ORCHESTRATION OF STARBIRTH ACTIVITY IN DISK GALAXIES: New Perspectives from Ultraviolet Imaging

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Abstract. Ultraviolet imaging of nearby disk galaxies reveals the star-forming activity in these systems with unprecedented clarity. UV images recently obtained with the Shuttle-borne Ultraviolet Imaging Telescope (UIT) reveal a remarkable variety of star-forming morphologies. The respective roles of tides, waves, and resonances in orchestrating the observed patterns of starbirth activity are discussed in terms of the extant UV data.

WHY ULTRAVIOLET IMAGING?

Despite the potential for obscuration by dust, a significant fraction of a disk galaxy’s UV emission manages to escape and thus be detected by instruments located beyond the Earth’s atmosphere. Even in disk galaxies of high inclination, UV imaging can reveal widespread emission (cf. Fanelli et al., Neff et al., & O’Connell, these Proceedings).

Ultraviolet imaging of nearby disk galaxies reveals the star-forming activity with unprecedented clarity. Unlike imaging at Hα, UV imaging directly traces the full range of OBA stellar spectral types, thereby sampling the recent-epoch

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FIGURE 1. FUV (λ1520) image of the Sab galaxy M94 (inner disk), showing bisymmetric star-forming knots, a resonant ring of starburst activity and diffuse FUV emission interior to the ring — where Hα is in absorption due to the underlying B & A-type stellar populations.

“Population I” component of each galaxy more completely. UV imaging also provides a cleaner separation of the hot star component in regions dominated by cooler stars (e.g. central disks & bulges). Moreover, UV imaging is unaffected by line absorption in the atmospheres of B & A-type stars — unlike imaging at Hα and Hβ — thereby providing a truer representation, where these populations are concentrated (see FIGURE 1). Finally, the UV colors of OB/HII regions can be used to derive extinction-free UV luminosities [1] [2], whereas few constraints exist for deriving extinction-free EUV (e.g. Lyman continuum) luminosities based on H-line, radio-continuum, or other indirect indices.

UV MORPHOLOGIES OF DISK GALAXIES

UV images of nearby disk galaxies obtained with the Shuttle-borne Ultraviolet Imaging Telescope (UIT) reveal a remarkable variety of star-forming morphologies. These Pop I patterns yield important insights to the respective roles of tides, waves, and resonances in orchestrating starbirth activity in disk galaxies.

A comparison of M33 (Scd), M74 (Sc), and M81 (Sb) at UV and visible wavelengths highlights the Pop I character of the UV imagery [3]. Flatter radial distributions are evident in the UV — with exponential scalelengths that are 20–45% larger. The effects of reddening, abundance, and IMF variations do not fully explain the differences. The flatter UV profiles most likely indicate that the median radius of star-forming activity has migrated outward over the past several Gyrs [4].

The UV morphologies also show narrower arms — delineated by a combination of direct starlight from OBA associations and indirect (scattered) radiation from dust associated with the massive young stars [1] [5]. The narrower UV features indicate that star formation over the past ∼10 Myrs
occupies a significantly smaller areal domain than the \( \sim 1-1000 \) Myr legacy of star formation that is traced at longer wavelengths.

**Tides**

In the giant ScI spiral M101, multiple linear arm segments (“crooked arms”) can be traced throughout the disk (see FIGURE 2). These features, along with a faint spiral arm and “curly tail” feature that links the outermost supergiant HII region with the rest of the galaxy, indicate that *tidal processes of both external and internal origin* are directing the current starbirth activity [5].

Numerical simulations of isolated disk galaxies show that the “crooked arm” behavior can arise through the action of “massive disturbers” orbiting within the disks. The outermost supergiant HII region, NGC 5471 may represent one of these massive disturbers. Larger-scale morphological and kinematic anomalies in M101, including the faint arm and “curly tail” feature, require external interactions with companion galaxies. Such interactions can induce the formation of massive condensations at the ends of the tidal tails, perhaps explaining the origin of NGC 5471 at the terminus of M101’s “curly tail” [5]. Similar behavior can be found in other giant Sc galaxies with “companions,” including M51, NGC 1232, NGC2805, and NGC 4303.
Waves

In the “grand-design” ScI galaxy M74 (NGC 628), reflection of the UV-emitting disk upon itself shows the spiral structure to be more symmetric than is observed at visible wavelengths — thus arguing for large-scale dynamics (e.g. density waves) governing the current-epoch star formation [6].

Evidence for spatio-temporal sequences of molecular-cloud aggregation, massive star formation, cluster evolution, and cloud disruption can be found in M74, M51 (O’Connell, these Proceedings), and the inner disk of M101 [5]. In M101, far-UV emission is often found on the outer (downstream) side of the inner-disk CO arms. Modeling the FUV–CO displacements according to density-wave dynamics results in a wave pattern speed and co-rotation radius remarkably similar to those derived from a multi-mode analysis of the optical spiral structure [5]. Similar downstream displacements between the FUV and Hα emission is evident in the SE arm of M74, again indicating density-wave dynamics at work.

Resonances

In the Sab spiral M94 (NGC 4736), UV imaging reveals an inner starbursting ring and bi-symmetric outer knots in high contrast against the underlying visible bulge and disk (see FIGURE 1). Dynamical resonances seem to best explain these transient features. Similar UV rings are evident in the inner disks of NGC 1317 (SBA), NGC 1512 (SBb), NGC 3351 (SBb), and M100 (NGC 4321) (Sc) — most of which are also of “early” morphological type.

Resonances may also explain the dearth of UV emission interior to M81 and M31’s ring-like spiral arms [7], whereby star-forming gas migrates outwards from the interior and piles up near the Inner Lindblad Resonances (Kenney, these Proceedings). Because the longer-wavelength emission traces the older stellar populations and is so prominent interior to the ringlike arms, we conclude that the resonant locations and their constructive/inhibiting effects must have evolved with time.

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