Time Allocation Committee for
MPG time at the ESO 2.2m-telescope
c/o MPI für Astronomie
Königstuhl 17
D-69117 Heidelberg / Germany

Application No.	
Observing period	110
Received	

APPLICATION FOR OBSERVING TIME

from [X] MPIA [ ] MPG institute [ ] other

1. Telescope: 2.2-m [X]

2.1 Applicant

Dr. Eva **Schinnerer**	MPIA
Name	Institute
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2.2 Collaborators

Congiu, Kreckel, Belfiore	UdeChile, ZAH/ARI, INAF
name(s)	institute(s)
Stuber	MPIA
name(s)	institute(s)

2.3 Observers

Stuber, Congiu	
name	name

By specifying the names under item 2.3 it is obligatory to also send out these observers to La Silla, if required. Correspondence on the rating of this application will be sent to the applicant (P.I.) as quoted under 2.1 above.

3. Observing programme: Category: [C]

Title : **WFI's legacy for the PHANGS galaxy sample**

Abstract : We request 30 hours of WFI time to observe Hα and R-band images of 20 nearby star-forming galaxies. This program is designed to complement the MPIA-led PHANGS survey which uses ALMA, MUSE, HST, and soon JWST data to study the physics of star formation and feedback at $\sim$100 parsec resolution (or $\sim$1"). The requested WFI imaging will provide critical information on the star formation rate at matched resolution for galaxies without MUSE data and it will be instrumental to anchor the absolute astrometry and validate the flux calibration for planned MUSE observations. These ancillary data will maximize the legacy value of the PHANGS sample of 90 galaxies.

4. Instrument: [X] WFI [ ] FEROS [ ] GROND

5. Brightness range of objects to be observed: from 9.31 to 13.5 B-mag

6. Number of hours:

applied for			already awarded	still needed
		30	none	none
no restriction	grey	dark		

7. Optimum date range for the observations: .... 01.10.22 – 31.03.23
Usable range in local sideral time LST: .... 02:30h – 23:00h

Astrophysical context – Significant progress has been made in the past decade to understand the star formation process across cosmic time. A tight relation between the (global) star formation rate (SFR) and (molecular) gas mass has been observed locally (Kennicutt 1989), and it appears to hold out to z$\sim$4 (Tacconi et al. 2020). This suggests that the star formation uniformly proceeds from early times until today. Detailed studies in local galaxies also show that the Kennicutt-Schmidt relation (KS, Kennicutt 1998), which connect the surface gas density with the SFR, holds on kpc-scales. However, an intrinsic scatter persists (e.g. Leroy et al. 2013) and galactic structure (bars, spiral arms, bulges) significantly influences its exact shape (e.g. Pessa et al. 2021). Thus next generation surveys must reach the scale of giant molecular clouds (GMCs) and HII regions to gain new insights in the underlying physics of the star formation process.

Cloud-scale resolution observations of nearby galaxies are starting to transform our understanding of the star formation process and its impact on the interstellar medium. Our PHANGS[1] collaboration has been actively collecting high spatial resolution data for 90 nearby (< 20 Mpc), main-sequence star-forming galaxies (Leroy et al. 2021). At such distances, 1" resolution is approximately few tens of parsecs, a critical scale for resolving GMCs, HII regions and thus the relevant physics of star formation and feedback (Fig. 1). The major observational effort includes accessing the cold molecular ISM through CO(2-1) emission using ALMA, the warm ionised ISM using MUSE/VLT, (young) stellar clusters via HST and soon deeply embedded star-forming sites via JWST. While ALMA CO(2-1) data exist for all 90 galaxies, the other instruments targeted only subsets. We are currently in the process to increase our initial MUSE coverage of 19 galaxies to obtain optical IFU imaging for the full ALMA sample. This pan-chromatic dataset forms the foundation of understanding ISM in nearby galaxies at high angular resolution for decades to come.

Immediate aim – We propose to acquire broadband (R) and narrowband Hα images for 20 galaxies in 2022B to deliver two immediate goals. First, narrowband imaging is the only tool available to measure the unattenuated component of the SFR at arcsec resolution across the full extent of our galaxies. This is critical for understanding the spatial distribution of massive star-forming regions, the resolved KS relation and how HII regions and GMCs properties (size, luminosity, mass) vary with galactic environment and galaxies' physical parameters, (Fig. 1). Second, wide-field images are critical to 1) anchor the absolute astrometry, and 2) validate the absolute flux calibration and sky subtraction (Fig. 2), for the galaxies we are planning to observe with MUSE. WFI wide field capabilities will ensure a proper registration of the images by comparing multiple bright stars with Gaia star catalogs (see Razza et al. in prep.). This absolute calibration is essential to mosaic and align our MUSE pointings (with 1arcmin FoV they often contain no foreground stars), bring them to a common flux scale, and it enables comparisons between the MUSE and ALMA data at subarcsec scale accuracy (Emsellem et al. 2022). Comparing the narrowband images with MUSE line maps can be used to study the biases introduced by using narrowband images to study the Hα emission (due to diffuse emission, stellar absorption, extinction, [NII] contamination, etc.; see Pan et al., in prep.).

