VIKING: (VISTA Kilo-degree INfrared Galaxy survey) : followup with 4MOST

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# VIKING basics:

- 1500 deg<sup>2</sup>, high |b|, in two stripes, NGP + SGP.
- Area matches 2dFGRS and VST-KIDS.
  - Optimal for Southern followup: VLT, ALMA, etc.
  - NGP stripe on Equator: overlaps UKIDSS, Sloan, GAMA-1.
  - SGP stripe: overlaps DES, GAMA-2.
- 9-band combined survey: ugri (KIDS), ZYJHK<sub>s</sub> (VIKING)
  - Depth: ~ Sloan + 2 mag, UKIDSS-LAS + 1.2 mag .
  - ~ 220 nights of VISTA time total.
- PI: A. Edge. Co-PIs: WJS, K. Kuijken, S.Driver, S.Eales
  - 30 co-I's (expanding...)





#### VIKING Exposure times + depths.

Filter	Exp. time	Med.seeing	$5\sigma, 2''$ aperture mag.		$f_{\lambda}$	UKIDSS
	(sec)	(arcsec)	(AB)	(Vega)	$(10^{-20} \mathrm{erg}\mathrm{s}^{-1}\mathrm{cm}^{-2}\mathrm{\AA}^{-1})$	(Vega; actual)
Z	500	0.8	23.1	22.6	75	
Y	400	0.8	22.3	21.7	114	20.2
J	$400 \ (2 \times 200)$	0.8	22.1	21.3	94	19.6
Н	300	0.8	21.5	20.2	94	18.7
Ks	500	0.8	21.2	19.4	77	18.2
i (KIDS)	1080	0.7	24.1	23.8	40	

VIKING typical total ~ 400 sec per filter per sky point.

2 visits per tile, Z,Y, J<sub>1</sub> (dark/grey time); J<sub>2</sub>,H,Ks (any Moon)
50s or 60s per jitter position, 8 or 6 total jitters per sky pixel.
J split between two visits, 200 sec each, for optimal rare-object searches – flag variable/moving objects.

 $8\sigma$  depth ~ zCOSMOS-bright, ~ 1000x area.

## Sky coverage (June 2012)



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# Data processing status

- VIKING using "standard" VDFS, CASU pipeline + WFAU archive.
- No major issues identified at present; builds on proven UKIDSS-LAS experience, with minor differences:
  - Persistence and cross-talk both substantially improved.
  - More jitters per sky point in VIKING (~ 8).
  - Two J epochs per sky point.
  - Detector cosmetics (dead/hot pixels) somewhat worse, but mostly stable except for bad half in detector#16.
- Data volumes smaller than VHS, VMC ; sky-subtraction less critical than VIDEO, UltraVISTA.

# Mag. limits vs observing conditions



# QC ongoing:

- Image quality pretty good: median ~ 0.9 arcsec, 90% < 1.1 arcsec.</li>
- Most analysis so far based on processed pawprint images and band-merged single-pawprint catalogues from VSA.
  - Tiles exist at VSA, but some issues with checkerboard background; tile-based catalogues not yet band-merged.
- Astrometry: very good. Bright stars show mean offset ~ 0.03 arcsec in overlap regions.
- Photometry: stability very good. Offset vs UKIDSS LAS stable to ~ 0.03 mag across many pawprints. Some systematic offsets ~ 0.08 – 0.1 mag at Z,Y bands: need more work on colour terms.
- Depth: median depth ~ 0.2 0.3 mag worse than ETC predictions. (Slightly larger aperture corrections, mean sky brightness a bit higher).

#### giJK two-colour diagram (Fleuren et al 2012):



clean star/galaxy separation: cf Baldry et al 2010, GAMA



One tile: VIKING objects, with VIDEO+CFHLS deep photometry.



Blue: point-like . Red = extended .

## Investigation of "discrepant" classifications

- Investigated ~ 1000 objects where morphological and 2colour classifications disagree.
- "Blue extended objects": a few are real low-z late-type galaxies... most are blended stars, stars in halos of bright stars, etc.
- "Red point sources" ... most are apparently stellar. Some will be QSOs, plus fraction TBC of compact galaxies.
- Conclusion: a combined colour+morph. classification can give highly complete galaxy samples, or very pure star samples; e.g. useful for weak lensing.

