

# ***Internal Gravity Waves & Cloud Evolution in Substellar Atmospheres***

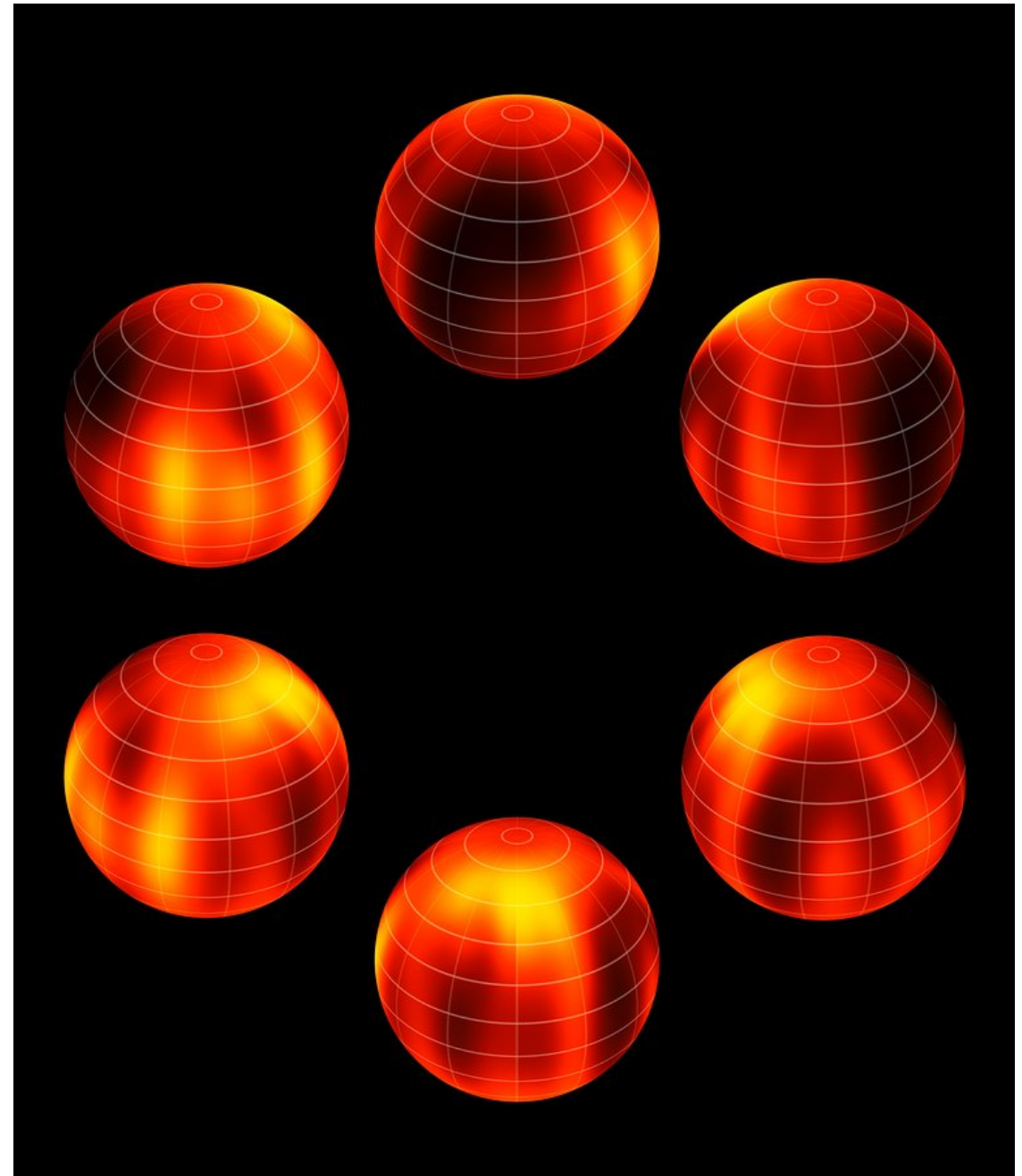
**NUMERICAL SIMULATIONS  
& FUTURE CAPABILITIES**

