Origin of the 2.17 feature on the Kepler next-neighbor period ratio diagram: Collision or Migration

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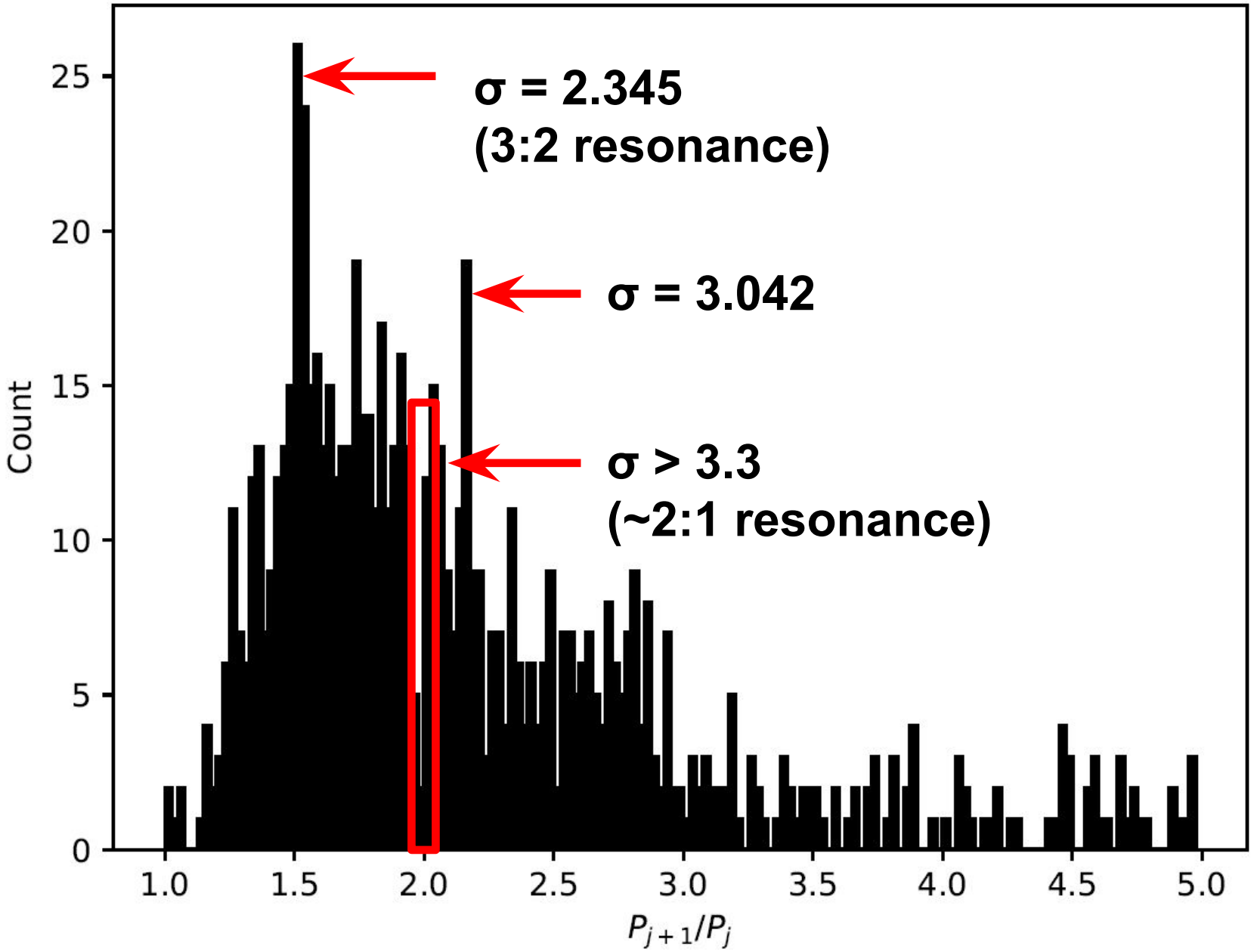
Presented at Exsocal

Significant Features



Explaining the 2.17 Feature

- Migration creates resonance systems:

