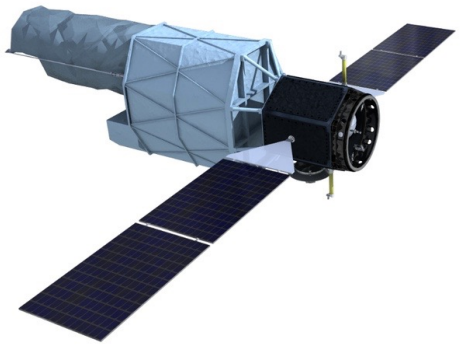
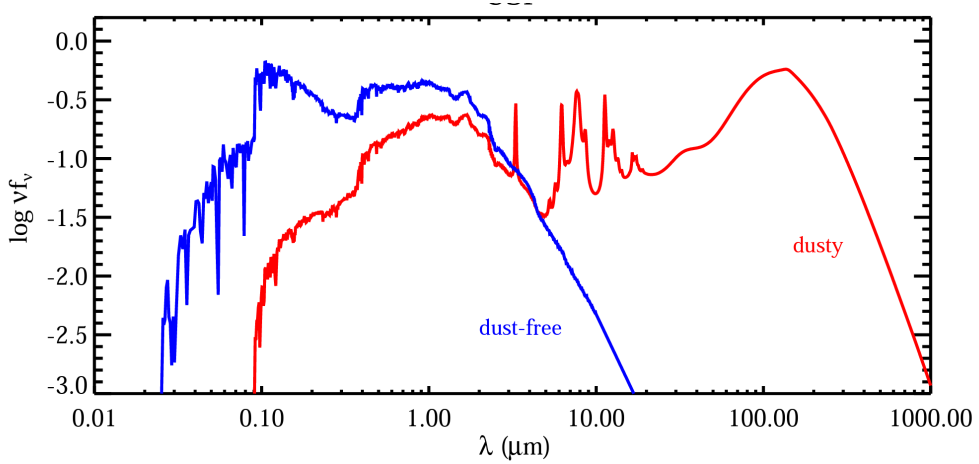
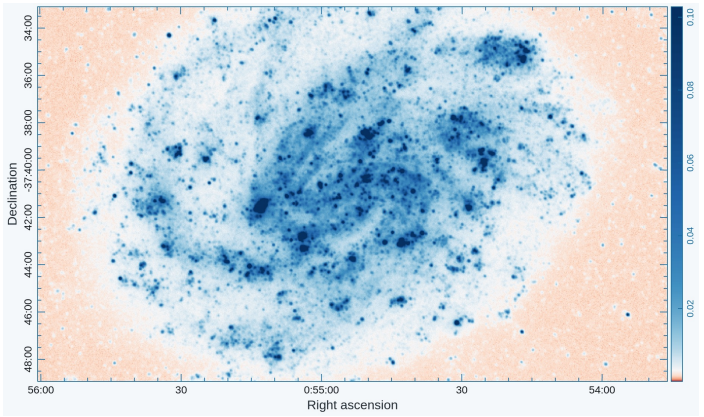
UVEX from the Perspective of an Eager Community Member Who Works on Local and Low Redshift Galaxies







Images: UVEX website; Conroy 2013 ARAA; *z0mgs* NGC 300 NUV image

Adam K. Leroy (Ohio State University)

Based on work in collaboration with Karin Sandstrom, Dustin Lang, Samir Salim and the "z0mgs" team

UVEX and Local or Low Redshift Galaxies

Trying to give a complementary perspective to Janice, Mark, and Phil …

- Deep UV coverage of the whole sky is critical to place high-detail studies of local galaxies in clear context.
  - Still incomplete from GALEX for both local (d < 50 Mpc) or low redshift SDSS galaxies.
  - There's significant value in trying to get images of big things right.
- Scattered UV light is visible in galactic winds, and benefits from similar capabilities.
- Out to 5-10 Mpc, expect UVEX to capture individual star-forming regions and be highly complementary to ALMA, JWST, VLT or Keck IFU to study feedback and star formation efficiencies and timescales.
- UVEX's focus on the Magellanic Clouds and the Milky Way aligns well with major next efforts from SDSS V and GASKAP to obtain complementary views of the ionized and neutral gas. Other Local Group galaxies?
- The UV is a natural pair to HI mapping and UVEX is a timely pair to a revolution in 21-cm capabilities.

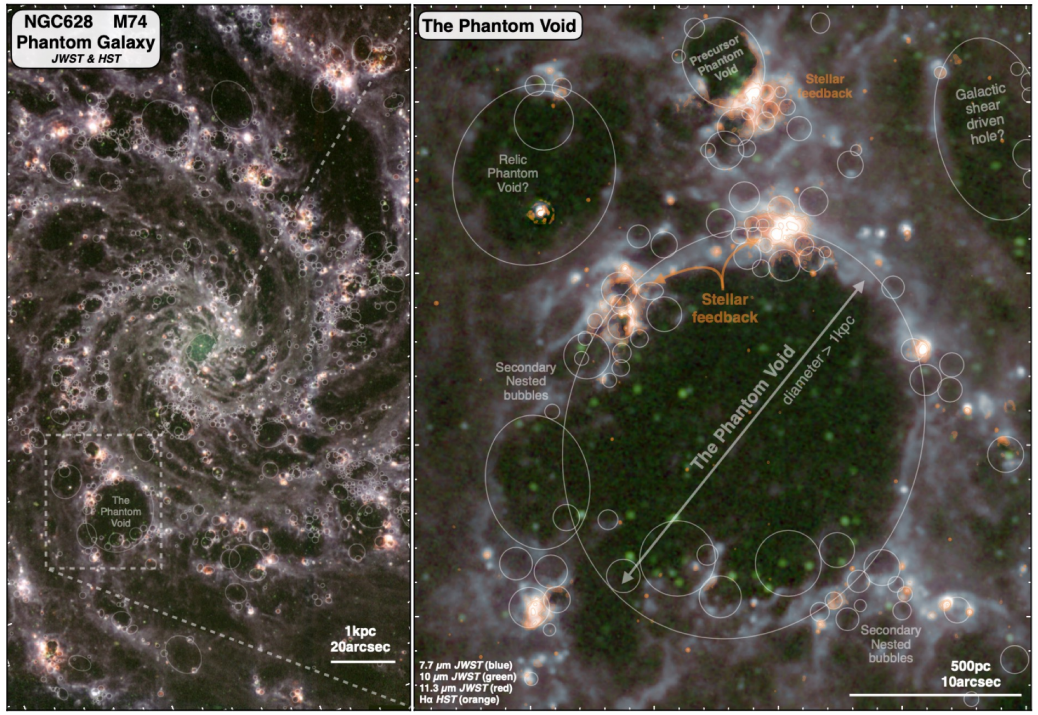
UVEX and Local or Low Redshift Galaxies

~~Blue~~ Ultraviolet collar work on known local and low redshift galaxies is still super important and super timely.

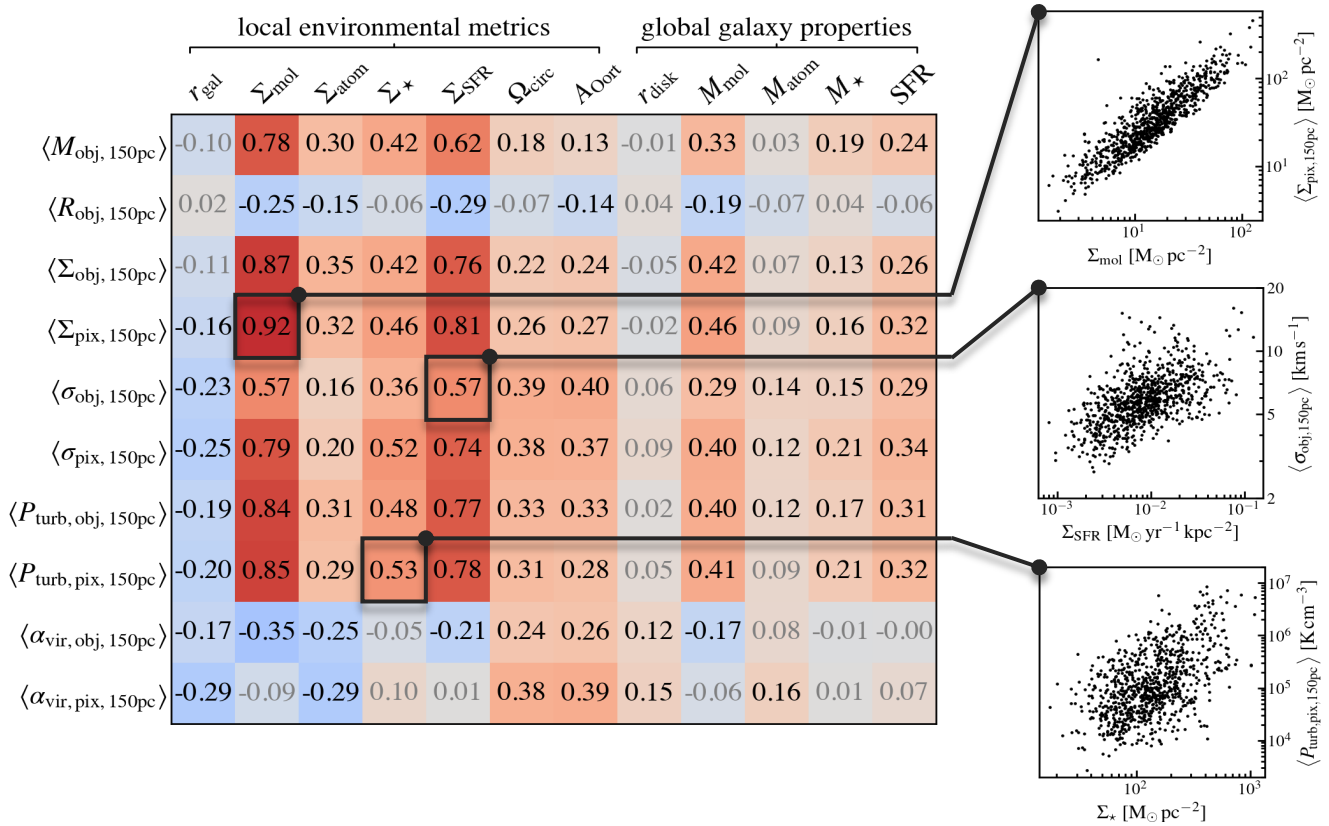
Don’t forget the ability to deliver high quality, well calibrated images of UV intensity for big things!

Huge progress on the context-dependent matter cycle in galaxies

The last decade has seen major advances in our detailed knowledge of feedback, the interstellar medium, star clusters, star formation, the structure of stellar disks, and a host of other “small scale” phenomena related to the matter cycle. A repeated theme is that many small-scale phenomena reflect the large scale environment where they play out.



