# Gravitational Waves from AM CVn Systems

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# Collaborators

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arXiv:1201.4613: Graviational-Wave Emission from Compact Galactic Binaries (Nissanke, Vallisneri, Nelemans, Prince)

Revisit the question: What is the contribution of WD binaries (detached and AM CVn) to the low-frequency GW spectrum (0.1 -10 mHz)?

# This talk:

GW emission for compact binaries

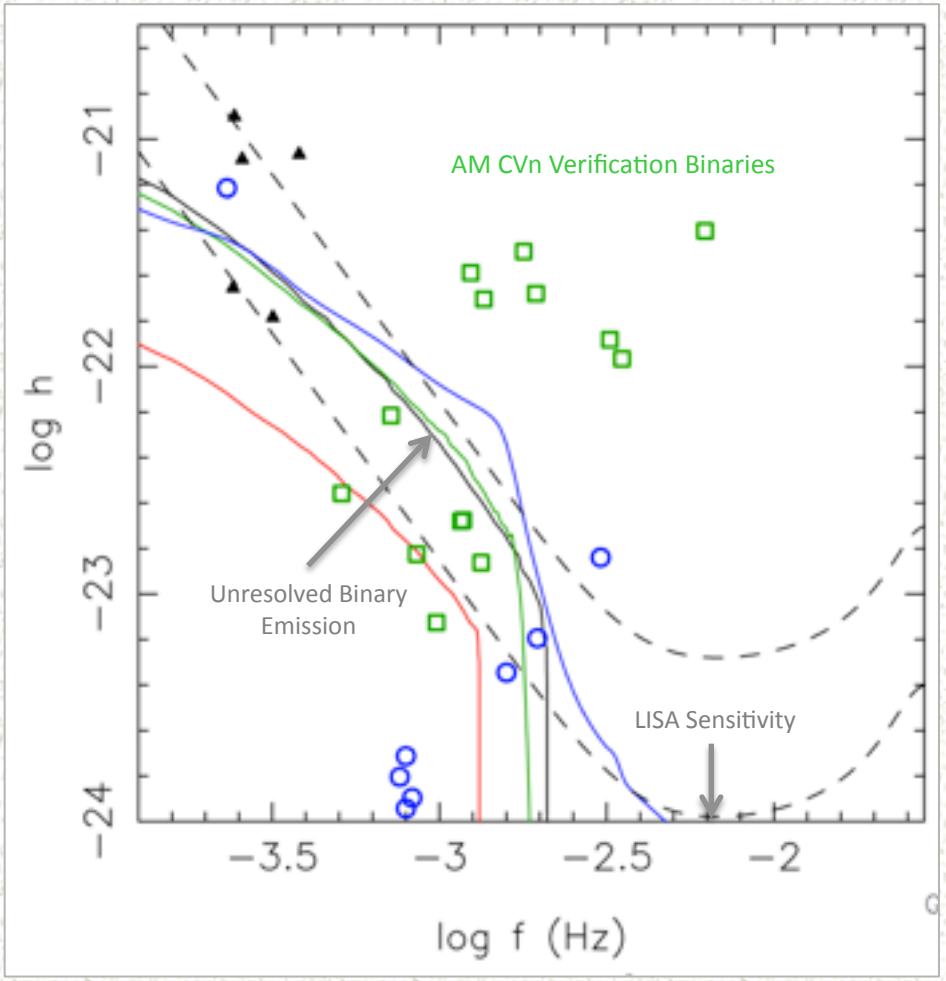
- Summary of results from Nissanke+12
- Emphasis on AM CVn

What is the scale height of AM CVn systems?

- Simulations of modified Galactic disk model from Nissanke+12
- Thin/thick disk?

# WD binaries numerically dominate the low-frequency GW spectrum (0.1 – 10 mHz)

- Known "verification" sources
- Resolved sources
  - More than 10,000 predicted
  - More than 100 on "1st day" of observation
- Unresolved Galactic foreground




[see e.g. Nelemans et al. 01,04]

Prime targets for NGO & LISA

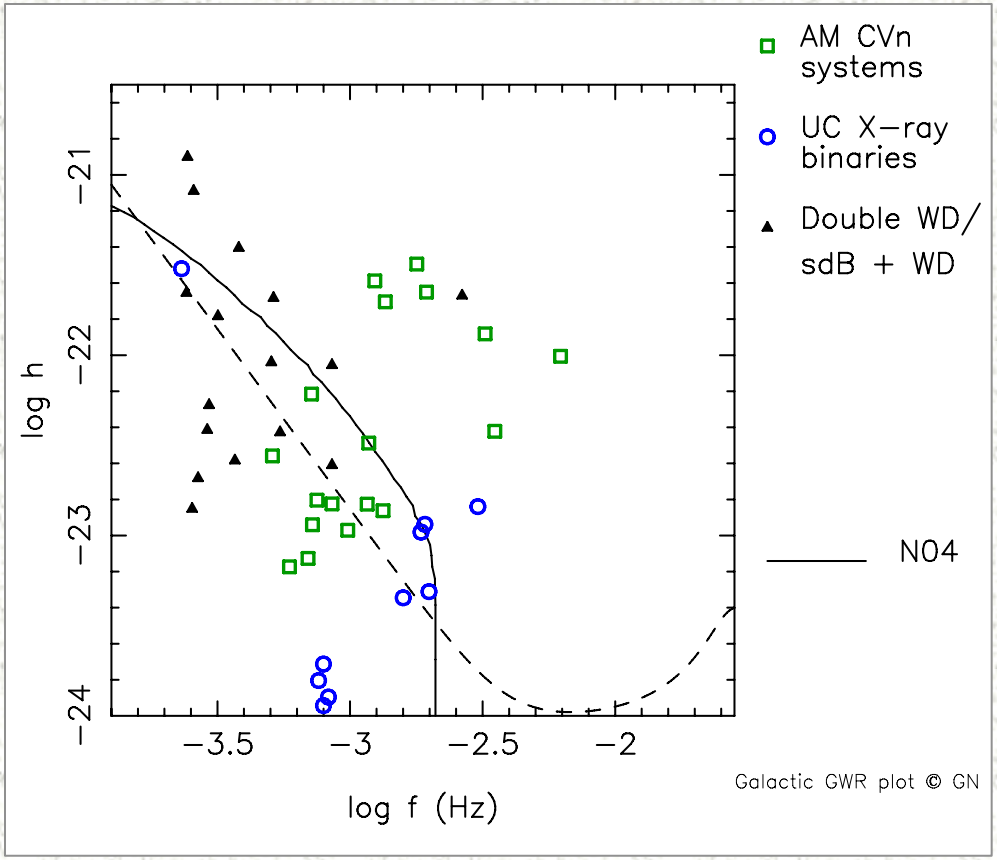
# Revisiting GW emission from WD binaries

