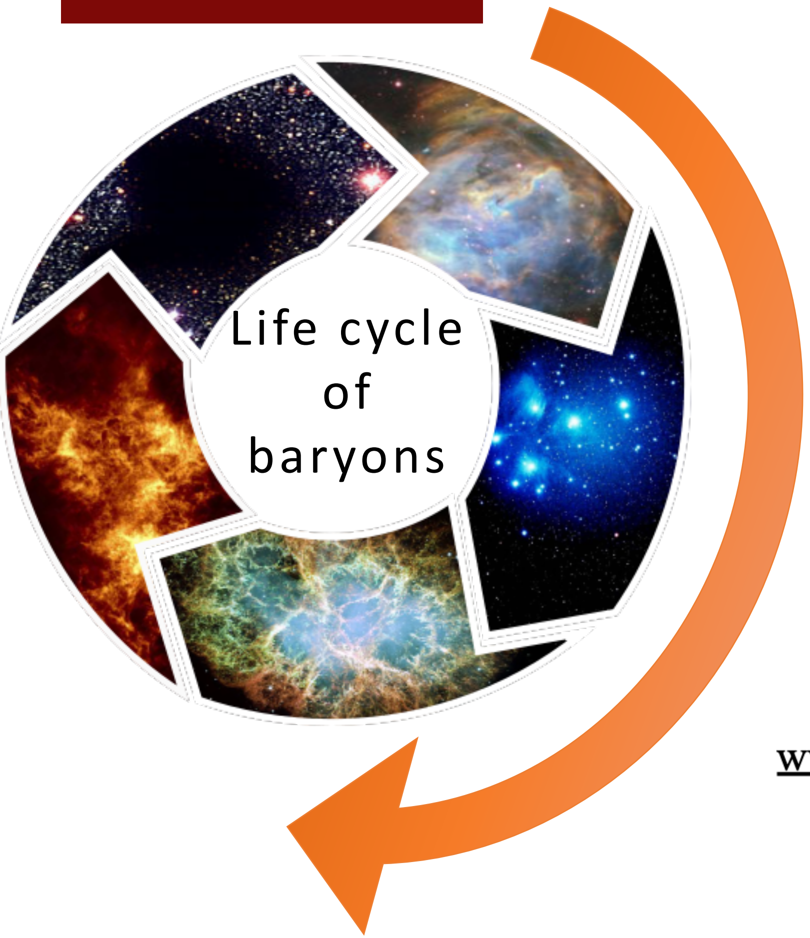
PHANGS: Physics at High Angular Resolution in Nearby Galaxies

The PHANGS collaboration is using surveys on a wide range of facilities to achieve a complete, high resolution view of gas, stars, and recent star formation across the nearby galaxy population.



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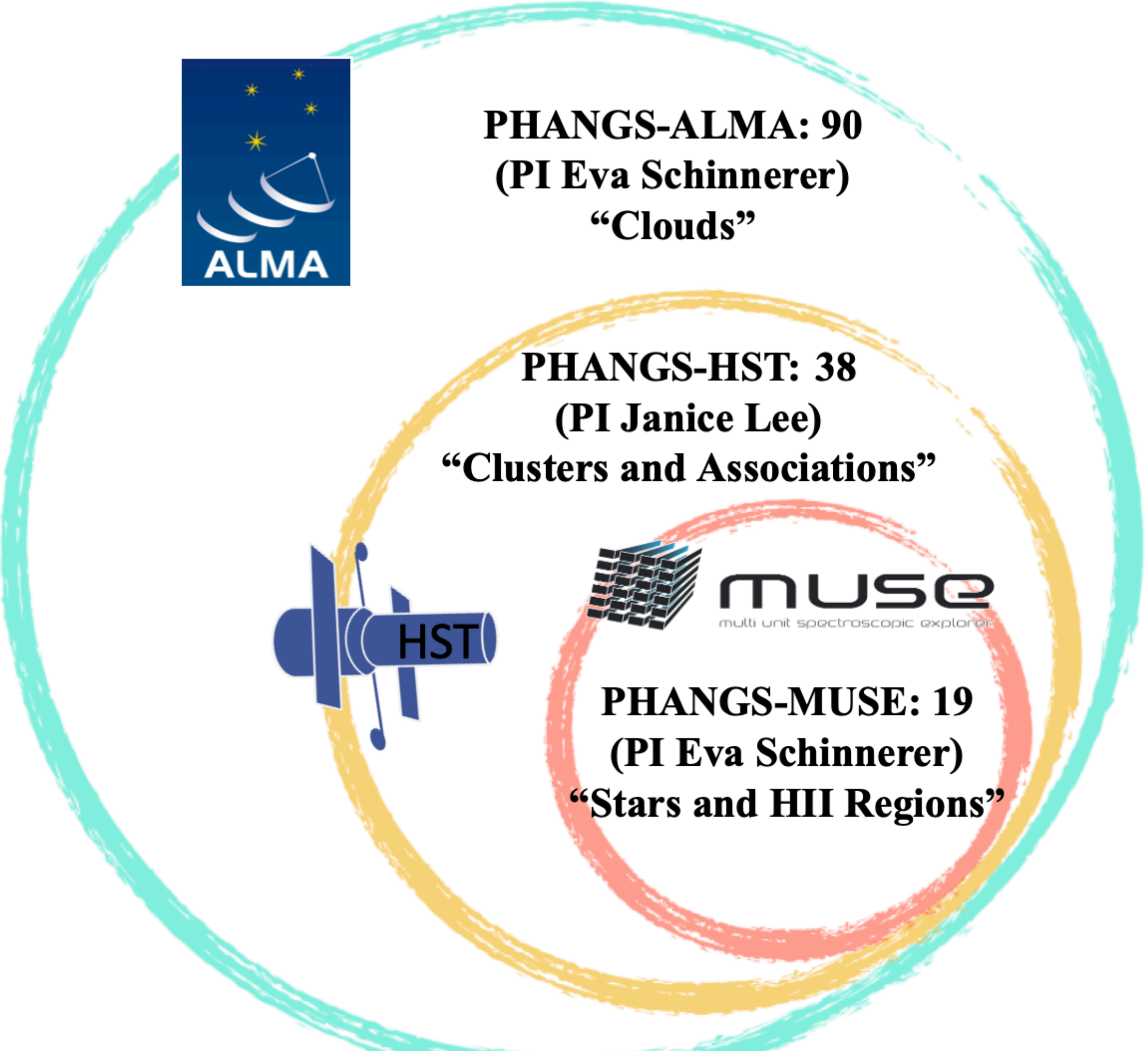

Diagram by F. Santro & K. Kreckel

PHANGS–ALMA: Arcsecond CO(2–1) Imaging of Nearby Star-Forming Galaxies

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PHANGS-ALMA

- Опубликованы данные в CO(2-1) для 90 галактик со звездообразованием
- 12<D<17Mpc (на самом деле < 22 Mpc)
- Угол наклона i<75^o
- $M_* > 10^{9.75} M_{sun}$

- 1-2 часа экспозиции на объект (для сравнения: в PAWS потребовалось 130 часов для M51)
- Разрешение – 1’’ (~100pc), поле зрения – 2’x2’
- Спектральное разрешение – 2.5 км/с
- Чувствительность по массе: $M_{cloud} > 10^5\ M_{sun}$

Основные задачи:
- **Свойства GMC vs свойства окружения**
- **Эффективность звездообразования**
- **Численных характеристик фидбэка и разных фаз ЗО**
- **Балланс давления и определение шкалы, где начинается саморегуляция МЗС**
- **Локальная кинематика холодного газа в МЗС**

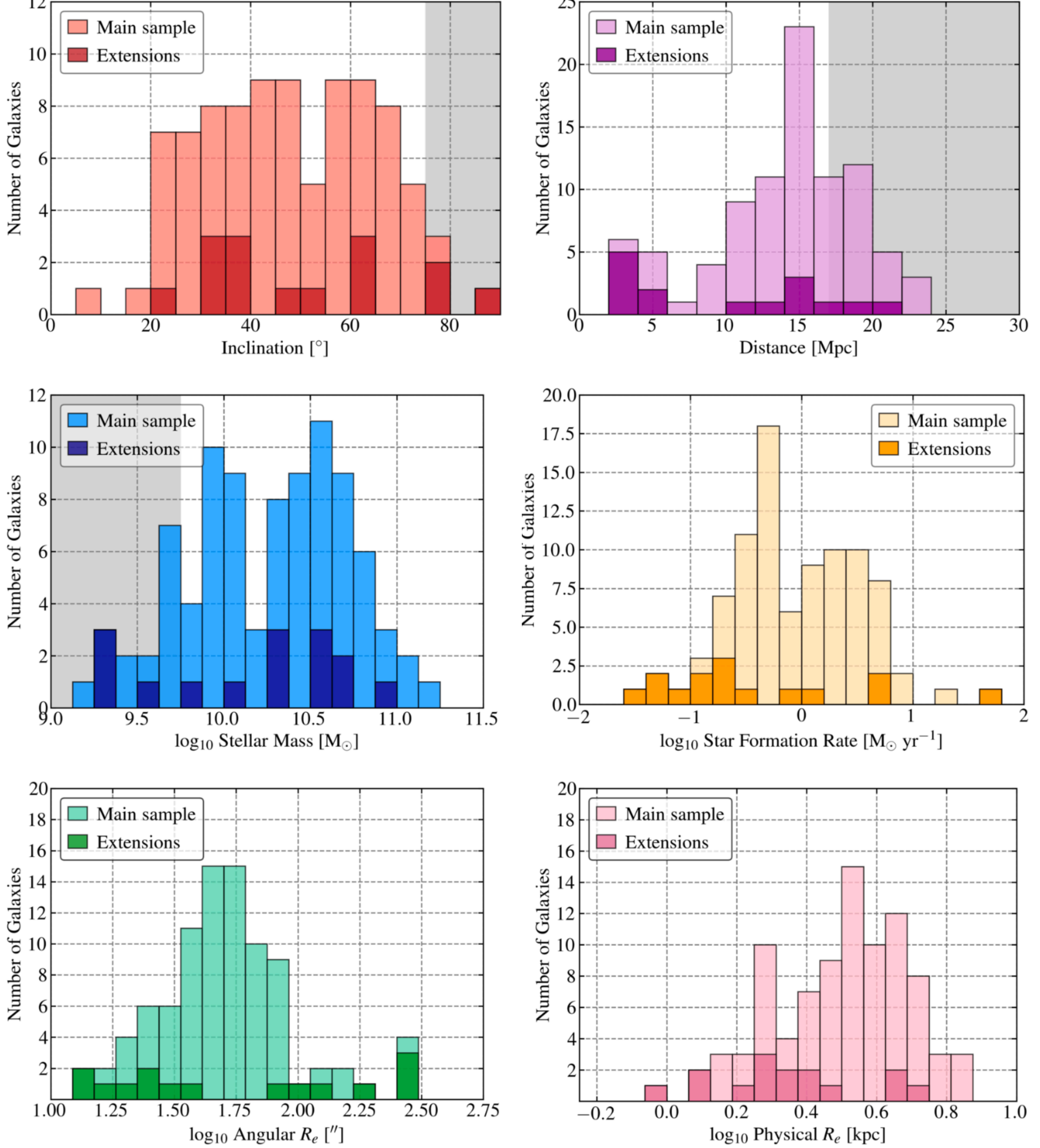
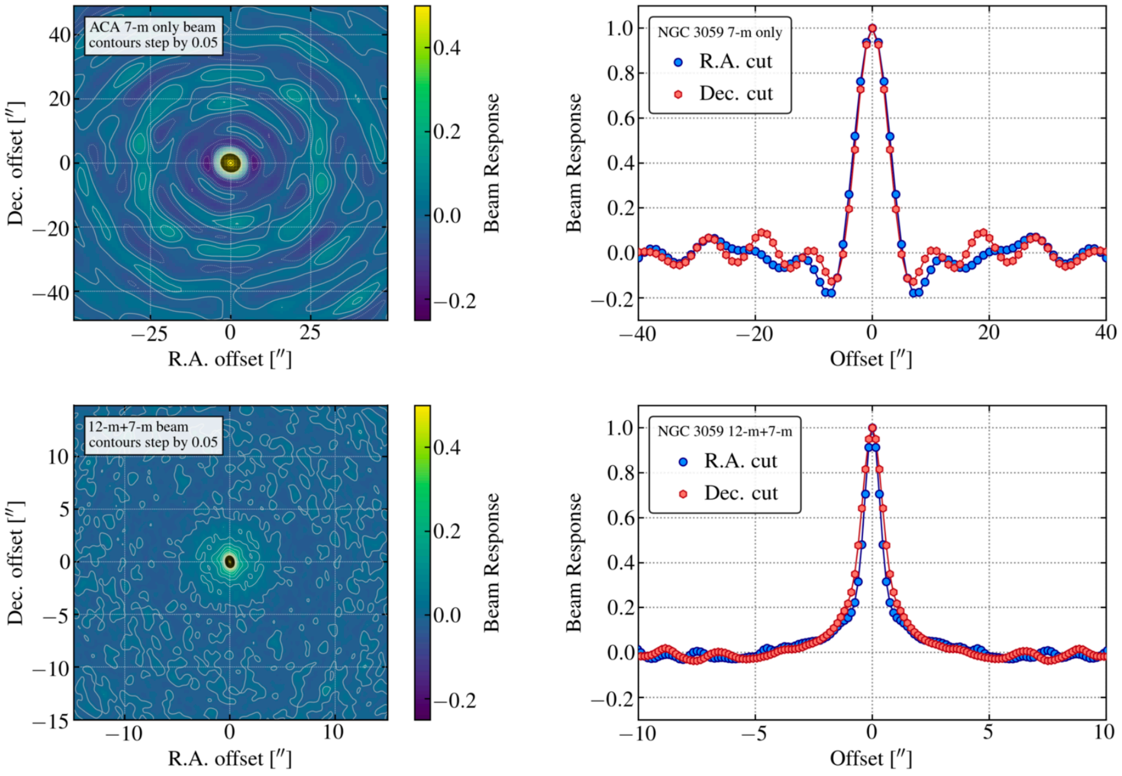
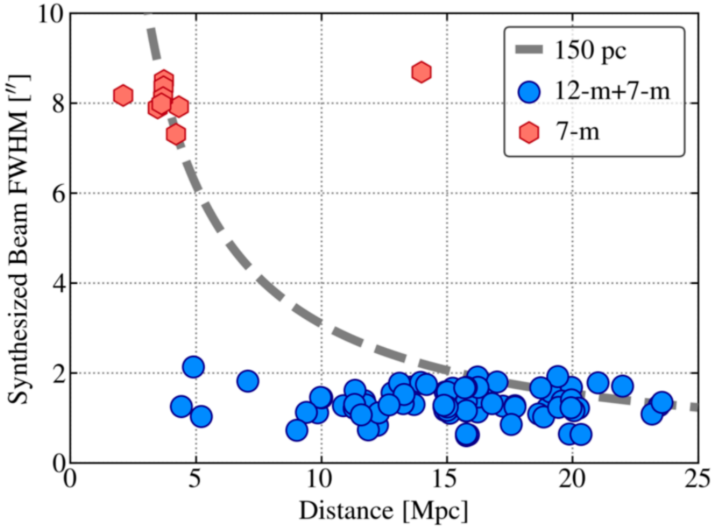
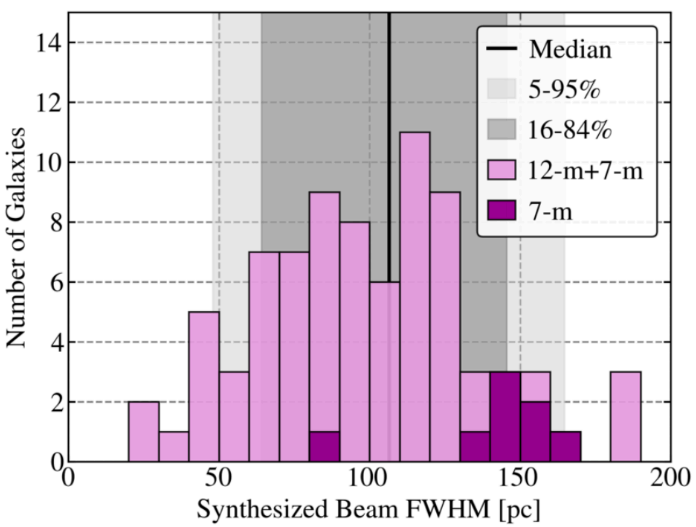


