The Young Star Groups in Dwarf Galaxies

Scientific Category: UNRESOLVED STAR FORMATION

Scientific Keywords: Dwarf Galaxies, HII Regions, Star Formation, Young Star Clusters In External Galaxies

Budget Size: Regular

Abstract

Dwarf galaxies are the building blocks of all galaxies observed today, but star formation is still an ill-understood process in these unevolved systems. This archival project aims at obtaining a comprehensive census of all young (<100 Myr) clusters and associations in a complete sample of dwarfs within the local ~3.5 Mpc. ACS and/or WFPC2 images in V and I exist for all the galaxies, and these will be supplemented by ground based UBR and H-alpha images, most already available, to obtain full spectral energy distributions (SEDs) for all sources at UBVRHaI. Bayesian routines that implement stochastic sampling of the stellar Initial Mass Function will be used to obtain physical parameters (age, mass, extinction) for the sources from their SEDs. Our novel approach for the identification of clustered structures indicates a ten--fold improvement in the statistics of clusters/associations over existing literature. We will use the data to investigate (1) whether the dearth of ionizing photons in dwarfs is an effect of deficiency in the production of massive stars, and (2) provide robust estimates for the cluster formation efficiencies in these low star formation rate systems. Our study, and the resulting catalogs of clusters and associations, will maximally leverage the HST archival holdings in order to place dwarfs more securely within the broader perspective of galaxies as a whole, and will provide a unique resource for the broader community.

Investigators:

	Investigator	Institution	Country
PI&	D Calzetti	University of Massachusetts - Amherst	USA/MA
CoI	J Andrews	University of Arizona	USA/AZ
CoI	D Cook	University of Wyoming	USA/WY
CoI	M Krumholz	University of California - Santa Cruz	USA/CA
CoI	D Dale	University of Wyoming	USA/WY

Number of investigators: 5

& Phase I contacts: 1

Dataset Summary:

Instrument	No. of Datasets	Retrieval Method	Retrieval Plan
ACS	48	FTP	Retrieval of higher level products through the HLA
WFPC2	18	FTP	Retrieval of higher level produtcs through the HLA, where possible

■ Scientific Justification

1. BACKGROUND

In the hierarchical galaxy assembly framework of a ΛCDM Universe, dwarfs ($M_{star} \lesssim 10^8$ $M_\odot$) are the building blocks of galaxies, and may have been the main drivers of the cosmic re–ionization. Their large gas fractions ($M_{gas}/M_{star} \gg 1$), typically low star formation rates (SFR<0.1 $M_\odot$/yr), and low metal contents suggest that star formation is an inefficient process in these systems (Guo et al. 2010). The reasons are still debated, as are other aspects of the dwarfs' formation and evolution, including the link between one type of dwarf (e.g., irregulars) to another (e.g., spheroidals), and the low star/dark matter ratios (Moster et al. 2013). Gas outflows from the feedback of the sporadic star formation in the galaxies' shallow potential wells may cause the star formation to remain generally low (Onorbe et al. 2015), although gas accretion suppression due to heating by the UV background may be a concurrent mechanism (Bullock et al. 2000, Kravtsov et al. 2004).

The mechanisms that govern and regulate star formation in dwarf galaxies, therefore, remain a central issue to be addressed. Star formation is a scale–free hierarchical process, in which bound clusters occupy the densest regions; most of the structures are unbound, and their stars disperse over time, forming the field population (Elmegreen 2010). In the low–density environments of dwarf galaxies bound clusters are a rare event, with the exception of the super–star–clusters formed in star bursting dwarfs (Bergvall 2012). The most common star forming structures are young star groupings that range from low–mass, compact clusters, to semi–resolved clusters, to loose associations.

The rarity of massive star clusters, together with a general deficiency of ionizing photons relative to the non–ionizing UV light (Lee et al. 2009, Meurer et al. 2009) has led to the suggestion that dwarf galaxies may be *systematically* deficient in massive stars relative to their more massive counterparts (Pflamm-Altenburg et al. 2009). Alternative interpretations include: leakage out of the galaxies (Hunter et al. 2010), stochasticity in the sampling of the stellar Initial Mass Function (IMF) in the low–mass star groupings (Fumagalli et al. 2011), and sporadic star formation (Weisz et al. 2012). These different, and for many aspects degenerate, scenarios can only be discriminated by the investigation of complete samples of young star groups in dwarfs (Calzetti et al. 2010, Andrews et al. 2013, 2014).

