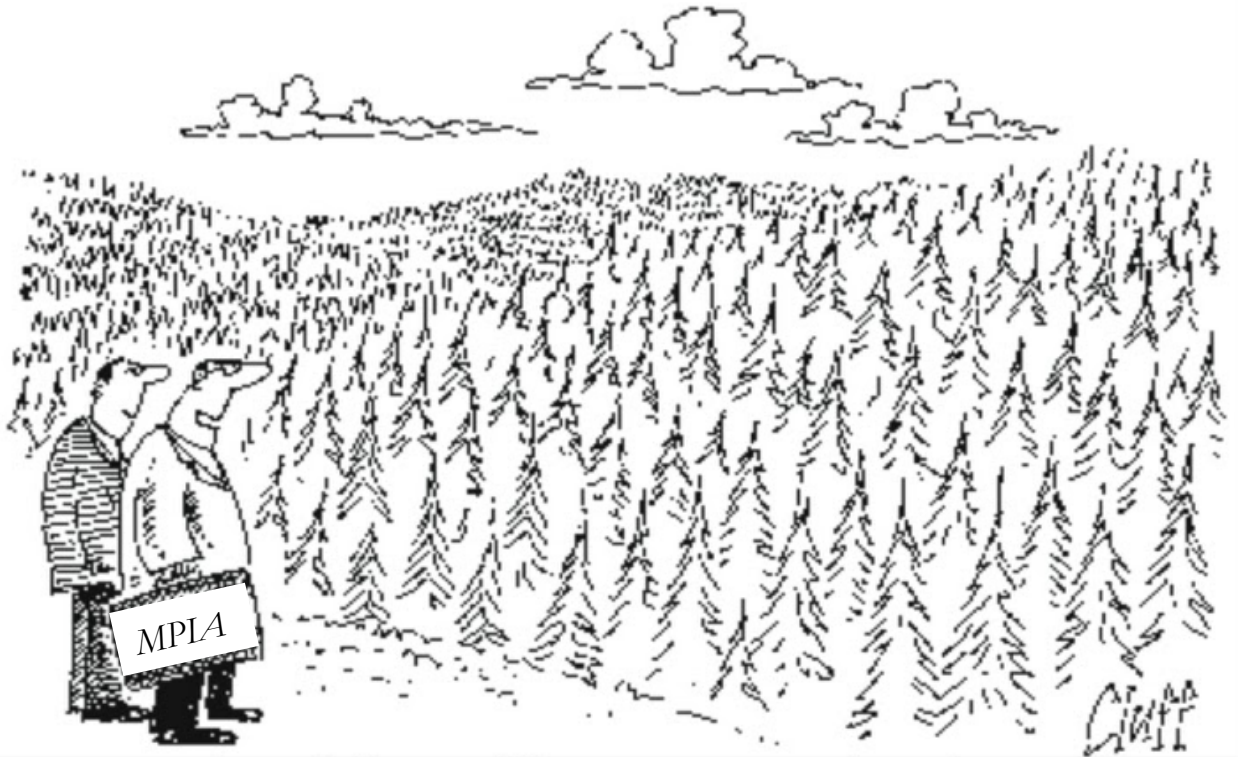
Munich 2012



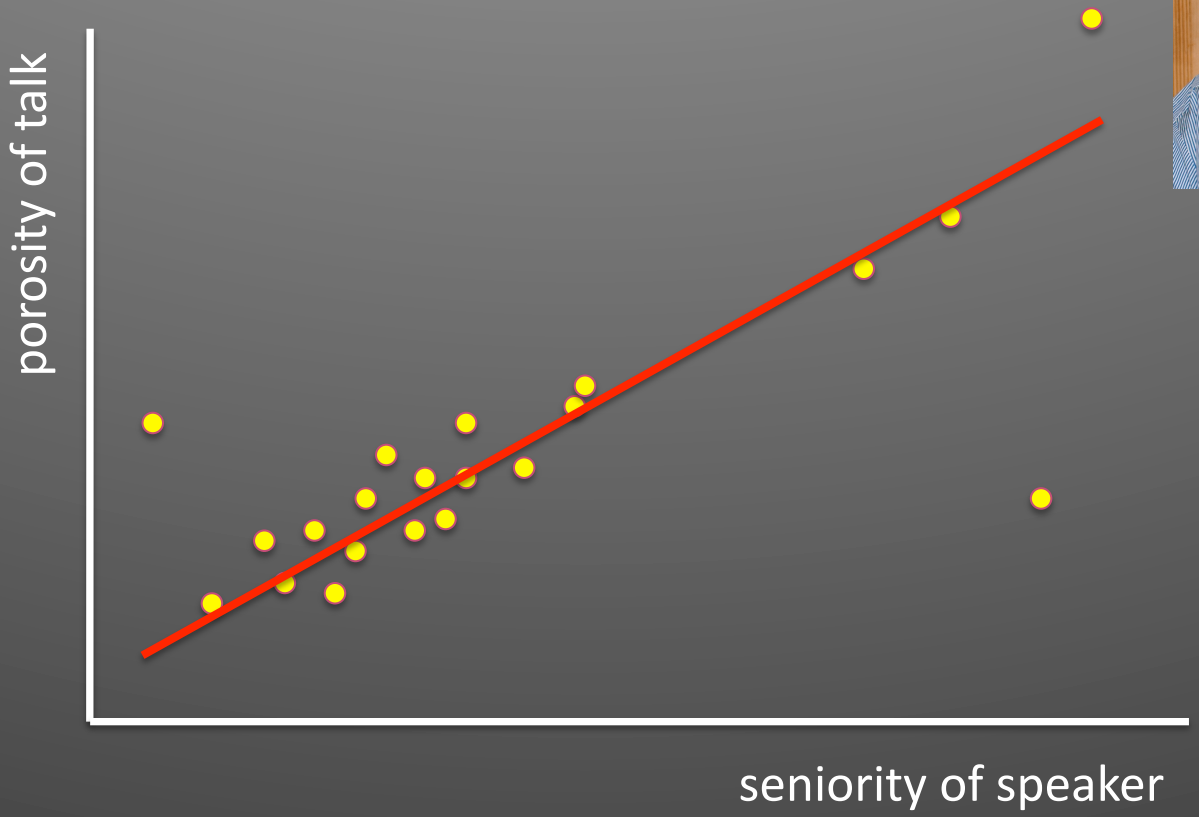
One day all these will be papers on planetesimal formation

Phil Armitage

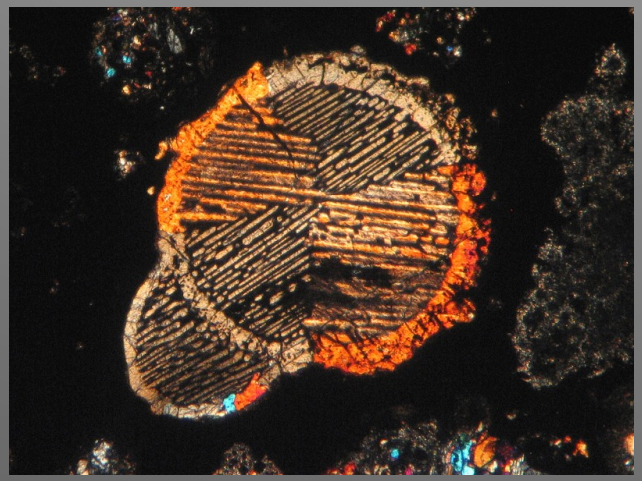
Colorado

- Chondrules & planetesimals
- Transition disks
- Planets
- Problems solved
- Problems created
- Novel ideas

A new correlation in exoplanet science



Solar System and planetesimals…



Almost directly inferred density ~close to self-gravitating conditions (Trieloff)

"Chondrules are formed by the chondrule forming process"

