Wide Angle Surveys

ROYAL OBSERVATORY EDINBURGH

- Why are surveys good ?
- UKIDSS overview
- Recent survey science
- The future

Why are surveys good ?

What is a survey ?

- Two step process
- Summarise sky
- The archive becomes the sky
- Science done with the archive

===> backbone of Virtual Observatory
(see AstroGrid demo !)

Why survey ?

- cost effective
  - many experiments from same data
- supports other experiments
  - create samples to observe elsewhere (follow-up)
  - match with observations made elsewhere (follow-down ?)
- produces surprises
  - first looks in new corners of parameter space
  - new populations

Why wide angle ?

- statistics : large samples
  - accurate function estimation : eg galaxy power spectrum
  - weak signal recovery : e.g. grav lensing
  - wider always faster than deeper
- large structures
  - eg Clusters, Milky Way, Dipole
- rare objects
  - eg Y dwarfs, z=7 quasars

Rich Heritage

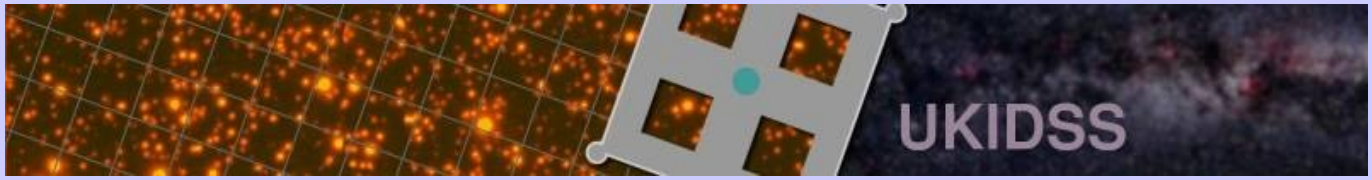
- Radio : 3C, 4C ...
- IR : IRAS, 2MASS, **UKIDSS**
- Optical : APM, SuperCOSMOS, SDSS
- X-ray : Ariel-V, XMM
- Z-surveys PSC-z, 2dFGRS, SDSS-z

the core of modern astronomy

UKIDSS overview

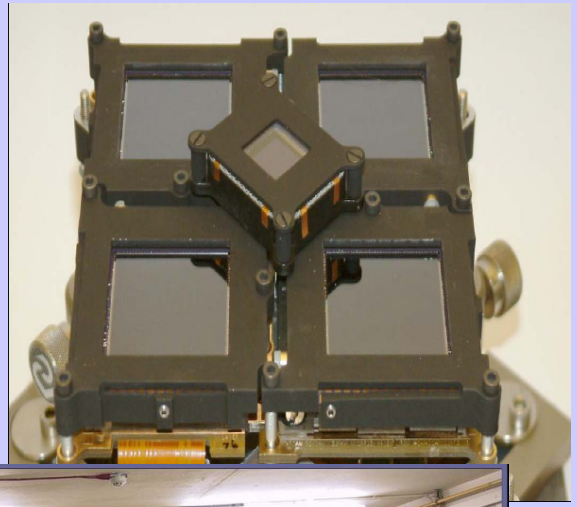
The UKIRT Infrared Deep Sky Survey

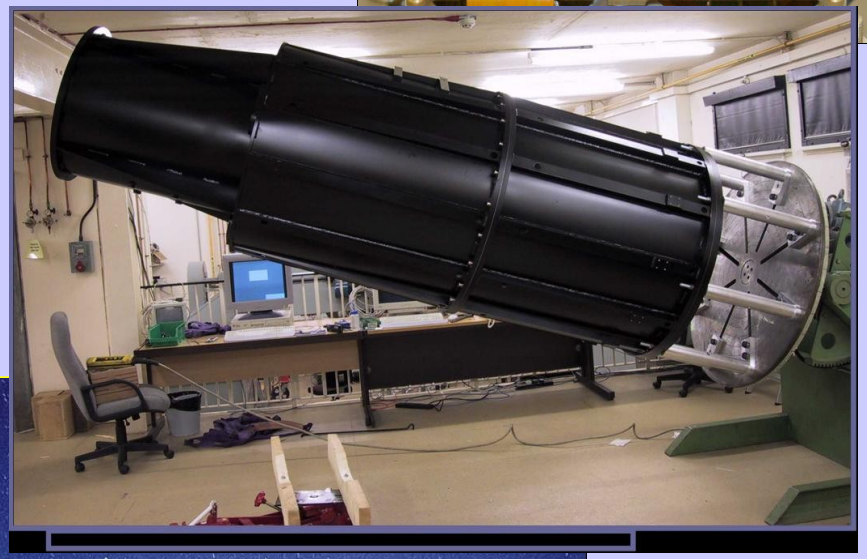
- Andy Lawrence, Steve Warren, Omar Almaini, Richard Jameson, Alastair Edge, Phil Lucas, Nigel Hambly, Mike Irwin, Mark Casali, Simon Dye, Andy Adamson, Paul Hirst ... and about a hundred others ....

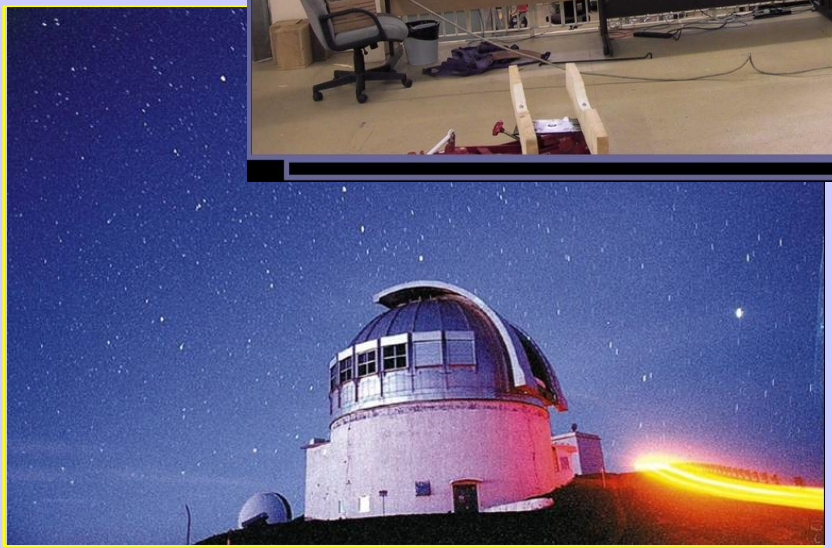


UKIDSS

- ESO public survey
- uses new UKIRT
  Wide Field Camera (WFCAM)
- 1000 nights over 7yrs
- UKIDSS = 20 X 2MASS volume
- near-ir SDSS
- began 2005 May 13

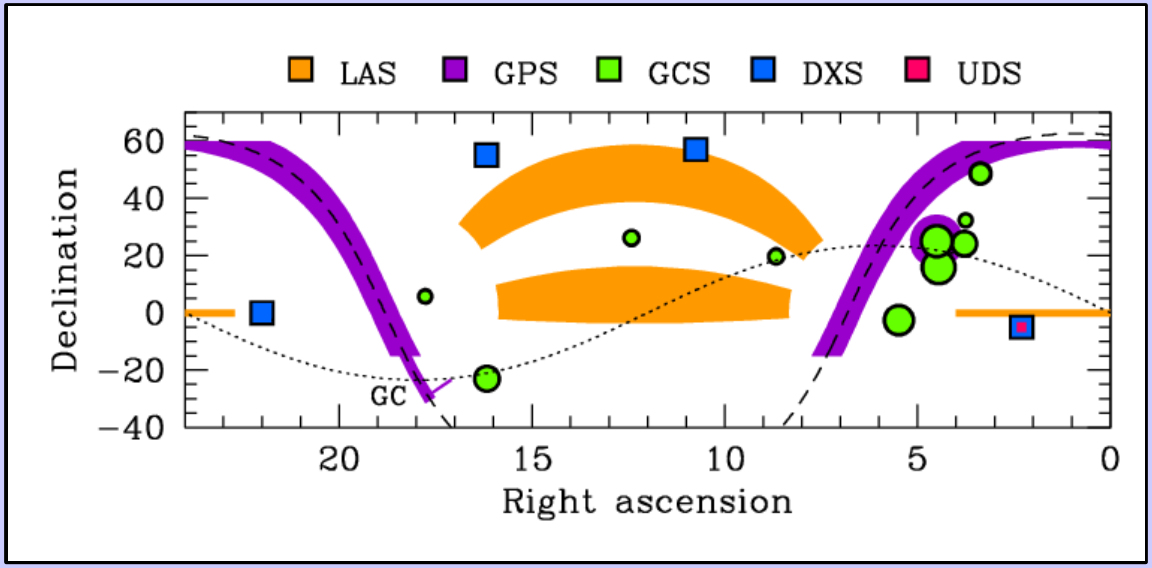






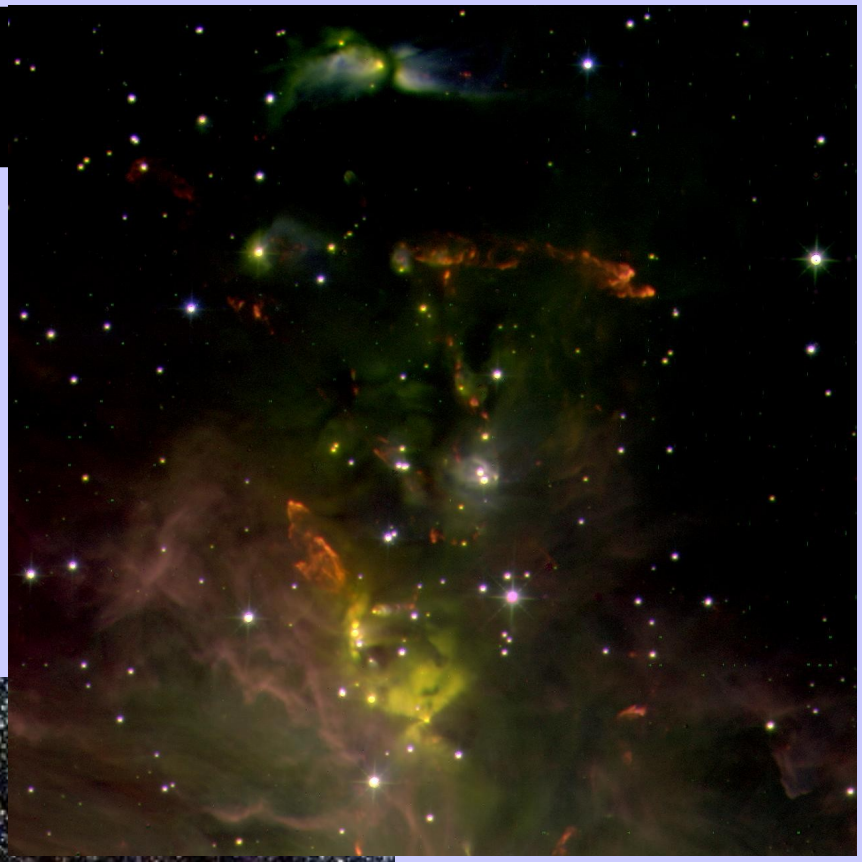
UKIDSS design

Large Area Survey	LAS	YJHK	18.2K	4028 s.d.	262n	ExGal
Deep Extragalactic Survey	DXS	JK	20.8	35	118	ExGal
Ultra Deep Survey	UDS	JHK	22.8	0.77	296	ExGal
Galactic Plane Survey	GPS	JHK	19.0	1868	186	Gal
Galactic Clusters Survey	GCS	ZYJHK	18.6	1067	84	Gal

