# VVV Survey

V. D. Ivanov (ESO) and the VVV(X)/VMC teams

PIs: VVV: Dante Minniti (Univ. de Catholica) and Phil Lucas (Univ. of Hertfordshire) VMC: Maria Rosa Cioni (AIP)

#### 20.11.2017, SAAO



### VISTA the telescope

4.1-m f-ratio 3.25 FOV 1.65 deg, mean scale 0.34 arcsec/px

Built by an UK consortium (QMUL et al.)

VVV allocation: 193 nights over 5-7 years







# 16 VIRGO detectors, 2048x2048 px each, populating ~1x1.5 deg of the focal lane













### **VIRCAM** the camera

- FoV in one pawprint: 1.5x1 deg
- 6 pointings (AKA "paw prints") to form a contiguous "tile"



pixels

X

To centre of

filter wheel

### From Pawprints to Tiles

#### 6 pointings (="paw prints") to form a contiguous "tile"





Exposure time coverage (on the right) for a contiguous-coverage tile of 6 pawprints: dark green = 1, light green = 2, magenta = 3, red = 4, yellow = 6. In units of the single-pawprint exposure time.



### **VIRCAM** the camera

- Filters: ZYJHKs, NB980+NB990, NB118 + visitor's filters (?)



### **Advanced Hardware**

#### Product of many years of gradual technological improvement:



### **OPERATIONAL OPTIMIZATION**

Back to the future of the semi-classical observing or SciOps 2.0 at VISTA:

- ---- no dedicated full night-time support astronomer
- ---- the (super-)TIOs run VISTA (!!!) and do on-the-fly ground-zero QC
- --- the Shift Coordinator prepares the night (flats, std, 1-2 hrs of science)
- --- Quality control on the fly (scripts + ftp opslogs + Garching)
- --- Intelligent tools: SADT, OT3, Calchecker, pipeline+scripts

Why?

- --- VIRCAM is a simple single-mode instrument
- --- only 6+ programs (albeit, many OBs), for now
- --- no visitors



VMC - VISTA Magellanic Survey : PI Maria-Rosa Cioni (Edinburgh) -- This survey will image 184 sq.degr of the Magellanic System, i.e., the LMS, SMC, the Bridge, and the Magellanic Stream in YJKs. Multi-epoch observations will constrain the mean magnitude of short-period variables. The survey will be used to study resolved stellar populations, the star formation history of the system as well as to trace its 3D structure. VHS - VISTA Hemisphere Survey : PI Richard McMahon (Cambridge) -- The VHS will image 20 000 sq.degr of the Southern Sky (exception areas covered by the other surveys) in JKs, 4 mag deeper than 2MASS and DENIS. The 5000 square degrees covered by the Dark Energy Survey (DES), another imaging survey scheduled to begin in 2010 at the CTIO 4 metre Blanco telescope, will also be observed in H-band. The area around both of the Galactic Caps will be observed in YH as well to be combined with the data from the VST ATLAS survey. The main science drivers of the VHS include: examining low mass and nearby stars, studying the merger history of the Galaxy, measuring the properties of Dark Energy through the examination of large-scale structure to a redshift of ~1, and searches for high redshift quasars.

VISTA survey observing strategies									
Survey	Area (deg <sup>2</sup> )	Filters and Depth Measure(mag (10σ, AB)	Depth (mag)						
Ultra-VISTA	0.73 (ultra-deep)	5α, ΑΒ	Y=26.7	J=26.6	H=26.1	K <sub>s</sub> =25.6	NB=24.1		
VIKING	1500	5α, ΑΒ	Z=23.1	Y=22.3	J=22.1	H=21.5	K <sub>s</sub> =21.2		
VMC	184	10α, Vega	Y=21.9	J=21.4	Ks=20.3				
vvv	520	5α, Vega	Z=21.9	Y=21.2	J=20.2	H=18.2	K <sub>s</sub> =18.1		
VHS	20 000	5α, ΑΒ	Y=21.2	Y=21.2	J=21.2	H=20.6	Ks=20.0		
VIDEO	15	5α, ΑΒ	Z=25.7	Y=24.6	J=24.5	H=24.0	K <sub>s</sub> =23.5		

**UltraVISTA** : PIs Jim Dunlop (Edinburgh), Marijn Franx (Leiden), Johan Fynbo (Copenhagen), Olivier LeFevre (Marseilles) -- Ultra-VISTA aims to image <u>one patch of the sky (the COSMOS field)</u> in YJHKs filters plus one NB at Lyα emitters at z~8.8 (~30 are expected to be found). The science goals are: <u>first galaxies, the stellar mass build-up during the peak epoch of star formation activity, and dust obscured star formation</u>.

