Close-in Giant Planet Formation via In-situ Gas Accretion & the Natal Disk Properties

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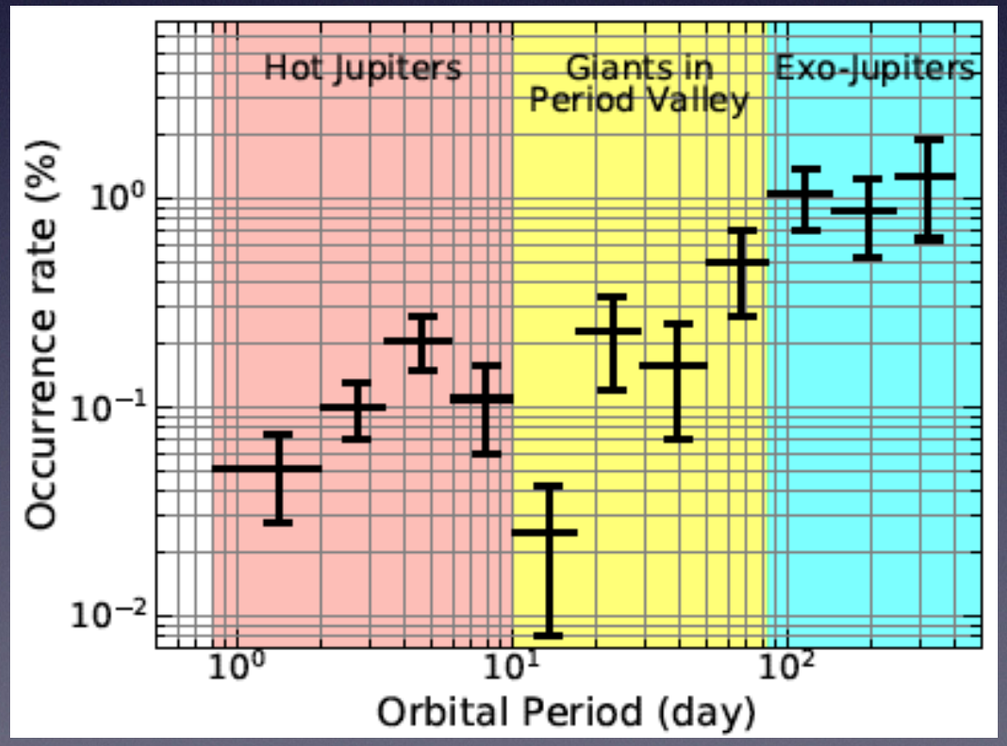
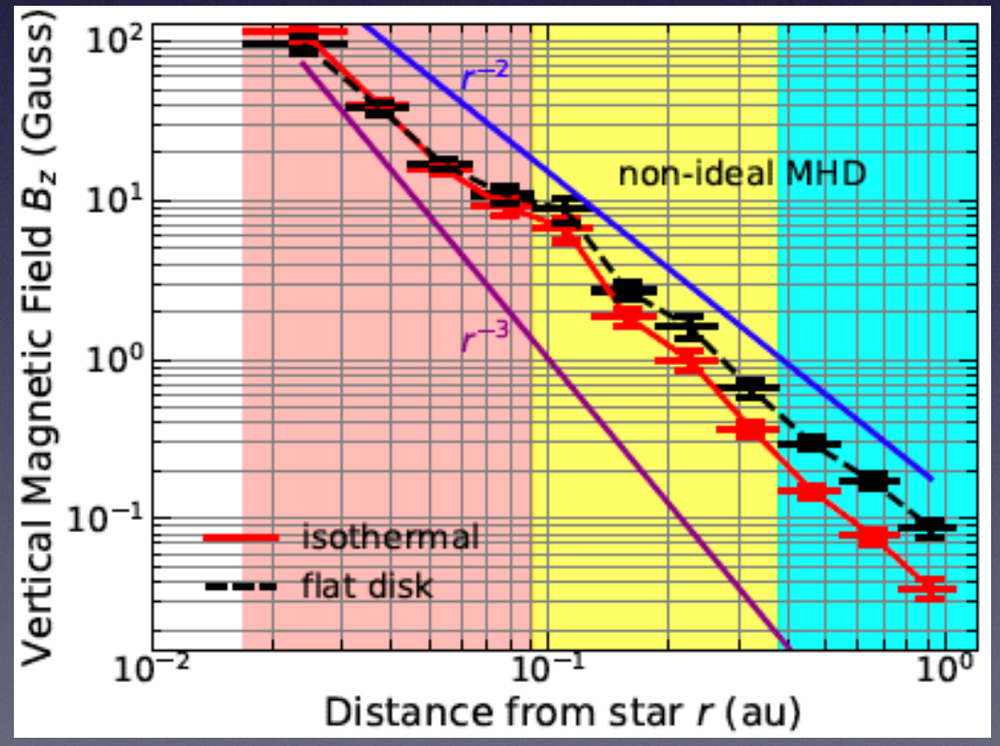
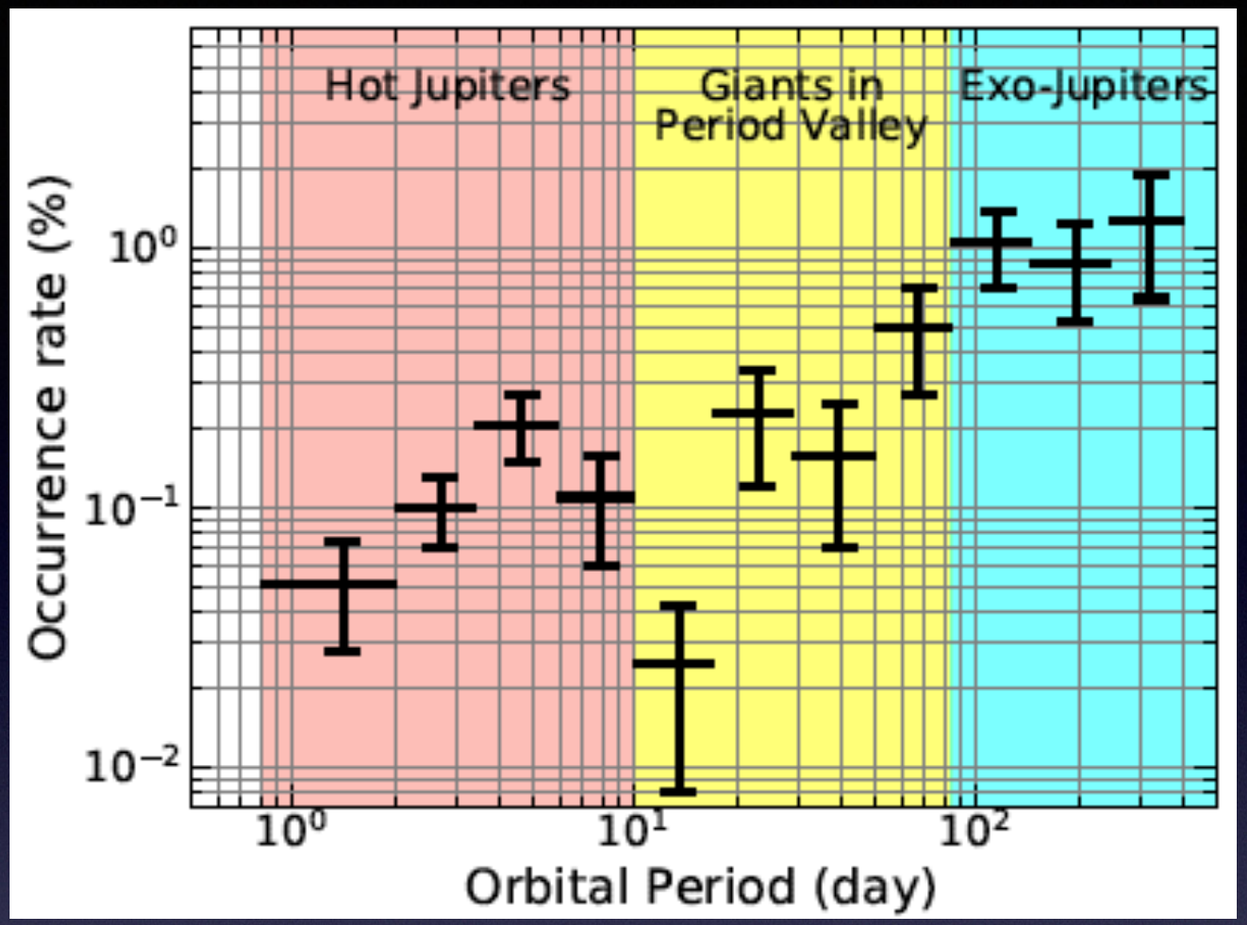