THE FORMATION OF PLANETESIMALS*

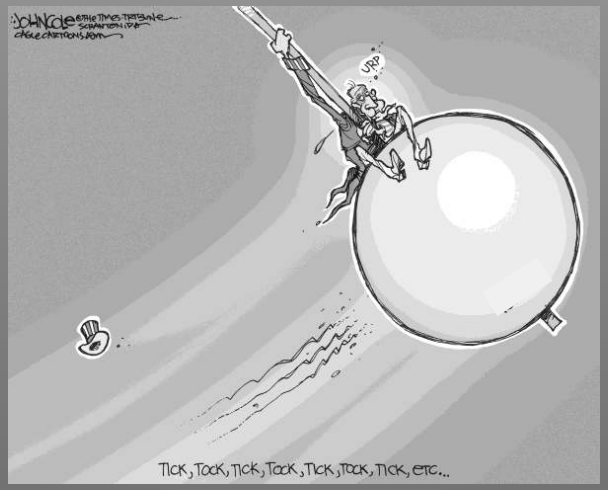
PETER GOLDREICH AND WILLIAM R. WARD
California Institute of Technology, Pasadena
Received 1972 November 20

"Planetesimals are formed by the planetesimal forming process"

Substantial lab and model-building progress!

Planetesimal formation

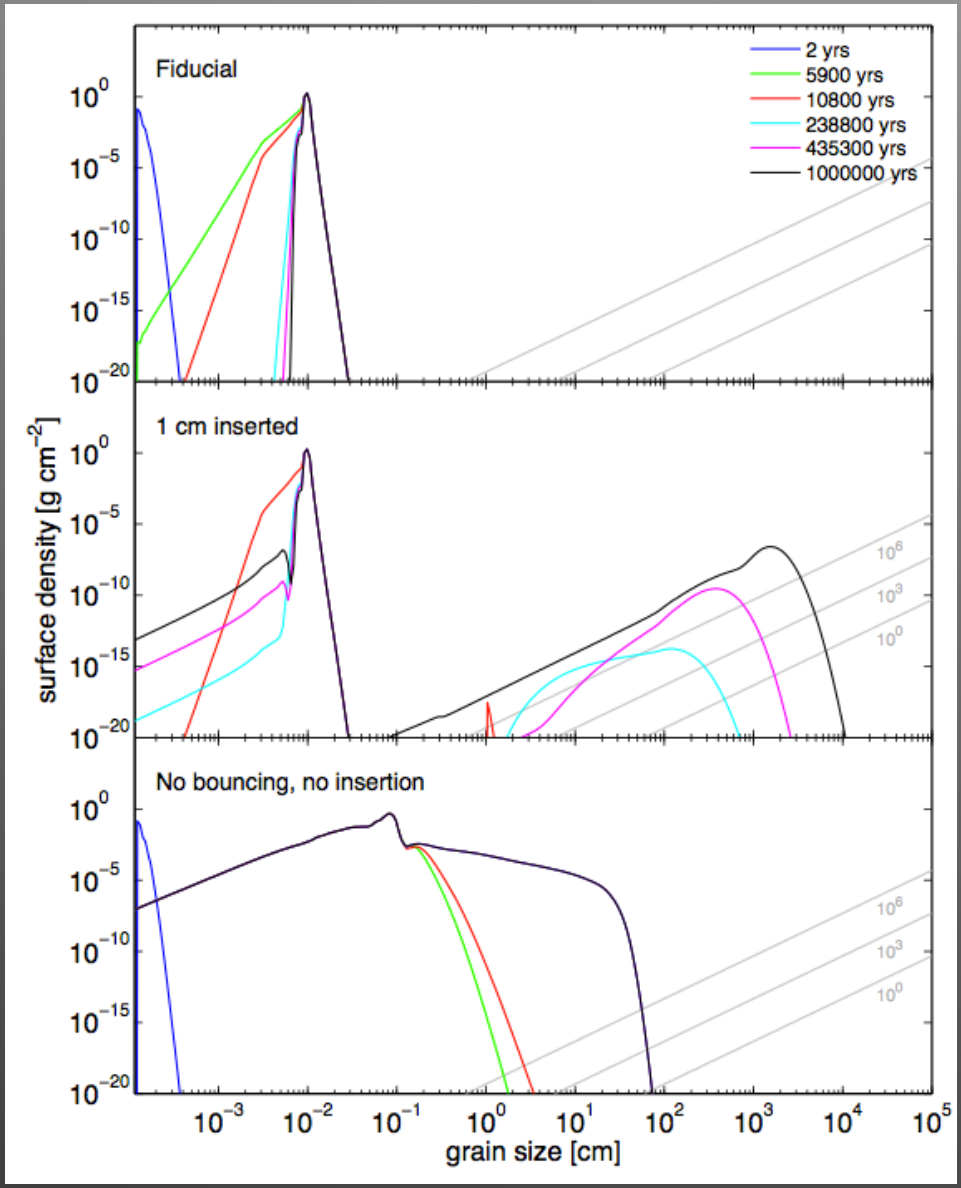
Collective instabilities



Coagulation models

- Smooth sticking / bouncing transition (Weidling, Blum)
- Dust-coated "chondrules" stick easily (Beitz)