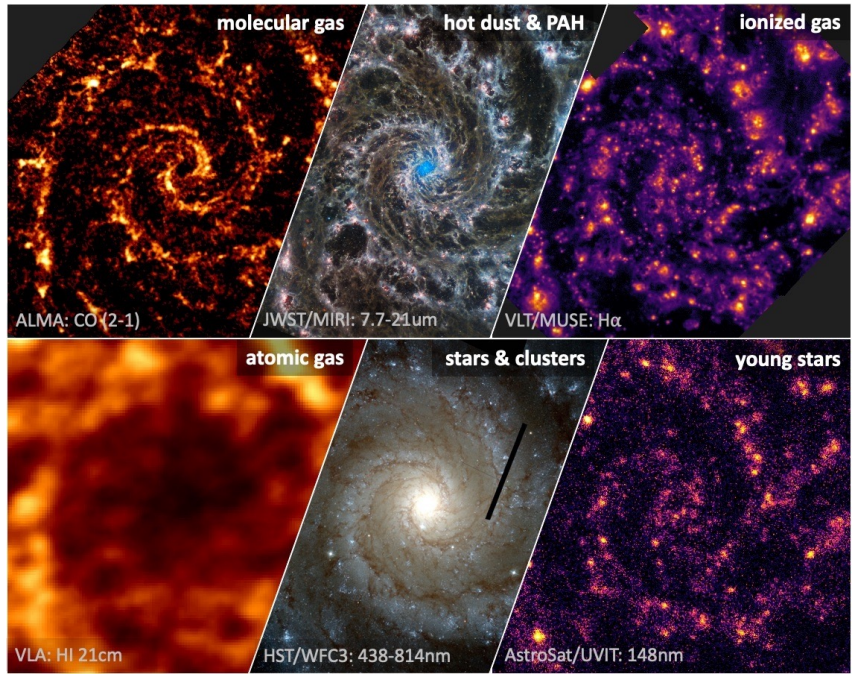
Ashley Barnes, Elizabeth Watkins et al. (2023)
ISM shells linked to stellar feedback in the ISM of NGC 628



Jiayi Sun et al. (2022)
Molecular clouds couple to host galaxy properties and disk structure

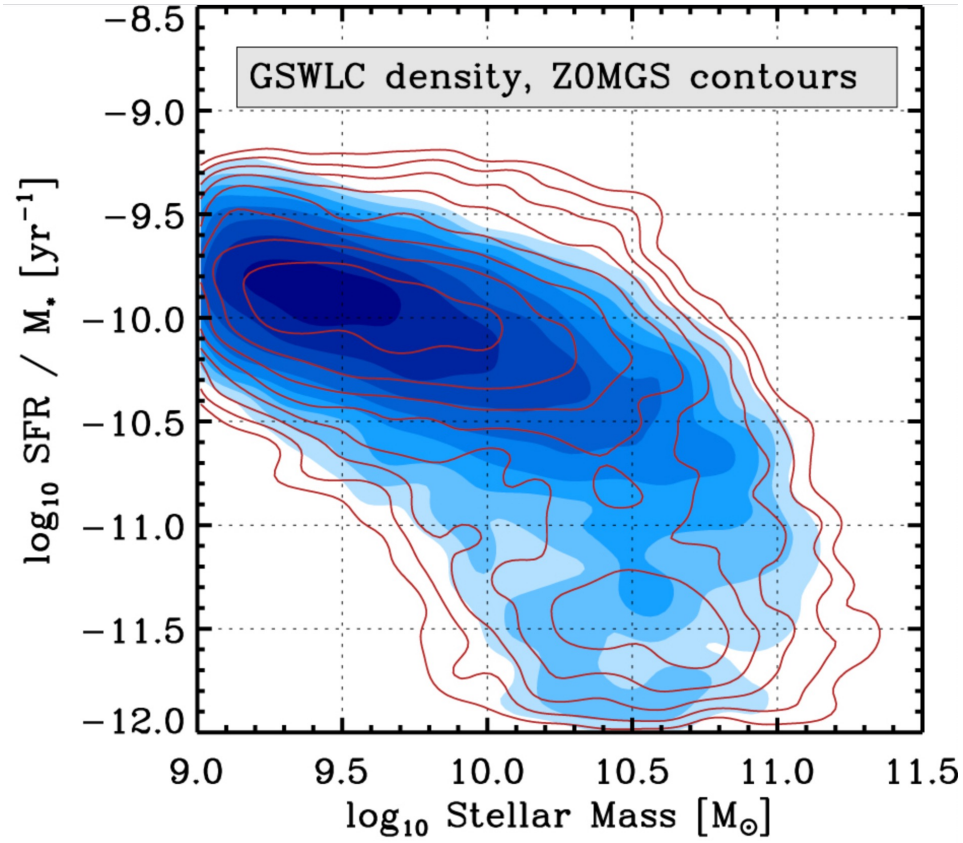
Linking this progress to galaxy evolution and the larger population is important

Linking detailed studies of the matter cycle in local galaxies to our broader picture of galaxy evolution is crucial. This means treating whole local galaxies, parts of galaxies, and the broader set of "low z" galaxies consistently and accurately.



ALMA, JWST, HST, Keck, the VLT, MeerKAT, the VLA, and more are making groundbreaking measurements across the local galaxy population
Image credit: Jiayi Sun

We want to target and place these studies in the subject of the full galaxy population …



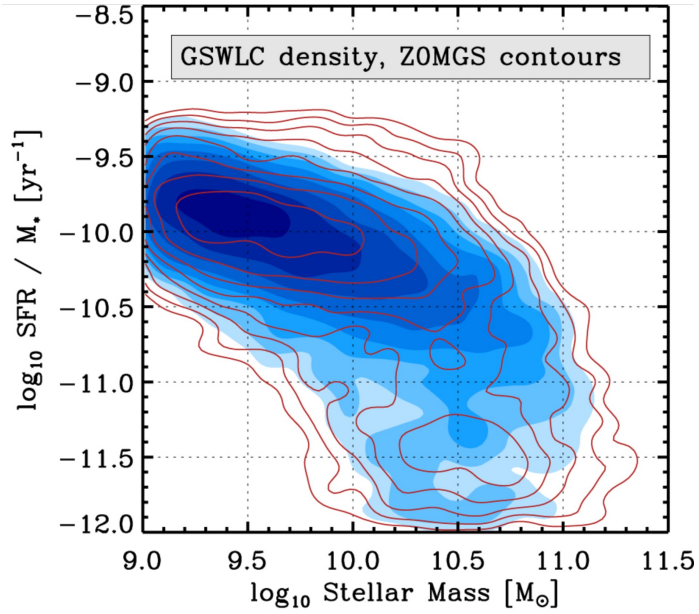
D < 50 Mpc galaxies in contour (AKL, Sandstrom, et al.)
SDSS main galaxy sample galaxies in color (Salim, Lee et al.)

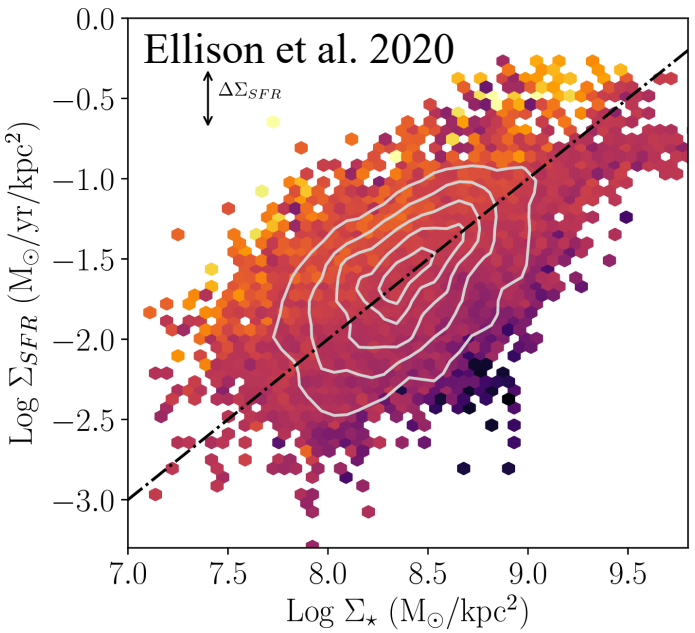
A way to treat local galaxies, low z galaxies, and parts of galaxies on equal footing …

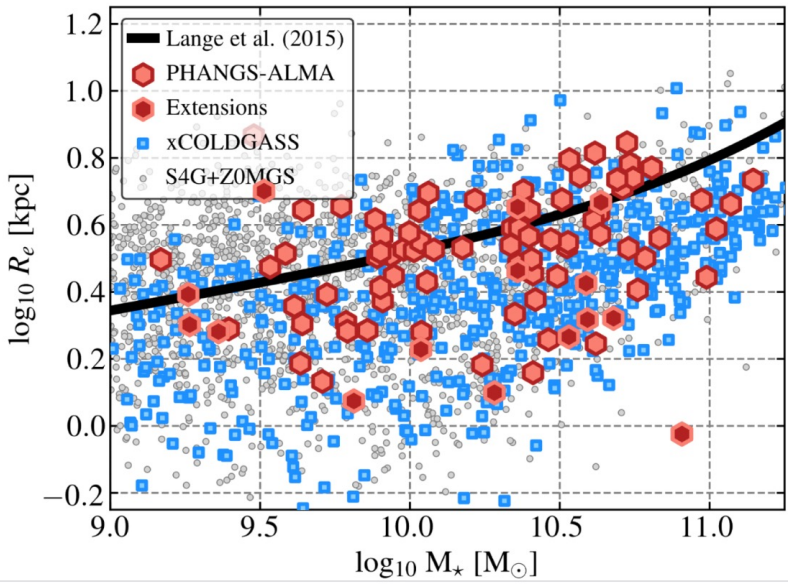
To do this, we would like a self-consistent data set spanning from the UV through the optical and the IR …

… that includes integrated photometry for both **local, big on the sky**, < 50 Mpc galaxies
… and the **larger population of low redshift** galaxies (including key IFU samples like MaNGA)
… and **parts** (individual regions) of local galaxies

And we'd like to model these data with modern population synthesis codes, CIGALE, Prospector, etc..



