Pioneering SMA Studies of Lensed Dusty Star-forming Galaxies Found by Herschel

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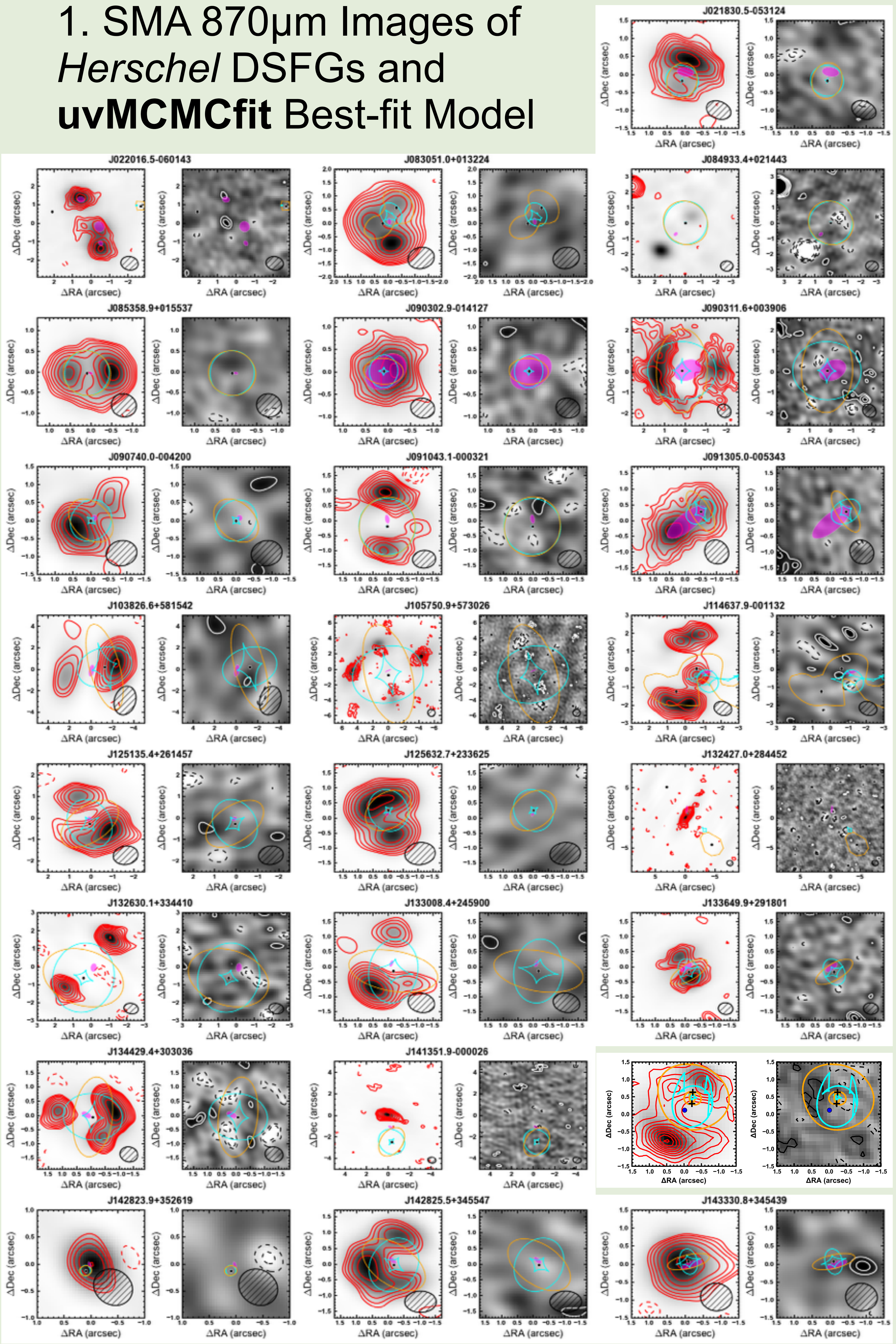
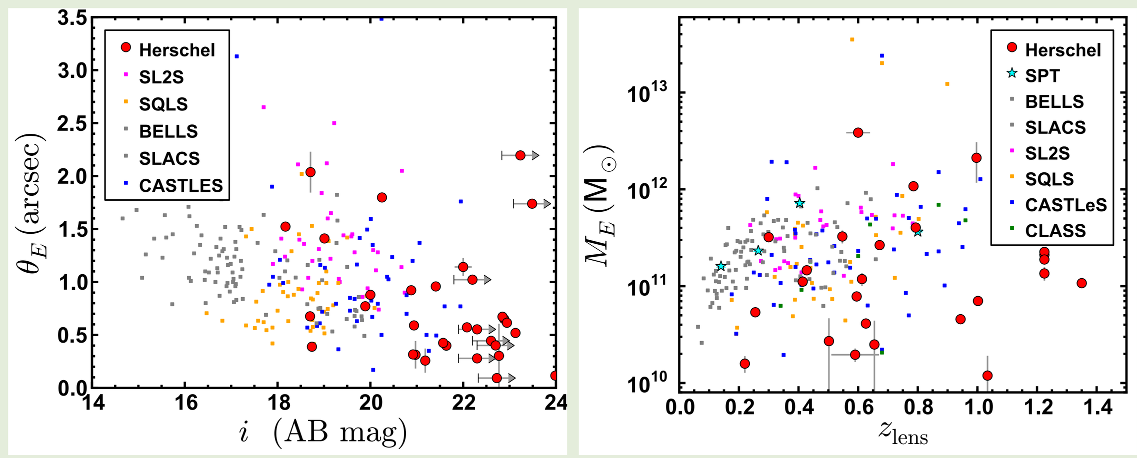
Oliver et al. 2012, MNRAS, 424, 1614