#### Astrometry: VIKING-UKIDSS RA/Dec offsets



VIKING Science drivers (1)

## z> 6.5 quasars, ultracool brown dwarfs: colour selection in Z,Y,J :



#### VLT-FORS2 confirmation spectra, z > 6.5 quasars



(Upper 3 are VIKING discoveries; ULAS J1120 from UKIDSS)

Yield per spectrum is good: 5 FORS spectra, 3 quasars so far. Few more candidates in the queue ...

# VIKING science – II

- Herschel-ATLAS identifications (S. Fleuren).
  - 21,000 submm sources in GAMA-09 field (48 sq.deg).
  - 72% statistically detected, 50% have reliable single-object VIKING ID's.
- Galaxy evolution:
  - Intermediate between "local" SDSS and "deep" few deg<sup>2</sup> VVDS, DEEP2, COSMOS, VIDEO ;
  - Probe evolution at  $z \sim 0.2 0.8$ , in *restframe*  $0.4 1.2 \mu m$ .
- Galaxy Morphologies:
  - ~ 100,000 galaxies at z < 0.1 ; 2x better resolution and 4x deeper surface brightness limit cf SDSS.
  - Fundamental local benchmark sample probing all environments.

## Synergy with Herschel-ATLAS

- Herschel-ATLAS = Advanced Terahertz Large Area Survey (PIs S.Eales, L.Dunne).
- ATLAS = 550 deg<sup>2</sup>, 600 hours in "Pmode"; the largest Herschel Open Time project.
- 5 bands (100, 160, 250, 350, 500 μm) to ~ 30 mJy; spans peak of dust SED from z ~ 0 to z ~ 2.
- 400 deg<sup>2</sup> of ATLAS is inside VIKING footprint ; VIKING has prioritised this area – mostly done.
- Expect to detect ~ 2/3 of > 200,000 ATLAS sources. Non-detections will have v  $f_v(FIR) / v f_v(NIR) > 40$ .

#### Herschel-ATLAS sky coverage.

Colourmap = 100um cirrus White = H-ATLAS Purple = DES Light blue = VIKING Green = RA/Dec lines.





VIKING Identifications for H-ATLAS submm galaxies (Fleuren et al 2012):



Black: reliable ID Red: low-rel ID(s) Hatched: blank





J085116.1-001410: zspec = 0.268



J084706.4+021212: zspec = 0.074











J083848.1+014536: zphot = 0.546







J091858.3+013454: zphot = 0.814

#### Redshift distribution for H-ATLAS reliable ID's.



Herschel-ATLAS Lensed Object Survey (HALOs) : (Gonzalez-Nuevo et al 2012)

- H-ATLAS successful at finding lensed SMGs: 5 confirmed lenses in first 3% of the area (Negrello et al 2010): expect 150 lens systems in full H-ATLAS.
- Improved selection using H-ATLAS + VIKING can reach fainter submm fluxes, potentially 1000 lens systems.
- Joint selection: f\_350 > 80 mJy, colours indicating high-z source, plus VIKING red galaxy within 4 arcsec (candidate lens).
- A short ALMA image (~ 2 mins) can show high confidence lensing: e.g. multiple submm peaks on either side of VIKING galaxy.



GAMA: 250,000 galaxies with spectro-z's, UV, Opt/IR, submm and radio.

(Andrews et al 2012, in prep)

## Lots more multiwavelength data soon...

- KiDS is observing, ugri, gradually catching up in area.
  - i-band coverage pretty good, others smaller.
- DES and HyperSuprime about to start...
  - DES will cover VIKING-S, HSC (probably) VIKING-N.
- WISE full-sky data release was out in Apr. 12. Crossmatch is pending in next VSA data release.
  - VIKING should detect "almost all" WISE sources within coverage– eventually over 12 million.
  - WISE is more sensitive for Y-dwarfs; but cross-match will give large sample of robust L/T-dwarfs.
- eROSITA launch 2014 :
  - VIKING/KIDS will provide lots of cluster photo-z's, and identifications for AGNs.