*Amy Parent (she/her)  
R. Falconer, K. Meyer, C.R. Stark  
University of Abertay, Dundee*

# Clouds in Brown Dwarfs

- ▶ Photometric variability observed in brown dwarfs, mapped (Crossfield+ 2014)
- ▶ Current atmosphere models suggest variability is due to dust clouds (Helling+ 2008)
- ▶ *Models suggest internal gravity waves impact cloud evolution (Freytag+ 2010)*

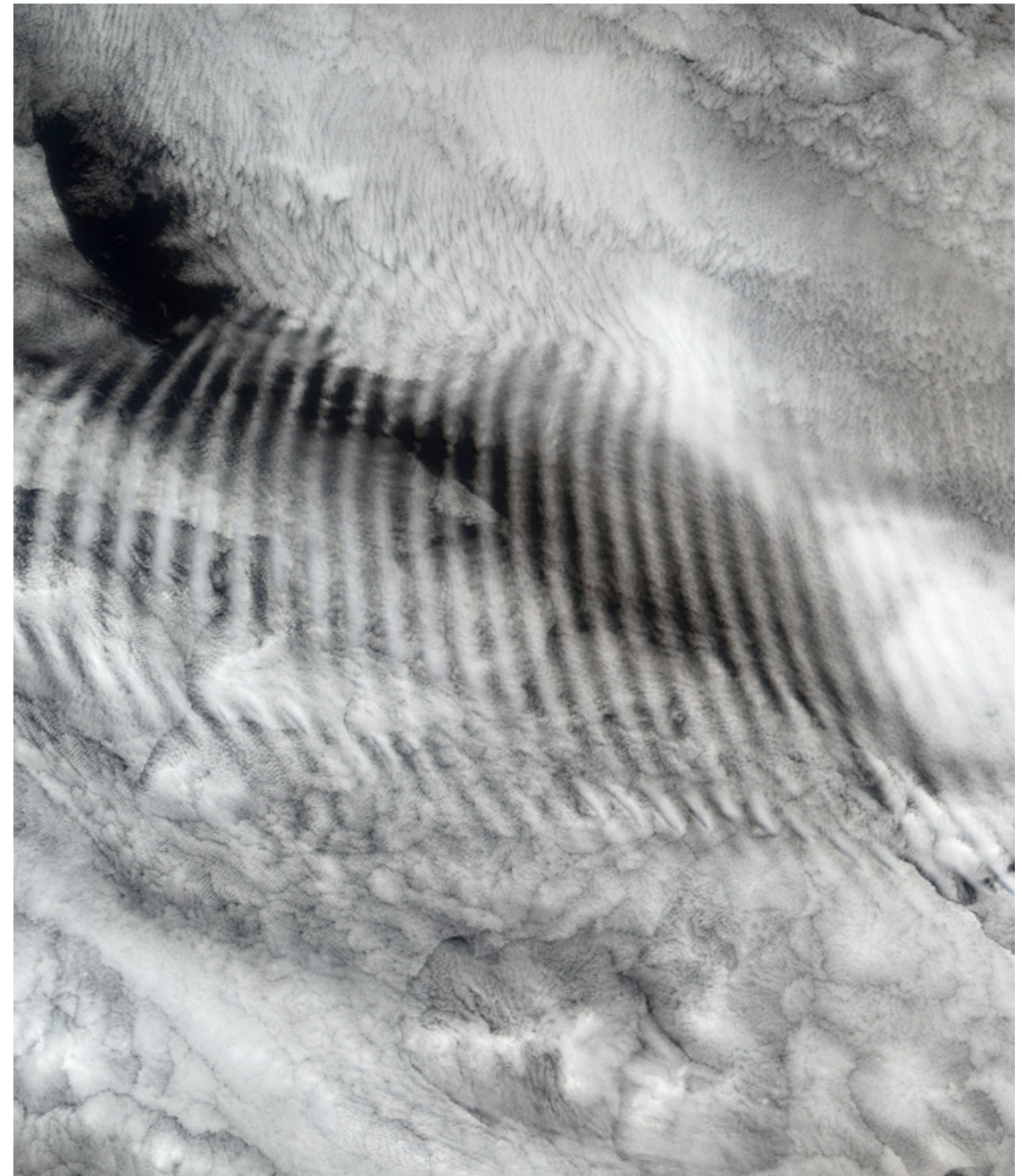
*Cloud map of Luhman-16B*  
*Crossfield et al. 2014, Nature, 505, 654.*