With this study, we propose to obtain a complete census of all the young star groups that are present in the dwarf galaxies within the local ∼3.5 Mpc. The archival HST images will be supplemented with ground–based images to provide a characterization of the physical properties (mass, age, extinction) of the less crowded among these structures, by fitting their spectral energy distributions (SEDs) with a Bayesian approach. Although a similar study was conducted by Cook et al. (2012), new data and major recent advancements in the identification and characterization of young stellar groups warrant a revisit of that study. We will disseminate to the community the full list of sources with locations, luminosities, and concentrations, together with the sources' physical parameters and uncertainties. This effort will provide a secure foundation for any follow-up investigation of the star formation mechanisms and the stellar IMF in dwarf galaxies.

2. MOTIVATION

The ACS Nearby Galaxy Survey (ANGST; GO–10915, Dalcanton et al. 2009) is an iconic complete survey of the 69 galaxies within the local ∼3.5 Mpc. About 50 of these are low-luminosity ($M_B \gtrsim -18$) dwarfs, 37 of which were observed with ACS. Cook et al. (2012) performed the most comprehensive, to date, search for young clustered systems in these dwarfs. For sake of clarity, we will refer to young star groups with age <10 Myr as 'YSGs' and those with intermediate ages, ∼10–100 Myr, as 'ISGs'. Cook et al. (2012) find that few dwarfs (11/37) contain either YSGs or ISGs, and even fewer (6/37) contain YSGs. Furthermore, only 12 YSGs and 32 ISGs were recovered in total.

This result challenges expectations based on constant cluster formation efficiencies (CFE, Portegies-Zwart et al. 2010), but is almost consistent with models for an environment–dependent CFE (e.g., Kruijseen 2012). For a 10% CFE (Bastian et al. 2012), UGC8833 and UGC5139, with SFR=3E−3 and 2E−2 $M_\odot$/yr, respectively, should contain 3 and 15 YSGs with mass ∼500–2000 $M_\odot$. Both, like most others, have been found having none. CFEs are an important tool to establish the extent to which star formation depends on local environmental variables; they need to be placed on a solid observational footing to provide a foundation for models of star formation over galactic scales.

A combination of improved cluster identification techniques, developed for the LEGUS project (GO–13364, Calzetti et al. 2015), and ground–based Hα images, which trace the compact emission of ionizing YSGs, is yielding significantly larger samples of candidates than originally suggested by Cook et al.

When cross-correlated with the ACS images, the Hα images identify two main avenues of further investigation: (1) as exemplified by Figures 1 and 2, numerous low–mass (∼1000 $M_\odot$), ionizing YSGs were not identified in the original study of Cook et al.; (2) Figure 1 (left) further shows that employing a tracer of ionizing photons (Hα) provides more robust constrains for age–dating ionizing YSGs. **A preliminary inspection of the 29 galaxies with Hα images shows a total of at least 150 ionizing YSGs candidates in 26 galaxies (Table 1), a factor >10 increase relative to Cook et al. (2012)**. To these numbers, we need to add at least as many non–ionizing YSGs (i.e., <10 Myr in age, but not emitting in Hα): the deficiency of ionizing stars in these systems is a consequence of stochastic sampling of the stellar IMF in low–mass YSGs (e.g., Calzetti et al. 2010, Fumagalli et al. 2011). When also adding ISGs, we reach numbers around several hundred, although cluster survival arguments (e.g., Gieles 2009), may drastically reduce these estimates for the older systems.