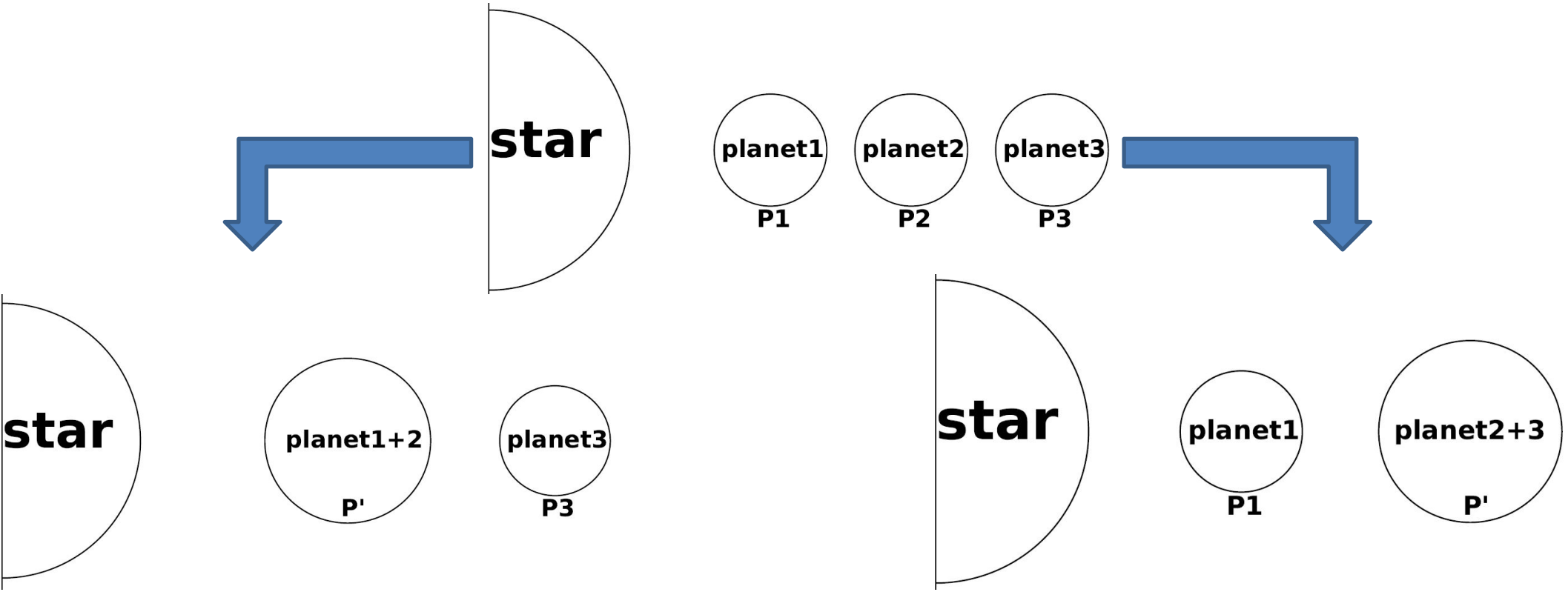
→ Possibility #1: Instabilities and Collisions

  - Instabilities predicted by resonance overlap criterions (Wisdom 1980)

