Data characteristics and scientific results

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S. F. Sánchez (PI) and the CALIFA collaboration

OPINAS seminar - 2014 May 14

Outline

The idea for CALIFA

Legacy survey of a large and representative sample of galaxies in the local Universe using integral-field spectroscopy

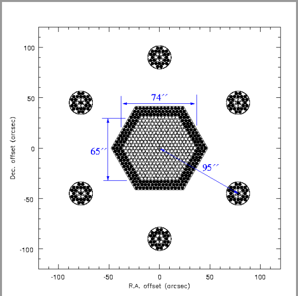
- 250 dark nights over 3 years at the Calar Alto Observatory
  - Large investment in telescope time
  - Selected after competitive review process for a large program
- Collaboration of more 80 members across 13 countries
  - PI: S. F. Sánchez (UNAM)
  - PS: J. Walcher (AIP)
  - Chair of Board: L. Wisotzki (AIP)
- Project started July 1st 2010 and is almost completed

The PMAS integral field spectrograph

Potsdam Multi-Aperture Spectrophotometer

- 3.5 telescope (Cassegrain focus)
- optimized for 350nm-900nm
- $\geq 30\%$ throughput
- Exchangeable and rotatable grisms
- 2 integral field units (IFUs):
  Lens Array (LArr)
  16×16 lenslets $(0.5'' - 1.0'')$
  Pmas fiber PAck (PPak)
  coarse fibre bundle
  $\sim 1'$ Field-of-View (FoV)
  $\Rightarrow$ Among the largest IFU FoV's

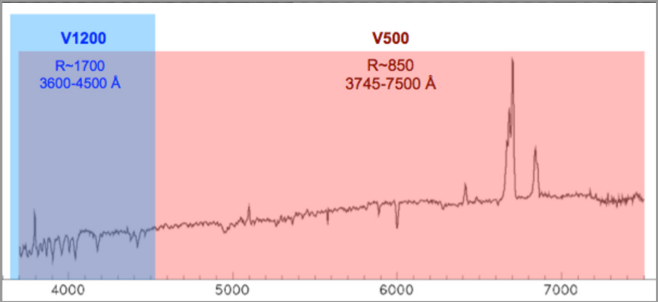
PPak fiber bundle



- 331 science fibers
- 36 dedicated sky fibers
- 2.7″ diameter fibers
- 1 arcmin FoV
- 2/3 filling factor

Wavelength coverage for CALIFA

Two setups are used to cover the entire optical wavelength range:



higher resolution ⇒ Galaxy kinematics from Ca H+K region
lower resolution ⇒ Stellar population and ionized gas

The CALIFA galaxy sample

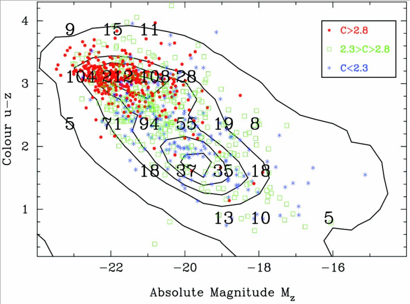
Mother sample is drawn from SDSS:

1. Diameter cuts: $45'' < D_{25} < 80''$
   $\Rightarrow$ effective usage of FoV
2. Redshift cuts: $0.003 < z < 0.03$
   $\Rightarrow$ excludes dwarf galaxies

987 galaxies within SDSS match these basic criteria

CALIFA will observe 600 galaxies!

