredths of potentials transits need to be confirmed by multi-colors observations

<u>Kepler targets</u>



(Carpano et al. , 2009)

starting night 11-03-2009

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Observatory: Paranal, Latitude = -24.6251, Longitude = -70.4027, Height = 2635.43 m, Sun Set: 20090311 23:08, Sun Rise: 2

Transit type = Primary, Minimun object altitude = 20, Maximum Sun altitude= -12, Minimun moon distance = 0

Object	RA	DEC	E	JD	YYYYMMDD	UT	ERROR	ALT	HA	SUNALT	MD	MI	VMAG	DEPTH	T14
						[hh:mm	hh:mm]	[deg]	[hh:mm]	[deg]	[deg]	[%]		[%]	[hh.h
LRa01 E2	[illegible]	[illegible]	404	2454902.51589	20090312	00:23	2:20	65.8	00:18	-19.1	80.9	98.8	16.09	0.84	2.8
LRa02 E2	[illegible]	[illegible]	113	2454902.52405	20090312	00:35	0:00	69.5	00:21	-21.7	78.3	98.8	12.52	0.66	1.9
LRa02 E1	[illegible]	[illegible]	163	2454902.54636	20090312	01:07	0:02	65.7	00:52	-28.7	78.3	98.8	15.41	0.52	1.2
LRa01 E2	[illegible]	[illegible]	534	2454902.57076	20090312	01:42	2:34	57.1	01:35	-36.1	80.9	98.7	11.67	0.03	1.1
LRa02 E2	[illegible]	[illegible]	76	2454902.59430	20090312	02:16	0:05	55.6	01:59	-43.0	78.4	98.7	16.03	0.68	1.5
LRa02 E2	[illegible]	[illegible]	51	2454902.61053	20090312	02:39	0:04	50.0	02:26	-47.4	79.4	98.6	14.65	0.39	3.3
LRa02 E1	[illegible]	[illegible]	70	2454902.67529	20090312	04:12	0:02	28.5	04:02	-60.5	80.8	98.5	13.63	1.59	2.3
LRc01 E1	[illegible]	[illegible]	576	2454902.85445	20090312	08:30	??:??	23.2	-04:18	-30.2	106.2	97.9	15.20	0.13	1.0
LRc01 E2	[illegible]	[illegible]	638	2454902.88450	20090312	09:14	??:??	32.7	-03:30	-20.8	104.9	97.9	15.23	0.32	1.9

Previous < | Observatory home | All | Calendar | Candidate list | > Next

UltraPhot : scientific specifications

•300-900 nm spreaded in 3 colors
• acquisition frequency ≥ 100 Hz
• number of targets ≈ 100
• photometric precision

$$SNR = \sqrt{T}.6.\frac{10^{5-0.2m}}{\sqrt{f}}$$

- T: transmission factor > 20%
  (Ultracam/VLT => T=30%)
- input aperture on the sky >5 arcsec diameter
- temporal and relative stability of the fibres

Two operating modes :
• dedicated program
• survey mode (occultations, transits)
simultaneously with Giraffe/UVES

UltraPhot concept

Ultraphot is composed of :

- a multi-object fibres link + Ozpoz (magnetic buttons + retractors)
- a photometer :optics (relays, mirrors, lenses, dichroics…) + CCD-camera

The photometer is

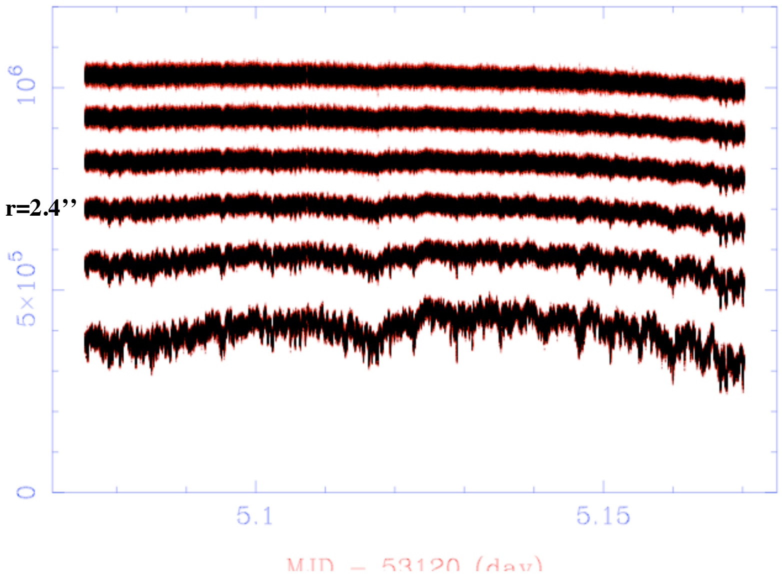
- small (600x600x60mm)
- with no moving part
- motorized setting

