astro-ph seminar 2022.12.14 (大澤)

The Contribution of Evolved Stars to PAH Heating and Implications for Estimating Star Formation Rates

LULU ZHANG[1,2] AND LUIS C. HO[1,2]

ABSTRACT

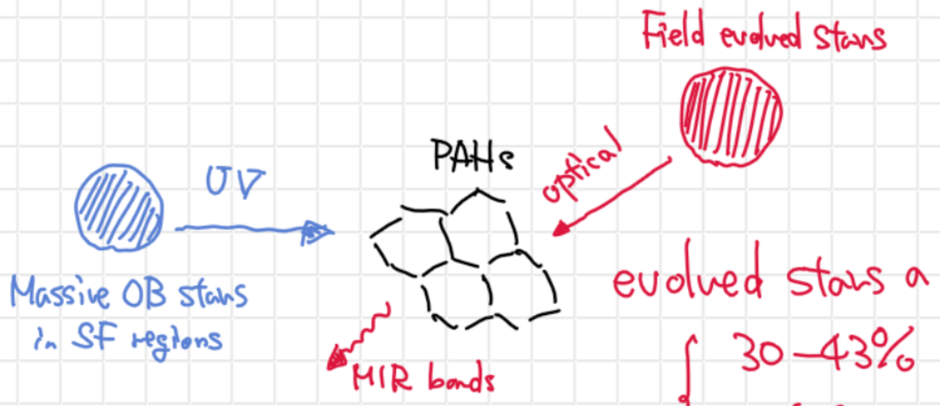
Emission from polycyclic aromatic hydrocarbons (PAHs) is a promising tool for estimating star formation rate (SFR) in galaxies, but the origin of its sources of excitation, which include not only young but possibly also old stars, remains uncertain. We analyze Spitzer mid-infrared mapping-mode spectroscopic observations of the nuclear and extra-nuclear regions of 33 nearby galaxies to study the contribution of evolved stars to PAH emission. In combination with photometric measurements derived from ultraviolet, Hα, and infrared images, the spatially resolved spectral decomposition enables us to characterize the PAH emission, SFR, and stellar mass of the sample galaxies on sub-kpc scales. We demonstrate that the traditional empirical correlation between PAH luminosity and SFR has a secondary dependence on specific SFR, or, equivalently, stellar mass. Ultraviolet-faint regions with lower specific SFRs and hence greater fraction of evolved stars emit stronger PAH emission at fixed SFR than ultraviolet-bright regions. We reformulate the PAH-based SFR estimator by explicitly introducing stellar mass as a second parameter to account for the contribution of evolved stars to PAH excitation. The influence of evolved stars can explain the sub-linear correlation between PAH emission and SFR, and it can partly account for the PAH deficit in dwarf galaxies and low-metallicity environments.

Backgrounds

PAH bands (UIR) = 星間空間の有機分子が UV を吸収 MIR で再放射する現象
ほぼ dust extinction free な SFR indicator として有用

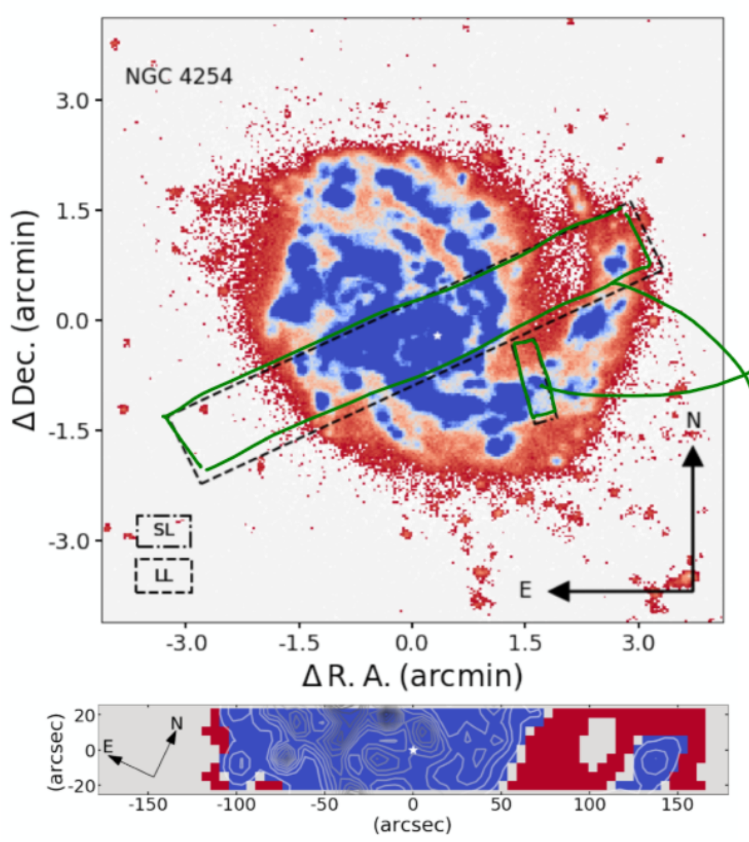
band の励起源は主に massive stars からの UV だが
evolved stars からの寄与も無視できない (Li & Draine, 2002)

