# From Neutron Star Observables to the Dense Matter Equation of State

**Carolyn Raithel**

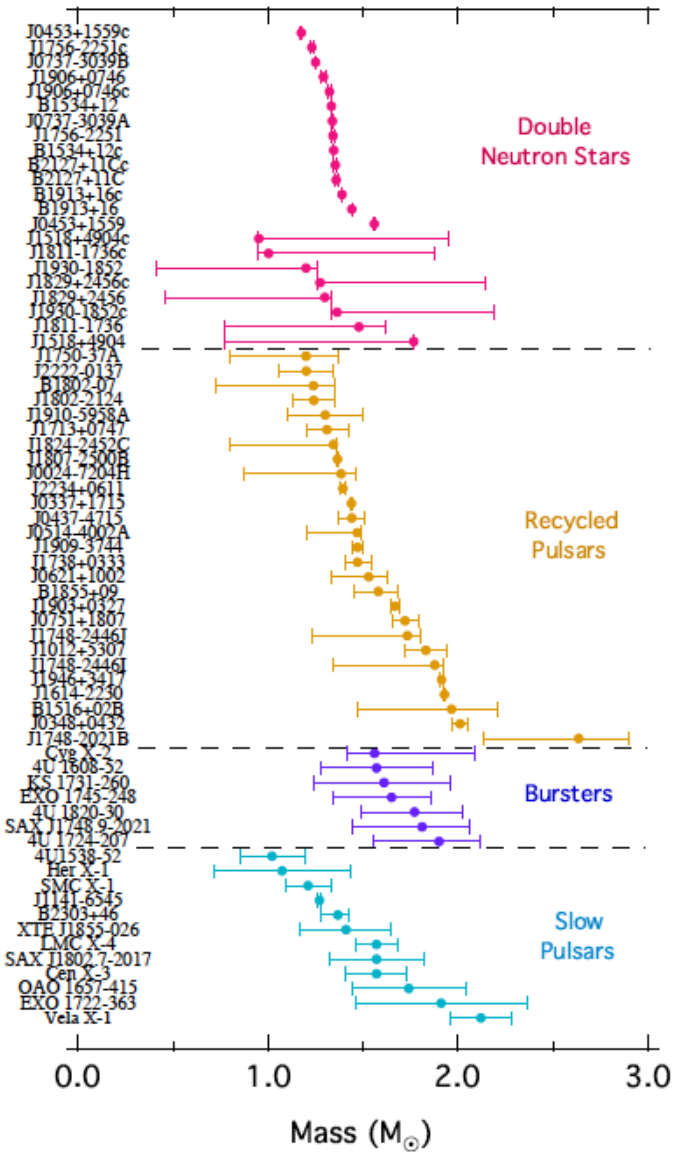
Feryal Özel & Dimitrios Psaltis

University of Arizona / Steward Observatory

July 14, 2016 - INT *Phases of Dense Matter* Workshop


# Background

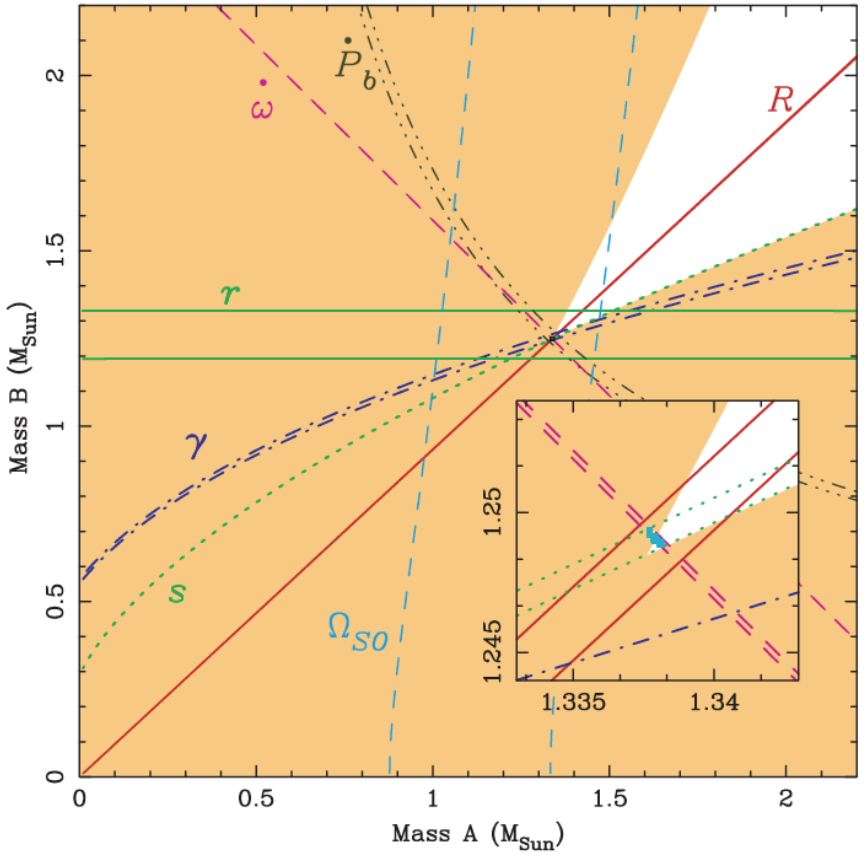
- Many mass measurements already made
- ~15 radius measurements
