10 Gyrs of galaxy evolution with LSST

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on behalf of a larger team including

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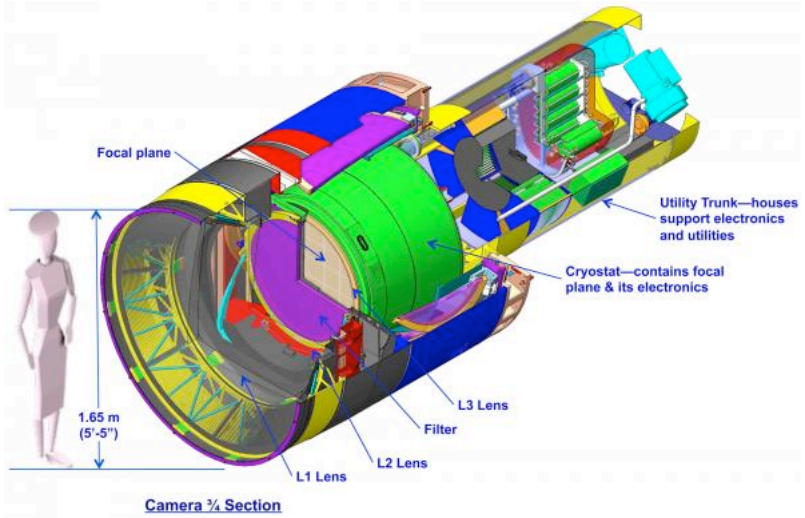
Giuseppe Longo (University of Naples)
Mario Radovich (INAF -OAPD)
Valeria Amaro (University of Naples)
Civita Vellucci (University of Naples)

LSST Camera

- large-aperture, wide-field optical imager
- near ultraviolet to near infrared (0.3-1 µm)
- 3.5-degree field of view; **~9.6 deg^2**
- 10 µm pixels and **0.2”/pixel** sampling
- optimized pixel sensitivity vs pixel resolution
- mosaic of 189 16-megapixel silicon detectors
- 21 "rafts" to provide a total of about **3.2 gigapixels**
- Median delivered image quality ~0.7’’ FWHM



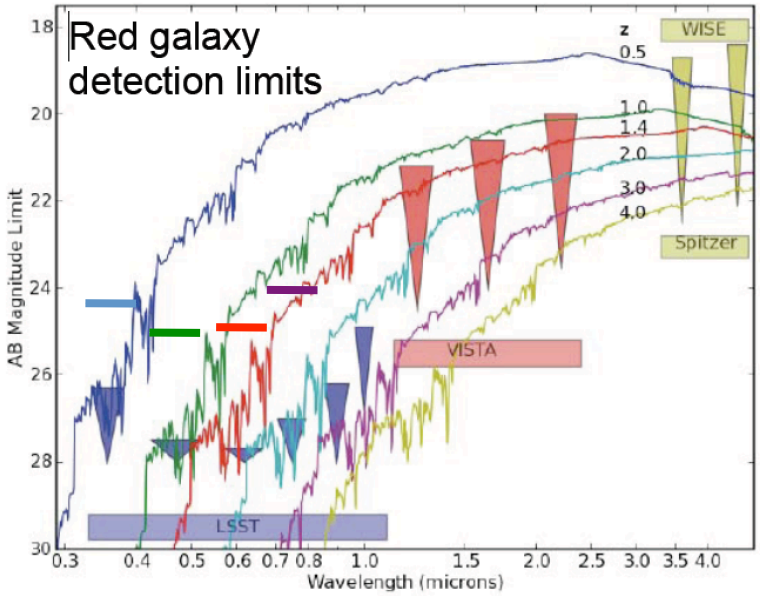
LSST Deep Sky

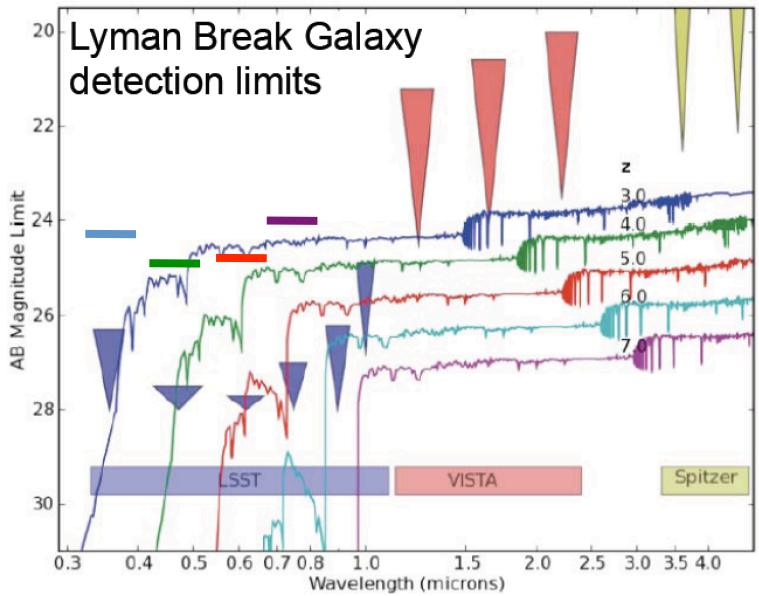
Area: 18,000 deg^2

Single epoch: 5σ pt. source detection limits *u~23.9, g~25.0, r~24.7, i~24.0, z~23.3, y~22.1 AB*

After 10 years: 5σ pt. source detection limits *u~26.3, g~27.5, r~27.7, i~27.0, z~26.2, y~24.9 AB*

- a total of >10^{10} galaxies detected up to z ~ 6 – and ~10^{10} stars
- >10^9 galaxies detected at z > 2
- >10^7 galaxies detected at z > 4.5
- structural measurements and *ugrizy* photometry for 4x10^9 galaxies at z < 1.5