- Reasons not to revisit:
  - Large number of previous studies (>20!)
  - No GW mission likely in forseeable future?
- Reasons to revisit:
  - 2007 population estimates from SDSS sample
    - Roelofs, Nelemans, & Groot, MNRAS (2007)
    - 1-3 x $10^{-6}$ $pc^{-3}$ compared to 6-27 x $10^{-6}$ $pc^{-3}$ from population synthesis estimates – *at least an order of magnitude difference assuming a thin disk origin*
      - Population synthesis from Nelemans et al. 2001 & 2004
      - Rau et al. ApJ (2010) – even lower space density than 2007 paper
  - Significant implications for both science and design of low-frequency GW detectors (LISA/NGO)
  - Another look at underlying assumptions of estimates

# Implications of SDSS observations for GW emission?

Questions:

- Does diffuse continuum from DDWDs decrease?
- Do number of resolved DDWDs decrease?
- Do numbers of resolved AM CVn decrease?



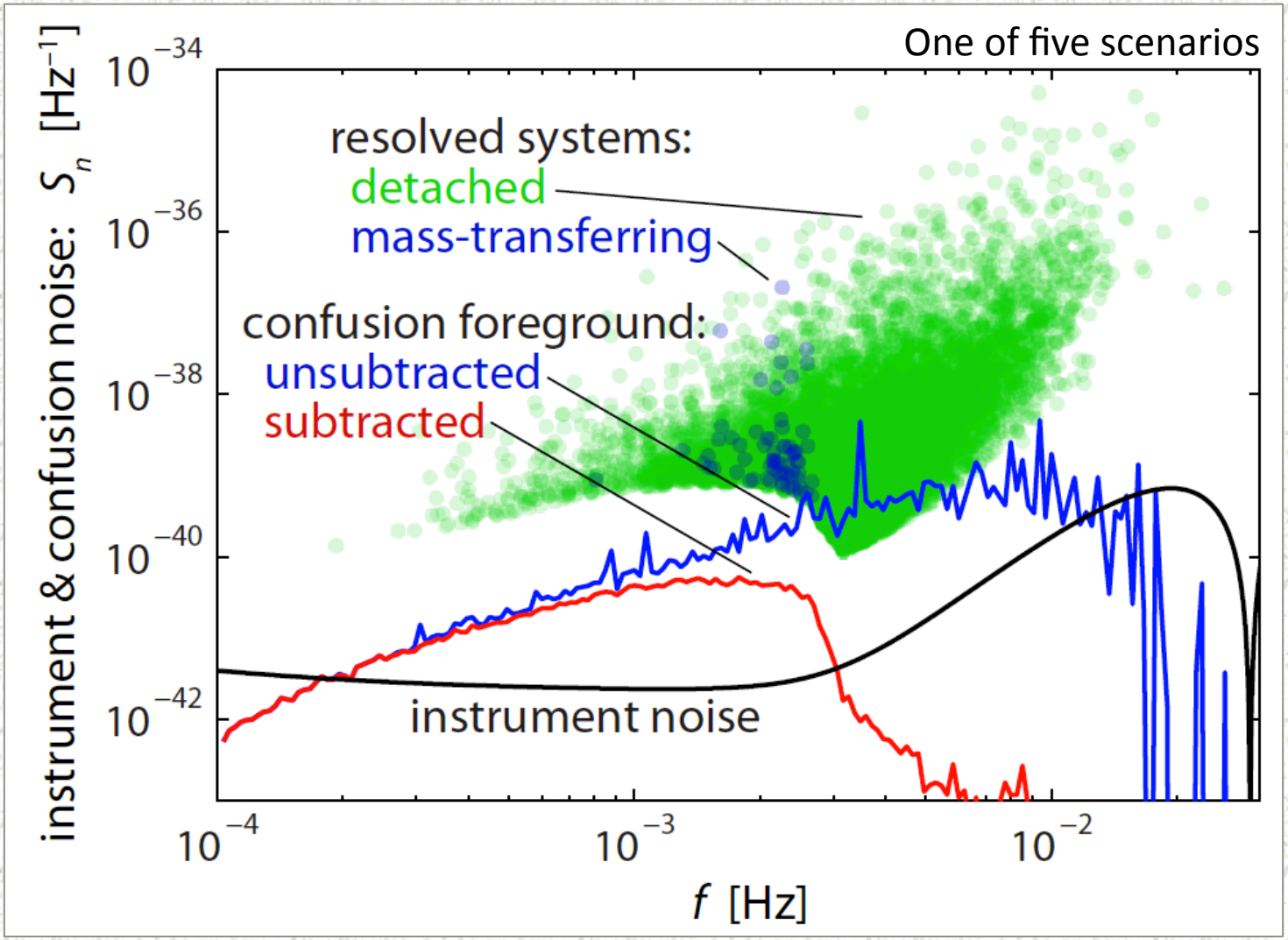
# Scope of Nissanke et al. (2012)