- Forthcoming new measurement: moment of inertia




*Özel & Freire, ARAA (2016)*

# Moment of Inertia

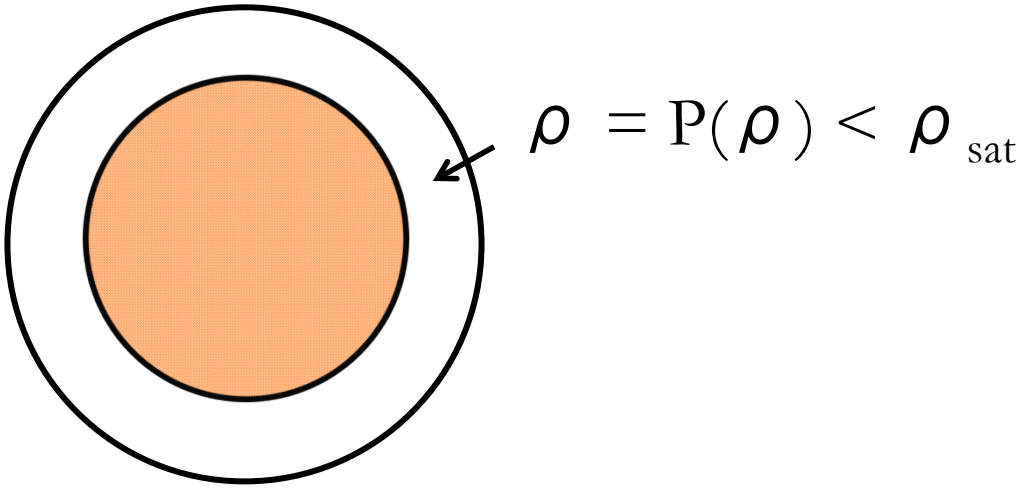
- From double pulsar system J0737–3039
  - Highly relativistic, edge-on system
- Measurement expected within ~5 years to 10% accuracy
- Implications of MoI on EoS have been studied in past
  - E.g., Lattimer & Schutz (2005), Morrison et al. (2004), Bejger et al. (2005)