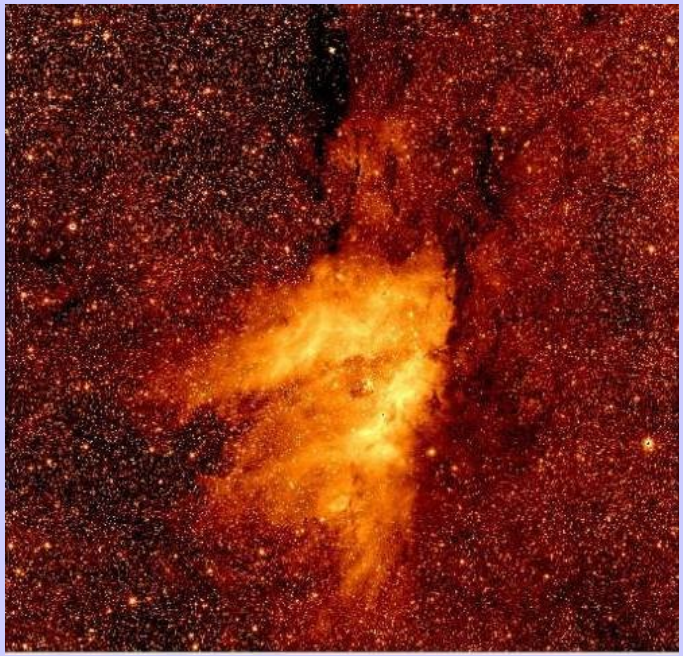


WFCAM pix

NGC 891



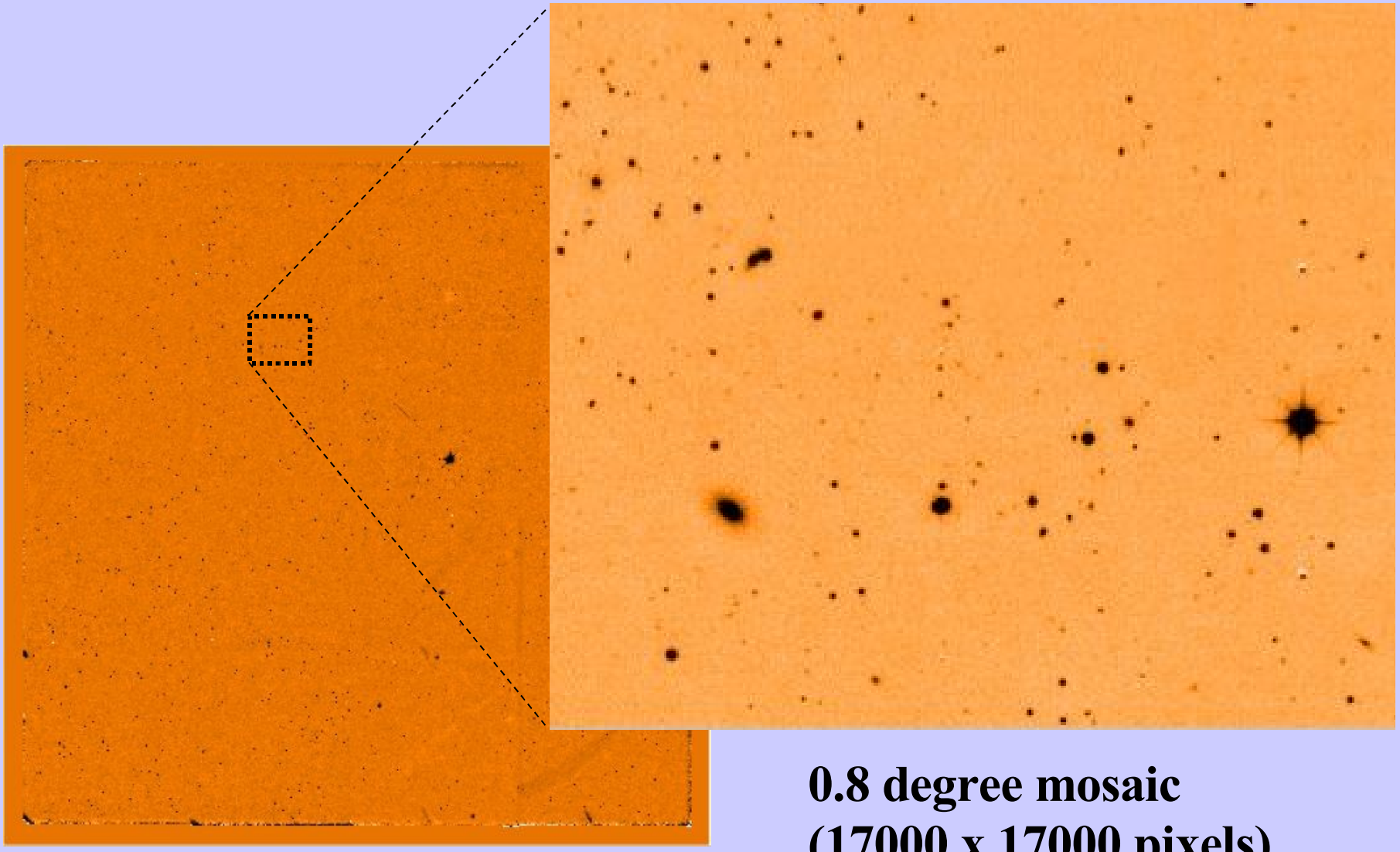
ORION



M17 UKIDSS

M17 2MASS

scary amounts of data



0.8 degree mosaic
(17000 x 17000 pixels)

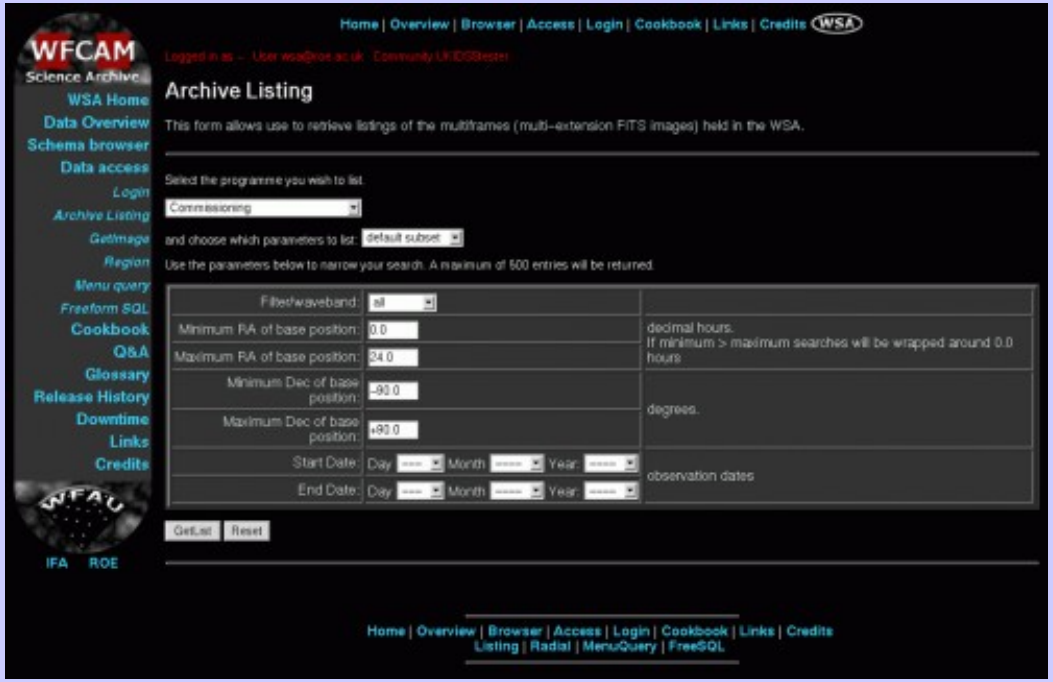
Specific goals

- find the nearest and faintest sub-stellar objects
- break the z=7 quasar barrier
- determine the epoch of re-ionisation
- determine the substellar mass function
- discover Pop II brown dwarfs, if they exist
- construct a galaxy catalogue at z=1 as large as the SDSS catalogue
- measure the growth of structure and bias from z=3 to the present day
- determine the epoch of spheroid formation
- clarify the relationship between quasars, ULIRGs, and galaxy formation
- map the Milky Way through the dust, to several kpc
- increase the number of known Young Stellar Objects by an order of magnitude, including rare types such as FU Orionis stars