Table 16. PHANGS-ALMA Cube Properties

Galaxy	Arrays	Resolution		Area Mapped		Noise			Completeness		Notes
		Angular	Physical	Angular	Physical	Natve	150 pc	Natve	Native	150 pc	
		($''$)	(pc)	(arcmin^2)	(kpc^2)	(mK)	(mK)	$\left(\frac{\mathrm{mJy}}{\mathrm{beam}^{-1}}\right)$	(%)	(%)	
NGC 0247	7m+TP	8.51	153.1	80.7	93.9	23	23	73.9	7.2	7.2	
NGC 0253	7m+TP	8.37	150.2	98.7	114.4	36	36	108.2	85.8	85.8	
NGC 0300	7m+TP	8.18	82.8	57.0	21.1	35	13	100.4	36.7	51.3	
NGC 0628	12m+7m+TP	1.12	53.5	14.7	120.7	115	41	6.3	44.7	64.5	
NGC 0685	12m+7m+TP	1.69	163.0	4.8	162.4	40	40	4.8	36.5	36.5	
NGC 1068	7m+TP	8.69	588.6	6.5	106.6	18	...	58.9	96.6	...	
NGC 1097	12m+7m+TP	1.70	111.7	13.4	208.7	52	37	6.4	79.9	82.7	
NGC 1087	12m+7m+TP	1.60	123.1	6.8	145.4	66	52	7.3	64.7	67.5	
NGC 1313	7m	7.93	166.0	55.7	88.0	28	28	75.0	11.6	11.6	







- Данные пока здесь: https://www.canfar.net/storage/list/phangs/RELEASES/PHANGS-ALMA/

(Кубы и карты с разным разрешением)

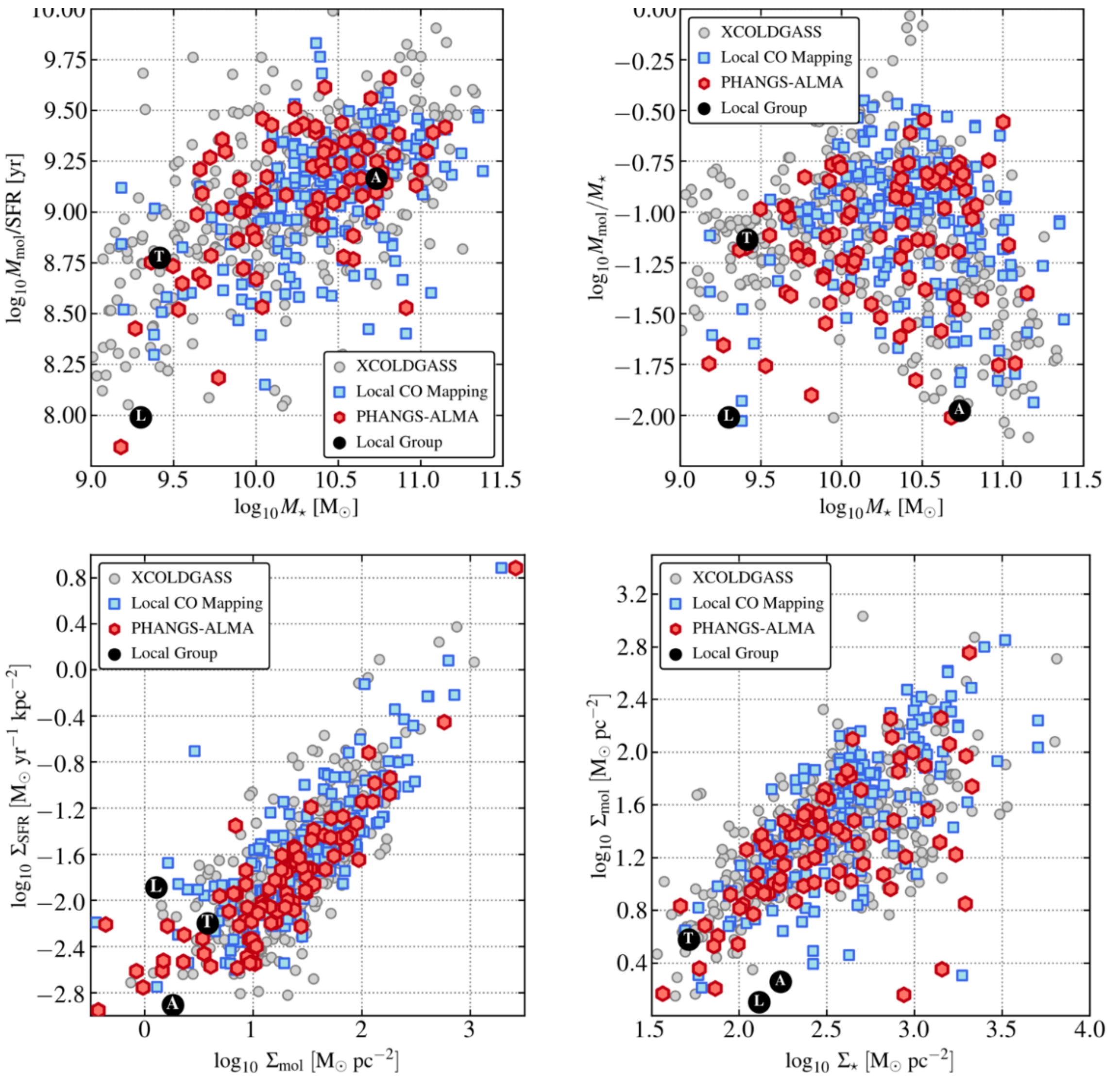
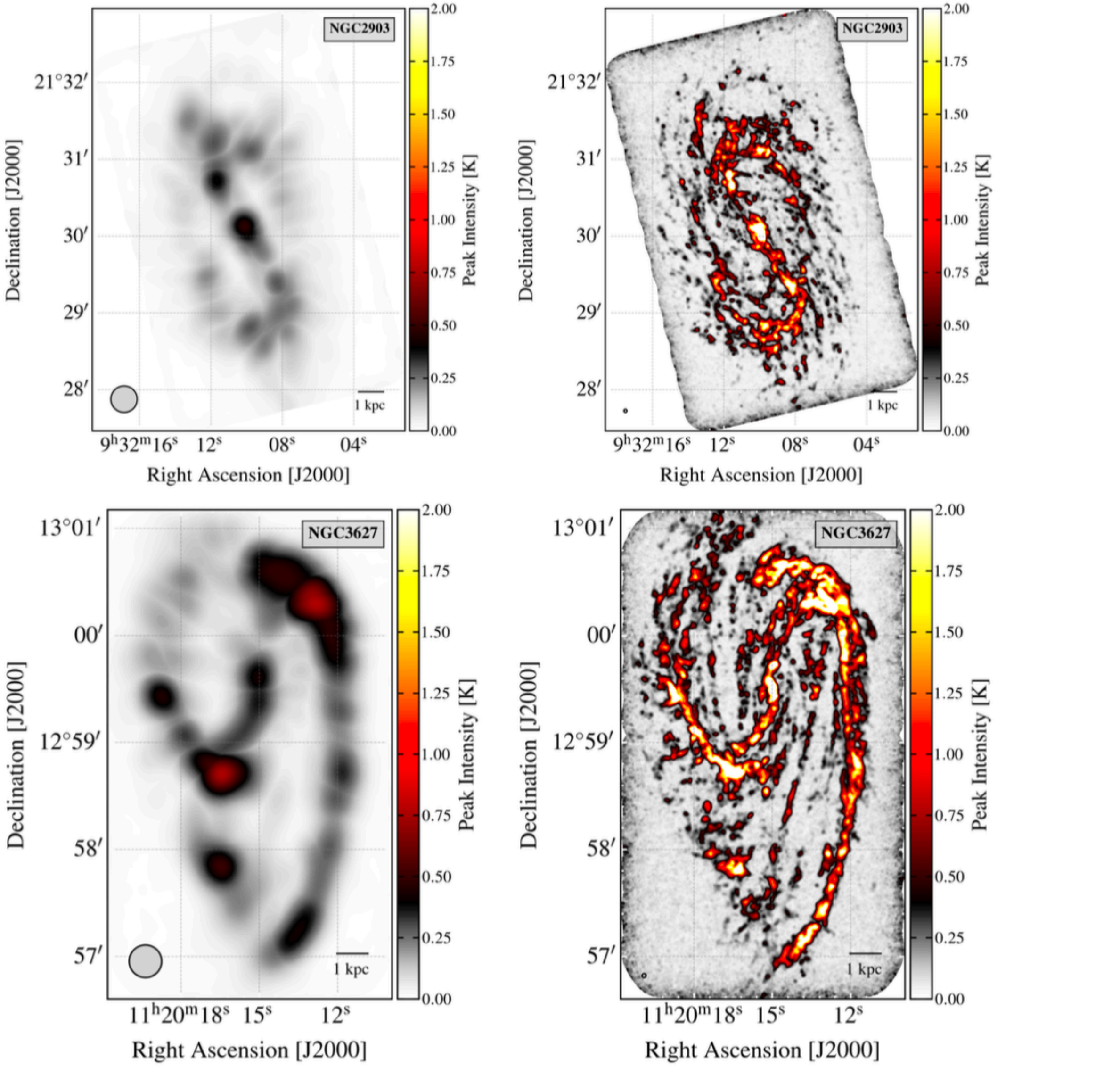
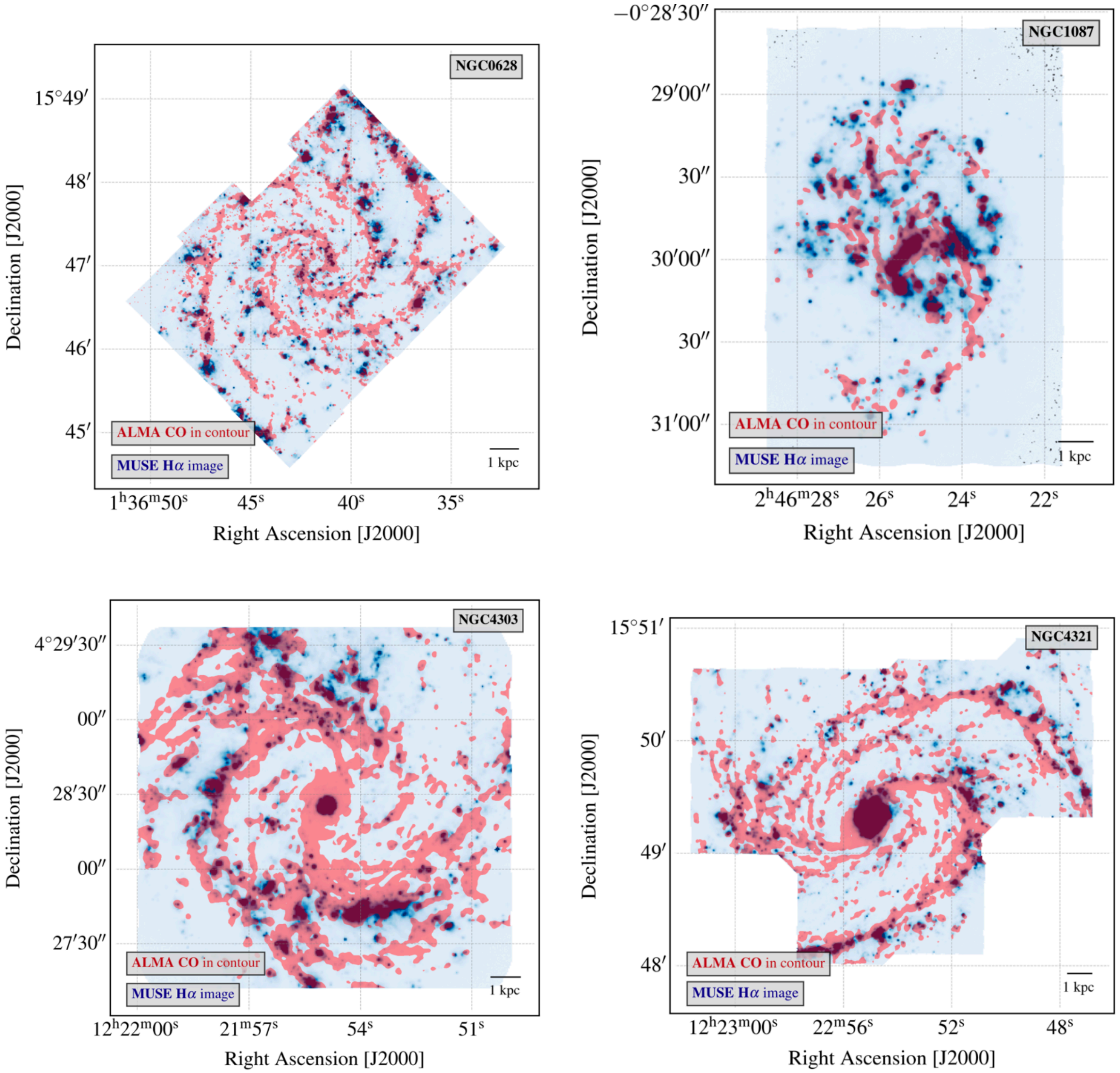