*Kramer & Wex (2009)*

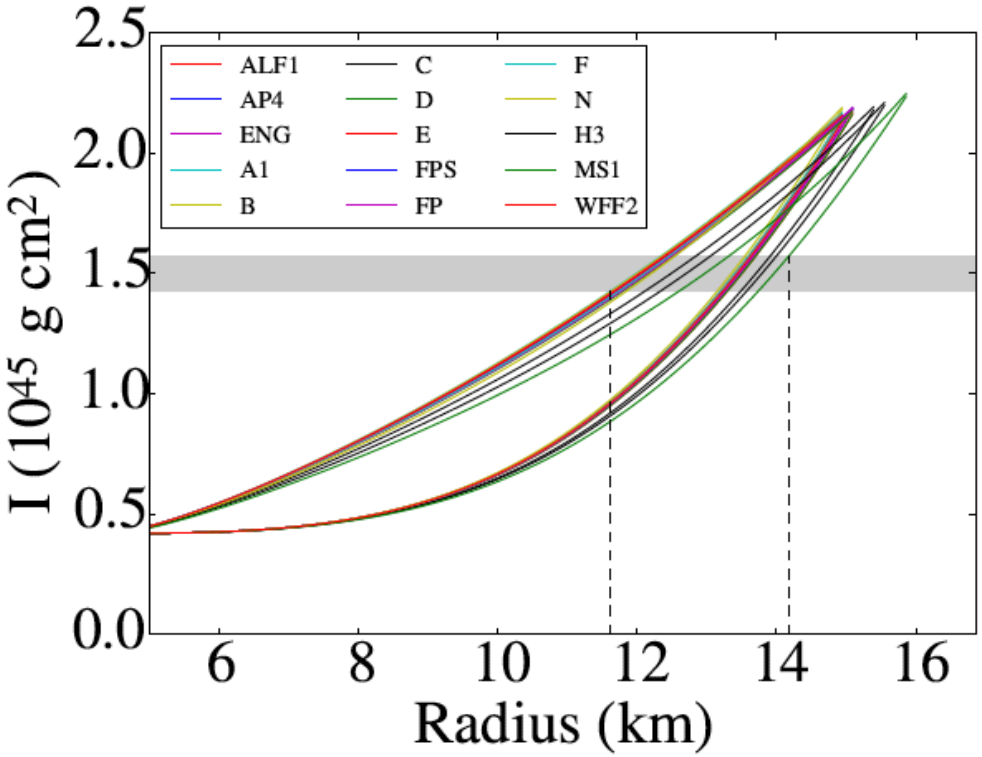
# Inferring the Radius from the Moment of Inertia

- Use bounds on moment of inertia from GR
  - Assume an EoS only up to $\rho_{sat}$
  - Configure remaining star to either maximize or minimize the moment of inertia



# Inferring the Radius from the Moment of Inertia

- A moment of inertia measured with 10% accuracy maps to a radius to within 1-2 km