- (small) agglomerates form at 50 ms^{-1} (Meisner)
- Ice very likely stickier than silicates (Tanaka)
- *very* low porosity growth (Okuzumi)

s > 1 mm by new collision model; sweep-up (cm seeds); velocity distribution (Guttler, Windmark +++)



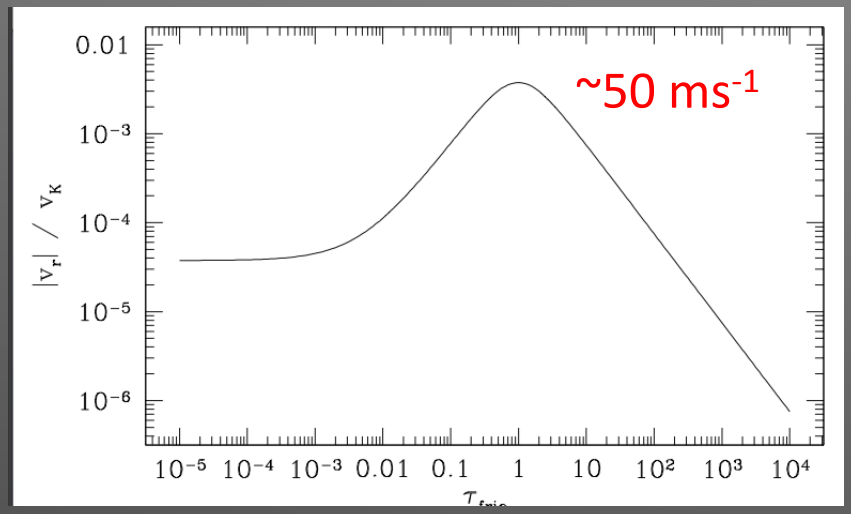
Windmark et al. (2012)

Opens new possibilities: episodic accretion ubiquitous (Wasson, Thies, Banzatti); shocks may sweep inner disk, forming seeds?

Observational tests: ALMA observations and transitional disks (Birnstiel, Ricci, Carpenter, Testi)