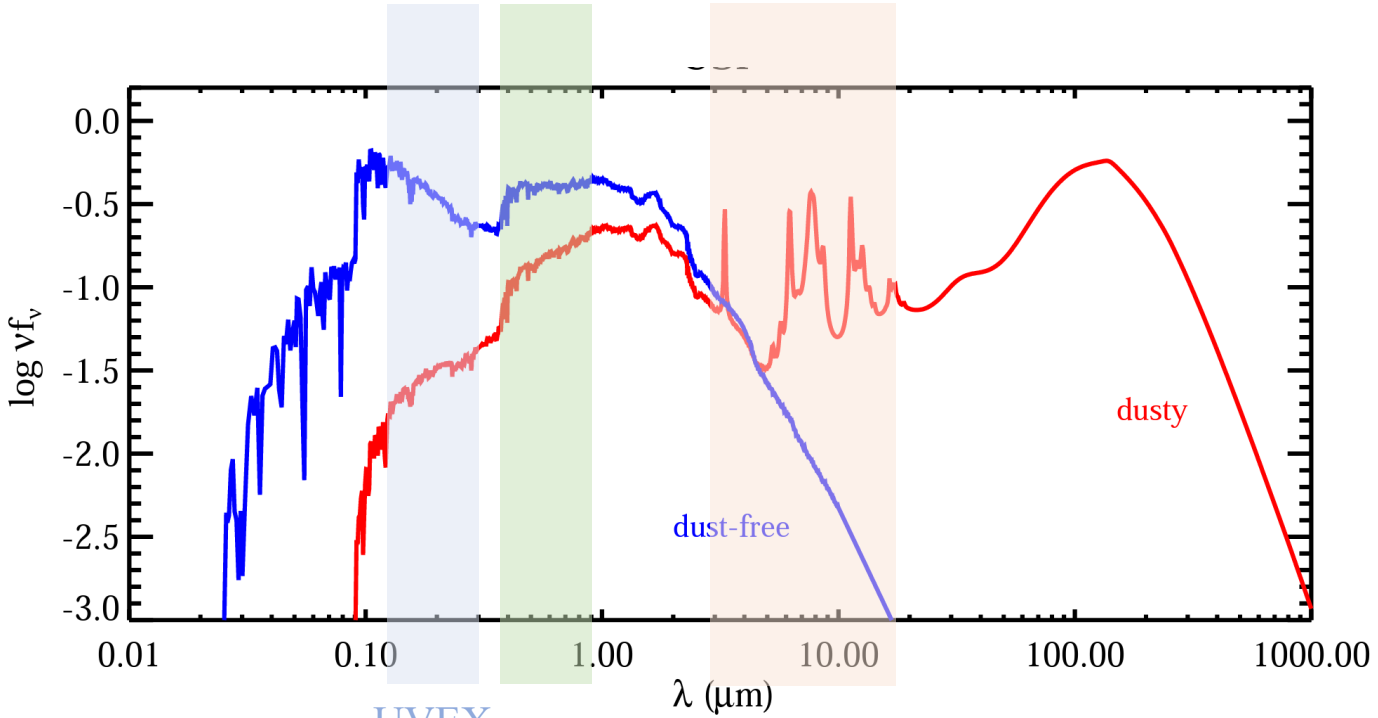


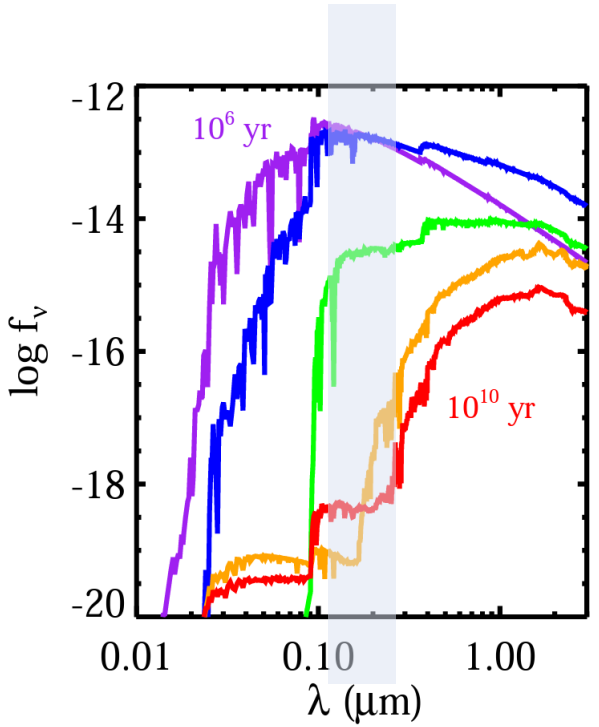


This lets us put every detailed or case study in the context of
the integrated SFR-stellar mass, resolved "star forming main sequence," mass-size relation, and so on …

The UV is critical for population synthesis, star formation rates, extinction, and stellar masses

Full-sky imaging from the UV to the IR is key to make this happen. UV coverage offers sensitivity to the recent and intermediate star formation history, giving us a handle on the amount of attenuation due to dust, and can even be key getting stellar masses right. GALEX has been incredible here, but there is a lot left to do.

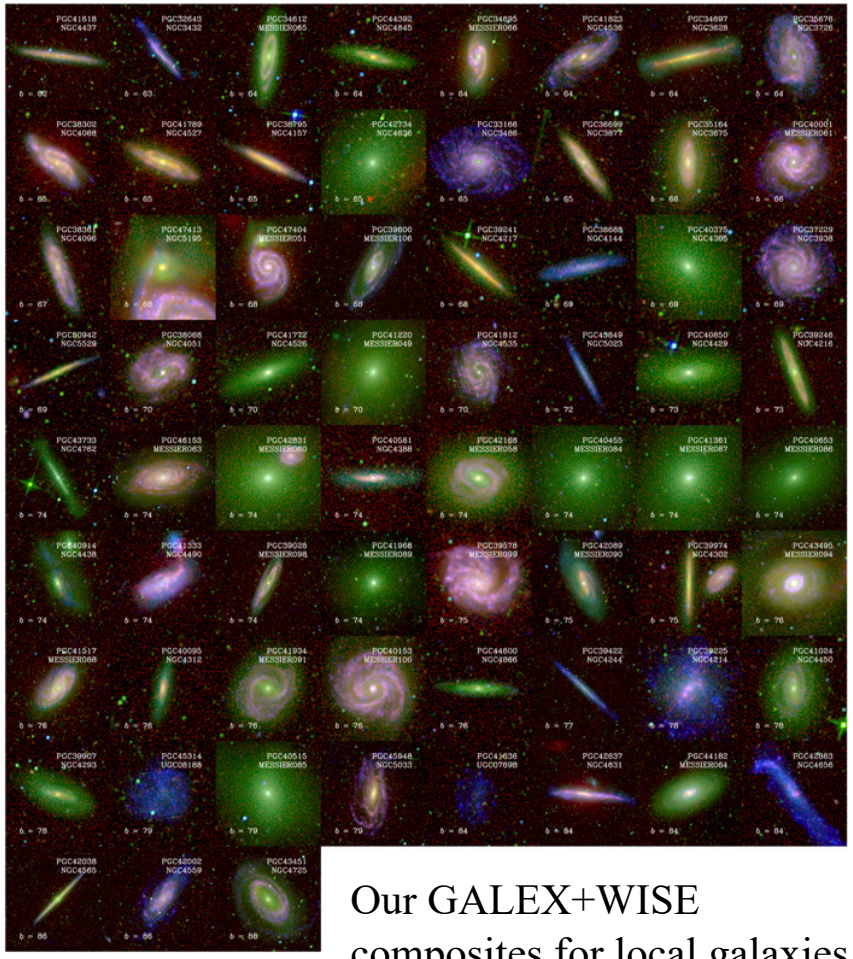




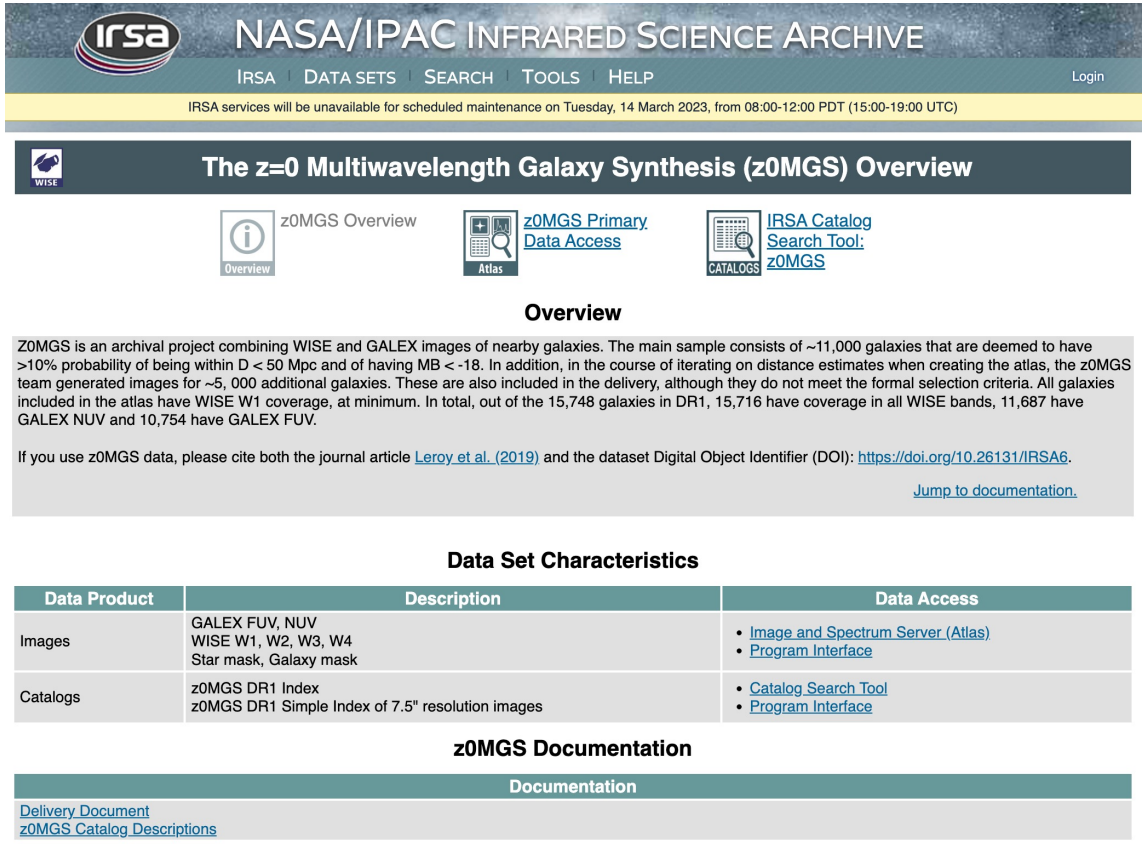
Stellar populations from Conroy 2013

Stitching together “local” and “low redshift” galaxies

We have been pursuing this goal by building matched, processed GALEX UV, WISE near- and mid-IR maps for all galaxies within 50 Mpc (~ 11,000 current targets) and then linking the results to the current premier UV through IR analysis of SDSS main galaxy sample – the GSWLC (Salim, Lee, et al. 2016, 2018). Maps and catalogs are public, with more (Herschel) soon.