Santerne et al 2016

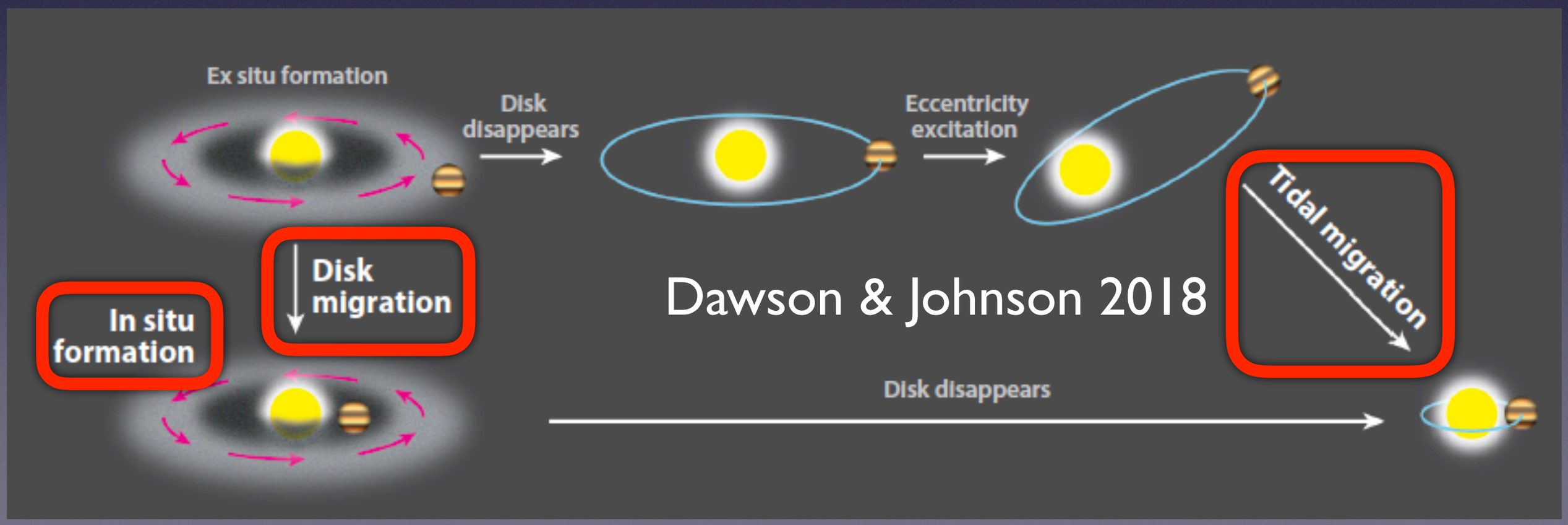


in collaboration with Mathew Yu (UCLA) and Brad Hansen (UCLA)