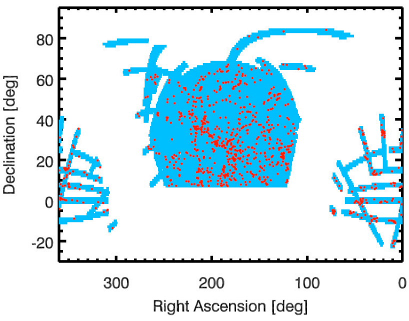
Color-Magnitude space



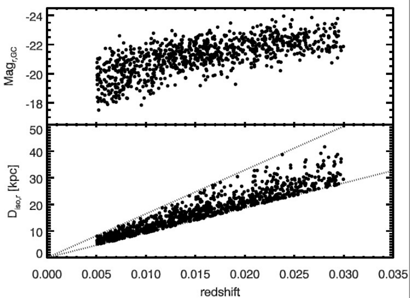
Sanchez et al. 2012, A&A, 538, A8

Sample: footprint

Footprint on sky



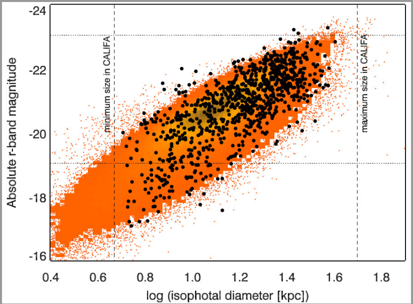
Redshift selection



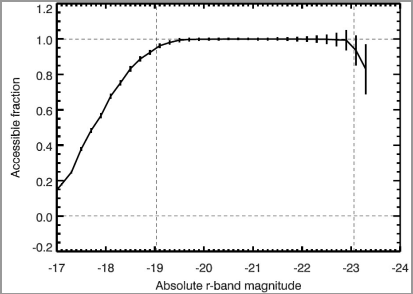
Walcher et al. in prep. 2014

Sample: completeness

Implicit selection



Completeness range

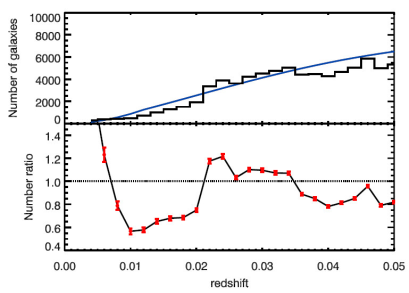


Walcher et al. in prep. 2014

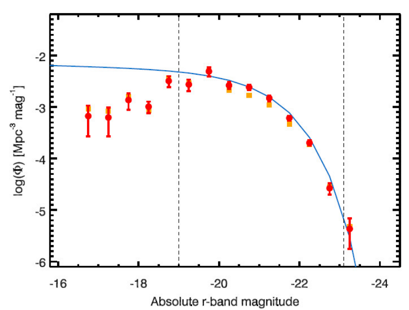
⇒ CALIFA sample can be volume corrected!

Sample: Luminosity function

Density variations



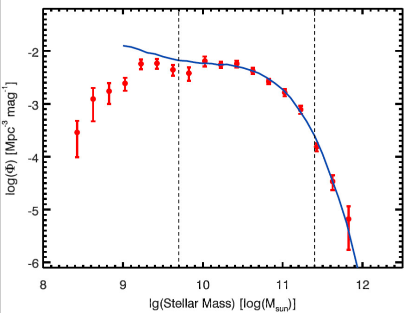
CALIFA Luminosity function



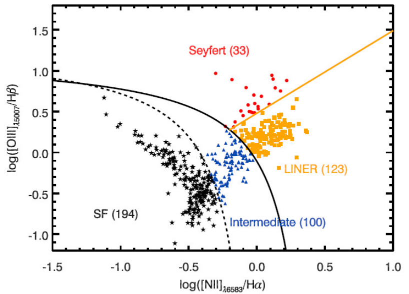
Walcher et al. in prep. 2014

Sample: Galaxy characteristics

Stellar mass function

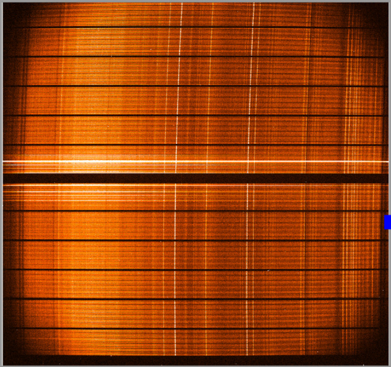


Nuclear activity (SDSS)



