The Galactic Underworld: The spatial distribution of compact remnants

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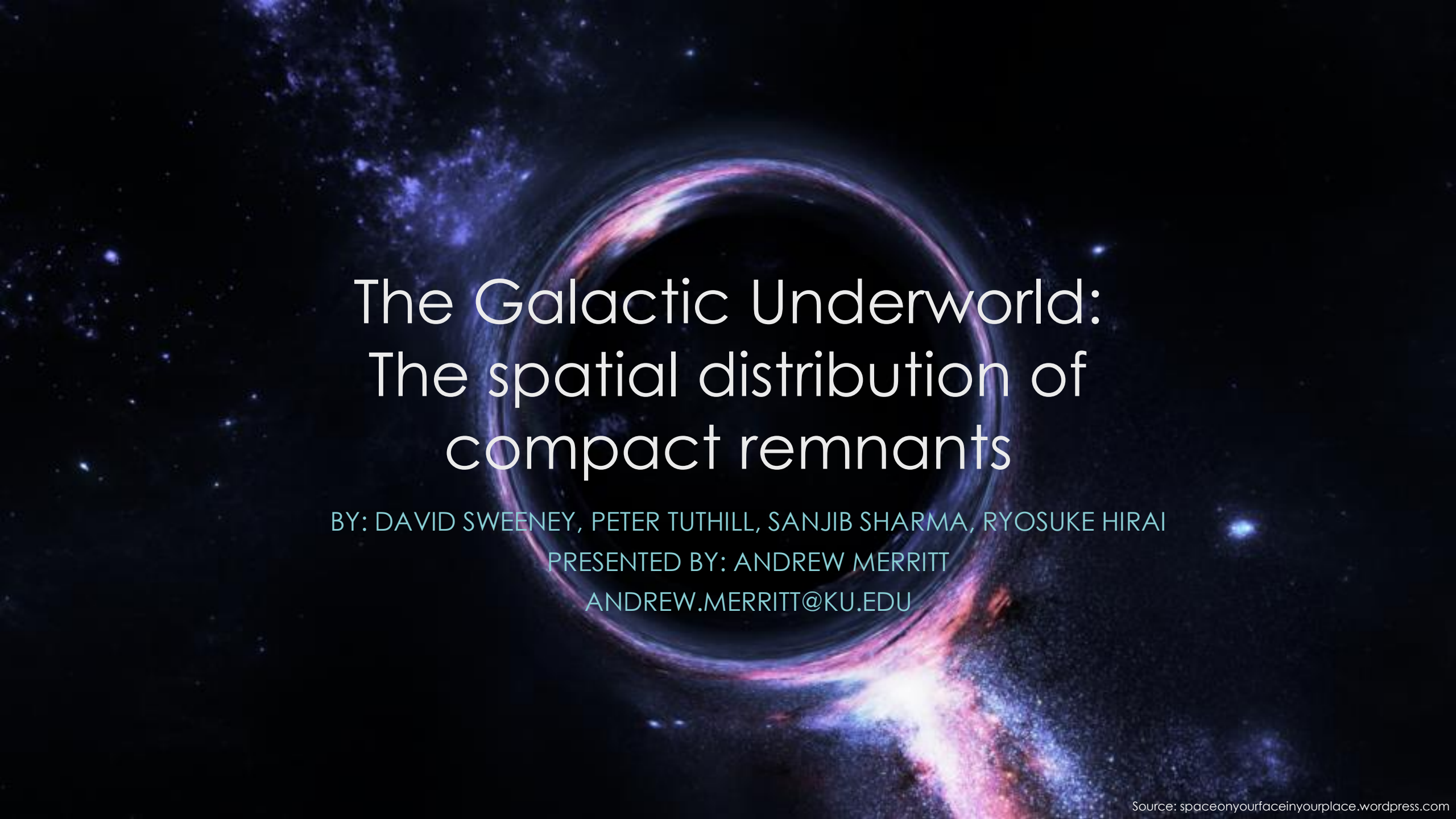


