SPLUS: Using probabilistic programming to study stellar populations of galaxies

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Abstract

The stellar population gradient of galaxies provide important information about the mechanisms involved on their formation. However, the steep radial decrease of luminosity of galaxies severely affects the signal-to-noise ratio at large galactrocentric distances, hampering the properly measurement of the variation of metallicities reliably. In this work, we introduce a Bayesian hierarchical method to model the stellar population properties of galaxies of different regions of the galaxies under the same statistical model, which can be used in different contexts such as SED fitting and integral field observations. We have been applying this method to determinte extinction, ages and metallicites of galaxies observed by the S-PLUS survey, and have been validating our results by comparing our results with those obtained by CALIFA integral field observations. The preliminary results indicate that our method is promising, and may be used to study the stellar populations of thousands of local galaxies.

S-PLUS DR1 data

The Southern Photometric Local Universe Survey (S-PLUS, Mendes de Oliveira et al., in press.) is an ongoing large area surveys that probes the universe using a 12-filter photometric system with a 0.8 m robotic telescope mounted at Cerro Tololo, Chile. The survey aims to cover an area of 9000 deg^2 (see Fig. 1) in the next 3 years, and the first data release (DR1) will include the whole STRIPE-82 equatorial field. We selected a sample of 30 galaxies available in the first S-PLUS data release (Mendes de Oliveira, in prep.) also observed by CALIFA (DR3, Sánchez et al., 2016) to test the viability of the methods in comparison with spectroscopic data.