3. SCIENCE GOALS

With a statistically robust sample of YSGs and ISCs, we expect to accomplish the following two goals:

- use the aggregate information from all the ionizing YSGs to establish whether a trend exists between the most Hα–luminous star cluster at a given mass as a function of cluster mass. This will help determine whether the deficiency of ionizing photons in dwarf galaxies is related to a deficiency in the *production* of massive stars in low–mass clusters.
- Compare the cluster formation rates (total mass in potentially bound YSGs and ISGs

divided by the respective durations) with the SFRs over 10 Myr and 100 Myr. The SFRs have been extensively measured for our sample galaxies (Lee et al. 2011). We will add new, secure data points on CFEs in the underrepresented regime of dwarfs (e.g., Mora et al. 2015), and will test models for the dependency of CFEs on the SFR density (e.g., Kruijssen 2012).

If the ionizing photon deficiency of dwarf galaxies is due to a systematic under–production of massive stars, low–mass ($\sim$1,000 $M_{\odot}$) YSGs are expected to be typically under–luminous in Hα for their mass. Conversely, if the stars in YSGs are randomly drawn from a 'universal' IMF, some low–mass YSGs will be over–luminous in Hα for their mass, on account of hosting by chance a very massive star. The latter scenario has been shown to be true for massive, high–SFR galaxies (Andrews et al. 2013, 2014), but has not been tested yet in dwarf galaxies. With masses derived from U–to–I SED fitting (Figure 2, right), the ionizing YSGs will provide enough statistics to perform this test in low–mass dwarfs, with a SFR in the range 0.001–0.1 $M_{\odot}$/yr.

The derivation of CFEs over timescales shorter than 100 Myr will be complicated by the degeneracy in the U–to–I SEDs between ISGs and non–ionizing YSGs. As discussed in the Analysis section, this age–extinction degeneracy can only be broken by sampling the SED in the UV (Andrews et al. 2013, Calzetti et al. 2015). However, if the ionizing YSGs turn out to be the result of random sampling of a universal IMF, we will use statistical arguments to separate ISGs from non–ionizing YSGs (e.g., Fumagalli et al. 2011), and assign a total mass in clusters over the two timescales of 10 Myr and 100 Myr. In addition, if the galaxy is dust–poor ($A_V \lesssim$0.3 mag), the degeneracy is not present and the age of a cluster can be determined with accuracy (Figure 3).

Our re–analysis of the HST archival imaging holdings of nearby dwarf galaxies will help shed light on the governing mechanisms of star formation, by placing these relatively unevolved systems within the broader perspective of galaxies as a whole.

4. PRODUCTS

We will produce a complete and homogeneous census of all young clusters/associations in a representative set of dwarf galaxies in the local Universe, by employing the LEGUS–developed technique on the archival HST images. We expect to mainly collect star groupings younger than 100 Myr; for older ages the sample will be highly incomplete, as most (unbound) structures are erased in 100–200 Myr in low–mass galaxies (e.g., Baumgardt et al. 2013). We will publish and make available through the HLA (or other suitable archive):

• Catalogs of the YSGs and ISGs, including positions, photometry from HST and ground–based imaging, effective radii, and crowding flags.

• Ages, masses, and extinctions, together with uncertainties, derived from the U–to–I plus Hα SEDs. These will be fit with populations synthesis models via a Bayesian approach (see Analysis section). Systems without Hα emission will be flagged, if they yield large age and mass uncertainties due to the age–extinction degeneracy.

These catalogs will provide a unique resource for a wider range of applications than described above, and will, ultimately, maximize the scientific return of the HST.

