

OPERATIONAL INNOVATIONS

Andy Adamson

Associate Director, UKIRT

Preparation and Execution

Scheduling

Evolution



Categorizing Innovation

TECHNICAL

Telescope Mechanical Design

High-level Software

Low-level Software

Upgrades / image quality

Instrument Integration

OPERATIONAL

Science Programme Mix

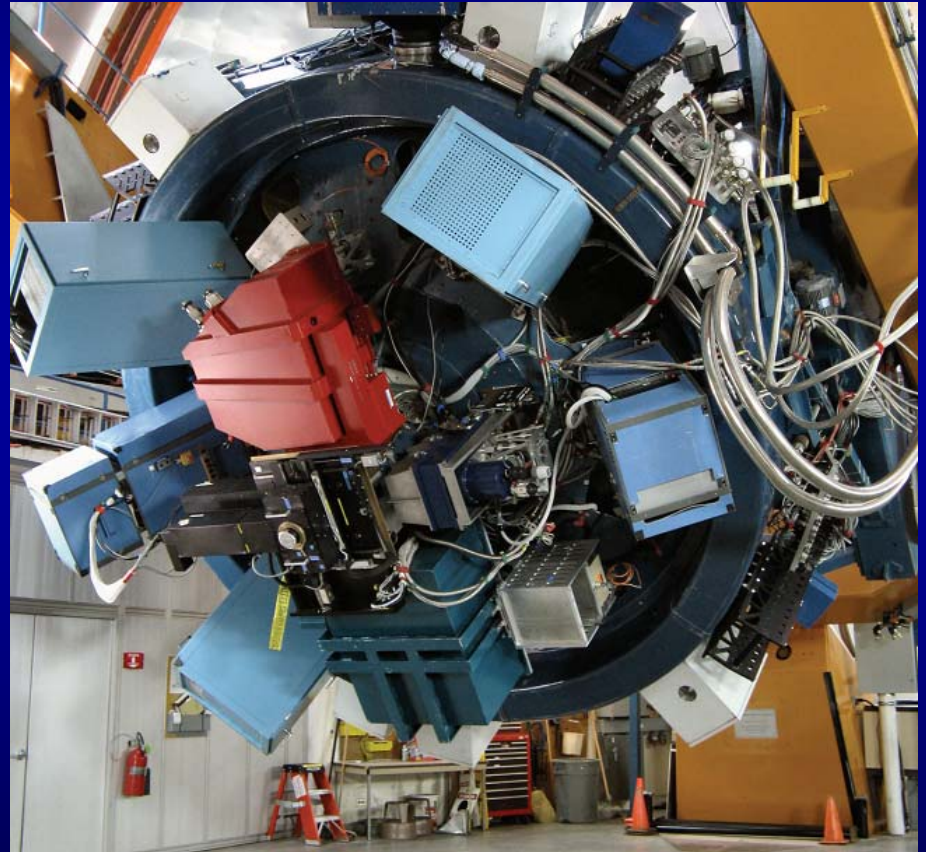
Scheduling

Responsiveness



Telescope

A key design decision: ISU and tertiary mirror



PREPARATION AND EXECUTION

ukirtprep

ORAC

ORACDR

OMP



Observation Preparation - ukirtprep

Required advance preparation of observations

...advance meant "in Hilo"

SMS-based system (VT100 terminals, menus etc.)

Paved the way for later systems and moved the preparation stage off the summit

Standard across facility instruments (e.g. CGS4, IRCAM)

Wrote Execs and Configs – still relevant



SMS

```
CGS4 Instrument Control
File Edit Commands Options Print Help
SMS CGS4 control system
├── Take Movies with CGS4
│   └── Set to Intermediate Configuration
│       Image_Rotator 2.779
│       Filter blank open IJ B1 B2 B3 B4 B5 B6 N1 N2 N3 N4 N5 lens B2+prism
│       Slit 0m 0w 0ew 36.9m 36.9w blank pinhole
├── Slit_Offset 7.201
├── Da Cvf 1.3-2.5 2.0-3.7 3.7-5.5 open undefined
├── Ba Cvf_Wavelength 0.000000
├── Us Grating 40_lpmm 150_lpmm echelle_auto_order echelle safe
├── Ba Wavelength 2.200258
├── Bi Order 1
├── Se Focus 1.967089
├── -- Det_Offset 0.00000
├── B1 Calibrator off 5.0 3.2 2.0 1.3 0.8 0.5 0.1 0.05 argon krypton xenon t_h
├── Wa T_H_Level 0
├── Da Effective_Ap 10
└── AL
    ASTRONOMICAL configuration file cgs4_config:401220.AIM read OK
    Setting configuration to FLAT
    FLAT configuration achieved OK

Set values then hit PF1 PF2 recalls basic defaults PF4 aborts without action
```