- Explore a range of scenarios that bound the probable outcomes for GW emission
  - Varied assumptions on formation of AM CVn and detached double WD (DDWD) systems
    - AM CVn from He-star and DDWD channels
- Five different scenarios in paper
  1) Optimistic/upper bound (LISA estimates)
  2) Pessimistic/lower bound
  3) No AM CVn from He-star channel
  4) Reduce DDWDs by x 5
  5) Modified Galactic disk model:

     $Z_{disk}$= 300 pc for $t_{age}$<7 Gyr and $Z_{disk}$= 1250 pc for $t_{age}$>7 Gyr

Alternative formation scenarios assuming thin disk

# New aspect: Identify and subtract resolved sources iteratively

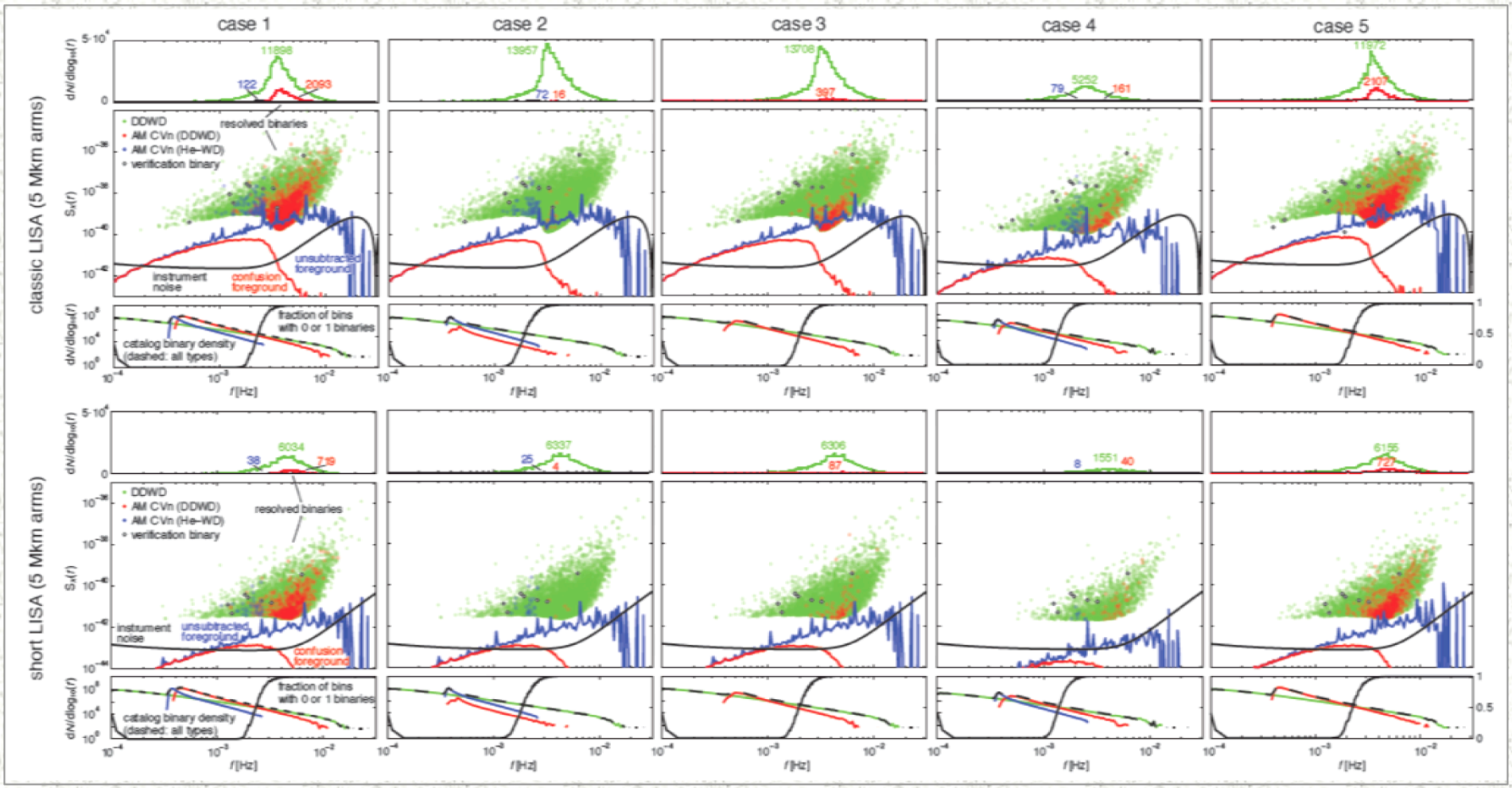





Nissanke et al. (2012)