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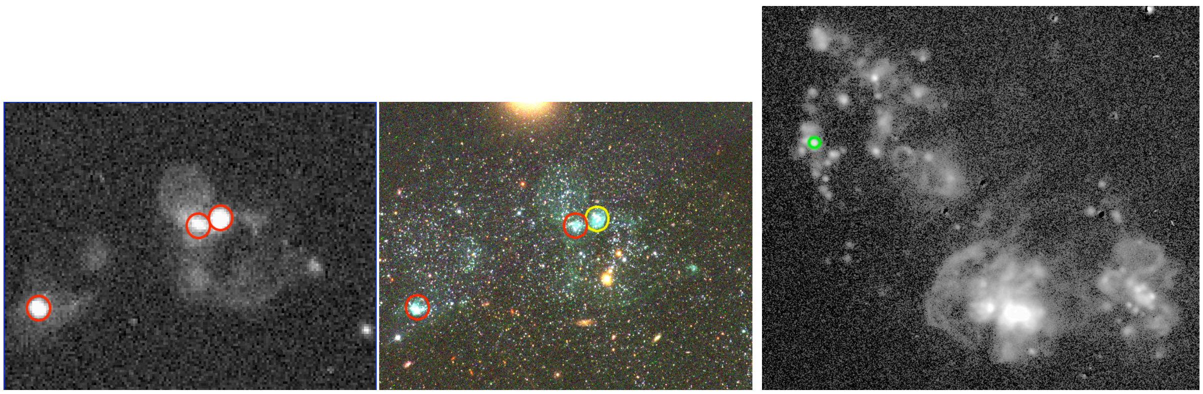

Figure 1. LEFT and CENTER: A 75″×55″ (1300 pc x 960 pc) detail of the galaxy UGCA292, with the ground–based Hα to the left and a 3–color ACS B,V,I composite in the center. The yellow circle is the only cluster identified by Cook et al (2012) in this galaxy, with age of 40 Myr. The presence of Hα emission indicates an age <6–7 Myr. Two additional ionizing YSGs, not identified by Cook et al., are indicated by red circles. **RIGHT:** A 3′.5×3′.5 (1.2 kpc x 1.2 kpc) Hα image of NGC2366, in log intensity scale, covering roughly the same area as the two ACS pointings. The green circle is the only YSG (∼3 Myr) identified by Cook et al. in this galaxy. The image highlights the presence of many ionizing YSGs.

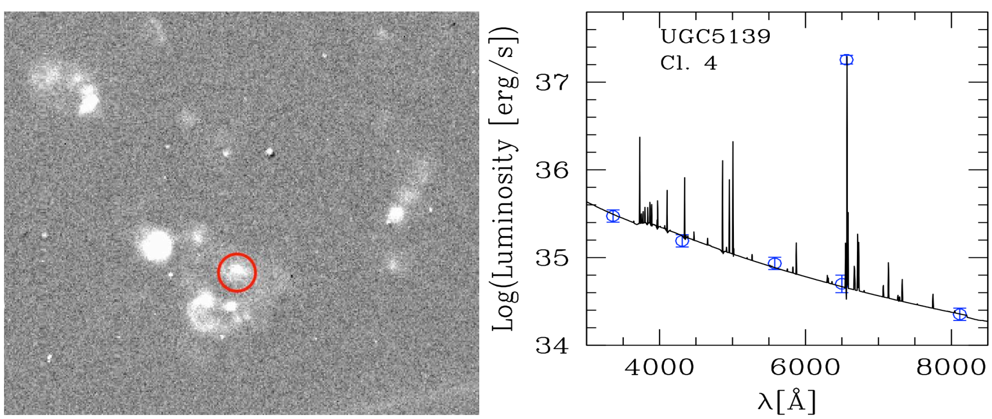

Figure 2. LEFT: A 2′×2′ (2.2 kpc x 2.2 kpc) detail of UGC5139 in Hα. The red circle marks the position of the fifth-brightest YSGs. No YSGs or ISGs were found by Cook et al. in this galaxy, while at least 8 are present. **RIGHT:** The U–to–I SED of the source marked to the left with a red circle. Both the U–to–I SED and the EW(Hα) are consistent with a dust–free, 5 Myr old, 2,000 $M_\odot$ star cluster. The SED template is rescaled from the deterministic models of Zackrisson et al. (2011). Better estimates for masses and ages will be obtained with Bayesian stochastic sampling models (Krumholz et al. 2015, and Fig. 3).