Figure 1. Global trends in the molecular gas content of galaxies relative to their stellar mass and star formation rates. PHANGS–ALMA aims to link these global trends to local properties and local physics in the molecular gas. Each point in each panel shows an individual galaxy from PHANGS–ALMA (red), xCOLD GASS (gray; Saintonge

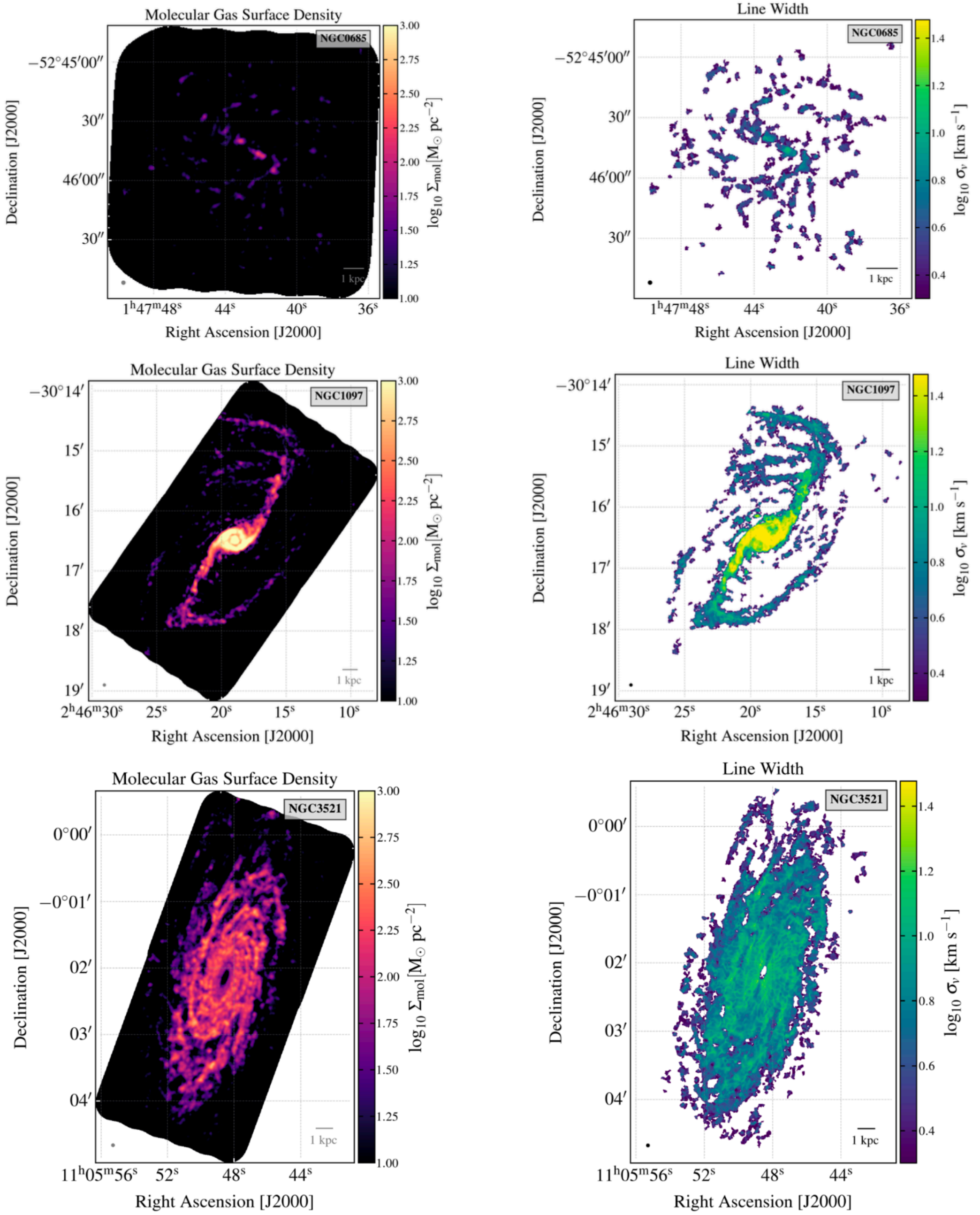


igure 2. CO emission at the kiloparsec resolution of previous surveys and the "cloud scale" resolution of 'HANGS–ALMA. The *left* panels shows CO(2–1) emission measured by PHANGS–ALMA for NGC 2903 and NGC 3627 onvolved to 1 kpc resolution, roughly corresponding to the resolution of previous large CO mapping surveys. The *right* panels show the CO(2–1) emission from the same galaxies at the typical 120 pc resolution of PHANGS–ALMA. Circles show the beam in each panel, and each map shows the maximum intensity of emission along a line of sight at 12.5 km s^{-1} velocity resolution. The high resolution view shows clumpy structures corresponding to individual massive molecular clouds. The high resolution images also show a strong influence of dynamical features; both galaxies have strong stellar bars and spiral arms.

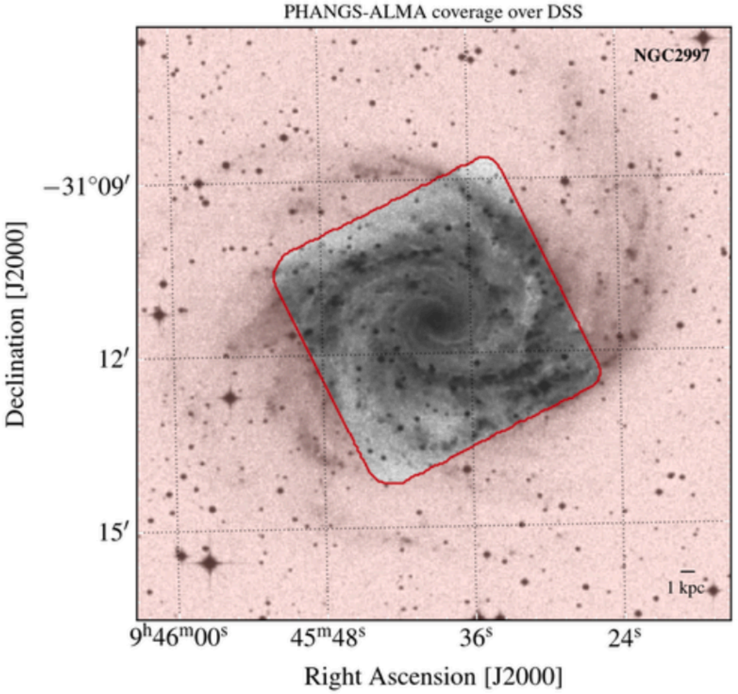


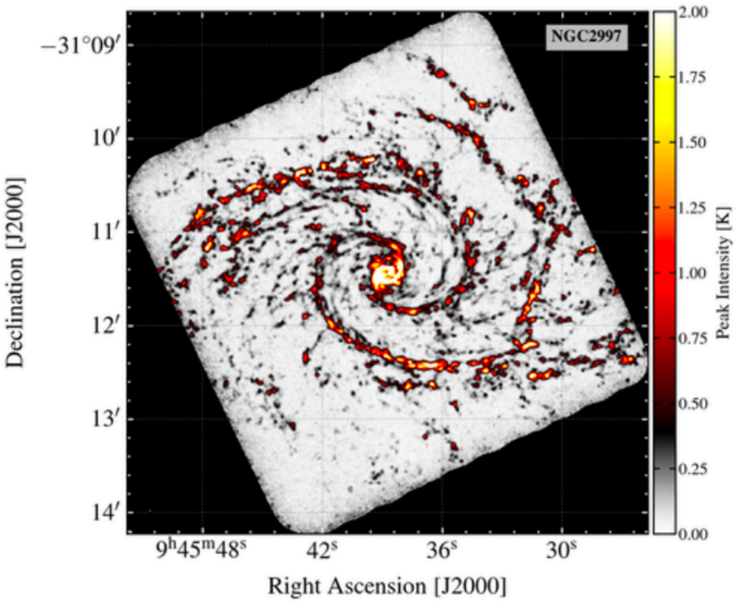
См. Chevance+(2020)