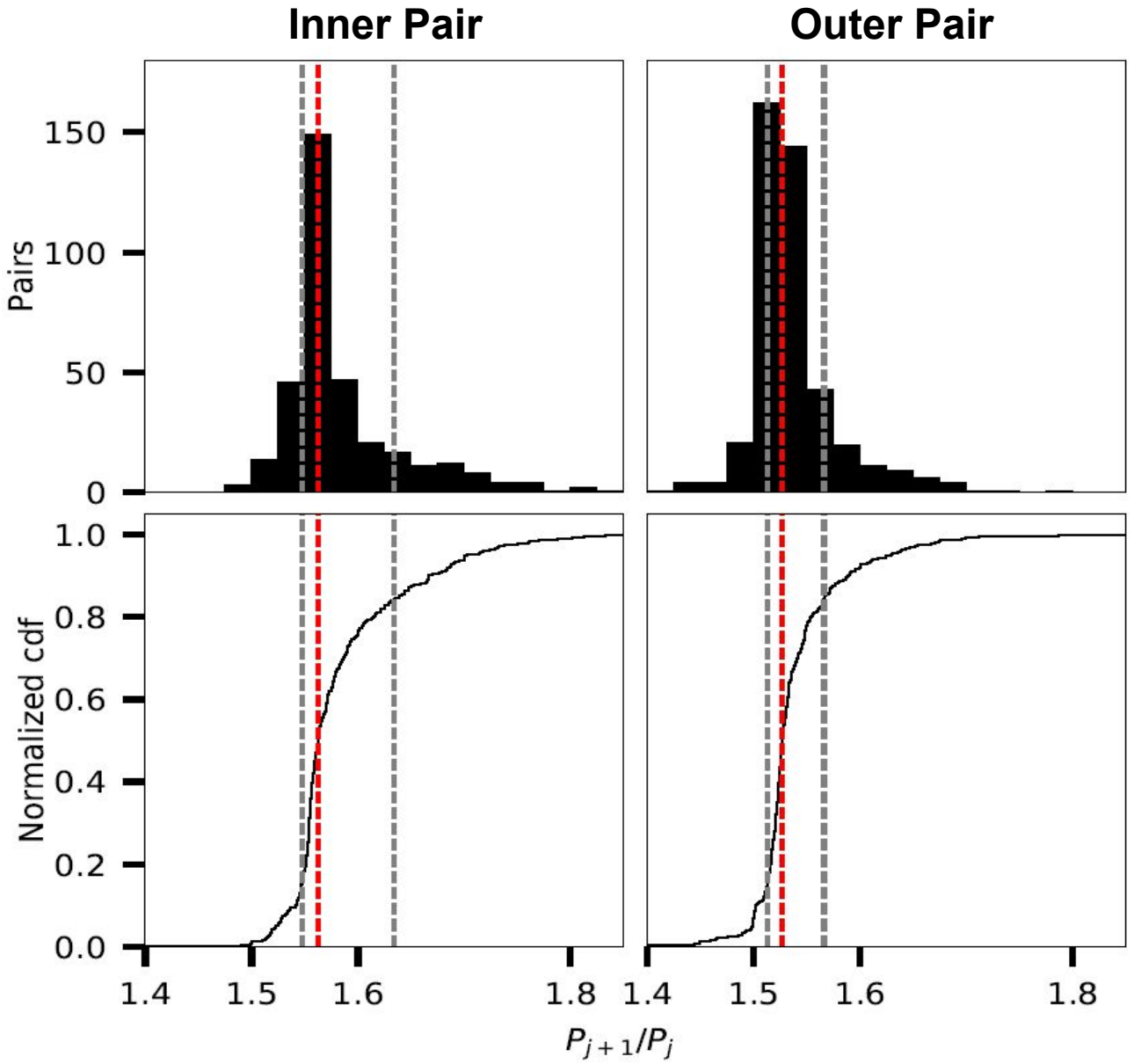
→ Possibility #2: Tidal Dissipation near disk edge

  - Secularly interacting (Greenberg and Laerhoven 2010)
  - Resonantly interacting (Batygin and Morbidelli 2012)

Collision Physical Picture:



N-Body Simulations (example): 4:3+4:3 -> 1.54



Red: median

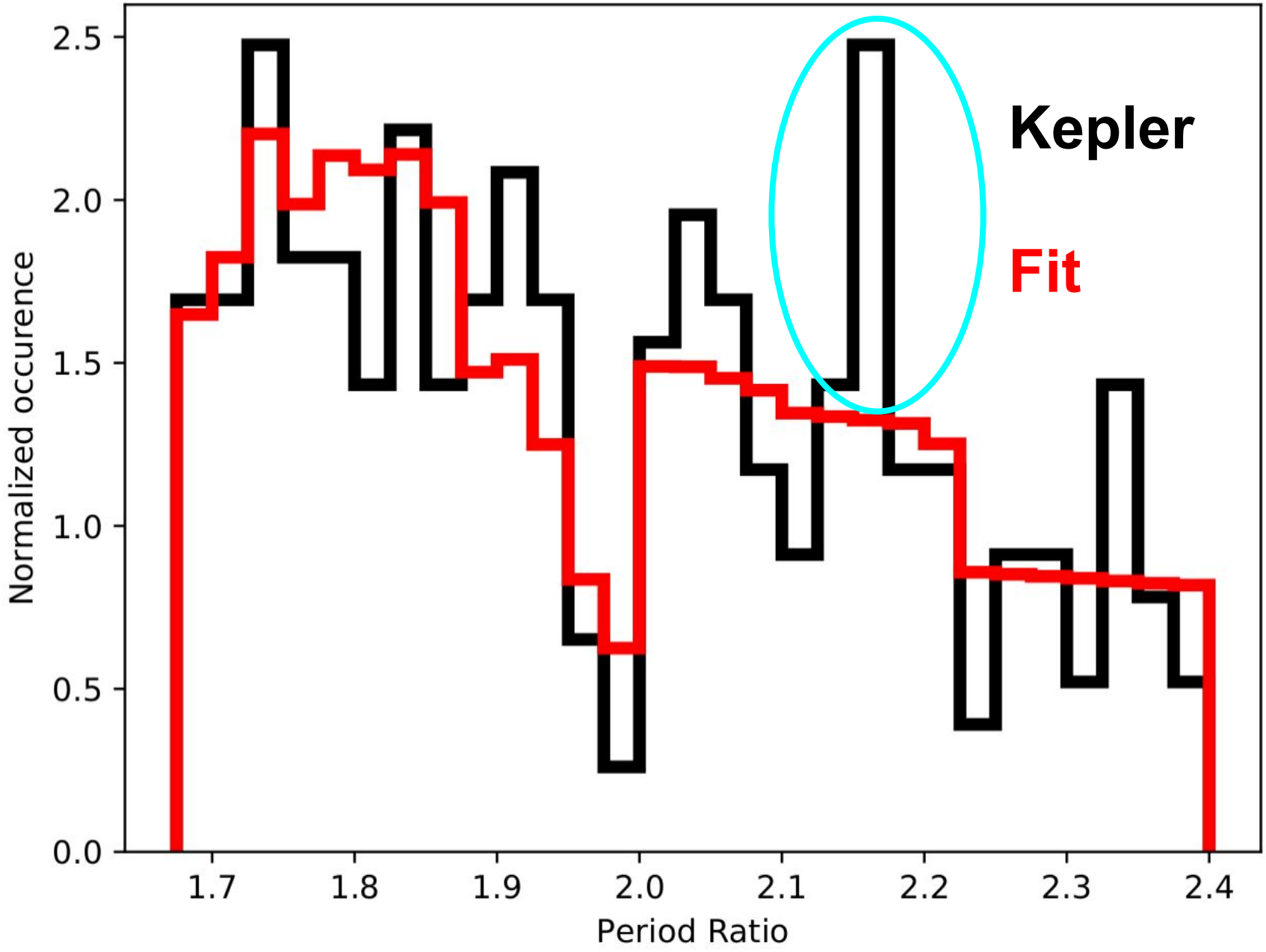
Gray: 1 sigma

A few thousands simulations later...

We have the following results:

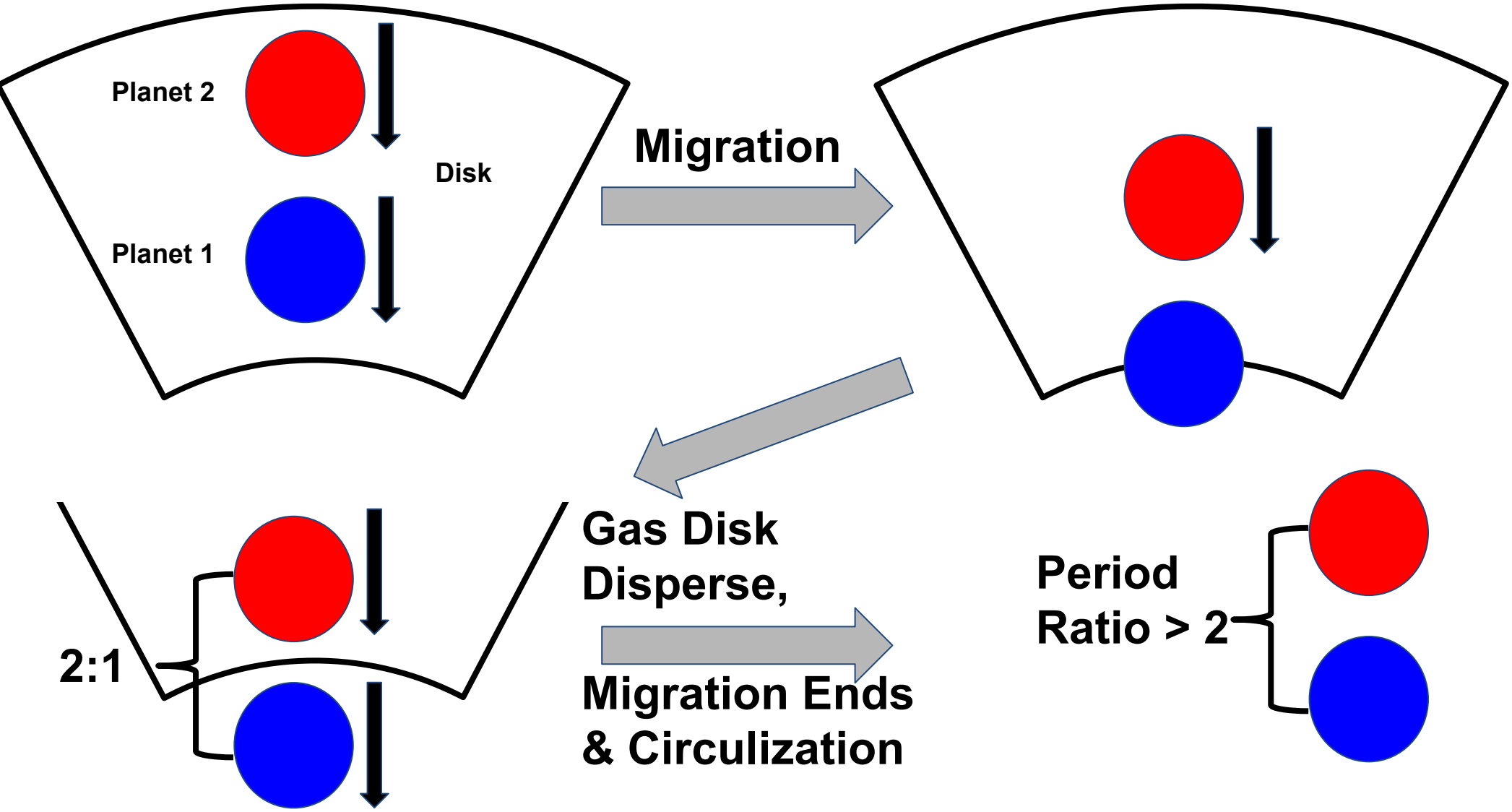
- If the pairs go unstable, features are sharp and match largely with predictions
- Instability is not guaranteed (as in the 2:1 case)
- Increase eccentricity leads to features that are much broader and do not agree with predictions

Relaxing equal mass assumption



How about migration near disk edge?