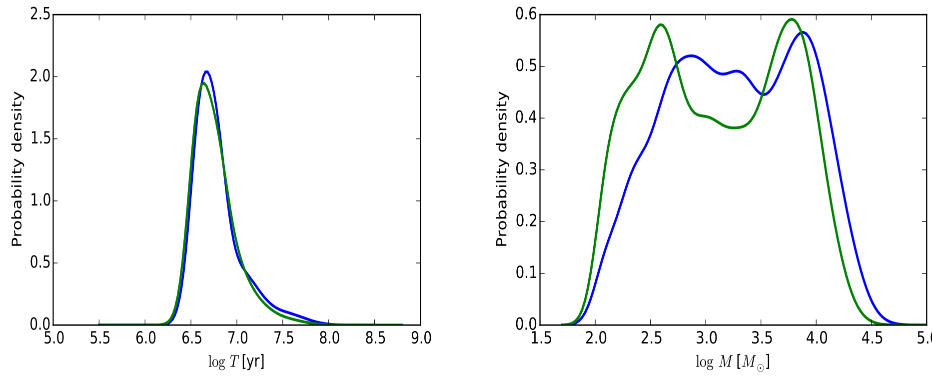

Figure 3. The probability functions for age (left) and mass (right) for two non–ionizing YSGs in UGC5139, obtained from the Bayesian SLUG models (Krumholz et al. 2015). This galaxy is dust–free ($A_V \lesssim 0.3$ mag), and SED fitting provides a well–defined age for non–ionizing YSGs. Similar dust–poor conditions are present for about 1/4 of our sample.

Table 1: Dwarf Galaxies with Hα imaging

Name	YC[1]	IC[1]	YSGs[2]	HST[3]	Name	YC[1]	IC[1]	YSGs[2]	HST[3]
NGC2366	1	3	>20	A/555W,814W	UGC8833	0	0	2	A/606W,814W
UGC4305	3	3	>17	A/555W,814W	UGC9128	0	1	1	A/606W,814W
UGC4459	1	0	10	A/555W,814W	UGC9240	0	1	>6	A/475W,606W,814W
UGC5139	0	0	8	A/606W,814W	M81DwA	0	0	0	A/606W,814W
UGC5336	1	5	2–3	A/435W,555W,814W	KDG73	0	0	0	A/606W,814W
IC2574	4	11	>20	A/435W,555W,814W	UGCA276	0	0	0	A/606W,814W
UGC5692	1	0	4–5	A/435W,555W,814W	Sextans A	N/A	N/A	5–6	W/439W,555W,814W
NGC3741	0	0	3–4	A/435W,814W	NGC3109	N/A	N/A	>12	W/606W,814W
NGC4163	0	0	2–3	A/435W,555W,814W	Sextans B	N/A	N/A	2–3	W/606W,814W
UGCA292	0	1	>3	A/435W,606W,814W	IC5152	N/A	N/A	4–5	W/606W,814W
UGC8091	0	0	2	A/555W,814W	UGCA438	N/A	N/A	1?	W/606W,814W
UGC8201	0	7	2	A/555W,814W	UGC7577	N/A	N/A	4–5	W/606W,814W
UGC8508	0	0	5–6	A/475W,814W	UGC6817	N/A	N/A	2	W/606W,814W
UGC8651	0	0	3–4	A/606W,814W	NGC4190	N/A	N/A	4–5	W/450W,555W,814W
UGC8760	1	0	3	A/606W,814W					

[1]Clusters from the analysis of Cook et al. (2012) that have ages <10 Myr (YC) or between 10 Myr and 100 Myr (IC). Galaxies marked with 'N/A' were not analyzed by Cook et al.

[2]Young Stellar Groups candidates, as identified from the cross–correlation of ground–based Hα images with the HST images. These candidates all show concentrated Hα emission, and are likely clusters or associations with age <6–7 Myr. These YSGs are a subset of all YSGs that are present in the images, since at least as many will not show Hα emission, due to stochastic sampling of the stellar IMF (Fumagalli et al. 2011). The numbers in this column should be compared with the second column (YC) in this table.

[3]Available HST imaging data from ANGST: A=ACS, W=WFPC2. NGC2366, IC2574, NGC3109, IC5152, UGC7577 have been observed with two or more pointings, covering most of the galaxy. NGC2366, NGC3741, Sextans A, NGC4190 have additional imaging data in the archive that will be used as appropriate. Three galaxies, UGC4305, UGC4459, and UGC5139 are part of the LEGUS project and are listed here for completeness. We will not request resources for the analysis of these three targets, since all Co-Is of this proposal are LEGUS team members.