Observation Prep & Exec - ORAC

Prerequisite for queue scheduling

Introduced initially with UFTI

Backported to CGS4 and IRCAM

Standard with Michelle, UIST and WFCAM

Elements: OT, Translator, Sequence console, Exec/Config system

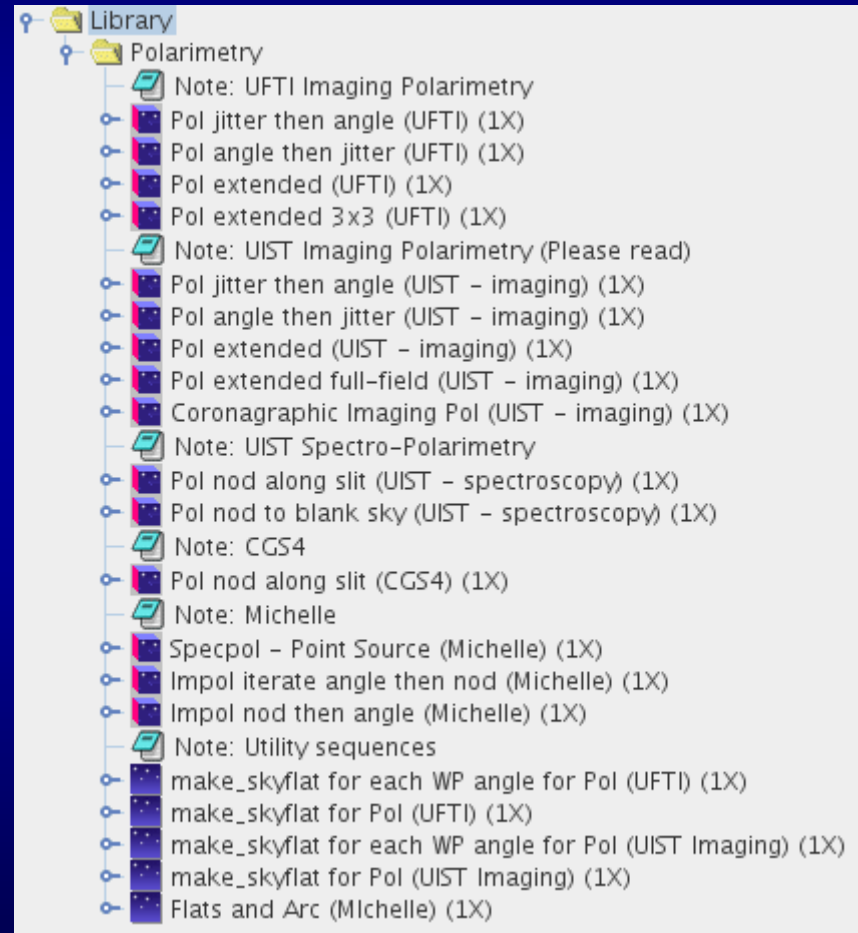


Observation Prep & Exec - ORAC



Ukirtot launch screen

Template library (example: polarimetry)



Side benefit: rapid instrument commissioning



Reduction Pipelines: CGS4DR

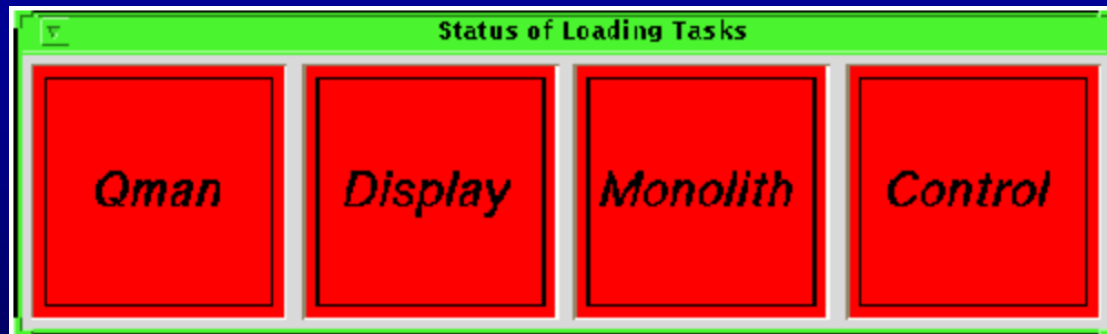
(Very) early example of reduction pipeline technology

Almost publication-quality reduced data

Reduction was customizable on the fly

Queue mode, automatic reduction of the incoming stream

Distributed to the user community with Starlink



Reduction Pipelines: ORACDR

Standard issue at UKIRT since UFTI

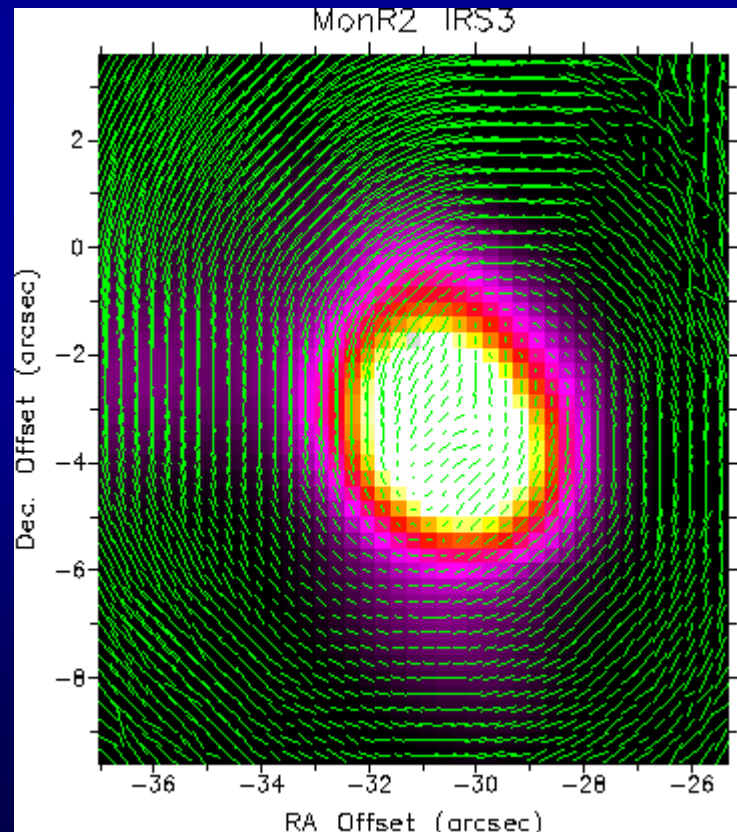
Almost publication quality results

Useful in classical scheduling; critical prerequisite for flexible scheduling

Data-driven

Recipe/primitive structure

Available for all obs. modes



Observation Management (2003-)