Abstract: Wide-field surveys by the *Herschel Space Observatory* have discovered extremely luminous, gravitationally lensed galaxies at z>1.5 that offer a unique window on star-formation in extreme environments. The SMA is playing a pioneering role in providing spatially resolved 870μm imaging that is critical to develop lens models and study both the lensing and lensed galaxies in unprecedented detail. We develop a new analysis tool for interferometers (**uvMCMCfit**) and apply it to our SMA data to show that a wide range of physical mechanisms must be responsible for the prodigious luminosities in these galaxies.

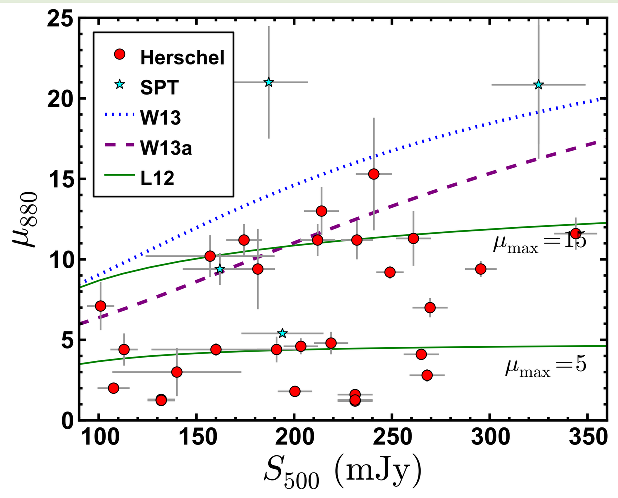
1. SMA 870μm Images of *Herschel* DSFGs and **uvMCMCfit** Best-fit Model



