disk evolution at 1 Myr: dust settling?

“normal” disk

flat disk: \( \tilde{F} \sim \frac{1}{r^{4/3}} \)

disk evolution at 1 Myr: inner disk holes

\( \sim \) 5% of all disks

\( \sim \) grain growth? planet formation?

as in CoKu Tau/4, TW Hya

"normal" disk
brown dwarfs

- $M \sim 0.075 \, M_{\odot}$
- $t \sim 1-3 \, \text{Myr}$
- disk models require $R_{\text{in}} \sim 0.5 - 1 \, \text{AU}$
  - strong limits on formation mechanisms: no accretion; photoevaporation unlikely
  - if planet, $M \sim 2-20 \, M_{\text{Earth}}$

---

age trend?

<table>
<thead>
<tr>
<th>Region</th>
<th>Age (Myr)</th>
<th>Fraction of disks with holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGC 1333</td>
<td>&lt;1</td>
<td>1/66 (1%)</td>
</tr>
<tr>
<td>Ophiuchus</td>
<td>1</td>
<td>1/70 (1%)</td>
</tr>
<tr>
<td>NGC 2068/2071</td>
<td>1</td>
<td>8/174 (5%)</td>
</tr>
<tr>
<td>IC 348</td>
<td>1-3</td>
<td>10/75 (13%)</td>
</tr>
<tr>
<td>Orion OB1b</td>
<td>3-5</td>
<td>~14%</td>
</tr>
<tr>
<td>Orion OB1a</td>
<td>10</td>
<td>~6%</td>
</tr>
</tbody>
</table>
Embedded protostars: HH 24 region

IRAC 3.6, 4.5, 8 microns
MIPS 70 microns
SCUBA 850 microns

A puzzle – disk gaps??

NGC 2068 H9

NGC 2068 H13
Debris disks in open clusters

- 24 micron excesses in the Pleiades (100 Myr):
  - 9/28 B9-A9 (30%)
  - 7/33 G0-K0 (20%)
- Similar results for A stars from other clusters, field stars at similar ages
- Upper envelope decreases exponentially as a function of age
- Possible discrepancy in IC 2391 (~30 Myr), only 1/15 A-stars (7%) shows excess