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Secular evolution in young galaxies

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Abstract. Young galaxies viewed at high redshift have high turbulent velocities, high star formation rates, high gas fractions, and chaotic structures, suggesting wild instabilities during which giant gas clumps form and make stars in their dense regions, stir other disk stars and gas, and transport angular momentum outward with a resulting net mass flow inward (e.g., Ceverino *et al.* 2010). At $z = 1.5$, 40% of star-forming galaxies have significant clumps (Elmegreen *et al.* 2007; Wuyts *et al.* 2012), and in these, 10%-20% of the stellar mass is in clumps that last ∼150 Myr (Elmegreen *et al.* 2009; Wuyts *et al.* 2012). The thick disk and bulge in modern galaxies could form in this phase. The similarity in the α/Fe ratio (Meléndez *et al.* 2008), K-giant abundances (Bensby *et al.* 2010) and ages for the Milky Way bulge and thick disk suggest they formed at the same time. High dispersion gas at $z \sim 1.5$ can do this because it makes the young disk thick and the SF clumps big enough to drive fast secular evolution (Elmegreen *et al.* 2006; Genzel *et al.* 2008; Bournaud *et al.* 2009). Local analogues might be present in dynamically young galaxies like BCDs (Elmegreen *et al.* 2012). The high fraction of $z \sim 1.5$ galaxies with massive clumps suggests clump formation is a long-lived phase and that clump torques should last $\sim$ 1 Gyr or more even if individual clumps come and go on shorter timescales. Clump formation may cease when stars finally dominate the disk mass (Cacciato *et al.* 2012).

Keywords. galaxies: bulges, galaxies: dwarf, galaxies: evolution, galaxies: high-redshift

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