Walcher et al. in prep. 2014

The long way from IFU raw to reduced data



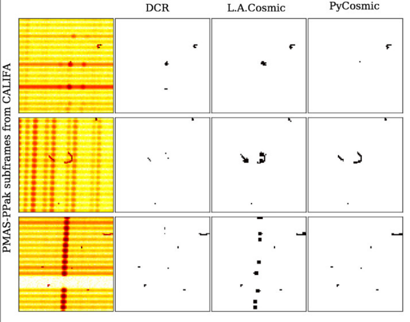
- Automated data reduction pipeline developed for CALIFA
- Quality control measurements are part of the pipeline
- Lot of effort to allow reasonable error propagation

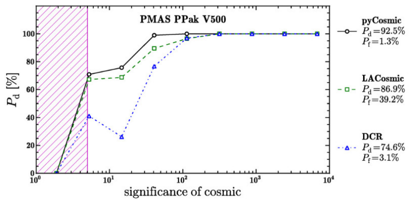
Data reduction and processing issues

- cosmic ray rejection
- fibre tracing
- optimal fibre extraction
- flat-fielding
- wavelength calibration
- homogenization of spectral resolution
- atmospheric dispersion correction
- astrometric registration and image reconstruction
- spectrophotometric calibration
- variance propagation
- bad pixel propagation
- QC parameters

PyCosmic: Cosmic-ray rejection for fibre-fed spectrographs

Cosmic ray detection is difficult for CALIFA given that only 1-2 frames are taken per pointing



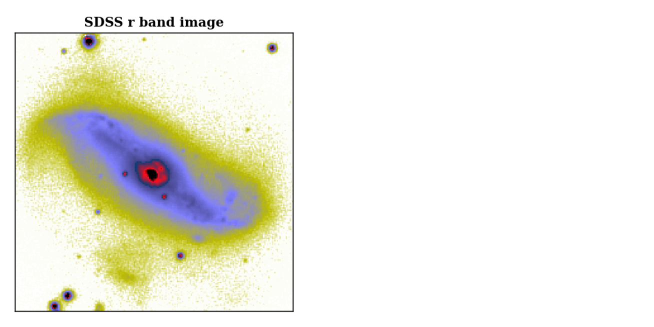


Husemann et al. 2012, A&A, 545, A137

PyCosmic combines two things for better performance:

- edge-detection similar to L.A.Cosmic
- Spectrograph-PSF to avoid false detection of real signal

Dither pattern and image reconstruction



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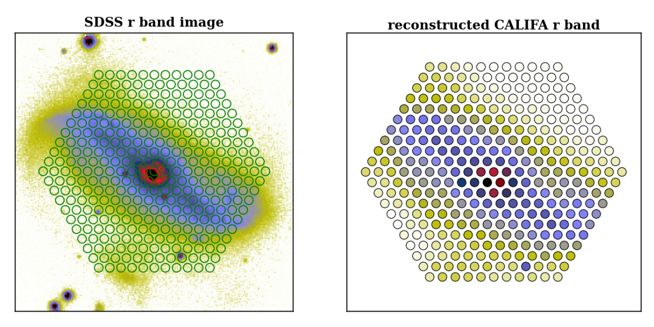
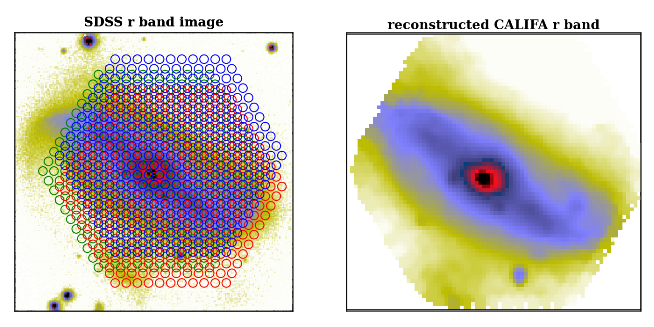