**VIDEO - VISTA Deep Extragalactic Observations Survey** : PI Matt Jarvis (Hertfordshire) -- VIDEO is a <u>15</u> <u>sq.degr</u> ZYJHKs survey to study <u>galaxy evolution as a function of epoch and environment to redshift of ~4</u> using AGNs, galaxy cluster evolution, and very massive galaxies. <u>Four fields</u>: CDFS, XMM-Newton LSSS, ISO fielf , and a new field. VIDEO is intermediate between the wide/shallow VIKING and the small/deep Ultra-VISTA. **VIKING - VISTA Kilo-Degree Infrared Galaxy Survey** : PI Will Sutherland (Cambridge) -- The VIKING survey provides an <u>NIR complement to the optical KIDS project</u>. VIKING will image the same <u>1500 sq.degr</u> of the sky in ZYJHKs to a limiting magnitude 1.4 mag deeper than the UKIDSS LAS. The main goal is to obtain accurate <u>photometric redshifts</u>, (z > 1), important for weak lensing analysis and observation of baryon acoustic oscillations. Other goals: hunt for <u>high redshift quasars</u>, <u>galaxy clusters</u>, and the study of galaxy stellar masses.

### Wide Infrared Milky Way Surveys





#### **UKIDSS**

- **VISTA Strategy:**
- semi-simultaneous YZ and JHKs
- multiple Ks re-visits
   separated by up to 5 yrs



110 tiles, 184 sq. deg *YJKs* 12+ Ks epochs

### Cioni et al. (2011, A&A, 527, 116)



**σ=80-85 mas** 









## The Milky Way, our Galaxy

Minniti, Lucas et al. 2010, NewA, 15, 433

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What is the 3-D structure of the Milky Way



#### Photo album of the MW

vvvsurvey.org

#### Milestones:

- Galileo 1609 the Milky Way is made of stars
- Herschel 1800 first star counts (Sun still et the MW center)
- Kapteyn 1910 more star counts (the Kapteyn shoe)
- Shapley 1920 GC distance from globular clusters
- Trumpler 1930 dust absorption



Photo album of the MW

vvvsurvey.org

#### WISE: 3.3, 4.7, 12, 23 micron

#### Bulge – 300 sq. deg: -10<l<+10, -10<b<+5 Disk – 220 sq. deg: -65<l<-10, -2<b<+2

### 2MASS JHK 2000

Photo album of the MW

#### vvvsurvey.org

#### WISE: 3.3, 4.7, 12, 23 micron



### 2MASS JHK 2000

### Do it in the NIR – to see through!



#### Globular Cluster UKS-1 on DSS2 Red and 2MASS J (5'x5')

# Do it with the highest available angular resolution!



Globular Cluster UKS-1 on 2MASS Ks and VVV Ks (5'x5')

### Obtain multiple epochs to do 3D tomography with RR Lyr and Cepheids! ==> 60-100 epochs



#### Catalan et al (2006)

Solima et al. (2006)

### ... And do it in multiple bands to broaden the community interest in your survey!



#### WISE selected brown dwarfs (Kirkpatrick et al. 2011)



30.0001

### Wide Infrared Milky Way Surveys





1	<ul> <li>6 epochs in K for bulge and disk; K<sub>im</sub>=18/20 mag (single/combined epoch</li> <li>Z,Y,J,H, K single (quasi-simultaneously) epoch observations (bulge &amp; dis</li> </ul>	multicolor maps	2010		
2	- 4 epochs in K for bulge and disk	variability	2011		
3	- main part of bulge variability campaign (80 epochs, 652 h)	variability	2012		
	<ul> <li>map bulge and disk once per night</li> </ul>	variability	2013		
4	<ul> <li>main disk variability campaign (similar to bulge, but 70 epochs, 525 h)</li> </ul>	variability	2014		
5	<ul> <li>bulge and disk observations in K band</li> <li>20/9 epochs spread over the whole year</li> <li>subset will be observed more frequently (10-40 times per night)</li> </ul>	proper motions	2015		
	100% observed		2016		
	100% reduced >75% released				

# VVV limiting magnitudes



R. Saito

# Completeness tests

M. Hempel



vvvsurvey.org



# VVV CMDs

Color-magnitude diagrams of bulge and disk fields compared with 2MASS.



#### vvvsurvey.org

# Variability

Combined VLT-optical and VISTA-IR photometry

230 new variables from VLT/ VIMOS observations matched to VVV IR photometry

Many more than expected!

1/1000

#### Total in VVV Survey ~1 million variables

Pawel Pietrukowicz

few/1000



### A few RR Lyrae light curves



Istvan Dekany

very rare (<10^-6)</li>
different types: dN, RCB, FUOri...









Minniti et al. (2017, ApJ, 849, L23)



#### |=347.14539, b=0.88522 => Av = 10-15 mag





### - broad emission lines (upward of 3000 km /s)

- VVV-WIT06 may be:
- (i) the closest Type I SN observed in about 400 years (0.7-2.2 Mpc),
- (ii) an exotic high-amplitude nova that would extend the known realm of such objects, or
- (iii) a stellar merger.

# ~35,000 GALAXIES

### Galaxies in Field d003

vvvsurvey.org

Eduardo de Amores





#### vvvsurvey.org

### **Background Galaxies**



#### VVV field d003

### Data Access (= Survey Success)



### Data Access (= Survey Success)





### Data Access (= Survey Success)







### Summary









### Surveys are great!