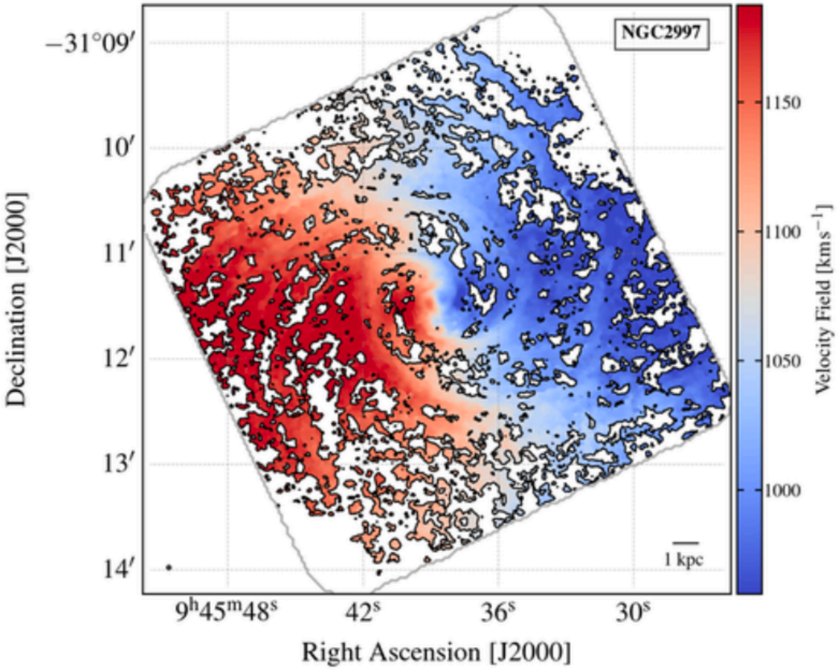
Figure 3. At high spatial resolution, tracers of massive young stars, here Hα, and cold star-forming gas, here CO, visibly separate, providing statistical constraints on timescales for star formation and feedback. Each

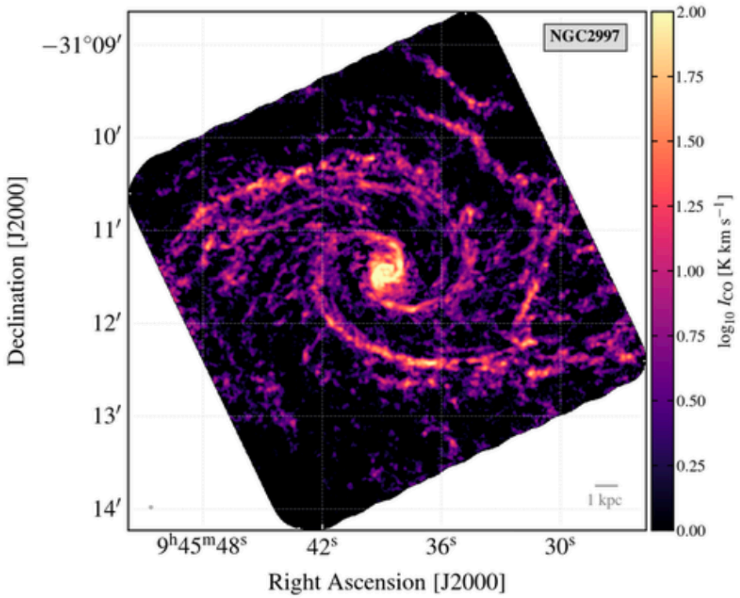


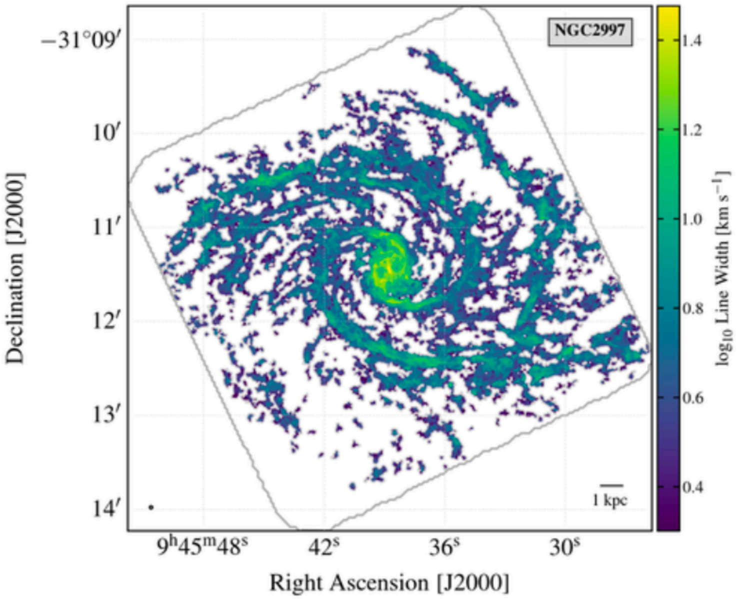
4. Cloud scale molecular gas properties depend on host galaxy and location in the galaxy. PH











NGC2997

Array: 12-m+7-m+TP

Morphology: SABc

SFR: 4.37 ± 1.13 $M_\odot$ yr^{-1}

$\log_{10}$ $\mathbf{M_\star}$ $[\mathbf{M_\odot}]$: 10.7 ± 0.1

Distance: 14.06 ± 0.08 Mpc

The PHANGS-HST Survey:
Physics at High Angular resolution in Nearby GalaxieS with the Hubble Space Telescope

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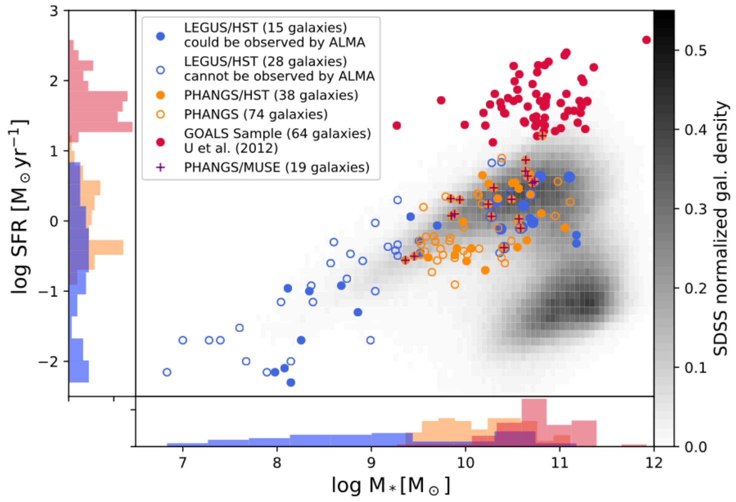
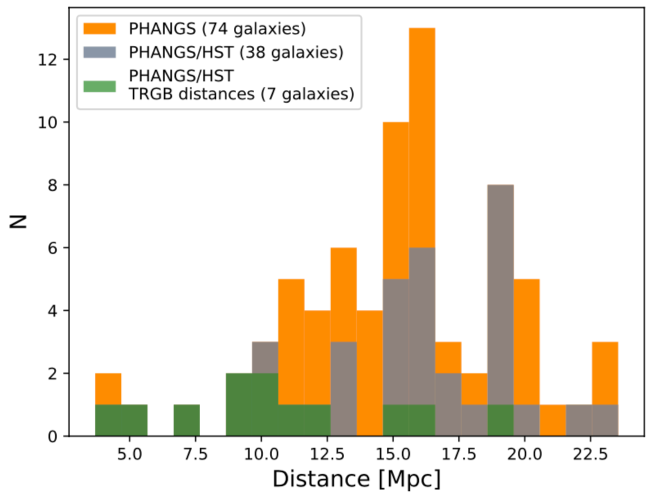
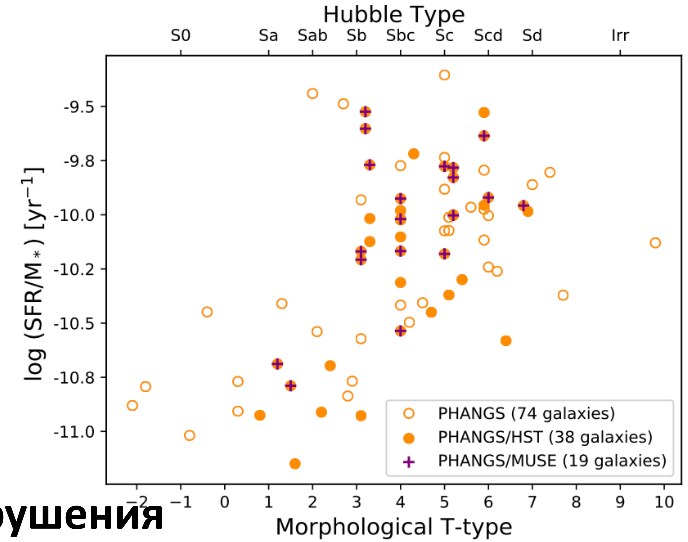
PHANGS-HST

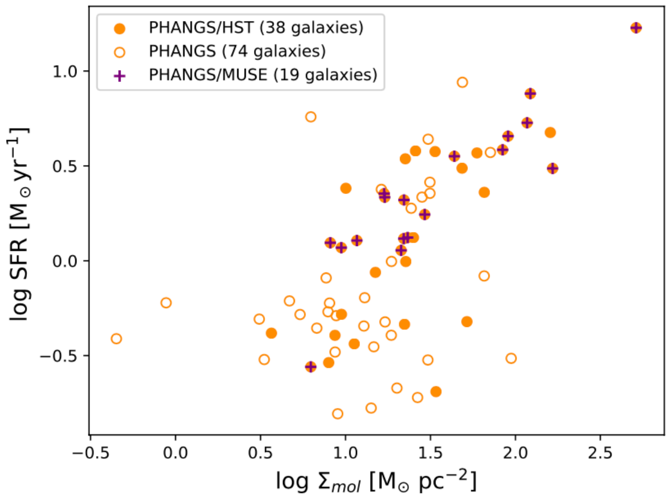
- 38 галактик, изображения в NUV-U-B-V-I
- ~100 000 скоплений/ассоциаций
- 122 орбиты в период с апреля 2019 – август 2020
- Данные тут

https://archive.stsci.edu/hlsp/phangs-hst









Основные задачи:

- **Характерные времена для «включения» ЗО, выметания газа из молодых скоплений, разрушения облаков**
- **Функция масс скоплений/ассоциаций vs функция масс молекулярных облаков**
- **Распределение ЗО и газа на разных масштабах, как оно меняется со временем**