$M_A = 1.338\ M_\odot$

*Raithel, Özel, &Psaltis, PRC (2016).*

# Inferring the EoS

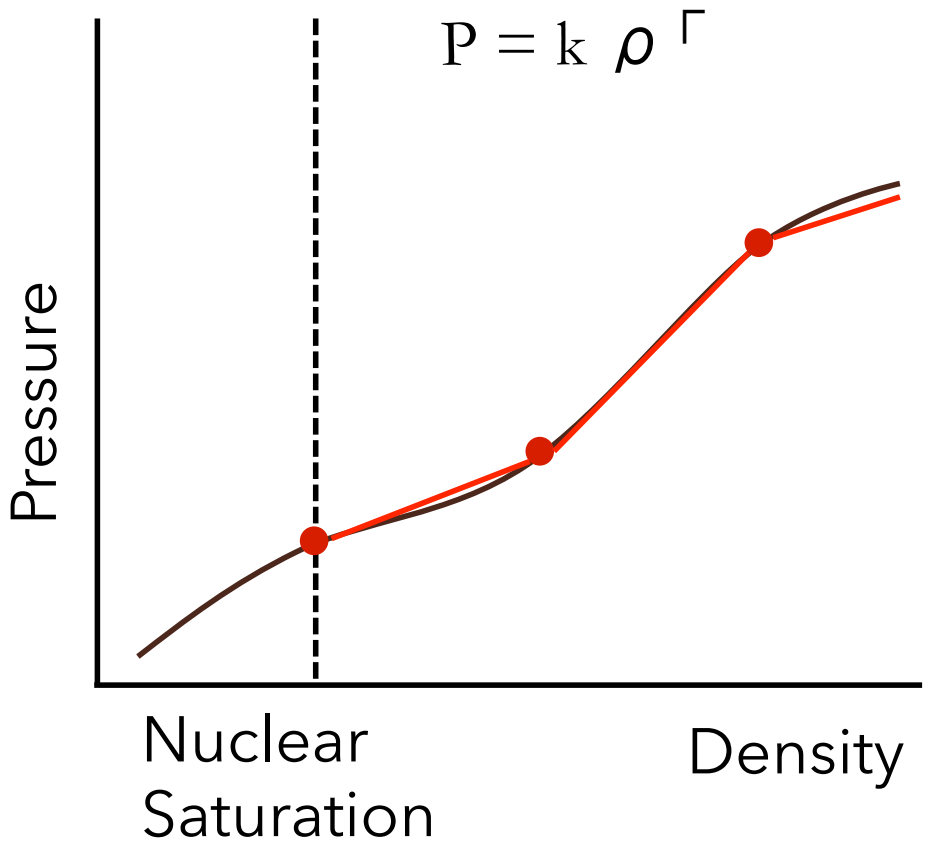
- Can use all three measurements – *M, R, I* – to infer the neutron star EoS

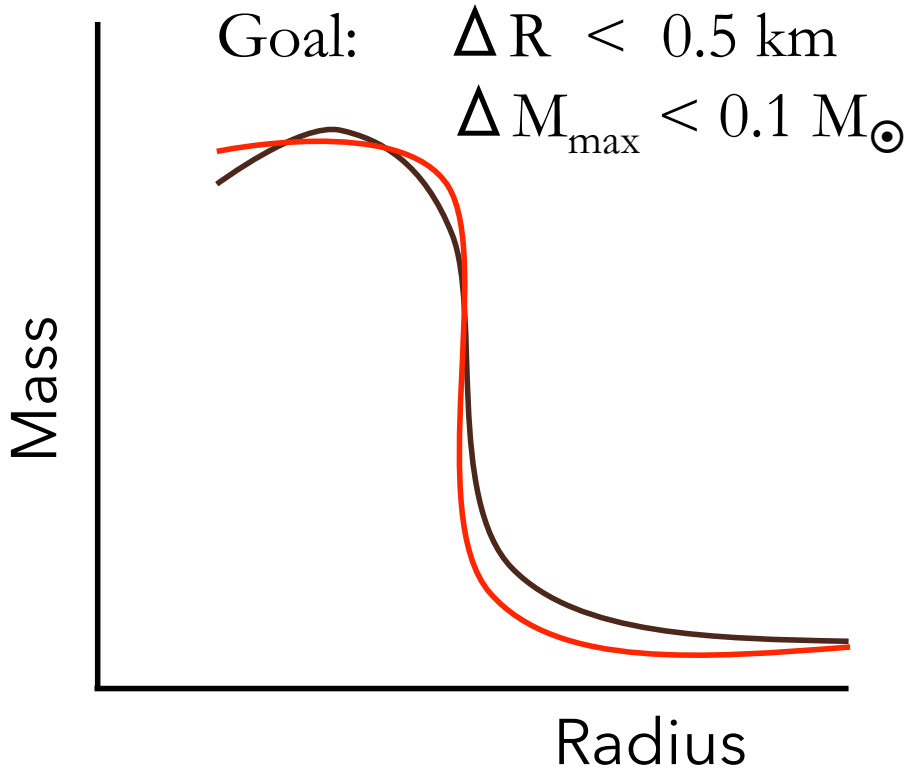
- One-to-one mapping of EoS to mass-radius curve
  - Formally possible to invert, but observationally unrealistic

