Quasar Host Galaxies in the FORS Deep Field

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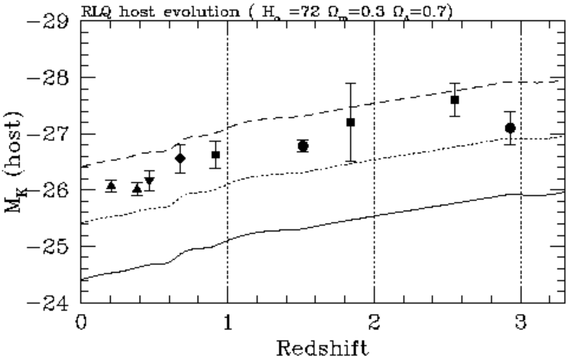
Contents

Cosmology and Magnitude System

- cosmology is: $H_0 = 70 km/s/Mpc, \Omega_m = 0.3, \Omega_\Lambda = 0.7$, unless otherwise stated
- all magnitudes are in Vega-system

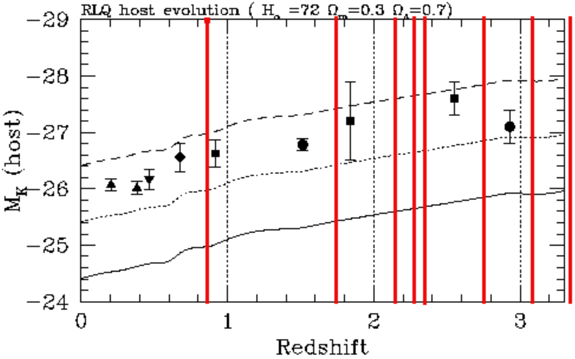
Motivation

Falomo et al. 2005



Motivation

Falomo et al. 2005



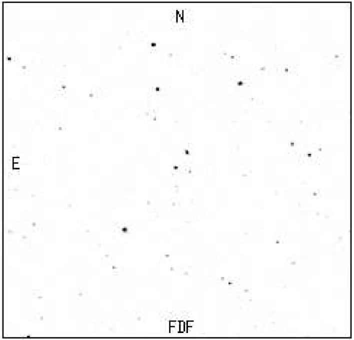
$\Longrightarrow$ our quasars lie in a very interesting redshift range!

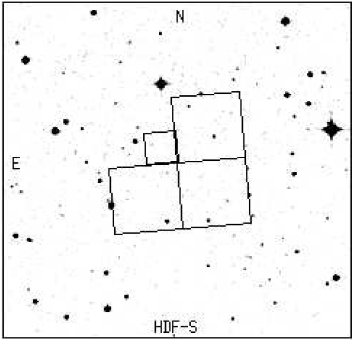
The FORS Deep Field

- field around high-redshift (z=3.3650) radio-loud (?) QSO Q0103-260
- size of field: 6.8'x6.8'
- about 9000 objects in photometric catalog
- spectroscopy for about 350 objects, including all 8 identified quasars

The FORS Deep Field - FDF vs. HDF

Heidt et al. 2003





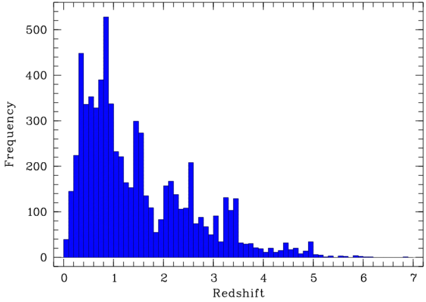
- FDF is distinctly larger than HDF $\Longrightarrow$ better statistics
- FDF contains far less bright stars than HDF

The FORS Deep Field - Data

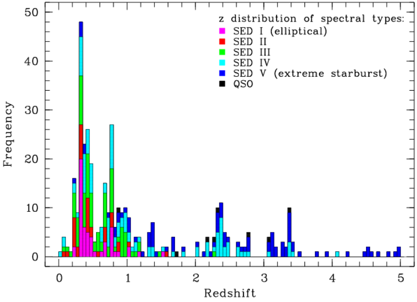
filter	telescope	exposure time [s]	FWHM ['']	50% compl. limit
U	VLT	44400	0.97	25.64
B	VLT	22660	0.60	27.69
g	VLT	22145	0.87	26.86
R	VLT	26400	0.75	26.68
I	VLT	24900	0.53	26.37
J	NTT	4800	1.20	23.60/22.85
Ks	NTT	4800	1.24	21.57/20.73
F814W	HST	2400	0.12	?