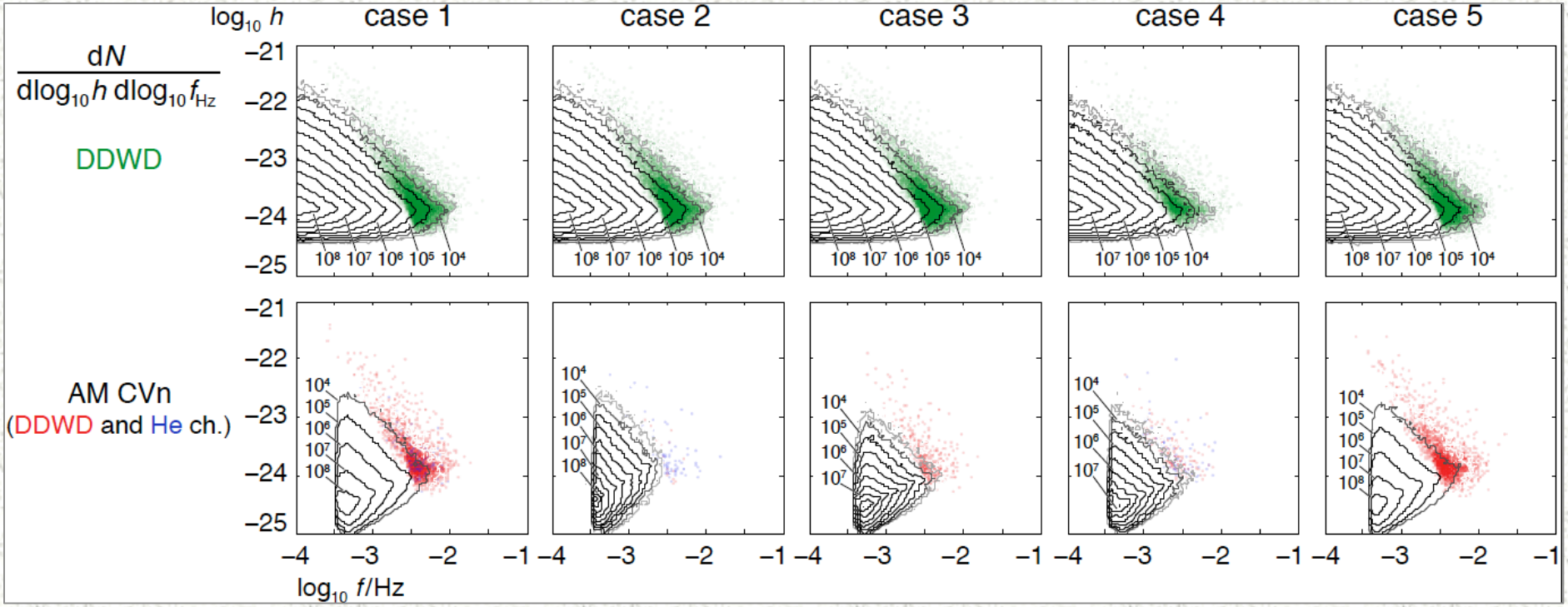
# 2 GW missions/5 scenarios

(Classic LISA: 5 Mkm arms & Short LISA: 1 Mkm arms)




Nissanke et al. (2012)

# Frequency-Strain number densities: DDWD and AM CVn




Nissanke et al. (2012)

DDWD number densities: relatively unchanged

AM CVn number densities: large differences

# Numbers of resolved AM CVn

| | DDWD Channel | He-star Channel |
|---|---|---|
| Case 1: Optimistic | 2093 | 122 |
| Case 2: Pessimistic | 16 | 72 |
| Case 3: No He-star channel | 397 | -- |
| Case 4: DDWDs/5 | 161 | 79 |
| Case 5: Modified disk | 2107 | -- |

# Why consider a modified Galactic disk?

- Recent work by Schönrich and Binney (2009)
  - Combine chemical evolution model with radial migration in the disk – fit to local stellar metallicity observations
  - Yields a single component with asymptotic thin and thick disk exponential behavior
- Observed distances and velocities of AM CVn do not dictate a thin-disk population

| Object | Period (min) | Velocity (km/s) | Distance (kpc) |
|---|---|---|---|
| RXJ0806.3+1527 | 5.36 | 91 | $\sim 1$ |
| AM CVn | 17.1 | 98 | 0.6 |
| HP Lib | 18.4 | 30 | 0.2 |
| CR Boo | 24.5 | 53 | 0.34 |
| V803 Cen | 26.6 | 12.2 | 0.35 |
| CP Eri | 28.4 | 77 | $\sim 1$ |
| GP Com | 46.5 | 118 | 0.08 |
| CE 315 | 65.1 | 122 | 0.09 |