Analysis Plan

Sample Selection. Among the ∼50 low–luminosity dwarfs contained in the volume–complete (up to ∼3.5 Mpc, and outside both the Local Group and the Galactic Plane) ANGST survey, 37 were observed with ACS and the remaining with WFPC2. For completeness, we include galaxies observed with both instruments in our sample, while realizing that any search for clusters/groups in WFPC2 frames will be complicated by the lower angular resolution (0.1″/pixel versus the 0.05″/pixel of ACS). A total of 29 galaxies have also publicly available, flux calibrated Hα and R–band images from the 11HUGS survey (Kennicutt et al. 2008), and these are listed in Table 1. Ground–based UBR images are available for 15 of the 29 galaxies (Cook et al. 2012), and the rest of the sample will be obtained using Northern telescope facilities (all accessible, except for IC5152).

Star Grouping Identification and Selection. The technique for YSG and ISG selection and identification that we will apply to the archival HST images has been developed by our group for the LEGUS project (GO–13364, Calzetti et al. 2015); it has been successfully tested on the LEGUS dwarfs (including UGC4305, UGC4459, and UGC5139, see Table 1; Cook et al. 2015a; in prep), yielding the most complete YSGs and ISGs catalogs to date. The technique relies on the combination of two approaches: an automated search algorithm for compact sources (r∼1–3 pc) and visual inspection for more extended sources (r>3 pc).

Compact YSGs and ISGs are sources with a broader FWHM than the stellar PSF (r∼1 pc at 4 Mpc). The Concentration Index (CI), defined as the flux difference at 1 and 3 pixels, has different distributions for isolated stars and star clusters, and can be used to separate the two types of sources (Whitmore et al. 2010). Tests with artificial clusters of different effective radii enable refinement of the CI separation threshold. This selection is then followed by visual inspection by multiple team members to exclude contaminants (e.g., background galaxies, asterisms, etc.).

Extended YSGs and ISGs (e.g., loose clusters and associations) will be selected directly via visual inspection of the HST color composites. These objects appear as semi–resolved or resolved bright stars coincident with an unresolved, nebulous component, and are usually missed by automatic search algorithms, due to their diffuse nature. Visual selection will rely on groupings of stars, spherical symmetry, and the presence of an unresolved component. The addition of Hα will increase the probability of identifying low–density associations that appear as compact sources in the ground–based images; however, non–ionizing low–density associations will likely be under–represented in our catalogs.

The final catalog for each galaxy is a combination of candidates from these two identification methods, and will be merged during the visual inspection process. Each candidate is classified on a 1–to–5 scale, where: 1 is a single, centrally concentrated compact source, 2 is a single, centrally concentrated source with some degree of asymmetry, 3 is an ambiguous source which may be two or more sources, 4 is a contaminant, and 5 is a non-centrally concentrated grouping of stars with an unresolved component. The combined identification methods will, thus, provide a quantification of potentially gravitationally bound sources (i.e., class 1 and 2) and unbound ones (i.e., class 3 and 5). Additionally, each catalog will include effective (projected half–light) radii for each 1,2,3 or 5 source, and a flag qualifying whether it is within 1″ of other sources in the catalog (1=non–isolated; 0=isolated). The isolation criterion is based on the typical FWHM of ground–based images, to establish the reliability of the photometry.

Our team (Cook et al. 2015b, in prep.) has also completed the identification of compact sources in the ANGST dwarfs using the GALEX UV images. These will be used to further aid the confirmation of YSGs and ISGs candidates for suitably isolated sources (the GALEX PSF is $\sim 5''$).

Class 1 and 2 sources (potentially bound clusters) will be employed for CFE calculations, while ionizing YSGs of all classes will be used for investigating potential variations of the upper IMF.

Sources' Physical Parameters via SED Fitting. For each source in our catalogs, we will have either HST or ground–based UBVRI and Hα (line upper limits in case of non–detections) photometry.