The FORS Deep Field - Redshift Distribution

Appenzeller et al. 2004
photometric redshifts



Noll et al. 2004 (∼350 objects)
spectroscopic redshifts



The QSO-Sample

FDF-ID	z	m_I	M_B	M_B $H_0 = 50$ $\Omega = 0$	type	radio
FDF0809	0.8650	21.4	-20.65	-21.29	QSOI	RQQ
FDF1837	2.2540	22.9	-21.88	-22.79	QSOI	RQQ
FDF2229	2.1560	20.8	-23.57	-24.56	QSOI	RQQ
FDF2633	3.0780	22.8	-22.33	-23.59	QSOI	RQQ
FDF4683	3.3650	18.6	-27.19	-28.53	QSOI	RLQ
FDF5962	1.7480	21.9	-22.29	-23.15	QSOI	RQQ
FDF6007	2.7515	24.1	-21.10	-22.27	TypeII	RQQ
FDF6233	2.3215	23.9	-19.73	-20.77	BAL	RQQ

Data Analysis

- construction of Point Spread Function (PSF) (IRAF)
- fitting the object (kimage)
    - fitting the central point source
    - fitting a core+galaxy-model
- error simulations (fitsimul, to be done)

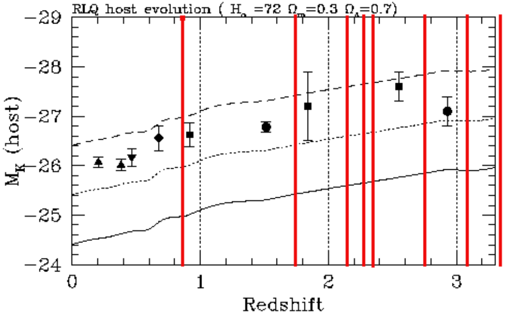
Fits

different models are fitted to each object:

- core-fit(AGN): scaled PSF is fitted
  3 free parameters: magnitude, x- and y-position
- core+galaxy-fit: scaled PSF(AGN) + either disk (β=1) or bulge (β=0.25) galaxy model
  3 free parameters: magnitude of core, magnitude of galaxy, effective radius of galaxy, coordinates fixed, β fixed
- FDF0809: additional fit with 5 free parameters, additionally ellipticity and position angle of galaxy

Results

- for 4 out of 8 quasars, the host galaxy could be resolved



- redshifts of resolved host galaxies lie between z=0.8650 and z=2.7515

Results

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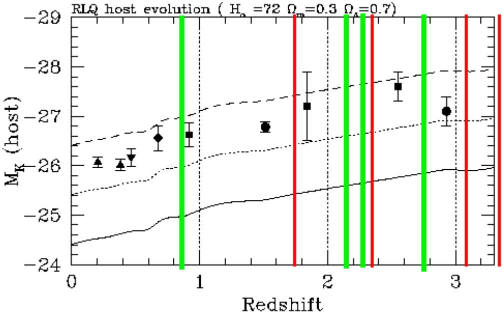
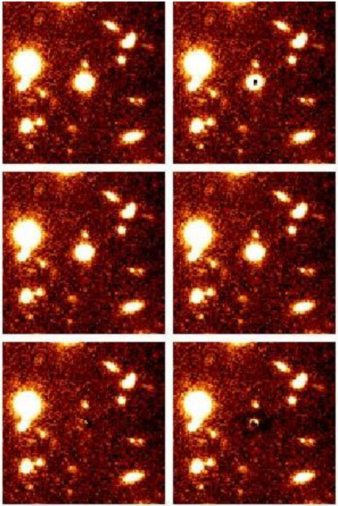


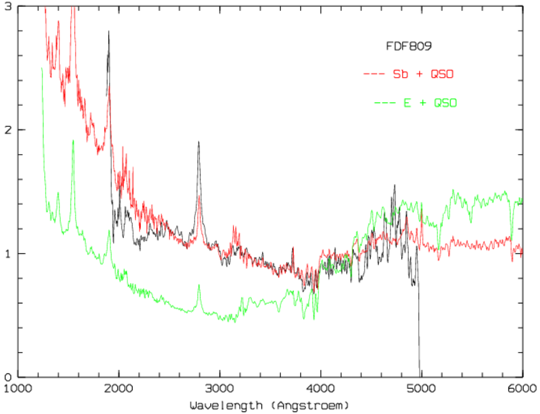
- redshifts of resolved host galaxies lie between z=0.8650 and z=2.7515