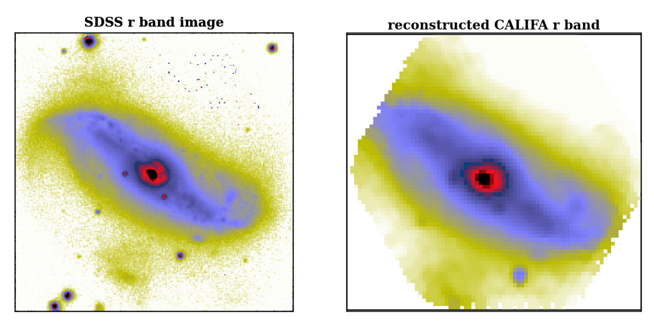
- An individual PPak pointing has a low filling factor

Dither pattern and image reconstruction



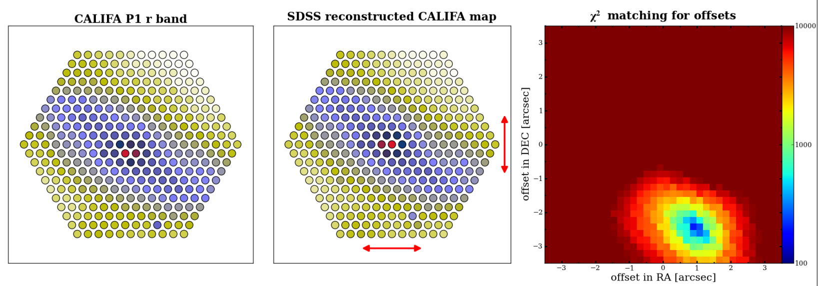
- An individual PPak pointing has a low filling factor
- 3 dither pointings allow image reconstruction ($1''$)

Dither pattern and image reconstruction



- An individual PPak pointing has a low filling factor
- 3 dither pointings allow image reconstruction (1″)
- Intrinsic spatial information still undersampled

Astrometric registering with SDSS images



How to properly register the CALIFA data to SDSS images?

1. Overlay fiber pattern
2. Re-construct flux from SDSS images
3. Offset fiber pattern and compute $\chi^2 = \sum_i \frac{(f_i^{\mathrm{CALIFA}} - f_i^{\mathrm{SDSS}})^2}{\sigma_i^{\mathrm{CALIFA}\,2} + \sigma_i^{\mathrm{SDSS}\,2}}$

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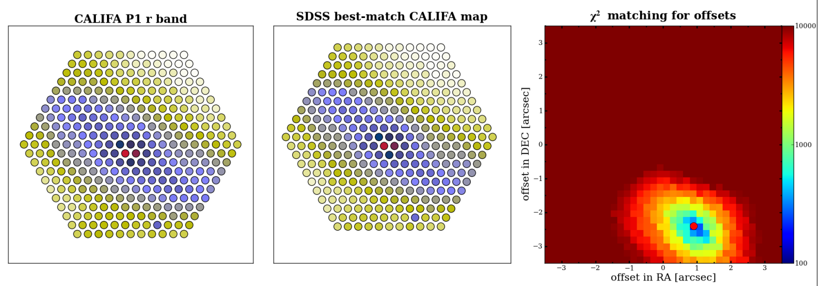

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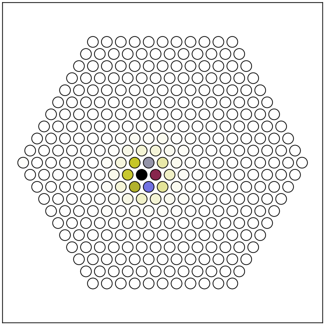
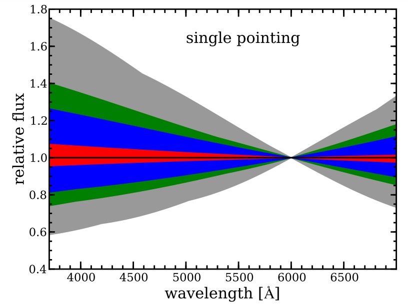
4. Pointing position can be estimated with sub-arcsec precision