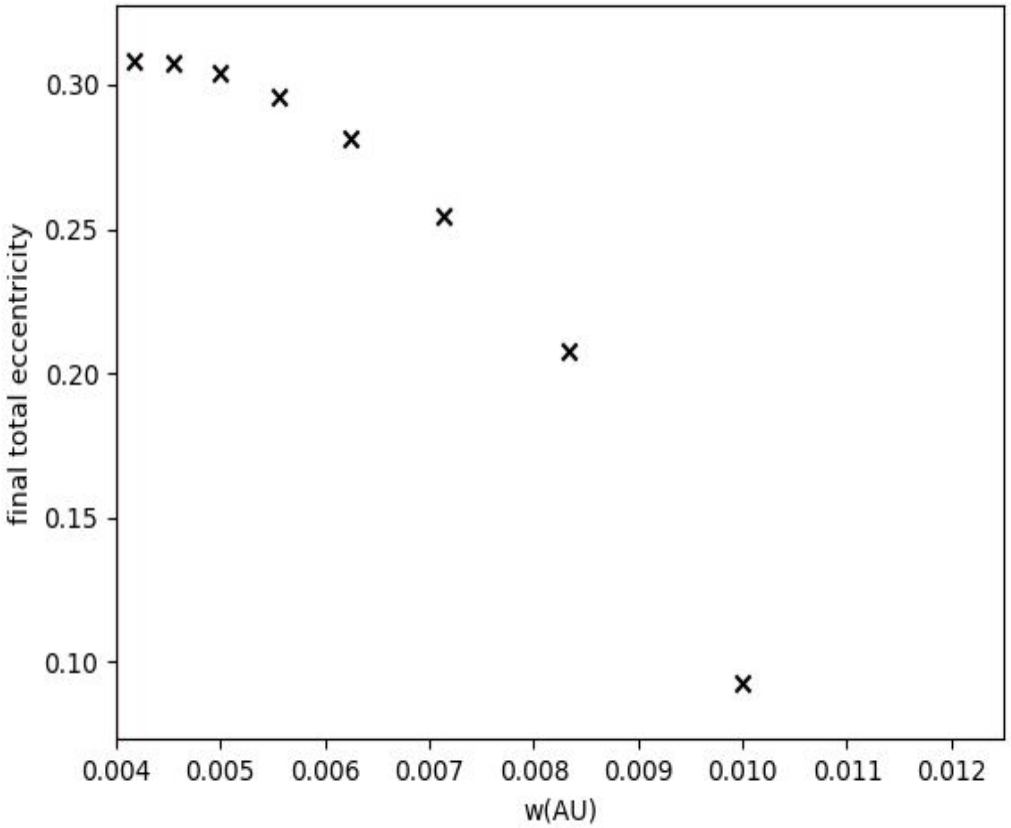
(Physical Picture)



How about migration near disk edge?

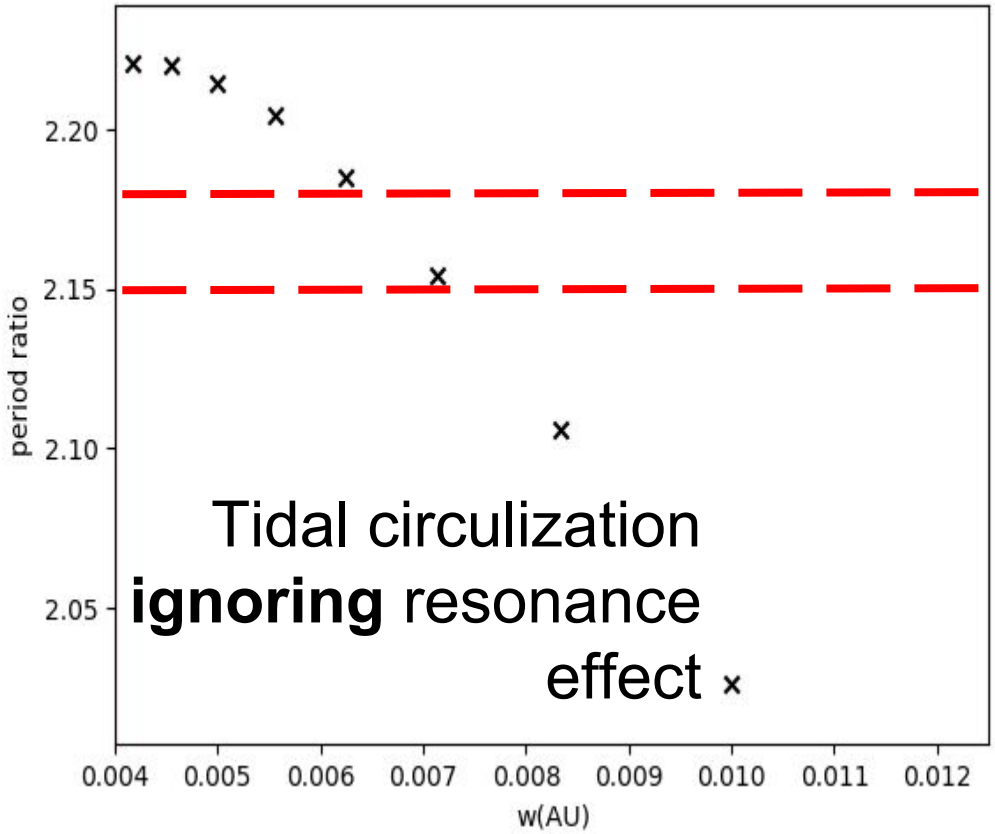
(Preliminary)