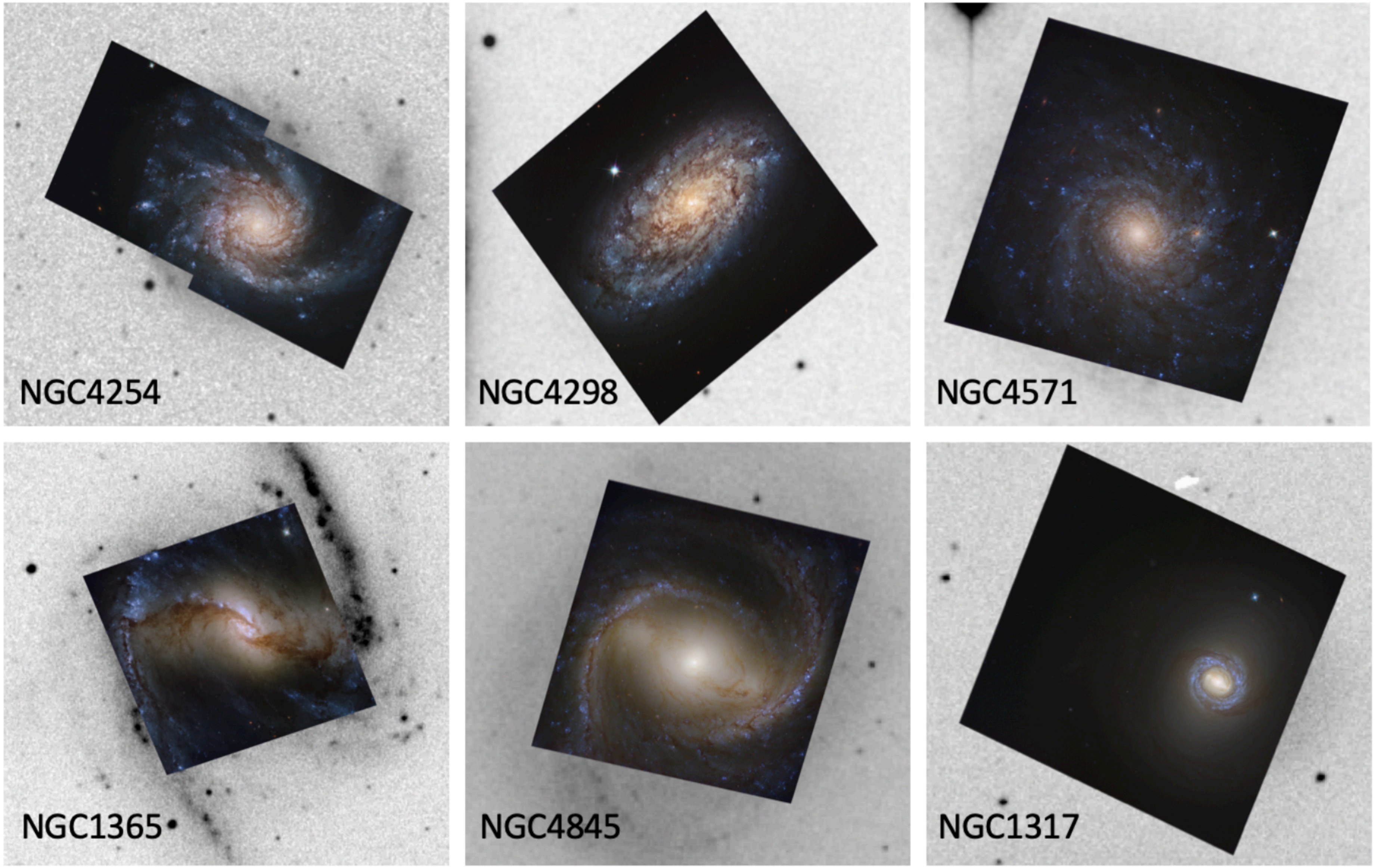


Figure 4. Color composites of PHANGS-HST imaging (Red: WFC3/UVIS F814W, Green: WFC3/UVIS F555W, Blue: WFC3/UVIS F438W+F336W+F275W), overlaid on DSS imaging for the same 6 galaxies as in Figures 2 and 3.

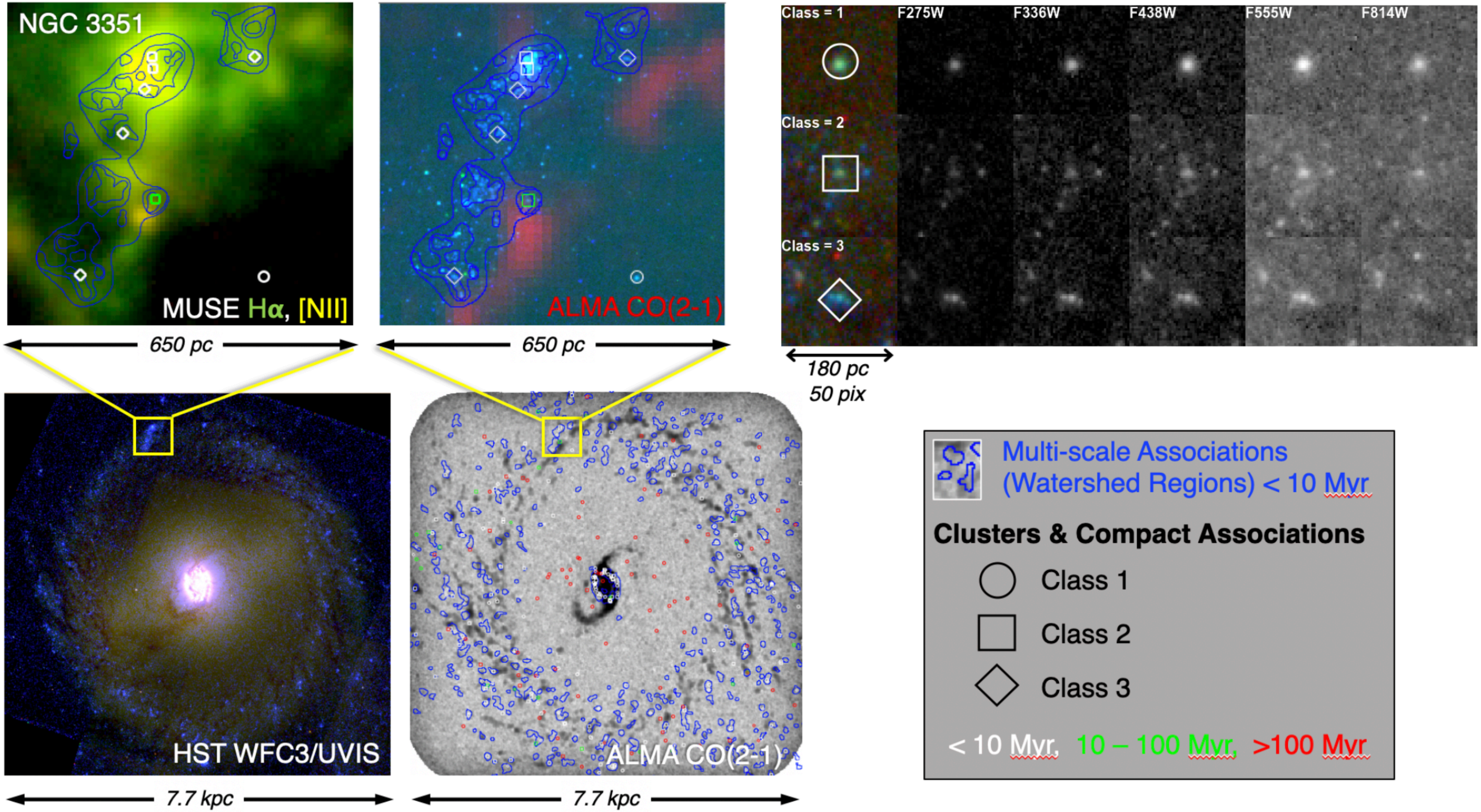


Figure 9. Structures across the physical scales of the star formation hierarchy in NGC 3351, identified by the PHANGS-HST pipeline, from single-peaked compact star clusters, the densest structures, to larger scale multi-peaked stellar associations.

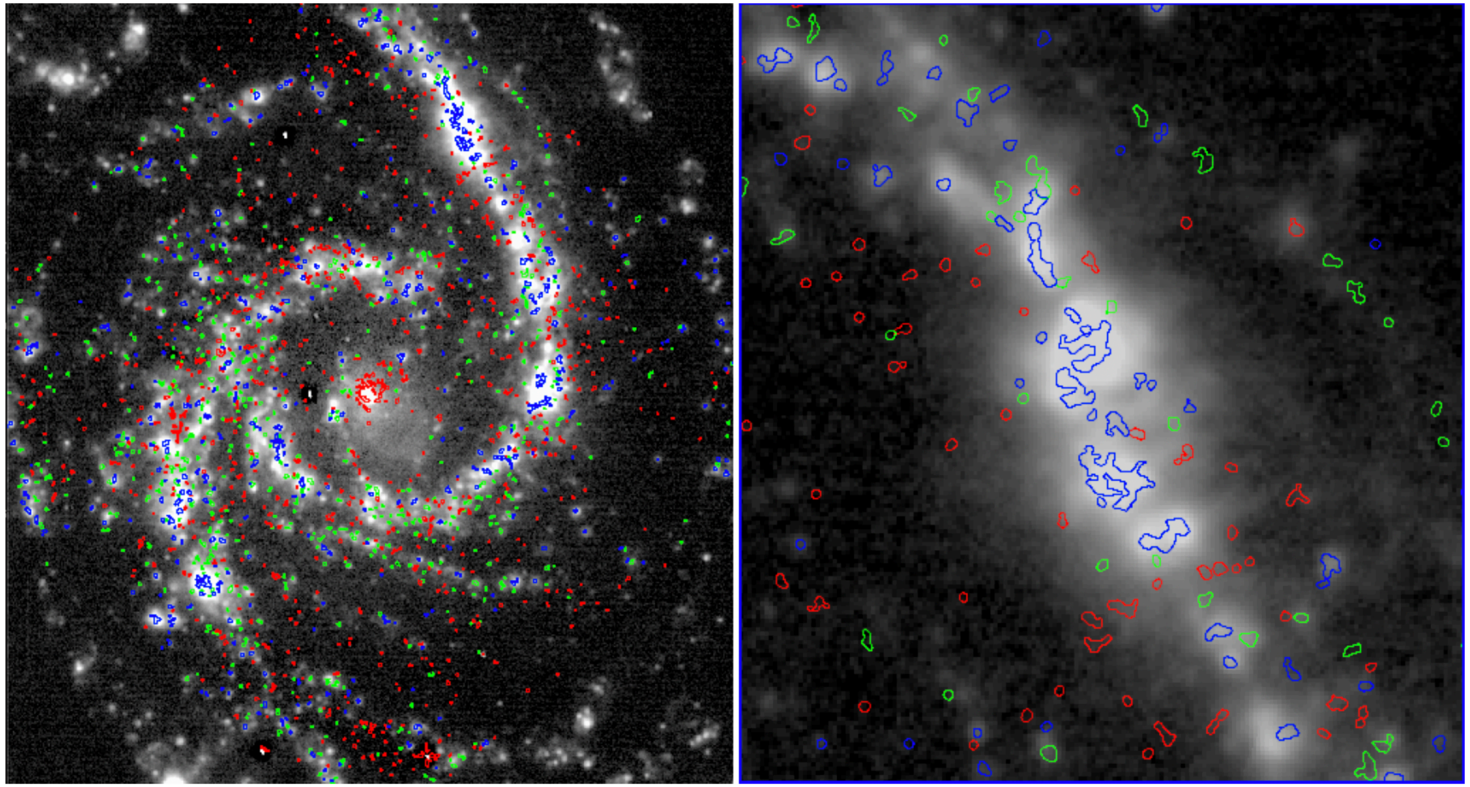


Figure 11. Stellar associations overlaid on PHANGS ground-based Hα narrow band imaging for NGC 1566 (A. Razza et al. in preparation), color-coded by SED-fit age (1−3 Myr: blue, 3−5 Myr: green, >60 Myr red). Stellar associations have been identified from a V-band map of point source positions smoothed with a 32 pc FWHM gaussian kernel, and SED fitting perfomed with CIGALE assuming a single-aged stellar population. The right panel shows a expanded view of the northern spiral arm.

PHANGS-MUSE

Готовится к печати…
В arxiv ожидается к 20-м числам июня

Probing the chemo-dynamical evolution of disc galaxies

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PHANGS-MUSE

- Мозаики MUSE для 19 галактик (overlap=2”)
- Каждое поле – 43 минуты + 4 минуты на небо
- Суммарно – 172 часа
- PSF ~ 0.8”
- Разрешение 2.5-3 А

- Будут доступны:
    - Кубы (по >10-70 Гб каждый)
    - Карты со всевозможными параметрами (потоки и кинематика в линиях, масса звезд, возраст, металличность и тд. в виде **128-мерного fits-файла**

Основные задачи:

- Шкалирующие соотношения на локальных масштабах
- Фидбэк vs окружение
- Обогащение тяжелыми элементами и перемешивание газа в дисках
- Роль динамики в регулировании ЗО
- Свойства HII областей

Table 1. General properties of the PHANGS-MUSE sample.