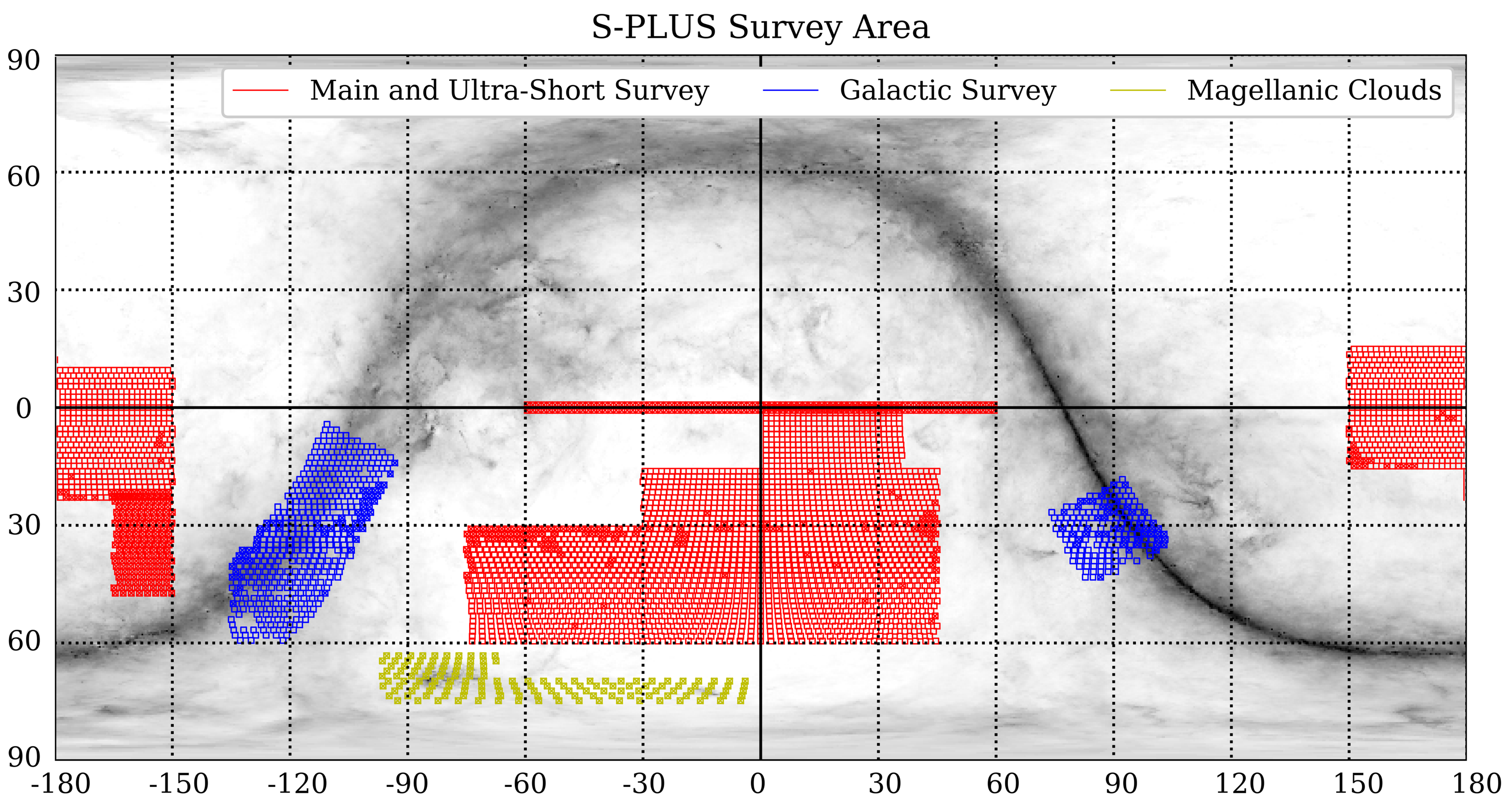

Figure 1: Footprint of S-PLUS and its main sub-surveys. Filled squares indicate fields already observed while hollow squares indicate planed observations.

Method

Bayesian methods have gained popularity owing to advances in the processing speed and parallelization and the development of new numerical methods. One important pratical aspect is the use of probabilistic programming languages, which allow the construction of hierarchical (multilevel) models and inference. In our work, we use a model that simultaneously adjust all the regions in a given galaxy while also modeling their prior distributions, as shown in Fig. 2 using the PYMC3 package (Salvatier et al., 2016).

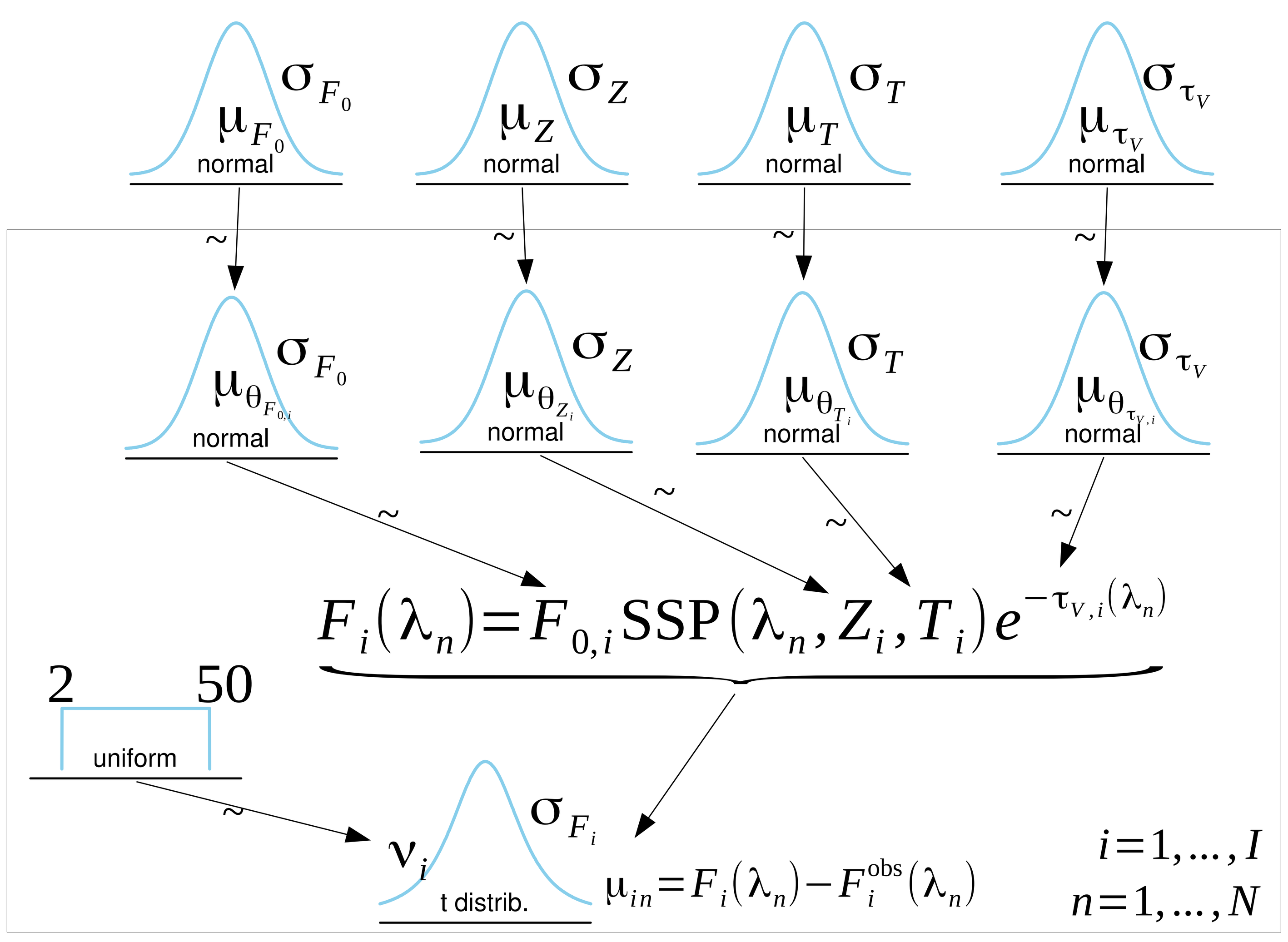

Figure 2: Scheme of the statistical model used in the modelling.

