The MAGPI Survey: Using kinematic asymmetries in the stars and gas to understand drivers of dynamical evolution

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Stellar and gas kinematics are sensitive to the underlying mass distributions within galaxies; hence we can use them to study the assembly and evolution of galaxies. Similarly, gas kinematics will be sensitive to elements of galaxy evolution that stellar kinematics are not (e.g., gas flows, feedback) . The Middle Ages Galaxy Properties in IFS **(MAGPI)** Survey (Foster+21) is targeting galaxies in the 'middle ages' of the Universe at a physical spatial resolution comparable to IFS surveys in the local Universe to understand the **dynamical evolution of galaxies over cosmic time. Fig. 1** shows a velocity map for a typical MAGPI galaxy & fitted velocity profile . As galaxies evolve, signatures of their evolution remain in the kinematics, we can look for disturbances in the velocity maps, and investigate the physical drivers behind these disturbances.

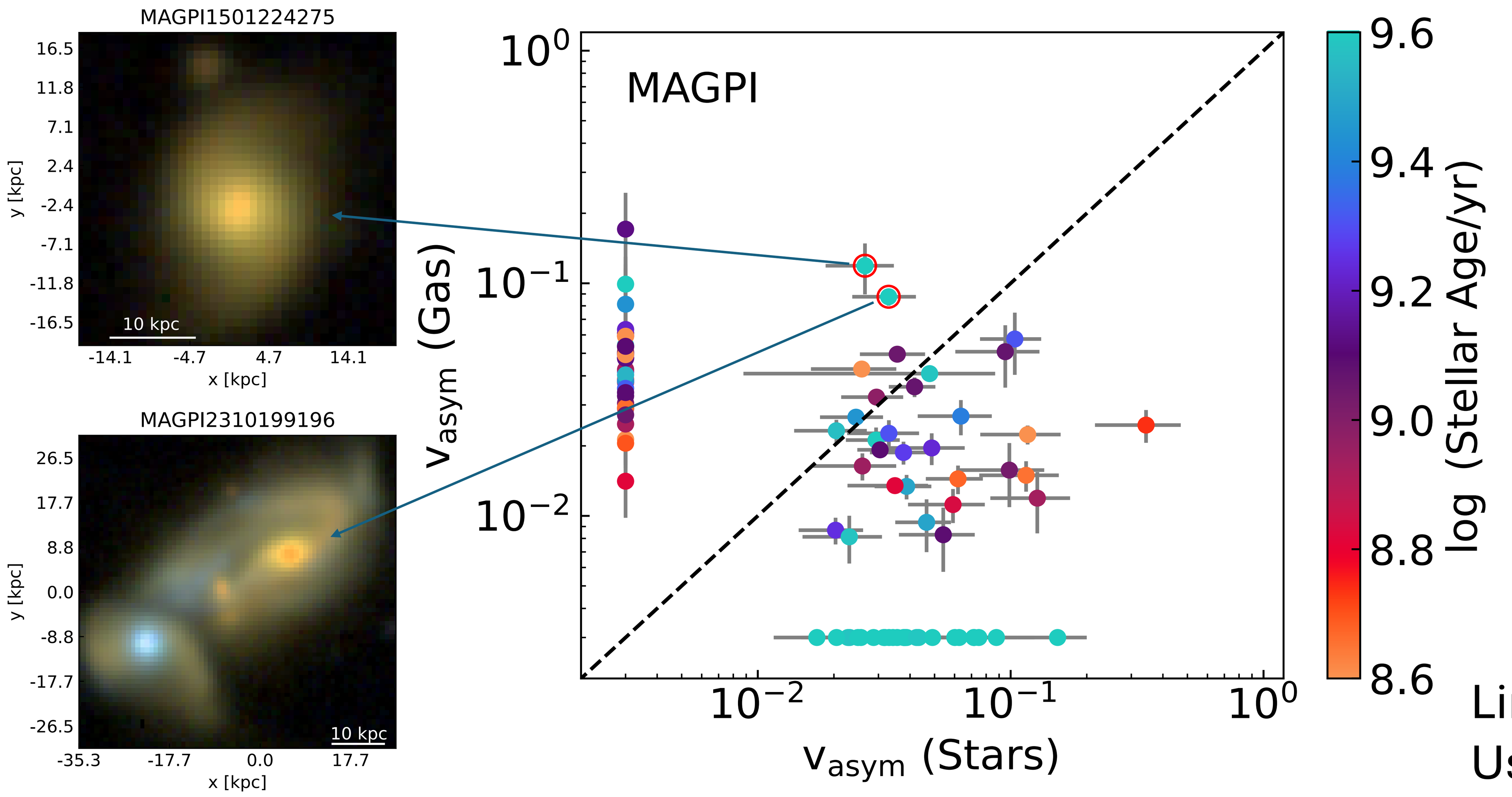
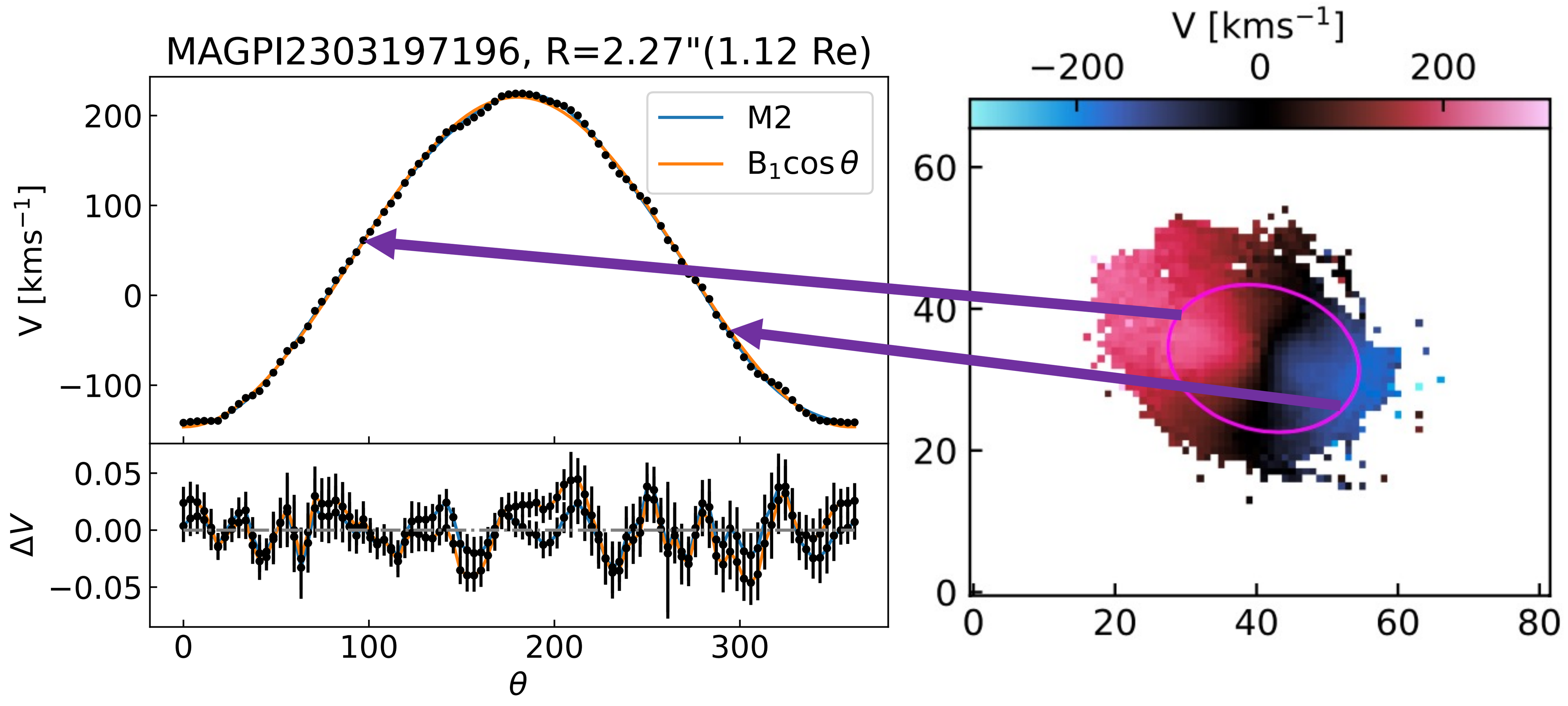