Data Access

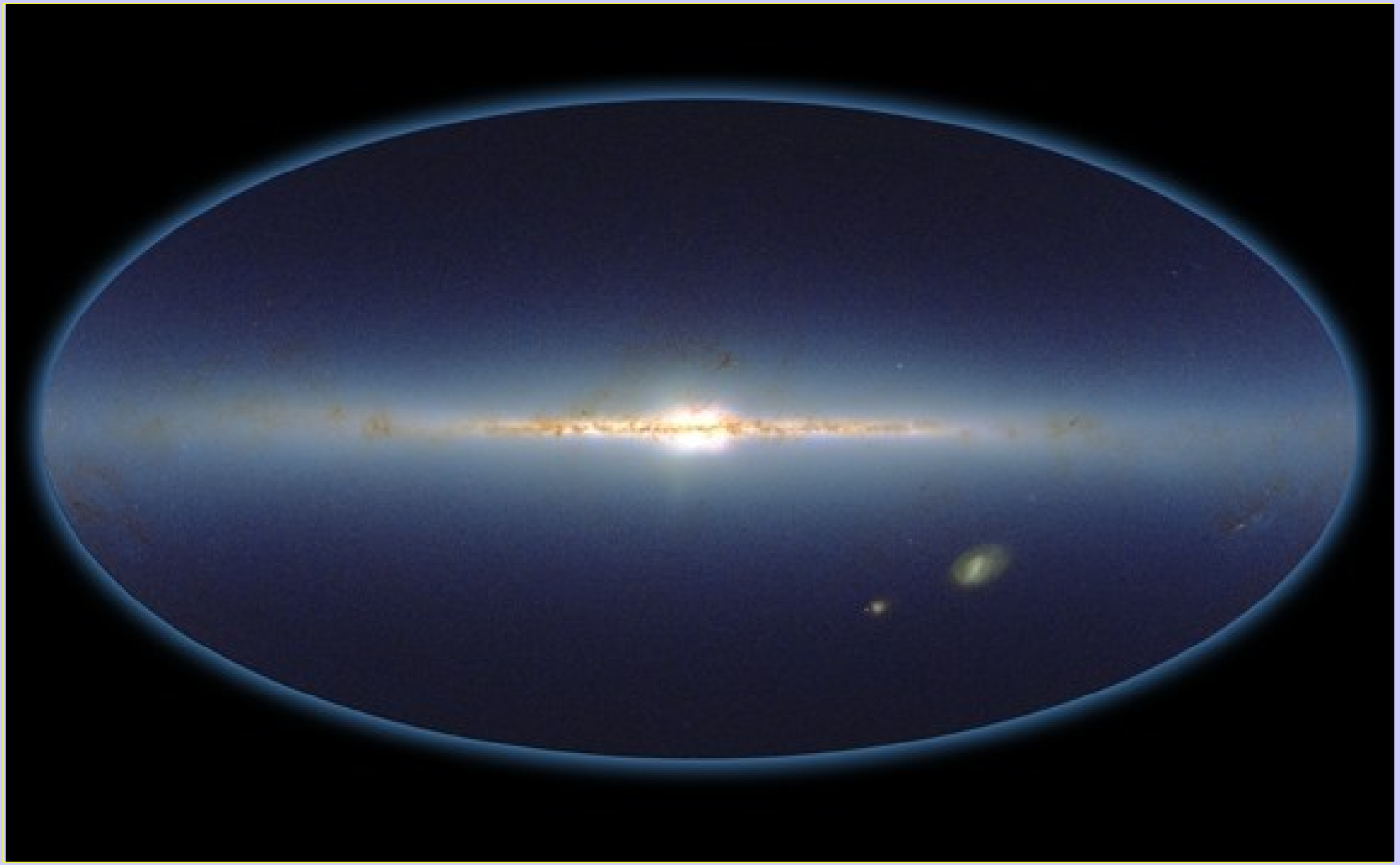
- Raw data : CASU and ESO
- Science ready data : WFCAM Science Archive
  - **http//surveys.roe.ac.uk/wsa**
- Public ESO wide in staged releases
- Public World-Wide at +18months

- Early Data Release (EDR)
  10 Feb 2006 (~1%)
- Data Release One (DR1)
  July 2006 (~10%)
- Completion ~2012



Survey Science

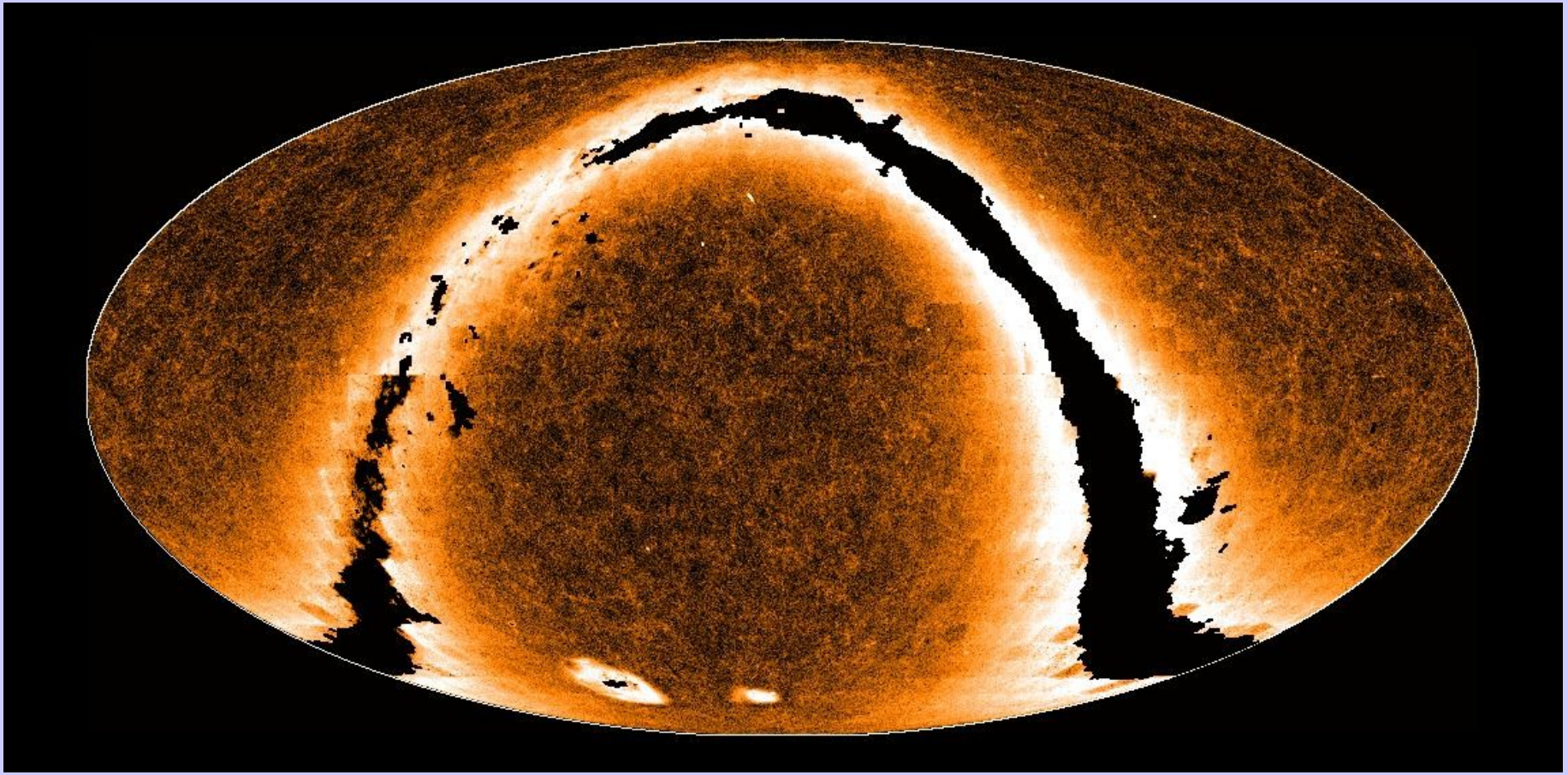
Large Structures : Milky Way



2MASS all sky map

Large Structures : local Universe 2D

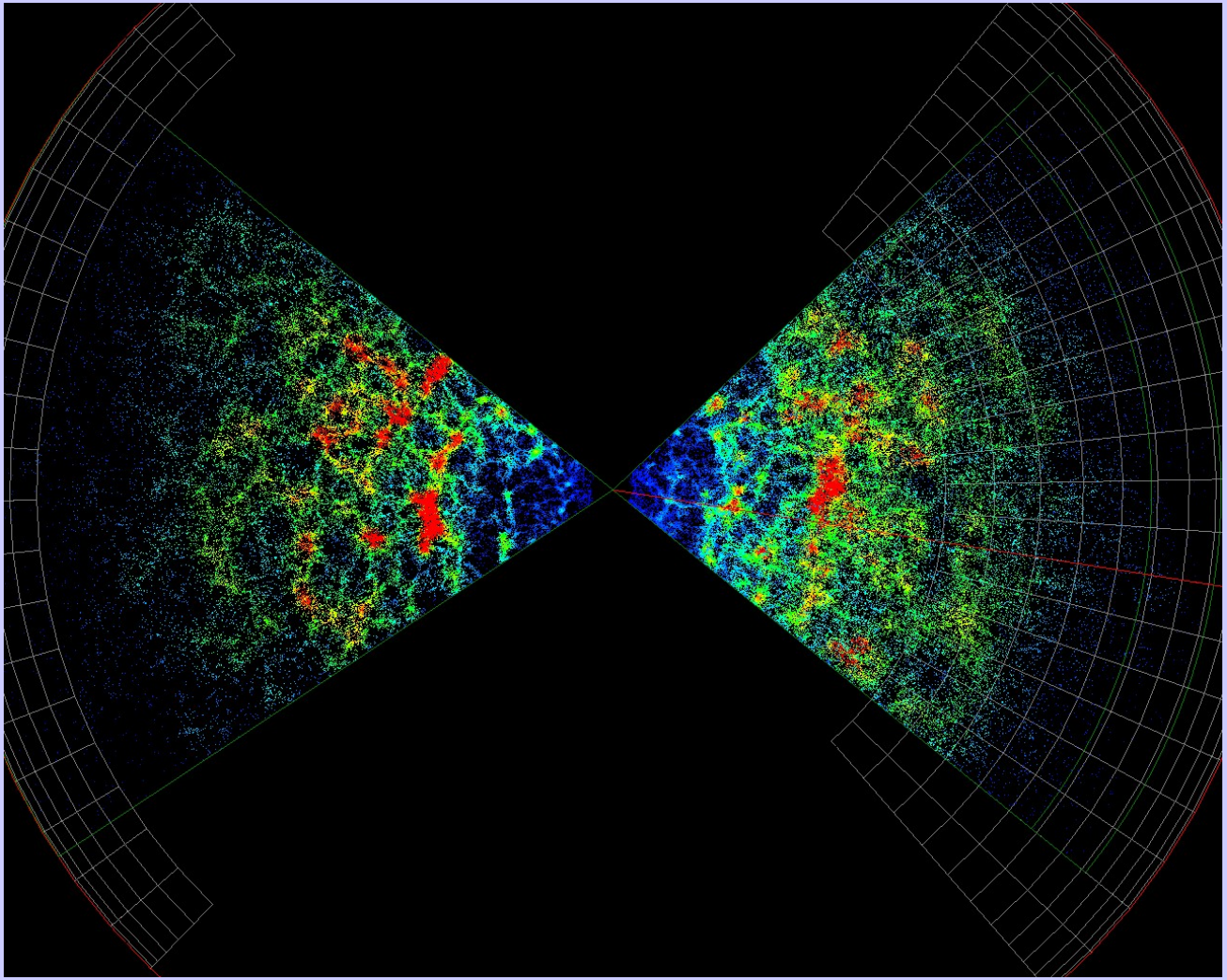
SuperCOS + 2MASS BRJHK nearby galaxy catalogue