PAH 放射と他の SFR indicator (Hα) の
luminosity が 1 対 1 の関係に従わない
(sublinear) ことが知られている
→ hard UV での PAH molecule の破壊??



evolved stars の寄与は
30–43% in NGC628 (Crocker+ 2013)
~67% in M81 (Lu+ 2014)
この割合が変化すると PAH で調べた銀河の SFR を比較できない
⇒ revisit a L_{PAH} to SFR conversion function!!

SINGS (Spitzer) の分光, multiband imaging のデータを使用 (UV → MIR)
75 の近傍銀河, 23 の HII region の SED を解析して $L_{H\alpha}$, L_{PAH}, SFR の関係を調べた.



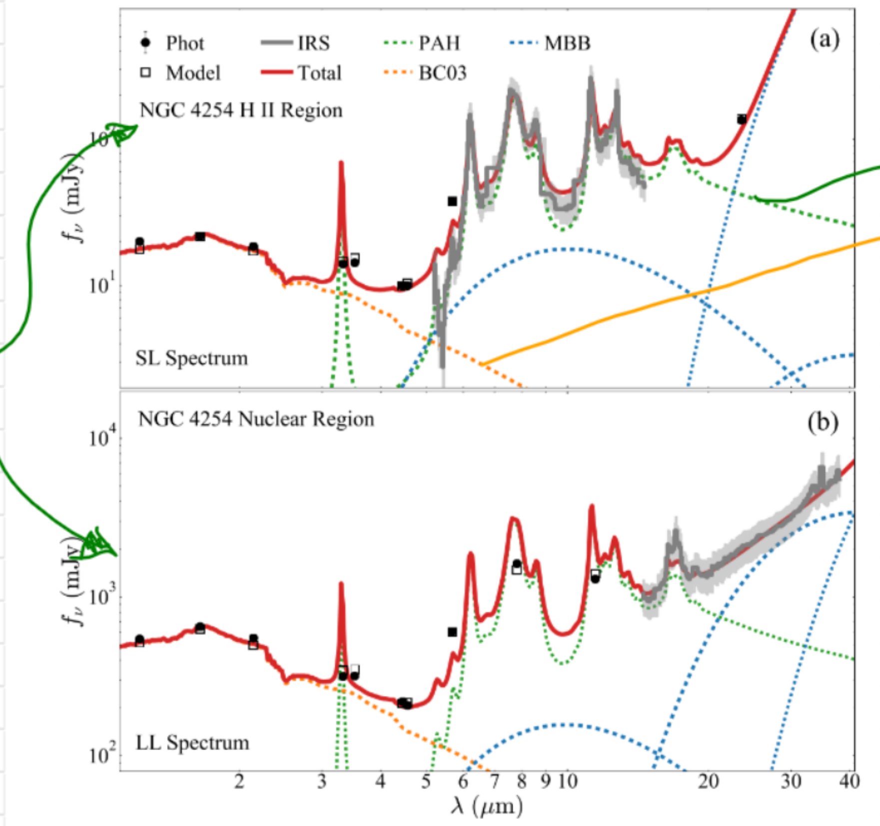


Table 4. Spatially Resolved Measurements

Region	log L_{PAH} (erg s^{-1})	log $L_{H\alpha}$ (erg s^{-1})	log $M_\star$ ($M_\odot$)
(1)	(2)	(3)	(4)
NGC628_UVB_C	41.22 ± 0.09	39.79 ± 0.11	8.75 ± 0.13
NGC628_UVF_C	41.62 ± 0.10	40.00 ± 0.10	9.27 ± 0.13
NGC628_UVB_H1	40.39 ± 0.09	39.36 ± 0.13	7.29 ± 0.13
NGC628_UVF_H1	40.57 ± 0.09	39.12 ± 0.11	7.83 ± 0.13
NGC628_UVB_H2	40.36 ± 0.09	39.16 ± 0.11	6.82 ± 0.14
NGC628_UVF_H2	40.36 ± 0.09	38.96 ± 0.10	6.32 ± 0.25
NGC628_UVB_H3	40.59 ± 0.09	39.46 ± 0.08	7.20 ± 0.14
NGC628_UVF_H3	40.14 ± 0.09	38.69 ± 0.07	6.10 ± 0.25
NGC628_UVB_H4	39.71 ± 0.09	38.62 ± 0.07	6.08 ± 0.16
NGC628_UVF_H4	40.00 ± 0.09	38.76 ± 0.07	5.67 ± 0.19

NOTE—Col. (1): Resolved region. Col. (2): Integrated (5 – 20 μm) PAH luminosity. Col. (3): Extinction-corrected Hα luminosity. Col. (4): Stellar mass. (This table is available in its entirety in machine-readable form.)