Standard spectrophotometric calibration is difficult

A star observed with PPak



Simulating IFU position and atmospheric dispersion

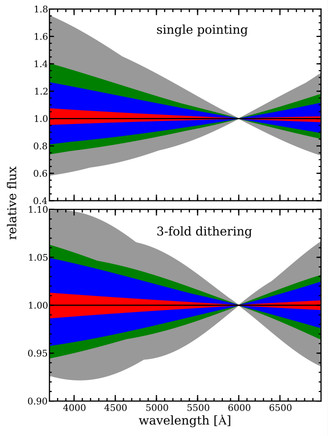


⇒ Sensitivity functions based on single PPak pointings on stars are very uncertain in their blue-to-red slope

Possible solutions for this problem

How to solve the low covering factor and undersampling of point sources for PPak?

1. Dithering on the calibration star
    - Not available for first 1.5y
    - How to check accuracy?
    - Rely on known offsets and time stability



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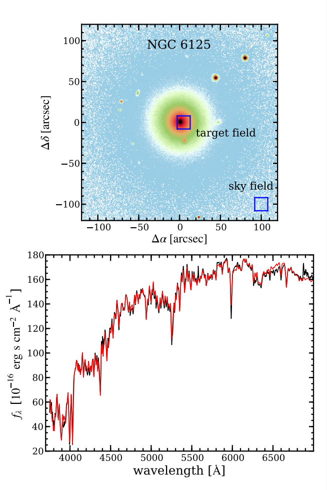
2. Early-type galaxies as calibrators
   - high surface brightness
   - smooth radial surface brightness
   - small variations in the consortium
   - almost insensitive to seeing/DAR



Early-type galaxies as extended spectroscopic standards!

Observing strategy

- PMAS Larr $16'' \times 16''$
- V300 grating (3600–7000Å)
- 2x1500s exposure time
- sequence:
  sky-target-sky-target-sky
- primary standard star
  observed in between

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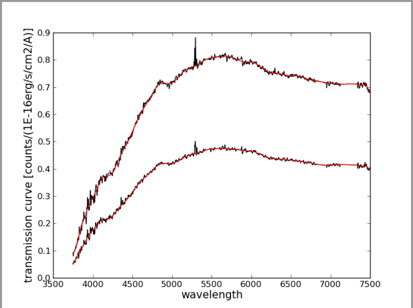
CALIFA transmission curve derive from LArr data of NGC 3158



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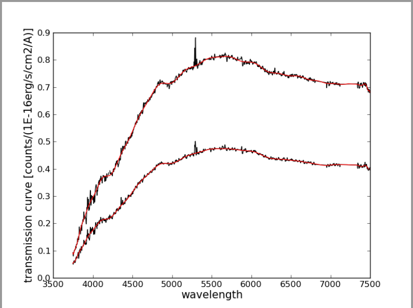
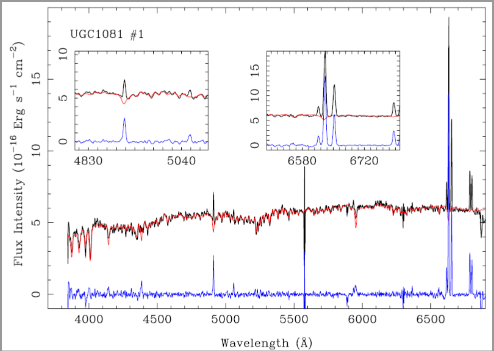


⇒20 early-type galaxies established as secondary spectro-photometric standards across the sky (Husemann et al. in prep. 2014)