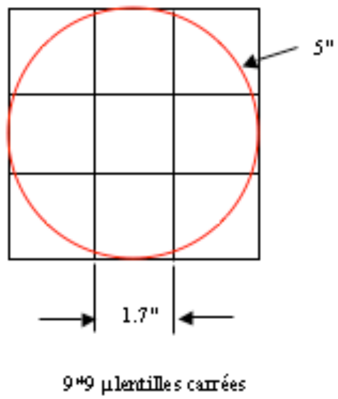
Two options :

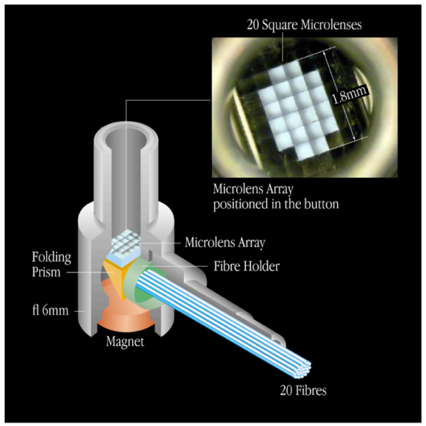
- equipate free places (84-69) on existing plates
- build 2 supplementary plates

UltraPhot - aperture size

UltraCam data







Mechanical Design of an IFU

ESO PR Photo 03d/02 (28 January 2002)

UltraPhot - Optical design

The optical design below allows to throw 3 images of fibres in 3 different spectral ranges.
The parabolic mirror collimates the beam and allows to use a dichroic mirror.
The camera reduces the image size of the entrance field to the dimensions of the detector.