# VST sky coverage – (Aug 2012)



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#### DES planned footprint (RA/Dec) :



Green = VIKING-S, hatched = year-1, yellow/red = SN fields

## Hypersuprime-Cam provisional coverage plan (Miyazaki)



# Followup with 4MOST :

- Total VIKING sample > 20 million galaxies to Z\_AB ~ 22.5 ; followup of everything is too much !
- By 2016, expect deep visible coverage also (KiDS, DES, HyperSuprime): 9-band colours give good photo-z's, excellent stargalaxy separation, good classification of AGN's - very promising for selecting subsamples of interesting objects.
- The H-ATLAS id's are a very promising list ;  $\sim 200 / \text{deg}^2$  with reliable id's ;  $\sim 100 / \text{deg}^2$  with low-reliability ID's (often 2 or 3 candidates).
- Some are faint, but probably have strong emission lines... tbc .
- Quasars are promising: target 2.5 < z < 5, and extinction-free selection at all redshifts; combination of optical, VIKING + WISE should give very complete quasar samples.
- "Foreground of Euclid" cross correlate redshift-space distortion from 4MOST with Euclid shears. Euclid has no spectro-z at z < 0.7, i.e. most lenses only get photo-z's.

# Herschel-ATLAS submm id's :

- Total surface density of H-ATLAS sources (f\_250 > 30 mJy) ~ 400 /deg2, 160,000 in VIKING overlap area.
  - 51% have reliable ID's to K\_AB  $\sim$  19.
  - ~ 33% have low-reliability or multiple candidates, of which ~ half are expected to be genuine.
  - ~ 16% are blank to VIKING limits.
- Expect identifications for most of the submm galaxies at z < 1. Need two or three visits in order to explore the multi-candidate sources.
- Some are optically faint, r > 22, but may well have strong emission lines... TBC ; (the population of SMG's at  $z \sim 0.4 1.0$  is not well explored).
- Candidate HALOS lenses are an obvious high-priority target sample: only ~ 1000 candidates, but very challenging to do one-at-a-time with Xshooter.

# Selected galaxy subsamples :

- Luminous Red Galaxies easily selected at 0.7 < z < 1.0. Modest surface density (few tens per sq.deg);
  - BAO measurement complementary to Euclid emission-line galaxies, in overlapping volume for cross-correlations.
- Dwarf galaxies: e.g. photo-z < 0.1, r < 22.
  - Get a large sample of satellites around GAMA primaries.
- Wider GAMA: full 1500 deg<sup>2</sup> with GAMA selection would deliver > 1 million galaxies at ~ 700 / deg<sup>2</sup> in ~ 800 hours.
- Deeper GAMA: sparse-sample at r < 21, 0.3 < z < 0.6, to give a "foreground of Euclid" survey:
  - Cross correlate redshift-space distortion from 4MOST with Euclid shears. Euclid has no spectro-z at z < 0.7, i.e. most lensing structures only get photo-z's.

# **Conclusions :**

- VIKING should be complete by ~ 2017, and have deep visible coverage also (KiDS, DES, HyperSuprime): 9-band colours give good photo-z's, excellent star-galaxy separation, good classification of AGN's very promising for selecting subsamples of interesting objects.
- Photometry and astrometry are comfortably good enough for selecting interesting objects and fibre placement. Also provides a "test sample" for hemisphere surveys: 5% of hemisphere with > 1 mag deeper.
- The H-ATLAS id's are a very promising list: ~ 150,000 targets in only 100 4MOST pointings.
- Quasars are promising: target 2 < z < 5, and extinction-free selection at all redshifts; combination of optical, VIKING + WISE should give very complete quasar samples.
- Numerous interesting options for selecting galaxy subsamples: needs further study...

# Summary:

- Nearly 400 deg<sup>2</sup> observed so far, including most of Herschel-ATLAS.
- Data quality is generally fine ; depth slightly worse than predicted, due to known factors
- High-z quasars are a science highlight : 3 out of 4 known at z > 6.5.
- Projected reliable ID's for 100,000 Herschel sub-mm sources to  $z \sim 1$ .

• Projected selection of ~ 1000 candidate gravitationally lensed SMGs: bright and excellent ALMA targets, ~ 2 min snapshots sufficient to confirm lens morphology.

• Several analyses have been stalled by absence of adequately deep visible data: recently changing:

- VST KIDS now well under way.
- DES and Hypersuprime first light in Sept 2012 ...

Extra slides after here ...

# Mag. limit distribution over tiles



## J mag vs (J-Ks) distance from stellar locus







## 45 VIKING Quasar candidates – NTT i, z followup. (Bram Venemans + Joe Findlay).



# Quasar selection simulations, completeness model (Findlay et al 2012).





## Herschel-ATLAS Lensed Object Survey (HALOs) :