Our GALEX+WISE composites for local galaxies



NASA/IPAC INFRARED SCIENCE ARCHIVE

IRSA | DATA SETS | SEARCH | TOOLS | HELP | Login

IRSA services will be unavailable for scheduled maintenance on Tuesday, 14 March 2023, from 08:00-12:00 PDT (15:00-19:00 UTC)

The z=0 Multiwavelength Galaxy Synthesis (z0MGS) Overview

z0MGS Overview | z0MGS Primary Data Access | IRSA Catalog Search Tool: z0MGS

Overview

Z0MGS is an archival project combining WISE and GALEX images of nearby galaxies. The main sample consists of ~11,000 galaxies that are deemed to have >10% probability of being within D < 50 Mpc and of having MB < -18. In addition, in the course of iterating on distance estimates when creating the atlas, the z0MGS team generated images for ~5, 000 additional galaxies. These are also included in the delivery, although they do not meet the formal selection criteria. All galaxies included in the atlas have WISE W1 coverage, at minimum. In total, out of the 15,748 galaxies in DR1, 15,716 have coverage in all WISE bands, 11,687 have GALEX NUV and 10,754 have GALEX FUV.

If you use z0MGS data, please cite both the journal article Leroy et al. (2019) and the dataset Digital Object Identifier (DOI): https://doi.org/10.26131/IRSA6.

Jump to documentation.

Data Set Characteristics

Data Product	Description	Data Access
Images	GALEX FUV, NUV WISE W1, W2, W3, W4 Star mask, Galaxy mask	• Image and Spectrum Server (Atlas) • Program Interface
Catalogs	z0MGS DR1 Index z0MGS DR1 Simple Index of 7.5" resolution images	• Catalog Search Tool • Program Interface

z0MGS Documentation

Documentation
Delivery Document z0MGS Catalog Descriptions

AKL, Sandstrom, Lang, Lewis, Salim et al. 2019

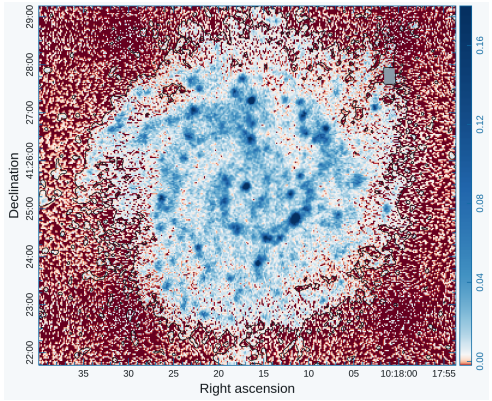
Chastenet, Sandstrom et al. to be submitted – Herschel extension

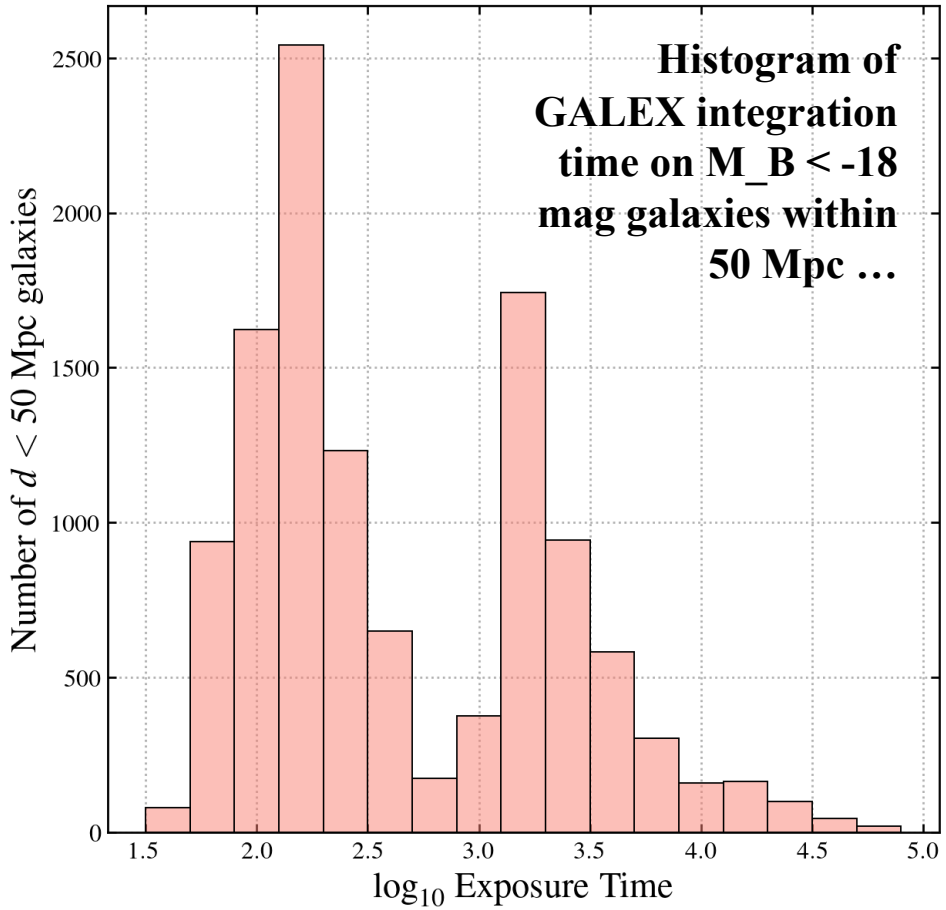
Why might you want this?

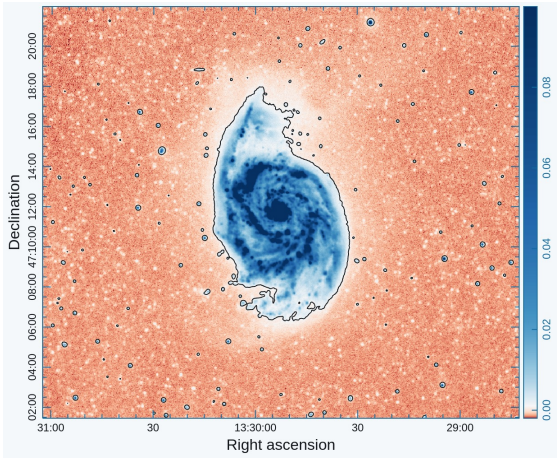
- Know the properties (global and local) of transient/SN hosts or environments, anchor specific rates, etc..
- Link resolved CMD and stellar population studies to large sample integrated galaxy studies.
- Connect detailed observational studies of the matter cycle to appropriate simulations.
- Plan a new survey of local galaxies for maximum impact on galaxy evolution studies.
- Link detailed local studies, e.g., of metallicity, back to the full galaxy population.
- Place low luminosity galaxies in context and reference their properties to more massive targets.

High quality UV coverage of the local galaxy population is significantly incomplete

Despite major pointed survey efforts, the galaxy population out to ~ 50 Mpc has patchwork coverage in the UV. About 1/3 lie outside GALEX's coverage. Of the rest, > 50% had depth <~ 500s and extended disks, interarm regions, and lower surface brightness galaxies are only poorly recovered, especially in the FUV band.







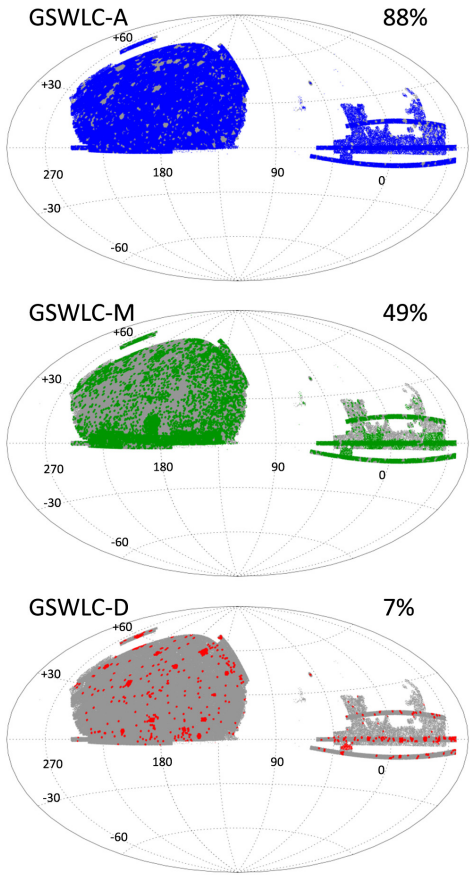
AKL, Sandstrom, Lang, Lewis, Salim et al. 2019
Gil de Paz et al. 2007 and following for pointed surveys

Coverage of more distant low redshift galaxies also has significant limitations

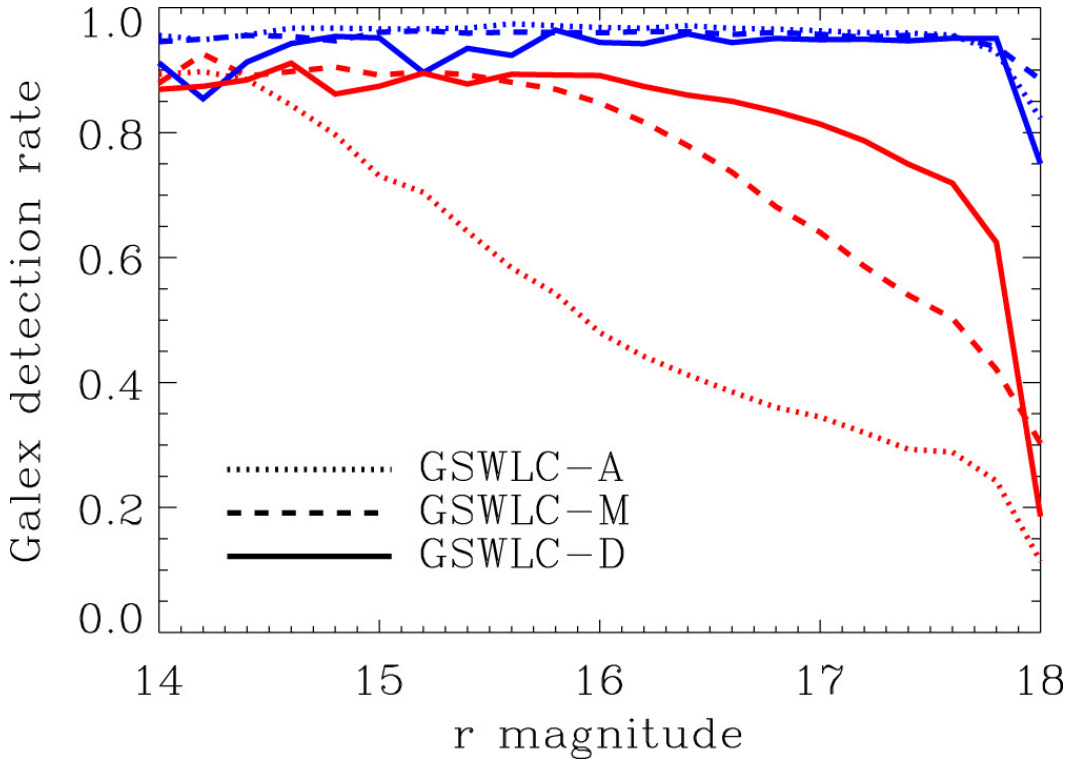
The “unresolved” low redshift galaxies that make up the SDSS main galaxy sample remain incompletely covered in the UV, especially redder galaxies. This limits our knowledge of their mass, star formation history, dust content, etc.. With depth comparable to the “deep” regions of GALEX coverage, UVEX would dramatically increase detection of red z <~ 0.3 galaxies.