Mapping stellar populations with multi-band observations

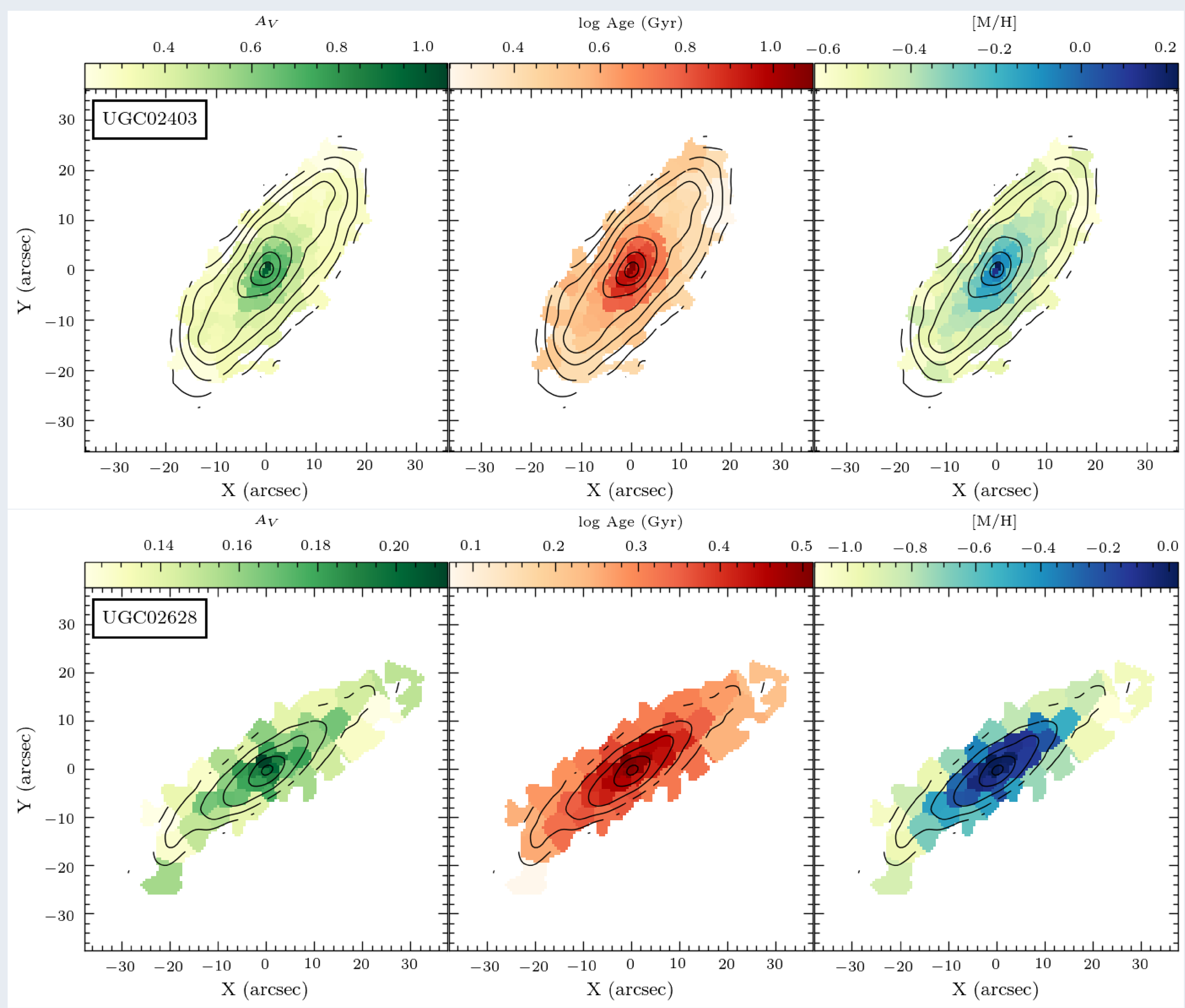

Figure 3: Extinction, age and metallicity maps for two galaxies in the sample, UGC 2403 (top) and UGC 2628 (bottom) obtained from S-PLUS data. Black countours indicate S-PLUS r-band observations.