- Parametric EoS allows for a simplified inversion
  - e.g., Read+ (2009), Özel+ (2009), Hebeler+ (2010), Steiner+ (2016)

- **Goal**: Create a parametric EoS that reproduces the mass, radius, *and* moment of inertia of the fully-specified EoS with a minimum set of parameters

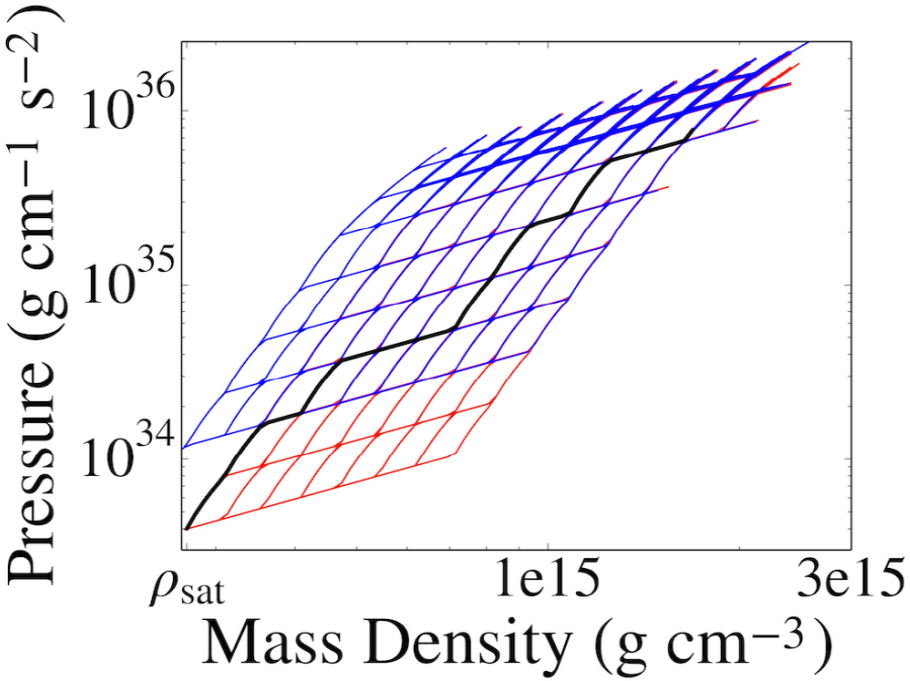
# Parametrization of the Equation of State