Resolved Objects: FDF0809



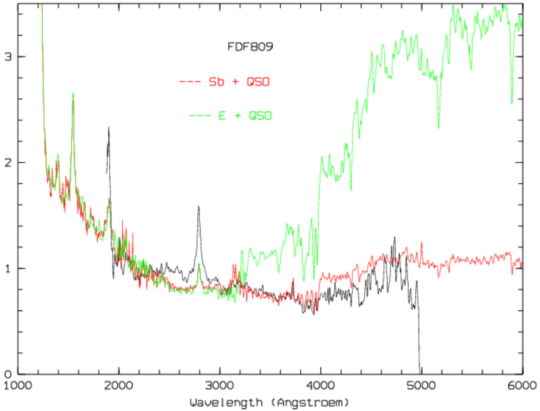
- z=0.8650
- type: QSO
- resolved in all filters
- clearly better fits for disk-model
  $\Longrightarrow$ simulation of spectra
- k-corrected absolute magnitudes (galaxy) in I:
  M(disk) = -22.22, M(bulge) = -23.12

Simulation of Spectra - Result for FDF0809 (I)



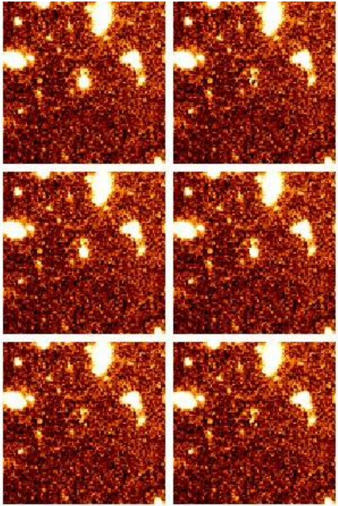
⟹ disk galaxy is clearly preferred

Simulation of Spectra - Result for FDF0809 (B)



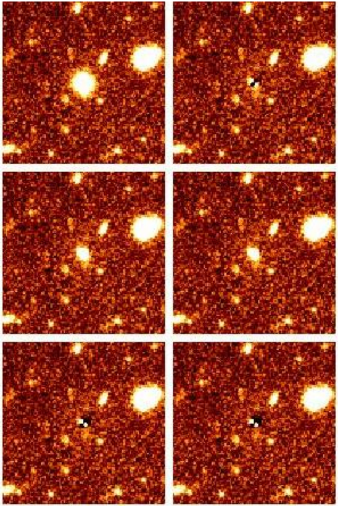
$\Longrightarrow$ disk galaxy is clearly preferred

Resolved Objects: FDF1837



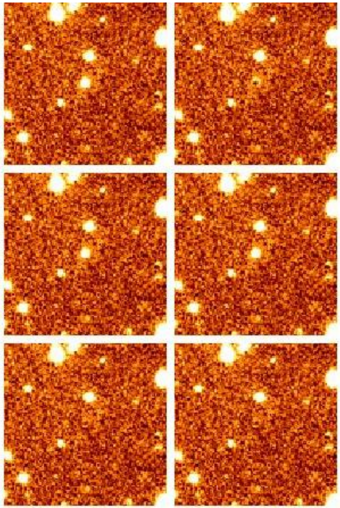
- z=2.2540
- type: QSO
- resolved in filters UBgRI
- slightly better fits for disk-model
- k-corrected absolute magnitudes (galaxy) in I:
  M(disk) = -23.89, M(bulge) = -26.29

Resolved Objects: FDF2229



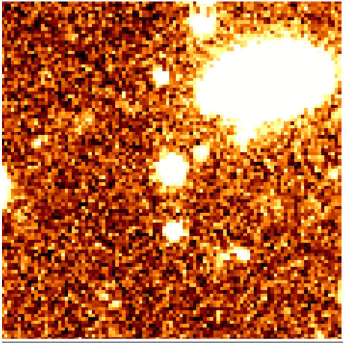
- z=2.1560
- type: QSO
- resolved in filters UBgRI
- slightly better fits for disk-model
- k-corrected absolute magnitudes (galaxy) in I:
  M(disk) = -24.66, M(bulge) = -26.76