Peacock et al in progress

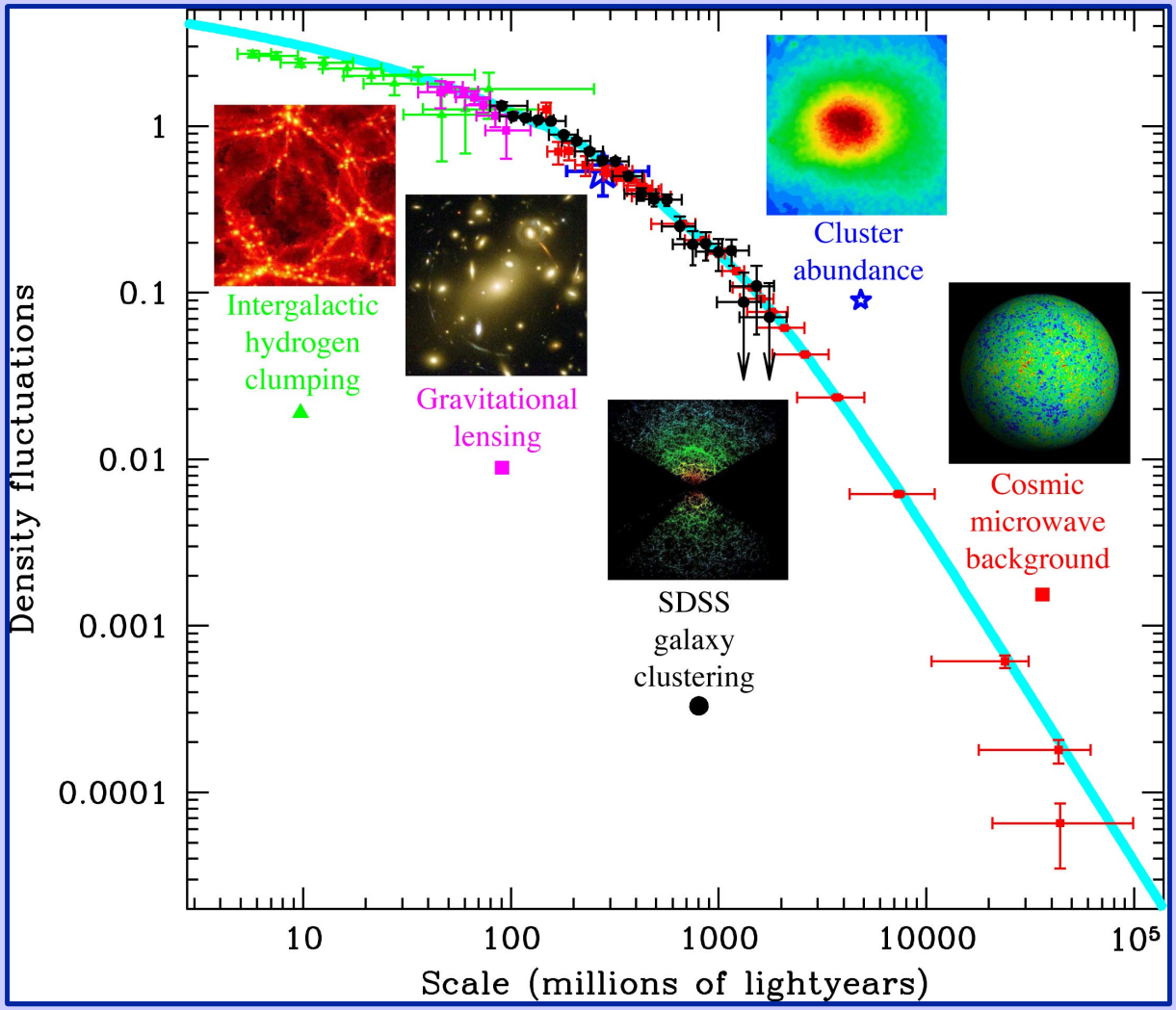
Large Structures : Local Universe 3D

3000 Mpc



2dF Galaxy Redshift Survey

Power spectrum

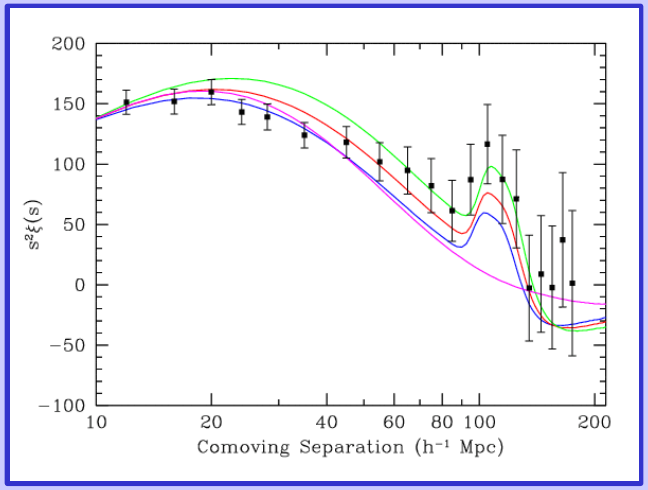


fit requires

1% matter
29% dark matter
70% vacuum energy

From SDSS website

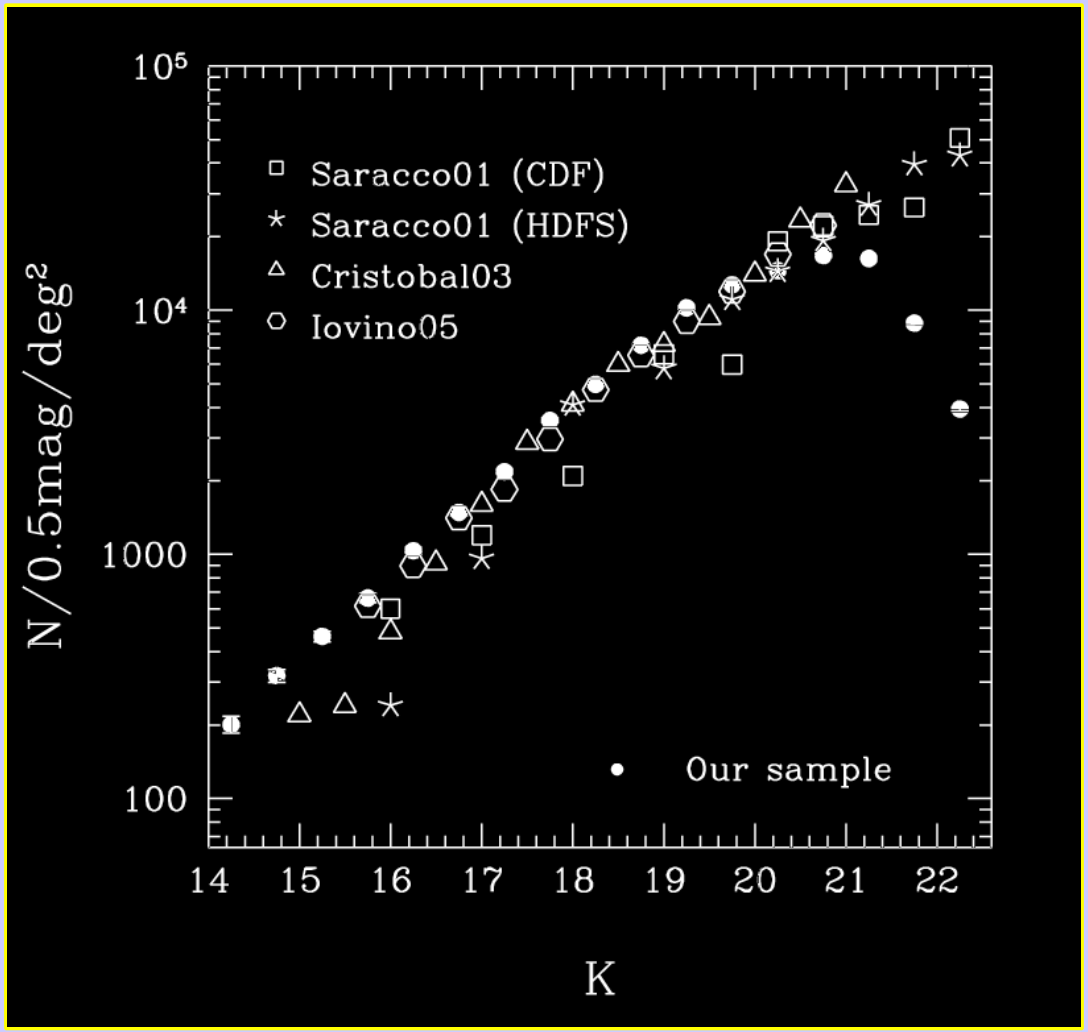
detection of baryon acoustic oscillations



UKIDSS DXS : LSS at z=1

- Result from SV programme
- 6 hours data
- 0.8 sq.deg.