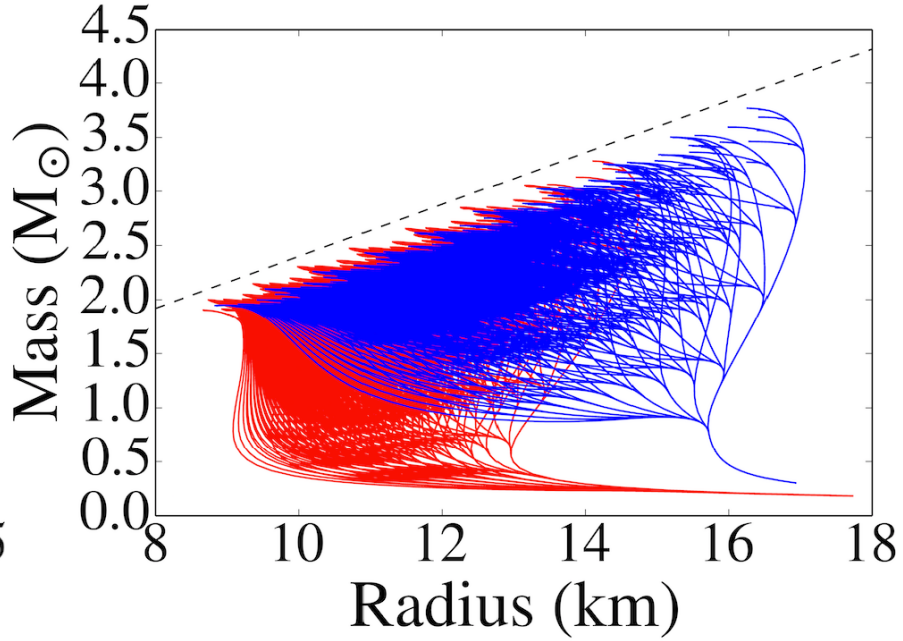


# Generating Mock EoS

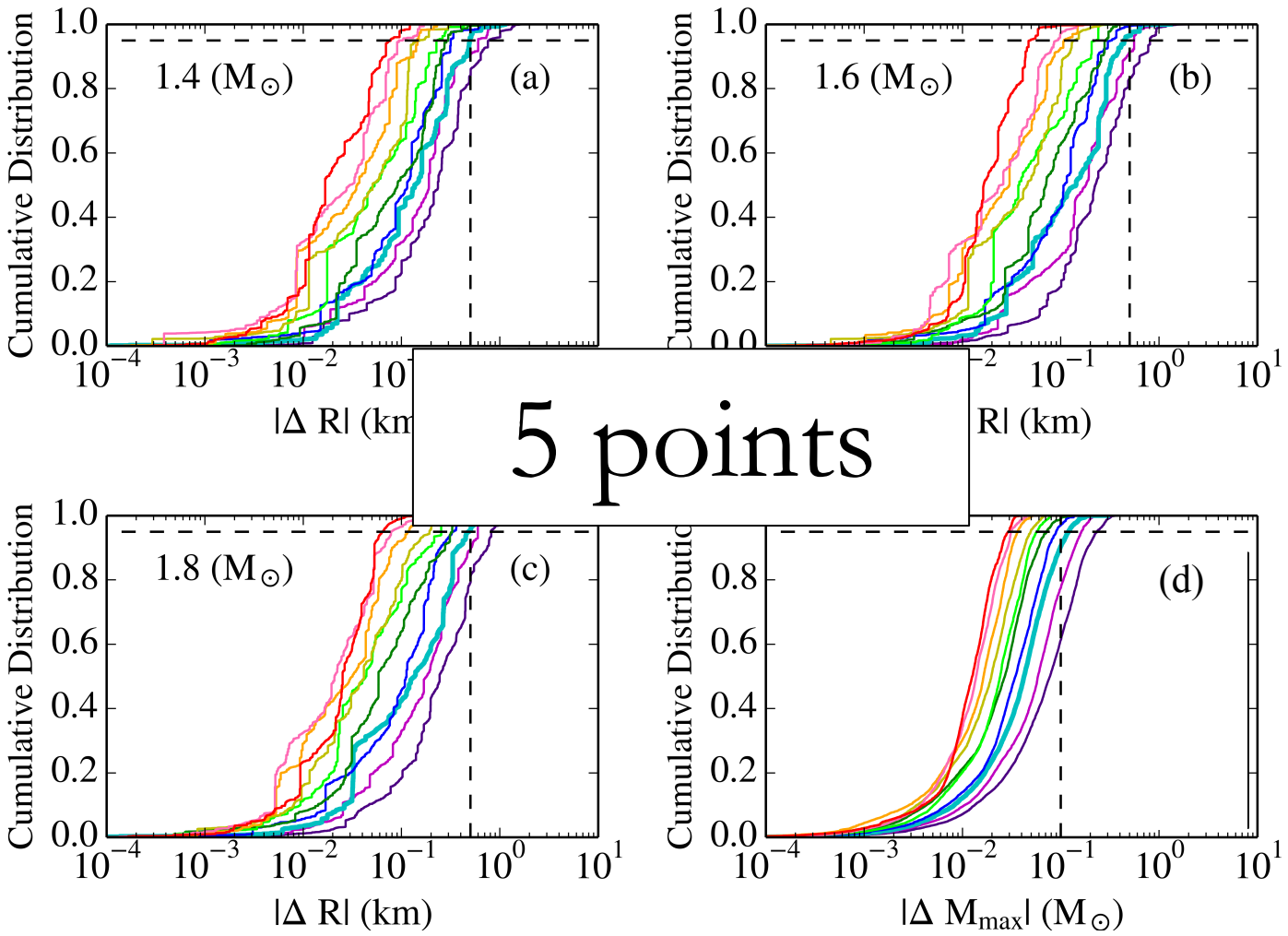
- 53,000 extreme, mock equations of state fully span P-$\rho$ and M-R space




