SEARCH FOR PRIMEVAL GALAXIES WITH THE "CALAR ALTO DEEP IMAGING SURVEY"

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1. Introduction

Understanding the formation of galaxies is certainly one of the major challenges in astrophysics. Observationally, the most important insight will be provided by the detection and study of primeval galaxies. With the large telescopes and the efficient detectors available today, it seems feasible to observe those early stages of galaxy evolution directly. Despite considerable efforts with different techniques (Cowie *et al.* 1990; De Propris *et al.* 1993; Pritchet & Hartwick 1990; Thompson *et al.* 1995; Djorgovski *et al.* 1993) no primeval galaxy is found yet, in contradiction with predictions by model calculations (e.g. Baron & White 1987). What could be the reason for this lack of sucess ?

First, it seems that former searches were done at too low redshifts. Although Cold Dark Matter models tend to place the epoch of galaxy formation at $2 \lesssim z \lesssim 4$, there are reasons to believe that it took place at higher redshift: Quasars and radio galaxies are found out to $z \gtrsim 4$ and show strong metal lines; damped Ly-α systems, detected out to $z \simeq 4$ also contain a considerable amount of heavy elements; the old stellar population of elliptical galaxies at intermediate redshifts must have formed at $z > 3$ (Ziegler & Bender, this conference, poster 53).

Second, the predicted number of observable galaxies is grossly overestimated since the models did not take into account that the duration of the "primeval galaxy" phase could be short-lived. After several 10^8 years the first generation of stars may enrich the primordial material with metals causing significant UV extinction by dust (Thommes & Meisenheimer, poster 124, this conference).

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2. Search Strategy for Primeval Galaxies

How do we recognize a primeval galaxy? By definition, its main characteristics are an almost pure hydrogen emission line spectrum over a faint continuum ($R \gtrsim 25$ mag) with Lyman break. The brightest line is Ly α with an expected equivalent width of the order of $W_{obs} \gtrsim 50$ nm at $z > 4$. At this redshift all other strong hydrogen lines are shifted beyond $2.4\,\mu$m where groundbased observations are very difficult. Although at later stages in the galaxy formation process Ly α might be suppressed strongly by dust extinction, this complication is of little relevance for the first burst of star formation which we are looking for.

Any search for emission line objects of unknown redshift requires a trade-off between spectral coverage and field of view. In principle a longslit spectroscopic survey has the same efficiency as a narrow-band imaging survey with the same spectral resolution. In practice, however, narrow-band imaging has the advantages that the optimum sampling aperture can be chosen for each object individually when analysing the exposures, and that background subtraction is much more accurate on imaging data. In our approach only three narrow windows in the atmospheric spectrum, around $\lambda = 700$, 820, and 918 nm will be searched for emission lines.

Where shall we look for? Biased searches around known radio galaxies or quasars are subject to unknown selection effects and thus may even reduce the success rate. In order to get astrophysical insight into the galaxy formation process we need the unbiased statistics of primeval galaxies and therefore have to carry out the survey in the general field.

Along these lines we have developed an optimized strategy to search for primeval galaxies: the Calar Alto Deep Imaging Survey (CADIS). Though this survey project is specifically designed to detect primeval galaxies it will in addition produce a large data base for investigations of faint galaxies and quasars, by combining a very deep emission line survey with deep broad- and medium-band photometry. So the effort will not be lost even if no primeval galaxies can be found.

3. The CADIS Concept and First Results

The search for Ly α emission from primeval galaxies is done with an imaging Fabry-Pérot-Interferometer (FPI) in the three windows mentioned above, corresponding to redshifts of $z \sim 4.7$, 5.7, and 6.5. The spectral resolution is $\delta\lambda \sim 2.0$ nm and each window will be covered by 10 wavelength settings.

In most cases the emission line objects detected in the FPI images will be foreground galaxies seen in H_α, [O III] $\lambda 500.7$, *etc.* In order to recognize these cases we carry out additional medium-band observations at those wavelengths where one expects a second line for the above identifications. These filters are called veto filters because a signal in them excludes Ly-α.

Moreover, since most foreground objects have spectral energy distributions (SED) which significantly differ from that expected for a primeval galaxy we do observations with a set of 9 medium-band filters covering the wavelength range from 450 to 920 nm plus three broad band filters, including a deep K-band observation (limiting magnitude for 10% photometry: $R \simeq 23\overset{m}{.}5$, $K \simeq 20\overset{m}{.}5$). For more details see Meisenheimer *et al.*, 1995). In order to avoid color selection effects in the data reduction, all filter images have the same priority. Object lists are produced independently for every filter and FP image by using FOCAS and are merged into a master list, where objects found within 1″ of each other on different frames are assumed to be the same. The SED for every object is then determined from accurate CCD photometry on each individual image.

