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"The document" is @:

https://goo.gl/ZX1kgQ

Many unsolved ("unresolved")

problems in disks

Discussion session @ SPF2 3/13/18
Moderators: Jim Stone & Jonathan Williams

1. Do all disks have rings?
   ---Probably (at least Class II, maybe class I), but ALMA may not be able to image them all.
   ---Yes, all disks with mm size dust have rings ;-)

---Yes. If the gap is opened by X-ray photoevaporation (Owen's model of X-ray photoevaporation).
---Probably yes because if HL Tau has rings and it looks spectroscopically like a Class I (rapid rotation, high veiling) then it is likely fairly young and it is striking that rings have already formed… so it's likely that by the time you can see a disk and image it with ALMA you are likely to have structure already -- probably the disk shaping and evolution begins very early -- the planet formation, too!
---But have we observed the precursors of the 'boring' compact disks in Lupus in Class I? The sample so far seems to be focused on large, bright continuum objects, which *may* be different from early times (Class I/0?)
--Time will tell, but we have only looked at the big, bright disks so far. What if they are the outliers and most disks are small because rings (pressure bumps) don't stop dust drift?

2. And spirals? Why spirals?

(maybe specify Class 1, 2 vs gas poor debris disks? Gas disks.)

   a. Probably planets
      i. But how many?
   b. This may be a very wavelength-dependent question. In mm, probably not always. (But resolution has been a limit so far)
   c. When the disc is massive it could be self-gravity
   d. Giant planet gas accretion
      i. Spirals in CPDs?
   e. Large m=2 spirals are probably induced externally
      i. No, GI can give m=2 as well -> well said
   f. Are they related to shadowing from misaligned inner/outer disks? - seen to be launched near shadowed points in several disks
      i. How open are those spirals?

            1. pitch angle \propto H/R (assuming they are pressure supported waves in the linear theory: planet mass << thermal mass)
                a. Cannot imagine the force or torque due to pressure/temperature gradient can be as strong as that of a planet..
        ii. Does it match observation? A subsample
    g. Binaries or close encounter with another star
    h. Does it last long enough to see?
        i. Spirals are less frequently detected than rings
    i. Flyby
        i. Are there any kinematic signatures showing the disk has gone some tidal encounter?
            1. This is been discussed for some strongly asymmetric debris disks (e.g., HD 15515, see Kalas et al. 2015, https://arxiv.org/pdf/0704.0645.pdf)
            2. The model of Larwood & Kalas (2001) involves a perturber capturing disk material and producing asymmetric tail of escaping material
    j. Besides GI and externally excited spirals, there are also instabilities / stable modes associated with gravitational stable disks (Q>1):
        i. One arm:
            1. SLING instability (Adams, Ruden & Shu 1989, Shu+ 1990)
            2. Nonlinear one-arm spiral (E. Lee and J. Goodman, 1999)
            3. Trapped one-arm spiral (Lin 2015), see also Lee's poster at 1300
        ii. Unstable m=2 modes (Laughlin+ 1996, 97)
    k. Vortex..

3. How does structure evolve?
   ---From rings to gaps = accretion to planets
   ---How much do we need to be worried about Class I TD-detection in this context? Seems to imply TDs are a special kind of evolution
   --What do simulations show?

4. Are transition disks “just” circumbinary disks?
   Vote:

Yes	- 3
Probably	- 1
Probably not	- 4
No	- 12

---No, I don’t think so, there are evidence for transition discs around single star.
---If this were true, then we should see the incidence of transition disks change as a function of mass with the multiplicity fraction of the stars (more transition disks around higher mass stars, modulo typical binary separations w/different stellar masses) --- Not really - the companion occurrence rate per (log) bin of semimajor axis isn't really that variable with mass. The declining binary fraction with declining mass is because wider binaries are less common at lower masses.
---No, as the cavities are sufficiently large that near-IR imaging should be able to detect a second stellar component. The central holes are comparable in size to the solar system interior to Neptune. So we may seeing the initial state of the Kuiper Belt region.
---There are known binaries within some large TD holes but these stellar binaries seem insufficient to create the large holes. Multiple planets could work.
---^Also companions on inclined orbits, and large eccentricities would change the projected distance from the central object. In fact this implies that you are not anyway able to exclude the presence of a companion.

--- Anyway, I think that we do not really need a unique mechanism to form cavities. Some of them might be due to companions others need different mechanisms.

a. But how complete are the surveys to look for binaries?
   ---Can NIR detect brown dwarfs and fainter objects? Yes, especially for young systems like these. 1 MJup objects can be detected if the host is bright enough for AO. *Do you mean 10 MJup?*
   ---What about the distance they have from the main object? I mean what is the minimum distance at which you would be able to detect them.
   If we defined the cavity size from the mm/submm images, the substellar object will be ~0.2 arcsec from the star and can be resolved from the star. But if you define size from the SED, then the answer is no because the holes in the SED correspond to just a few AU (~0.03 arcsec for nearby SFR)

Perhaps H-alpha emission from accreting planet will help in this case? If we can get it, but visible AO is hard ...

Class I!!