Santerne et al 2016

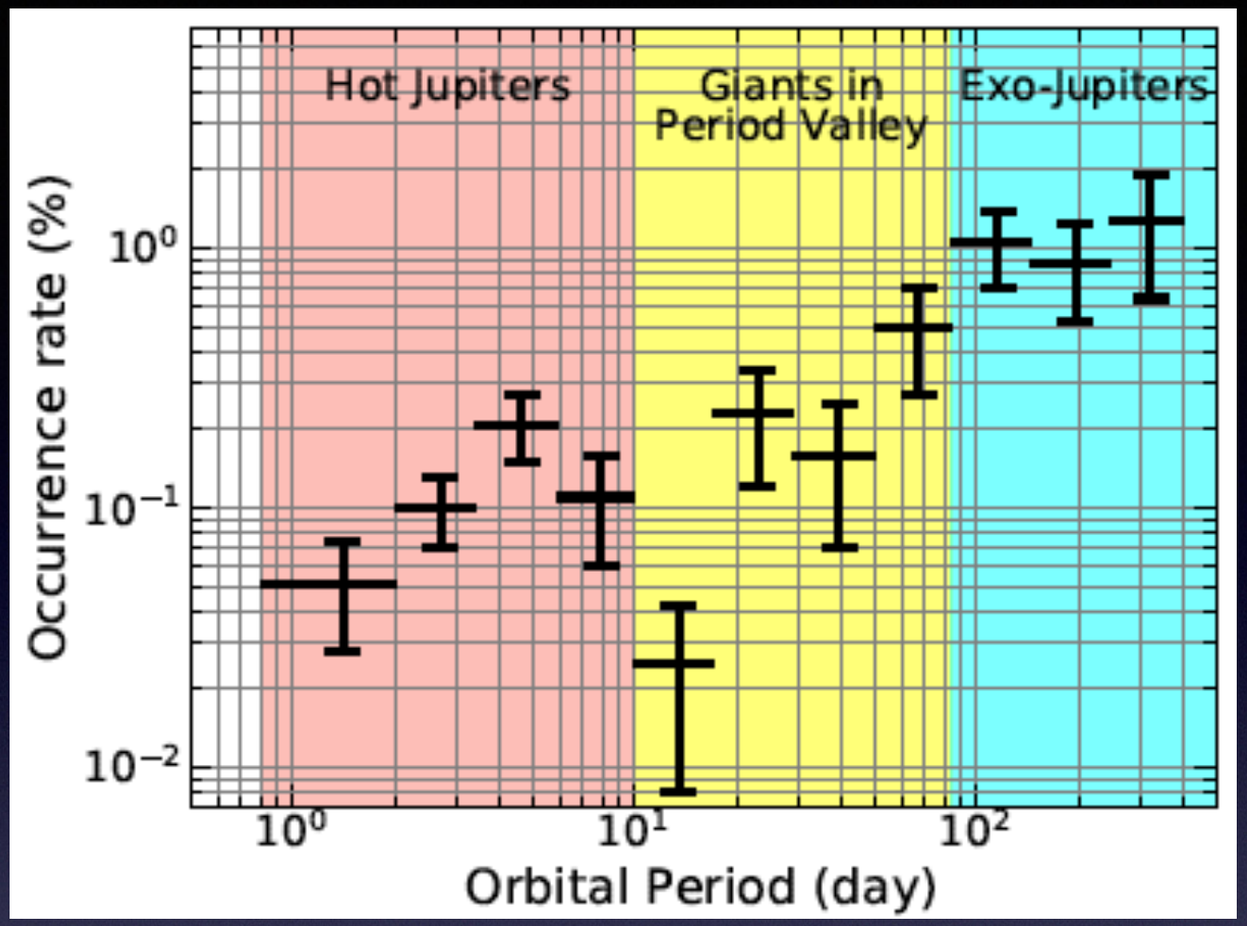


How to form close-in gas giants?



Dawson & Johnson 2018

Santerne et al 2016



How to form close-in gas giants?

Use the observed occurrence rate in order to derive some observables (e.g., the gas surface density) under the in-situ gas accretion scenario

Basic Hypothesis:

the occurrence rate ~ gas accretion onto planets

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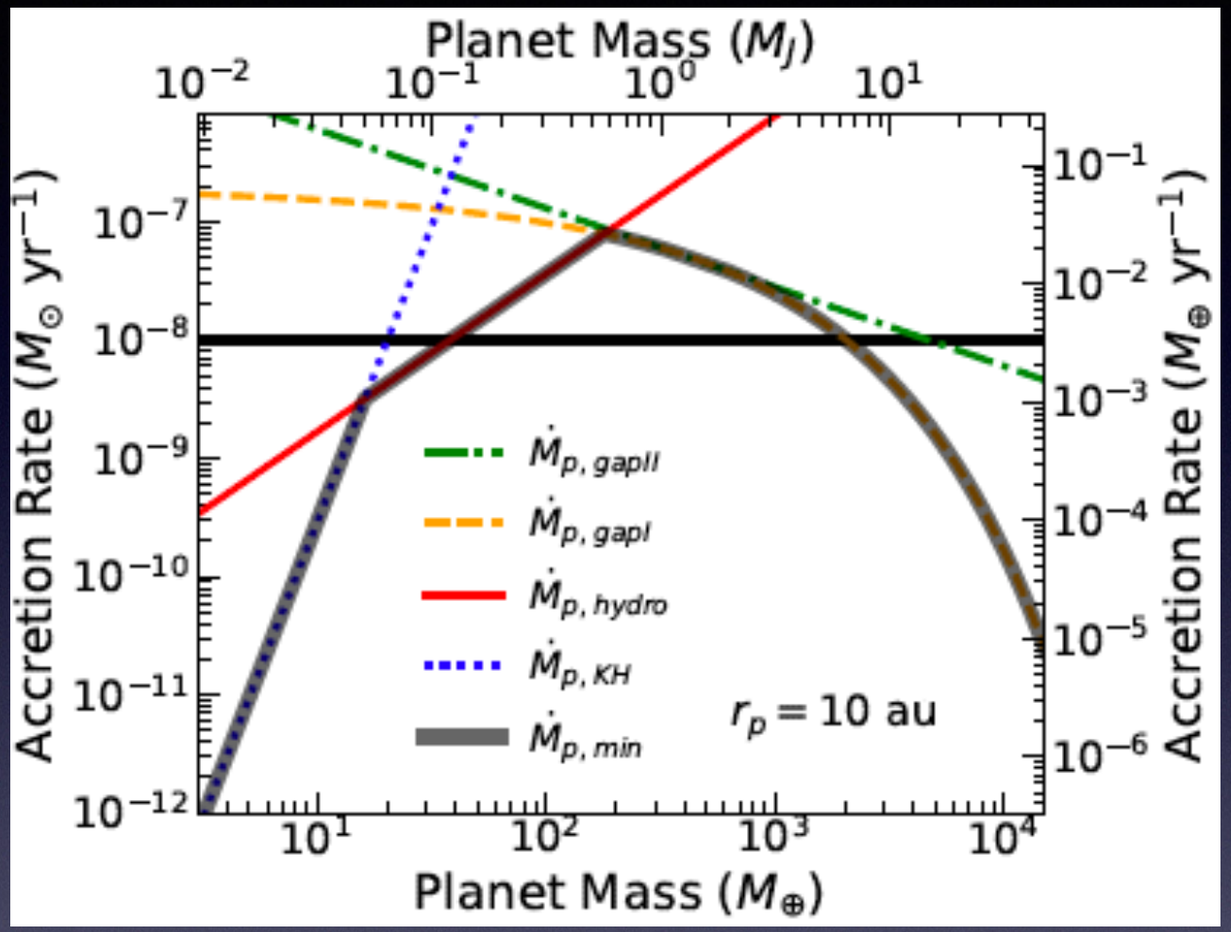

Hasegawa et al 2019a

Gas accretion

Kelvin-Helmholtz contraction

Disk-limited accretion

Accretion through gas gaps

Basic Hypothesis:

the occurrence rate ~ gas accretion onto planets

Gas accretion

Kelvin-Helmholtz contraction

$$\dot{M}_p \simeq 0.29 \left(\frac{H_{\rm g}}{r_p}\right)^{-2} \left(\frac{M_p}{M_*}\right)^{4/3} \Sigma_{\rm g} r_p^2 \Omega$$

Tanigawa & Ikoma 2007

Disk-limited accretion

Accretion through gas gaps

the occurrence rate $\propto \dot{M}_p \equiv f(T_{\rm d}, \Sigma_{\rm g})$

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Gas accretion

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$$\dot{M}_p \simeq 0.29 \left(\frac{H_{\rm g}}{r_p}\right)^{-2} \left(\frac{M_p}{M_*}\right)^{4/3} \Sigma_{\rm g} r_p^2 \Omega$$