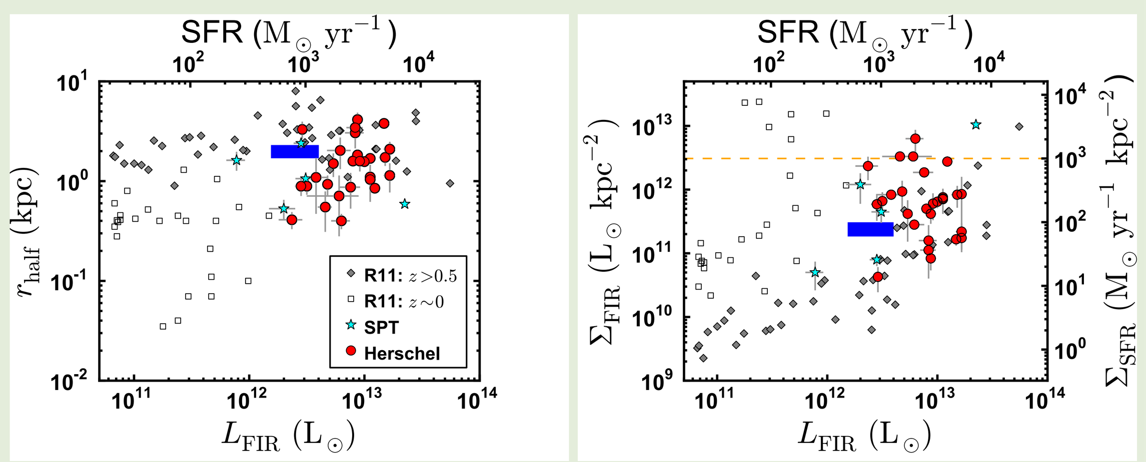
Postage stamp cutouts of SMA 870μm imaging of bright *Herschel* sources from Bussmann et al. 2013 (red contours; starting at ±2σ and increasing by factors of √2; σ ≅ 1-2 mJy/beam). Grayscale shows the best-fit model obtained using an early version of **uvMCMCfit**. We assume a Sérsic profile for each background source. The half-light area of the background sources are traced by magenta ellipses. Foreground galaxies are accounted for when acting as a lens. Their positions, critical curves, and caustics are indicated by black circles, orange lines, and cyan lines, respectively. In most cases, the residual emission obtained by subtracting the best-fit model from the data reveals no significant emission (Bussmann et al. 2012, 2013).



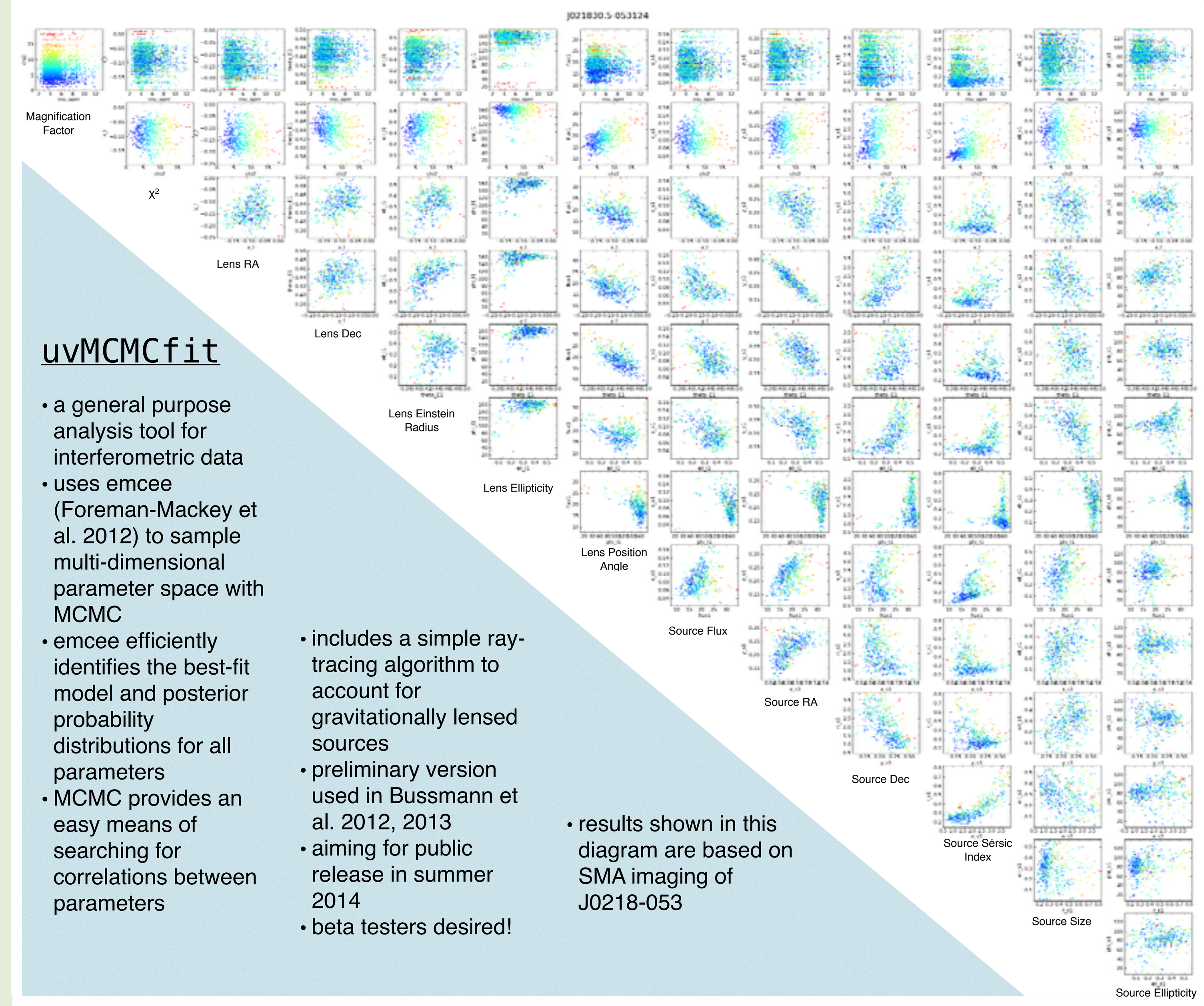
2. Lenses in the SMA Sample. Left: Einstein radius as a function of i-band AB magnitude. The Herschel sample is fainter and shows a wider range in Einstein radius values than any of the previous samples of lenses. **Right:** Mass enclosed within the Einstein radius as a function of lens redshift. Herschel has identified lenses that are lower in mass or higher in redshift than any of the optically-based searches (SLACS, BELLS, and SL2S). The range in parameter space occupied by the Herschel data points is comparable to that of CASTLES, CLASS, and SQLS, but Herschel promises to provide a sample size that is over an order of magnitude larger (Gonzalez-Nuevo et al. 2012)