Resolved Objects: FDF6007



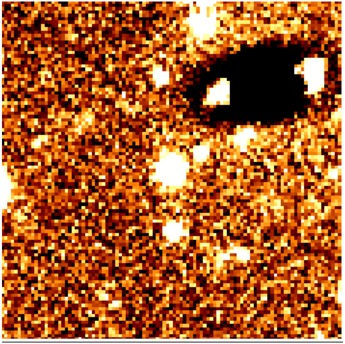
- z=2.7515
- type: TypeII Quasar
- resolved in filters BgRI and F814W(HST)
- no model preferred in fits
- k-corrected absolute magnitudes (galaxy) in I:
  M(disk) = -22.90, M(bulge) = -26.80

Unresolved Objects: FDF2633



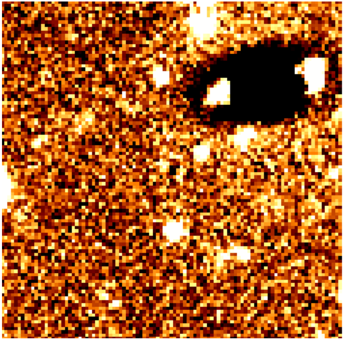
- z=3.0780
- type: QSO
- not resolved
- problems due to close-by elliptical galaxy
- close-by galaxy was fitted to improve the fits

Unresolved Objects: FDF2633



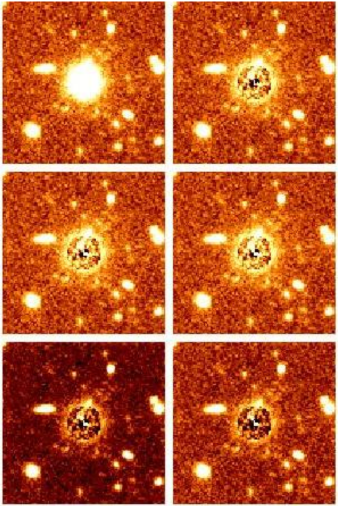
- z=3.0780
- type: QSO
- not resolved
- problems due to close-by elliptical galaxy
- close-by galaxy was fitted to improve the fits

Unresolved Objects: FDF2633



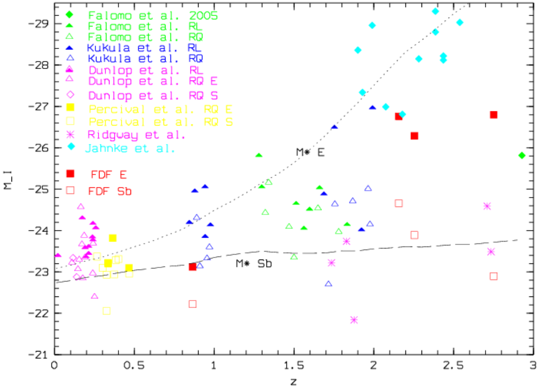
- z=3.0780
- type: QSO
- not resolved
- problems due to close-by elliptical galaxy
- close-by galaxy was fitted to improve the fits

Unresolved Objects: FDF4683



- z=3.3650
- type: QSO
- not resolved
- problems due to brightness of quasar
- PSF does not work as it is built out of distinctly fainter PSF-stars

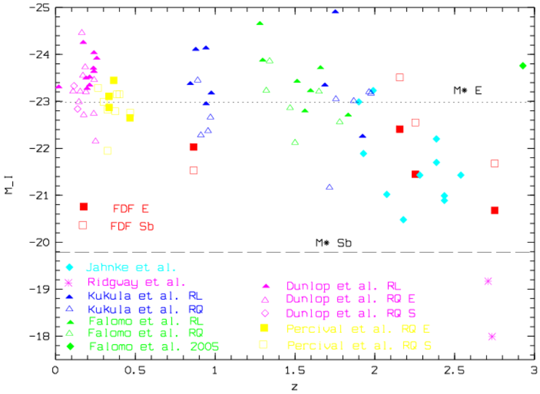
Comparison of k-corrected Absolute Magnitudes



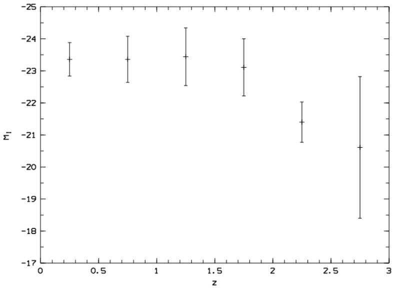
k-corrections (redshift) by Bicker et al. 2004, k-corrections (different filters) by Poggianti 1997