[1] www.phangs.org

Previous work– The 20 proposed galaxies are the only galaxies from the full PHANGS-ALMA sample that lack high-quality literature data or observations from our previous PHANGS-Hα survey (see Razza et al. in prep.). We have a working pipeline for the reduction of WFI broad- and narrowband data which was successfully applied to 68 galaxies (Razza et al. in prep.). Narrowband Hα maps have been used to study the timescale of the gas-star formation cycle in nearby galaxies (Kruijssen et al. 2019, Schinnerer et al. 2019, Chevance et al. 2020, Pan et al. 2022, Kim et al. in prep.) while the broadband images have been instrumental to correctly calibrate the data of the PHANGS-MUSE survey (Emsellem et al. 2022).

Layout of observations – The optical disks of all our targets have sizes of $1' < R_{25} < 12'$ and thus fit easily into one WFI FoV. We aim to reach a target SFR rate surface density of 0.01 $M_\odot y^{-1} kpc^{-2}$.This is comparable to the turn-over of the HII region luminosity function as measured with narrowband Hα surveys in the literature, and allows us to easily detect HII regions in the outskirts of the galaxies. The narrow-band Hα/7 filter contains the Hα emission line for our full sample (V_{helio} = 400–1700 km s^{-1}), while the broadband filter Rc/162 will allow us to subtract the underlying stellar continuum contribution. We will employ the automatic dithering patterns recommended in the WFI Observers Guide to fill the gaps between the detectors. For each galaxy we will observe both the Hα and R filters on the same night, to minimize calibration issues. Changing filter between observations should result in minimal overheads. We will perform the photometric calibration by comparing the brightness of the field stars with their Gaia magnitudes, using the relations described in Chapter 5.3.7 of the Gaia documentation. Still, photometric conditions are needed to ensure a precise background subtraction.

Strategic importance for MPIA – This strategic WFI imaging program will complement the MPIA-led PHANGS survey to explore the full potential of the unique dataset and ultimately ensure the quality of the legacy products that will be released to the community.

8b. Figures and tables

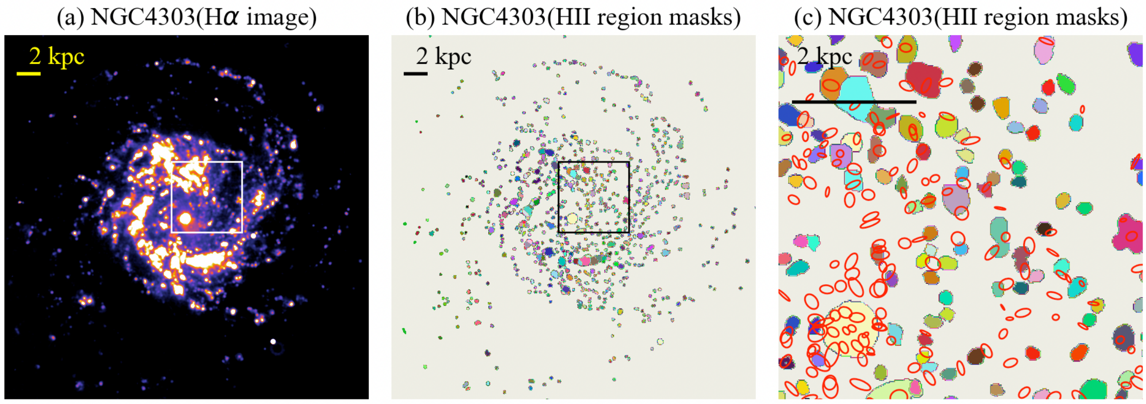

Figure 1: Distribution of HII regions in NGC 4303. **Panel a)** shows the background subtracted Hα image observed during our previous WFI survey (Razza et al. in prep.). **Panel b)** shows the HII regions identified by HIIphot (Thilker et al. 2000). The black box highlights the region shown in panel c. **Panel c)** shows a zoom on a particular region of the galaxy and it compares the position and size of the HII regions with the giant molecular clouds identified in the PHANGS-ALMA data of the galaxy by Leroy et al. 2021 (red ellipses).