Source: spaceonyourfaceinyourplace.wordpress.com

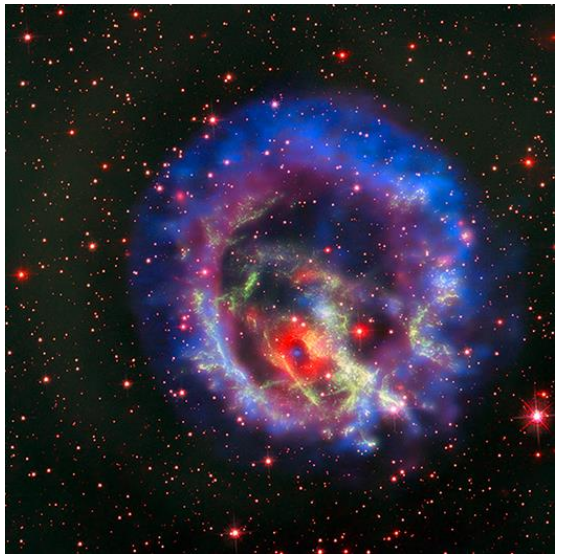
Introduction / Motivation

- Galactic distribution of neutron stars (NS) and black holes (BH) is not well known
- NS observed through radio astronomy
- BH very hard to detect
  - LIGO, Virgo
  - Microlensing
- Can we predict / simulate the distribution of galactic remnants?

Objects of Interest

Neutron Stars

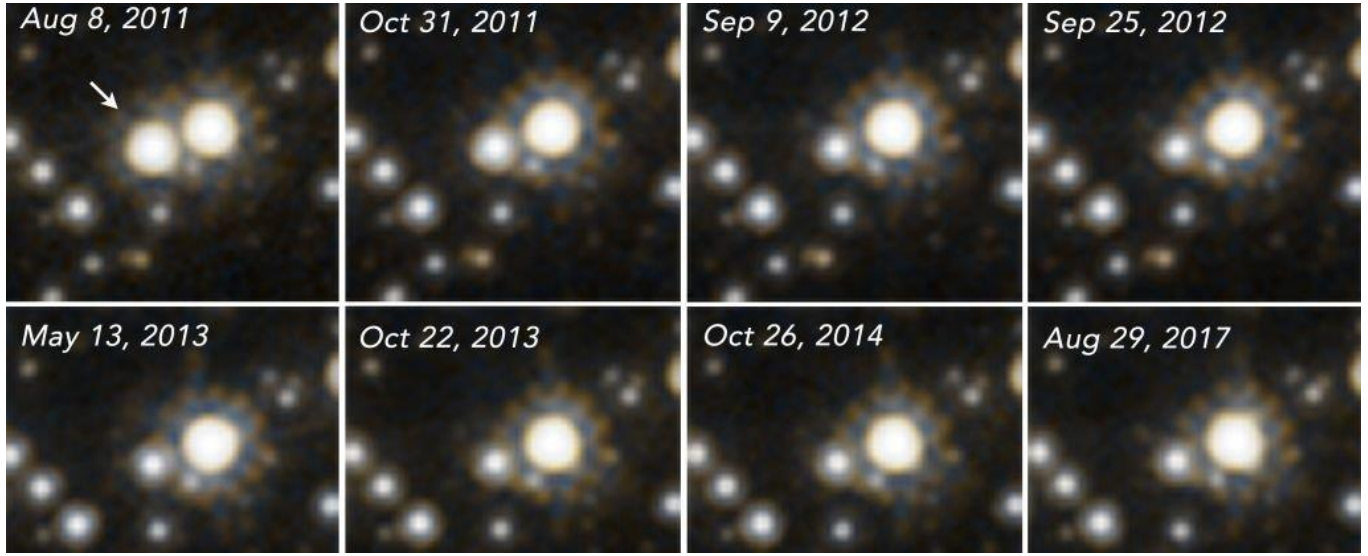
- Core collapse remnant
- Initial mass ~ 8-25 $M_\odot$