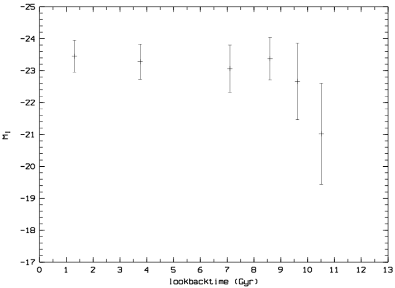
Comparison of k- and e-corrected Absolute Magnitudes

e-corrections by Bicker et al. 2004, passive evolution
cosmology is: $H_0 = 70km/s/Mpc, \Omega_0 = 0.1$



Evolution of Elliptical Quasar Host Galaxies (e-corrected)

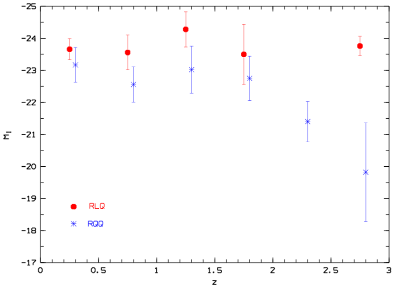


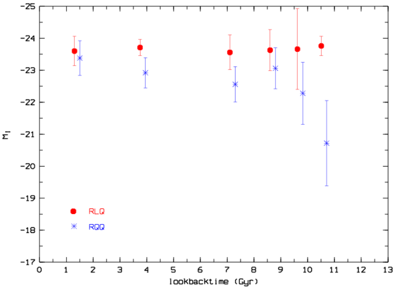


cosmology is: $H_0 = 70km/s/Mpc, \Omega_0 = 0.1$

$\Longrightarrow$ absolute magnitude of elliptical quasar host galaxies decreases beyond z≈2

Evolution of Elliptical Host Galaxies of RLQ and RQQ (e-corrected)





cosmology is: $H_0 = 70km/s/Mpc, \Omega_0 = 0.1$

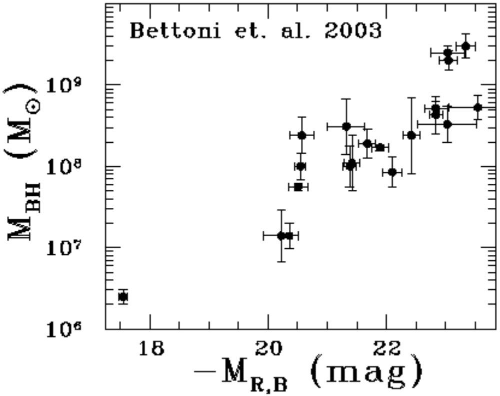
$\Longrightarrow$ host galaxies of RLQ and RQQ evolve differently

Mass of Central Black Hole - Method

M_{BH} in nearby elliptical galaxies correlates with properties of galaxies

- we used these correlations to measure M_{BH} for the resolved host galaxies
- correlations are from the paper Novak et al. 2006, used correlations are based on data from Bettoni et al. 2003, Marconi & Hunt 2003, Gebhardt et al. 2003 and McLure & Dunlop 2002
- correlations use M_B, M_R and M_J of galaxy
- e-corrected absolute magnitudes are used, as the correlations are based on z≈0 data $\Longrightarrow$ values are only upper limits!!!

Mass of Black Hole - Plot



Novak et al. 2006

Mass of Central Black Hole - Results

object → ↓ paper (filter)↓	FDF0809	FDF1837	FDF2229	FDF6007
Gebhardt(B)	(8.48)	6.76	9.45	7.27
Marconi&Hunt(J)	(7.39)	–	–	–
Bettoni et al.(R)	(8.39)	7.35	7.53	7.45
McLure&Dunlop(R)	(8.29)	7.35	7.51	7.44
average	(8.1)	7.2	8.2	7.4

$log(M_{BH}/M_{\odot})$ for resolved objects using different correlations

Conclusions and Outlook

- elliptical quasar host galaxies were less luminous at redshifts higher than z≈2
- host galaxies of RLQ and RQQ evolve differently
  - host galaxies of RLQ are more luminous, their absolute e-corrected magnitude stays constant up to z≈3
  - host galaxies of RQQ are less luminous, their absolute e-corrected magnitude decreases distinctly beyond z≈2
- open questions:
  - why do host galaxies of RQQ and RLQ evolve differently??
  - what happens beyond z≈3 ??