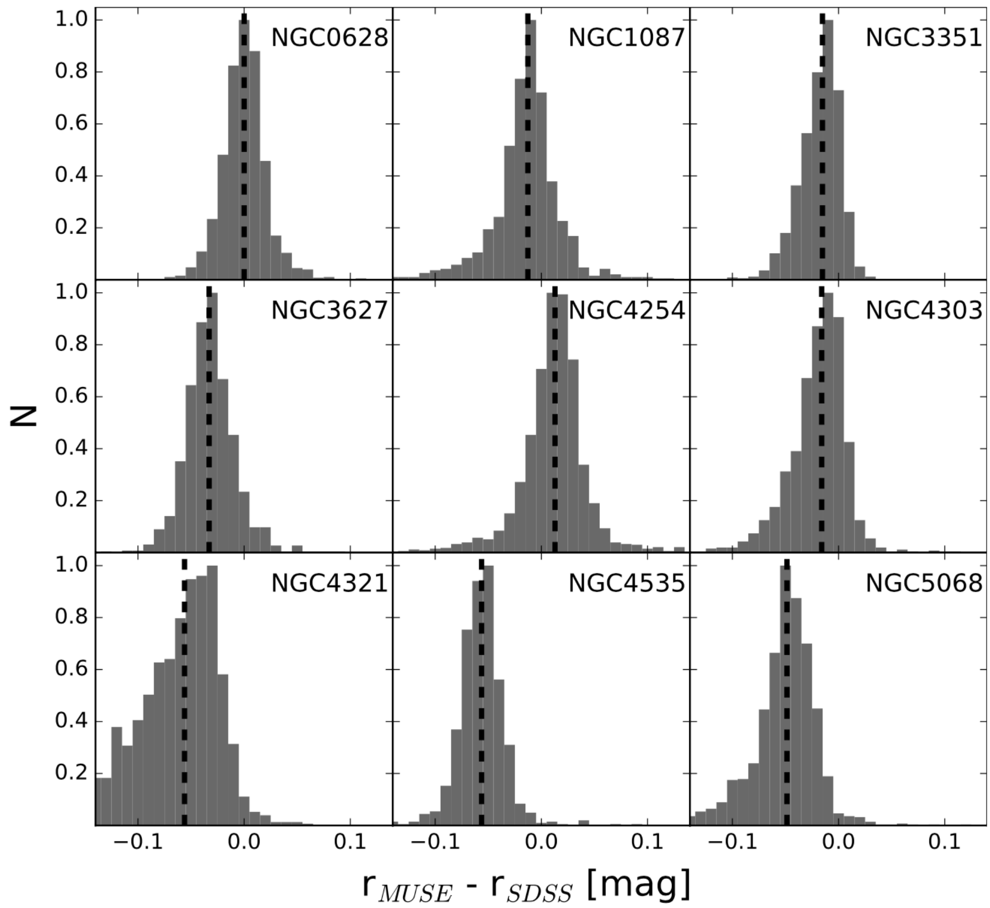

Figure 2: Comparison of r-band magnitudes measured over 5 arcsec apertures with MUSE synthetic images (r_{MUSE}) and SDSS images (r_{SDSS}) for the nine galaxies with available SDSS data. Histograms are normalized for each galaxy and the median offset indicated with a dashed line. Across this sample of galaxies, the median offset ranges from -0.06 to 0.01 mag. Typical scatter within any galaxy is ~ 0.04 mag. Image adapted from Emsellem et al. (2022).

9. Objects to be observed

(Objects to be observed with high priority should be marked in last column)