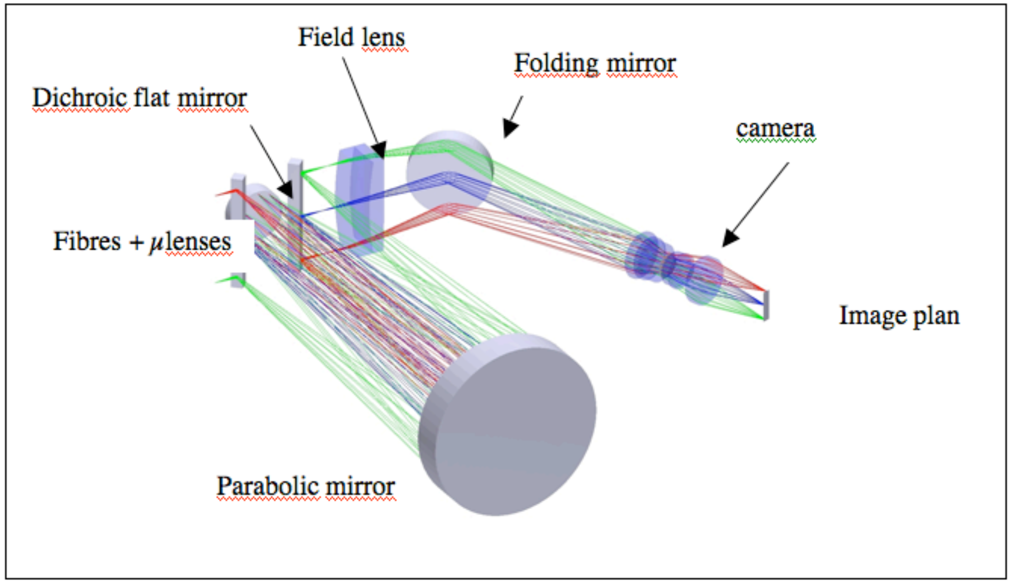
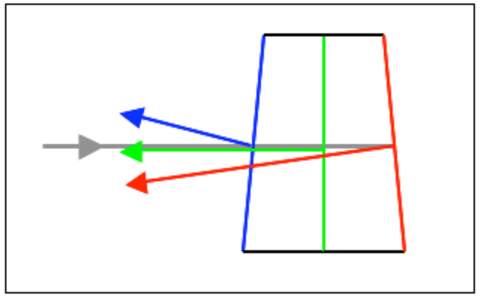
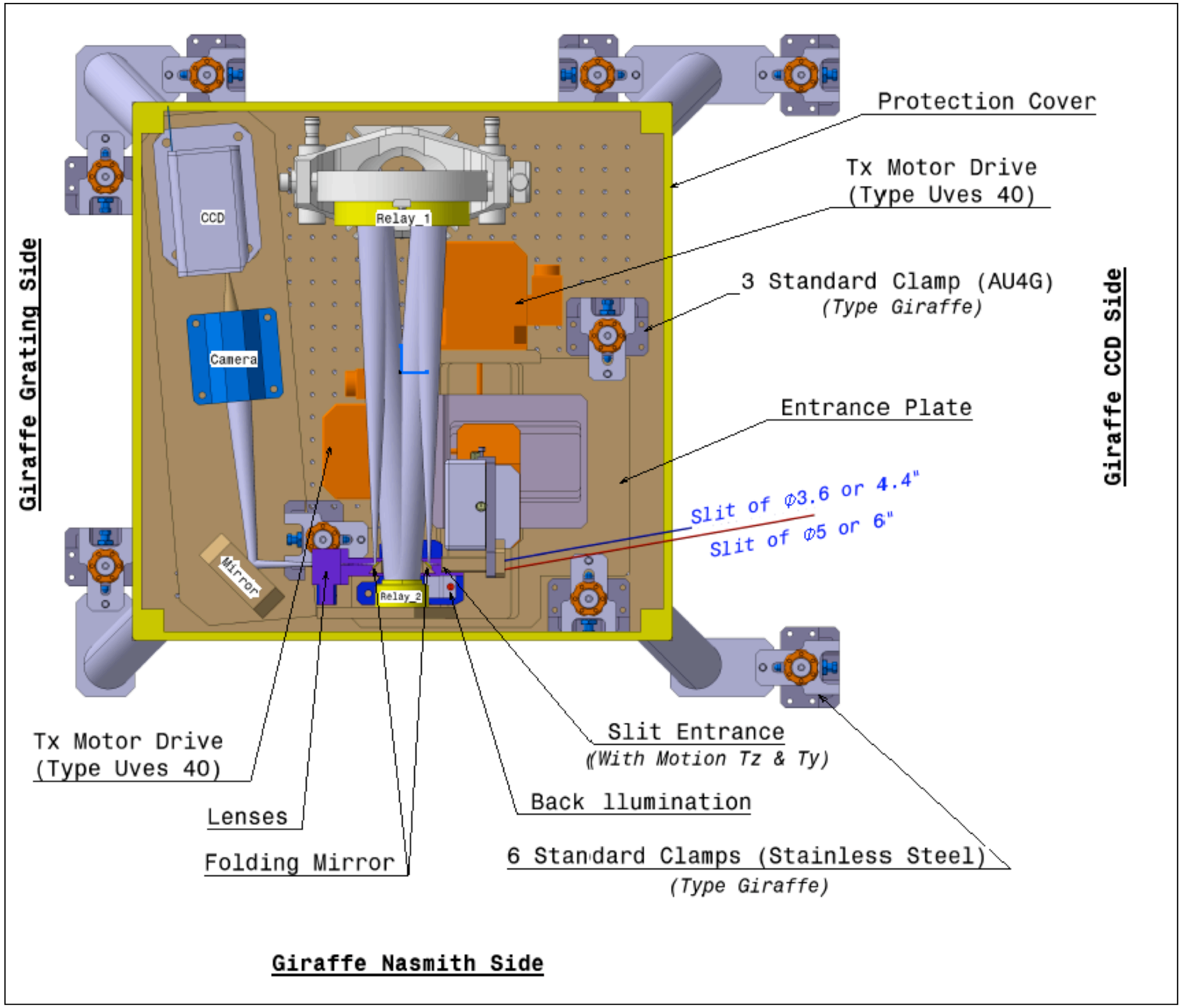