*Raithel, Özel, & Psaltis, ApJ (in press).*

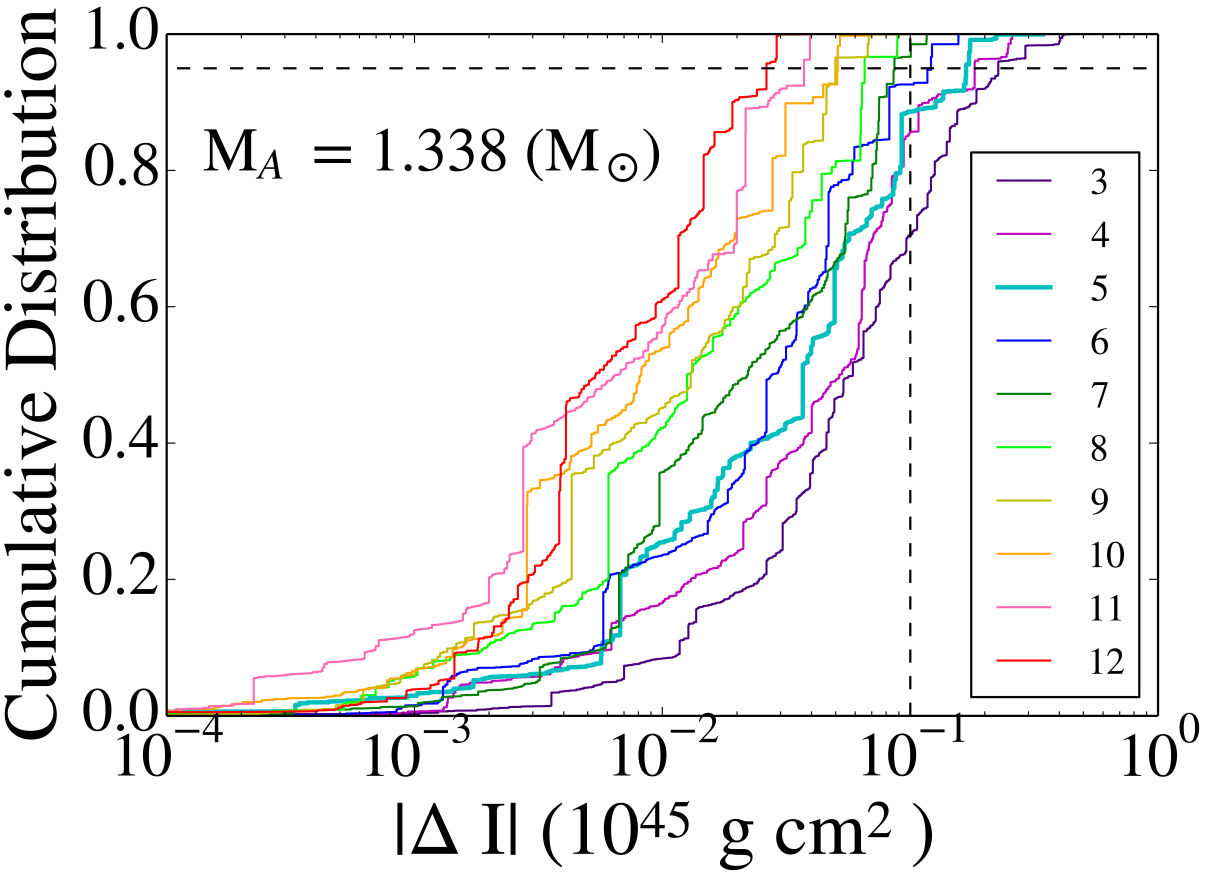
# Results for Mock Equations of State




*Raithel, Özel, & Psaltis, ApJ (in press).*

# Moment of Inertia

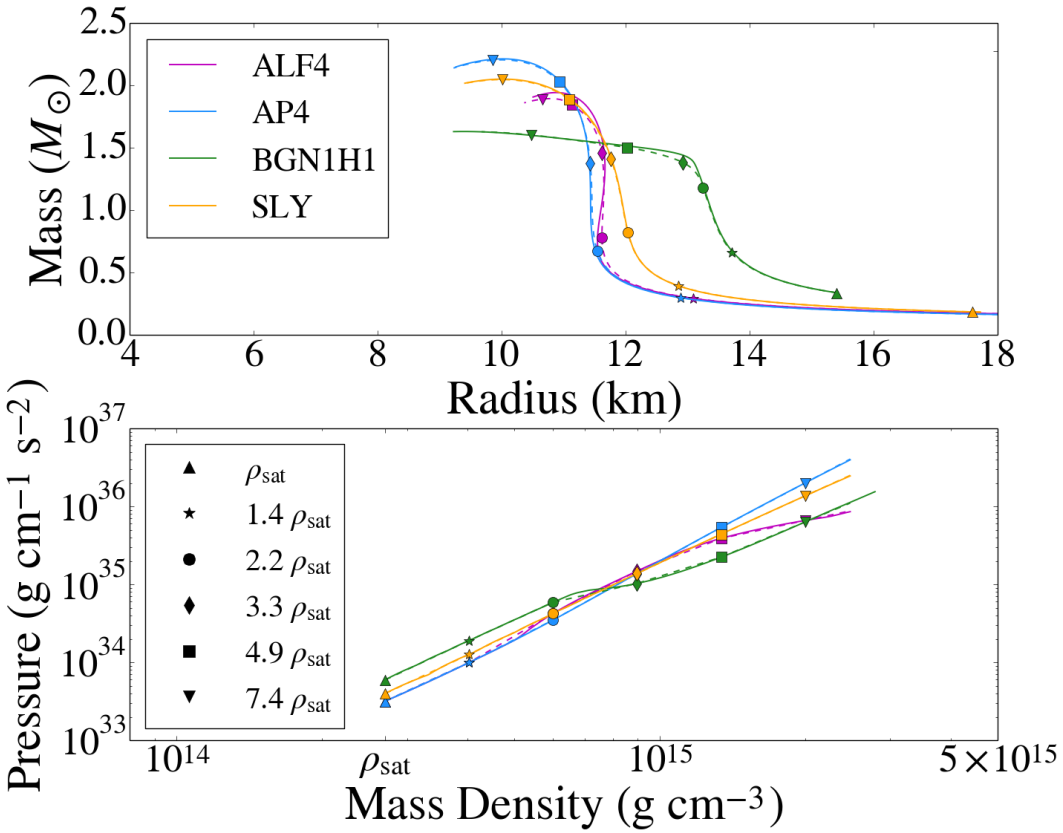
- Our parametrization recreates I to within $\lesssim 10\%$




*Raithel, Özel, & Psaltis, ApJ (in press).*

# Application to Proposed EoS

- Five-polytrope parametrization applied to physically-motivated EoS
  - Radius errors
    **< 0.12 km**
  - Maximum mass errors
    **< 0.04 $M_\odot$**
  - Moment of inertia errors
    **< 0.02 x $10^{45}$ g cm$^2$**




*Raithel, Özel, & Psaltis, ApJ (in press).*

# Conclusions

- The forthcoming moment of inertia measurement offers a new way to constrain the EoS and to assess systematic uncertainties in spectroscopic radii.
- A five-polytrope parametrization is sufficient to reproduce observable quantities (mass, radius, and moment of inertia) to within expected uncertainties.

Contact:
craithel@email.as.arizona.edu