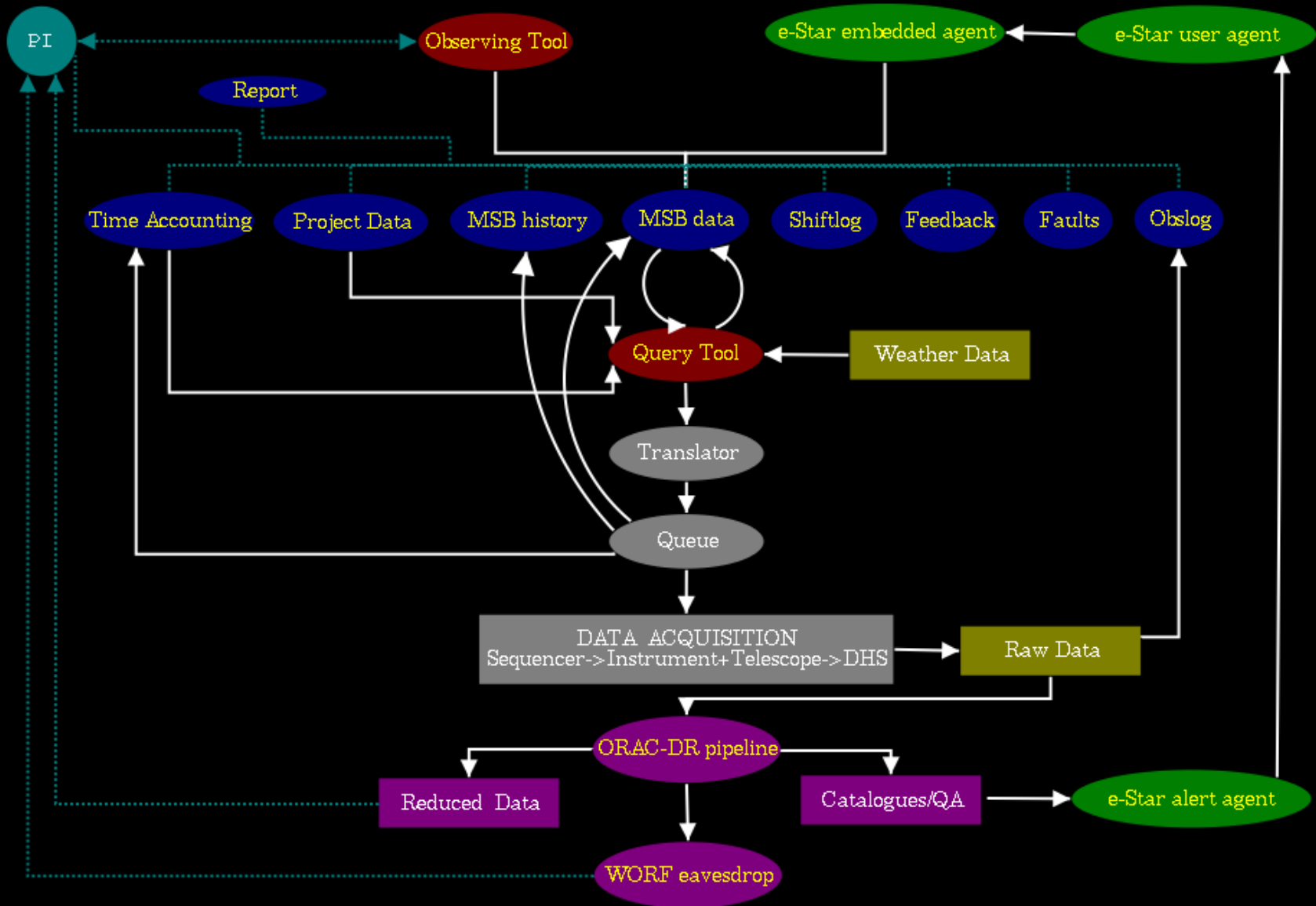
The OMP (Observation Management Project)

Central databases for observation storage, history, users, communications etc.

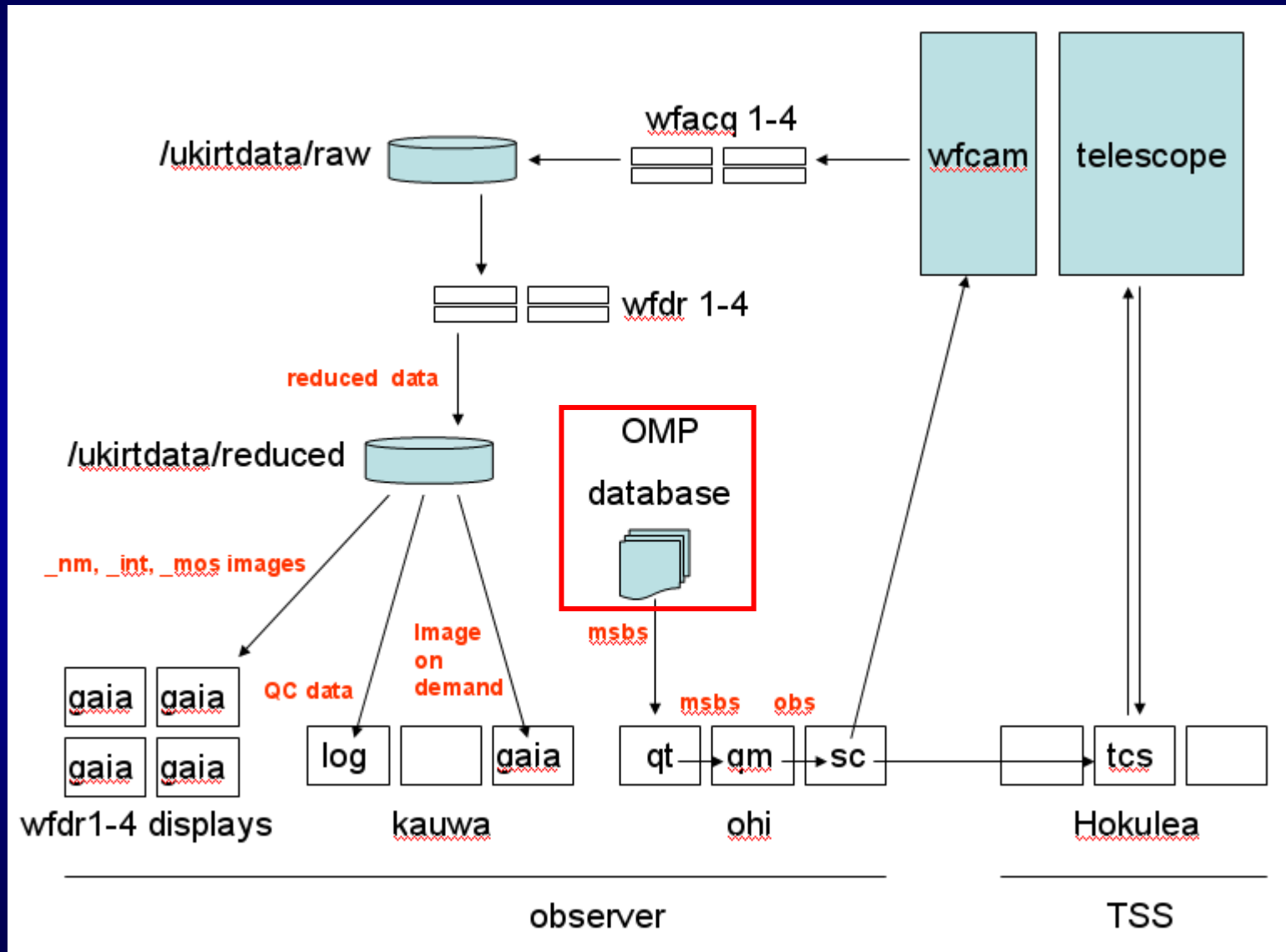
"MSBs"



OMP Block Diagram



Summit information flow



Observation Management (2003-)

The screenshot displays the Observation Management software interface. It features a main window with a menu bar (File, View, Edit, Help, Calibrations) and a toolbar with buttons for Search, Fetch MSB, and Exit. A sidebar on the left shows 'Current Info' for 'goeswest.4km UTC' with fields for CSO Tau, Seeing, and Airmass, along with a 'Set Default' button. The main area is divided into several panels:

- Query Panel:** Shows 'No Observations' and a 'Project ID' field.
- Retrieved MSBs Panel:** Lists observation requests, with a red box highlighting the text 'Change Filter and Flush - H(38.5 seconds)' and a series of 'H obs(54.0 seconds)' entries.
- Deferred MSBs Panel:** Currently empty.
- Observer Notes Panel:** Contains text under the heading 'LAS EXECUTION NOTES':

There are two types of MSB in this project: YJ and HK types.