Figure 15 : Optical design



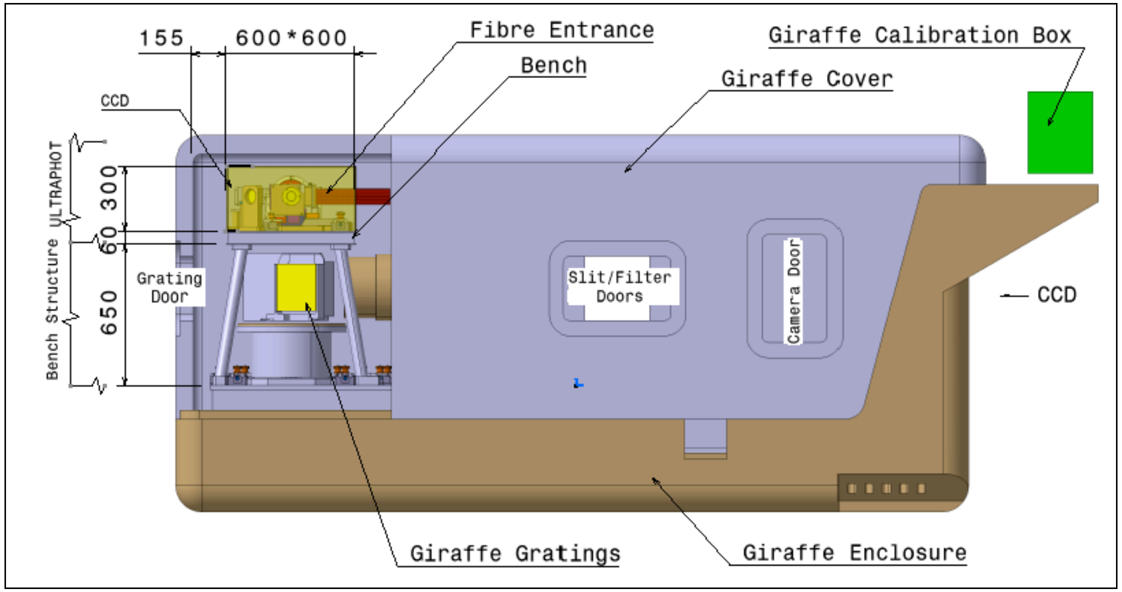
David Horville, GEPI

UltraPhot - photometer design



Michel Marteaud, LESIA

UltraPhot - position



Michel Marteaud, LESIA

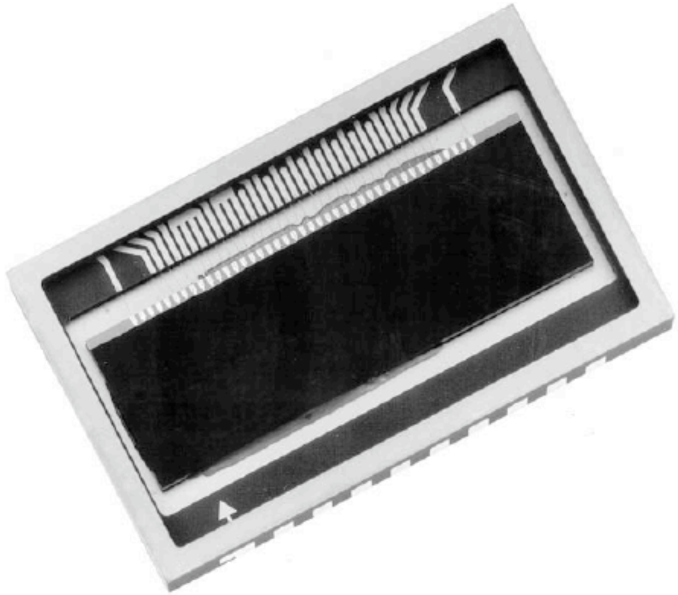
or
under the floor?