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Disk-limited accretion

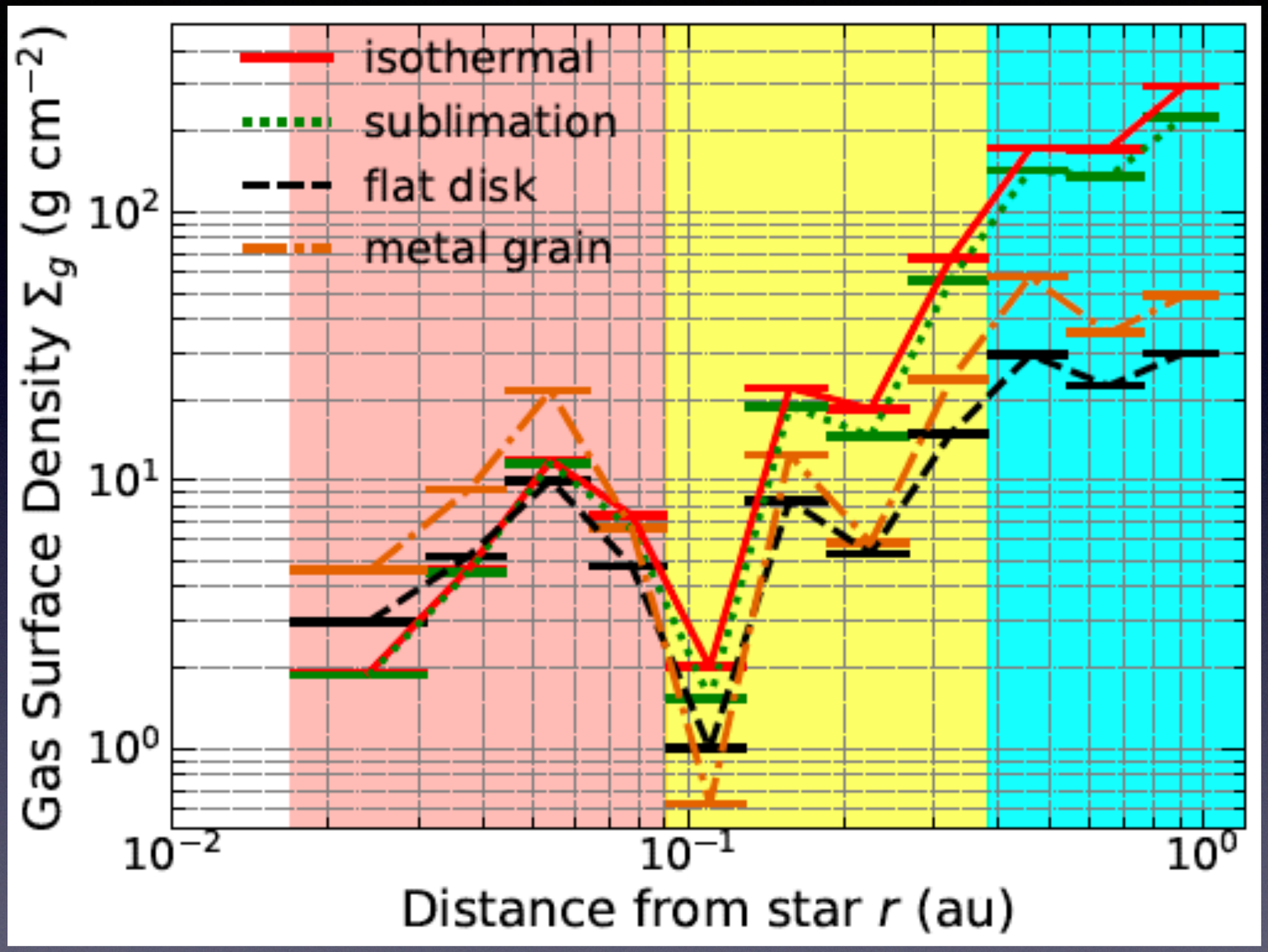
Accretion through gas gaps

the occurrence rate $\propto \dot{M}_p \equiv f(T_{\rm d}, \Sigma_{\rm g})$

$$\Sigma_{\rm g} \propto f(\text{Occurrence rate})$$