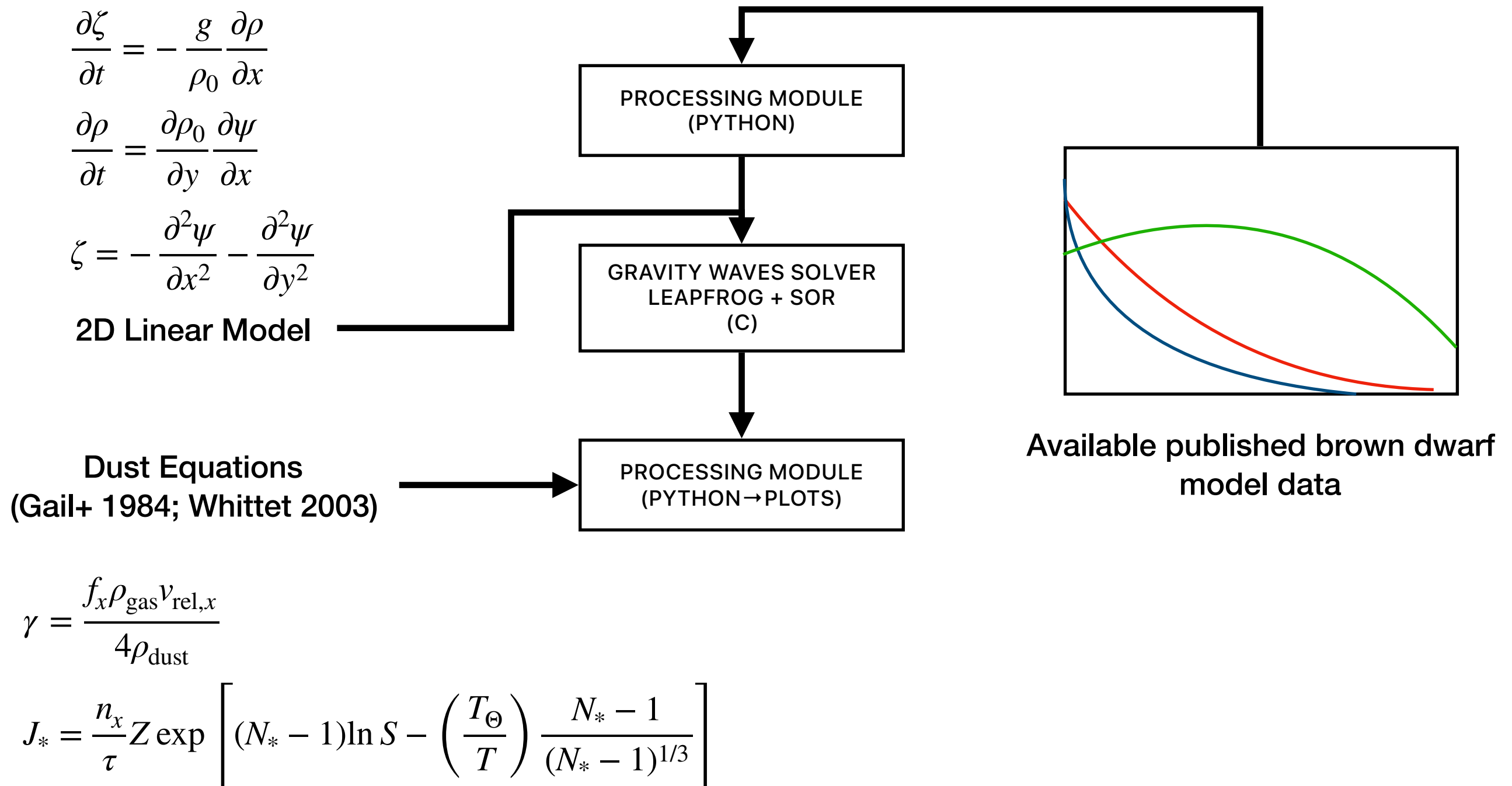
# ***Internal Gravity Waves***

- ▶ Density or velocity perturbations create atmospheric oscillations;
- ▶ IGW lead to banded structures in clouds on Earth & Solar System Planets