Comparison with CALIFA

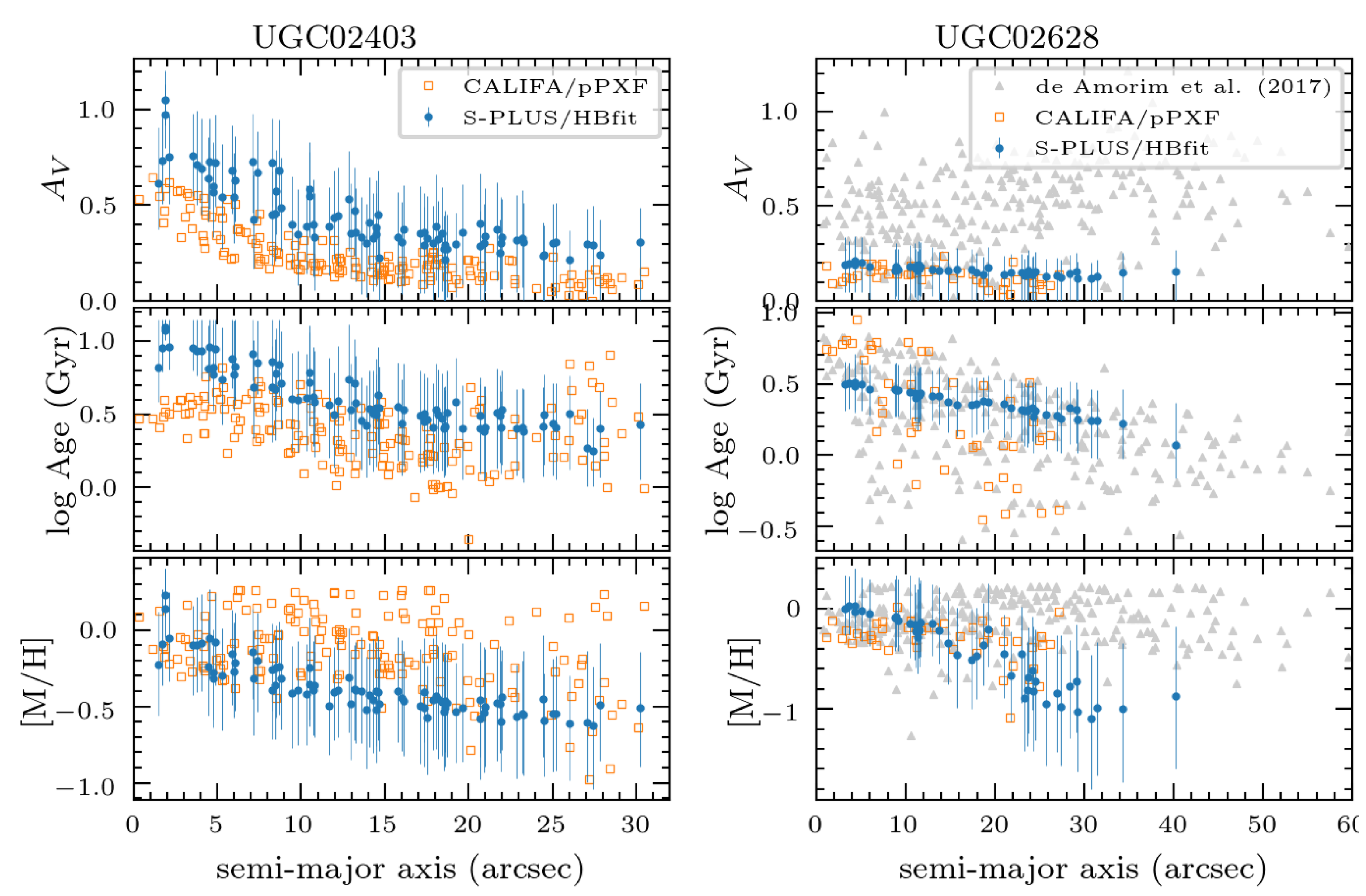

Figure 4: Comparison of results obtained with SPLUS and our hierarchical method using EMILES models (Vazdekis et al., 2016, in blue) and those determined using CALIFA data cubes with the same models with PPXF (Cappellari, 2017, in orange). Gray dots show the results from de Amorim et al. (2017), determined from CALIFA observations using STARLIGHT (Cid Fernandes et al., 2005) and slightly different stellar population models.

Conclusion

The initial results of our methods suggest that we are able to determine stellar populations and their gradients with performance similar to those determined from integral field observations, even using a limited set of filters, a small telescope, and including regions inside the galaxies with signal-to-noise around and below ~ 10 in the r-band assuming a single stellar population model. We plan to use similar methods to improve the analysis of integral field observations as a way to lessen the requirement of large signal-to-noise observations at the outskirts of the galaxies, diminish the use of Voronoi tesselation techniques to lower signal-to-noise requirements, and to study of galaxies at high redshift galaxies.

Acknowledgments

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