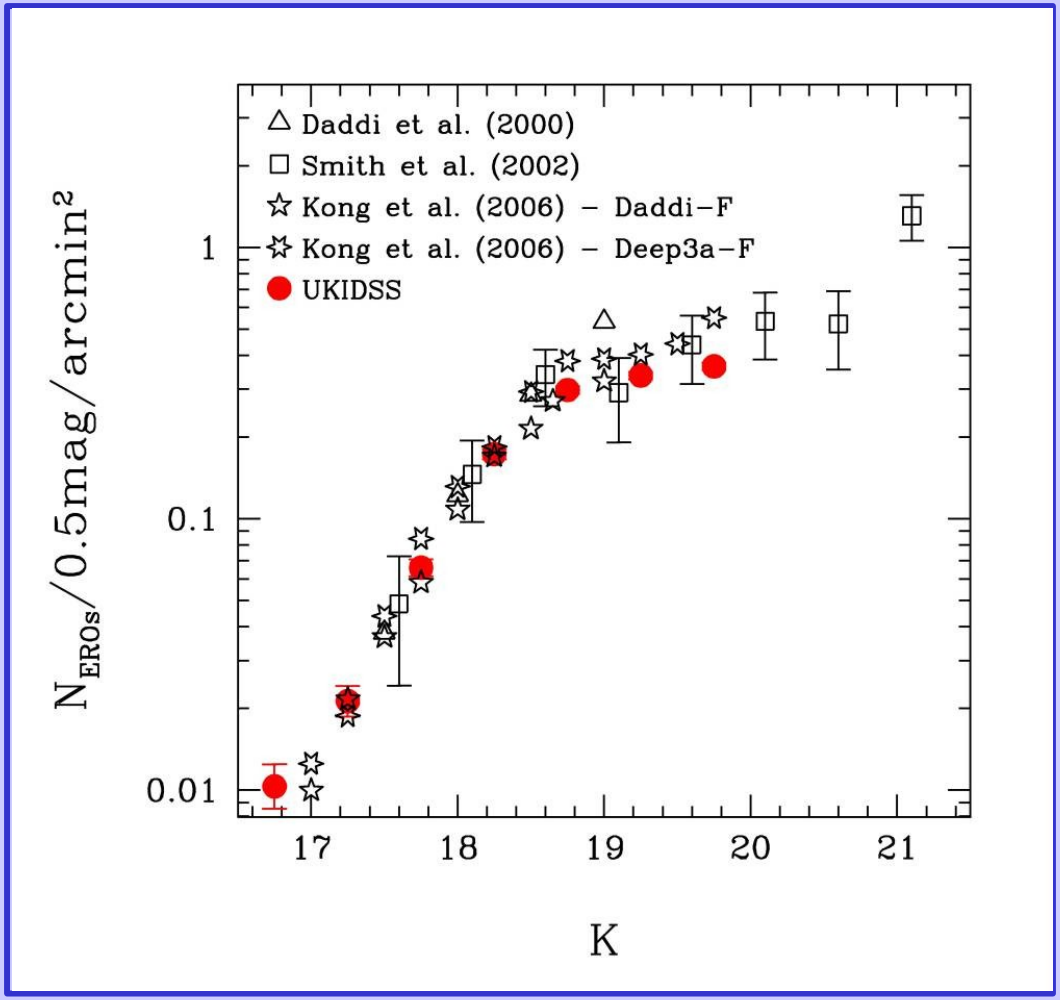
- Final dataset will be one mag deeper and 45 times larger



Almaini, Edge, Foucaud, et al

rare objects : EROS

- crossmatch with INT-WFS
- select R-K>5
- 1660 EROs with tiny fraction of DXS and UDS data



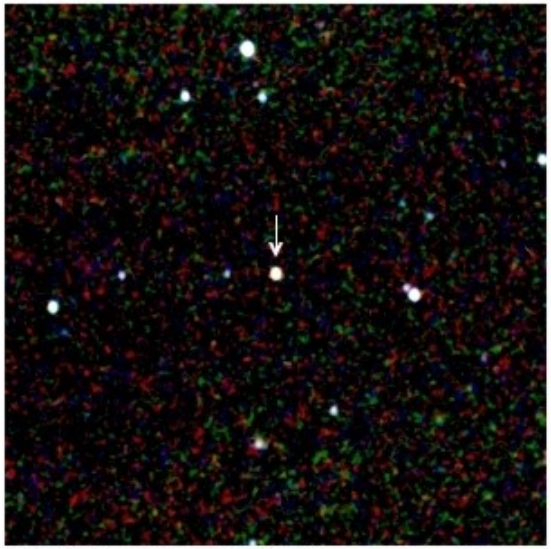
Almaini, Edge, Foucaud, et al

Rare objects : Brown Dwarfs

2MASS J1146+2230

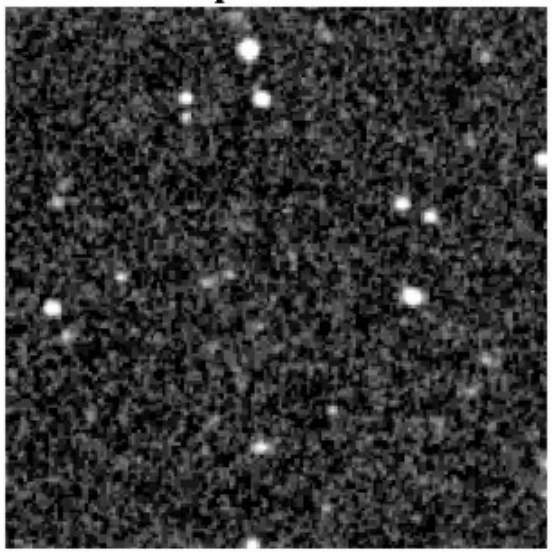
An L–type dwarf in the constellation Leo

The near–infrared view



2MASS Atlas JHK_s Composite Image

The optical view



Palomar Digitized Sky Survey

2MASS
2 MICRON ALL-SKY SURVEY

J.D. Kirkpatrick (IPAC/Caltech), I.N. Reid (Caltech), R.M. Cutri (IPAC/Caltech), C.A. Beichman (IPAC/JPL/Caltech), J. Liebert (U of A), M.F. Skrutskie (UMass)

The 2MASS project is a collaboration between the University of Massachusetts and IPAC

Kirkpatrick et al

rare objects : very nearby stars

SCR1845-6357

d=3.5pc M8.5

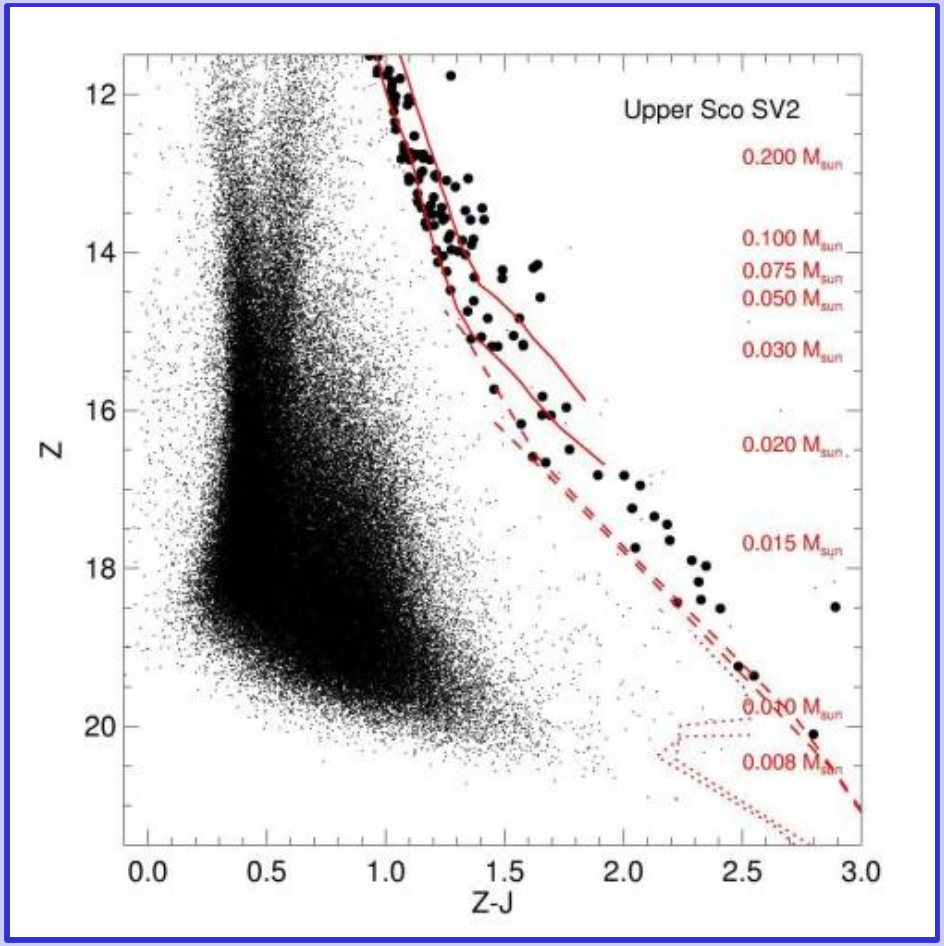
Deacon et al., 2005

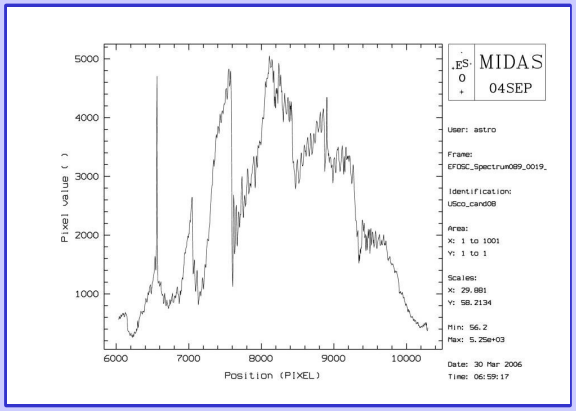
found with
2MASS colours and
SuperCOSMOS proper motions