In the entire survey we expect to discover several tens of primeval galaxies, > 1000 emission line galaxies in several narrow redshift bins between $z = 0.24$ and $z = 1.4$ at least 500 early type galaxies in the range $0.5 < z < 1.2$), with redshifts determined within $\sigma(z) \lesssim 0.02$) with the multicolor method developed by Belloni *et al.* (1995) , and several hundred faint quasars, most of them at redshifts $z > 3$. Thus, CADIS will not only probe the space density of primeval galaxies to unprecedented depth and redshift but also provide a unique data base to study the evolution of the luminosity function and clustering properties of faint field galaxies.

The survey is carried out with the focal reducers at the Calar Alto 2.2 m and 3.5 m telescopes, with a 2k×2k optical CCD (field of view $\gtrsim 10' \times 10'$) and a 1k×1k NICMOS array for the NIR observations. We will observe 10 fields (total field 0.28 □°) distributed over the northern sky in order to assure that at least one field is observable at any time. The fields have been selected on the IRAS maps and the Palomar Sky Survey plates to minimize galactic extinction and the presence of bright stars.

The attempted limiting flux for Ly-α is $3 \times 10^{-20}\,\mathrm{W\,m^{-2}}$ (5σ-detection), equivalent to a star formation rate of $15\,M_{\odot}\,\mathrm{yr}^{-1}$ at $z = 6.4$ (for $H_0 = 50$ and $q_0 = 0.5$). This limiting flux is reached after an integration of 15 ksec with the focal reducer CAFOS 2.2 at the 2.2 m telescope (or 6 ksec at the 3.5 m-telescope). The required integration per medium-band filter to reach a (5σ) flux limit of 1.5 μJy is typically 15 ksec. The total integration time per field is thus 130 hours (at the 2.2 m telescope, the 3.5 m is 2.5× faster). So we need about 120 clear nights distributed among both telescopes for the project which will be distributed over a span of about 3 years.

Due to delays in getting the 2k×2k CCDs, only a few preparatory observations with a 1k×1k CCD (field of view $8' \times 8'$) at the 2.2 m telescope on two survey fields have been done so far. In Fig. 1 we present typical SEDs

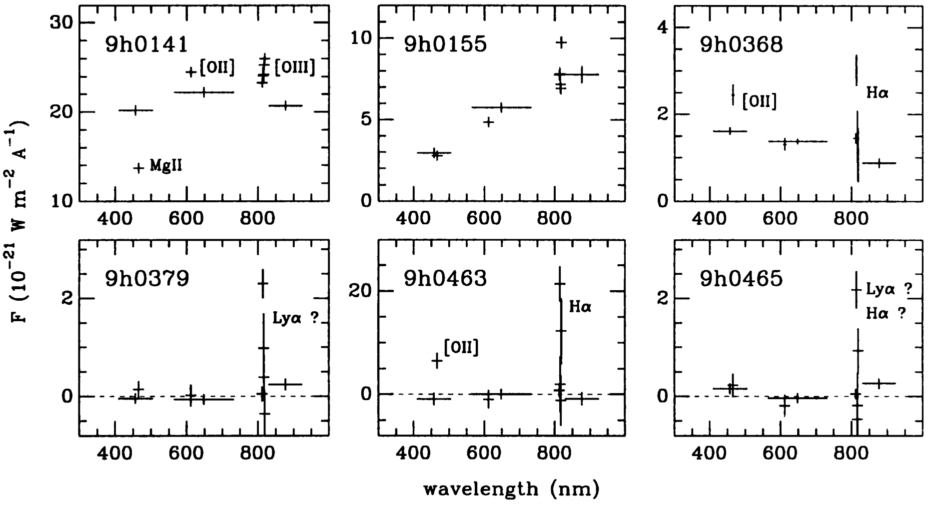

Figure 1. SEDs of emission line objects in the 9h field. Object 9h0141 is probably a spiral at redshift 0.62 with distinct oxygen lines and magnesium absorption falling right in the 466 nm filter window. 9h0155 could be an M star. Object 9h0368 has a faint blue continuum ($R = 23.1$ mag) and two relatively strong emission lines and therefore is most probably a faint blue galaxy at redshift ~ 0.25. The strong line in the spectra of 9h0379 and 9h0465 may be Ly α which would make these objects candidates for primeval galaxies. In the case of object 9h0463, the presence of a second line in the 466 nm filter indicates an H II galaxy at redshift 0.25. Since only half of the data set is completed, the classification is still somewhat ambiguous.

for some of the $\sim$ 400 emission line objects sofar detected in our 9h field. These spectra do not only demonstrate that we are able to identify the most likely contaminants (faint galaxies at $z < 1$) but also show that we indeed detect a considerable number of promissing PG candidates which have been overlooked by previous surveys. Even if many of them will be identified with HII galxies at redshifts $\lesssim 1$ we regard their detection as first proof that the CADIS concept does find the right type of objects.

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