Large Synoptic Survey Telescope
www.lsst.org

LSST Deep Sky

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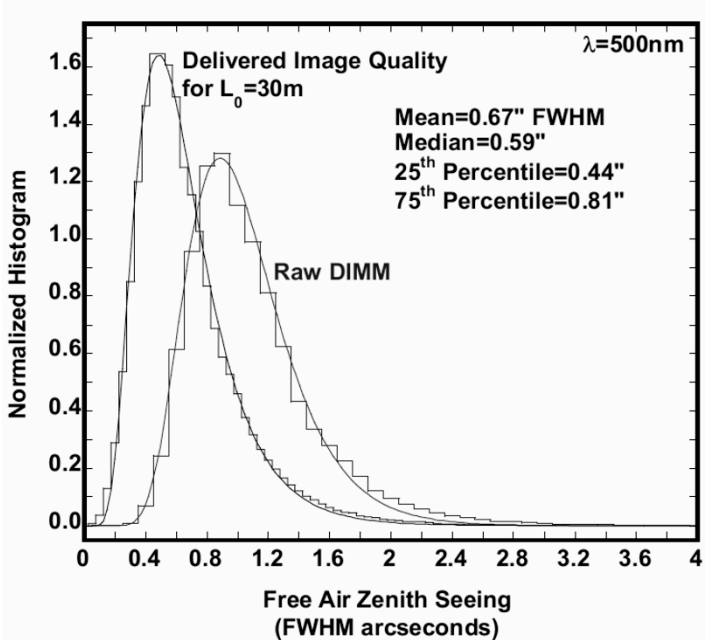
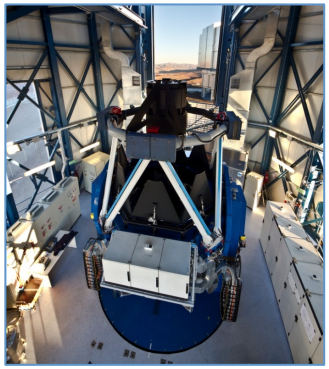
- median seeing is 0.65“ -> 4 kpc at z= 0.5 ~ typical L_* size.
- parametric models will be able to discriminate between bulge- or disk-dominated galaxies up to z~0.6,
- the 25th percentile has FWHM=0.44”-> ~3.7 kpc at z~1.5!! yet around the typical L_* sizes.
- ~4 Billons of L_* galaxies at z=1.5

9.4 Gyr lookback time



VST People and Institutes

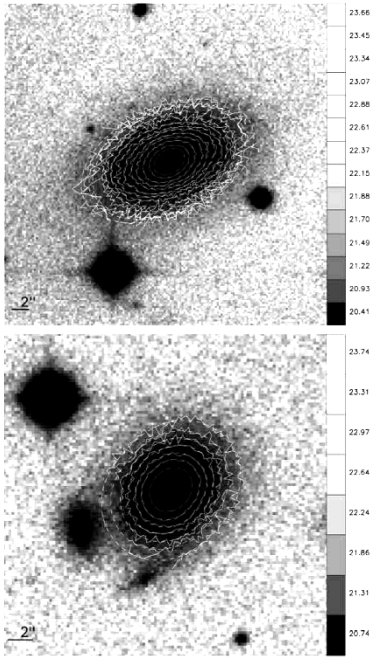


PSF convolved Sersic fit

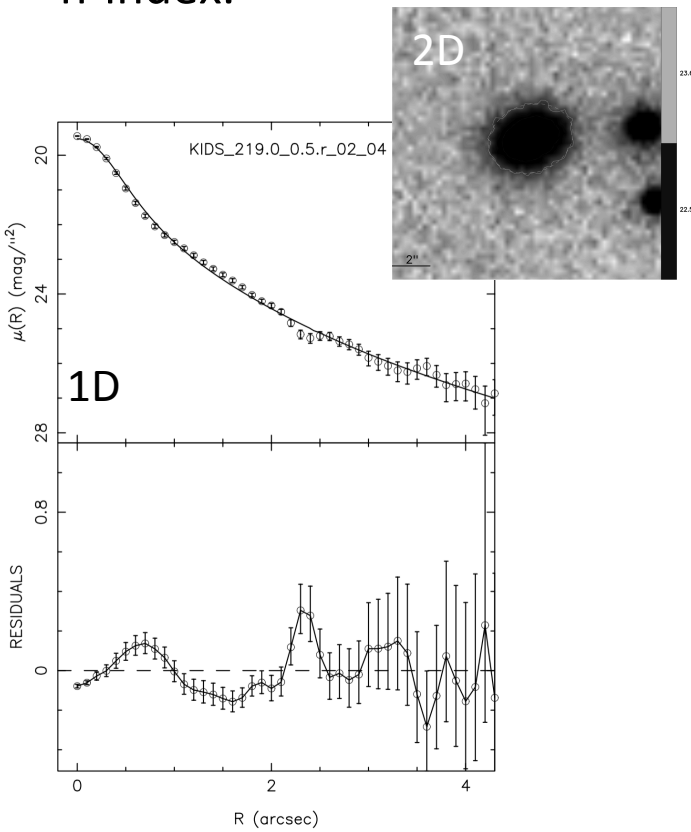
2DPHOT main parameters (Roy et al., 2016, in preparation)

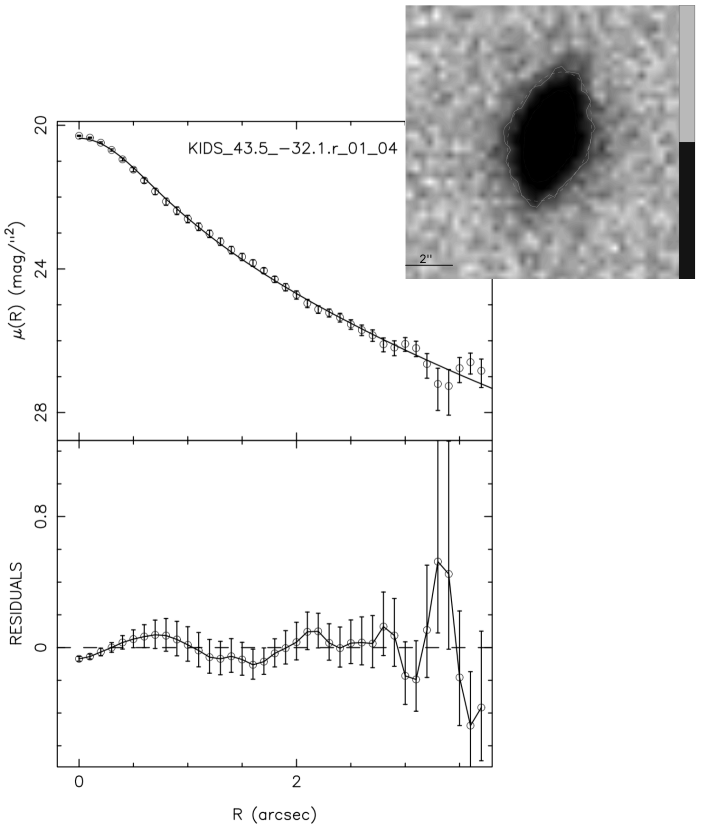
R_e, $<\mu>_e$, magnitudes, Sersic index n, b/a, PA, a_4

with typical expected accuracy of ~20% in R_e, and the Sersic n-index.