UltraPhot - camera

E2V Technologies
CCD42-10 Back Illuminated
High Performance AIMO CCD Sensor

FEATURES

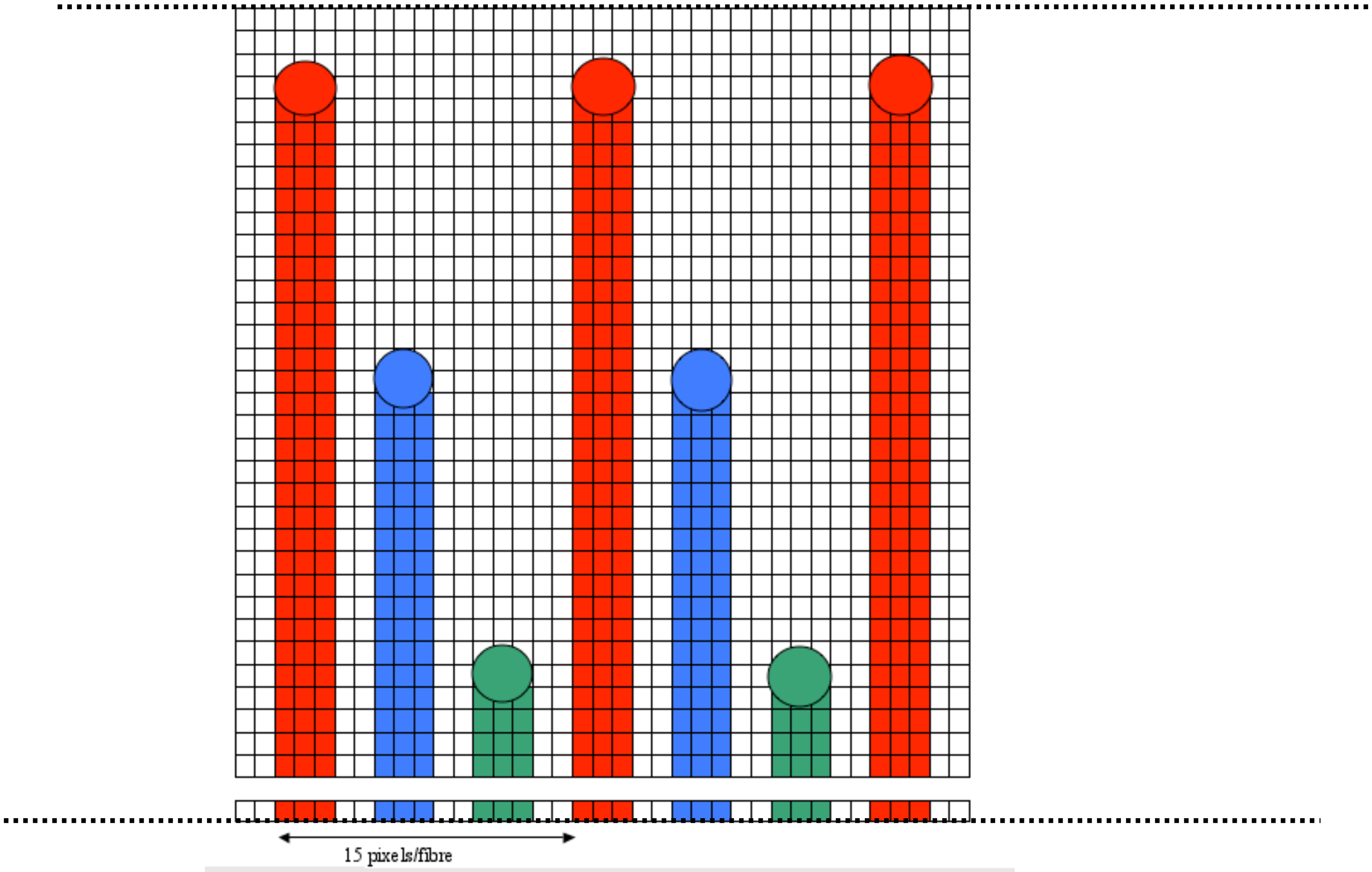
- 2048 by 512 Pixel Format
- 13.5 µm Square Pixels
- Image Area 27.6 x 6.9 mm
- Wide Dynamic Range
- Symmetrical Anti-static Gate Protection
- Back Illuminated Format for Enhanced Quantum Efficiency
- 3 Standard Anti-reflection Coatings
- Advanced Inverted Mode Operation (AIMO)
- Dump Gate on Readout Register
- Zero Light Emitting Output Amplifier



APPLICATIONS

- Spectroscopy
- Scientific Imaging
- TDI Operation

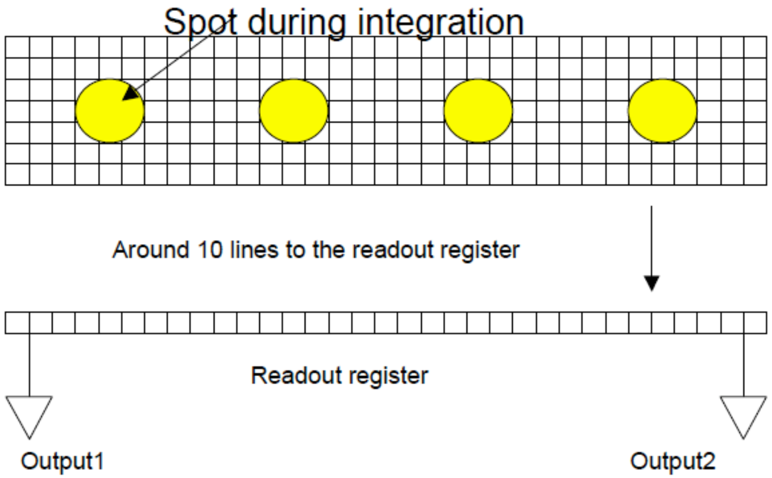
UltraPhot - camera



UltraPhot - camera

- **First step : Integration of light.**

This duration is called the "integration time". During it, no phases are clocked and the photo integrated and stocked in the pixels.