What can be inferred from the data



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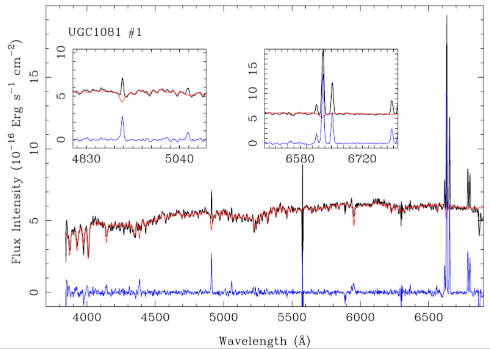
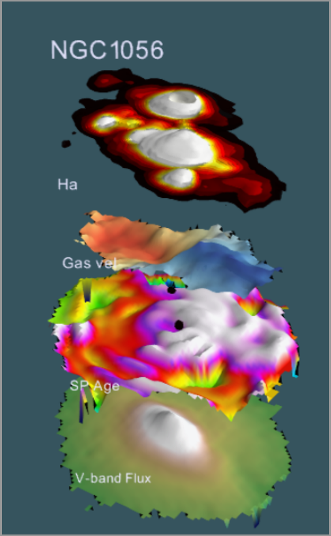
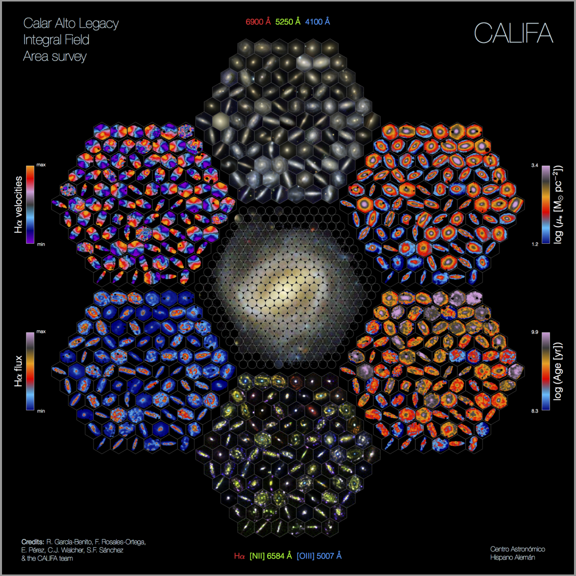
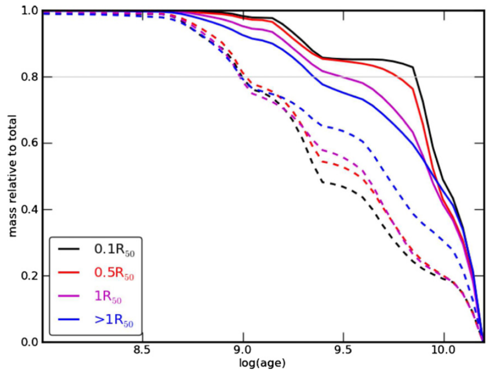




The wealth of information to digest from CALIFA...



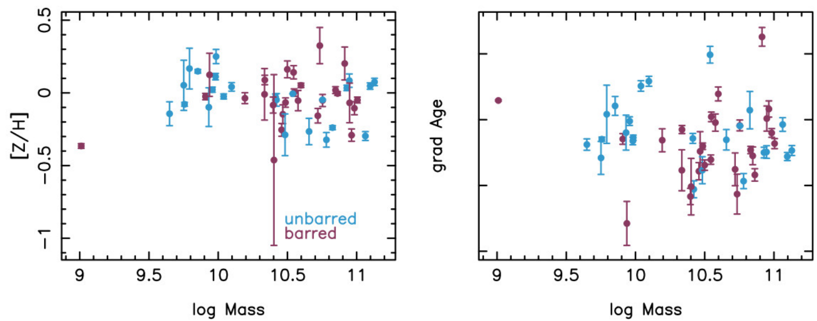
The inside-out growth of galaxies



(Perez et al. 2013, ApJL, 764, L1)

