Review of Demographic Protoplanetary Disk Surveys

Great Barriers in Planet Formation Palm Cove, 22 July 2019

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why conduct demographic Surveys of protoplanetary disks?

even with ALMA... high-XX surveys are still blased

ALMA provides detailed structure
roughly one hour per target
cannot observe "typical" disks



DSHAR

demographic surveys take "snapshots" of complete populations

- all protoplanetary disks
 one minute per target
 fundamental bulk proper
- fundamental bulk properties







1) observe the **overall population** to **overcome biases**

3) combine populations of different ages to study disk evolution

2) tease-out any hidden correlations in disk-star observables



taurus / lupus (1-3 Myr)

young Ansdell+2016/18 Andrews+2013

see L. Cieza & G. Herczeg's talks up next

see also: Taurus (Feng+18/19, Manara+19, Andrews+13), rho Oph (Cieza+18, Williams+19), Orion (Eisner+17, van Terwisga+19), CrA (Cazzoletti+2019), IC 348 (Ruiz-Rodriguez+18)

cham I / σ orionis (**3-5** Myr)

middle-aged

Pascucci+2016 Ansdell+2017

upper sco (5-10 Myr)

evolved Barenfeld+2016/17



what can demographic SURVEYS of protoplanetary disks measure?



what processes are influencing disk evolution?

how much material is available for planet formation?

?	disk radius
5	for 20% of sources
st	for 30% of sources
35	for 20% of sources
ist	for 80% of sources

how to get 100 disk masses in just 2 hrs with ALMA





- H_2 does not emit in cold protoplanetary disks
- Optically thin CO isotopologues trace gas mass
- Grid-based modeling makes this quick



Williams & Best 2014, Ansdell+2016, Miotello+2017

how to get **100 disk masses** in just **2 hrs** with ALMA





¹³CO Luminosity



ALMA reveals declining dust mass distributions



Andrews+2013, Ansdell+2016, Ansdell+2017, Pascucci+2016, Barenfeld+2016

insufficient dust mass to form exoplanet core masses



implies rapid planet growth?

- core masses likely underestimated (sini effect, undetected planets, etc.)
- dust masses may be underestimated, but not by much (GI; faint CO/gas)
- ALMA probes > 10 au, while exoplanet surveys probe < 1 au







removal of gas-rich atmosphere?

Alexander+2014, Bai+2016, Gammie1996



removal of gas-rich atmosphere?

Alexander+2014, Bai+2016, Gammie1996

see talks by A. Miotello, I. Kamp, B. Veronesi on Friday

depletion of volatile carbon?

Bergin+2010, Eistrup+2016, Kama+2016, Yu+2017, Aikawa+1997





measuring the **radius** of dust & gas for **typical-ish** disks with ALMA



1.21 km/s	1.72 km/s	2.23 km/s	2.74 km/s	3.25 km/s	3.76 km/s	4.27 km/s	4.78 km/s	5.2
0	0	0	\odot	\bigcirc		$(\overline{})$	C	C
0	•	•	0	0	0	o''	· · ·	•
0		0	()	\bigcirc	0	0	0	
5.8km/s	6.31km/s	• ^{6.82km/s}	o ^{7.33km/s}	• ^{7.84km/s}	• ^{8.35km/s}	• ^{8.86km/s}	• ^{9.37km/s}	• ^{9.8}

"Keplerian masking" enhances fainter gas emission outer regions of disks where the SNR is lower



Salinas+2017, Ansdell+2018, Trapman+2019





the OCCURRENCE of radial drift in typical-ish Lupus disks



... often due to radial drift (rather than optical depth)





	•
or)



what's with all the small disks?





what external factors influence these observables?

external photoevaporation from nearby OB stars dominates disk evolution







- No massive (>9 M_{\oplus}) disks at < 0.03 pc (EUV)
- Normal at 0.03-0.30 pc (FUV) and beyond

external photoevaporation from Mars dominates disk evolution





- No massive (>3 M_{\oplus}) disks < 0.5 pc from σ Ori
- Dust masses affected to cluster edge (2 pc)
- Gas detections only at cluster edge



how & when does binarity impact planet formation?



close (<300 au) binaries truncate disks

see G. Duchene & M. P. Ronco talks on Friday

... but has the same effect as disk evolution?

....and may still inhibit planet formation?



can the Solar System help us "calibrate" protoplanetary disk Surveys?





adaţ



ALMA probes analogues to chondrules in our Solar System



Jupiter's core (20 M_{Earth}) formed in <=1 Myr

Kruijer+2013, 2014, 2017; Scott+2015; Bottke+2006; Jilly-Rehak+2017, Doyle+2015

asteroids formed in ~1-4 Myr

planetesimals also likely formed quickly in our Solar System



does observing MM grain growth also imply planetesimal formation in protoplanetary disks?

post-planetary

see discussion on Tuesday



Review of Demographic Protoplanetary Disk Surveys

demographic surveys have focused primarily on masses and sizes providing insights into disk evolution and planet formation processes combined with meteoritics/exoplanets suggests planet formation is quick

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