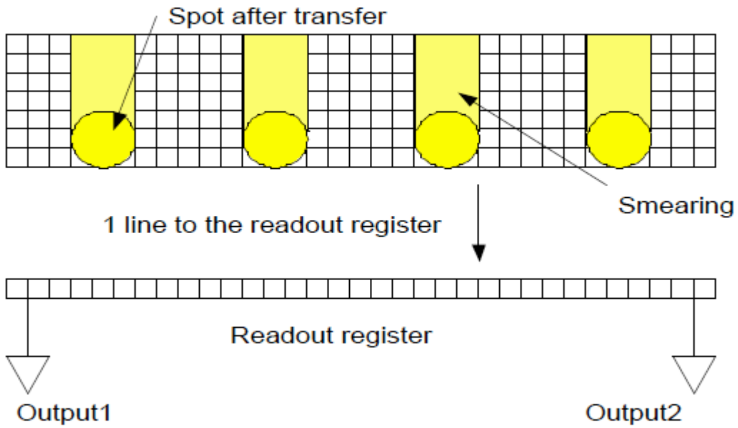


Figure 18 : Integration in the sensitive area of the CCD.

"Full Frame CCD" => no dead time

one cycle = integration : 8.7 ms - transfert+binning+reading : 1.3 ms

Jean-Tristan Buey, LESIA

UltraPhot - Software

- **Ozpoz Robot software** : introduction of more fibres, back-illumination system control
- **Fibres configuration program** to support the new fibre type
- **UltraPhot observing mode** :
- **P2PP software**
- Tests, calibration, documentation

The linear CCD can be read with the new NGC (Next Generation Controller)

Data rate is quite important : 20 Gbits/night

UltraPhot and Giraffe

A concern about this project is to assure it does not modify FLAMES programs.

The coexistence of UltraPhot and Giraffe must be studied at several interfaces :

1. focal plate and positioner: Buttons are added and the Ozpoz software must be modified to position the UltraPhot fibres.
2. UltraPhot inside the Giraffe enclosure presents several advantages but needs careful studied to insure no perturbation for the spectrograh : mecanic stability, thermal stability, accessibility
3. Software: the FLAMES observing mode and P2PP

UltraPhot - Realisation

Technical manpower :2.8 FTE   LESIA-GEPI implication >2.2 FTE

Estimation of cost (optics-mechanic): Lesia, Gepi, NTHU

Fibre link	50 k€
Mechanical	45 k€
Optical	30 k€
Camera	70 k€
Others	15 k€
Total	*210 k€*

Estimation of cost (retractors, soft) AAO

Total	*62 k€*

ANR (french research agency) : 140k€
NSC (taiwanese research agency): 70k€

Planning
T0 + 9 months : end of the design
T0 +21 months : end of the manufacturing
T0 + 24 months : end of integration

UltraPhot team

	Scientific PI	Technical PI	Scientific involvement	Technical involvement	***Financial involvement***
Paris O.-LESIA	X		X	X	***X***
Paris O.-GEPI		X		X	***X***
NTHU (Taiwan)			X	X	***X***
Napoli O. (Italia)			X		
Paris O.-Luth			X		
IAP			X		
AAO				X	

Paris observatory - LESIA :
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Paris Observatory - GEPI : I. Guinouard, D. Horville

National Tsing Hua University - Department of Physics :
H.-K. Chang, A. Kong, S.-P. Lai, I.-C. Shieh