Designation	α (2000)	δ (2000)	magnitude in spectral range to be observed	priority
NGC 1068	$02^h\,42^m\,40.74^s$	$-00°\,00'\,47.8''$	9.61	1
NGC 1291	$03^h\,17^m\,18.59^s$	$-41°\,06'\,28.8''$	9.83	1
NGC 1637	$04^h\,41^m\,28.18^s$	$-02°\,51'\,28.7''$	11.40	1
NGC 1808	$05^h\,07^m\,42.30^s$	$-37°\,30'\,47.0''$	10.80	1
NGC 2903	$09^h\,32^m\,10.11^s$	$+21°\,30'\,03.0''$	9.75	1
NGC 3137	$10^h\,09^m\,07.48^s$	$-29°\,03'\,51.5''$	12.21	1
NGC 3239	$10^h\,25^m\,04.87^s$	$+17°\,09'\,49.3''$	13.5	1
NGC 3489	$11^h\,00^m\,18.57^s$	$+13°\,54'\,04.4''$	11.12	1
NGC 3521	$11^h\,05^m\,48.57^s$	$-00°\,02'\,09.4''$	9.83	1
NGC 4380	$12^h\,25^m\,22.20^s$	$+10°\,01'\,01.0''$	13.40	1
NGC 4383	$12^h\,25^m\,25.50^s$	$+16°\,28'\,12.0''$	12.67	1
NGC 4651	$12^h\,43^m\,42.60^s$	$+16°\,23'\,36.0''$	11.30	1
NGC 4772	$12^h\,53^m\,29.10^s$	$+02°\,10'\,06.0''$	11.96	1
NGC 4826	$12^h\,56^m\,43.64^s$	$+21°\,40'\,59.1''$	9.36	1
ESO 97-G13	$14^h\,13^m\,09.90^s$	$-65°\,20'\,20.9''$	10.89	1
IC 5273	$22^h\,59^m\,26.68^s$	$-37°\,42'\,10.2''$	11.90	1
NGC 1097	$02^h\,46^m\,18.95^s$	$-30°\,16'\,28.8''$	9.97	2
NGC 3368	$10^h\,46^m\,45.70^s$	$+11°\,49'\,11.7''$	10.15	2
NGC 4536	$12^h\,34^m\,27.07^s$	$+02°\,11'\,17.7''$	11.16	2
NGC 4945	$13^h\,05^m\,27.30^s$	$-49°\,28'\,04.5''$	9.31	2

10. **Justification of the amount of observing time requested:**

In order to achieve a SFR surface density of $0.01 M_{\odot} yr^{-1} kpc^{-2}$ we need to reach a flux of $3.66 \times 10^{-16} erg\, s^{-1} cm^{-2} arcsec^{-2}$ using the calibration of Murphy et al. (2011). Using the WFI ETC (https://www.eso.org/observing/etc/bin/simu/wfi), 2700s with the Hα filter reaches this flux with a signal-to-noise of 25 per arcsec^2 (in dark time, FLI < 0.4). To correct for the underlying continuum we will need 900s in the R band filter. This will reach a depth of 24 mag arcsec^{-2} with a signal-to-noise ratio of $\sim$10. In order to fill the gaps between the chips, we will employ the standard automatic offset dither pattern suitable for the declination of the galaxy, resulting in a total of at least 7 exposures per pointing. Given the sizes of our targets ($1' < R_{25} < 12'$) a single pointing with WFI's FoV of 34' × 33' FOV is sufficient to observe the full optical disk of all galaxies in our sample. Assuming 30 min overhead (pointing, filter change, readout, set-up etc.) per galaxy, we therefore request 30 hours for 20 galaxies.
WFI at the ESO/MPG 2.2m is ideally suited as its FOV allows for the efficient imaging of our targets that are preferentially located in the southern hemisphere.

11. **Constraints for scheduling observations for this application:**

Given the RA distribution of our sample, we request two observing blocks optimized for the 6 targets in the table of section 14 with RA between 22h and 6hr and one for the remaining 14 galaxies centered around LST $\sim$ 12–14 hr.

12. **Observational experience of observer(s) named under 2.3:**
(at least one observer must have sufficient experience)

Several team members have ample observing experience at optical telescope and the reduction of WFI data (Razza, Blanc, Congiu). These team members will be closely involved in the preparation, execution and calibration of the observations.

13. **Observing runs at the ESO 2.2m-telscope (preferably during the last 3 years)**
and publications resulting from these

Telescope	instrument	date	hours	success rate	publications
2.2m	WFI	P101	19.5	100%	Razza et al., in prep; Pan et al. 2022
2.2m	WFI	P98	40	100%	Razza et al., in prep; Pan et al. 2022

14. References for items 8 and 13:

Chevance et al. 2020;
Emsellem et al. 2022;
Kennicutt 1998, ApJ, 498, 541;
Kennicutt et al. 2003, PASP, 115, 928;
Kruijssen et al. 2019, Nature, 569, 519;
Leroy et al. 2013, AJ, 146, 19;
Leroy et al. 2021, ApJS, 257, 43;
Pessa et al. 2021, A&A, 650, 134;
Murphy et al. 2011, ApJ, 737, 67;
Pan et al. 2022, ApJ, 927, 9;
Schinnerer et al. 2019, ApJ, 887, 49;
Tacconi et al. 2020, ARAA, 58, 157;
Thilker et al. 2000, AJ, 120, 3070.

Tolerance limits for planned observations:

maximum seeing:	1.5″	**minimum transparency:**	95%	**maximum airmass:**	1.5
photometric conditions:	yes	**moon: max. phase / ∠ :**	0.4/90°	**min. / max. lag:**	/ nights