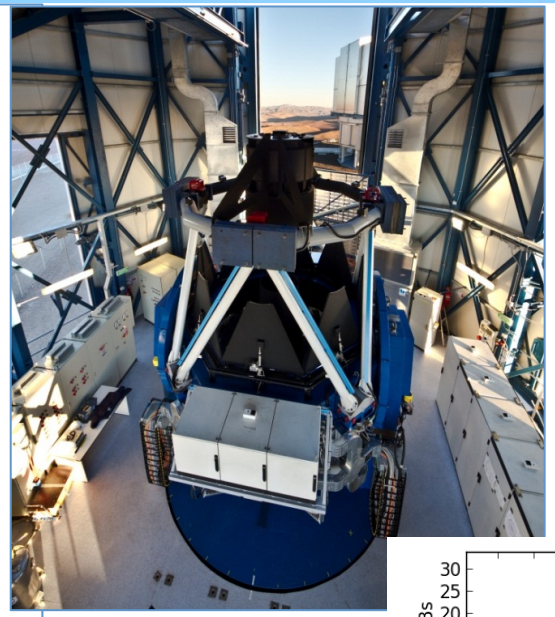
SB performed over a scale of sub-arcsec to few arcsecs

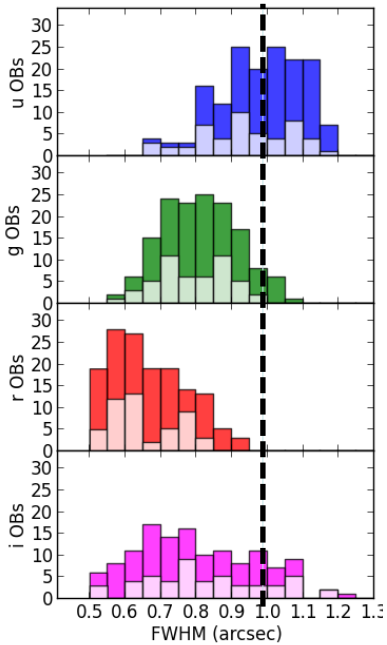




VST as LSST precursor

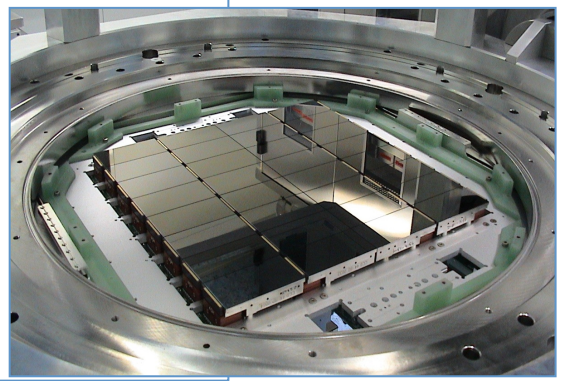
- Primary mirror: 2.6m
- Secondary mirror: 0.9m
- Field corrector with 3 lenses (2 in the telescope + 1 in the camera)
- **Field: 1° x 1°**
- Shack-Hartmann wavefront sensor
- **Active M1 shape control**
- **Active M2 positioning in 5 dof (hexapod)**
- Autoguiding with probe in polar coordinates
- ADC with counter-rotating doublet of prisms, exchangeable with 2 Lens corrector





median seeing 0.7”

- **0.27 Gpixel 1°x1° f.o.v.**
- **0.21 arcsec/pixel**
- 32 scientific CCDs + 4 outer CCDs
- Image analysis curvature sensor



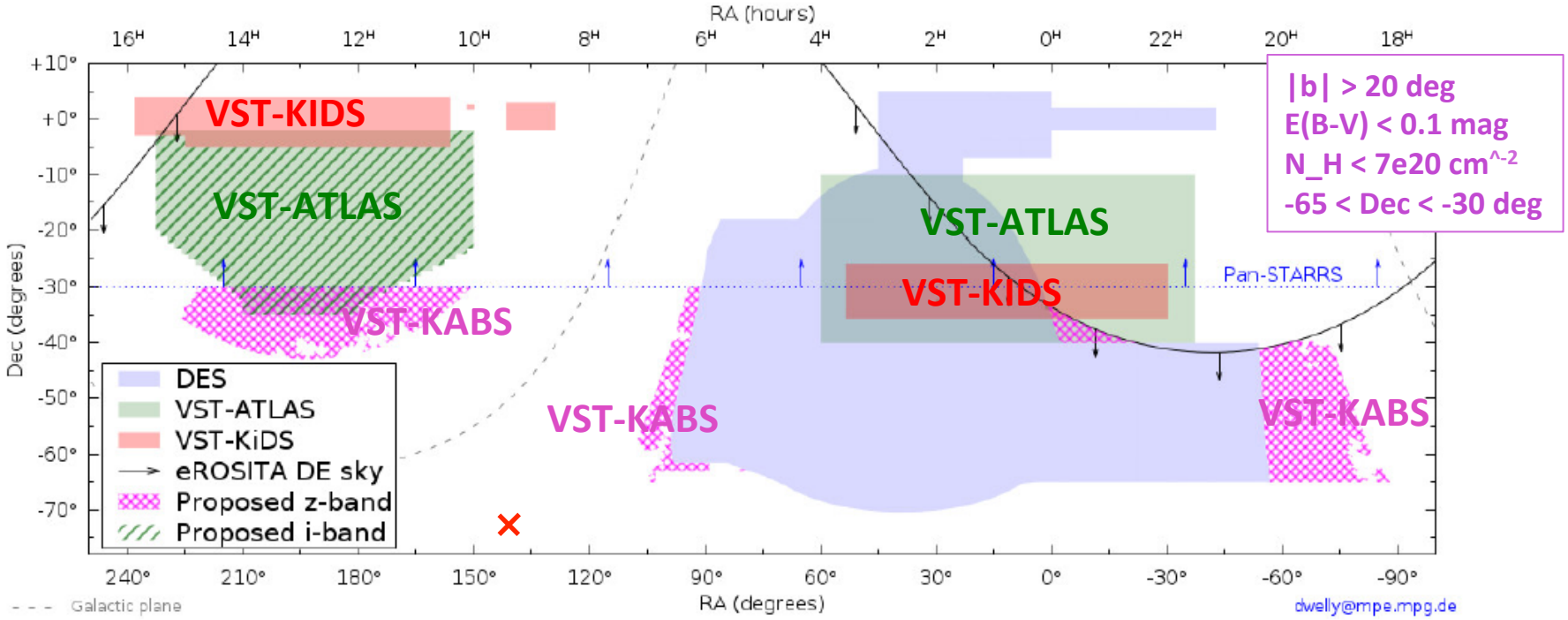
VST SKY

~6500 deg² by 2021

ATLAS: 4500 deg2 in ugriz (depth 23.5 in r-band – 5sigma 2” ap)