Naples Observatory - INAF : D. de Martino, R. Silvotti

Institut d'Astrophysique de Paris : J.P. Beaulieu

Paris Observatory - LUTH:J. Schneider

Anglo-Australian Observatory : T. Farrell, K. Shortridge

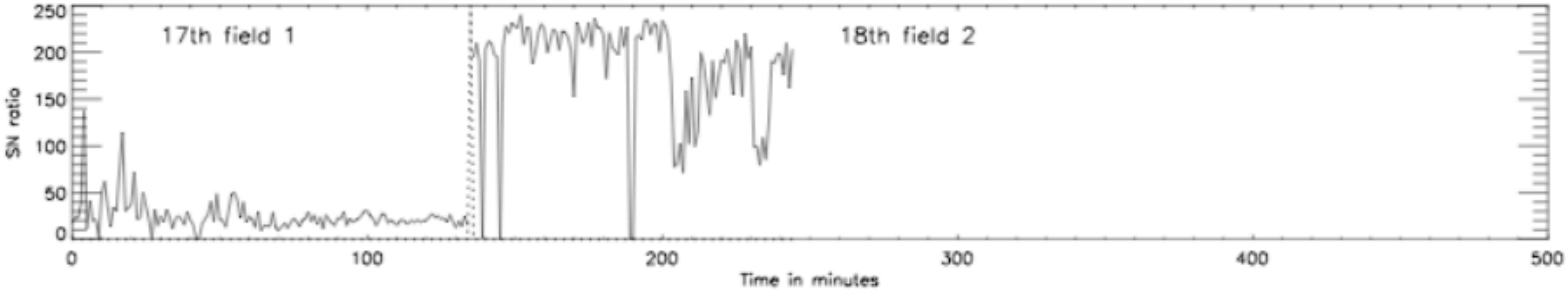
Conclusions

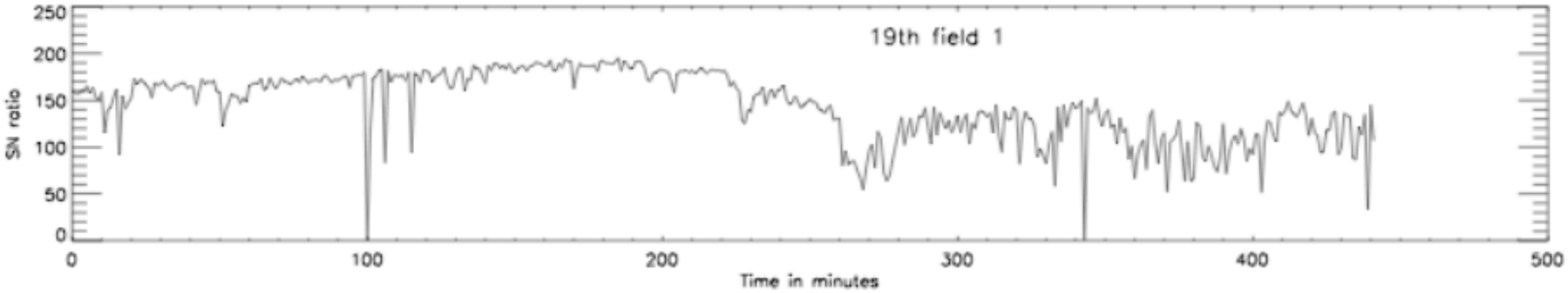
UltraPhot :
- unexplored domain of observation parameters
- challenging science
- reliable
- versatile
- small
- cheap
- rapid manufacturing
- experienced team
- test for more sophisticated instrument ?

so why not?

Thank you!

SNR :
VLT/ULTRACAM - 46 Hz





Whipple: A Space-Based Occultation Survey of the Outer Solar System

Smithsonian Astrophysical Observatory

Ball Aerospace

Jet Propulsion Laboratory

Spacecraft based on *Kepler* design

- 95 cm Schmidt optical system
- 100 square degree field of view
- Articulated solar arrays
- Hybrid CMOS focal plane array (Rockwell HyViSI/Hawaii-2RG)
- 140,000 stars, 40 Hz readout

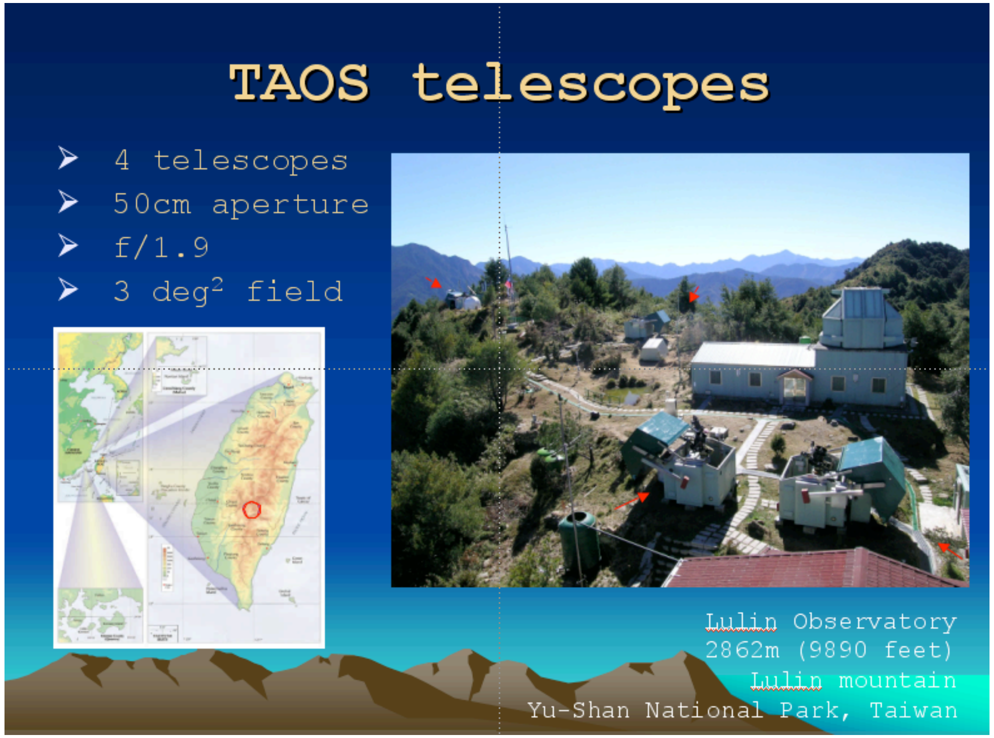
THE TAIWANESE-AMERICAN OCCULTATION SURVEY: THE MULTI-TELESCOPE ROBOTIC OBSERVATORY