YJ MSBs have priority over HK MSBs at all times. This means that if an LAS HK MSB is top of the queue, but there is a YJ MSB observable, please execute the YJ MSB.

Previously there was an attempt to pair up YJ and HK MSBs from the same area i.e. if one of the pair had been executed, to observe the other as soon as possible after. This no longer applies.
- Expand Observation Panel:** A button labeled 'Expand Observation'.

At the bottom, a table displays observation details:

projectid	priority	proj	projectid	priority	waveband	title	target	ra	dec	ha	airmass	seeing	timeest
All	0	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	las5e:LAS5...	23.3/23.1/...	4.5/4.3	-2.3/-2.0/...	1.250/1.20...	< 1.1	00h37m17s
U/UKIDSS/LAS5E	46	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.4/23.5/...	4.3/4.5	-2.3/-2.0	1.259/1.25...	< 1.1	00h37m17s
U/UKIDSS/GPS17C	49	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.6/23.7/...	4.3/4.5	-2.6/-2.3/...	1.325/1.31...	< 1.1	00h37m17s
U/UKIDSS/DXS26	49	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.9/24.0/...	4.3/4.5/5....	-2.9/-2.8/...	1.409/1.39...	< 1.1	00h37m17s
U/UKIDSS/GPS13D	50	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	las5e:LAS5...	23.3/23.4/...	5.2/5.4	-2.3/-2.0/...	1.250/1.24...	< 1.1	00h37m17s
U/CMP/2	55	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.7/23.8/...	5.2/5.4	-2.7/-2.6/...	1.347/1.33...	< 1.1	00h37m17s
U/CMP/3	56	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.4/23.5/...	5.2/5.4	-2.4/-2.1	1.271/1.26...	< 1.1	00h37m17s
U/UKIDSS/B1	99	U/UKIDSS	U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	22.6/22.7/...	8.8/9.0	-1.6/-1.5/...	1.104/1.10...	< 1.1	00h37m17s
			U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	23.7/23.8/...	5.2/5.4	-2.7/-2.6/...	1.347/1.33...	< 1.1	00h37m17s
			U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	22.9/23.0/...	8.8/9.0/9...	-1.9/-1.8/...	1.143/1.13...	< 1.1	00h37m17s
			U/UKIDSS/LAS5E	46	H/K	LAS_5e_eas...	WFCAM Cal/...	24.0/0.0/2...	5.2/5.4/6.0	-3.0/-2.9/...	1.427/1.41...	< 1.1	00h37m17s
			U/UKIDSS/LAS5E	46	H/K	LAS_5e_wes...	WFCAM Cal/...	22.8/22.9/...	9.7/9.9	-1.7/-1.4	1.124/1.11...	< 1.1	00h37m17s



SCHEDULING

Service Programme

Reactive Scheduling

Pair Flexing

Full Flexible Scheduling



Service Observing

Commenced in 1980s

One of the first such programmes

<3h projects

> 1700 projects

Produces 25% of UKIRT publications

First refereeing experience for many



UKIRT OPERATIONS

20

UKIRT NEWSLETTER • SPRING 2009 • #24

25 Years of Service Observing at UKIRT (and Counting...)

Chris Davis (UKIRT Senior Support Scientist)

Versatility and opportunity have always been key pieces of the observing puzzle at UKIRT. This is particularly true with the Service observing programme, which has been in operation since the early 1980s.

UKIRT was officially opened in October, 1979. Two of UKIRT's first instruments were UKT1 and UKT2, each a single-channel photometer/scanner working with a focal-plane chopper. The suite of detectors rapidly expanded (see Table 1 and Figure 1), and it was not long before a service observing programme was proposed. Andy Longmore recalls suggesting in 1983 (or thereabouts) a means by which U.K. astronomers could obtain quick follow-up observations to discoveries made with the soon-to-be-launched IRAS satellite. Such fast-track data collection might give UK astronomers an edge in the rapidly-advancing field of infrared astronomy. With email now linking astronomers across the globe, peer review of proposals without the panel ever having to meet was now a possibility. Tim Hawarden, based at the Royal Observatory, Edinburgh at the time (though part of the UKIRT Division), suggested extending 'IRASserv' to include any fast-turn-around observations. A fully fledged service programme would also allow astronomers to try out ideas before putting in full PATT proposals, and would facilitate synoptic studies that required relatively brief observations of slowly-varying objects spread over months or even years. The idea for UKIRTserv was put to the UKIRT Users Committee, and soon after, the Service observing programme was born.

By 1984 the programme was in full swing, and had already been awarded "long-term" status by the UKIRT Panel for the Allocation of Telescope Time (PATT). One of the first service projects undertaken was photometry of a supernova in NGC 991. The PI of the project, J. Gra-

ham (Imperial College, London), later reported in an *IAU Circular* that "the object has been designated as both Type I and Type II. The blue H-K colour [from the UKIRT observations] is atypical of Type II but similar to the colours of Type I supernovae". The supernova was later defined as a peculiar (under-luminous) Type I object.

Right from the start, a wide range of projects were attempted in service mode: from spectroscopic monitoring of Nova Vul between 1 and 4 μm to J -band spectroscopy of the active galaxy NGC 5506 (Figure 2); from some of the first maps and spectroscopy of molecular hydrogen line emission in outflows from young stars (Figure 3), to monitoring of "BL Lac type and Quasar-like" sources; from imaging of edge-on spiral galaxies and galaxies with cooling flows to spectroscopy of silicate features in galactic IRAS sources. At the time, these were often ground-breaking and very exciting observations!