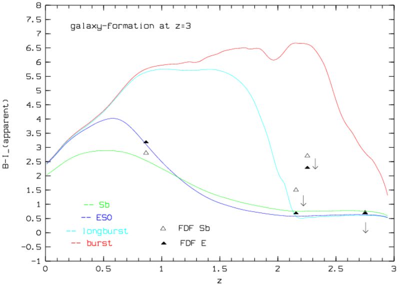
$\Longrightarrow$ future observations at even higher redshifts need excellent resolution and very deep images

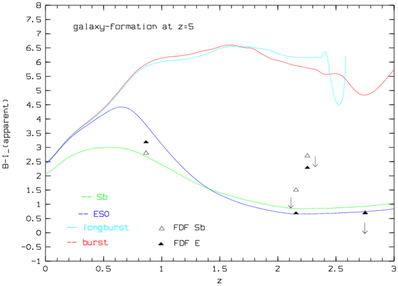
Colors of the Resolved Host Galaxies - Methods

investigation of galaxy type using colors

- colors, calculated using apparent magnitudes of L_* galaxies are plotted over redshift
- colors of resolved galaxies are plotted into the same diagram
- possible influences due to forbidden or semi-forbidden lines: these lines may come from expanded regions but belong to the core
  $\Longrightarrow$ magnitude of galaxy is overestimated