E0102 – Small Magellanic Cloud
Source: chandra.harvard.edu

Black Holes

- Core collapse remnant
- Initial mass > 25 $M_\odot$



MOA-11-191/OGLE-11-462
Source: Sahu et al. 2022

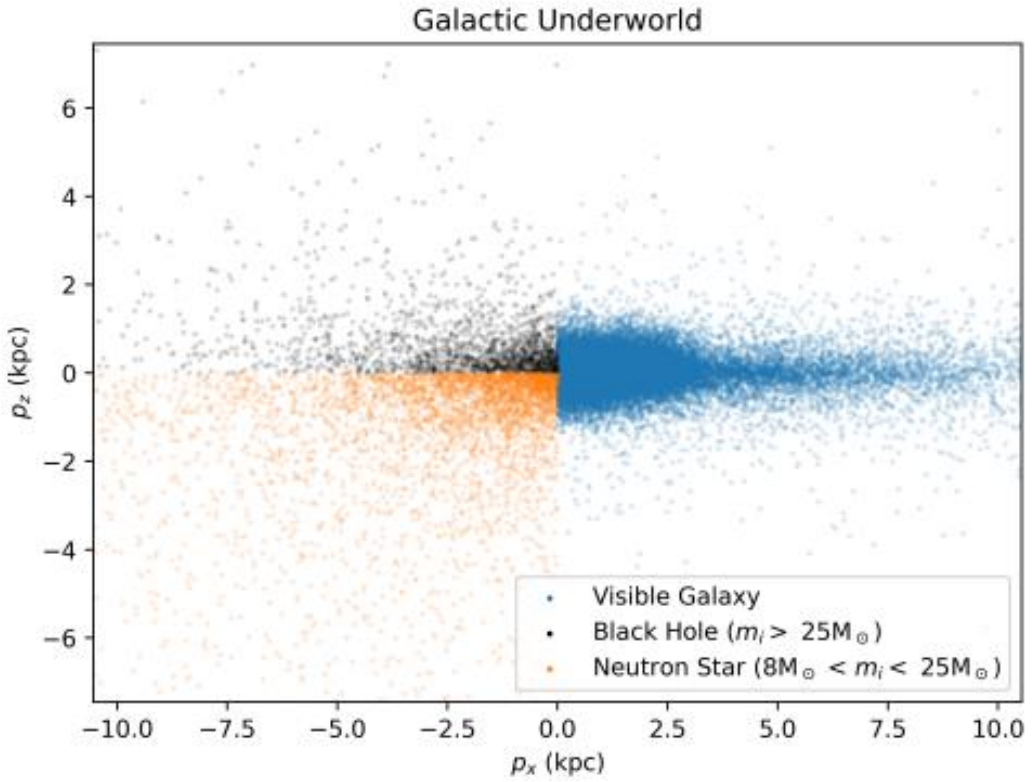
Method

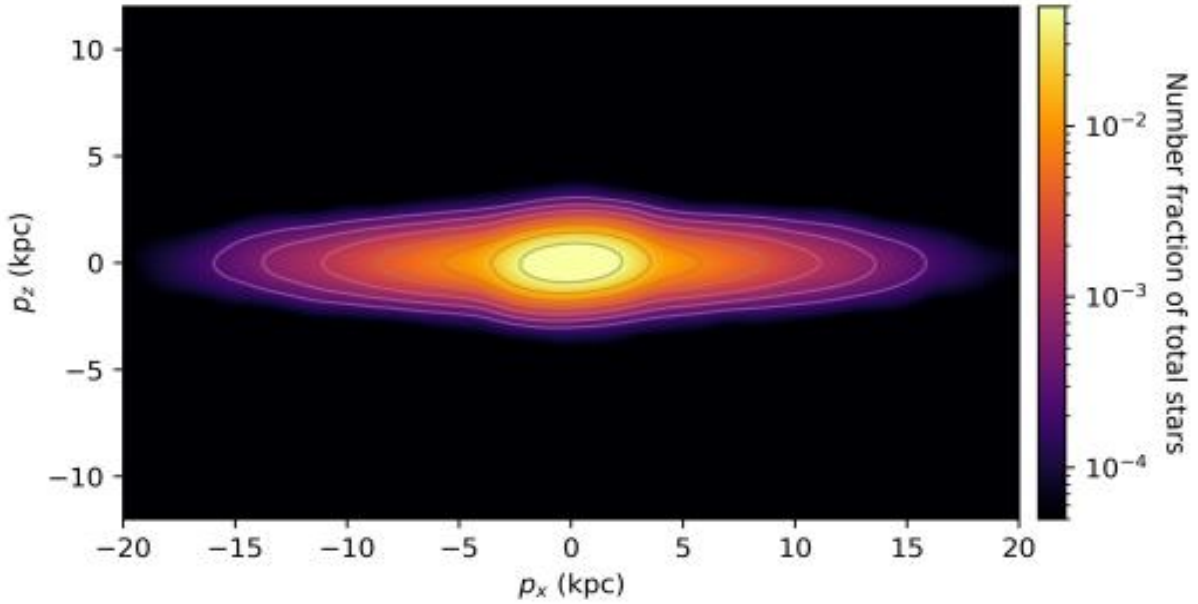
- GALAXIA
  - x, v, τ, M/H, m