- ▶ *Can similar structures teach us about brown dwarf atmospheres?*

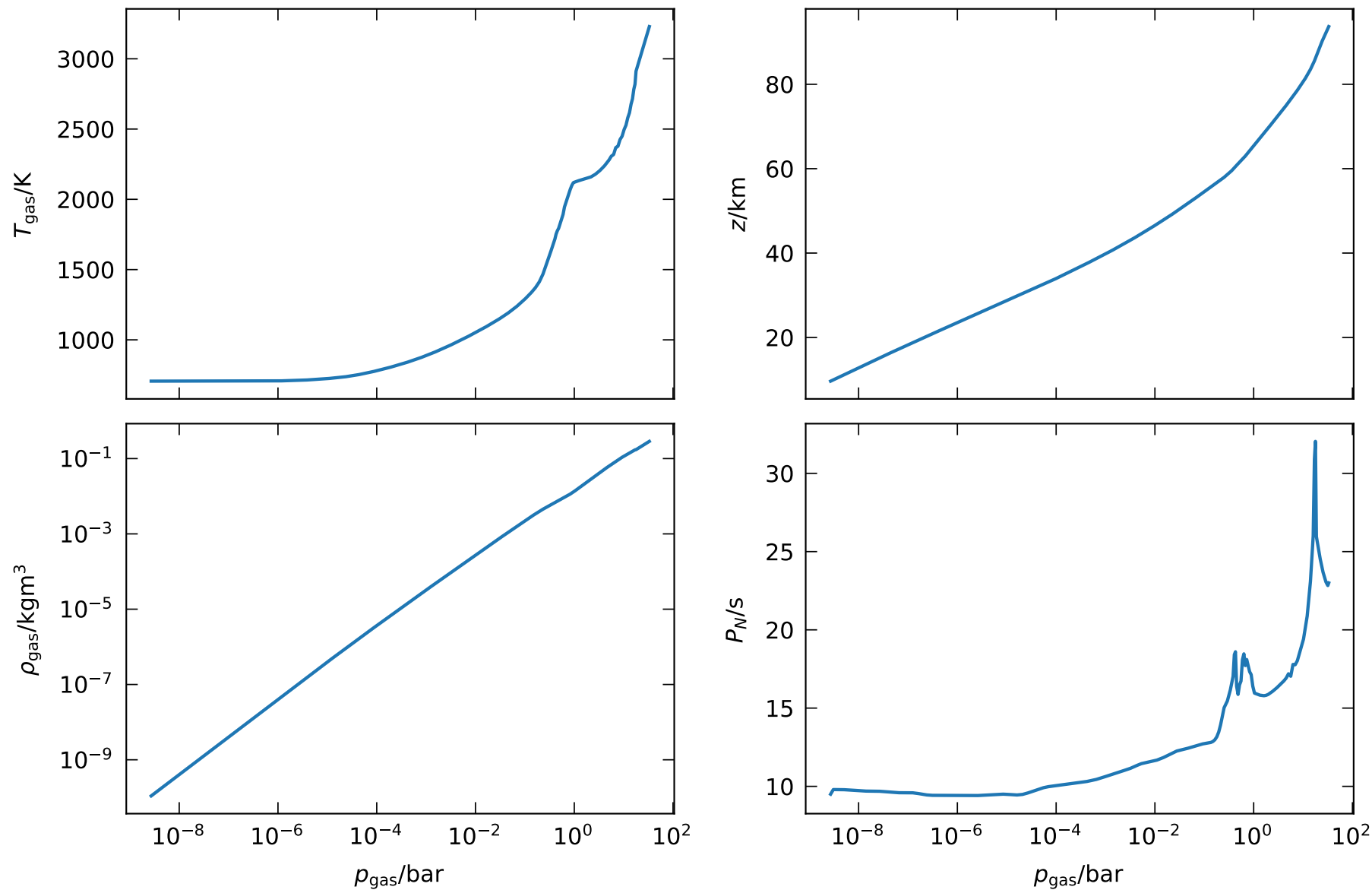
***Gravity Waves Ripple over Marine Stratocumulus Clouds***  
***NASA/GSFC/LaRC/JPL, MISR Team***