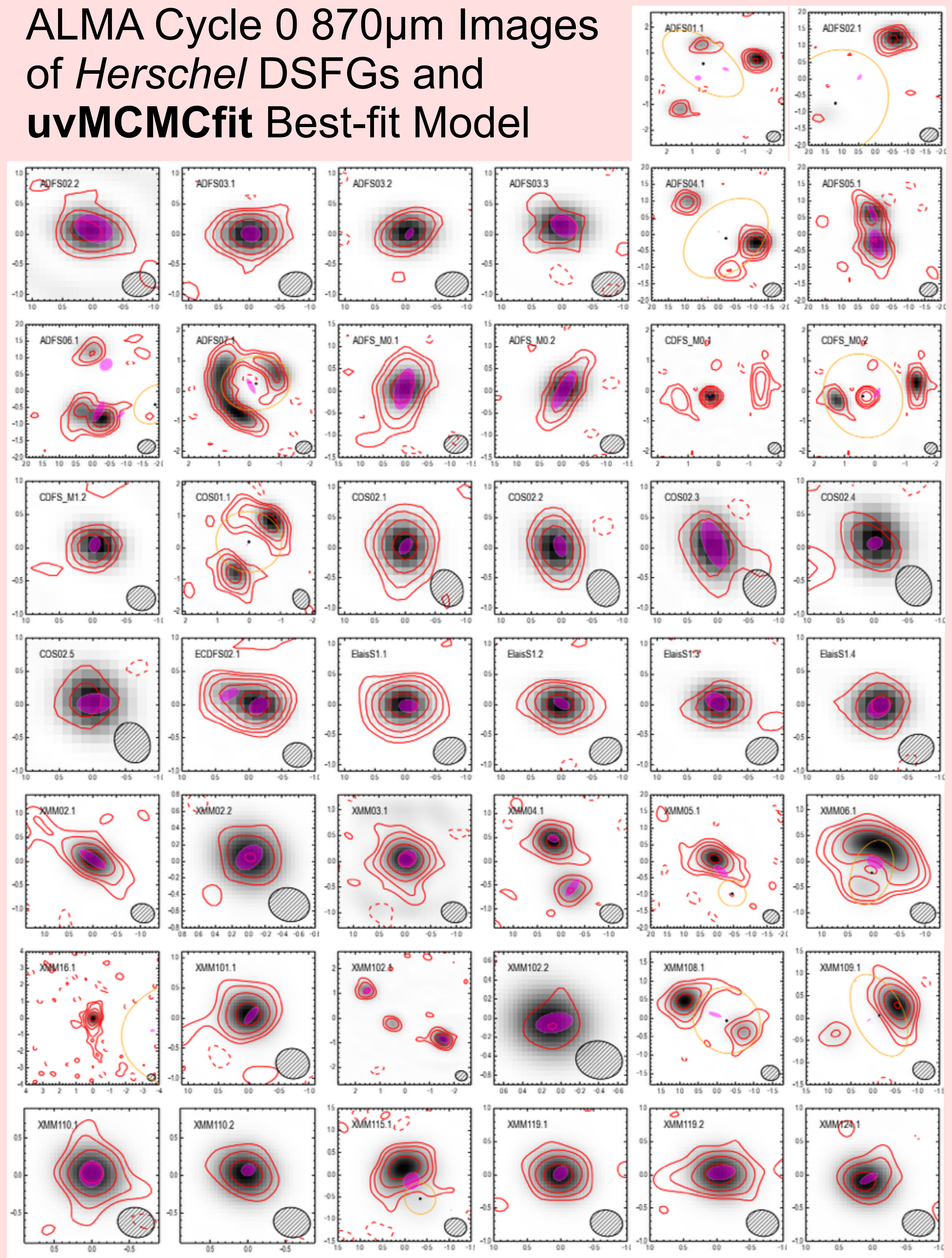
3. Magnification factor from the SMA lens models as a function of 500μm flux density: The predicted values from Wardlow et al. (2013) are shown by the dotted blue line. The dashed purple line traces the same model, but with parameters tuned to jointly match the observed number counts and magnification factors shown in this diagram. The solid green lines show the effects of different maximum magnifications and are taken from Lapi et al. (2012).