  - Four galactic components: thin disc, thick disc, stellar halo, bulge
  - 0.07 – 100 $M_{\odot}$
  - Stars < 8 $M_{\odot}$ filtered out
  - Natal kicks have the same momentum per object class

Results - Distribution

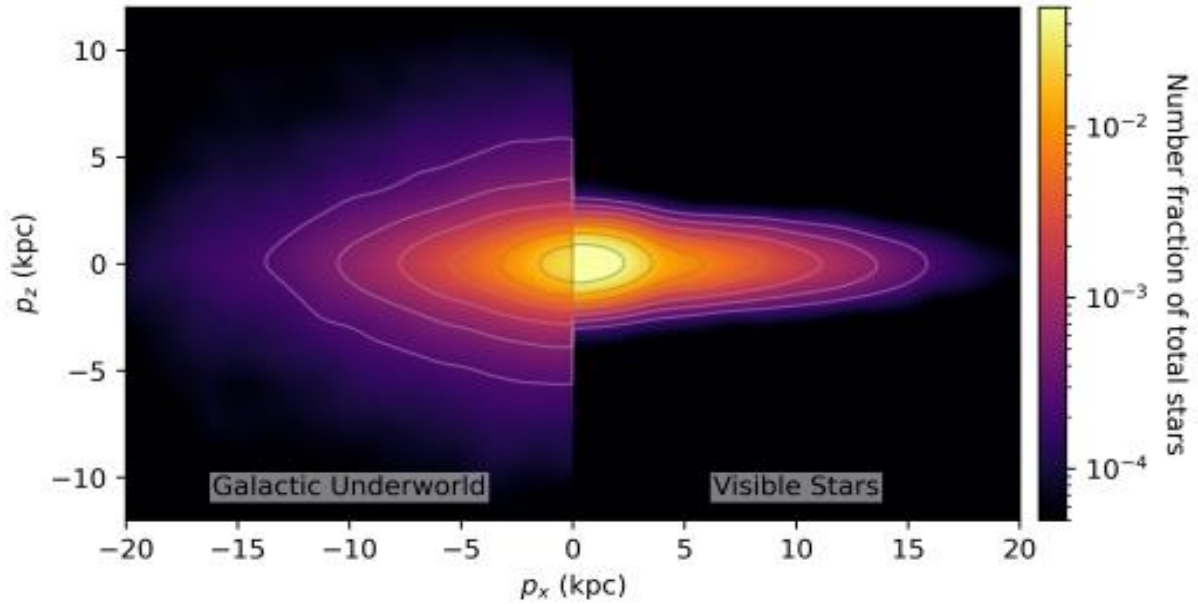
- Nearest remnant from Sun:
  - 19 pc (NS), 21 pc (BH)