M. J. Lehner[1,2], C.-Y. Wen[1], J.-H. Wang[1], S. L. Marshall[3,4], M. E. Schwamb[5], Z.-W. Zhang[6], F. B. Bianco[7,2], J. Giammarco[8], R. Porrata[9], C. Alcock[2], T. Axelrod[10], Y.-I. Byun[11], W. P. Chen[5], K. H. Cook[4], R. Dave[12], S.-K. King[1], T. Lee[1], H.-C. Lin[5] and S.-Y. Wang[1]

Draft version February 5, 2008

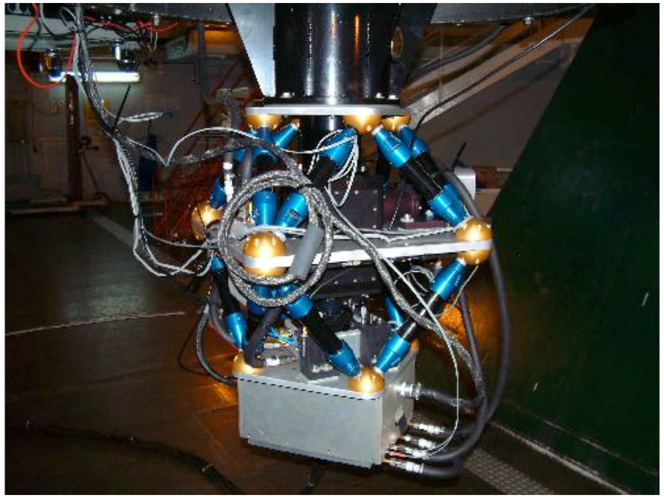
ABSTRACT

The Taiwanese-American Occultation Survey (TAOS) operates four telescopes to search for occultations of stars by Kuiper Belt Objects. This paper provides a detailed description of the TAOS multi-telescope system.

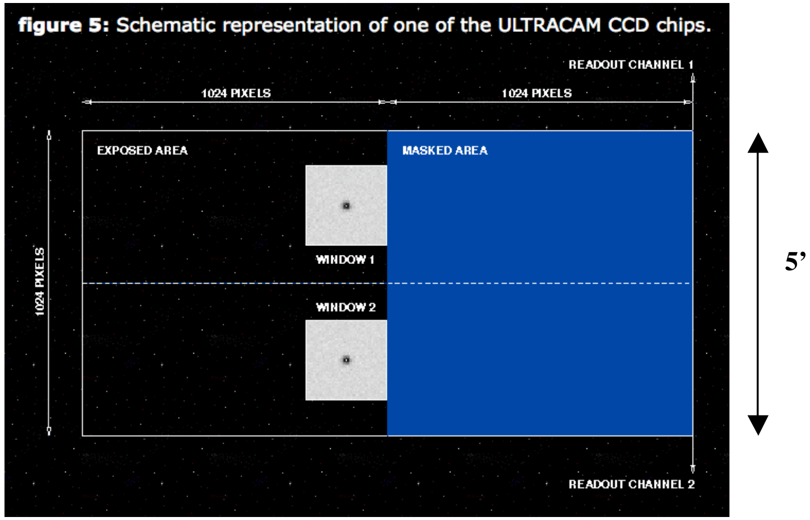


ULTRACAM :

an ultra-fast, triple-beam CCD camera (V. Dhillon and T. Marsh)



- **William Herschel Telescope**
- **VLT**



- u': 0.36 μm, g':0.48 μm and i':0.77 μm)

- two fields : one target + one reference