In the region of the SDSS main galaxy sample, ~88% of *z = 0.01-0.3* sample have some GALEX measurement, but only <~ 50% have medium integration and only <~ 10% have a deep integration.

As a result only ~ 1/2 the total SDSS main galaxy sample have a UV detection from GALEX in Salim et al. (2016).



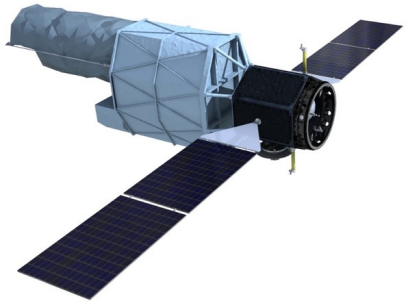
Left: Coverage of various GALEX depths,
Below: SDSS main galaxy GALEX detections

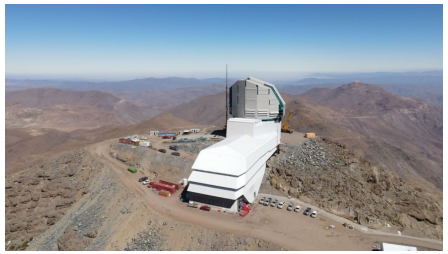


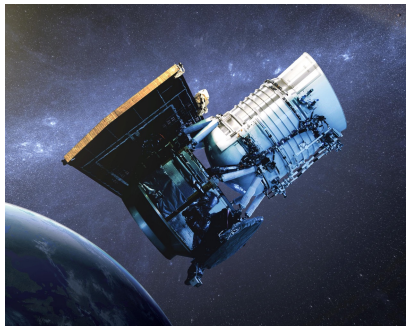
Salim, Lee, et al. 2016, Salim et al. 2018

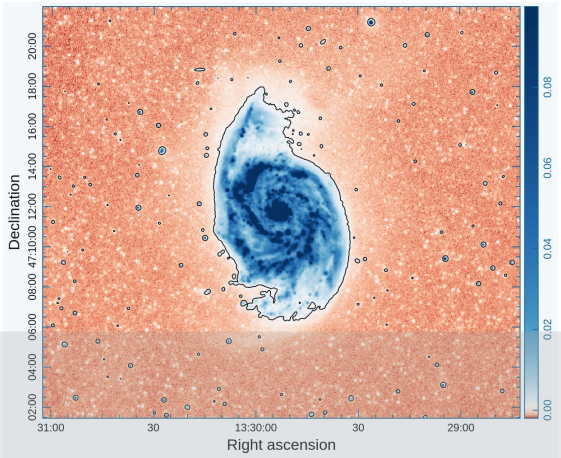
UVEX as a key part of the path forward

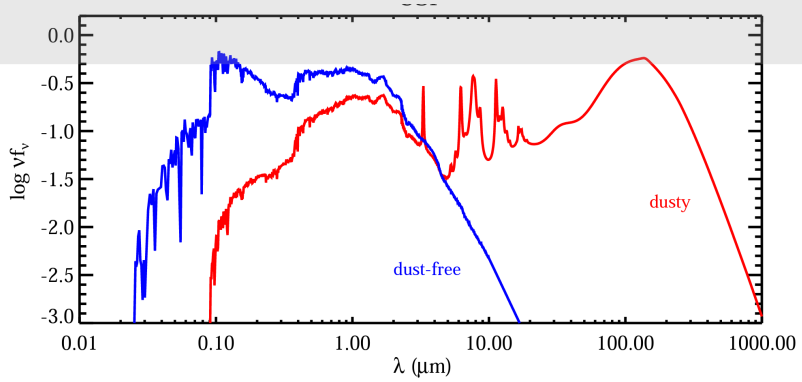
We will have major new optical coverage of the sky from the Rubin LSST, mid-IR coverage from WISE (and maybe an IR probe). This gives uniform, quite complete coverage that can be used to infer the properties of both very local and low redshift galaxies in a uniform way, to break apart local galaxies and treat their parts in a consistent way with this big picture.









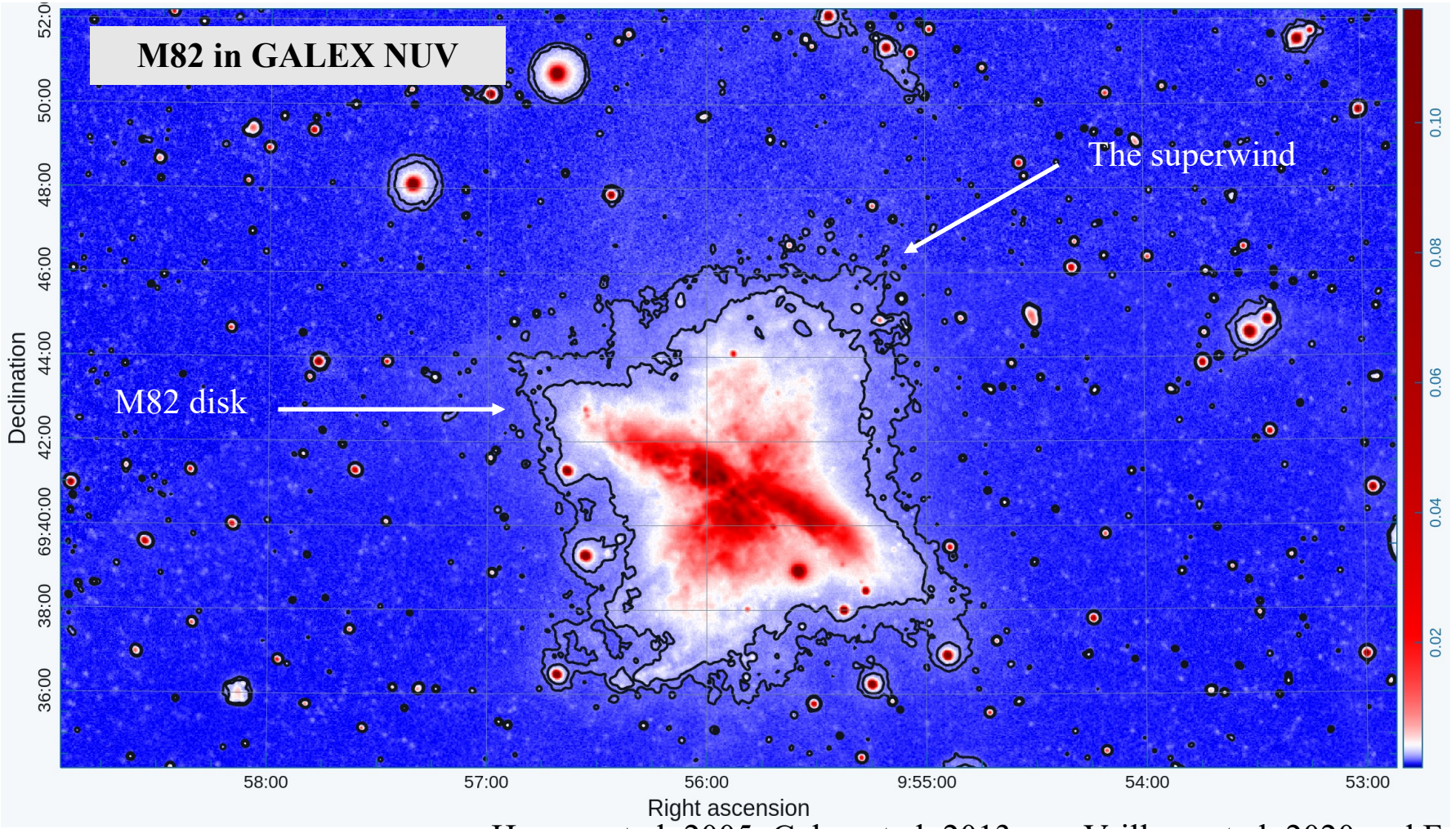


This requires getting images of big, extended things right.

Maybe this is easy for CMOS detectors in a Tess-like orbit?

Another high quality imaging driver - scattered light and galactic winds

Multiphase galactic outflows remain poorly understood but critical to understand chemical evolution, quenching, and the circum- and intergalactic medium. Dust in (edge-on) galactic outflows scatters ultraviolet light, potentially giving access to dust outflow structure, rates, and outflow acceleration mechanisms. These are also fantastic UVEX spectroscopy targets!