Fig. 2: 3-colour images (*i,g,r*) of MAGPI1501224275 & MAGPI2310199196; two galaxies in our sample that have larger gas asymmetries compared to their stars. They also have some of the oldest stellar populations in our sample. Given that their stars are dynamically relaxed, but their gas is not, we suspect that these galaxies are accreting gas. MAGPI2310199196 is clearly stripping gas from its neighbor, but MAGPI1501224275 does not have an obvious nearby galaxy. Given that MAGPI150122475 has old stellar populations, it is likely gas-poor and this leads to elevated asymmetries in the accreted gas.



$$V(R,\theta) = V_{sys}(R) + \sum_{m=1}^{m=5} k_m \cos[m\theta + \phi(R)]$$

$$v_{asym} = \frac{k_2 + k_3 + k_4 + k_5}{S_{05}}.$$

Fig. 1: The velocity map for MAGPI23197197 (left) and the fitted velocity profile along the magenta ellipse (middle). Allowing higher order terms in the fitted Fourier Series catches disturbed kinematics, and we use these higher-order terms to calculate the asymmetry in the velocity map.

KINEMATIC ASYMMETRIES

Line-of-sight velocity maps can be modelled with a set of tilted-rings (e.g., $V(R,\theta) = V_{rot}(R)\cos\theta\sin i$). Using **KINEMETRY** (Krajnovic+07), we can model the velocity maps of MAGPI, where disturbances are encoded as higher-order terms in a fitted Fourier Series. Stars and gas are fundamentally different fluids, and so their dynamics are also different. If a disturbance was triggered in **both** the stars & gas, we would expect the gas to remove this disturbance, **faster** than the stars are able to. And so, most galaxies should display larger asymmetries in their stars, rather than their gas. In **Bagge+24**, we found that MAGPI galaxies with larger stellar asymmetries are typically those with young stellar populations, whereas galaxies with older stellar populations has large gas asymmetries

TRENDS PERSIST AT LOW-REDSHIFT

The MAGPI Survey was designed to observe galaxies at similar spatial resolution to IFS surveys of the Local Universe (MAGPI~3 kpc; SAMI~1.5 kpc). We can leverage the higher lookback time of MAGPI to investigate **dynamical evolution in galaxies.** Applying the same KINEMETRY analysis to SAMI (Bryant+15, Scott+18, Croom+21) and exploring the same parameter space in **Fig. 2**. In SAMI, we find consistent trends between MAGPI. Namely, that star-forming galaxies with old stellar populations tend to have larger gas asymmetries, suggesting that this recent, but slow gas accretion is continuing in the present day. The source of stellar disturbances is nuanced, being effectively driven by mergers and interactions but is also correlated with stellar surface density (Bloom+18, Zhong+23). Our results are consistent with kinematic disturbances remaining after the photometric disturbances have dissipated (McElroy+22).