Colors of the Resolved Host Galaxies - Plots



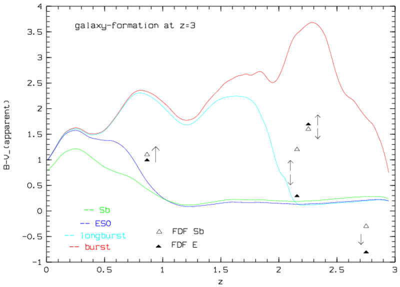


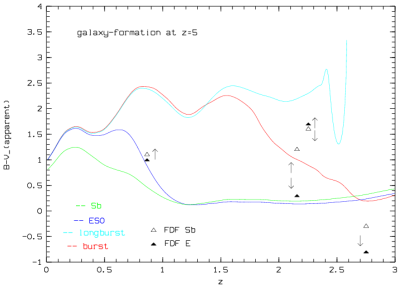
color: B-I

red is up, blue is down

arrows mark possible influences due to lines

Colors of the Resolved Host Galaxies - Plots



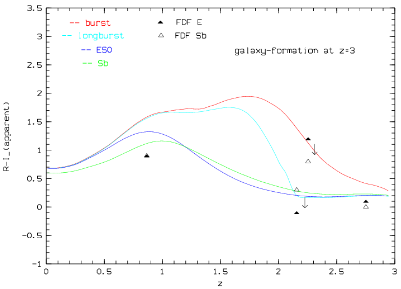


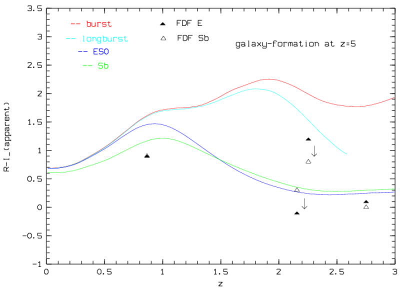
color: B-V

red is up, blue is down

arrows mark possible influences due to lines

Colors of the Resolved Host Galaxies - Plots



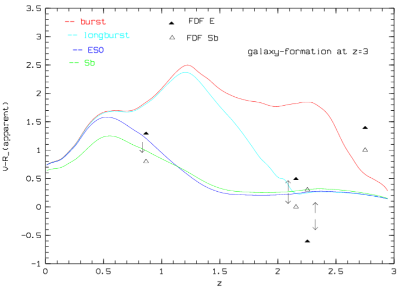


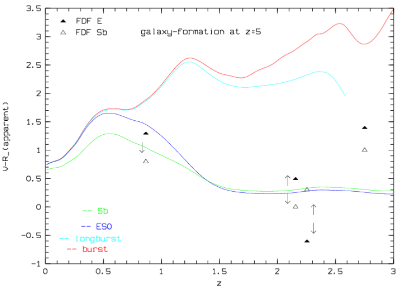
color: R-I

red is up, blue is down

arrows mark possible influences due to lines

Colors of the Resolved Host Galaxies - Plots



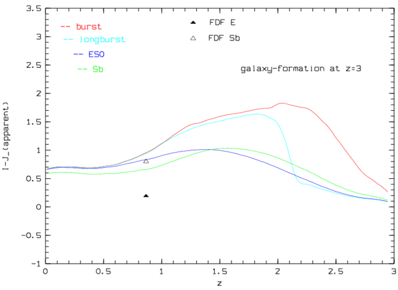


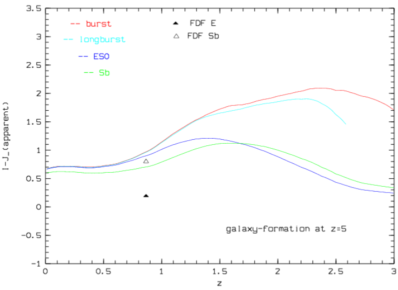
color: V-R

red is up, blue is down

arrows mark possible influences due to lines

Colors of the Resolved Host Galaxies - Plots





color: I-J

red is up, blue is down

arrows mark possible influences due to lines

Colors of the Resolved Host Galaxies - Results

- FDF0809: compatible with galaxy types E/S0 or Sb, no distinction between galaxy formation at z=3 or z=5
- FDF1837, FDF2229, FDF6007: compatible with types longburst, E/S0 and Sb at z=3 or E/S0 and Sb at z=5

Calculation of Star Formation Rate

SFR is calculated using rest-frame UV-fluxes

- method used is from the paper by Kennicutt 1998
- wavelength-range: rest-frame 1250-2500 Å
  $\Longrightarrow$ this range is dominated by young stars
  $\Longrightarrow$ can be used to calculate SFR
- $SFR(M_\odot/yr) = 1.8 \times 10^{-27}\{\frac{d_l^2 \times 10^{-0.4(m_{AB}+48.6)}}{1+z}\}$
- flux of forbidden or semi-forbidden lines was subtracted (may come from extended region but belong to central point source)
- problem: formula does not work properly if SFR changes on time-scales smaller than 10^8yr
  $\Longrightarrow$ this is likely in very young galaxies!!!
  $\Longrightarrow$ method will be tested on model galaxies

Star Formation Rate - Results

object(filter used)->	0809(B)	1837(R)	2229(R)	6007(I)
object(e)	1.8	0.03-4.7	15.8-33.0	6.9
object(d)	1.8	0.07-8.2	14.9-30.1	4.4
burst(z=3)	0.4	0.07	0.06	15.2
burst(z=5)	0.4	0.04	0.04	0.07
longburst(z=3)	0.5	391.2	300.9	288.8
longburst(z=5)	0.3	0.05	0.05	-
E/S0(z=3)	6.5	170.8	157.9	240.3
E/S0(z=5)	2.6	68.0	57.3	87.2
Sb(z=3)	5.4	8.2	8.3	6.6
Sb(z=5)	4.9	6.8	6.9	6.0

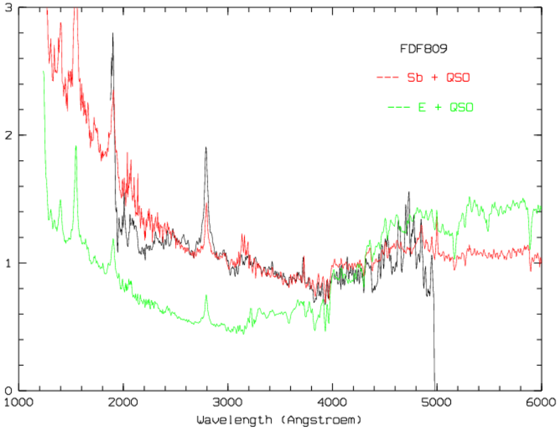
Simulation of Spectra - Method

simulating the FORS spectroscopy using fitted models

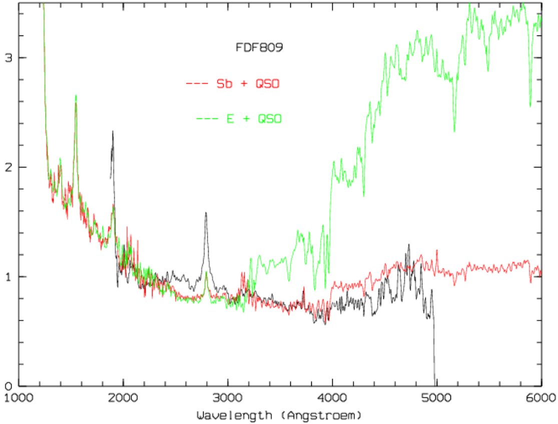
- flux ratio (central point source to galaxy) is calculated in a 1" slit (corresponding to FORS spectroscopy)
- template spectra for QSO, SeyfertII, E/S0 and Sb are calibrated in the used filter transformed to the rest frame of the object
- template spectra for QSO/SeyfertII and galaxy are weighted using the flux ratio and added up