# Schönrich and Binney: Radial migration – "churning"

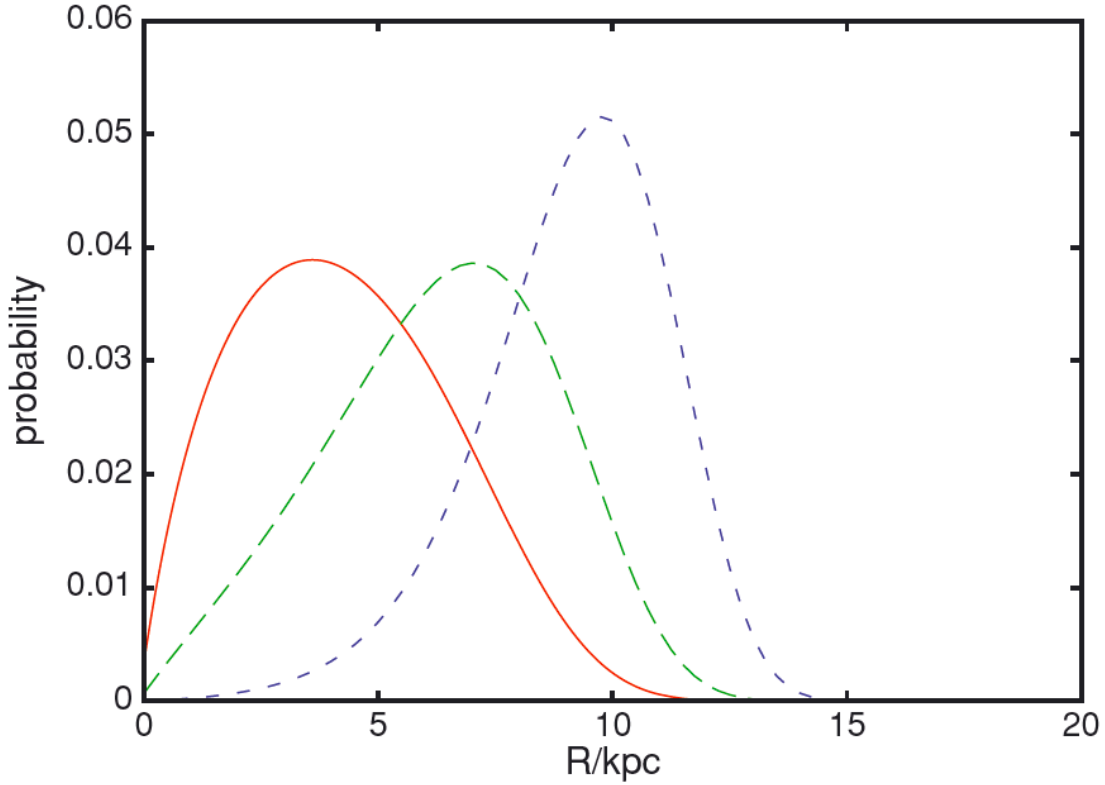
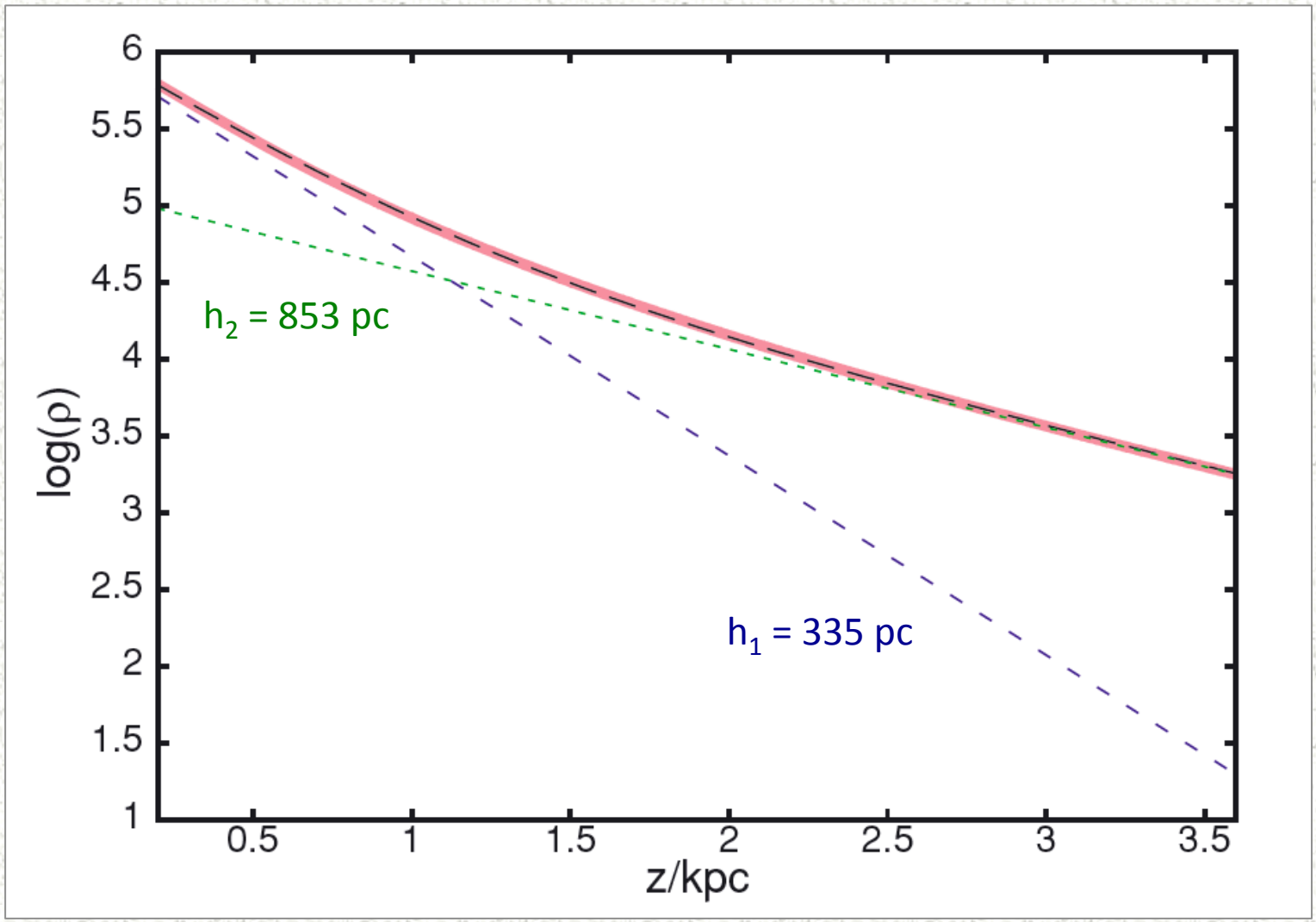



**Figure 3.** The radial distribution of the guiding centres of 12 Gyr old stars that were born at 5 (red), 7.6 (green, long dashed) and 10 kpc (blue, short dashed) when the churning fraction $k_{ch} = 0.25$.

