The Impact of Ram Pressure Stripping on Star Formation both Inside and Outside of Galaxies

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Density-Morphology relation (Oemler 1974, Dressler 1976)

Butcher-Oemler effect (Butcher & Oemler 1978)

Evolution of Spirals to S0s (Dressler et al. 1997)
How do you make an S0 from a Spiral?

1) Redden the spiral
   > Remove gas (passive spirals e.g. Moran et al. 2007; Poggianti et al. 1999)

2) Smooth out the spiral arms
   > Remove gas (Bekki et al. 2002 find spiral arms lost 3.5 Gyr after gas removal)

3) Increase the Bulge/Disk ratio
   > Dim the disk
   > Grow the bulge

   A history of discussion, e.g.: Solanes et al. (1989); Burstein et al. (2005); Christlein & Zabludoff (2004)
Ram Pressure Stripping

\[ P = \rho v^2 \]

(Gunn and Gott 1972)

Directly affects only gas

Kenney et al. (2004)
Long tails have been observed in HI, X-rays, and Hα

Oosterloo & van Gorkom 2005
Star Formation in Stripped Tails

Sun et al. (2009)

Yagi et al. (2010)
Enzo (AMR)
Resolution 38 pc
Cooling to 300 K

Zooming in to Highly Resolved Simulations of Ram Pressure Stripping
The ram pressure experienced at about the virial radius of a cluster with $M = 6 \times 10^{14} \text{ } M_{\text{sun}}$ (Tonnesen, Bryan & van Gorkom 2007)

$P_{\text{ram}} = 6.4 \times 10^{-12} \text{ dyn cm}^{-2}$

$n = 3 \times 10^{-4} \text{ cm}^{-3}$

$v = 1413 \text{ km s}^{-1}$
Star Formation in the Disk

![Graph showing Star Formation Rate (SFR) and Radius with 95% of SF over time.](Image)
Stellar Mass in the Disk and Bulge

Does RPS growth the bulge?

BUT, the galaxy began with $M_* = 10^{11}$ and $M_{\text{bulge}} = 10^{10}$

B/T ($M_{\text{new}^*}$): SFNW $\sim 0.1$ SFW $\sim 0.2$
The Stellar Tail
Does this add to the ICL?

Less than 1% of the mass of stripped gas turns into stars.

The stellar mass formed in the tail is less than 10% of the mass of new stars in the disk.
Conclusions

• RPS does not increase the total SFR inside a galaxy, either through the increase of the surrounding ICM pressure or through a shock
• RPS does not affect the relationship between $\Sigma_{\text{gas}}$ and $\Sigma_{\text{SFR}}$
• RPS increased the bulge stellar mass relative to a galaxy with no ICM wind
• RPS does add a small and seemingly insignificant amount of stellar mass to the ICL
The Local Schmidt Law

Whether or not wind is included, the galaxies fall along the same relationship between $\Sigma_{\text{SFR}}$ and $\Sigma_{\text{gas}}$.

The $\Sigma_{\text{SFR}}$ flattens at the same $\Sigma_{\text{gas}}$ observationally found by Leroy+ (2008) (THINGS)
Stars Throughout the Tail

Velocity in the wind direction (km s⁻¹)

Height above Disk (kpc)

Tidal radius at

\( r_{\text{virgo}} \sim 200 \text{ kpc} \)

\( r_{\text{coma}} \sim 300 \text{ kpc} \)

250 Myr after stripping begins
Clouds are marginally resolved and we do see mixing with the ICM.
Tonnesen vs Kapferer

AMR
- cells in disk: $5 \times 10^7$
- Mass refinement: $4900 \, M_{\text{sun}}$
- cooling: 300 K
- $T_{\text{SF}}: 1.1 \times 10^4 \, \text{K}$
- $\rho_{\text{SF}}: 3.85 \times 10^{-25} \, \text{g cm}^{-3}$

SPH
- particles in disk: $2 \times 10^5$
- particle Mass: $3.4 \times 10^4 \, M_{\text{sun}}$
- cooling: $10^4 \, \text{K}$
- $T_{\text{SF}}: 10^6 \, \text{K}$
- $\rho_{\text{SF}}: \sim 7 \times 10^{-26} \, \text{g cm}^{-3}$ (?)
$P_{\text{ICM}} = 2.66 \times 10^{-11}$ dyne cm$^{-2}$

$P_{\text{ICM}} = 1.76 \times 10^{-12}$ dyne cm$^{-2}$