KiDS: 1500 deg2 in ugri (depth 25.5 in r-band – 5sigma 2” ap)

KABS: 1000 deg2 in gri(uY) (depth 24.5 in r-band – 5sigma 2” ap)



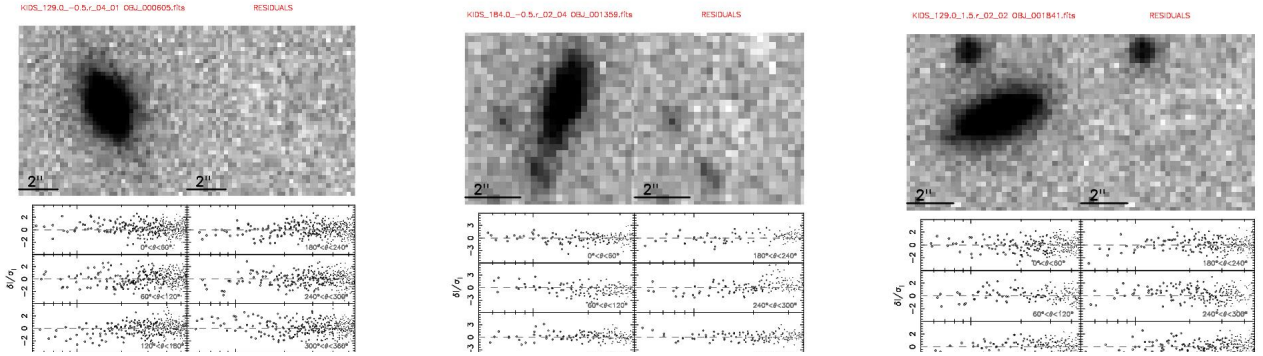
Galfit vs 2DPHOT

	Galfit	2DPHOT
PRO	Fast; Popular	PSF modeling; isophotal analysis (a4, b4); pixel integration convolution -> optimized for subarcsec objects
CONS	Initial Condition Set-up	slower (~min/gal)