Name	Distance[a] Mpc	Log($M_\star$)[b] [$M_\odot$]	Log(SFR)[b] [$M_\odot$ yr^{-1}]	$\Delta_{\rm SFMS}$[b] dex	R_{25}[c] arcmin	PA[d] deg	i[d] deg	pc/″	PSF[e] arcsec	copt PSF[f] arcsec
NGC0628	9.8	10.34	0.24	0.18	4.9	20.7	8.9	47.7	$0.73\pm^{0.11}_{0.13}$	0.92
NGC1087	15.9	9.93	0.12	0.33	1.5	359.1	42.9	76.8	$0.74\pm^{0.10}_{0.12}$	0.92
NGC1300	19.0	10.62	0.07	-0.18	3.0	278.0	31.8	92.1	$0.63\pm^{0.18}_{0.13}$	0.89
NGC1365	19.6	10.99	1.23	0.72	6.0	201.1	55.4	94.9	$0.82\pm^{0.26}_{0.24}$	1.15
NGC1385	17.2	9.98	0.32	0.50	1.7	181.3	44.0	83.5	$0.49\pm^{0.10}_{0.11}$	0.67
NGC1433	18.6	10.87	0.05	-0.36	3.1	199.7	28.6	90.3	$0.65\pm^{0.18}_{0.14}$	0.91
NGC1512	18.8	10.71	0.11	-0.21	4.2	261.9	42.5	91.3	$0.80\pm^{0.38}_{0.16}$	1.25
NGC1566	17.7	10.78	0.66	0.29	3.6	214.7	29.5	85.8	$0.64\pm^{0.09}_{0.10}$	0.80
NGC1672	19.4	10.73	0.88	0.56	3.1	134.3	42.6	94.1	$0.72\pm^{0.17}_{0.08}$	0.96
NGC2835	12.2	10.00	0.09	0.26	3.2	1.0	41.3	59.2	$0.85\pm^{0.23}_{0.18}$	1.15
NGC3351	10.0	10.36	0.12	0.05	3.6	193.2	45.1	48.3	$0.74\pm^{0.24}_{0.13}$	1.05
NGC3627	11.3	10.83	0.58	0.19	5.1	173.1	57.3	54.9	$0.77\pm^{0.21}_{0.10}$	1.05
NGC4254	13.1	10.42	0.49	0.37	2.5	68.1	34.4	63.5	$0.58\pm^{0.23}_{0.14}$	0.89
NGC4303	17.0	10.52	0.73	0.54	3.4	312.4	23.5	82.4	$0.58\pm^{0.12}_{0.07}$	0.78
NGC4321	15.2	10.75	0.55	0.21	3.0	156.2	38.5	73.7	$0.64\pm^{0.45}_{0.18}$	1.16
NGC4535	15.8	10.53	0.33	0.14	4.1	179.7	44.7	76.5	$0.44\pm^{0.03}_{0.01}$	0.56
NGC5068	5.2	9.40	-0.56	0.02	3.7	342.4	35.7	25.2	$0.73\pm^{0.23}_{0.21}$	1.04
NGC7496	18.7	10.00	0.35	0.53	1.7	193.7	35.9	90.8	$0.79\pm^{0.03}_{0.17}$	0.89
IC5332	9.0	9.67	-0.39	0.01	3.0	74.4	26.9	43.7	$0.72\pm^{0.08}_{0.12}$	0.87

Notes. (a) From the compilation of Anand et al. (2021). (b) Derived by Leroy et al. (2021), using *GALEX* UV and *WISE* IR photometry, following a similar methodology to Leroy et al. (2019). (c) From LEDA. (d) From Lang et al. (2020), based on CO(2–1) kinematics. (e) FWHM of the Moffat PSF across individual pointing (we report the mean and the extreme values). (f) FWHM of the Gaussian PSF of the homogenized (‘copt’) mosaic.

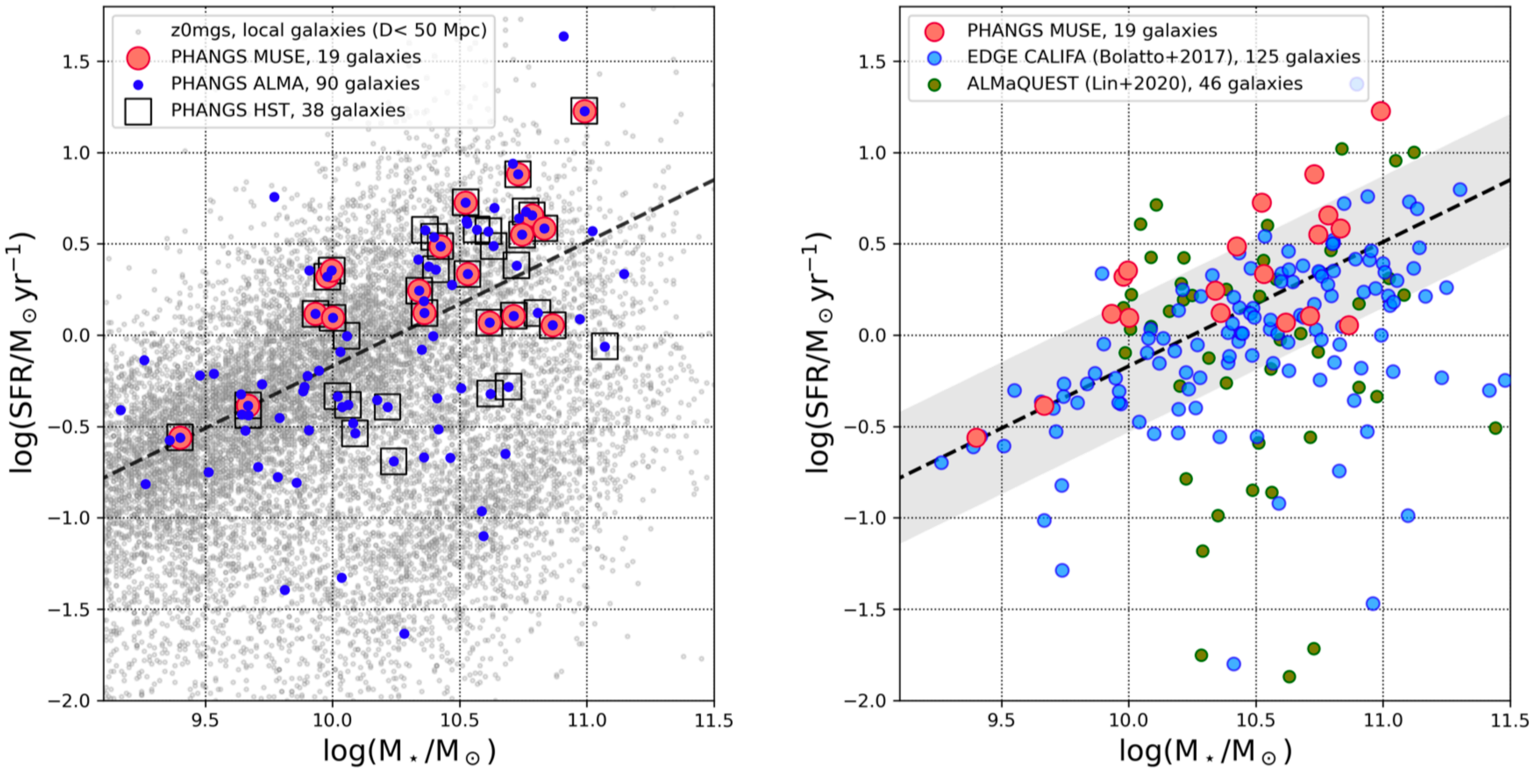


Fig. 2. The PHANGS-MUSE sample in the $M_{\star}$–SFR plane. *Left:* The PHANGS sample compared with the population of local galaxies from z0MGS (Leroy et al. 2019, small gray dots). The large red circles represent the PHANGS-MUSE galaxies. We show the overlap with the ALMA (blue dots) and HST (black empty squares) components of the PHANGS project. The dashed line is the best-fit to the star-formation main sequence from Leroy et al. (2019). *Right:* The PHANGS-MUSE sample compared to two complementary projects, EDGE-CALIFA (Bolatto et al. 2017) and ALMaQUEST (Lin et al. 2020), also targeting local galaxies with optical IFS and CO interferometric mapping. The dashed line is the best-fit to the star-formation main sequence from Leroy et al. (2019) with associated scatter (gray shaded area).