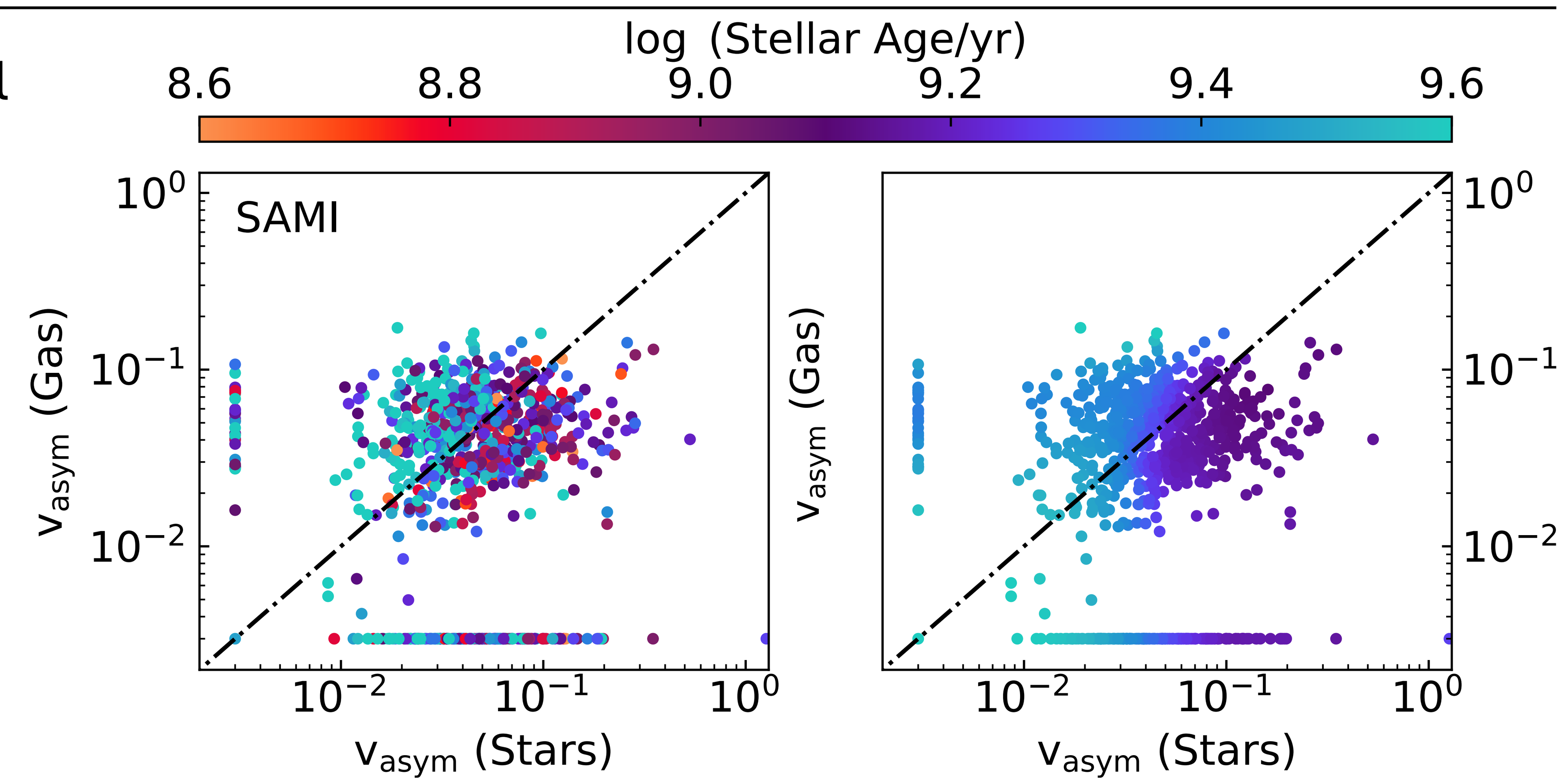


Fig. 3 v_{asym} (Stars) vs. v_{asym} (Gas) for SAMI galaxies (above). We again find that star-forming galaxies with old stellar populations typically have larger gas asymmetries. The right panel has been smoothed to aid visualization

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References: Bagge et al., 2024, RAS, MNRAS, **531**, 3, 3011-3022, Bloom et al., 2018 RAS, MNRAS, **476**, 2, 2339-2351, Bryant et al., 2015, RAS, MNRAS, **447**, 3, 2857–2879, Croom et al., 2021, RAS, MNRAS, **505**, 1, 991-1016, Foster et al., 2021, PASA, **38,** e031, 24 pages, Krajnovic et al., 2006, RAS, MNRAS **366,** 3, 787–802, McElroy et al., 2022, RAS, MNRAS, **515**, 3, 3406-3419, Scott et al.,2018, RAS, MNRAS, **481**, 2, 2299-2319, Zhong et al., 2023, ApJ, **957**, 1, L12