Tom Geballe, staff astronomer at UKIRT from 1981 to 1990 and Head of Operations from 1990 until late 1998, remembers one of the first service nights with CGS4. On June 29, 1991, Tom was the observer. He recalls that "the service night occurred after two array detectors had been damaged and we were



Figure 1. — A youthful Tetsuomi tops up the liquid nitrogen A UKT6 at the Cassegrain focus of UKIRT (c. 1982). UKT6 can be seen to its left. (Image courtesy Royal Observatory Edinburgh.)

down to the engineering detector — which turned out to be more stable and in some ways better than the 'science grade' arrays; the engineering device lasted until it was replaced by the (current) 256x256 array in 1995. CGS4 had been put on the telescope in the spring of 1991, although not a lot of science had been done with it up to that

Service Observing, continued on page 21)

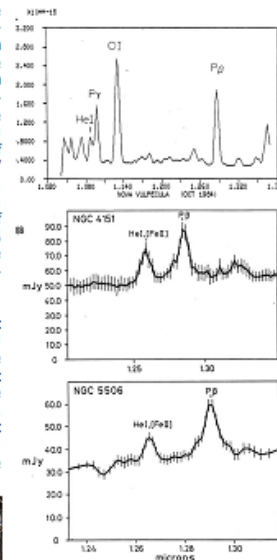
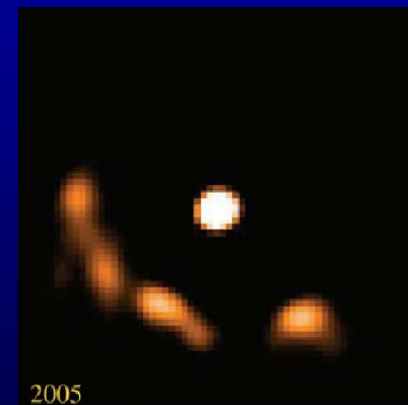
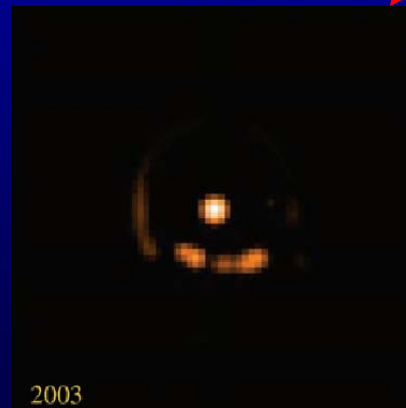
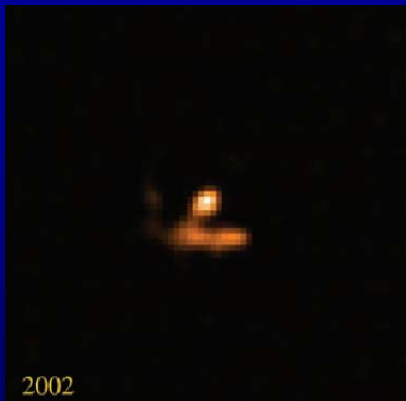
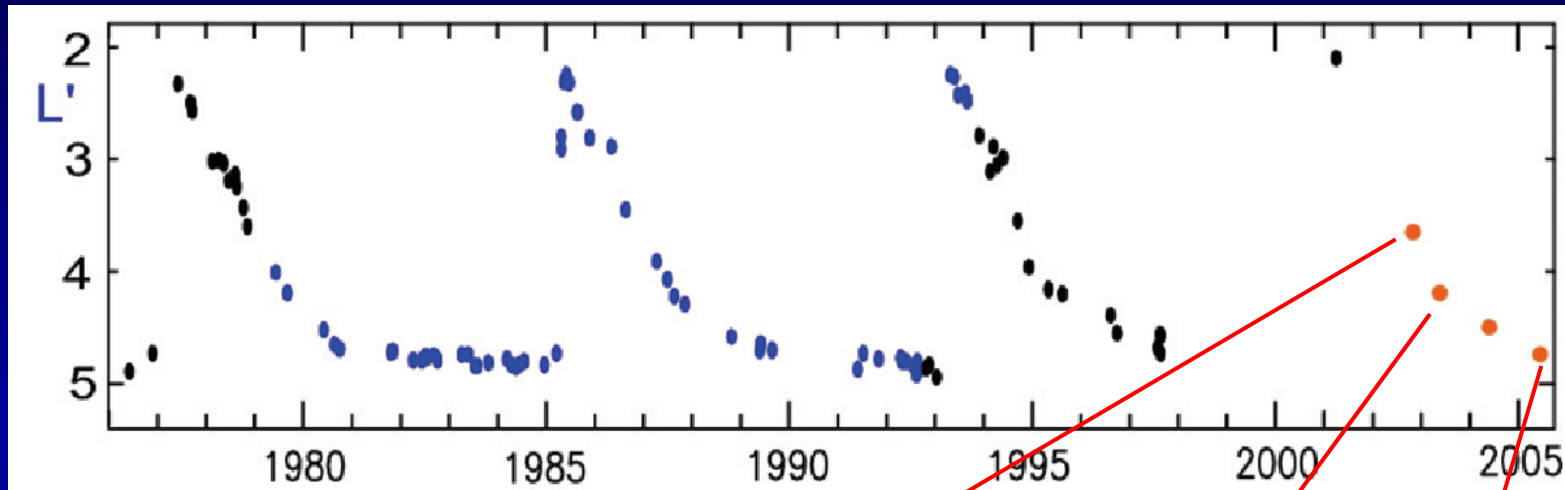


Figure 2. — (upper panel) A CCS2 spectrum of Nova Vul 1984 No. 1 (Nova Vul) taken in October 1984. This was one of a series of spectra covering 1-4 μm , taken at 2 month intervals following the Nova event. At the time, suggestions were sought for the narrow and intermediate transitions seen in the spectra. In 1984 a second nova in Vulpecula (Nova Vul 1984 No. 2) was also observed in UKIRT service time. (lower panels) A CCS2 spectrum of the active galaxy NGC 5506. Near-IR data were needed to probe the dust-obscured nucleus of this galaxy. These service data, acquired in 1988 also pilot study for Martin Hard et al., revealed for the first time both narrow and broad components to the Pa- β line, demonstrating the true nature of this Seyfert 1 nucleus (the Seyfert 1 galaxy NGC 4151) was observed for comparison.

