Gas Kinematics in the Nuclei of (U)LIRGs

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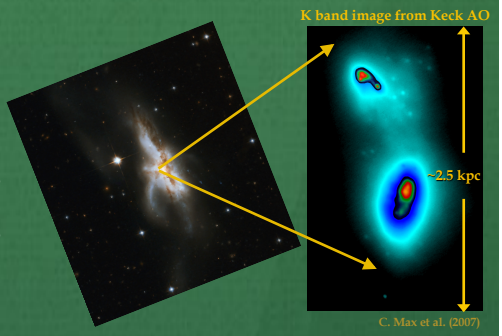
• Importance of Gas Kinematics in (U)LIRGs

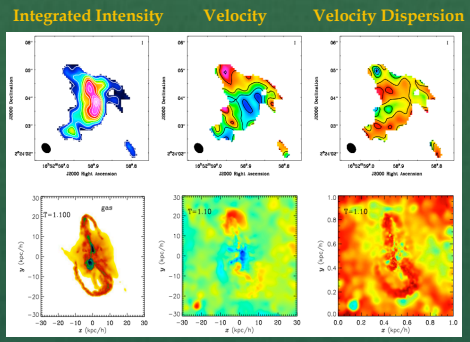
In the present paradigm of the merger-driven galaxy evolution scenario, gas-rich spirals interact and merge before a quasar emerges and a giant elliptical results. It is during the merging stage that starburst and/or AGN activities are triggered, leading to an infrared luminous stage of galaxy mergers. These objects provide the ideal nearby, extreme environments in which we study black hole (BH) accretion, AGN feeding and feedback, and the nature of star formation in starbursts, the connection among which remains poorly understood due to limitations of previous instrumentation. Here we present high-resolution submm and near-infrared 3D data cube of several (U)LIRGs at different stages of interaction. Our results give a detailed description of the gas kinematics in the nuclear region of these merging systems, and paint an overall picture of the evolution of the energetics in (U)LIRGs as the merger sequence progresses.

• Case Study 1: NGC 6240

NGC 6240 is a late-stage advanced merger hosting two AGN in its center. Its optical image features tidal tails as evidence for merger remnants on the large scale, as well as obscuring dust lanes in the center. Our 0.4" resolution SMA maps of the CO gas show the detailed distribution of the molecular gas in between the two nuclei.



(Top) HST image showing the large-scale structure with inset showing a *K*-band view of the double nuclei in the center. *(Bottom)* The integrated intensity, velocity, and dispersion maps of the observed CO gas on top as compared to that of their corresponding simulation counterparts.



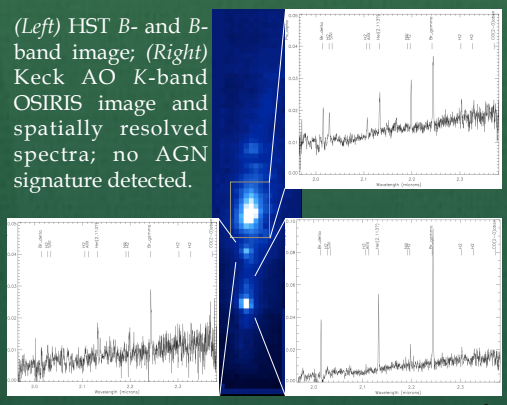
(Bottom) Table summarizes the gas and energetic properties of the three (U)LIRGs examined in order of the merging sequence. As galaxy mergers progress throughout their interaction, L_{IR} increases, gas kinematics become chaotic before settling into rotation, and the energetics evolve from being predominantly driven by starbursts to by AGN.

	IRAS F03359	NGC 6240	UGC 05101
Merger Stage	III	IV	V
L_{IR}	11.55	11.93	12.01
Gas	?	Chaotic	Rotation
SB/AGN	SB	Double AGN	Buried AGN

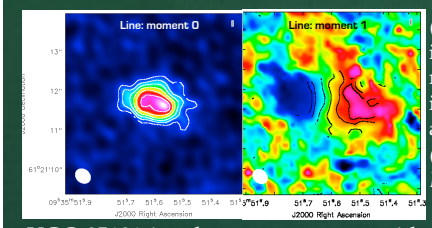
• Case Study 2: IRAS F03359

IRAS F03359 is an edge-on merger pair in an early stage of interaction as classified to have two nuclei sharing a common envelop. Spectra indicate uneven distribution of molecular gas and that the nuclear region is mainly powered by star formation.

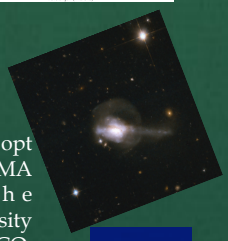
(Left) HST *B*- and *B*-band image; *(Right)* Keck AO *K*-band OSIRIS image and spatially resolved spectra; no AGN signature detected.

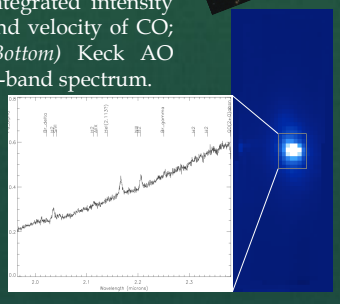


• Case Study 3: UGC 05101



(Top right) HST opt image; *(Left)* SMA maps of the integrated intensity and velocity of CO; *(Bottom)* Keck AO *K*-band spectrum.

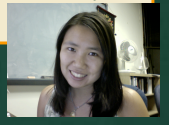




UGC 05101 is a late-stage merger with a single nucleus and long prominent tidal tail. The rotating CO gas in our SMA maps and the various signatures in our OSIRIS K-band spectrum lends support to a central buried AGN.

• Summary

Using the SMA and Keck Telescopes on Mauna Kea, we examine the kinematics of molecular gas, which fuels star formation and AGN activities, in the nuclear regions of several nearby merging galaxy systems. We compare observations to hydrodynamic simulations to gain intuition on the nature of the energetic processes during the collisions. With high-resolution infrared and submm 3D observations of the nuclei in merging systems at different interaction stages, we piece together a complete story of galaxy formation and evolution through mergers.



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