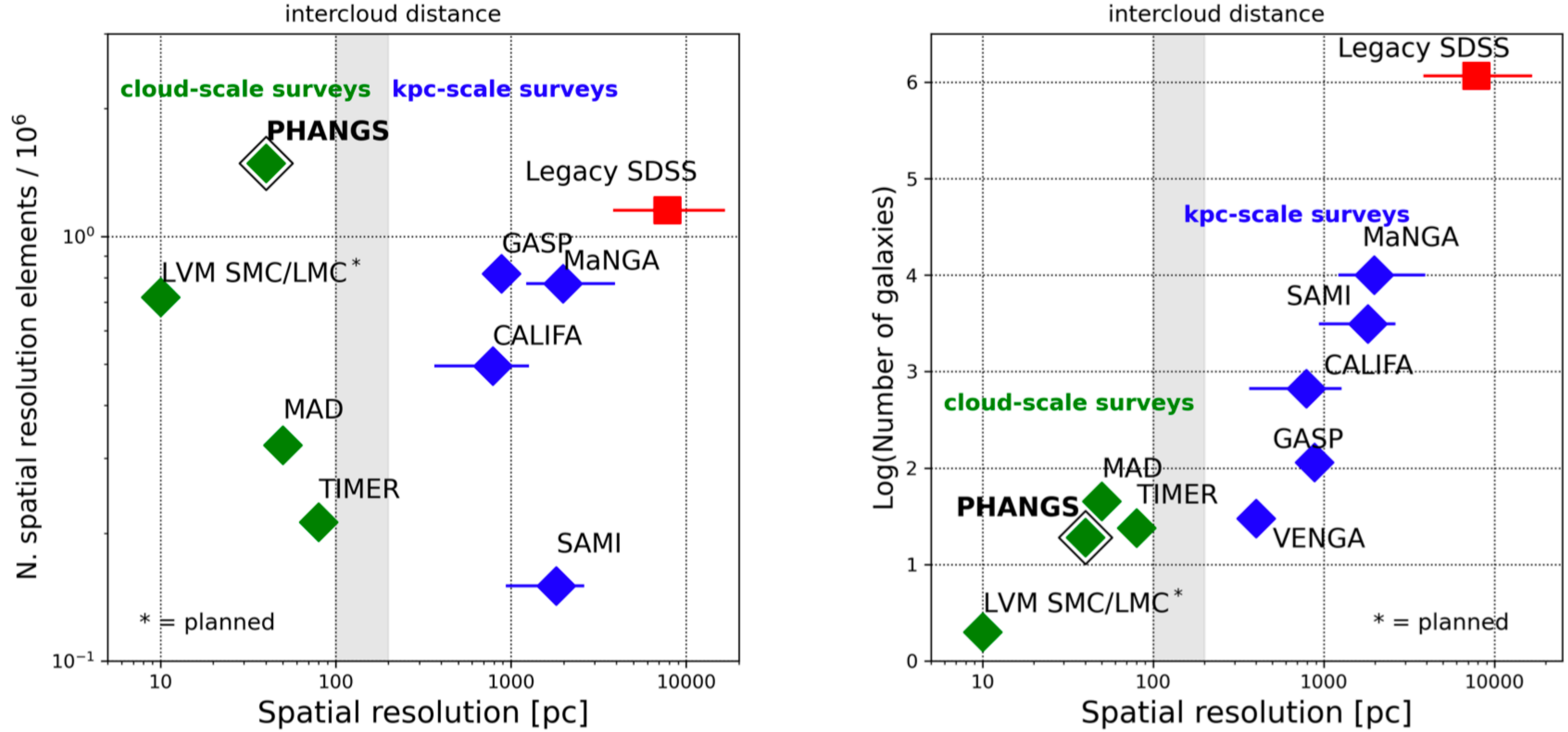
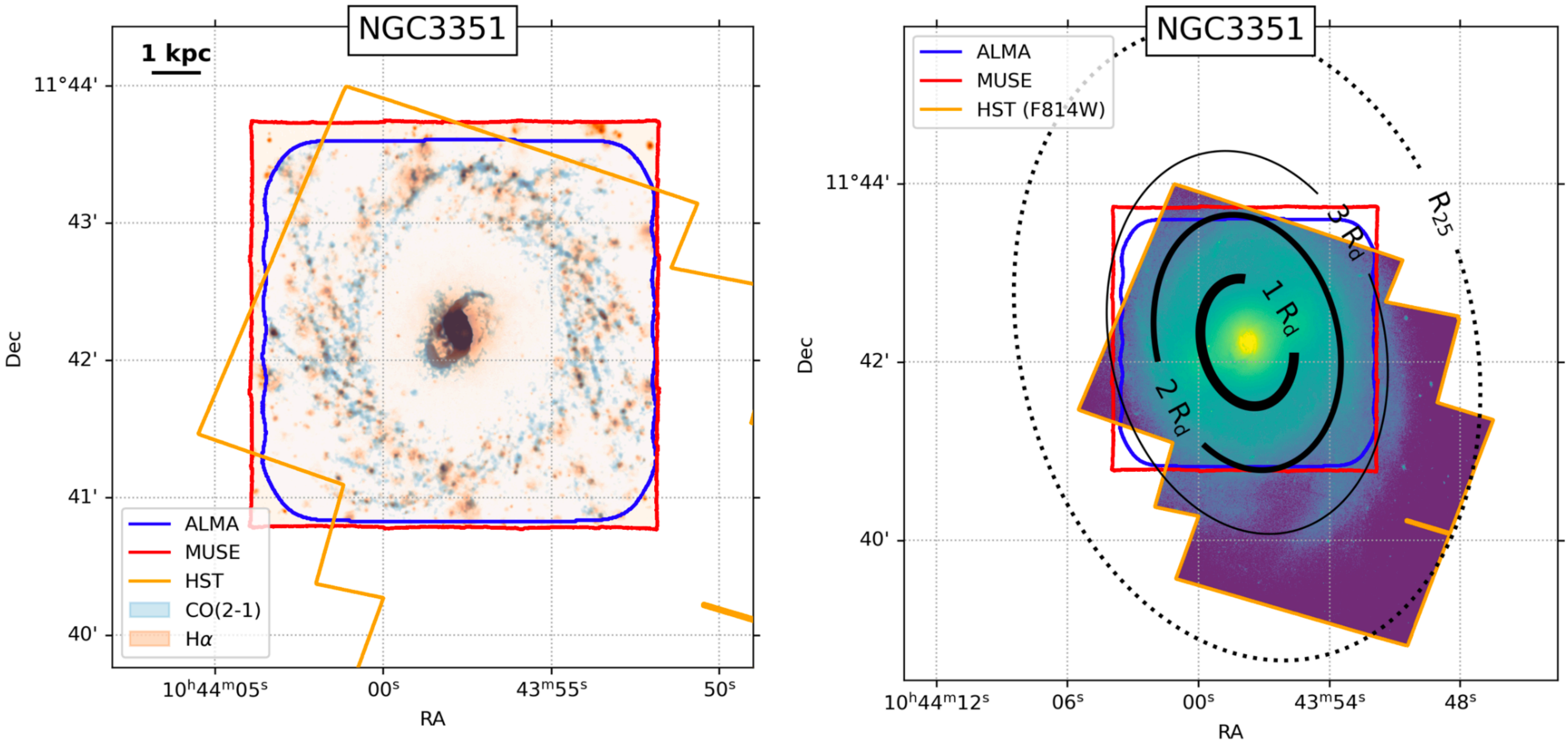
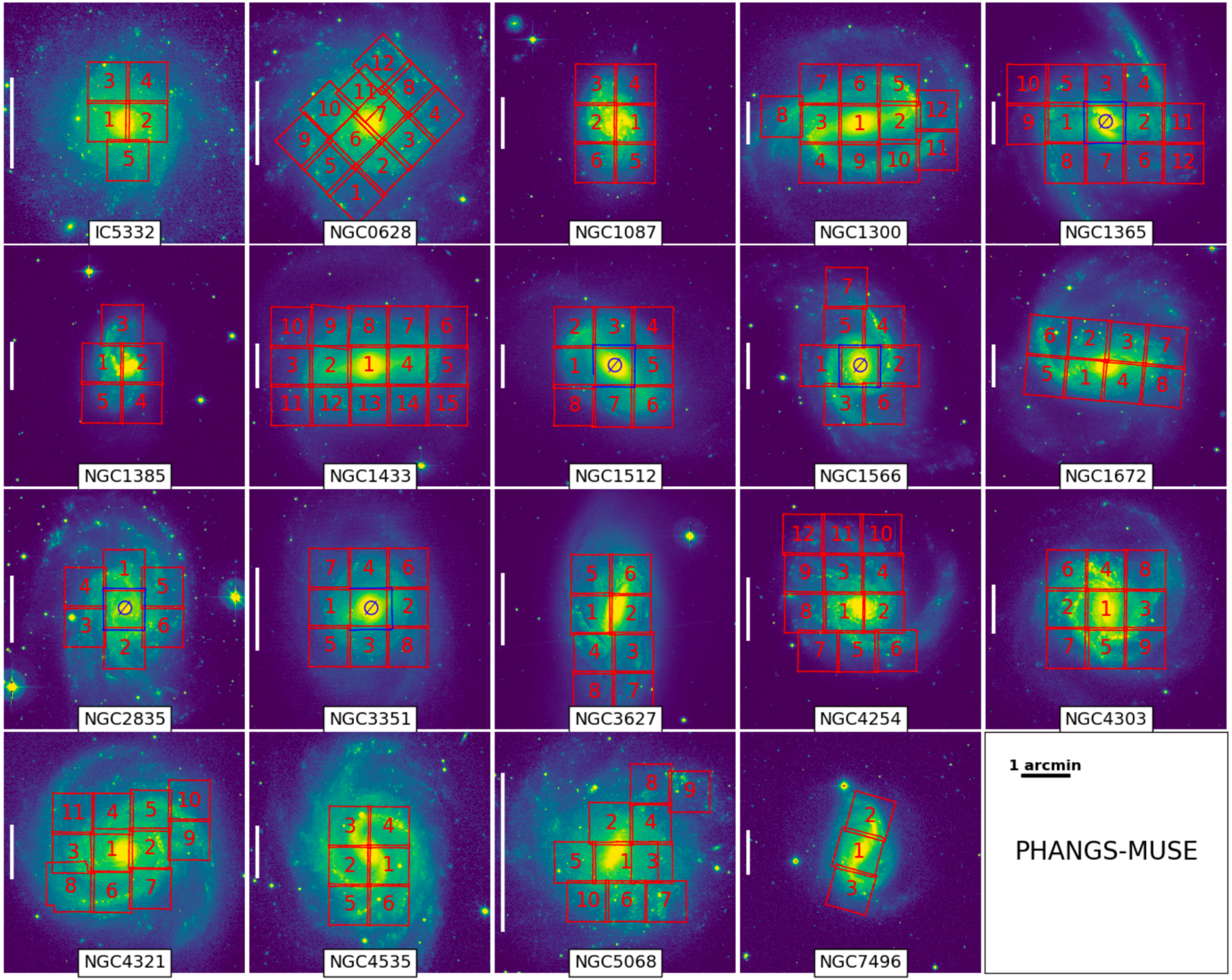
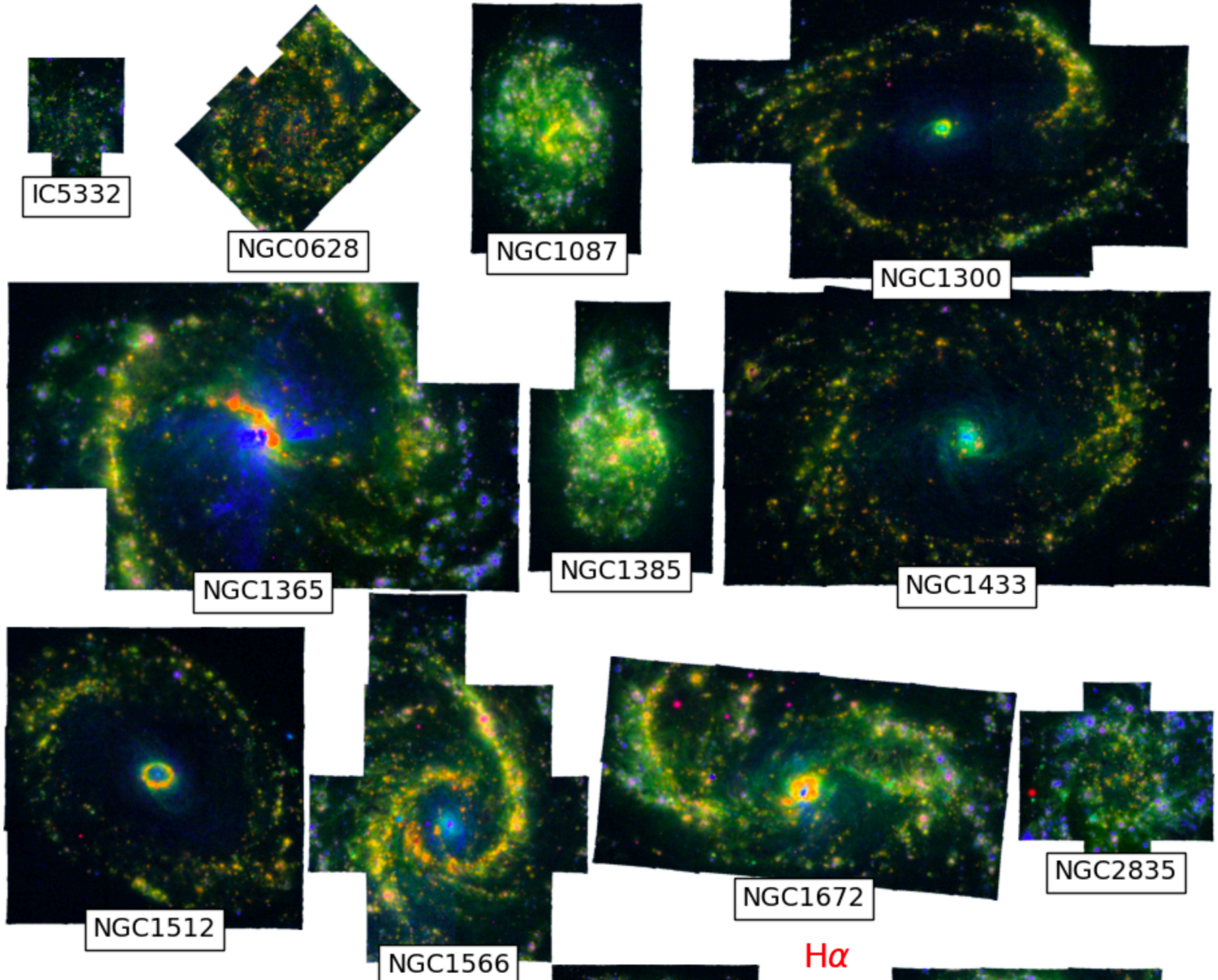


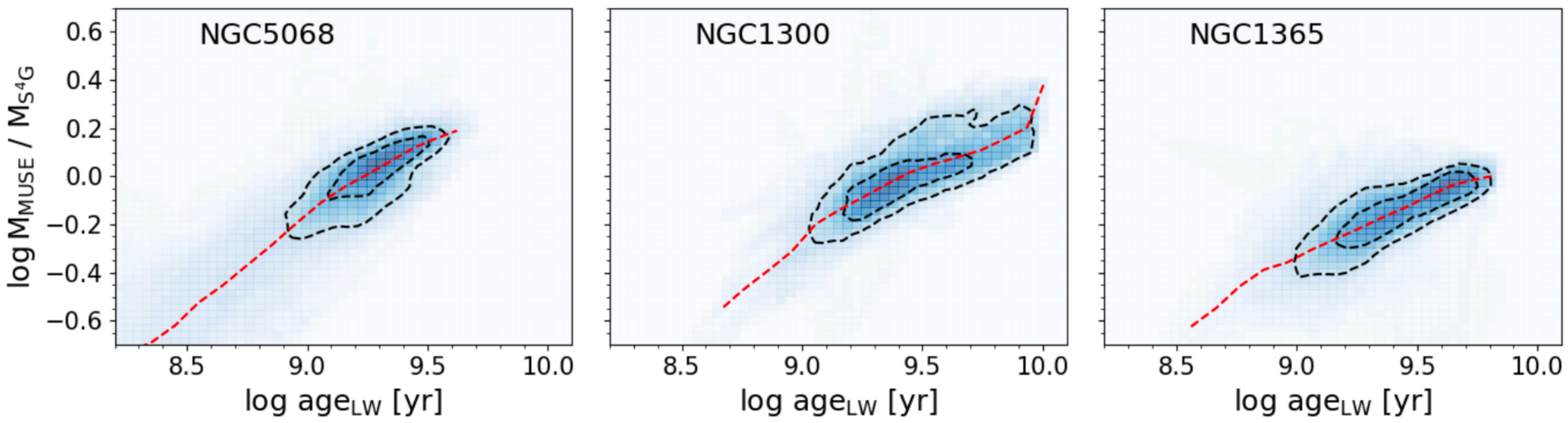
Fig. 3. Overview of large spectroscopic surveys of nearby galaxies. *Left*: Large spectroscopic surveys in the plane defined by their spatial resolution (in physical units) and the number of spatial resolution elements surveyed. IFU surveys are shown with diamond symbols (blue for those covering entire galaxies and green if covering only their central regions). VENGA (Blanc et al. 2013) is not shown because it features fewer than 10^5 resolution elements. For reference, the single fibre SDSS survey (Abazajian et al. 2009, red triangle) is added. PHANGS-MUSE sits in the top-left of this space, ranking highly on both metrics. *Right*: Large spectroscopic surveys in the plane defined by their spatial resolution (in physical units) and the number of galaxies surveyed. PHANGS-MUSE lies on the overall trend-line of other IFU surveys.