See article by Chris Davis in the most recent UKIRT newsletter



Service Observing



Reactive Scheduling (1999-2000)

Introduced as a prelude to flexible scheduling

Aimed at selective completion

Staff nights set aside in the semester



Reactive Scheduling (1999-2000)

nov1999

Date	Day	Observers	Prog	Inst	SS	TSS	Comment	Moon	UT
1NOV	Mon	Hodgkin,Jameson,Kenyon,Irwin	49*	UFTI	(Adamson)	Wold	-	3rd Q	2-nov
2NOV	Tue	" " " "	"	"	"	"	ESA Election Day.	-	3-nov
3NOV	Wed	Dunne	08*	UFTI	Kerr	Davis	-	-	4-nov
4NOV	Thu	" "	"	"	(")	"	-	-	5-nov
5NOV	Fri	" "	"	"	(")	"	-	-	6-nov
6NOV	Sat	" "	"	"	(")	Carroll	ESA Shift	-	7-nov
7NOV	Sun	Dobbie,Kenyon	React	UFTI	Davies	"	Rcvr 49,ESA Shift	New	8-nov
8NOV	Mon	" "	"	"	"	"	-	-	9-nov
9NOV	Tue	" "	"	"	"	"	Rcvr 49 or 08	-	10-nov
10NOV	Wed	Rees :Davies (Lucas)	ENG:42	UFTI	Davies	"	TCS +Service mode	-	11-nov
11NOV	Thu	Davies	Serv:ENG	UFTI:WFS	"	"	Veterans Day	-	12-nov
12NOV	Fri	Davis	ENG	TUFTI+POL	Davis	"	-	-	13-nov
13NOV	Sat	Kerr,Kuhn	ENG	CGS4	Kerr	Wold	CGS4 Checkout	-	14-nov
14NOV	Sun	" "	"	"	"	"	-	-	15-nov
15NOV	Mon	Garnavich	H16A	UFTI	"	"	-	1st Q	16-nov
16NOV	Tue	" "	"	"	(")	"	-	-	17-nov
17NOV	Wed	Dunne	08*	UFTI	(Davies)	"	-	-	18-nov
18NOV	Thu	Geballe	65	CGS4+ech	"	Kuhn	+Wold, o/r + visit	-	19-nov
19NOV	Fri	" "	"	"	(")	"	-	-	20-nov
20NOV	Sat	Chrysostomou	03*	CGS4+IRPOL	Davis	"	-	-	21-nov
21NOV	Sun	" "	"	"	(")	"	-	-	22-nov
22NOV	Mon	Chrysostomou	19	UFTI + IRPOL	(")	"	-	-	23-nov
23NOV	Tue	Davis,Ray	33	CGS4+ech	Davis	Carroll	ESA Shift	Full	24-nov
24NOV	Wed	" "	"	"	"	"	-	-	25-nov
25NOV	Thu	" "	"	"	"	"	Thanksgiving	-	26-nov
26NOV	Fri	Lucas:(Fassia),Geballe	42:16	CGS4(40)+TUFTI	Leggett	"	-	-	27-nov
27NOV	Sat	" "	"	CGS4(40)+UFTI	(")	"	-	-	28-nov
28NOV	Sun	" "	"	"	(")	"	-	-	29-nov
29NOV	Mon	" "	"	"	(")	Wold	-	-	30-nov
30NOV	Tue	Garnavich, Marx	H16A	UFTI	Kerr	"	-	3rd Q	1-dec



Pair Flexing (2001-2002)

An experiment in both scheduling and social engineering

Could observers do each other's projects and/or stand aside while at the summit?

Answer: yes, UKIRT observers could do it



Pair Flexing (2001-2002)

aug2000

Date	Day	Observers	Prog	Inst	SS	TSS	Comment	Moon	UT
1AUG	Tue	Kerr,Hirst	CGS4 ENG	CGS4	Kerr	Wold	Need to Chec	New	2-aug
2AUG	Wed	Kerr,Hirst	CGS4 ENG	CGS4	Kerr	"	before ORAC	-	3-aug
3AUG	Thu	Kerr,Hirst,Davis	ORAC ENG	UFTI,CGS4,FP,POL	Economou	"	Edge proj?	-	4-aug
4AUG	Fri	Kerr,Hirst,Davis,Leggett	ORAC ENG	UFTI,CGS4,FP,POL	Economou	Varricatt	Edge proj?	-	5-aug
5AUG	Sat	Kuhn	H29B	IRCAM+POL	Leggett	"	-	-	6-aug
6AUG	Sun	Kuhn	H29B	IRCAM+POL	(")	"	-	-	7-aug
7AUG	Mon	Staff	QA	WFS,UFTI	Adamson	"	-	1st Q	8-aug
8AUG	Tue	Hirst,Davis,Economou	ORAC ENG	UFTI,CGS4,FP,POL	Davis	"	-	-	8-aug
9AUG	Wed	Crawford,Fabian,Gandhi	20 F +	UFTI	Hirst	Carroll	Flex 62 for	-	10-aug
10AUG	Thu	Crawford,Fabian,Gandhi	20 F	UFTI	(")	"	Flex 62 for	-	11-aug
11AUG	Fri	Levine,Lada,Elston	62 F	UFTI	(")	"	Flex 62 for	-	12-aug
12AUG	Sat	Levine,Lada,Elston	62 F	UFTI	(")	"	Flex 62 for	-	13-aug
13AUG	Sun	Clark,Steele:staff	51 F :Serv	CGS4+150:UFTI	Kerr	"	Flex 60 for	-	14-aug
14AUG	Mon	Clark,Steele:Jones,Ellis,Fairly	51 F :28	CGS4+150:UFTI	(Kerr):Hirst	Wold	Flex 60 for	-	15-aug
15AUG	Tue	Clark,Steele:Jones,Ellis,Fairly	51 F :28	CGS4+150:UFTI	(") :Hirst	"	Flex 60 for	Full	16-aug
16AUG	Wed	Rawlings,Adamson:Staff	60 F :DDT +	CGS4+40+UFTI+IRCA	Adamson:Adamson	"	Flex 60 for	-	17-aug
17AUG	Thu	Rawlings,Adamson:Staff	60 F :DDT	CGS4+40+UFTI+IRCA	(") :Adamson	"	Flex 60 for	-	18-aug
18AUG	Fri	Rawlings,Adamson:Staff	60 F :DDT	CGS4+40+UFTI+IRCA	(") :TBD	"	Flex 60 Admi	-	19-aug
19AUG	Sat	Rawlings,Adamson:Staff	60 F :DDT	CGS4+40+UFTI+IRCA	(") :TBD	Kuhn	Flex 60 for	-	20-aug
20AUG	Sun	(Eyres),Geballe:Staff	LT46:Serv	CGS4+UFTI	Hirst	"	-	-	21-aug
21AUG	Mon	Staff	Serv +	CGS4+UFTI+IRCAM	Hirst	"	-	-	22-aug
22AUG	Tue	Bunker,Warren	25	CGS4+150	Kerr	"	-	3rd Q	23-aug
23AUG	Wed	TRISPEC Team	TRISPEC ENG	TRISPEC	Davis	"	-	-	24-aug
24AUG	Thu	Yamazaki,Sato,TRISPEC group,Hou	44	TRISPEC+IRPOL	(")	Carroll	-	-	25-aug
25AUG	Fri	Chrysostomou, Hough,Gledhill,M	23	TRISPEC+IRPOL	(")	"	-	-	26-aug
26AUG	Sat	Chrysostomou, Hough,Gledhill,M	23	TRISPEC+IRPOL	(")	"	-	-	27-aug
27AUG	Sun	Harries,Cropper:Jameson,Dobbie	22:54	TRISPEC+IRPOL	Davis	"	-	-	28-aug
28AUG	Mon	Harries,Cropper:Jameson,Dobbie	22:54	TRISPEC	(")	"	-	-	28-aug
29AUG	Tue	Harries,Cropper:Jameson,Dobbie	22:54	TRISPEC	(")	Wold	-	New	30-aug
30AUG	Wed	Harries,Cropper:Jameson,Dobbie	22:54	TRISPEC	(")	"	-	-	31-aug
31AUG	Thu	Kuhn	H29B	IRCAM+POL	Hawarden	"	-	-	1-sep