[Schonrich & Binney, MNRAS, 396, 203 (2009)]

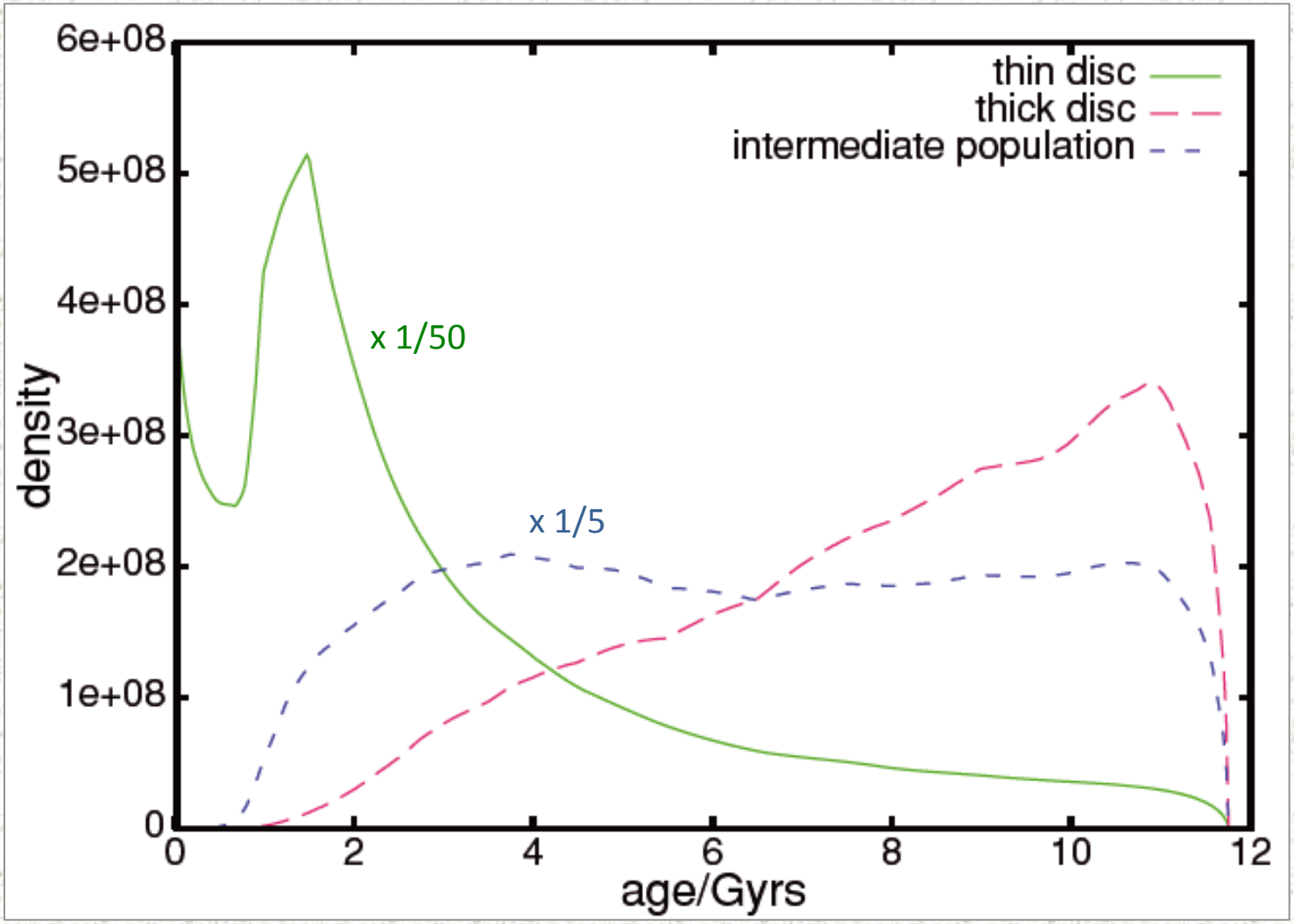
# Schönrich and Binney: Asymptotic scale heights from radial migration model




[Schonrich & Binney, MNRAS, 396, 203 (2009)]

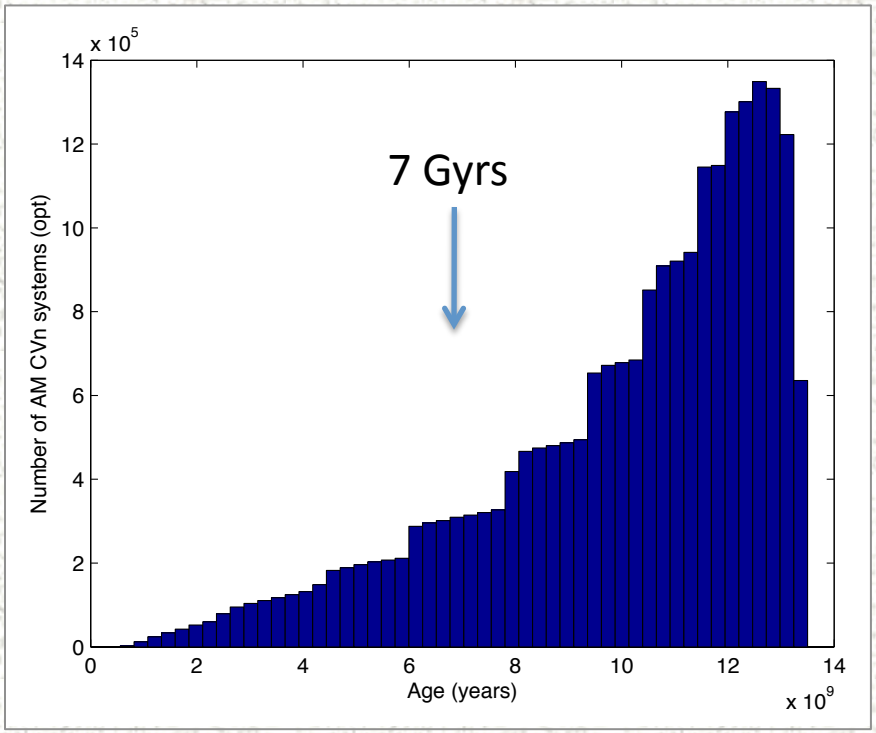
# Schönrich and Binney: Age Distributions