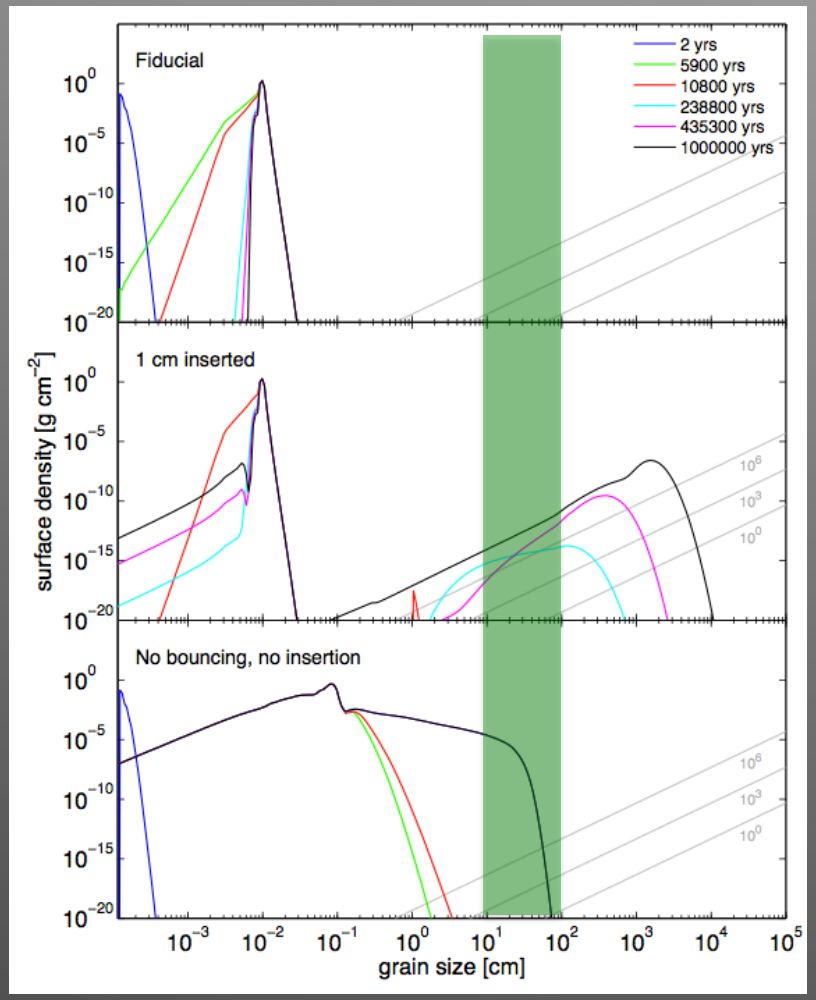
BUT…

Radial drift remains a problem even if material properties allow growth: $t_{grow} >> t_{drift}$, probably don't want $t_{grow} << t_{disk}$ (Trieloff)

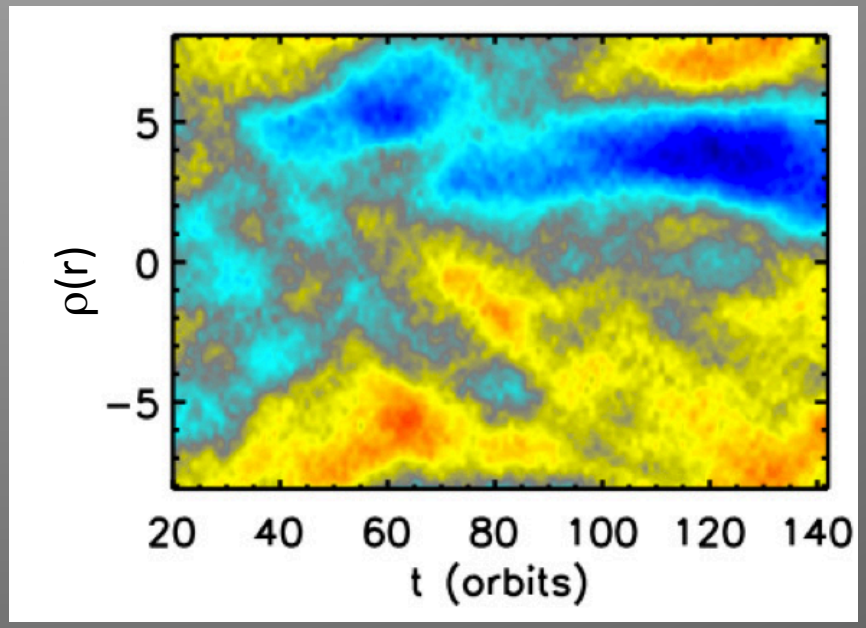


Unequal mass collision w/cratering

- particle traps at pressure maxima: MRI zonal flows, vortices, planet gaps (Pinilla, Dittrich)
- hybrid models: coagulation to St ~ 1 then streaming instabilities (Klahr)



Still need to put a large mass fraction into narrow size range for streaming



Simon, Beckwith & Armitage (2012)

Alcatraz they ain't…

Need to demonstrate strength and persistence of traps in realistic disks (non-ideal MRI; vortex formation in physical structure models)

Enough concentration in generic turbulence???