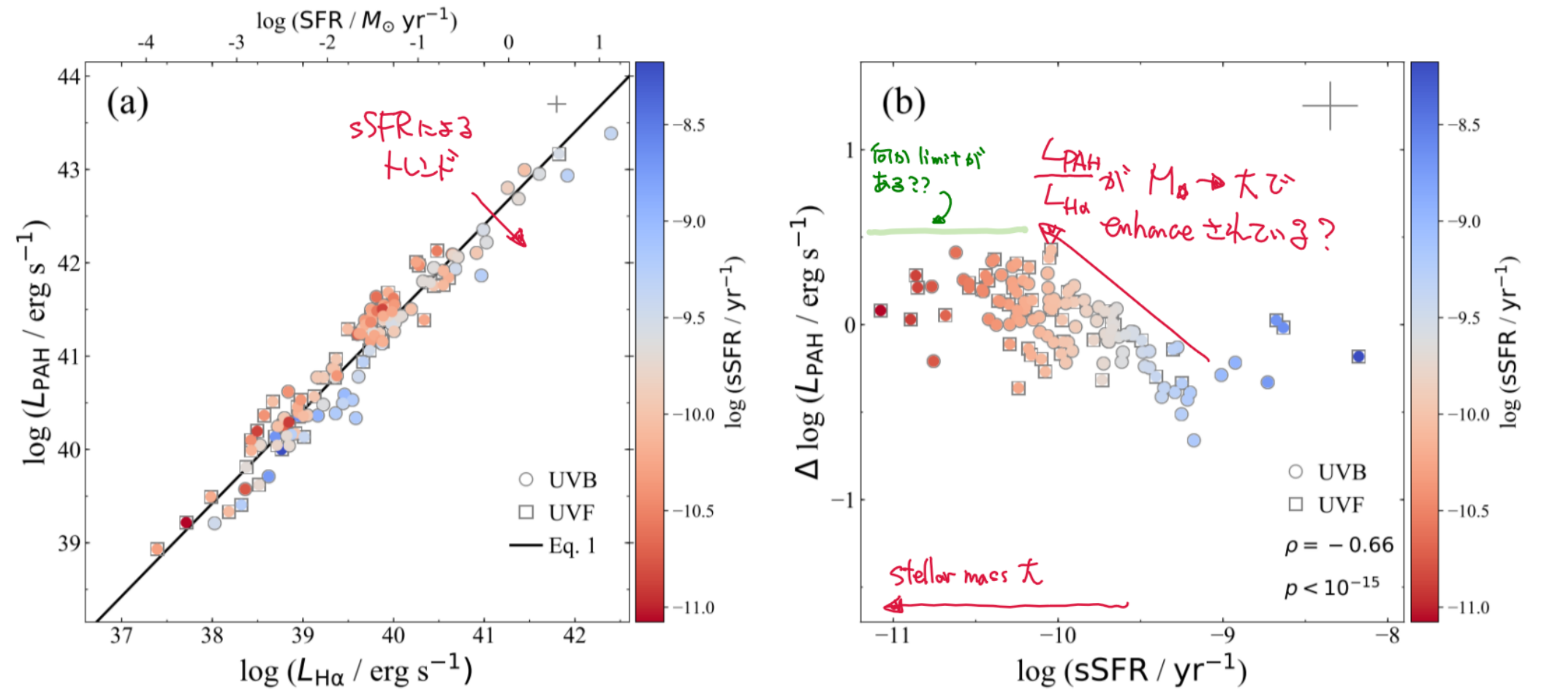
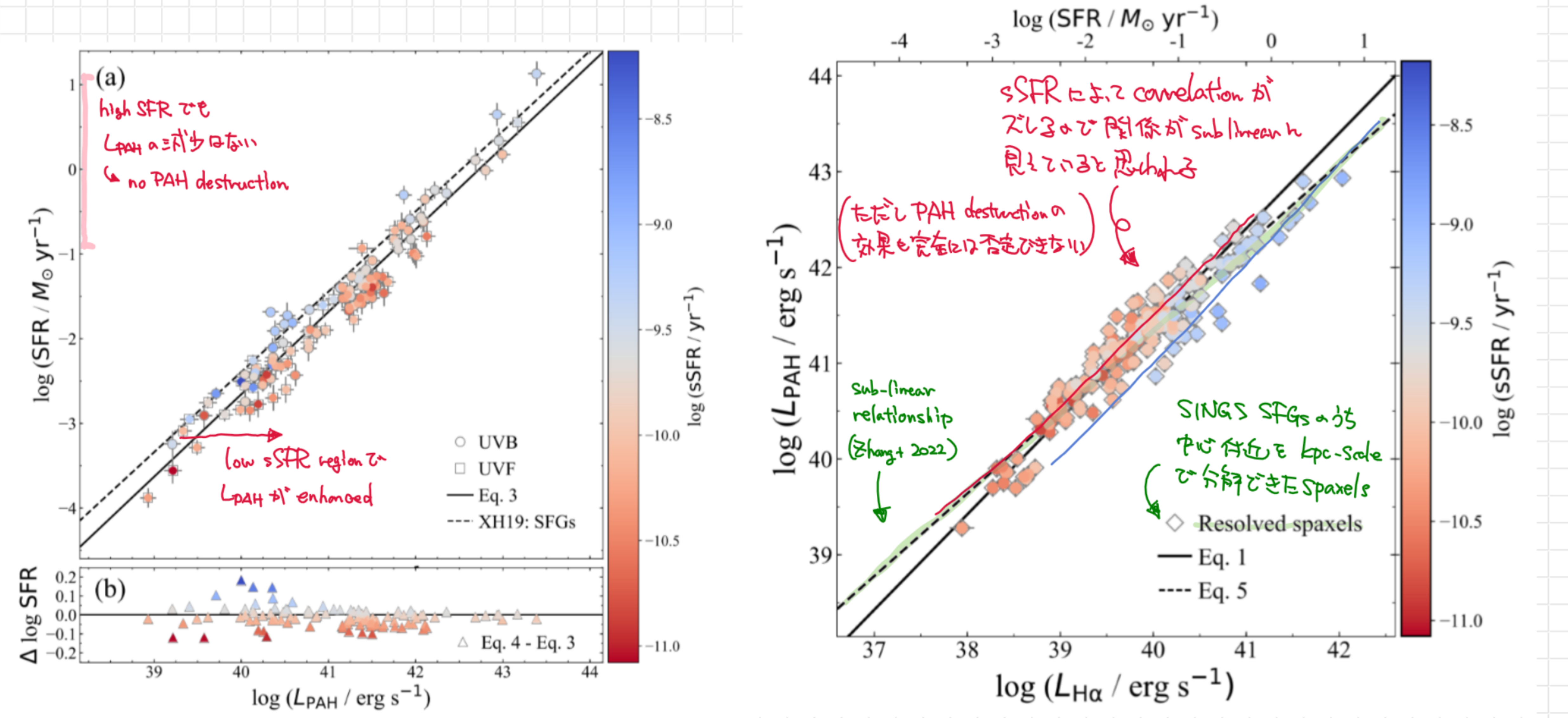


Figure 3. (a) The correlation between integrated PAH luminosity and extinction-corrected Hα luminosity for the UV-bright (UVB) and UV-faint (UVF) regions, color-coded according to the sSFR. The black solid line is the best linear regression fit for both regions combined (Equation 1). (b) The dependence of the residual PAH luminosity between the observed PAH luminosity and the best-fit value (the black solid line in panel a) on the sSFR, color-coded according to the sSFR. The lower-right shows the Spearman correlation coefficient ρ and its statistical significance p. The median uncertainty is shown in the upper-right corner of each panel.