	Scale Height (pc)	Scale Length (pc) (50 percentile)
Visible Galaxy	334 ± 8	920 ± 30
Unkicked Galactic Underworld	560 ± 10	930 ± 20
Galactic Underworld	1260 ± 30	860 ± 20
Neutron Stars	1490 ± 50	950 ± 20
Black Holes	900 ± 40	750 ± 20

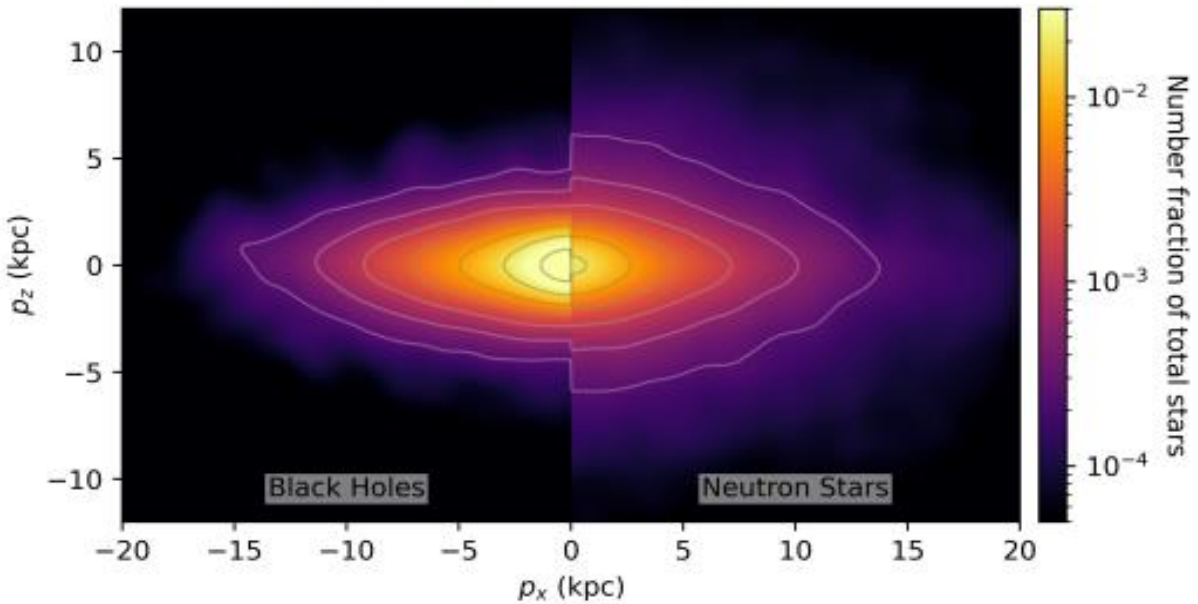




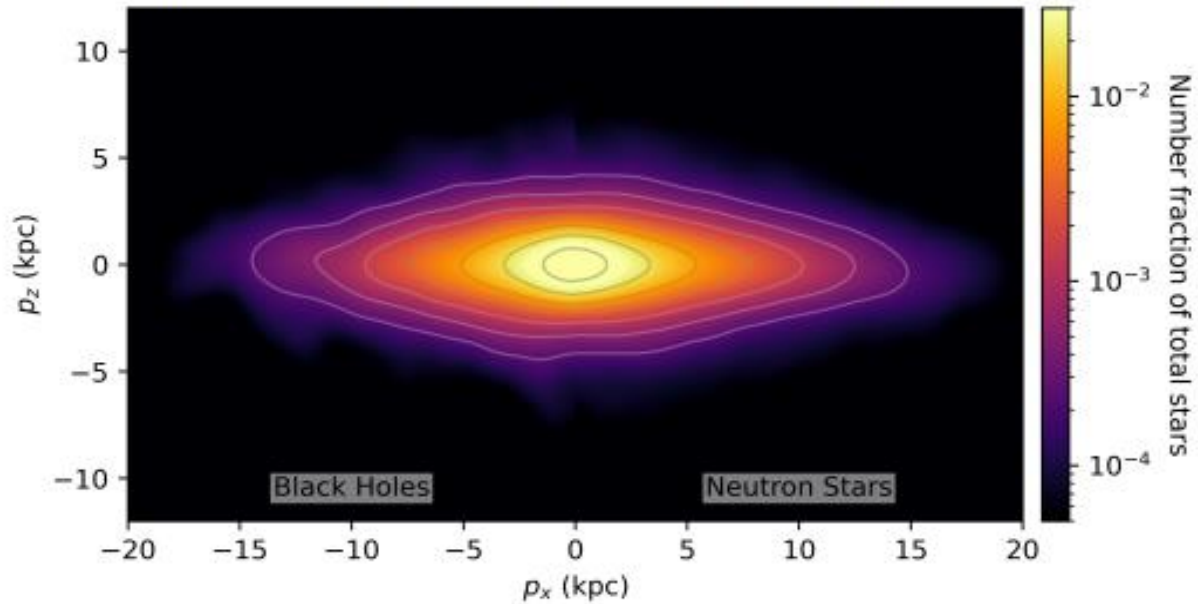
(a) Visible Galaxy rendered from GALAXIA