with the steady state disk accretion model

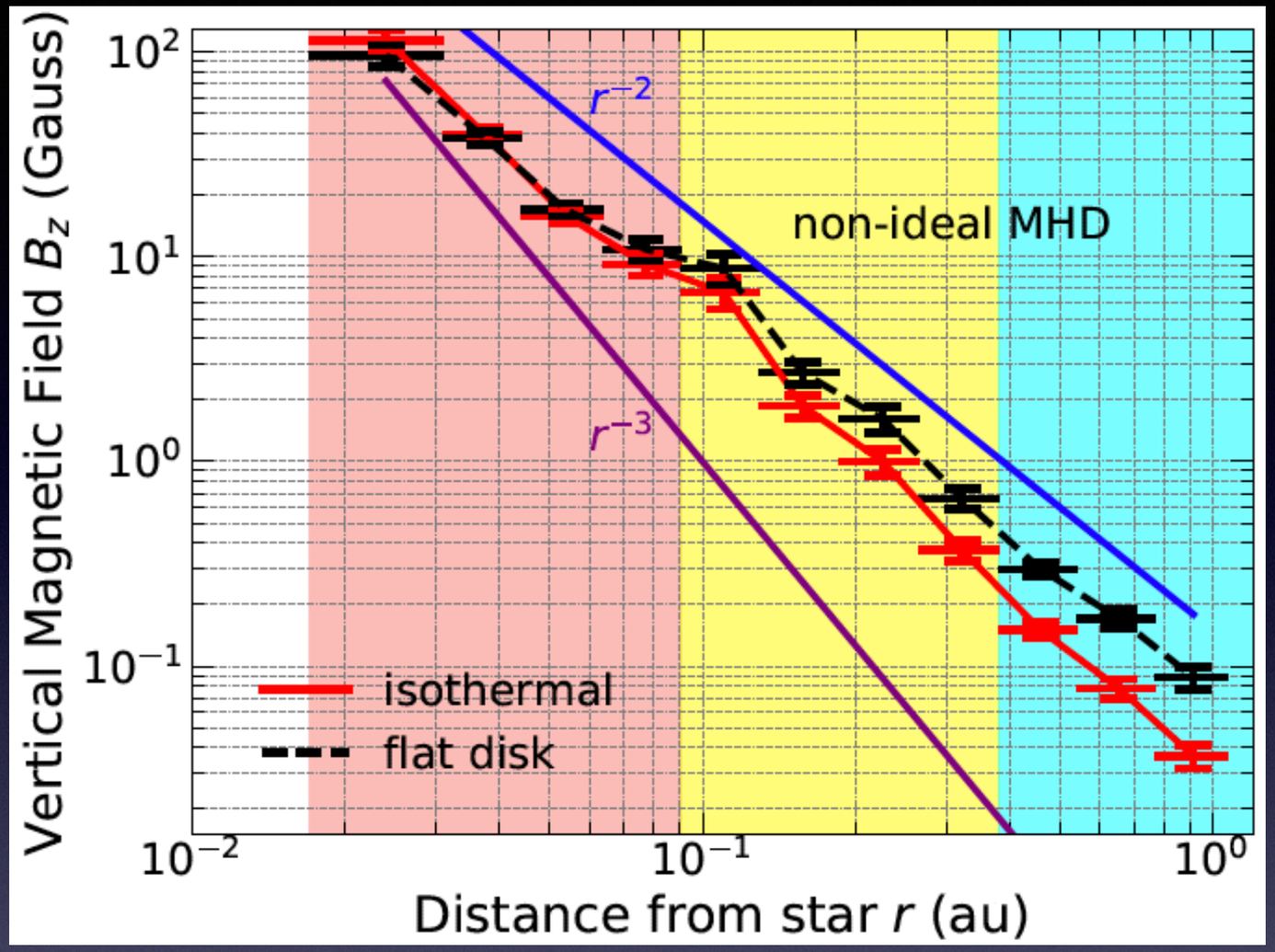
Results: Gas Surface Density Profile



Gas surface density increases with increasing the distance from the central star (cf. Minimum-mass solar nebula $\propto r^{-3/2}$)