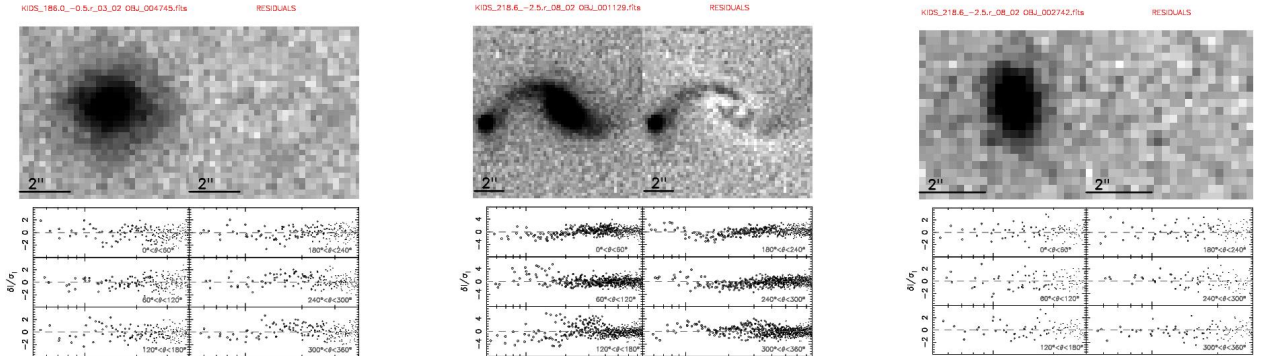
Analysis tools

Sample of higher-z galaxies

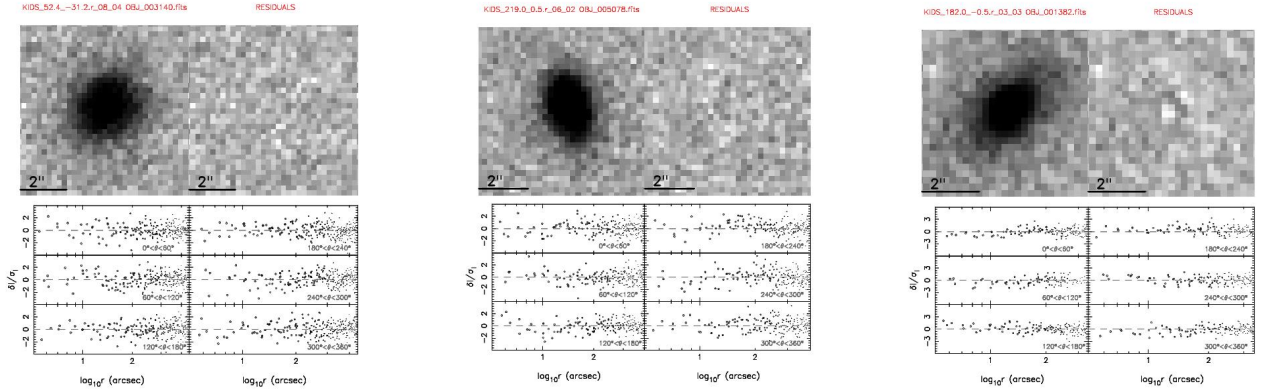
z=0.3



z=0.4



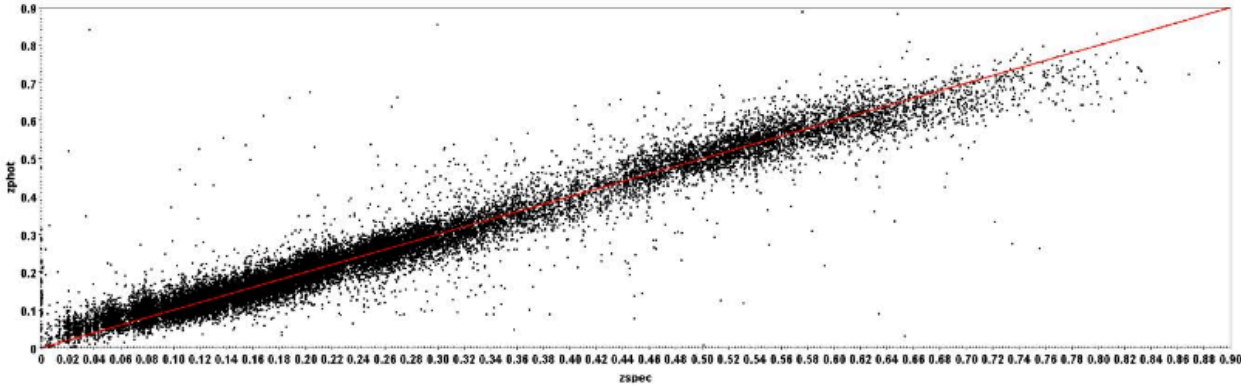
z=0.5

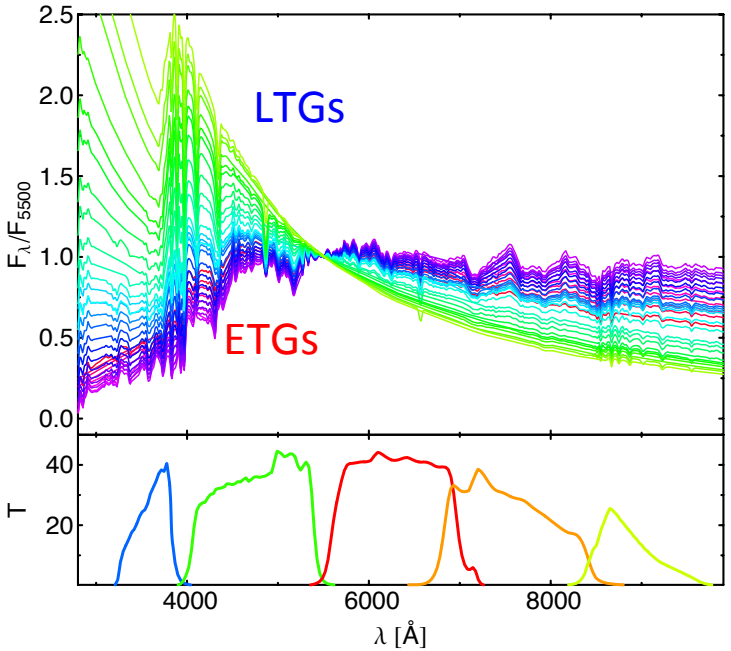


KiDS/KABS survey products

Cavuoti, Brescia, Tortora, Longo, et al. Cavuoti et al., METAPHOR: a new method …MNRAS submitted;
Cavuoti et al., A cooperative approach among methods for photometric redshifts estimation (KIDS) MNRAS, submitted

Machine learning tools
for photo-z and
galaxy classification

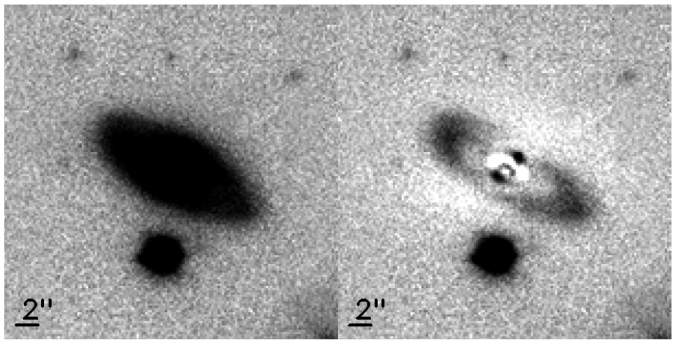


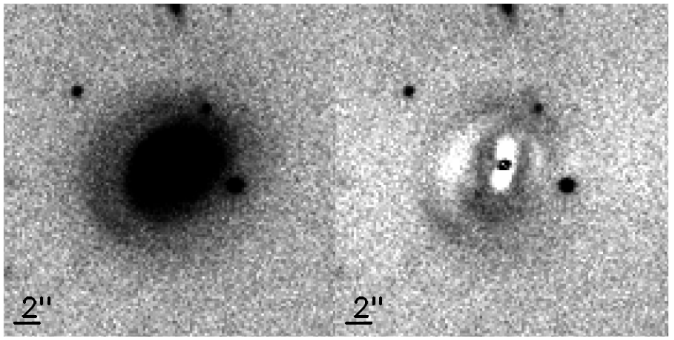


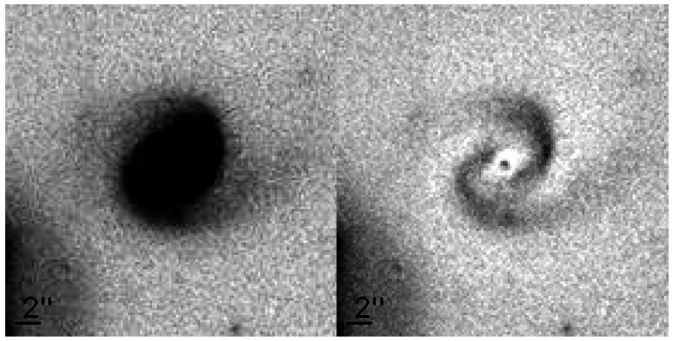
REF	ALL OK Photo	E type	Sbc type	Scd type	E+Sbc+Scd type	SB type	Im type	unknown type
number	22362	14806	5163	1872	21841	81	117	323
%		66.21	23.09	8.37	97.67	0.36	0.52	1.44
|bias| (DAME)	0.0008	0.0009	0.0011	0.0008	0.0008	0.0002	0.0008	0.0009
|bias| (SED1)	0.0043	0.0025	0.0067	0.0235	0.0053	0.1814	0.0686	none
|bias| (SED2)	0.0274	0.0425	0.0004	0.0211	0.0269	0.1261	0.0506	none
σ (DAME)	0.0300	0.0262	0.0350	0.0345	0.0293	0.0550	0.0459	0.0533
σ (SED1)	0.0720	0.0519	0.0813	0.0632	0.0614	0.5371	0.2131	none
σ (SED2)	0.0725	0.0528	0.0803	0.0575	0.0651	0.4790	0.1820	none
|Δz/(1+z)|>0.15 (DAME)	82	34	29	9	72	3	2	5
% (DAME)	0.37	0.23	0.56	0.48	0.33	3.70	1.71	1.55
|Δz/(1+z)|>0.15 (SED1)	523	243	202	45	490	16	17	none
% (SED1)	2.37	1.64	3.91	2.40	2.24	19.75	14.53	none
|Δz/(1+z)|>0.15 (SED2)	437	161	202	45	408	13	16	none
% (SED2)	1.98	1.09	3.91	2.40	1.87	16.05	13.68	none
|Δz/(1+z)|>2σ* (DAME)	703	360	189	76	625	12	5	61
% (DAME)	3.14	2.43	3.66	4.06	2.86	14.81	4.27	18.89
|Δz/(1+z)|>2σ* (SED1)	4132	2121	1484	474	4079	26	27	none
% (SED1)	18.75	14.33	28.74	25.32	18.68	32.10	23.08	none
|Δz/(1+z)|>2σ* (SED2)	7651	5902	1335	368	7605	24	22	none
% (SED2)	34.72	39.86	25.86	19.66	34.82	29.63	18.80	none