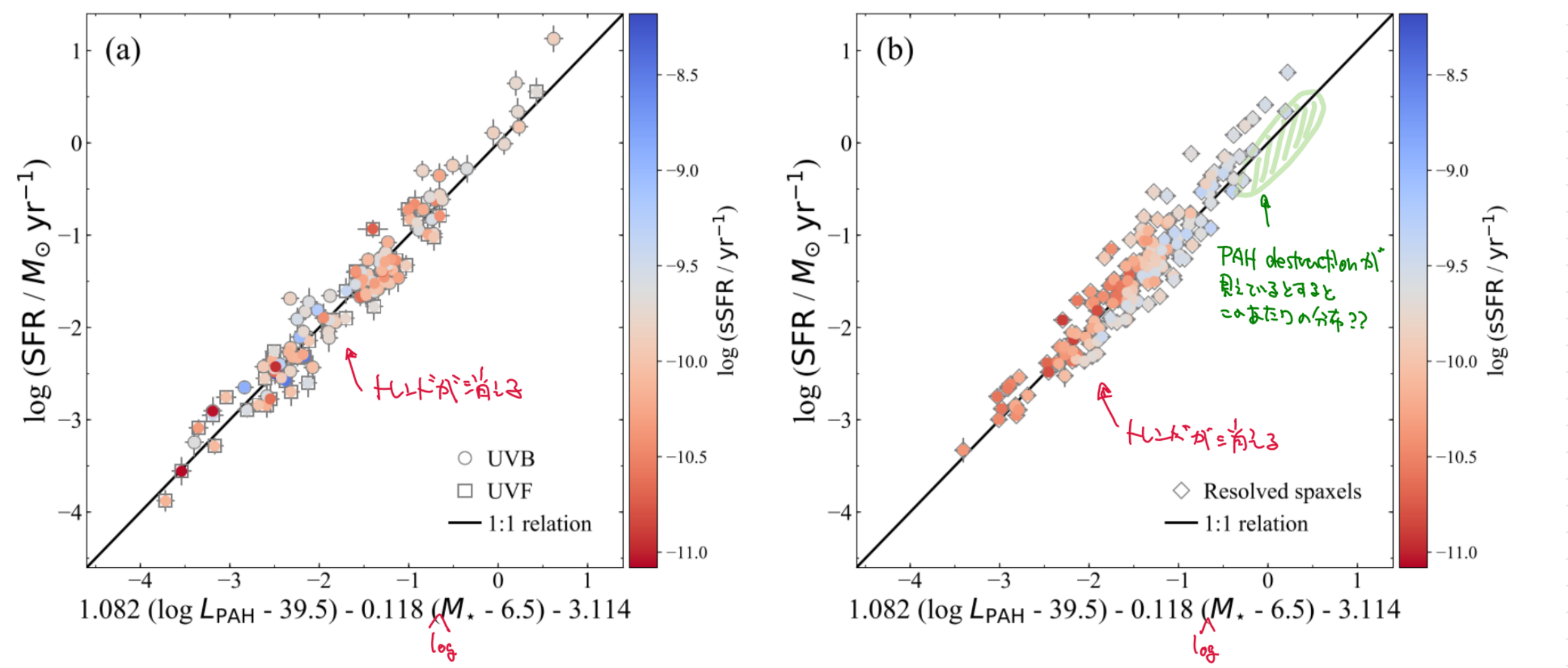


Figure 6. The correlation between observed SFRs and revised SFRs (Equation 4) for (a) UV-bright (UVB) and UV-faint (UVF) regions and (b) resolved spaxels from the central ~30″×50″ regions of SINGS SFGs (Zhang et al. 2022), color-coded according to the sSFR.