Transition Disks

Sean Andrews: ~50% of bright disks have large detectable sub-mm cavities, not all with absence of near-IR (as seen in Spitzer, Schreiber)

True mass loss processes (photoevaporation) + dynamical effects (planets)??? (Alexander, Meru, Rosotti)

- Photoevaporation unavoidable (Owen, Rigliaco, Sacco)
- Large population of very massive planets at large a? (surprising, HR 8799 uncommon???)
- observables coupled to the radial drift / growth problem for mm-sized particles (Birnstiel, Pinilla)

Planets: observations

Gregory: "Is there any other point to which you would wish to draw my attention?"
Holmes: "To the curious incident of the dog in the night-time"
Gregory: "The dog did nothing in the night-time"
Holmes: "That was the curious incident"

COROT / Kepler: cold, packed, "pot luck" planetary systems

Lack of co-orbital planets (Hatzes, Morbidelli)
- but they are predicted in some models

Lack of companions to hot Jupiters (TTVs; Seeliger)
- constrains dynamical vs Type II migration scenarios

Young planets… not found yet (Mohler-Fischer, Errmann)
- is migration occurring late? (Kozai, secular chaos, clusters; Davies)

Need to measure Δi (Libert)

Planets: theory

Good working hypothesis for early Solar System evolution, consistent (i.e. same physical processes) with extrasolar planetary systems (Morbidelli, Raymond, Libert, Jakubik, Kley)

Q: if Saturn has time to participate in gas-driven Grand Tacks, why is it not more massive?

Is "pebble accretion" important in terrestrial planet formation (Ormel)?

Problems solved (incomplete list)

- Turbulence pumps planetesimal σ to erosive regime?
  NO: dead zone can be quiescent enough at z=0 while supporting enough accretion away from midplane (Nelson)

- Origin of mid-IR variability of YSOs?
  Turbulent time-variable shadowing (Turner)

- Deficit of water in Herschel observations (Hogerheijde)?
  Mixing pushes ice below τ=1 (Dominik)

- Type I migration in realistic (but ~laminar) disk models?
  Rates understood (Kley, Bitsch, Baruteau); can be used in Pop Synth models (Fortier, Alibert, Mordasini)

Problems created

- Origin of cold (physically, dynamically) Herschel debris disks (Krivov)?
- Non-Keplerian lines from organic molecules in inner disk… winds? (Mandell)
- 140 AU gap in HD 142527 – how to make that?! (Casassus)
- How is (enough) dust transported to small scales to form exozodis (Bonsor)?
- What's wrong with the planets around CVs story (Gozdziewski)?

Sources of tension…

Dead zones: good for keeping planetesimals quiescent (Nelson); good if we believe in physics (Ilgner, Simon); not-so-good for Type I migration (lead to saturation); unclear if they're good for Grand Tacks and planet traps…

Planetesimal sizes: small is good for Pop Synth (Fortier, < 1 km); large remains best guess if self-gravity has a role in formation (Klahr); 10 km reaches 1600K @ 2 Myr / 30 km reaches 400K @5 Myr (Trieloff)

Novel ideas

- Episodic / extended accretion of heterogeneous material (Wasson): lab evidence, requires non-standard star formation
- Kinetic condensation model: growth of ices to mm without coagulation (Nagahara)
- Forming Mercury late after photophoretic separation (Wurm)
- Forming satellites from spreading of disk interior to Roche radius (Crida)
- Significant / dominant role for clump migration + tidal disruption (Nayakshin): I think FUOrs key observation

…and everyone on the LOC!

Thanks!