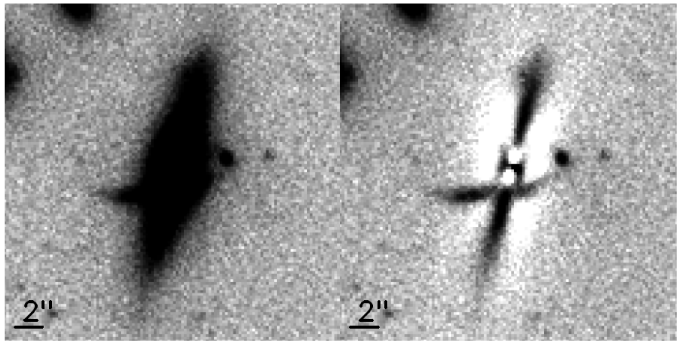
Analysis tools

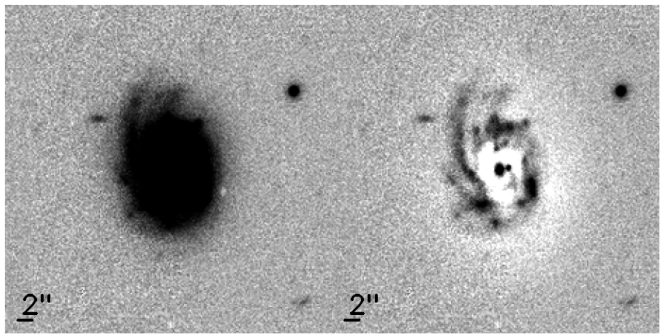
Sample of substructures







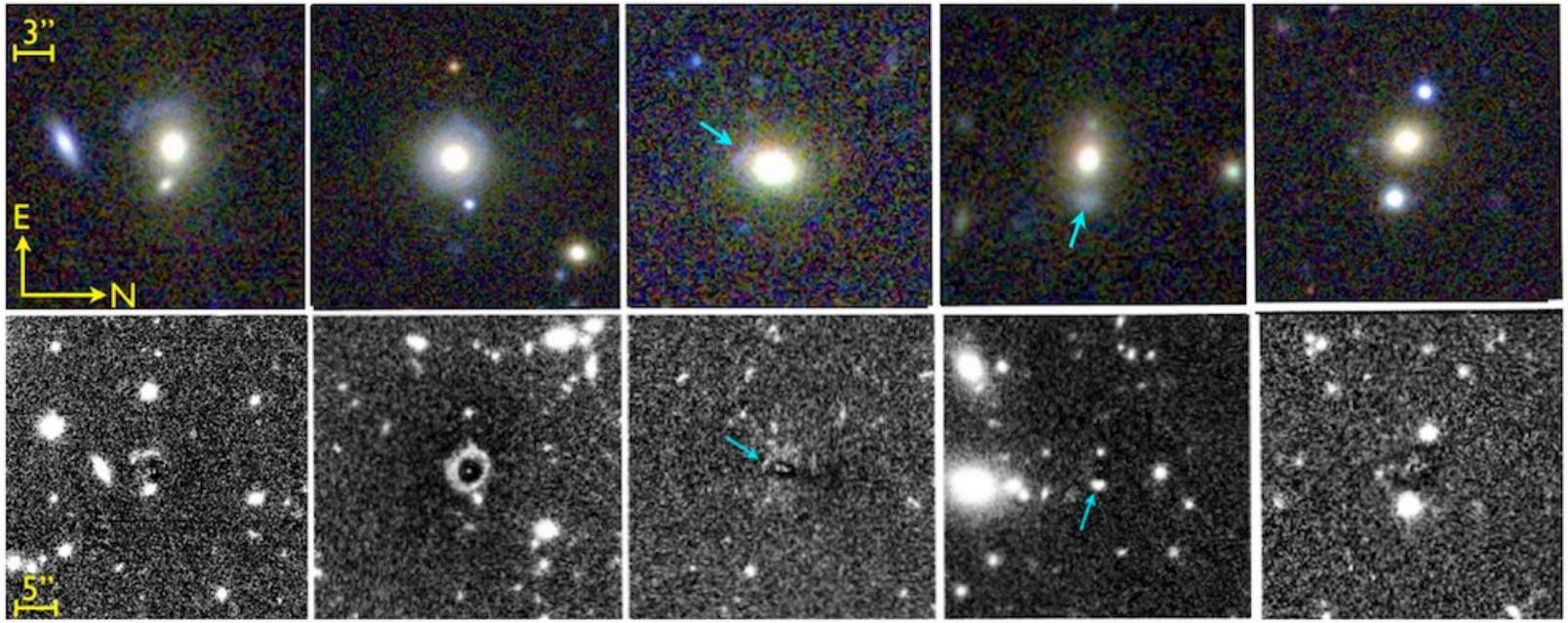




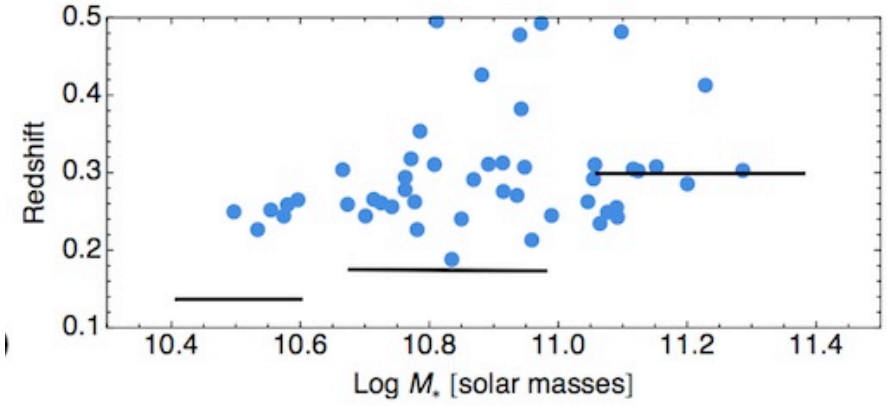
Bad fit ($\chi^2 > 1.5$, 5-10% of the selected sample)