Simulation result



Prediction

(Greenberg&Van Laerhoven 2011)



Disk surface-density profile:

$$\Sigma \propto \tanh\left(\frac{r-d}{2w}\right)$$

Summary

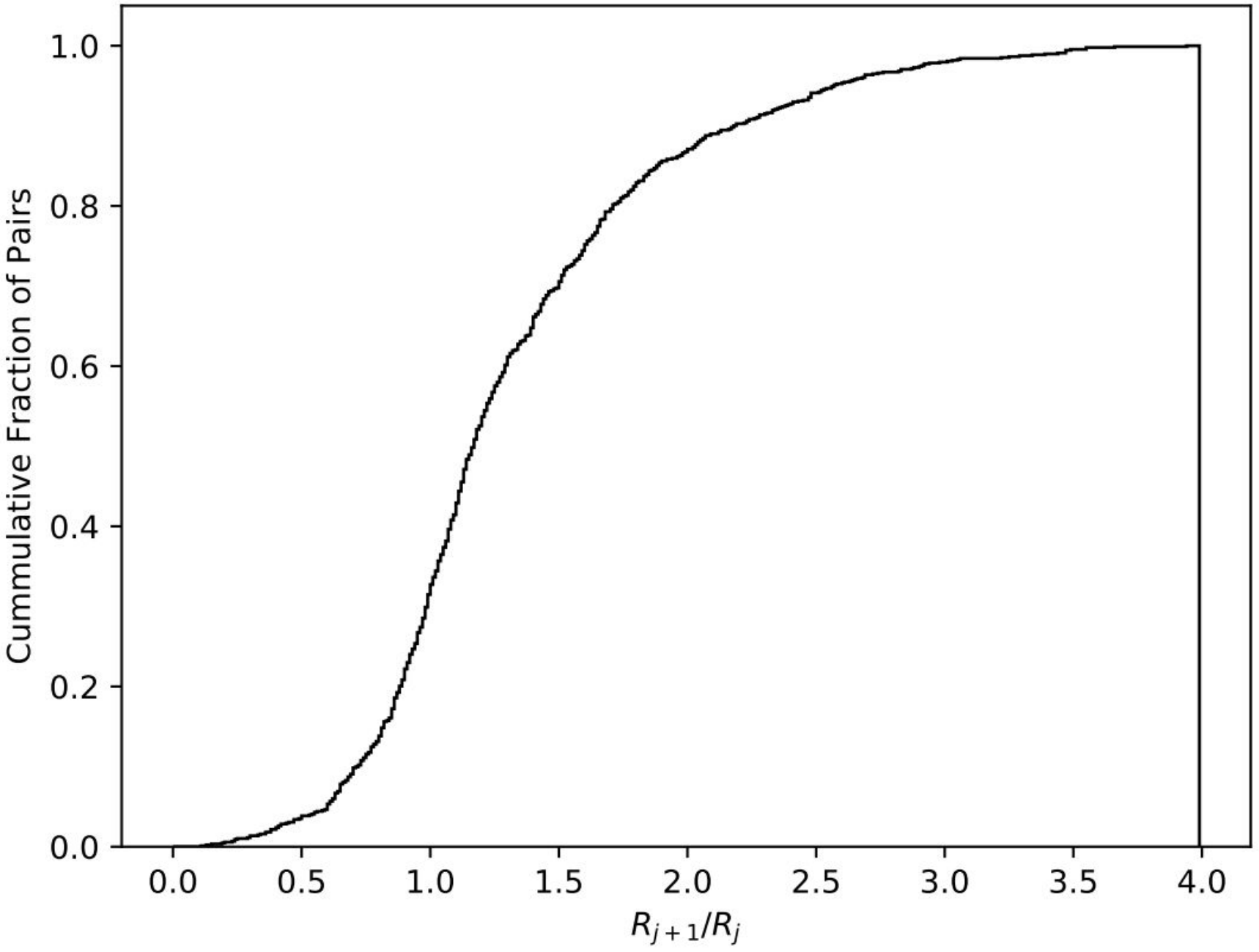
- Collision is unlikely the cause of the 2.17 significant feature
  - low ecc. systems: lack of collision
  - high ecc. systems: products shift away from prediction
  - relaxing equal mass assumption: fitting fails to form peak near 2.17
- Migration near disk edge holds promising result but would require more detailed studies