# Numerical Simulations/Methods



# Numerical Simulations/Data

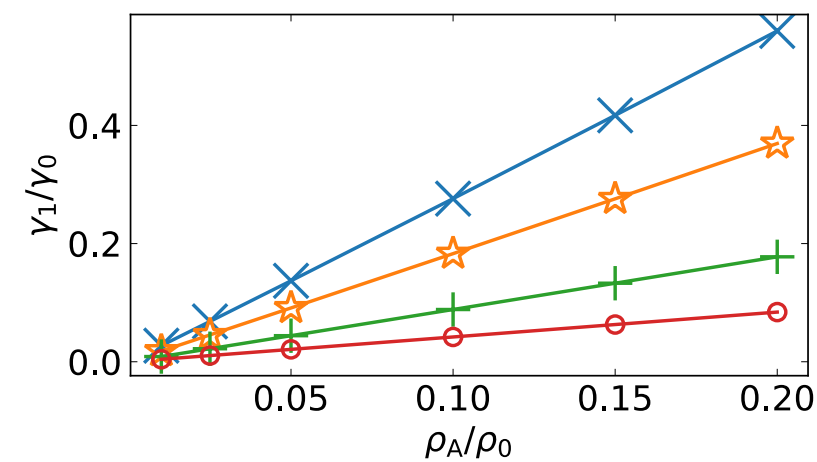
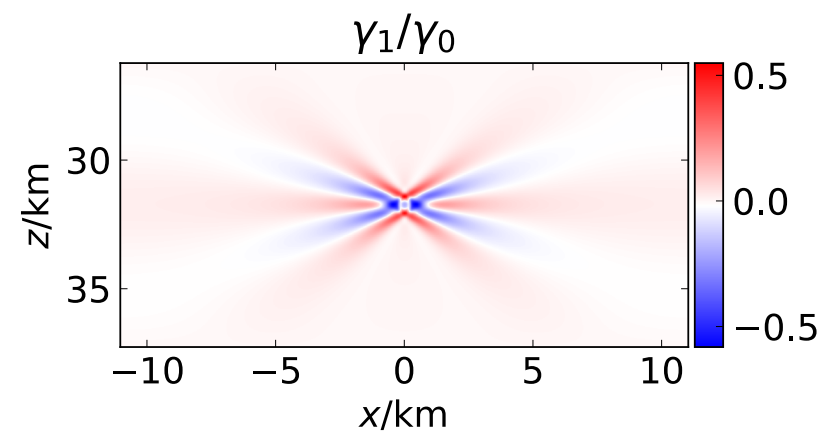
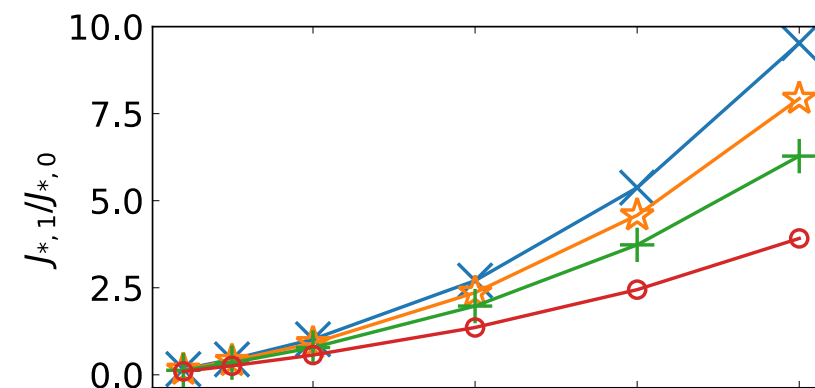