Flexible Scheduling (2003-)

Unique points:

- Visiting observers do all the observing
- Flexibility in submission and alteration
- Allows for significant involvement on the part of PIs through the semester

Prerequisites:

- DR pipeline for immediate feedback on data quality
- Distributed preparation tools
- Observation database



Flexible Scheduling (2003-)

jan2009

Date	Day	Observers	Prog	Inst	SS	TSS	Comment	Moon	UT
1-Jan	Thu	(Burningham)	(15)	uf	(wpv)	Ehle	New Year's Day em	-	2-jan
2-Jan	Fri	"	"	"	"	"	-	-	3-jan
3-Jan	Sat	"	"	"	"	"	-	1st Q	4-jan
4-Jan	Sun	"	"	"	"	Wold	-	-	5-jan
5-Jan	Mon	staff	QA	c/uf/ui	cjd	"	em	-	6-jan
6-Jan	Tue	staff	eng	"	cjd	"	em	-	7-jan
7-Jan	Wed	staff	serv	"	cjd	"	-	-	8-jan
8-Jan	Thu	Smith,Pathak,Kerr	22	ui	thk	Carroll	-	-	9-jan
9-Jan	Fri	"	"	"	thk	"	em	full	10-jan
10-Jan	Sat	"	"	"	thk	"	em	-	11-jan
11-Jan	Sun	"	"	c/uf/ui	"	"	-	-	12-jan
12-Jan	Mon	Yang	h85	ui	lr	"	-	-	13-jan
13-Jan	Tue	"	"	"	"	Ehle	-	-	14-jan
14-Jan	Wed	Aoki	j4	"	aja	"	em	-	15-jan
15-Jan	Thu	Cirasuolo,Pearce	12	uf	thk	"	em	-	16-jan
16-Jan	Fri	"	"	"	"	"	-	-	17-jan
17-Jan	Sat	"	"	"	"	"	-	3rd Q	18-jan
18-Jan	Sun	"	"	"	"	Wold	-	-	19-jan
19-Jan	Mon	"	"	"	"	"	MLK Day em	-	20-jan
20-Jan	Tue	Oi	j9	c/uf/ui	aja	"	em	-	21-jan
21-Jan	Wed	Simeonidis,Oates	32	"	aja	"	-	-	22-jan
22-Jan	Thu	"	"	"	"	Carroll	-	-	23-jan
23-Jan	Fri	"	"	"	"	"	em	-	24-jan
24-Jan	Sat	"	"	"	"	"	em	-	25-jan
25-Jan	Sun	staff	q/serv	c/uf/ui	cjd	"	-	new	26-jan
26-Jan	Mon	Closed (start of 09A)	-	-	-	-	WFCAM on	-	27-jan
27-Jan	Tue	Closed	-	-	-	-	-	-	28-jan
28-Jan	Wed	staff	eng	wfcam	thk	Ehle	-	-	29-jan
29-Jan	Thu	staff	eng	"	thk	"	07b20	-	30-jan
30-Jan	Fri	staff	QA	"	aja,jk?	"	-	-	31-jan
31-Jan	Sat	staff	ukidss	"	aja,jk?	"	-	-	1-feb



Flexible Scheduling (2003-)

The final Cassegrain night...

U/08B/32: Characterising the ionised winds in X-ray absorbed QSOs – UIST spec

U/08B/15: Follow-up of late T and Y dwarf candidates from UKIDSS – UFTI im

U/08B/24: H3+ in translucent cloud sight lines – CGS4 ech

U/SERV/1624: Infrared observations of nova V445 Puppis - UIST im

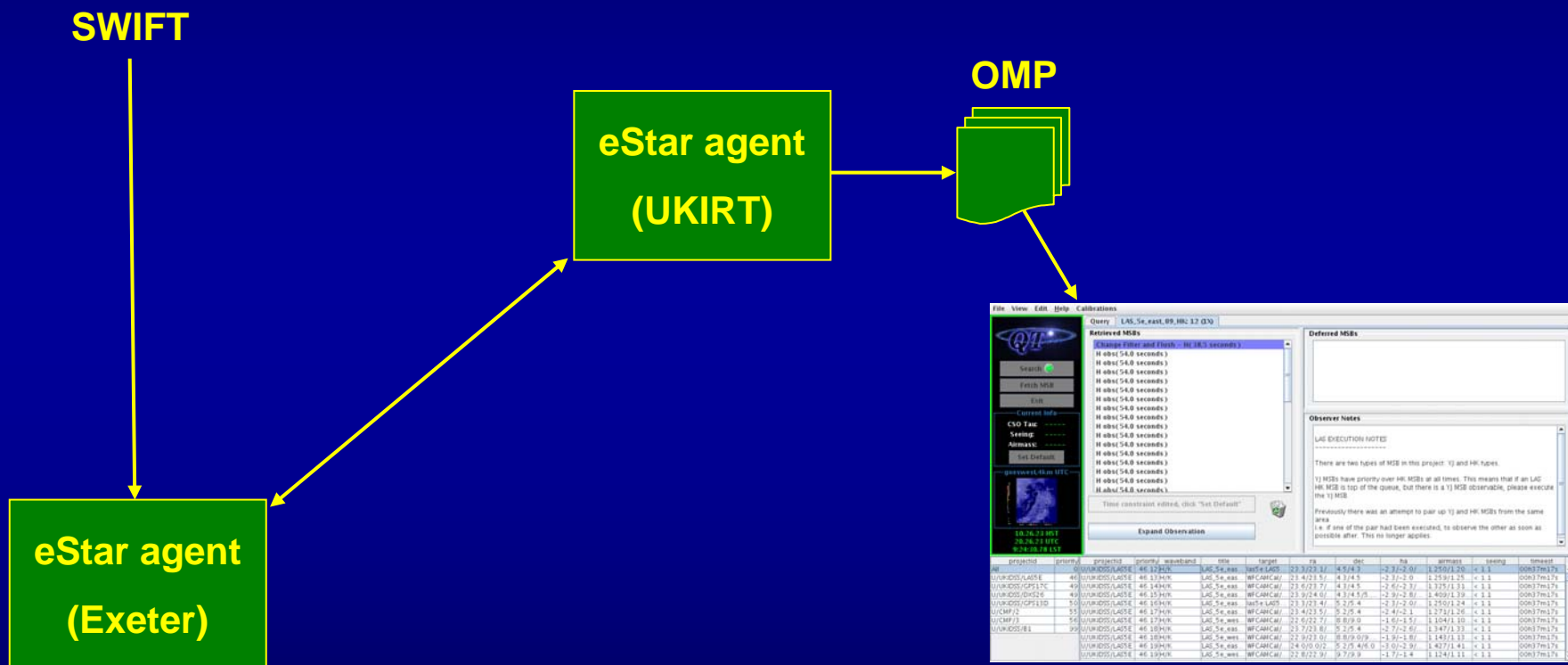
U/SERV/1810: Atmospheric structure of pulsating carbon stars – UIST spec