Fitting Equation and constants

$$N = C \times p^n / (A + p^m) + N_0$$

- A = 105.92269013
- n = 10.51543924
- m = 13.18190517
- C = 71.71200331
- N_0 = -0.42859534

Overall Radius Ratio



Equations for predicting collision products

$$\frac{P'}{P_1} = \frac{\left(1 + \left(P_3/P_2\right)^{1/3}\right)^3}{8} \frac{P_2}{P_1}$$

$$\frac{P_3}{P'} = \frac{8}{\left(1 + \left(P_1/P_2\right)^{1/3}\right)^3} \frac{P_3}{P_2}$$

Full collision product list

Triple	*Outcome*	*Triple*	*Outcome*
$(2:1+\underline{2:1})$	2.885	$(\underline{2:1}+2:1)$	2.772
$(2:1+\underline{3:2})$	2.466	$(\underline{2:1}+3:2)$	2.079
$(2:1+\underline{4:3})$	2.317	$(\underline{2:1}+4:3)$	1.848
$(2:1+\underline{5:4})$	2.241	$(\underline{2:1}+5:4)$	1.732
$(4:3+\underline{4:3})$	1.545	$(\underline{4:3}+4:3)$	1.534
$(4:3+\underline{2:1})$	1.924	$(\underline{4:3}+2:1)$	2.301
$(4:3+\underline{3:2})$	1.644	$(\underline{4:3}+3:2)$	1.726
$(4:3+\underline{5:4})$	1.494	$(\underline{4:3}+5:4)$	1.438

Triple	*Outcome*	*Triple*	*Outcome*
$(3:2+\underline{3:2})$	1.850	$(\underline{3:2}+3:2)$	1.825
$(3:2+\underline{2:1})$	2.164	$(\underline{3:2}+2:1)$	2.433
$(3:2+\underline{4:3})$	1.738	$(\underline{3:2}+4:3)$	1.622
$(3:2+\underline{5:4})$	1.681	$(\underline{3:2}+5:4)$	1.521
$(5:4+\underline{5:4})$	1.400	$(\underline{5:4}+5:4)$	1.394
$(5:4+\underline{2:1})$	1.803	$(\underline{5:4}+2:1)$	2.231
$(5:4+\underline{3:2})$	1.541	$(\underline{5:4}+3:2)$	1.674
$(5:4+\underline{4:3})$	1.448	$(\underline{5:4}+4:3)$	1.488

Collision Products Predictions:

(Equal Mass)

Combinations (P2/P1+P3/P2)	Outcome (P3/P' or P'/P1)
(4 : 3 + 4 : 3)	1.545
(4 : 3 + 4 : 3)	1.534
(3 : 2 + 2 : 1)	2.164
(3 : 2 + 2 : 1)	2.433

- Underlined resonances denotes the pair going unstable
- Only relevant combinations are listed