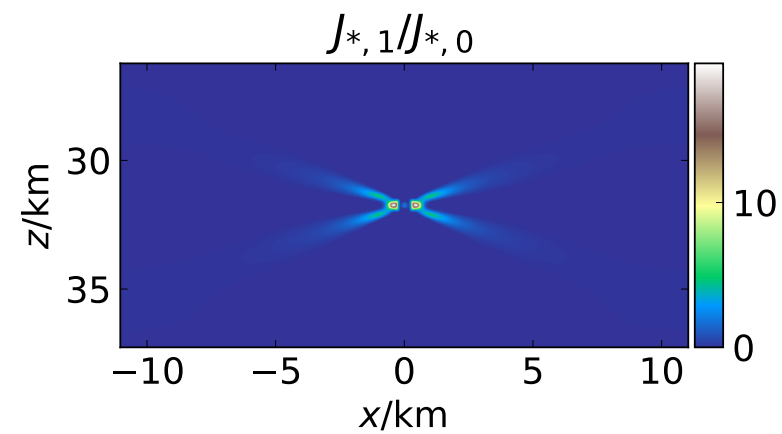
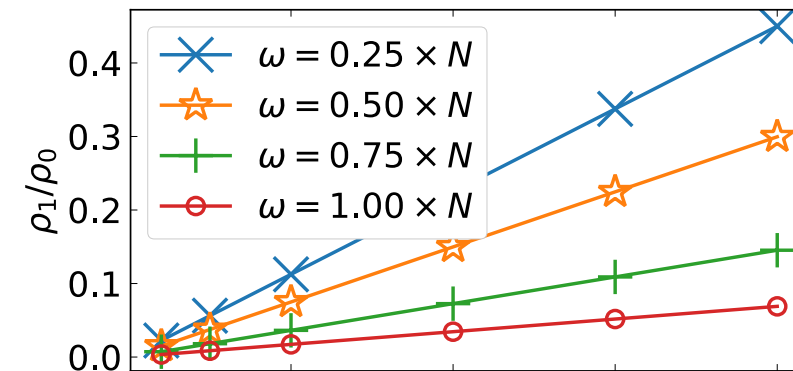
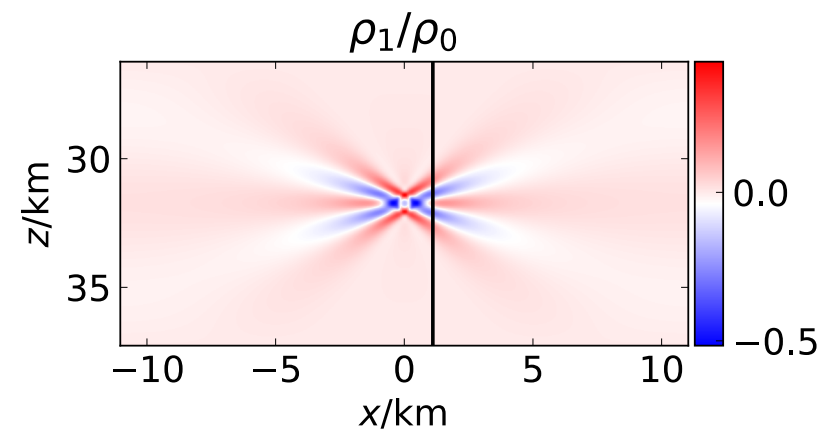


$$T_{\text{eff}} = 1500 \text{ K}, \log g = 5.0$$

(Stark+ 2013; Rodríguez-Barrera+ 2018)