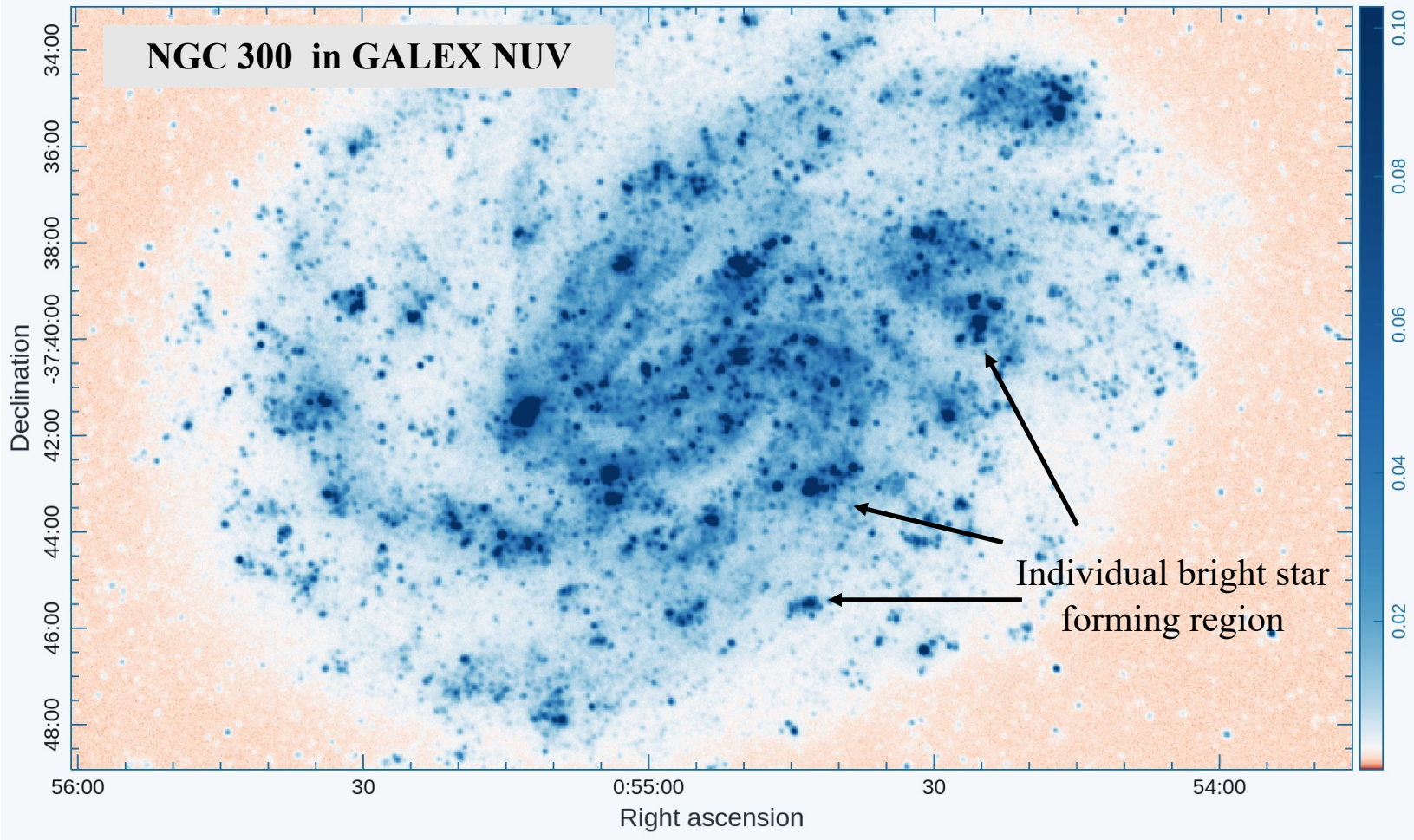


Scattered NUV light seen by GALEX above and below the disk of M82 from GALEX, revealing dust in the galactic wind.

Hoopes et al. 2005; Coker et al. 2013; see Veilleux et al. 2020 and Fukugita & Menard 2011

Isolating clusters and star forming regions in very nearby galaxies

At ~ 2” resolution, UVEX will resolve the closest galaxies into individual star forming regions (<~ 5-10 Mpc). Measurements of stellar mass and age, attenuation, spacing of regions are key to diagnose the strength and efficiency of various times of stellar feedback, to constrain time scales, and generally unpack the matter and energy cycle. Beautifully complements efforts with JWST, ALMA, MUSE, and likely Euclid and Roman (which lack good blue-UV).

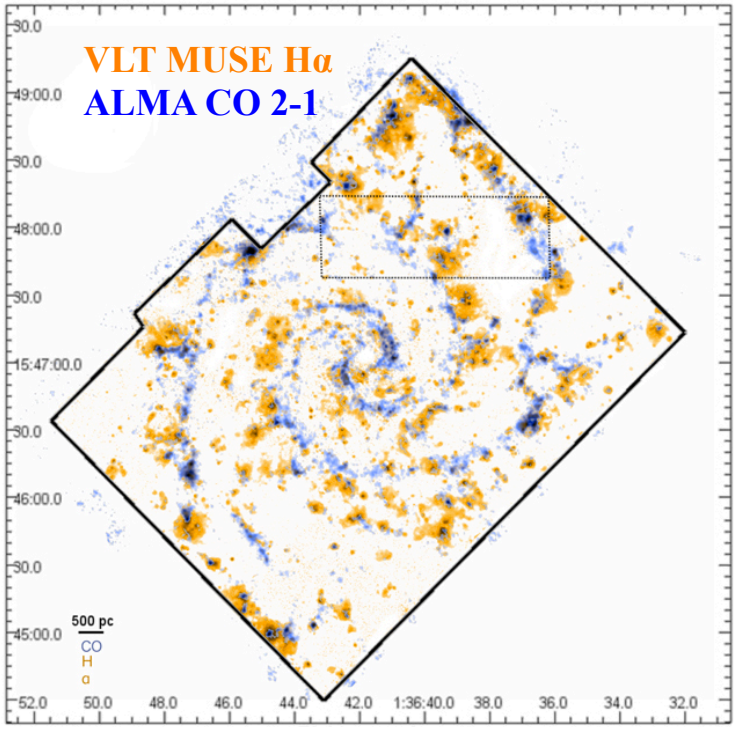


GALEX NUV at ~ 40 pc resolution in NGC 300, one of the closest galaxies beyond the Local Group.

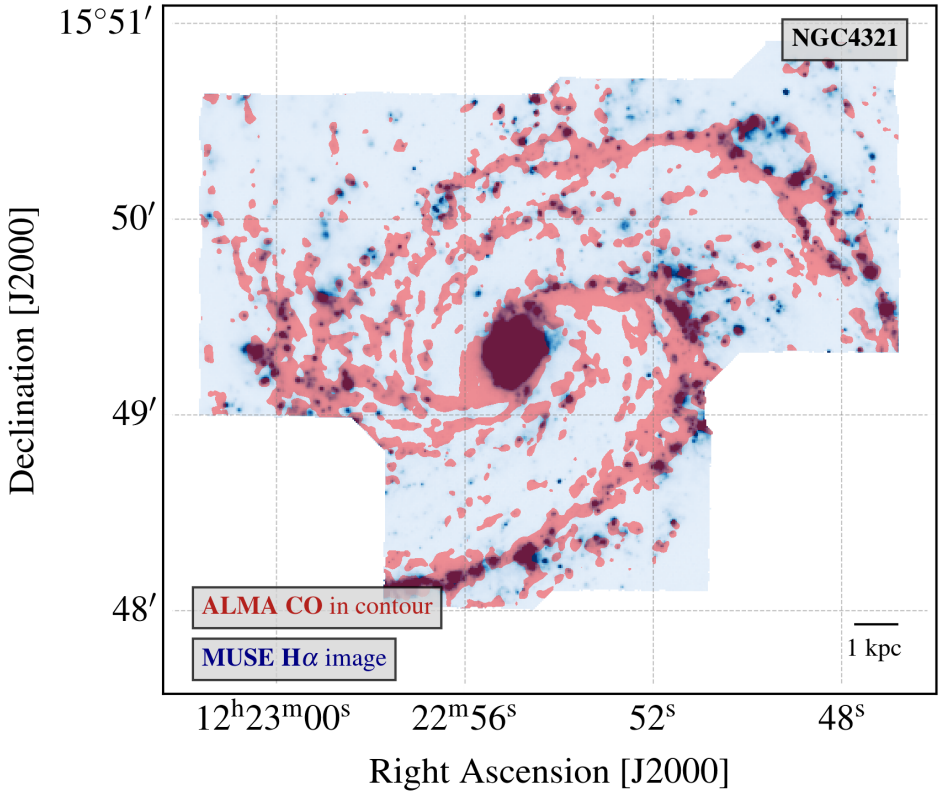
Individual star forming regions isolated and sometimes resolved.

Isolating clusters and star forming regions in very nearby galaxies

At these high ~ 40 – 80 pc resolution individual regions can be resolved and their properties fit. Structure of the UV light can be analyzed and compared (see Phil's talk) to other bands. The "bright spots" in different tracers appear distinct, reflecting violent, rapid evolution of star forming regions, and a host of other small scale science comes into focus.



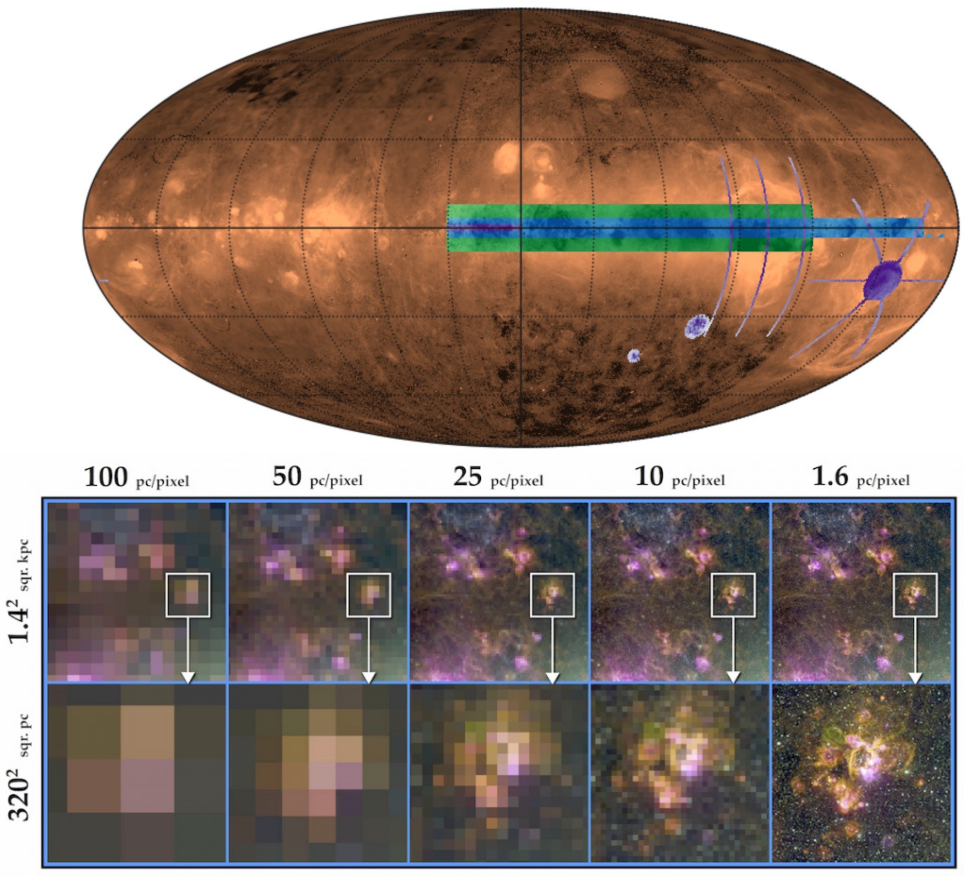
NGC 0628 (M74) from Kreckel et al. (2018)