Analysis tools

Strong lensing

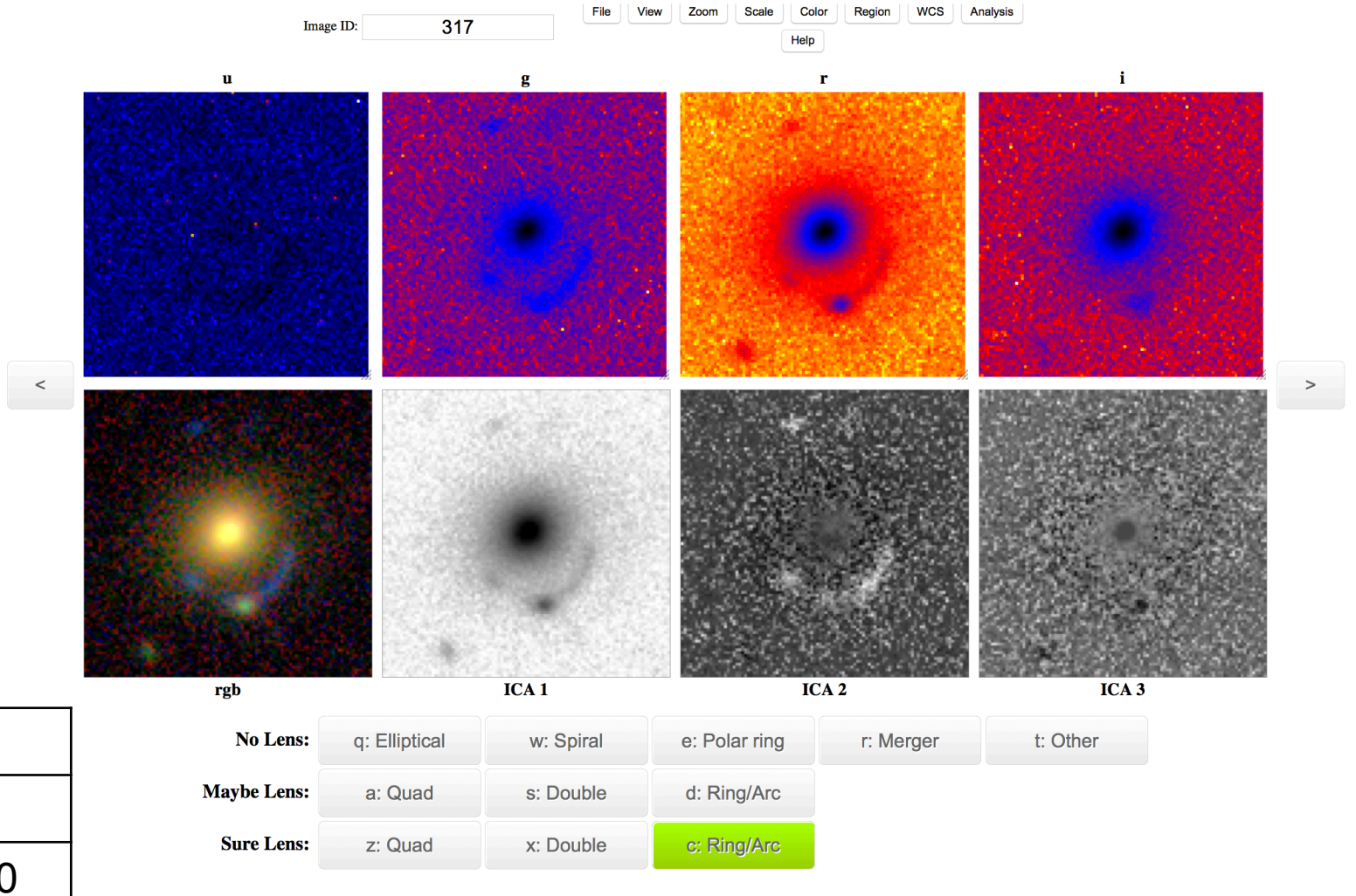


#SL - gal/gal	
now	KiDS
~650	~1500



Analysis tools

Strong lensing – web interface for visual inspection



#SL - gal/gal	
now	KiDS
~650	~1500

Big Data

Numbers

structural measurements and ugrizy photometry for $4x10^9$ galaxies at $z < 1.5$

~$2x10^{10}$ galaxies to be analyzed!!

Expected process time for the 4B gals in 6 bands TODAY

~300 gal/FPU/hour ➔ ~$3x10^6$/FPU/yr ➔

for ~$2x10^{10}$ galaxies: ~7000 yr/FPU ➔3.5yr with 2000 cores

Big Data

Numbers

structural measurements and ugrizy photometry for $4x10^9$ galaxies at $z < 1.5$

~$2x10^{10}$ galaxies to be analyzed!!

Expected process time for the 4B gals in 6 bands TODAY

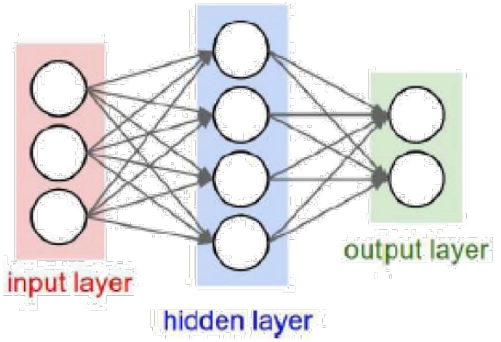
~1000 gal/FPU/hour ➔ ~$1x10^6$/FPU/yr ➔

for ~$2x10^{10}$ galaxies: ~2000 yr/FPU ➔1yr with 2000 cores

Analysis tools

Strong lensing – machine learning tools (convnets)

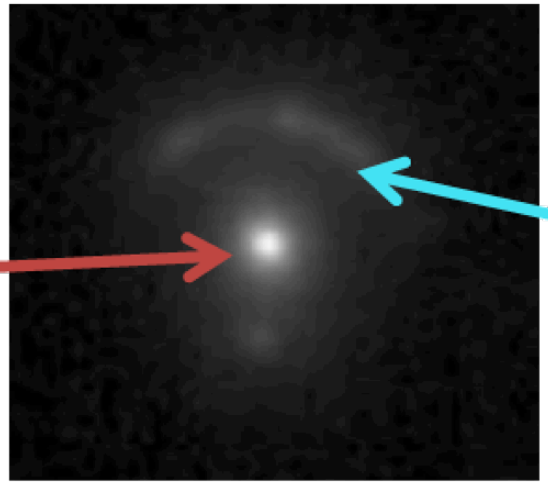
We need large datasets of known strong lenses in order to learn the classification lens-no vs. lens (~10^3-10^6), but such a "training set" is not still available!