# Numerical Simulations/Results



# Core Findings

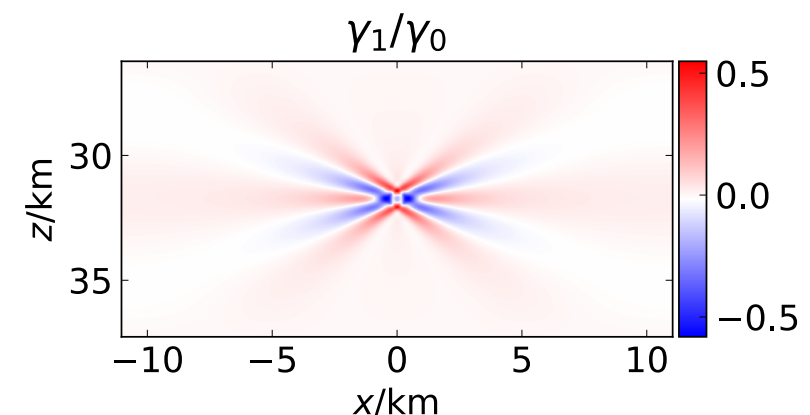
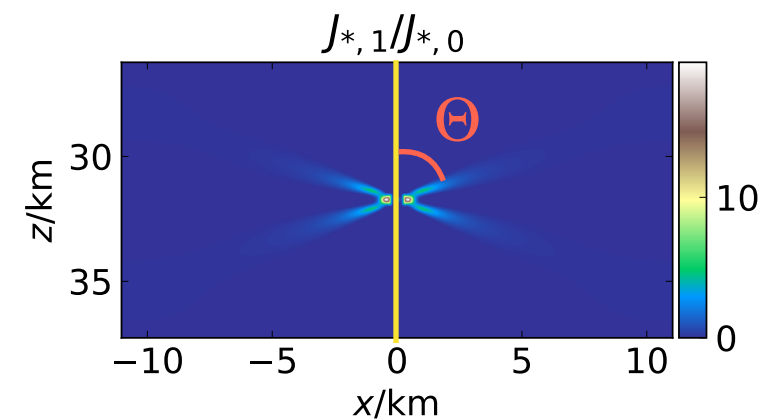
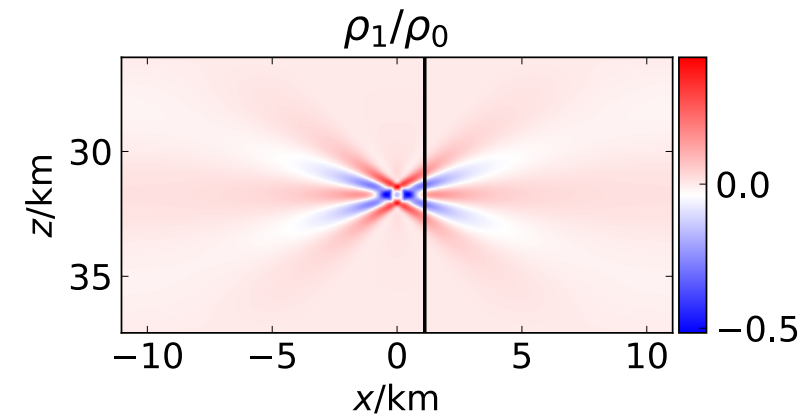
- ▶ X-shaped patterns, with banded areas of perturbed pressure, density and temperature
- ▶ Adiabatic process:
  - ▶ Lower  $\rho_{\text{gas}}, T_{\text{gas}}$  → higher  $S_x$   
→ *stronger nucleation rate*
  - ▶ Higher  $\rho_{\text{gas}}, T_{\text{gas}}$  → higher  $v_{\text{rel},x}, \rho_{\text{gas}}$   
→ *faster mantle growth*
- ▶ *Gravity waves → banded areas of faster cloud formation*

# Next Steps

*Linking (future) observable characteristics (magnitude, periodicity) to atmospheric density profile*

$$\omega^2 = -\frac{g}{\rho_0} \frac{\partial \rho_0}{\partial y} \cos^2 \Theta$$

$$\rho_0 \propto f(\Delta y, \Delta m, g, \omega, J_*)$$





***Thank you! Questions?***

@AMYINORBIT  
1303985@ABERTAY.AC.UK  
AMYPARENT.COM