UKIDSS GCS : large substellar sample

- SV obsvns : Upper Sco
- 6 square degrees
- 100,000 objects
- Cluster members clear
- down to 10Jupiter masses
- <10MJ by Z-dropout

```
-- Upper Sco CMD from SV data:
SELECT zAperMag3-jAperMag3 AS zmj, zAperMag3
FROM   gcsSource
WHERE  dec < 0.0 AND jAperMag3>10.5 AND zAperMag3>11.5
       AND zClass BETWEEN -2 AND -1
       AND jClass BETWEEN -2 AND -1
       AND jXi BETWEEN -1.0 AND +1.0
       AND jEta BETWEEN -1.0 AND +1.0
```



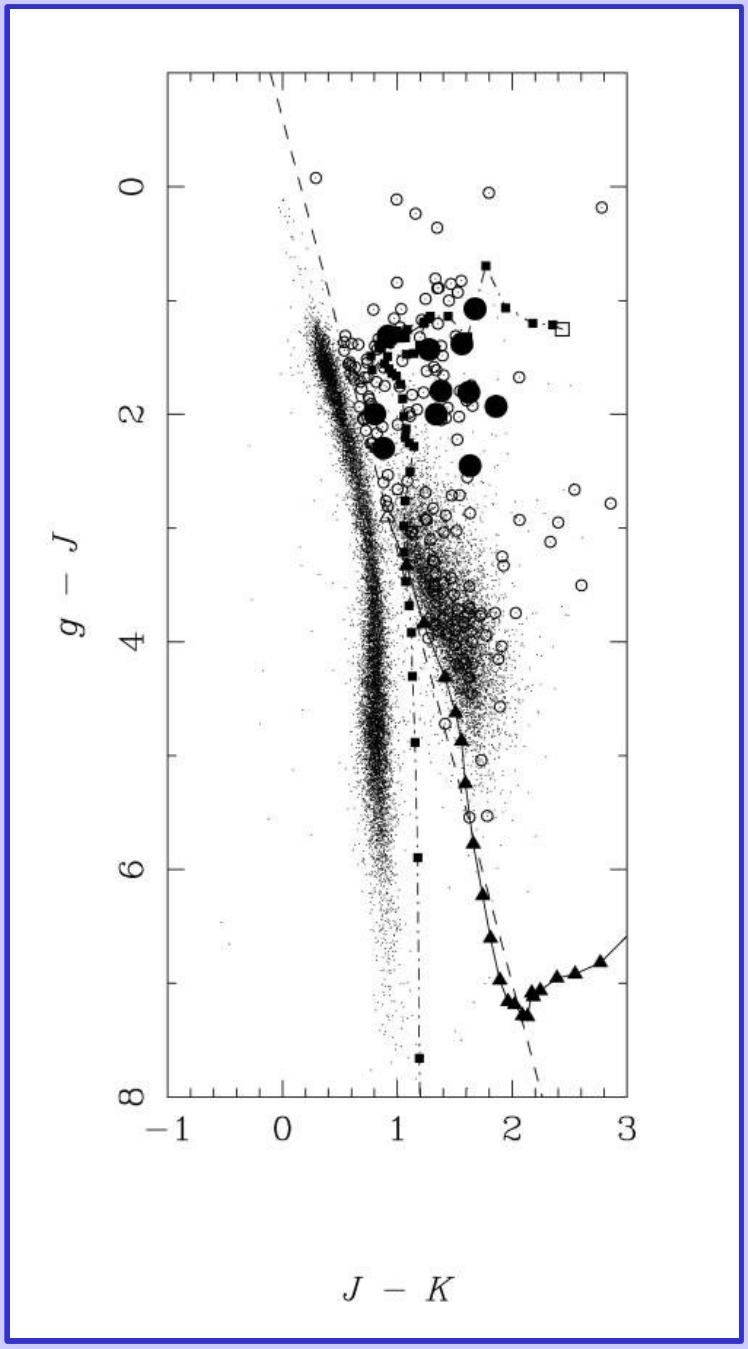


hot off the press...

Lodieu, Hambly, et al

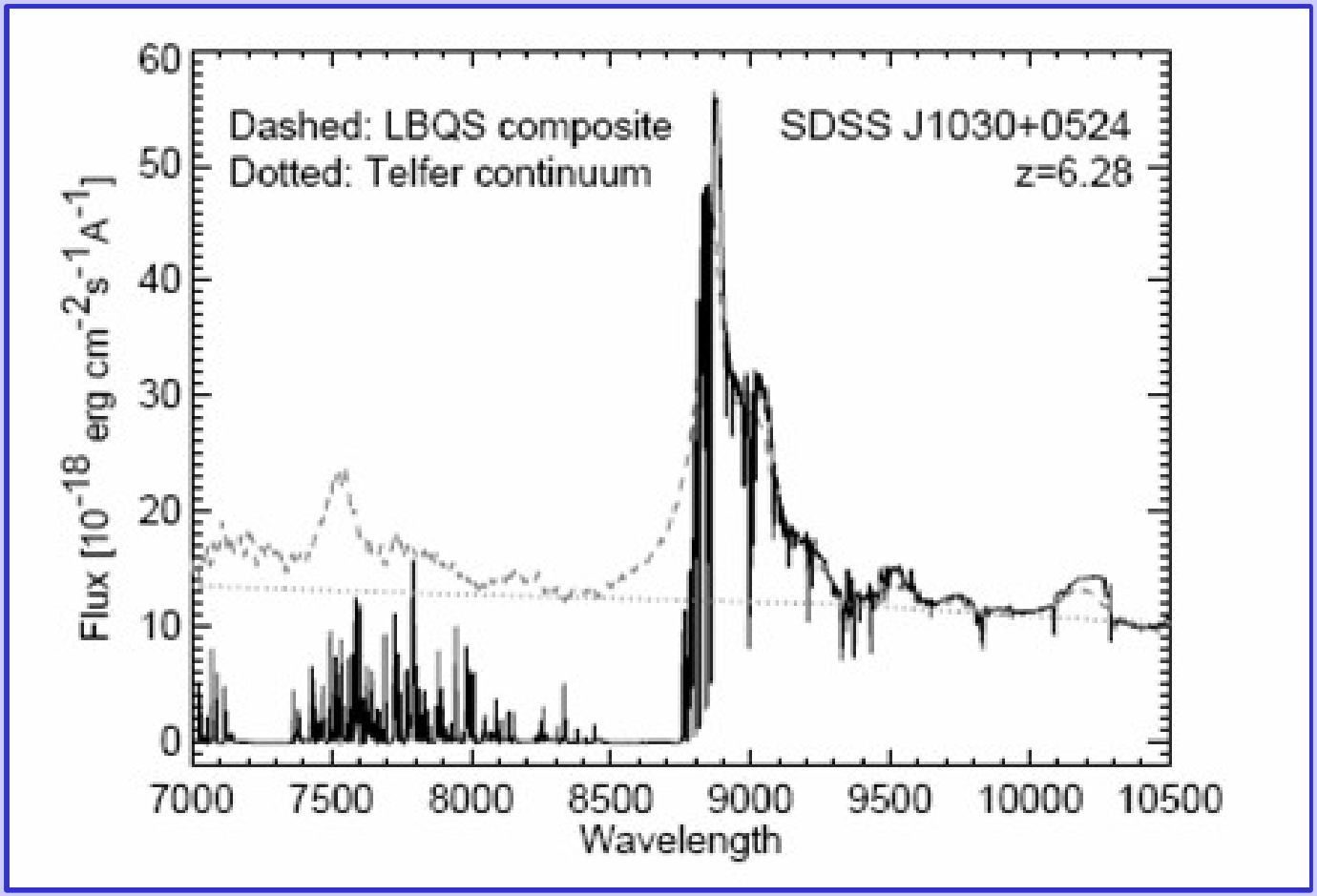
UKIDSS LAS : large reddened quasar sample

- LAS SV programme
- 20 sq.degrees
- 21,000 sources to K=16.5
- 11 SDSS quasars re-found
- 167 new quasar candidates
- final survey 2 mags deeper and 200 times larger



Mortlock, Warren, Hewett et al

Rare objects : z=6 quasars

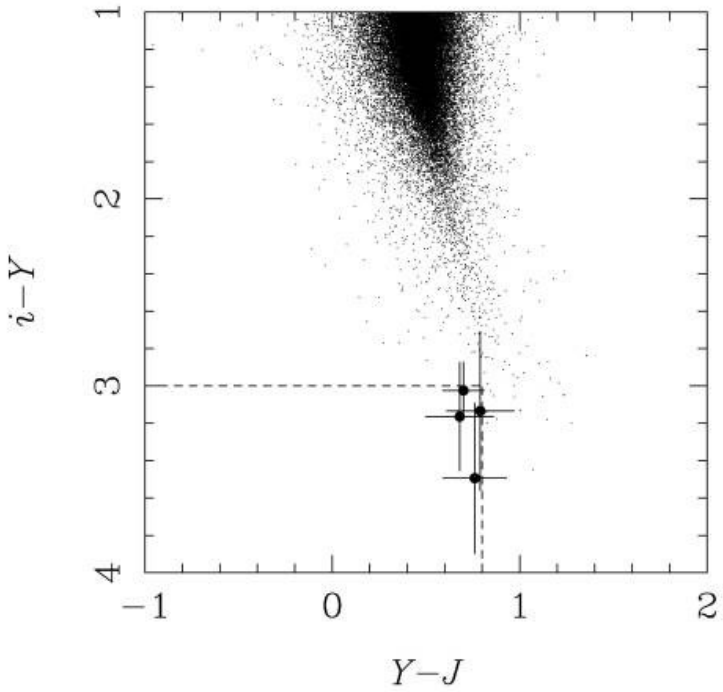


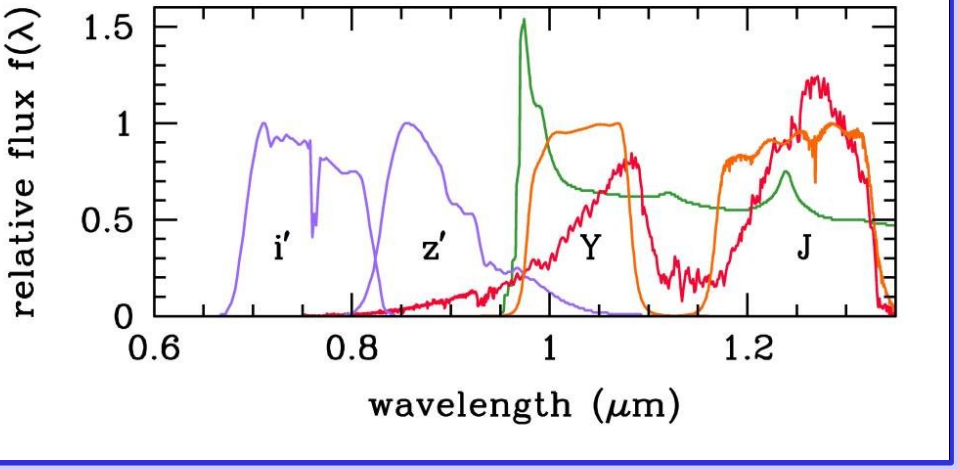
White et al 2001

first detection of Gunn Peterson trough (Becker et al 2001)
IGM re-ionised at z~6
WMAP-Y1 says z~10-20; WMAP-Y3 says z~8 ?