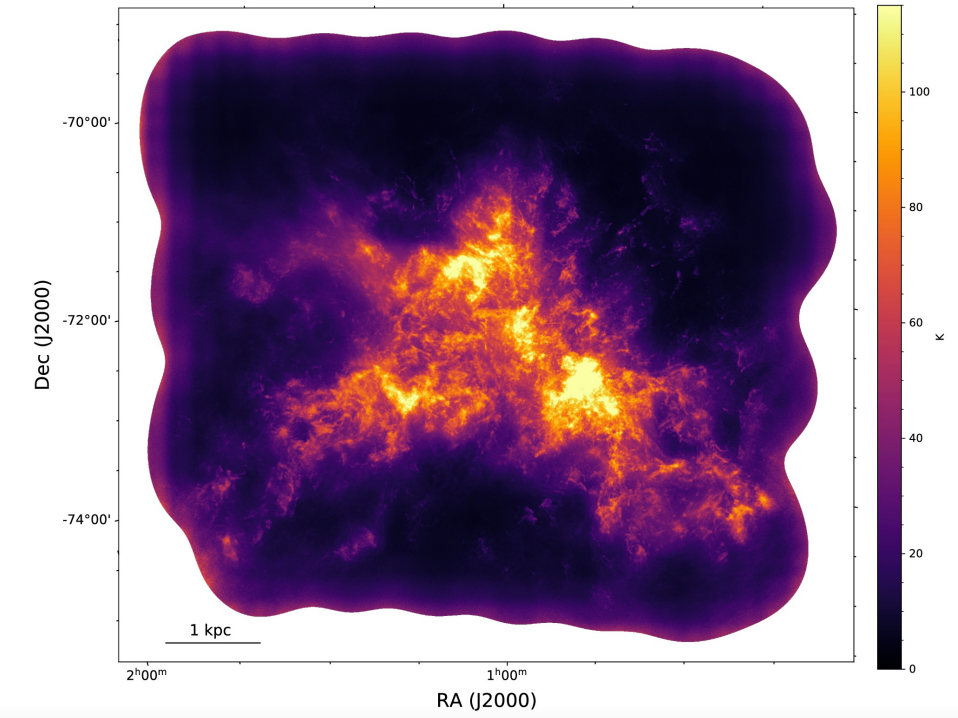


High resolution separation of gas (ALMA CO) and star formation (Hα) reflecting rapid region evolution. UVEX could plug sensitive FUV and NUV into this picture for a really wide range of local galaxies.

High resolved matter cycle in the Magellanic Clouds and Milky Way disk

The unique Magellanic Cloud and Galactic coverage is especially exciting in this regard. Currently the SDSS V Local Volume mapper is coming online and will spectrally mask the Clouds and part of the Galactic disk at 40” (~3600-10000 AA, R~4000). Meanwhile GASKAP is mapping the clouds and Galactic plane in 21-cm at high velocity and high-ish angular resolution.





Left: SDSS-V LVM (Drory+) coverage from Kollmeier et al.; **Above:** GASKAP (McLure-Griffiths+) image of the SMC from Pingel et al.

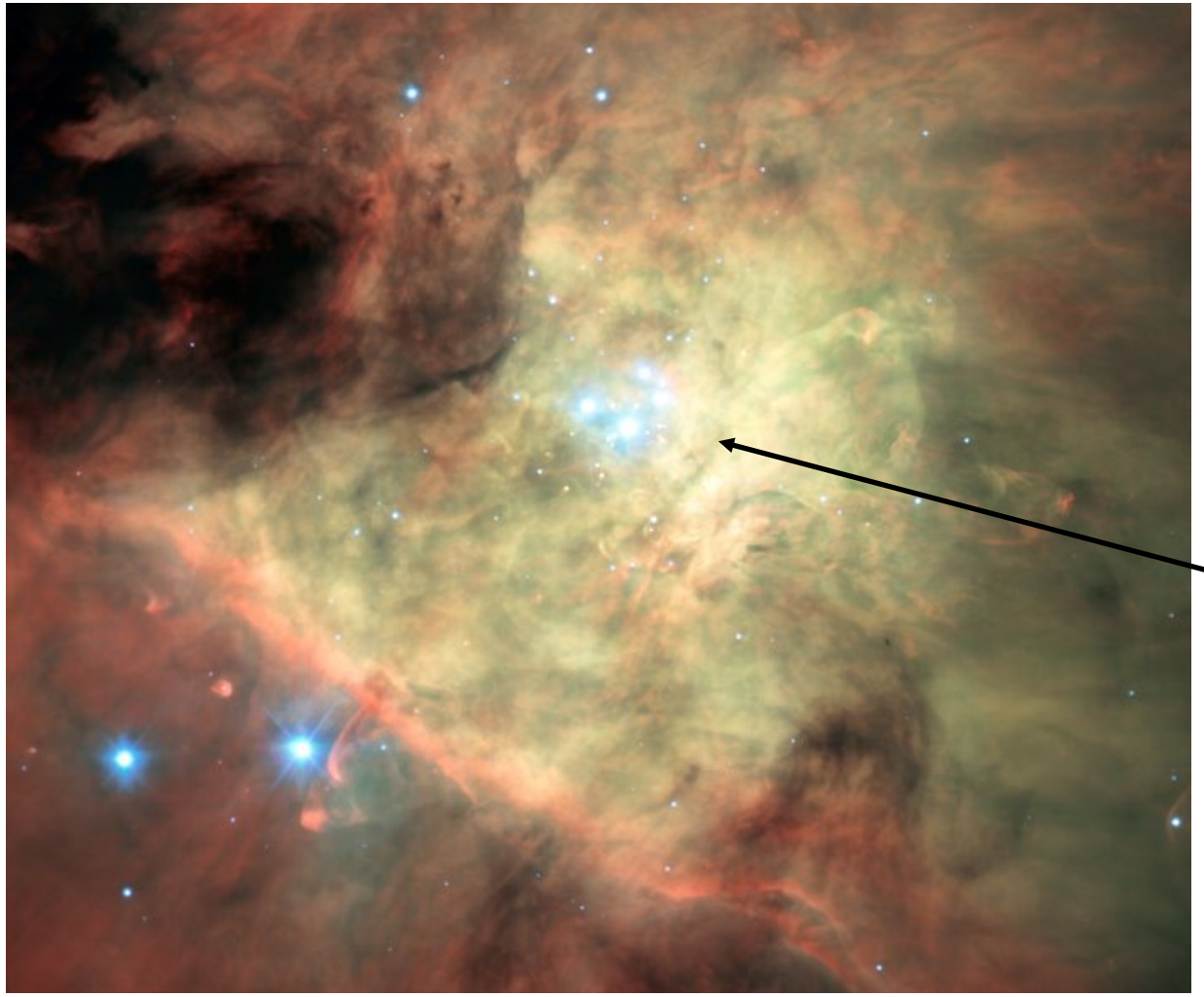
Local Volume Mapper: resolved ionized gas spectral line maps of star forming regions where UVEX observes the powering stars.

GASKAP: highly detailed maps of the atomic gas relevant to compared extinction, scattered light, stellar feedback.

Both uniquely go to the planned unique new areas for UVEX.

High resolved matter cycle in the Magellanic Clouds and Milky Way disk

Though there is a moderate resolution mismatch, these spectral mapping and HI data are actually potentially a very powerful match with UVEX if one considers that the UV is critical to understand the hot, powering stars while the new ionized and atomic gas mapping and kinematics maps out the surrounding ISM under the influence of the stars,



UVEX gets you the stars
(and some scattered light)

Image: ESO/MUSE/Bacon Orion + Trapezium from VLT MUSE

Is the rest of the star-forming Local Group also worth emphasis?

As raised (slightly differently) in Paul's talk there are actually only a very limited number of star-forming very close galaxies. M31, M33, NGC 6822, IC 10, and maybe a few others are really unique targets in terms of physical resolution, luminosity sensitivity, and more – including time domain science. Is there consideration to treat these beyond the all sky survey?