For isolated sources (see above), the physical parameters of age, mass, and extinction, together with their uncertainties, will be derived by fitting of the multi–band SED with the Stochastically Lighting Up Galaxies (SLUG) code and its Bayesian cluster fitting tool cluster_slug (da Silva et al., 2012, ApJ, 745, 145; 2014, MNRAS, 444, 3275; Krumholz et al. 2015, MNRAS, subm.). SLUG uses a library of synthetic star clusters to build a kernel density estimate of the joint probability distribution function of star clusters' physical parameters (mass, age, etc.) and their photometric outputs, and then performs implied conditional regression to derive posterior probabilities for all physical parameters based on the observed photometry. In contrast to conventional non-Bayesian methods, cluster_slug returns the full posterior PDF of all physical properties of each cluster, not simply a single best fit (Figure 3). Thus it properly captures ambiguities like the existence of multiple age and mass ranges that are consistent with the observed photometry. There are two additional advantages of SLUG for this project. First, it supports an extensive list of filters, both HST- and ground-based, and thus there will be no need for, or uncertainty arising from, filter transformations. Second, SLUG allows nearly-arbitrary forms for the IMF, so we will be able to investigate the hypothesis that dwarf galaxies have non-standard IMFs, and check whether libraries built on that assumption provide better matches to the observations than standard IMFs.

One of the anticipated ambiguities involves non–ionizing YSGs. The low–mass clusters/associations ($\lesssim$3,000 $M_\odot$) we expect to typically find in our dwarfs do not fully sample the stellar IMF, the latter requiring clusters above $\sim 10^4$ $M_\odot$ (e.g., Cervino & Luridiana 2004, A&A, 413, 145). Low–mass clusters can thus be deficient in massive, ionizing stars even when they are young, and non–ionizing YSGs are frequent at low masses (about 2/3 of the total at 1,000 $M_\odot$). The U–to–I SED of a slightly dust–extincted, non–ionizing YSG is indistinguishable from that of a dust–free ISG, which leads to the ambiguity mentioned earlier in this proposal. About 1/4 of our galaxies have $A_V \lesssim 0.3$ mag, and are unaffected by this problem (Figure 3). For the remaining of the sample, this age–extinction degeneracy will be present and can only be broken via the extinction handle provided by UV data (Andrews et al. 2013, 2014). UV data for our galaxies are only available from GALEX (for isolated and sufficiently bright sources) and, for three galaxies, from the data of the LEGUS survey. For most of the non–ionizing YSGs, we will rely on the information provided by the PDFs produced by SLUG, and statistical arguments based on expected frequency on non–ionizing versus ionizing YSGs as a function of mass (da Silva et al. 2014).

Our science goal of investigating potential variations of the IMF does not depend on our ability to separate non–ionizing YSGs from ISGs. The CFE calculations will depend on this; the overall added uncertainty ($\sim$2X) will still result in sufficiently accurate CFEs on the timescales of 10 Myr and 100 Myr to help constrain models, since the expected variation in CFE is over an order of magnitude between different models at low SFRs (e.g., Mora et al. 2015, Kruijssen 2012).

Management Plan

Team Composition and Roles. All Co-Is are experienced HST users and are all members of the LEGUS team, with full access to its pipelines and software. Calzetti is the PI of LEGUS, and Cook (graduate student working under the supervision of Dale) has been directly involved in the development of the strategies for star cluster searches and confirmation in the LEGUS galaxies. **None of this proposal's Co-I were Co-Is of the ANGST project (GO–10915).** PI Calzetti will manage the archival project by monitoring progress, defining products and timelines, and participating in all technical aspects of it. Cook (lead), Dale, Andrews, and Calzetti will perform visual inspection of all images for source confirmation, new identifications, and robust classification. Cook, Calzetti and Dale will perform HST and ground–based photometry of confirmed sources. Andrews has access to the University of Arizona/Steward telescopes (Bok, MMT, etc.), and will be primarily responsible for observations, reduction, and flux calibration of missing ground–based UBR images and spectra (see below). Krumholz will be primarily responsible for applying his Bayesian SED code SLUG to the multi–band photometry of sources, and derive physical parameters for them. All Co-Is will be involved in the scientific analysis of the data, and resulting publications.