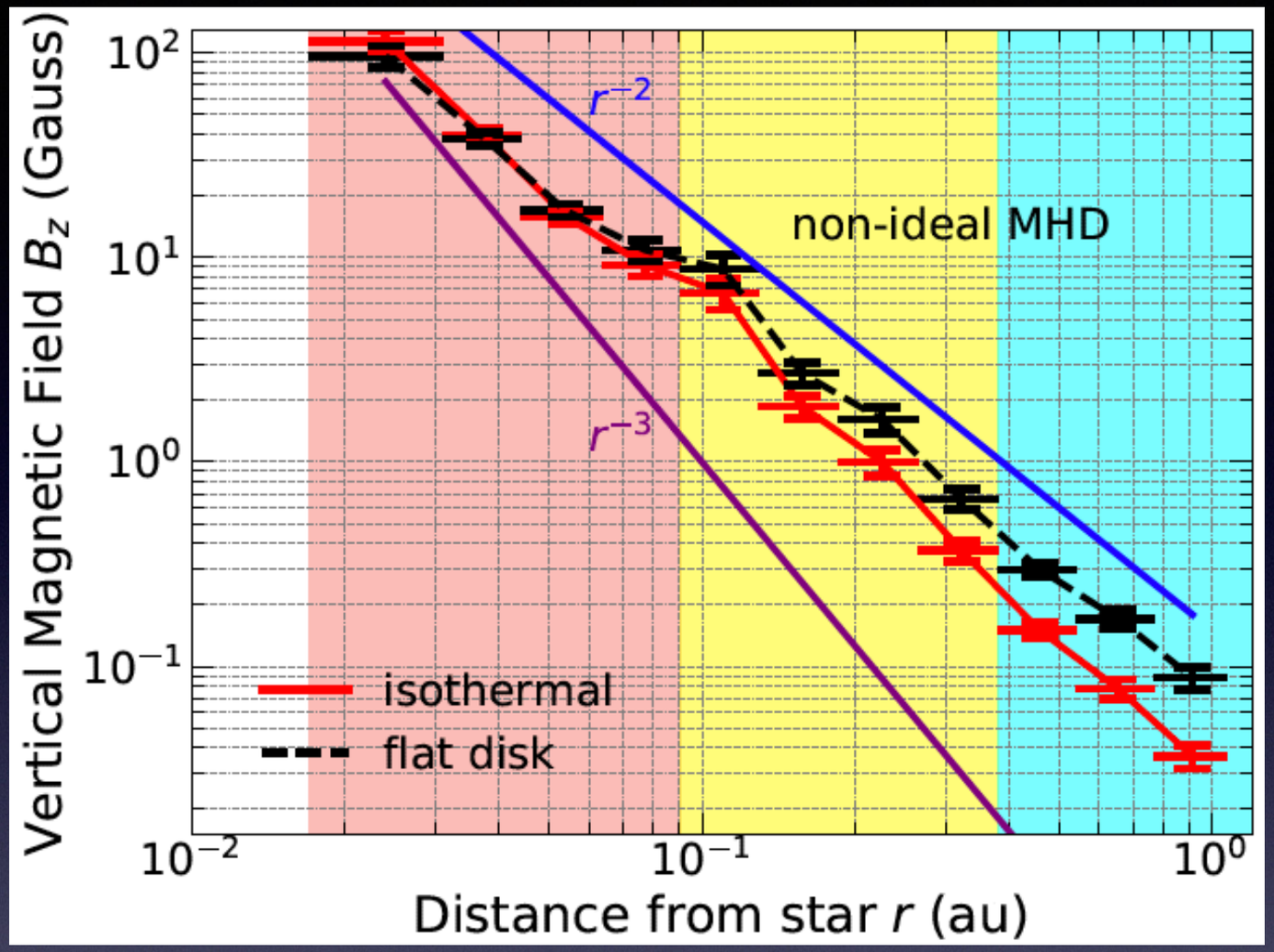
The overall profiles do not depend on opacities

Results: Magnetic Field Profiles



B-field profiles switch around at 0.1 au from $\propto r^{-3}$ to $\propto r^{-2}$

Implications



B-field profiles switch around at 0.1 au from $\propto r^{-3}$ to $\propto r^{-2}$

Stellar dipole fields

$$B_s \simeq 10^3 \left(\frac{r}{1.5R_\odot}\right)^{-3} \text{ G}$$

$$\simeq 41 \left(\frac{r}{2\times10^{-2}\text{ au}}\right)^{-3} \text{ G}$$

Large-scale disk fields

$$B_\text{d} \simeq 0.1 \left(\frac{r}{1\text{ au}}\right)^{-2} \text{ G}$$

Okuzumi et al 2014

Summary

Hasegawa et al, 2019b, A&A, 629, L1

- The origin of close-in giant planets is still unclear
- The occurrence rate distribution has some intriguing structure
- Developed the simple, semi-analytical model under the hypothesis that the occurrence rate distribution may reflect gas accretion rates onto protoplanets
- The gas surface density increases with increasing the distance from the central star (cf. MMSN model)
- The occurrence rate distribution may trace the magnetic field profile - stellar dipole fields dominate at $r < 0.1$ au and the large scale field may be important at $r > 0.1$ au