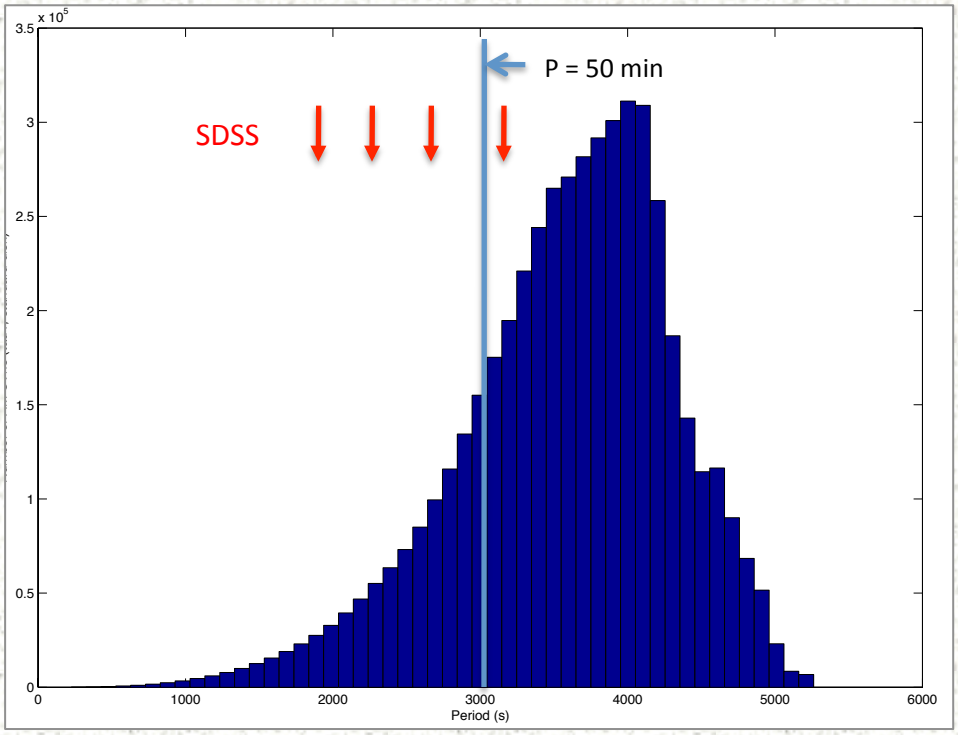
(Note: model populations kinematically selected)




[Schonrich & Binney, MNRAS, 399, 1145 (2009)]

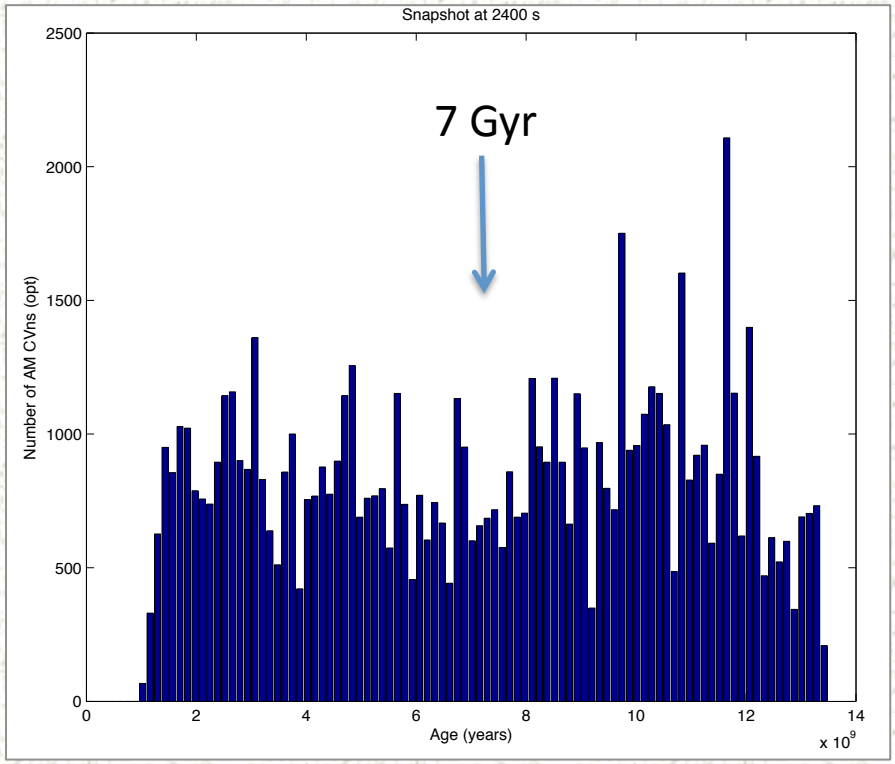
# Nissanke+12 Simulations: Ages and Periods




Simulations indicate that AM CVn are predominantly an old population (> 7 Gyr). Older AM CVn tend to have longer periods. SDSS objects do not fully sample the expected period distribution of AM CVns

