Understanding Planet Formation: Initial Disk Distribution

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Effects of Disk Density Profile on Planet Orbital Distribution

Disparity due to disk structure?

https://www.nasa.gov/
(Lissauer et al. 2011)
What do we expect?

Steeper Density Slope

Increase in # of Closer Planets

How do we check?

Vary Density Slope

\[ \sum_g \propto f_g r^{p_g} \exp[-r^{2+p_g}] \]

<table>
<thead>
<tr>
<th>Power Law Index</th>
<th>Migration On</th>
<th>Migration Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.5</td>
<td>1.2e-231</td>
<td>1.4e-232</td>
</tr>
<tr>
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<td>1.4e-178</td>
<td>1.4e-232</td>
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<tr>
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<td>6.6e-156</td>
<td>1.4e-232</td>
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<td>1.4e-232</td>
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<tr>
<td>-2.5</td>
<td>7.0e-182</td>
<td>1.4e-232</td>
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</tbody>
</table>
Simulations show...

**DENSITY SLOPE ITERATION**
**WITH NO MIGRATION**

**DENSITY SLOPE ITERATION**
**WITH LIMITED MIGRATION**
Simulations show...

DENSITY SLOPE ITERATION WITH NO MIGRATION

DENSITY SLOPE ITERATION WITH LIMITED MIGRATION
Comparing with Observations...

**DENSITY SLOPE ITERATION WITH NO MIGRATION**

**DENSITY SLOPE ITERATION WITH LIMITED MIGRATION**
Method-Specific Comparisons: 

![Graph showing Kepler Planets](image1)

![Graph showing Radial-Velocity Planets](image2)

\[
surface\ density = C \ r^{-1.5}; \text{ limited migration on}\]

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What do we expect?

Larger Scaling Factor (Total Disk Mass)

More large, close-in planets

How do we check?

Vary Normalization Constant

\[ \Sigma_g \propto f_g r^{p_g} \exp[-r^2 + p_g] \]

<table>
<thead>
<tr>
<th>Scaling Factor ( f_g )</th>
<th>Migration On</th>
<th>Migration Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
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<td>9.7e-236</td>
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<td>5.0</td>
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<tr>
<td>10.0</td>
<td>0.0</td>
<td>9.7e-236</td>
</tr>
</tbody>
</table>

* \( p_g = 1.5 \)
Simulations show...

**DISK MASS ITERATION WITH NO MIGRATION**

**DISK MASS ITERATION WITH (FULL) MIGRATION**
Simulations show…

**DISK MASS ITERATION WITH NO MIGRATION**  **DISK MASS ITERATION WITH (FULL) MIGRATION**
Comparing with observations…

**Disk Mass Iteration with No Migration**

**Disk Mass Iteration with (Full) Migration**

[Graphs showing the comparison between migration off and migration on.]
Method-Specific Comparisons:

Kepler Planets

Radial-Velocity Planets

MMSN disk; migration on full
Conclusions

Interesting way to see how the different physical processes interact with each other . . .

Some trends:
- Steeper disk slope -> more close-in planets
- Steeper disk slope -> more small planets
- Higher disk mass, no migration -> fewer small planets
- Higher disk mass, with migration -> lack of Jupiters

None of these match observations very well, especially super-Earth population . . . so lots of work for all of us to do!!
Acknowledgements

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