Work Plan. For the HST images (mainly in V and I, with some B–band; Table 1), we will use the High Level Products that are available from the Hubble Legacy Archive, already fully processed and aligned. Ground–based flux–calibrated UBR images for 1/2 of the sample (Cook et al. 2012) and Hα for the entire sample are in hand. The remaining of the images will be acquired through telescopes to which our team has access. Accurate relative calibrations between photometric bands, to better than 5%, between ground–based and HST data are critical for the success of this project, as they are required for the SED fits. We will obtain long–slit spectroscopy (at Bok, MMT) of selected sources in a subset of the galaxies covering the U–to–I range, to ensure the required relative accuracy. We will rely on the HST fluxes for the absolute calibrations, which directly affect mass determinations. All new ground–based images (including Hα) will be registered and aligned to the HST images, with WCS assigned. Existing UBR images are already registered.

The most time–consuming portions of the project are: (1) the visual inspection of the cluster candidates; (2) search for resolved/semi-resolved clusters/associations; (3) classification on the 1–to–5 scale. All of these steps require involvement of all team members to ensure robustness. Flags for crowding will also be assigned during visual inspection. Aperture photometry will be used; the aperture sizes and aperture corrections will be determined on a case–by–case basis. Physical parameters, with their uncertainties, of the sources will be obtained from Bayesian SED fitting.

Timeline. Data retrieval and consolidation is expected to take 1–2 weeks. Ground–based data acquisition, reduction, flux calibration, alignment will require about four months spread over one year (sources are spread across RAs). Visual inspection and photometry of the images will require 4 days to 2 weeks for each galaxy, depending on number of sources and crowding. SED fitting will require several CPU–minutes per source, but the SLUG pipeline is fully parallelized and Krumholz will run it on the UCSC cluster over a few days. Analysis of results and papers writing will require an additional 2–3 months.

Dissemination Plan. We expect a total of a few hundred confirmed YSGs and ISGs among all our galaxies, which can be easily accommodated in the electronic tables supported by most Journals. Papers reporting the results of our investigation will include such tables, with source coordinates, photometry, flags as described in the Analysis Plan, and derived physical parameters where appropriate. The flux–calibrated ground–based images will be deposited in stable archives, such as the Nasa Extragalactic Database.

Past HST Usage

• GO–13364: 'Legacy ExtraGalactic UV Survey (LEGUS'). Cycle 21 Treasury Program. PI: Calzetti. Andrews, Cook, Dale, and Krumholz Co-Is. Analysis of this massive dataset is still ongoing. The team counts over 57 members, working on different aspects of the project. Papers published/submitted so far:

a. Elmegreen, D.B., et al. 2014, ApJ, 787, L15, 'Hierarchical Star Formation in Nearby LEGUS Galaxies"

b. Calzetti, D., et al. 2015, AJ, 149, 51, 'Legacy Extragalactic UV Survey (LEGUS) With the Hubble Space Telescope. I. Survey Description.'

c. van Dyk, S., et al. 2015, ApJ, submitted, 'LEGUS Discovery of a Light Echo Around Supernova 2012aw'

Several additional papers are at various stages of completion, and are expected to be submitted over the next few months.

• GO–13773: 'Halpha-LEGUS: Unveiling the Interplay Between Stars, Star Clusters, and Ionized Gas'. Cycle 22. Calzetti and Andrews Co-Is. The data are still being acquired, and some are under processing.

• GO–13743: 'The Controversial Nature of the Diffuse UV Emission in Galaxies: Exploring NGC300'. Cycle 22. Calzetti and Andrews Co-Is. Data only partially obtained, some under processing.

• GO–13041: 'Diagnosing Ionization Mechanisms in Blue Compact Dwarfs, the Local Analogues to Primordial Galaxies'. Cycle 21. Calzetti Co–I. Data under analysis.

• GO–13313: 'Determining attenuation laws down to the Lyman break in z 0.3 galaxies'. Cycle 21. Calzetti Co–I. Data under analysis.