UKIDSS LAS : 10 pc *vs* z=7 ??

- z dropout finds very red objects
- Y-J separates T dwarfs and high-z quasars
- predict 10 quasars z=6-7
- predict 4 quasars z=7-8





EDR sample (30 sq deg) :
4 candidates (Mortlock, Warren et al)

DR1 expectation (150 sq deg) :
20 cands *vs* 1 quasar predicted at z>6

Low contamination rate

The future

Next steps in OIR surveys

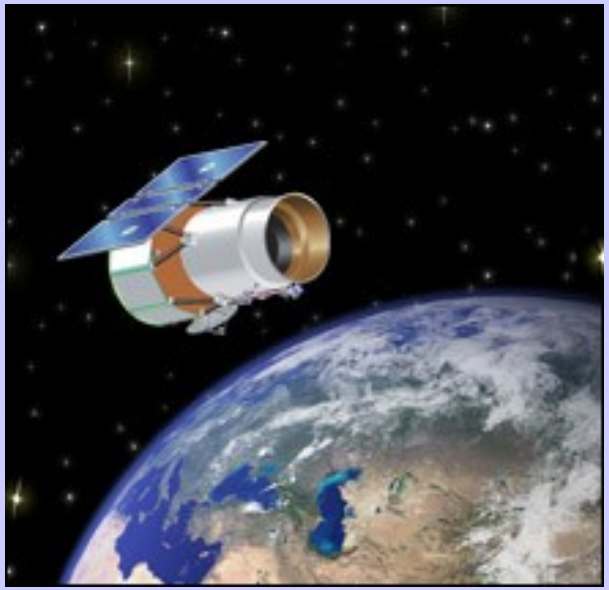
- Now : AKARI : all-sky FIR
- Soon : VST
- Soon : Pan-Starrs
- Soon : SkyMapper
- 2007 : VISTA : WFCAM x 6
- 2010 : WISE : all-sky MIR
- 2015 : LSST : half-sky every few nights

Future Skymapping Projects

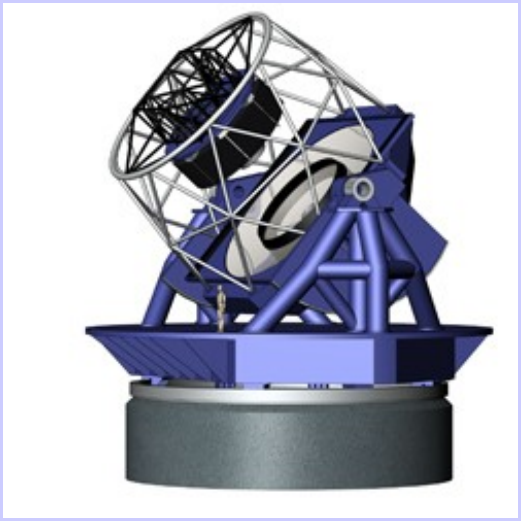
VISTA

VST

PanStarrs

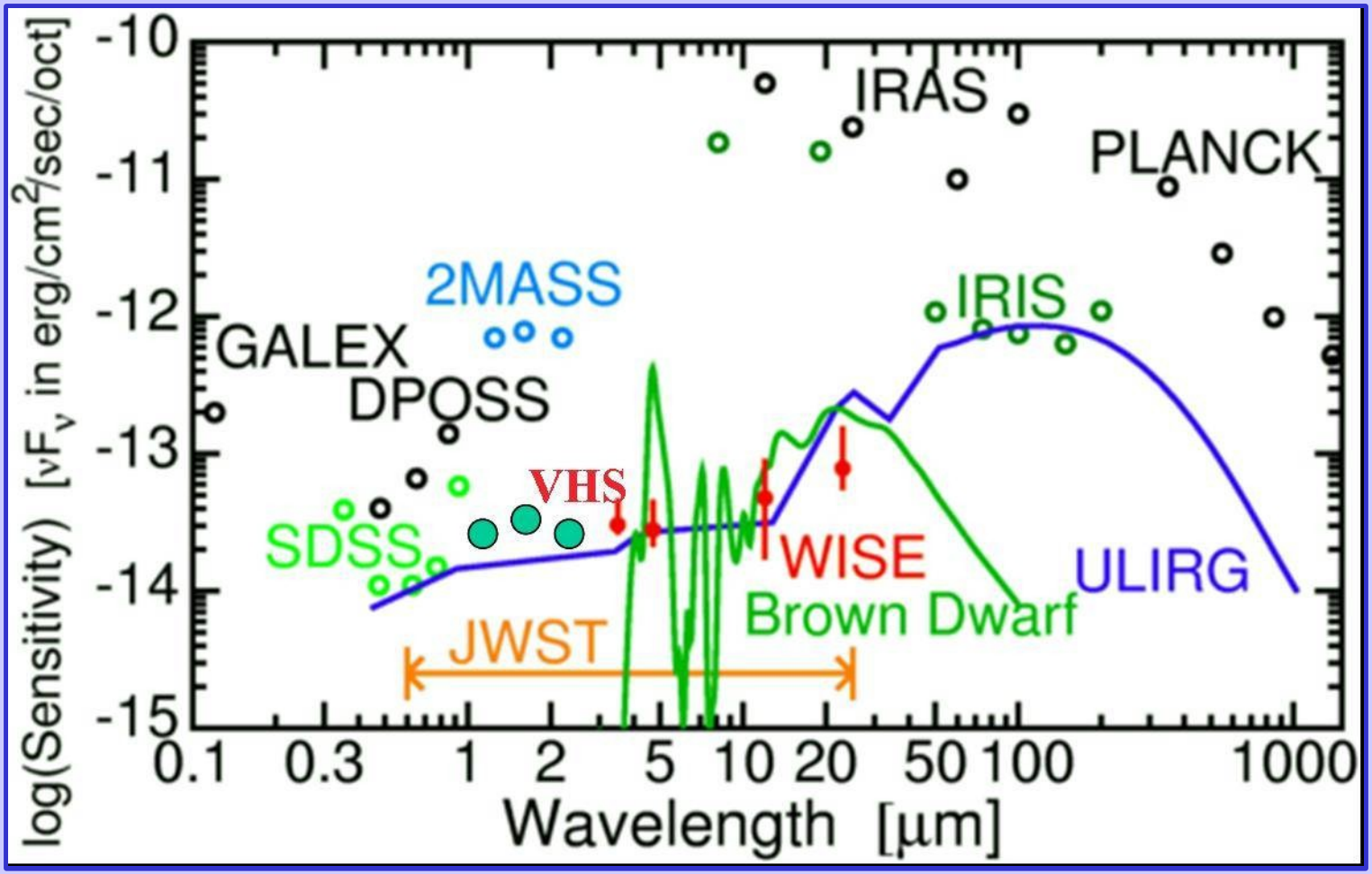


WISE



LSST

All-sky multi-lamda atlas ?



adapted from WISE website

Twentieth Century : the universe revealed

- radio : pulsars, quasars
- μwave : cosmic bgnd, molec clouds
- IR : ultraluminous galaxies, brown dwarfs
- X-ray : black holes, intra-cluster medium
- submm : galaxy formation with a bang

...any windows left ?

Discovery Space

• wavelength	done
• photon flux	almost done
• polzn	done but not all wavelengths
• time	current big thing
• spec. resoln	done but not all wavelengths
• spatial resoln	next big thing in optical-IR
• non-light channels	particles gravitational waves

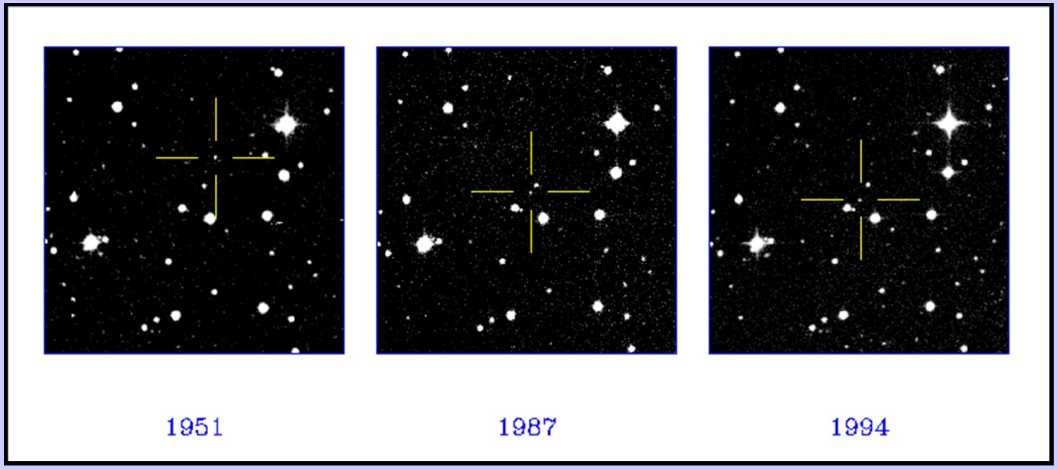
ever deeper ?