4. Intrinsic source properties of Herschel DSFGs in the SMA sample. Left: Half-light radius as a function of FIR luminosity for lensed DSFGs discovered by Herschel (red circles) and South Pole Telescope (cyan stars, Hezaveh et al. 2013), as well as galaxies from a compilation in (Rujopakarn et al. 2011) at z > 0.5 (filled grey diamonds) and at z ≅ 0 (open squares). The blue shaded region represents the median and 1σ range found for unlensed DSFGs by (Tacconi et al. 2006). **Right:** Far-IR luminosity surface density as a function of FIR luminosity. The orange dashed line traces the theoretical limit of Σ_{SFR} for an optically thick disk (Thompson et al. 2005). The SMA sample spans nearly one decade in L_{FIR} and two decades in Σ_{FIR}. A handful of sources approach or exceed the highest values observed in local LIRGs and ULIRGs ($\Sigma_{FIR} = 10^{13}\ L_\odot\ kpc^{-2}$).



ALMA Cycle 0 870μm Images of *Herschel* DSFGs and **uvMCMCfit** Best-fit Model



Postage stamp cutouts of ALMA 870μm imaging of bright *Herschel* sources from our Cycle 0 program (red contours; starting at ±2σ and increasing by factors of √2; σ ≅ 0.2 mJy/beam). Grayscale shows the best-fit **uvMCMCfit** model assuming a Gaussian profile for the background sources. Other plot symbols are the same as for the SMA postage stamp images. The fits are generally very good with little significant residual emission (Bussmann et al. in prep.). Many of the objects in our ALMA sample are fainter than the SMA sample. The ALMA sample therefore contains a much higher fraction of unlensed galaxies.

References: Bussmann et al. 2012, ApJ, 756, 134; Bussmann et al. 2013, ApJ, 779, 25; Gonzalez-Nuevo et al. 2012, ApJ, 749, 65; Hezaveh et al. 2013, ApJ, 767, 132; Lapi et al. 2011, ApJ, 742, 24; Rujopakarn et al. 2011, ApJ, 726, 93; Tacconi et al. 2006, ApJ, 640, 228; Thompson et al. 2005, ApJ, 630, 167; Wardlow et al. 2013, ApJ, 762, 59