$\Longrightarrow$ simulated spectrum is compared to measured spectrum

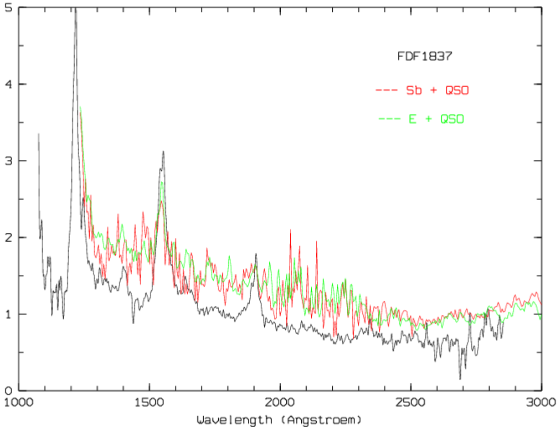
Simulation of Spectra - Result for FDF0809 (I)



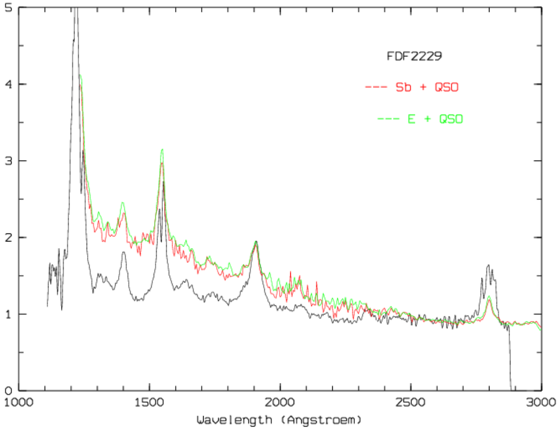
Simulation of Spectra - Result for FDF0809 (B)



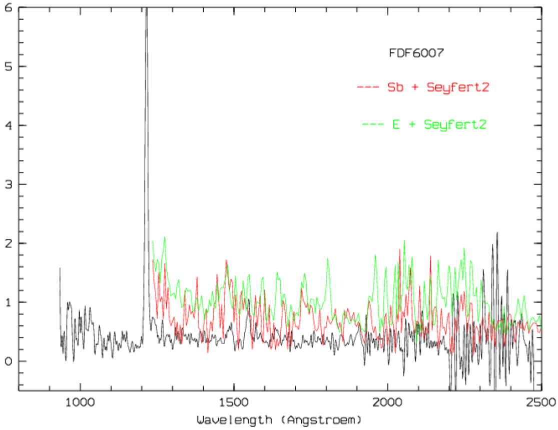
Simulation of Spectra - Result for FDF1837 (I)



Simulation of Spectra - Result for FDF2229 (I)



Simulation of Spectra - Result for FDF6007 (I)



Conclusions - FDF0809

- disk-model was clearly preferred in fits
- simulation of spectrum yielded excellent results for Sb, but strong deviations for E/S0
- colors of host galaxy are consistent with Sb or E/S0
- SFR: 1.8 $M_{\odot}/yr$
- $M_{BH} \leq\sim 10^8 M_{\odot}$
  $\Longrightarrow$ host galaxy is clearly identified as disk galaxy

Conclusions - FDF1837

- disk-model was slightly preferred in fits
- simulation of spectrum could neither exclude E/S0 nor Sb
- colors of host galaxy rule out bursts and longburst at high redshifts (z=5)
- SFR: 0.03-8.2 $M_{\odot}/yr$, value is only reasonable if SFR does not change on small time scales (e.g. Sb)
- $M_{BH} \leq 10^{7} \sim 10^{8} M_{\odot}$

Conclusions - FDF2229

- disk-model was slightly preferred in fits
- simulation of spectrum could neither exclude E/S0 nor Sb
- colors of host galaxy rule out bursts and longburst at high redshifts (z=5)
- SFR: 15-33 $M_{\odot}/yr$, value is only reasonable if SFR does not change on small time scales
- $M_{BH} \leq\sim 10^8 M_{\odot}$

Conclusions - FDF6007

- no model preferred in fits
- simulation of spectrum could neither exclude E/S0 nor Sb
- colors of host galaxy show strong deviations from all models in 2/4 colors, other two only rule out bursts and longburst at high redshifts (z=5)
- SFR: 4.4-6.9 $M_\odot/yr$, value is only reasonable if SFR does not change on small time scales
- $M_{BH} \leq 10^7 \sim 10^8 M_\odot$