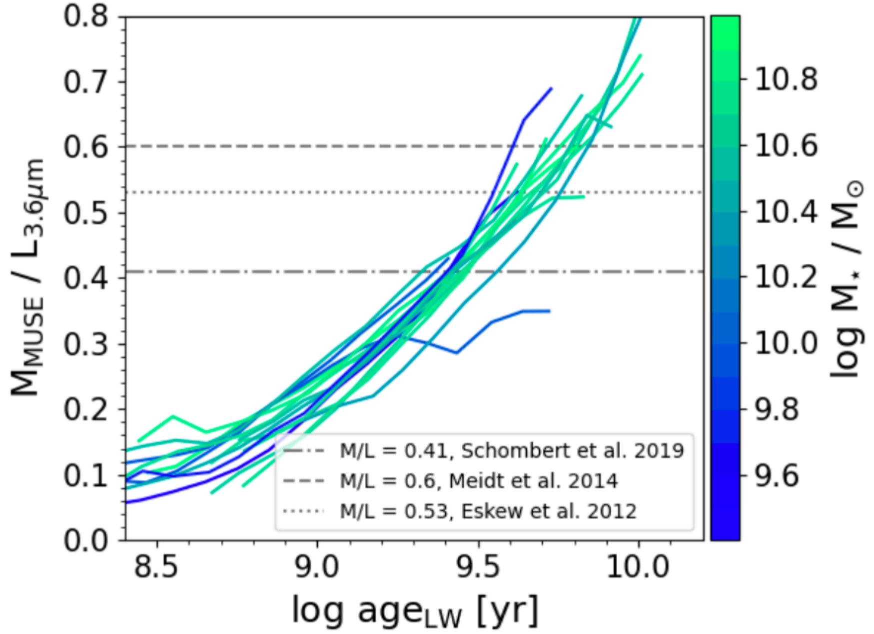


NGC3351
1 kpc
11°44'
43'
42'
41'
40'
Dec
RA
10h44m05s
00s
43m55s
50s
ALMA
MUSE
HST
CO(2-1)
Hα
NGC3351
ALMA
MUSE
HST (F814W)
R25
3 Rd
1 Rd
2 Rd
10h44m12s
06s
00s
43m54s
48s

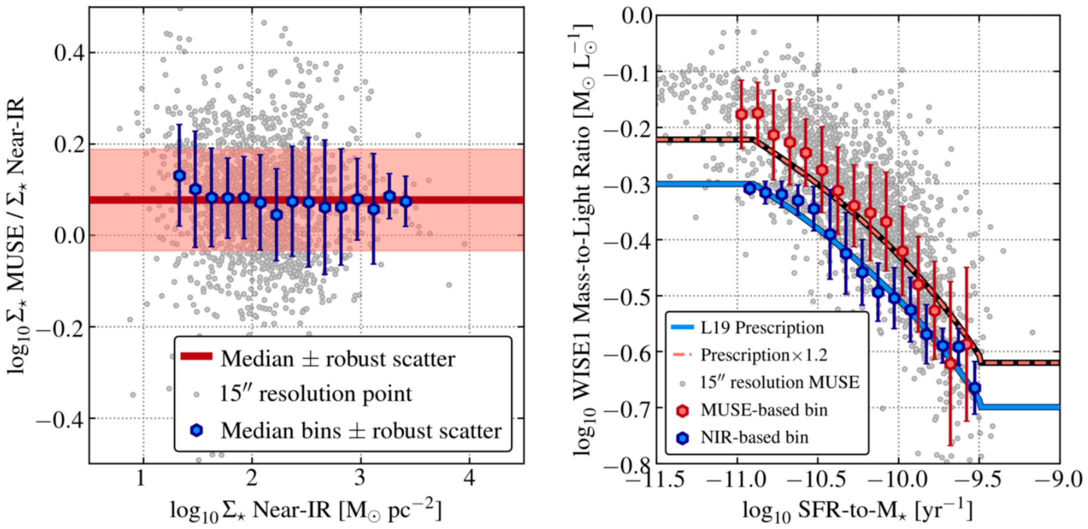

IC5332
NGC0628
NGC1087
NGC1300
NGC1365
NGC1385
NGC1433
NGC1512
NGC1566
NGC1672
NGC2835
NGC3351
NGC3627
NGC4254
NGC4303
NGC4321
NGC4535
NGC5068
NGC7496
1 arcmin
PHANGS-MUSE


IC5332
NGC0628
NGC1087
NGC1300
NGC1365
NGC1385
NGC1433
NGC1512
NGC1566
NGC1672
NGC2835
Hα



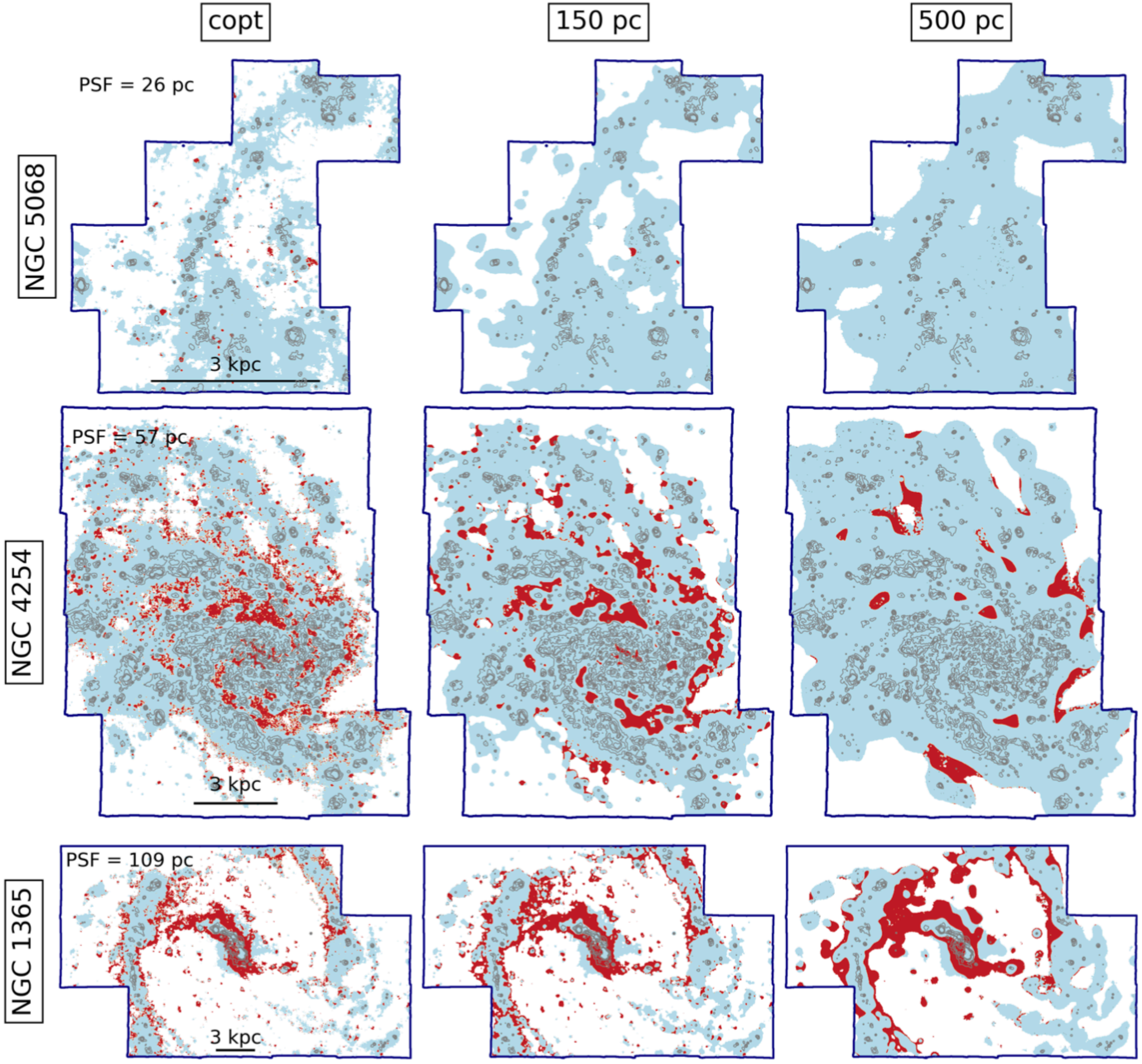


Хорошее согласие массы по данным MUSE и в ИК, но только для среднего возраста >4Gyr.



Отношение M/L, определяемое по данным MUSE, хорошо сходится с оценкам в NIR, но есть оффсет на 0.08 dex – вероятно, проблема SSP моделей

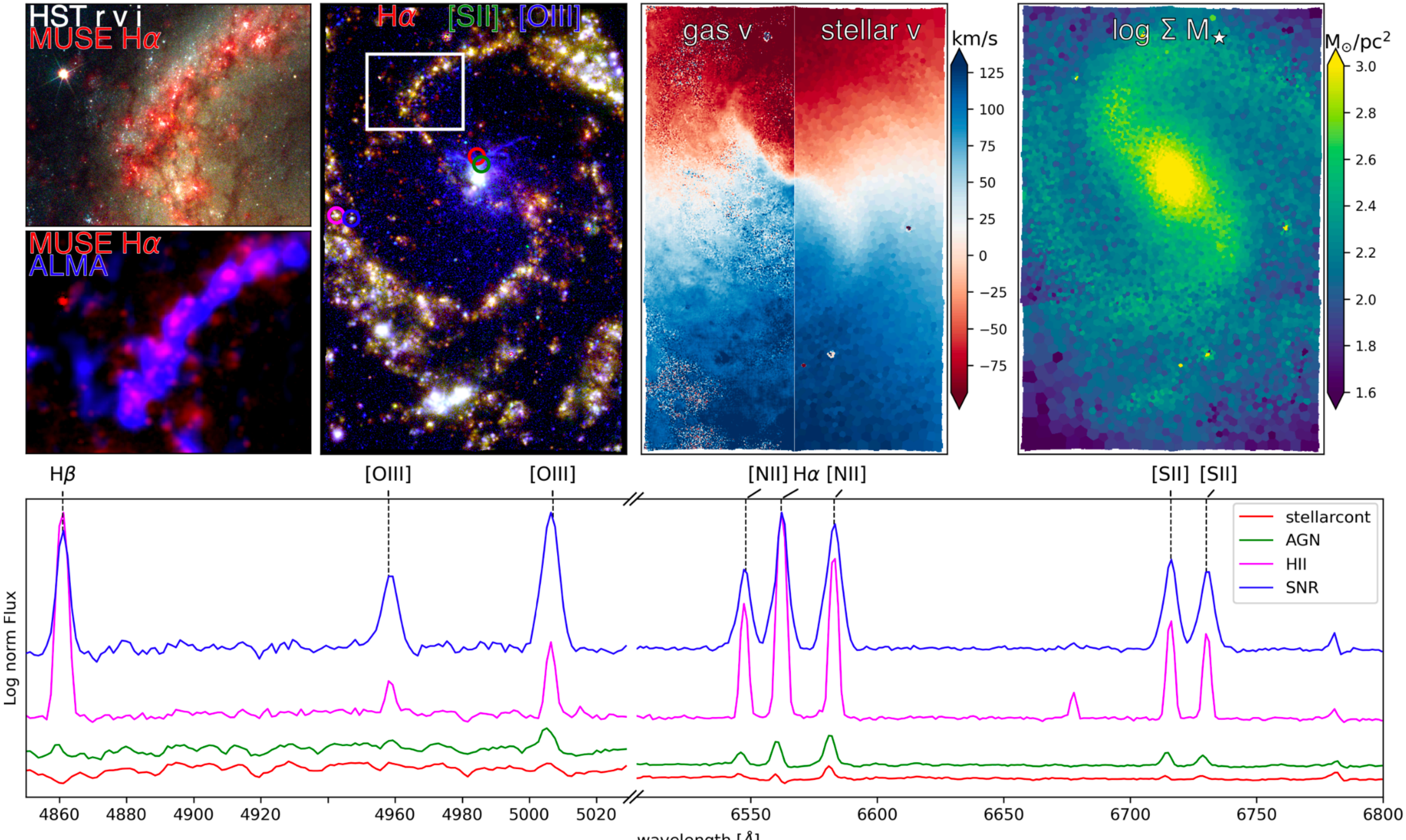
Leroy+ (2021) PHANGS-ALMA



Выше линии Kauffmann+2003

Ниже линии Kauffmann+2003

Недостаточное угловое разрешение ведет к ошибкам в диагностике BPT



HST r v i
MUSE Hα
MUSE Hα
ALMA
Hα [SII] [OIII]
gas v
stellar v
km/s
125
100
75
50
25
0
−25
−50
−75
log Σ M★
M⊙/pc2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
Hβ
[OIII]
[OIII]
[NII] Hα [NII]
[SII] [SII]
stellarcont
AGN
HII
SNR
Log norm Flux
4860
4880
4900
4920
4960
4980
5000
5020
6550
6600
6650
6700
6750
6800