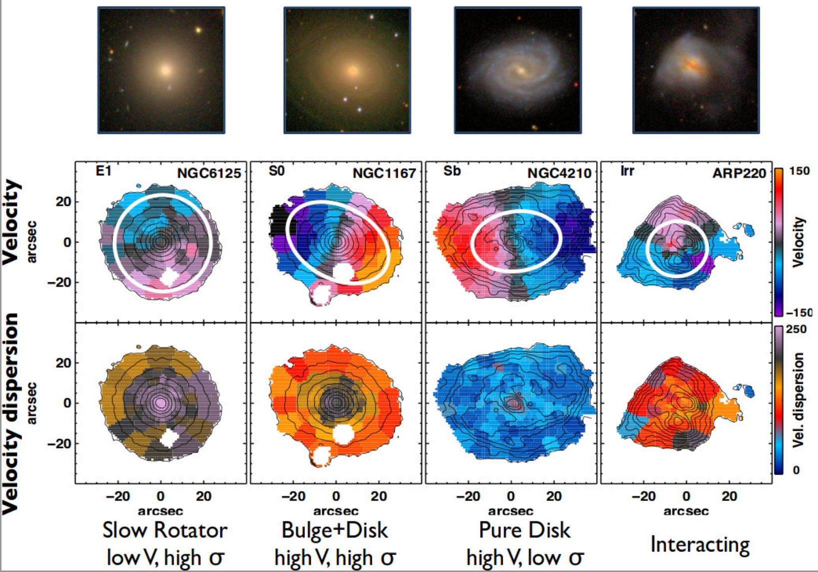
- high mass galaxies build up there mass inside-out
- lower mass galaxies build up there mass in the outskirts faster

The (non)-effect of bars

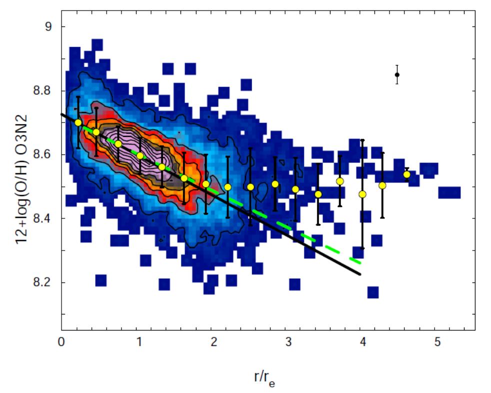


(Sanchez-Blazquez et al. in prep.)

The stellar kinematics



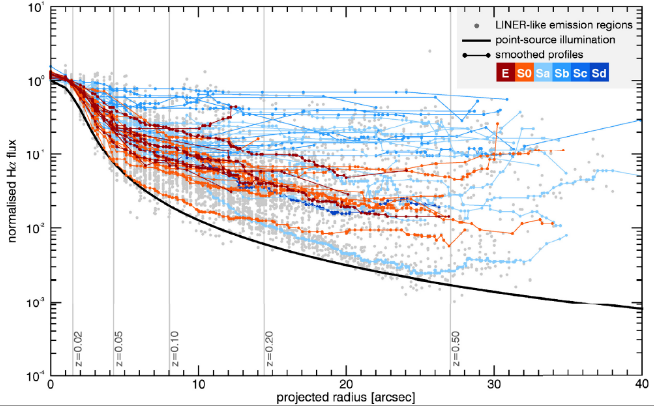
Gas-phase abundance gradients in galaxies



(Sanchez et al. 2014, A&A, 563, A49)

- disc galaxies follow a common gradient once normalized to R_e
- barred and non-barred galaxies have also the same slope
- evidence for a flattening at large radii

What is the ionizing source of LINERs



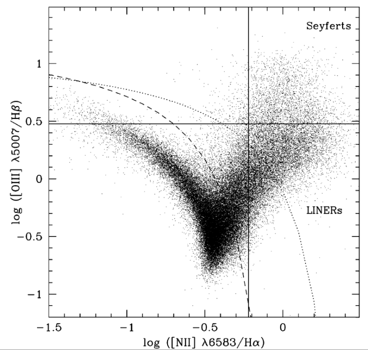
(Singh et al. 2013, A&A, 558, A43)

- LINER-like emission is an extended phenomenon in many galaxies
- excess of Hα emission compared to a point-like source i.e. AGN