U/SERV/1811: Photometry of a young embedded cluster – UFTI,UIST im



eStar

Fully automated GRB overrides



Recent result: z=8.2 GRB (Tanvir et al.)

Next: Neutrino triggering



Current UKIRT Science Mix

UKIDSS Sky Survey (flexed)

UH, Japan, Korea PI projects (mostly classical)

Campaigns (mix of semi-classical, reactive, overrides)

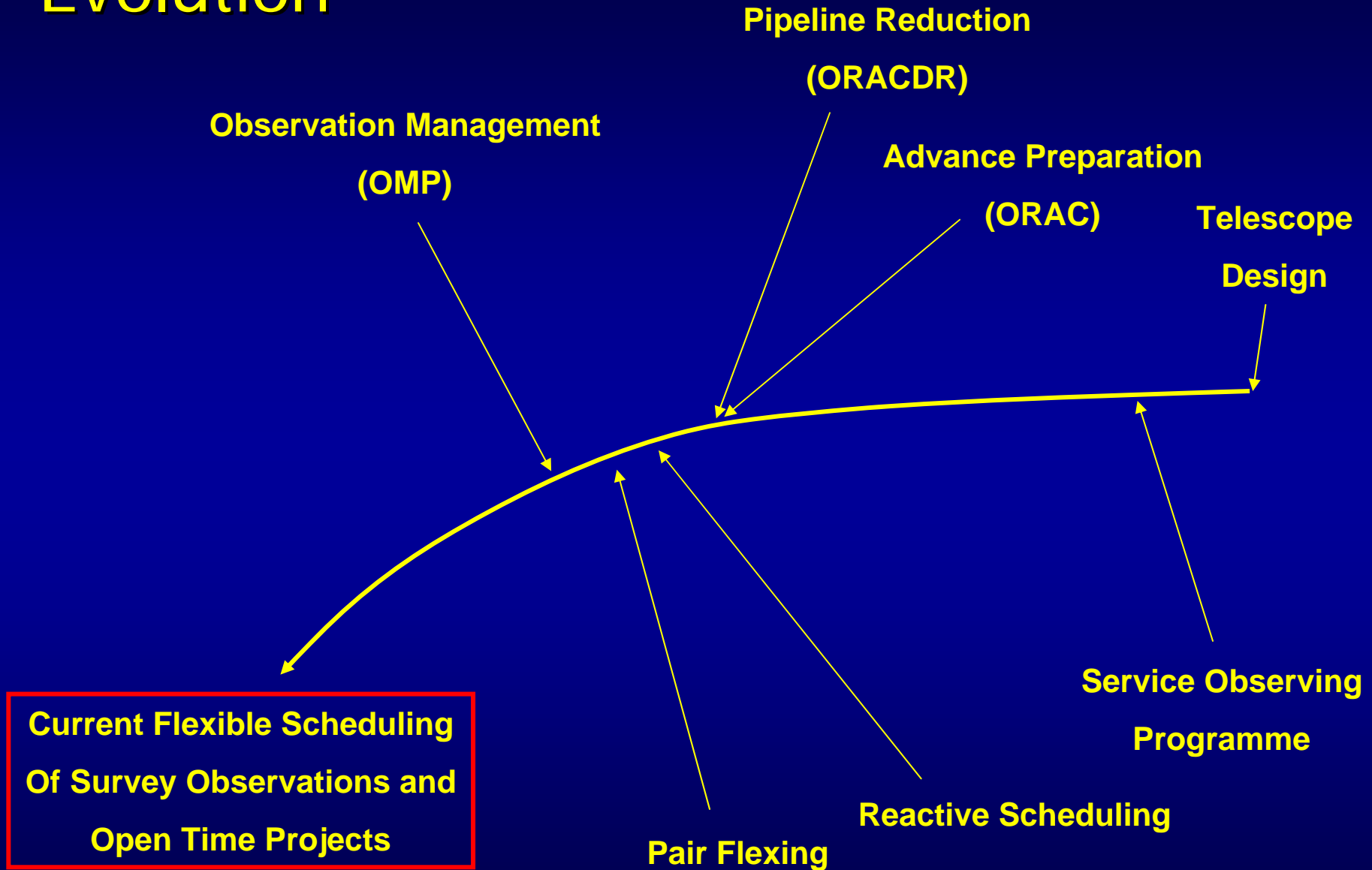
Open Time (flexed within defined schedule blocks)

Service Programme (flexed within defined schedule blocks)

Monitoring projects (UH, UKIDSS followup)



Evolution



In Conclusion



<http://outreach.jach.hawaii.edu/> ...and look for “The center of our milky way”



Caveats

A significant fraction of the development work referred to here was carried out outside the JAC.

The JCMT can also lay legitimate claim to some of the innovations described here.

Developments at UKIRT have often paralleled those elsewhere.

Preaching to the converted...



Evolution