If we include ‘pre-transition disks’ then no - we have evidence for these objects around single stars

We need to reconsider what we mean by transition disk. Transition to what ? I think this is transition out of the protoplanetary phase to the debris disk phase. This means transition from fractional IR luminosities of 10-20% to 0.1%. In terms of fractional IR luminosity, our current “transition disks” have the same values as protoplanetary disks … no difference. An actual transition disk is going to be something with a fractional IR luminosity of 1% or so. Example: HD 141569A. For reference, beta Pic is 0.2%.

- And some sources have variable inner disks, which complicates this further

What if they were binary systems once, and have since become single stars surrounded by a disc?

The reality is that there are quite a few circumbinary disks. If people knew about the binary before the gap, it never became a transitional disk and people mostly avoided observing it because binaries are annoying. If they called it a transitional disk and then found the binary, it's a binary transitional disk.

I meant, what if the system physically changed? Not so much how we classify it. It literally was once a binary system, and somehow become a single-star system. *How?*

Could the disk push the binary together? Only a very massive and viscous disk could exert enough torque but I don't know the numbers...

5. What is the role of FU Ori outbursts in disk evolution? How many discs have these outbursts? Is it a rare thing?
   ---Variation (x a few - 10) is probably not rare, but extreme FU Ori type events (x 100) likely are.
   ---It's not clear if all protostars undergo an FU Ori type event. Chemistry (e.g. gas phase CO in dense gas) indicates many/most undergo some type of luminosity variation.

6. Are there any estimates of pressure temperature spikes during the FU Orionis outbursts? If we were to look for evidence for FU orionis outbursts in our own early solar system objects (in chondritic materials) , what should we look for?
   -- Cieza et al. 2017 mapped the disk around V883 Ori and found it had raised the temperature of the disk to above 100K out to 40au (or suggested it had based on a change in the grain opacity there, presumably due to loss of water ice mantles)

7. What is the role of turbulence vs disk winds for driving accretion? How well do we know the ionization fraction in disks?
   Anyone??
   Bueller?

   

8. How can we measure the properties of the inner disk and constrain models of in situ planet formation?
    a. What properties do we want to measure?

   Inner disk surface densities need to be very high for in situ formation. Planet-disk interactions.

   Can we measure surface densities at scales less than 1 au where Kepler exoplanets are detected?

   It's tricky since the dust there is very optically thick; as for the gas, similar issues to gas at larger radii: 12CO is usually optically thick in the inner disk. (But even if you have an optically thin gas line you will not be able to see through the dust to below the disk atmosphere, since the dust opacity reaches 1 very high up in the disk. An exception would be for transitional disks, which can be optically thin in the vertical direction in the near-IR)

   What is the inner disk? 1au , 10au?
   = within the water snowline

   The "inner disk" to me would be well within 1 au. Actually, I guess it depends on the relative size of the disk… so… more generally, it would be where disk-locking is still the mechanism for modulating the disk's orbital (rotational?) speed?

   Molecular line observations other than CO

^ Building off of the above point, the “Snow Line” we’ve been talking about seems to exclusively refer to the CO snow line.
^^ why?

Is there a better molecular tracer for planet formation?
Water snowline but this is much closer to the star.
Should we look at the bigger Herbig disks?
The water snowline location has been measured for a few disks with IR spectroscopy (Zhang et al., Blevins et al.).

9. I would naively expect external and internal angular momentum dissipation mechanisms to predict quite different vertical temperature structures in the disk. Is this true? Is this detectable?
    a. Can you clarify external vs internal? e.g., shock/damping of a spiral wave?

10. I personally don’t but do you have a problem with having a low viscosity, say alpha of 1.0e-4? If you do, what kind of problem?
    -- With an alpha of 10^-4 it becomes very difficult to explain mass accretion rate observations.
    ^ It is actually not. At 1 au, 10^-8 msun/yr can be met with surface density of 10^4 g/cm^2, which is a factor of ~10 larger than the *minumum* mass solar nebula density.
11. What drives accretion in Class 0/I phase? I’d give some credit to GI but what about MHD winds, VSI, etc?
    VSI probably too weak during high accretion rate phase. Also unlikely to operate in entire disk, so needs help from other mechanisms in inner (maybe outer) disks.

Feedback Section:

I really liked this discussion format!
^ same here, it helped me to ask questions that I’d be too intimidated to ask in front of a more experienced audience.
Great and amazing source

Worked well to invite participation, then hide the doc for a while for some verbal conversation, then come back to the doc after folks had a chance to contribute

I appreciated this format for discussion because I have not yet built the courage to speak up in large audiences, especially in a professional setting. Although this format was slightly chaotic, it was really interesting to see the live responses unfold. Thanks!

JPW: Thanks everyone who participated! I’ll keep checking throughout the rest of the week for any updates.

Gender Proposal studies and increasing diversity

Here are the links to those gender/proposal studies discussed yesterday. NRAO and ALMA are in one study.

Also, people may be interested in an NRAO program which aims in increase diversity
by working with students from undergraduate through graduate school. I only heard about
this program recently but this is an excellent program and I’d encourage people to direct

students to it as appropriate.

https://arxiv.org/ftp/arxiv/papers/1409/1409.3528.pdf

https://science.nrao.edu/science/reports/gender-related-systematics-final-paper

https://science.nrao.edu/opportunities/student-programs/nac/goals