Planetary Collisions around Low-mass Stars: Constraining the Timescale for Collisions and Testing the Origin of the Kepler Dichotomy

2019 NHFP(b?) Symposium

Christopher A. Theissen (he/him)
UC San Diego
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The “Kepler Dichotomy”

The *Kepler* sample has a number of multi- and single-transiting planetary systems.

The best (single) models *underpredict* the observed number of singly-transiting systems.
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Lissauer+ (2012)
The “Kepler Dichotomy”

Possible explanations:

The primordial disks produced less planets in a subset of systems
  • Moriarty & Ballard (2016); Mulders et al. (2018, 2019)

The resulting planets were scattered, ejected, or collided with other planets or their host star
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nature of the “Kepler dichotomy” for both GK stars and M dwarfs, and find that it varies with stellar type. While the mode of planet formation that accounts for high multiplicity systems occurs in 24% ± 7% of planetary systems orbiting GK stars, it occurs in 63% ± 16% of planetary systems orbiting M dwarfs. Moriarty & Ballard (2016)
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Weinberger+ (2011)

“Extreme” mid-infrared excess
Signatures of Planet-Planet Collisions

Theissen & West (2014)

Theissen & West (2017)

Cotten & Song (2016)

SpT = dM1
$T_* = 3600_{-100}^{+100}$K
$T_{IR} = 175_{-10}^{+10}$K

"Extreme" mid-infrared excess

Log [$\lambda F_\lambda$ (erg s$^{-1}$ cm$^{-2}$)]

$\lambda$ ($\mu$m)

objID = 1237655129840353462
$T_* = 4091_{-84}^{+23}$K

Log [$\lambda F_\lambda$ (erg s$^{-1}$ cm$^{-2}$)]

$\lambda$ ($\mu$m)

 TYC8830-410-1

$T_{star} = 4900$ K
$T_{dust} = 425$ K

Wavelength (µm)
Signatures of Planet-Planet Collisions

Weinberger+ (2011)

"Extreme" mid-infrared excess

Theissen & West (2017)

1 billion year old systems!

Theissen & West (2014)

Cotten & Song (2016)
Low-mass Stars as Laboratories

Age trend observed with collisional signature.

May indicate a possible timescale for collisions.
Inhibiting giant planet formation can yield late time planetary collisions, and at a higher rate.
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We can search for MIR excesses in already known planetary systems using *Kepler* and K2!

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Gaia will provide distances and kinematics for age tracers
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*Planet candidate(s)*
*Confirmed planet(s)*

Extrem MIR excess candidates

Main sequence stars

**Gaia** will provide distances and kinematics for age tracers

83% matched
Low-mass Stars as Laboratories

Initial results may indicate that multi-planet (transiting) systems are younger than singles.

Multi-planet systems typically found closer to the galactic plane.
Low-mass Stars as Laboratories

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Lots of biases in this plot, but more results to come!
Constraining the Timescale for Collisions

We can model this trend to estimate a timescale for collisions.

Kepler + Gaia will give us further age constraints for MIR excess candidates (rotation rates, kinematics, galactic placement).

JWST will allow us to study the mineralogy of the disks to assess the collisional theory (e.g., looking for silicate dominant disks).

Credit: NASA/ESA
Planets orbit close-in!

Thanks!

Credit: Gillon+ (2016, 2017)/NASA