$\Rightarrow$ old post-AGB stars are likely the dominant ionizing source

A new view on the BPT diagram

SDSS emission-line galaxies



(Kauffmann et al. 2003)

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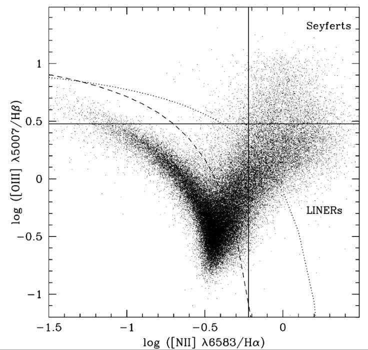
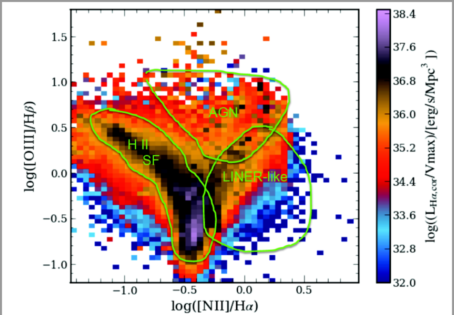


(Kauffmann et al. 2003)

Hα luminosity density of CALIFA



(Wisotzki, Husemann et al. in prep)

- BPT diagram is almost recovered just from ~200 galaxies
- CALIFA allows proper volume correction of properties
- most the Hα is emitted by star formation

Uniqueness of CALIFA

- **Large wavelength coverage**
  - Full optical emission-line diagnostic
  - Extended view on stellar populations
  - Suited to study galaxy kinematics
- **Spatial coverage and sampling**
  - Full optical size of galaxy covered
  - $\sim 1\,\mathrm{kpc}$ projected spatial resolution
- **Large homogeneous sample:**
  - Statistics, classification, rare objects
  - Comparison studies of different types

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- **Large homogeneous sample:**
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  - Comparison studies of different types
- **CALIFA is a legacy survey**
  - ready for your own ideas!!

CALIFA Data Release 1 since 1st of Nov 2012

- 100 galaxies in both setups (V500 and V1200)
- Fully calibrated datacubes + errors are distributed
- Extensive automatic and manual quality control checks
- Dedicated DR1 web service as well as VO access

http://califa.caha.es/DR1

See Husemann et al. (2013, A&A, 549, A87) for more details

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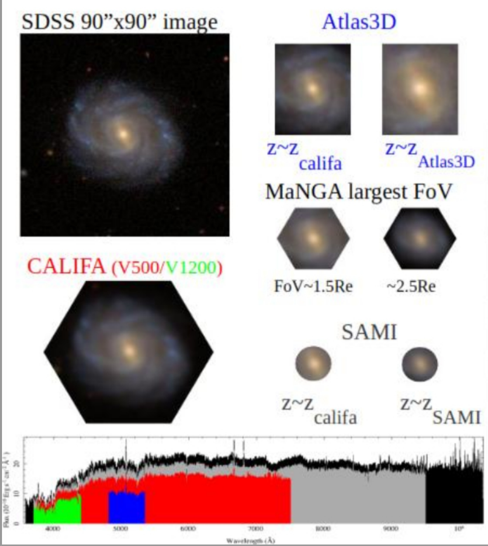
DR2 with 200-300 galaxies foreseen in autumn 2014

Comparison with other IFU surveys



CALIFA
2x3x331 spaxels; 2.7"/spaxel
600 galaxies of any type
~1.200.000 spec.; 3700-7500 Å

Atlas3D
1577 spaxels; 0.94"/spaxel
260 ETGs
~400.000 spectra; 4810-5350 Å

MaNGA
3x(19-127) spaxels; 2"/spaxel
7000 gal. of any type (~1.5Re)
2000 gal. of any type (~2.5Re)
1000 gal. of any type (any Re)
~800.000 spec.; 3550-10000 Å

SAMI
9x61 spaxels; 1.6"/spaxel
3400 galaxies of any type
~1.900.000 spec.; 3700-9500 Å