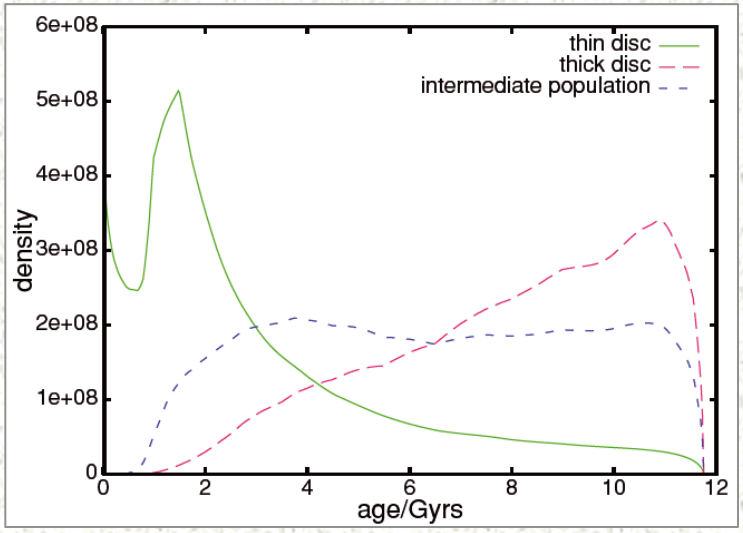
# Nissanke+12 simulations:
# At a given period, mixture of ages




Nissanke+12 simulation for P= 40 min

Corrected for volume, comparable numbers of older AM CVn from thin and thick disks

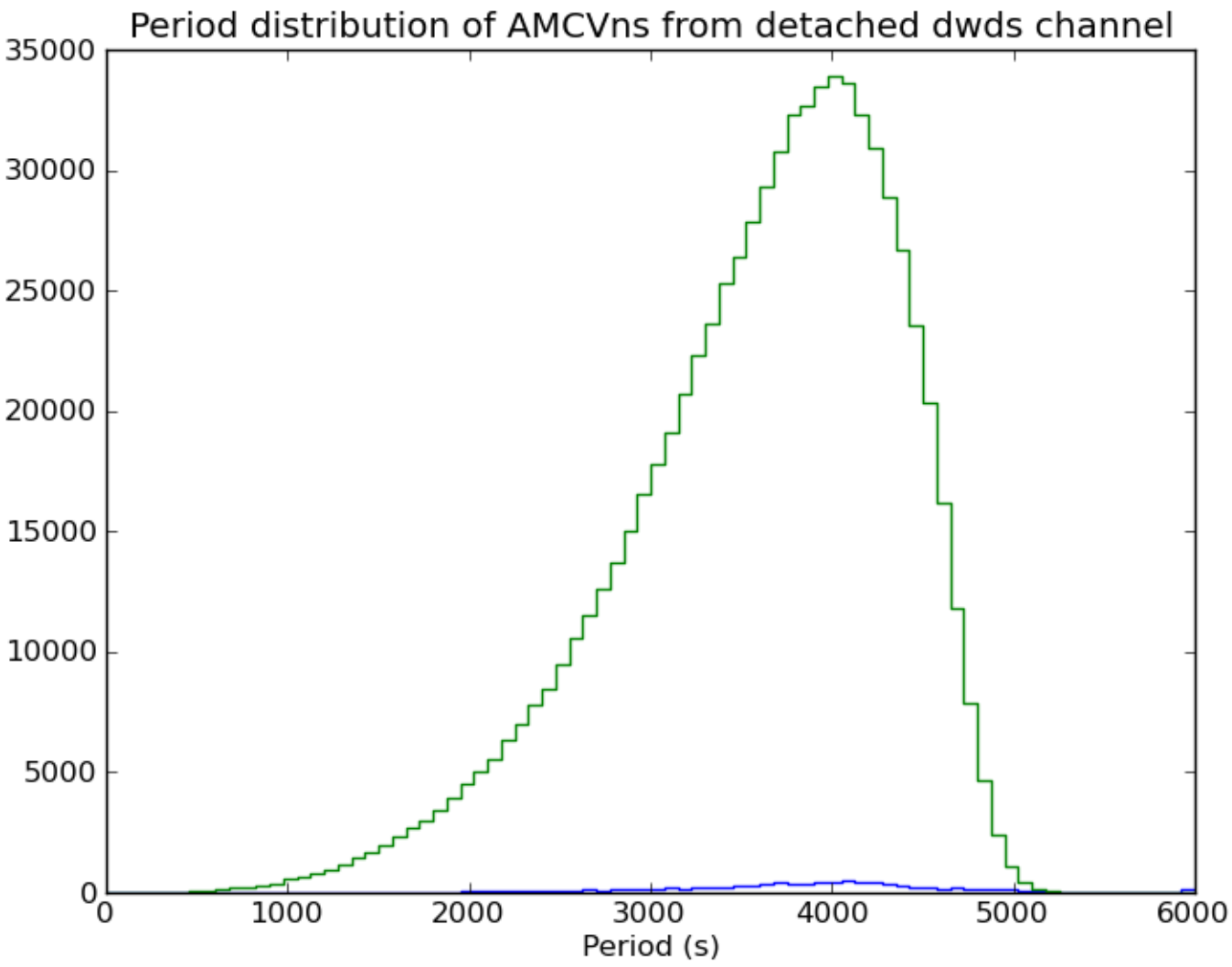
Schonrich & Binney model



# Summary

- Nissanke+12 explored a range of scenarios for populations of DDWDs and AM CVn
- Results:
  - Diffuse continuum dominated by detached systems in all cases
  - For thin disk population, the number of resolved AM CVn systems with detectable GW decreases by an order of magnitude or more
  - Modified models of the Galaxy (e.g. Schönrich and Binney) can have moderately large numbers of GW-detectable AM CVn and still be consistent with low number of SDSS-detectable AM CVn.
    - Detailed estimate with SDSS observations is desirable

# BACKUP SLIDES


Period distribution of AMCVns from detached dwds channel
35000
30000
25000
20000
15000
10000
5000
0
0
1000
2000
3000
4000
5000
6000
Period (s)