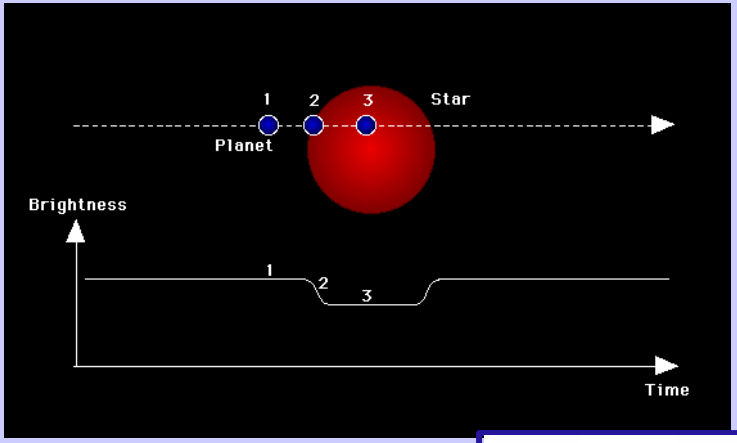
$$F \propto t^{-1/2} Q E^{-1/2} D^{-1} B^{1/2}$$

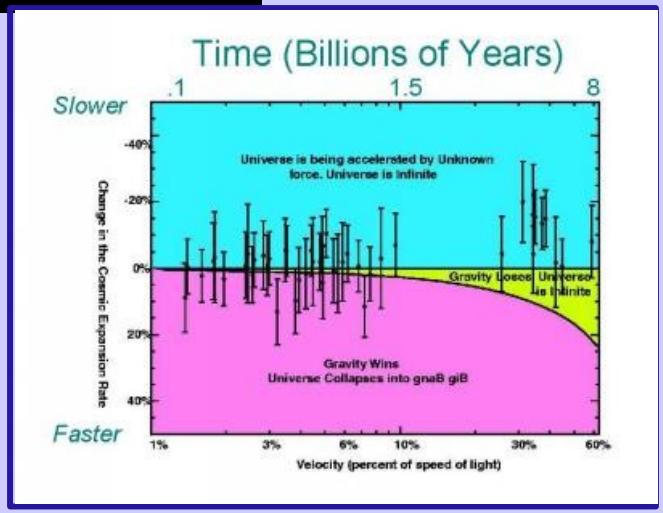
- integration : done
  - already used many day integns
- quantum efficiency : done
  - CCD QE ~ 80%
- sky background : done
  - space telescopes
- collecting aperture : expensive
  - 100m telescopes ?
  - depth goes as D but cost goes as D^3 ....

the watchers

- long term motions
  - substellar objects
  - Near Earth Objects
- periodic changes
  - exoplanet hunts
- transient events
  - high-z supernovae ==> vacuum energy
  - gamma-ray bursts
  - microlensing from MACHOs



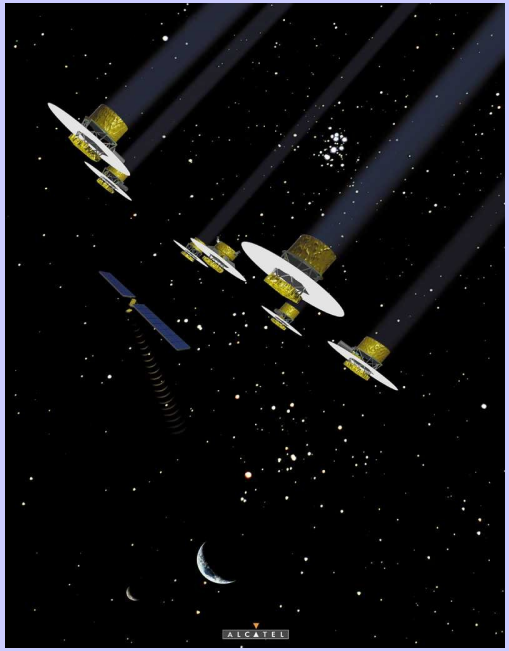




bigger is sharper

$\theta = \lambda / D$

- opt-IR 100m $\theta \sim$ milli-arcsec
  - deep and sharp : detect earth-like planets
- IR space interferometry (Darwin)
  - image earth-like planets
- space astrometry with GAIA
  - the Galaxy in 3D
  - watch external galaxies rotating



Darwin

Gaia

gravitational waves

- expected from changes in spacetime distortions
  - eg supernovae; black hole mergers
  - detect from tiny distance changes : $\Delta L/L \sim 10^{-18}$
  - very accurate interferometry with large arms
- Ground : high frequency only (T<100 sec)
  - km scale experiments now : no detections yet
  - next generation : cryogenic detectors : might see something
- Space : low frequency
  - arm length millions of km; drag free, phase locked spacecraft
  - LISA may get launched 2015
  - will almost certainly detect astronomical objects

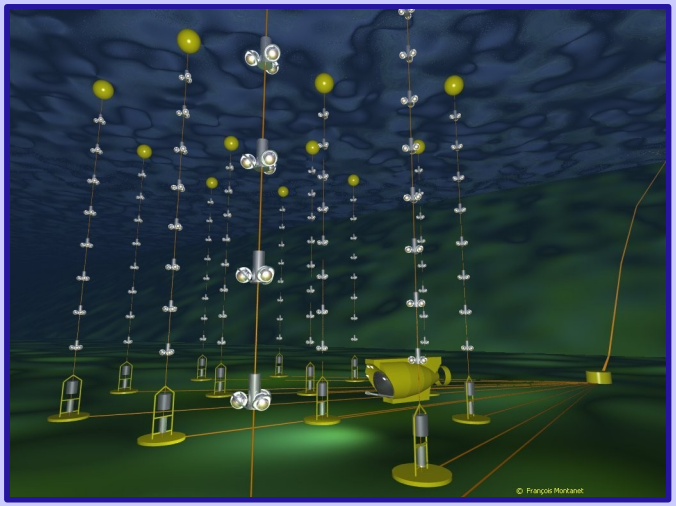
... but won't usually know where they are ...

particles from space

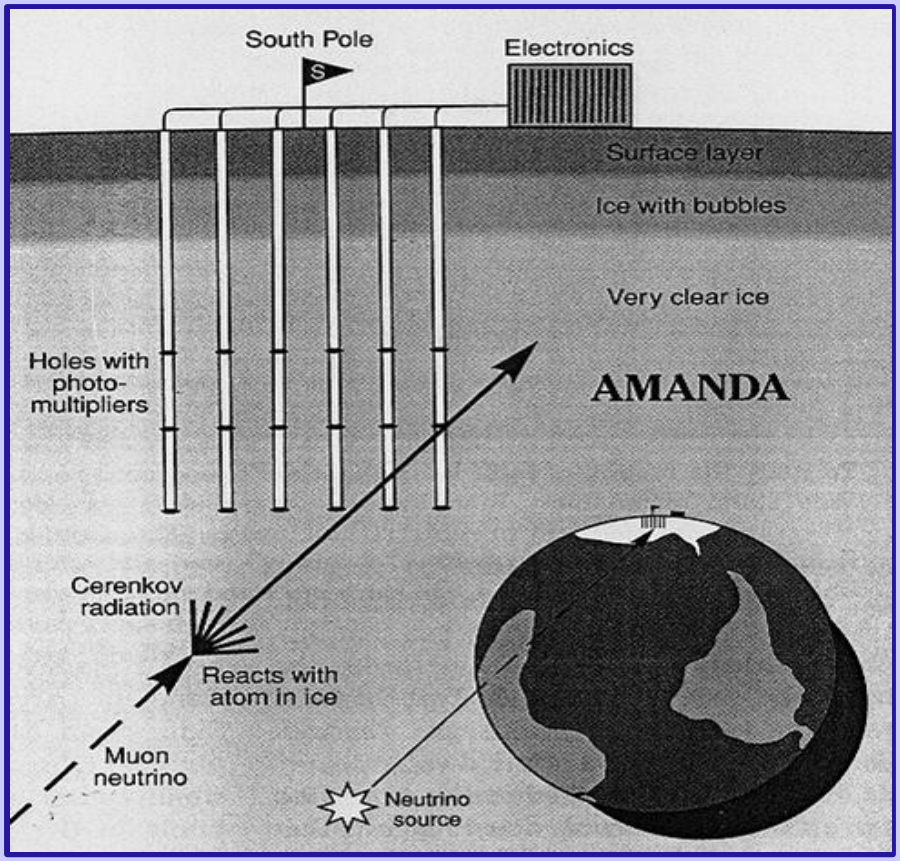
- Cosmic Rays : non-thermal sources
  - hundred year mystery still unsolved
  - current physics interest : very highest energies : shouldn't get here
  - needs very large detector arrays : AUGER
- Dark Matter : frozen relics of the Big Bang ?
  - deep mine experiments aim to detect directly
  - no results yet ...but next generation can rule out ~30% of models
- Neutrinos : messages from the core
  - solar neutrinos : solar models correct / neutrinos oscillate
  - so relic neutrinos have mass - cosmic background
  - supernovae : 19 neutrinos claimed from SN1987A !
  - quasars : no detections yet

The Neutrino Observatory

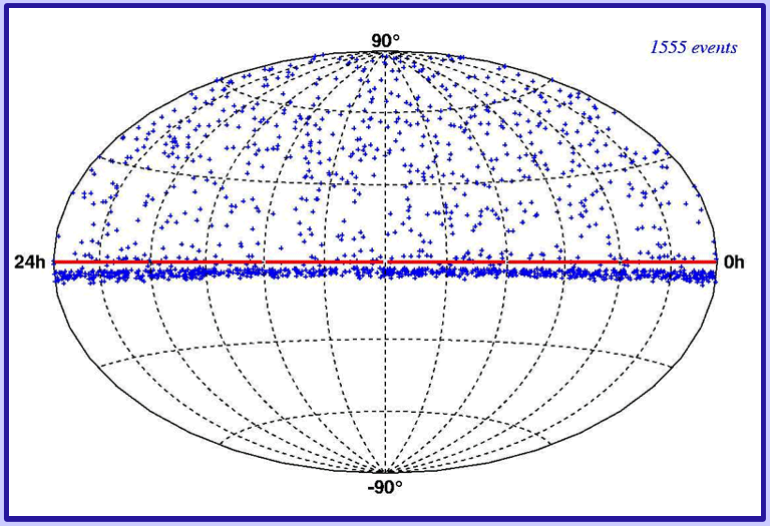
Neutrino Detectors



Antares



Amanda



Amanda results

the future .. ICECUBE

any surprises in discovery space?

- new windows opening :

  high res astronomy
  grav waves
  neutrinos

- will certainly do new science...

- ... but revolutionary surprises ...?