(b) Galactic underworld (left side) with visible Galaxy (right side)



(c) Black holes (left side) with neutron stars (right side)



(d) Undisrupted massive binaries: BH binaries (left side) with NS binaries (right side)

Results – Magnetar Question

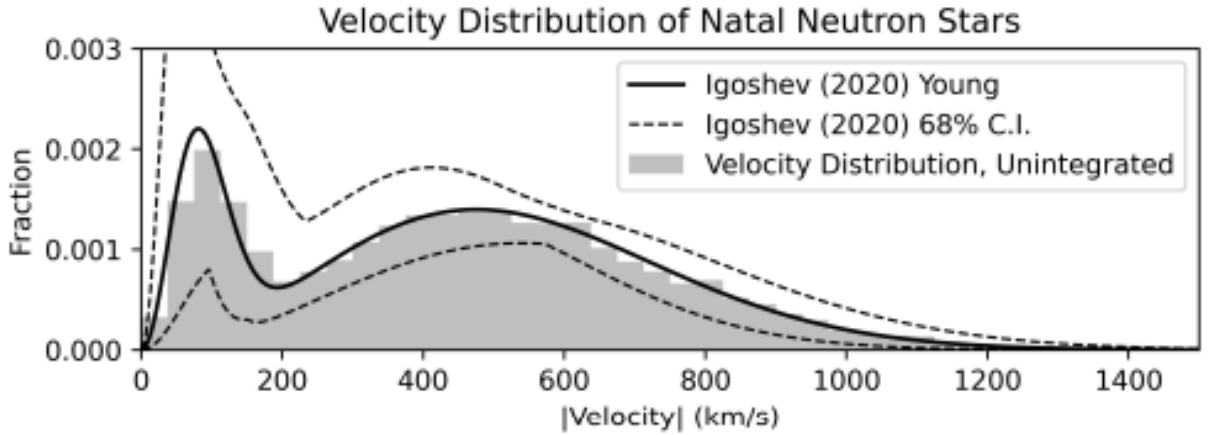
- Magnetar – neutron star variant
- Assumption: 50% of young pulsars in simulation are magnetars
- Magnetar birth: ~290 years
- Nearest magnetar probability:

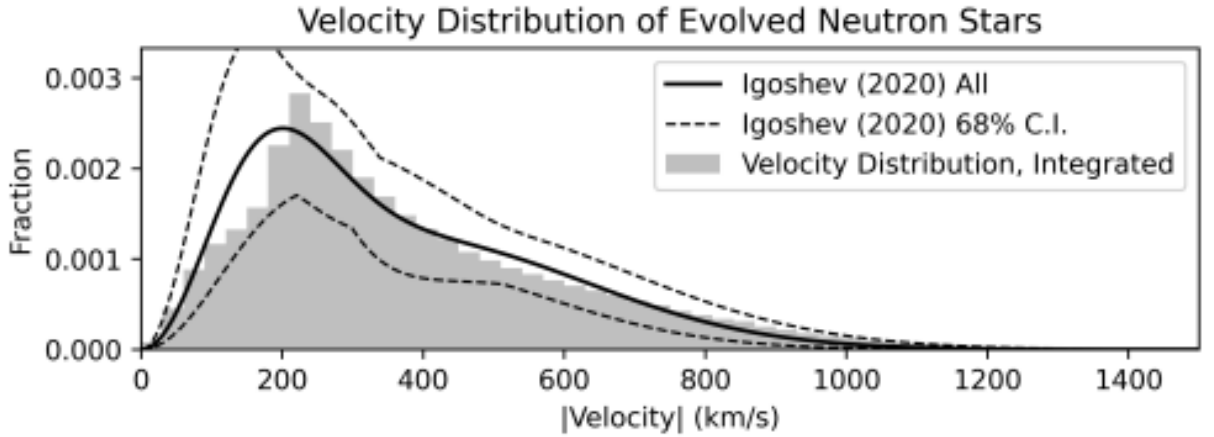
  4.2 kpc
- ^{14}C found in tree rings unaffected

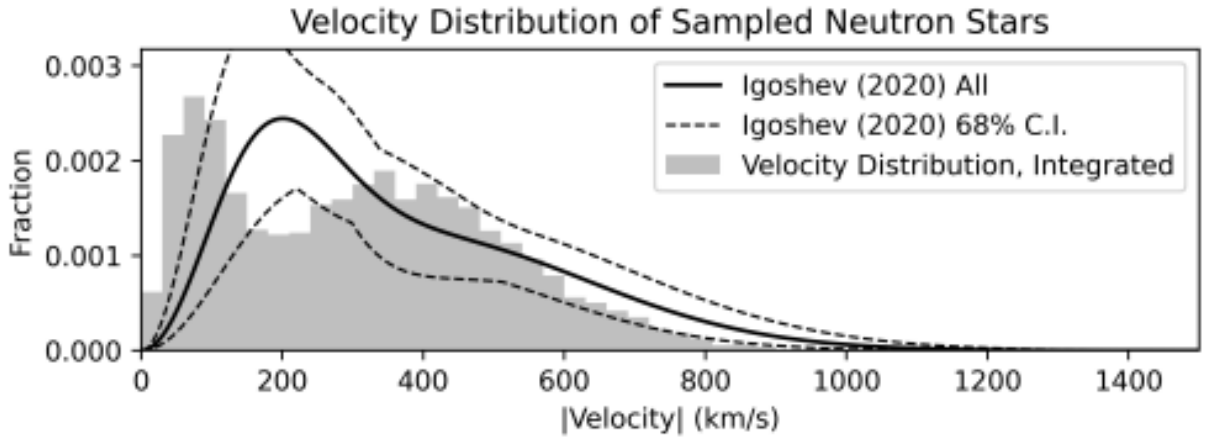
Source: photojournal.jpl.nasa.gov

Results – Neutron Star Distribution

- Comparing simulation data to observational data for NS, BH is difficult
- NS sample trends toward young NS's
- NS velocity relaxes through time, interactions
- Simulation shows inconsistency with Igoshev (2020) parameters







Results – Remnant Escape | Model Issues

Remnant Escape

- Galactic escape velocity is location dependent
- 30% of remnants have escape velocity
  - 40% of NS's, 2% of BH's
- Estimated mass loss: $2.1 \times 10^8 M_\odot$
  - ~0.4% present-day galactic mass

Model Issues

- Model ignores binary evolution
  - ~22% become single massive star
  - ~77-97% of remaining become unbound
- Most BH's have been discovered in binary systems

Conclusion

- The Galactic Underworld was examined through simulation creating time, location, kinematics of stellar remnants
- Remnants – particularly NS's – have ellipsoid galactic distribution opposed to typical disc-like distribution
- Magnetars not believed to account for increase in ^{14}C in tree rings based on this simulation
- Pulsar distribution model does not match observed data when filtered with observational filters
- 40% of NS and 2% of BH have high enough natal kick to overcome galactic escape velocity
- GALAXIA model can and will be updated with future information to create better models