Google's artificial neural network

Mock data is needed to train the network

KiDS real galaxy



Simulated arc

Petrillo et al. in preparation

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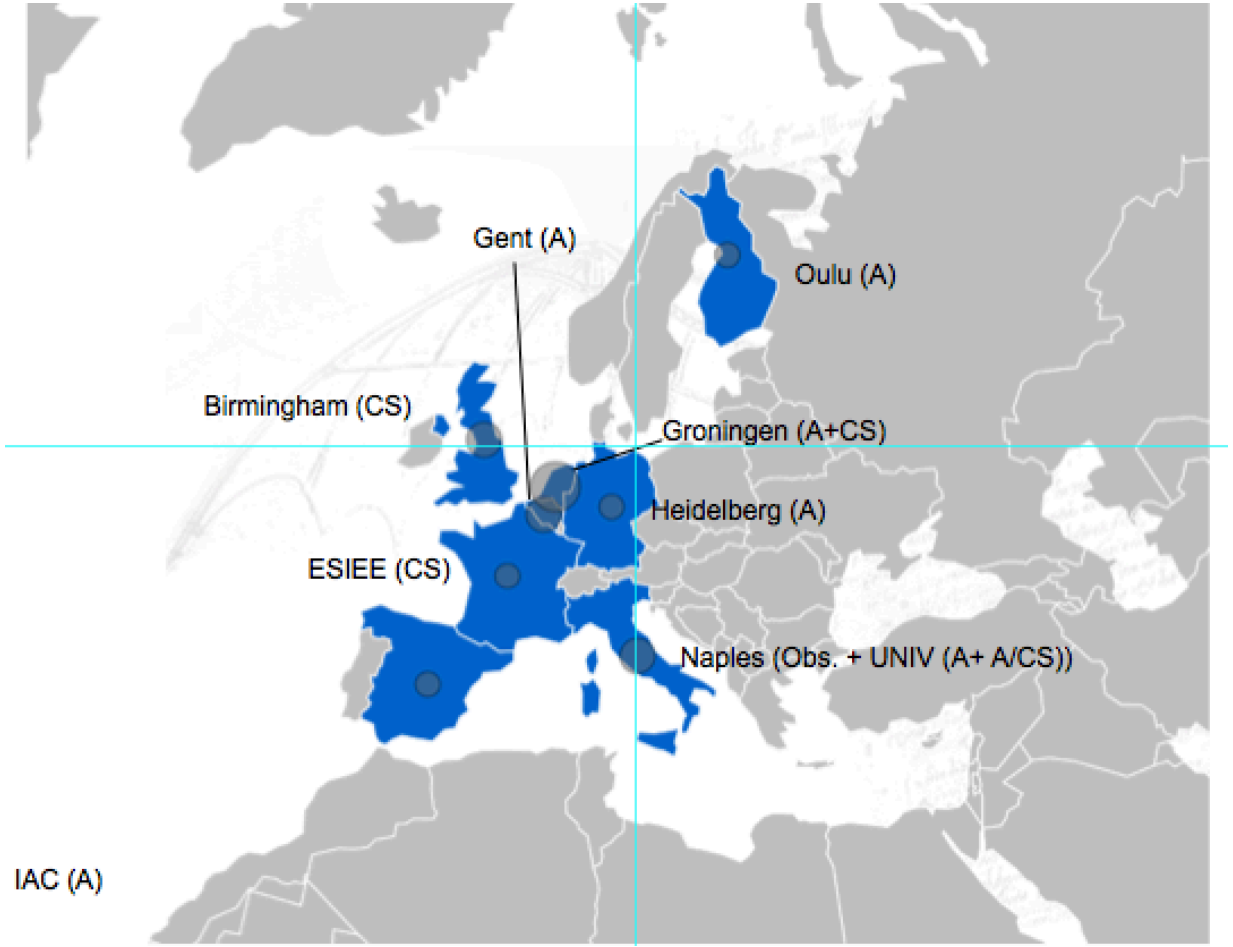
H2020 Innovative Training Network

GALAXY EVOLUTION and BIG DATA (2017-2021)



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GALAXY EVOLUTION and BIG DATA (2017-2021)

- IBM (Zürich) Cloud and Computing Infrastructure, and Cognitive Computing and Computational Sciences.

- TARGET Holding (Groningen) Big Data systems for Business Applications

- ADCIS (Caen) Imaging applications

- VICOMTECH (San Sebastian) computer vision, computer graphics and interaction

- CLEVER-FRANKE (Utrecht) Data visualization, design and development

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GALAXY EVOLUTION and BIG DATA (2017-2021)

Interdisciplinary collaboration of astronomers and computer scientists to determine novel algorithms to study galaxy evolution. In particular:

(1) Automatic detection of faint low surface brightness galaxy features

(2) Automated object recognition in Big Data sets

(3) Simulations of galaxy interaction, their characterisation and visualisation

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GALAXY EVOLUTION and BIG DATA (2017-2021)

- 14 PhD Students (2 in Naples) will work on the topics just mentioned

- Start date: 1 June 2017

- Number of students: Groningen (4), Birmingham (2), Gent (2), Naples (2), Heidelberg (1), IAC (1), Oulu (1), ESIEE (1)

- Every student will have a secondment of 6 months at a partner university or 3 months at a partner university and 3 months at a partner company.

- Yearly network meetings

- Training activities, at annual meetings, or in between

Conclusions

1) LSST is an optical machine to use for galaxy evolution (up to z~1.5)

2) LSST can be used for Strong and Weak lensing studies

3) There are many other science topics related (Galaxy Cluster search, AGN variability)

4) LSST needs strong investment in terms of technological developments for automated tools for galaxy classification, pattern/feature recognition etc.

5) LSST has strong capabilities for multi-instrument sinergies (astronomy), multi-disciplinarity (academy), industrial spin-off (industrial involvement)

⇩

PREMIALE LSST