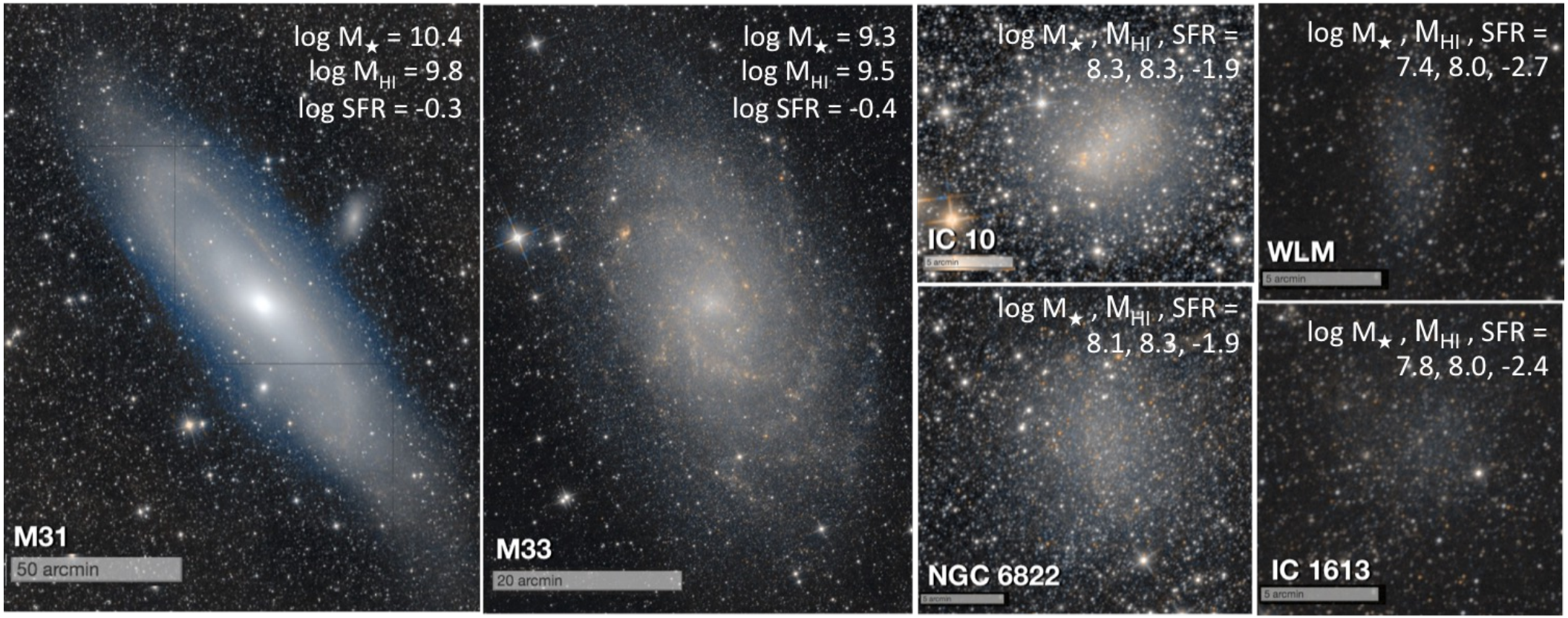
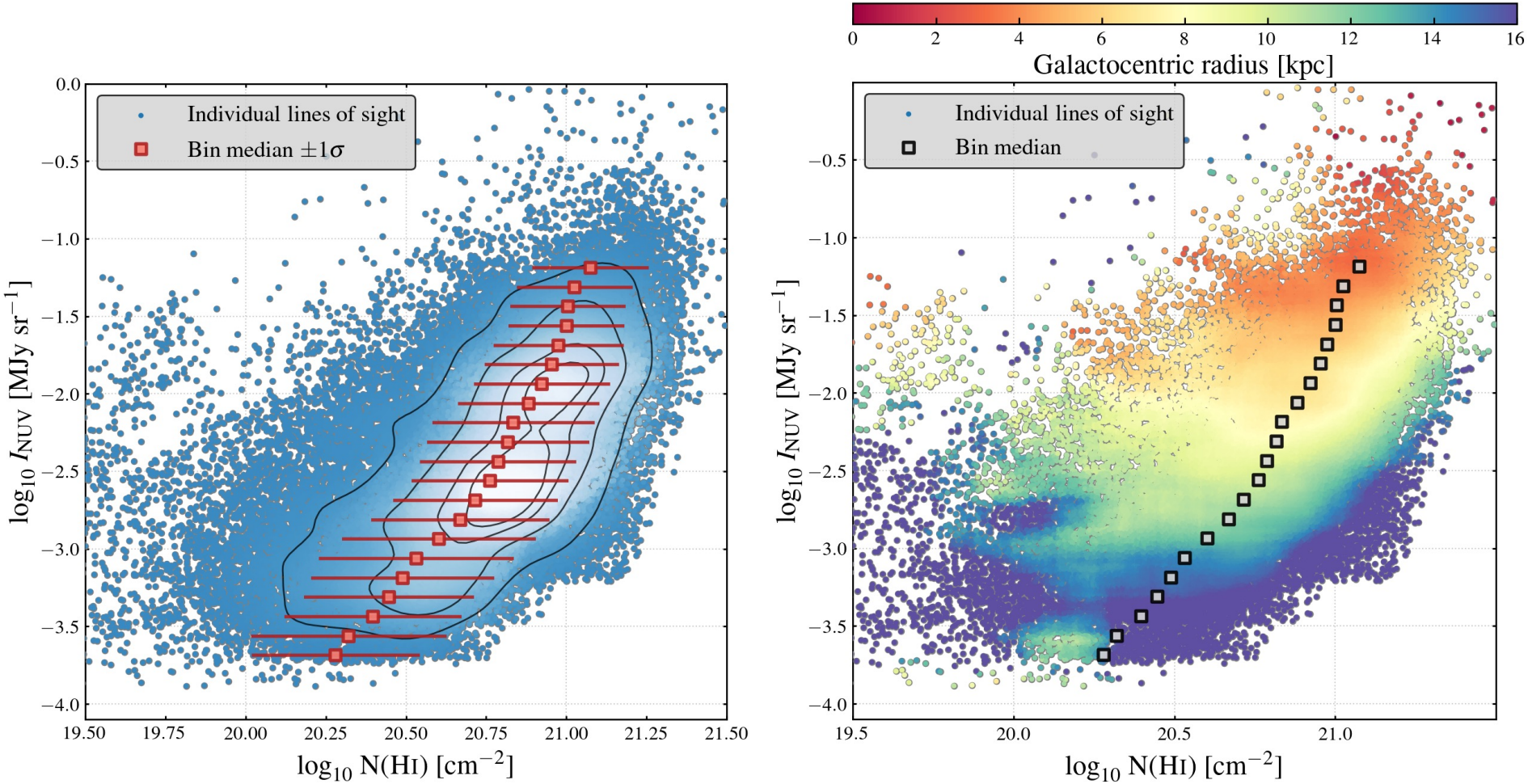


Image: unWISE (Lang et al 14) mosaics of Local Group galaxies. From J. Dalcanton.

Atomic gas and UV in outer galaxy disks (following up Mark's talk on *why* you want this)

With its mass sensitivity, relatively longer time window and wide field coverage, the UV is the essential for constraining the ability of gas to form stars in the extended outer disks of galaxies. Right now there are hundreds of 21-cm maps of galaxies and ~ 200 of these yield useful measurements of both atomic gas and UV emission in outer disks.



Individual lines of sight comparing GALEX NUV to 21-cm based atomic gas in ~ 143 resolved galaxies.

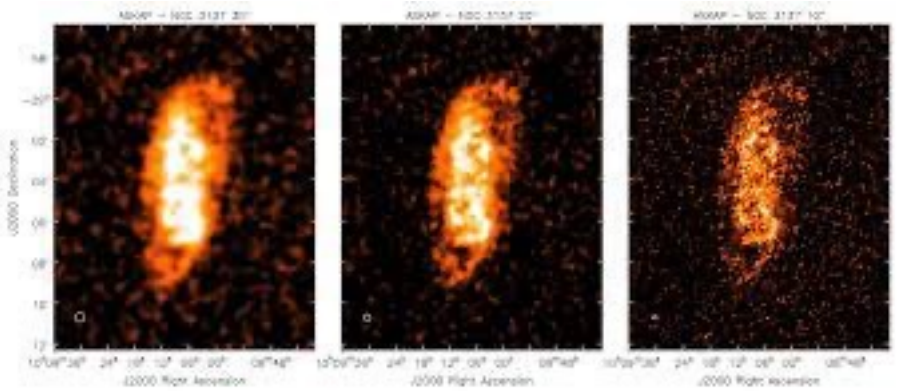
Left: data density

Right: same data colored by galactocentric radius

Combining our *z0mgs* UV with THINGS, LITTLETHINGS, VIVA, LVHIS, WHISP, VLA-ANGST, and a few more 21-cm surveys

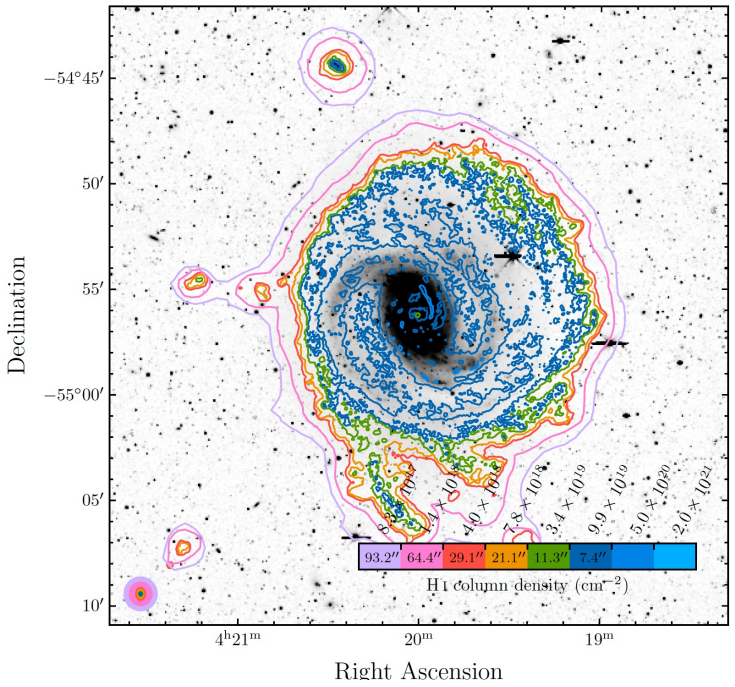
We're headed towards a 21-cm renaissance (which makes the UV critical)

Right now the ability to study gas and star formation in outer galaxies is limited by both axes. But a 21-cm revolution is in progress. ASKAP and (one hopes) the DSA 2000 offer the prospect of 21-cm "big data." MeerKAT and soon SKA-mid offers phenomenal depth and image quality, and the ngVLA and SKA-mid will match UVEX's resolution. On exactly the timescale of the mission, we will need wide area, sensitive maps of the UV to match the coming 21-cm boom …

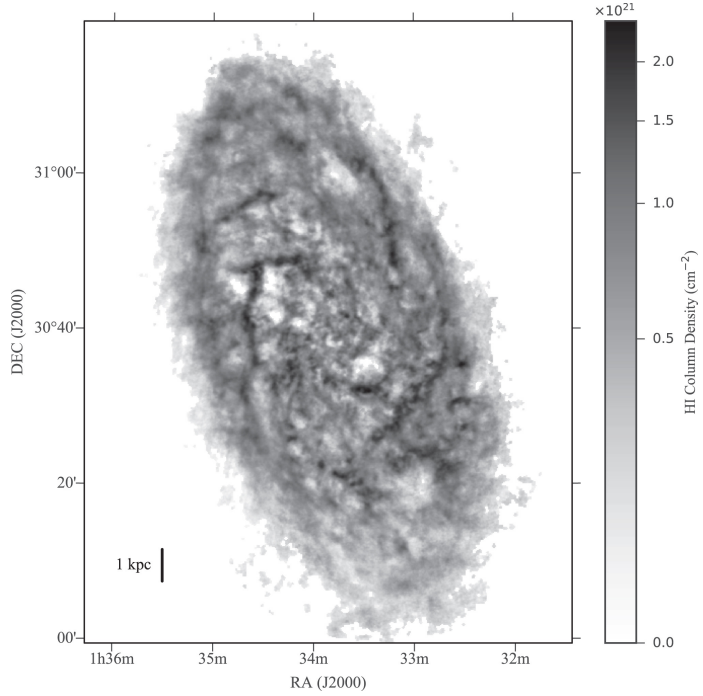


Koribalski et al. (2020) – WALLABY on ASKAP will give us thousands of moderate quality 21-cm maps of galaxies. The UV is the key to trace how well this gas forms stars over the vast area covered by this survey.

Possible similar (or better!) northern data set from a DSA2000



MeerKAT offers incredible sensitivity to low column gas over huge areas. **Credit:** MHONGOOSE de Blok et al. (2017)



With ngVLA and SKA we move into the era where 21-cm matching achieves 1-2 arcsec resolution, closely matched to UVEX. **Credit:** Koch et al. (2018, 2021) M33 HI

UVEX and Local or Low Redshift Galaxies

Trying to give a complementary perspective to Janice, Mark, and Phil …

- Deep UV coverage of the whole sky is critical to place high-detail studies of local galaxies in clear context.
  - Still incomplete from GALEX for both local (d < 50 Mpc) or low redshift SDSS galaxies.
  - There's significant value in trying to get images of big things right.
- Scattered UV light is visible in galactic winds, and benefits from similar capabilities.
- Out to 5-10 Mpc, expect UVEX to capture individual star-forming regions and be highly complementary to ALMA, JWST, VLT or Keck IFU to study feedback and star formation efficiencies and timescales.
- UVEX's focus on the Magellanic Clouds and the Milky Way aligns well with major next efforts from SDSS V and GASKAP to obtain complementary views of the ionized and neutral gas. Other Local Group galaxies?
- The UV is a natural pair to HI mapping and UVEX is a timely pair to a revolution in 21-cm capabilities.