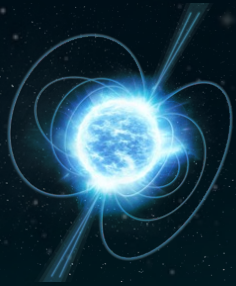


# Discovering quiet neutron stars with the Vera Rubin Observatory



Shirley Li (UC Irvine)

with Melanie Zaidel and John Beacom, in preparation

Pheno 2026



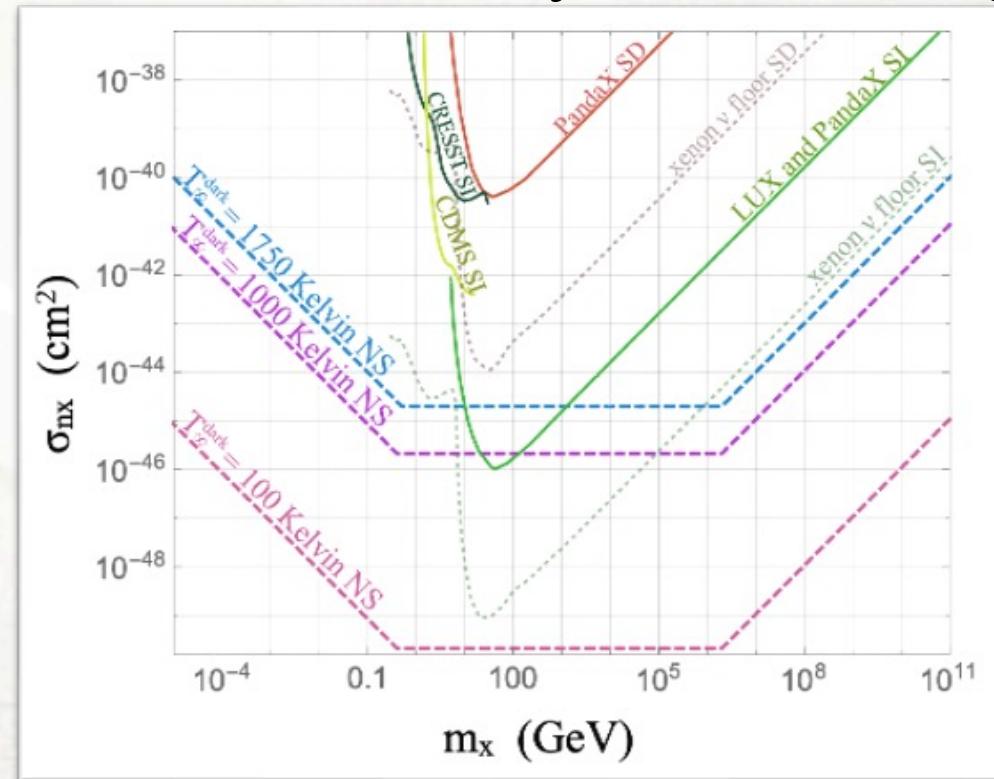
# Neutron stars are extreme laboratories

## Sensitive Probes of New Physics

### Dark Matter-Baryon Scattering

#### Neutron Star (NS) Properties:

- Mass:  $1.4 M_{\odot}$
- Radius: 10 km
- Density:  $10^{14}$  g/cm<sup>3</sup>
- Magnetic Fields:  $10^{12}$  G

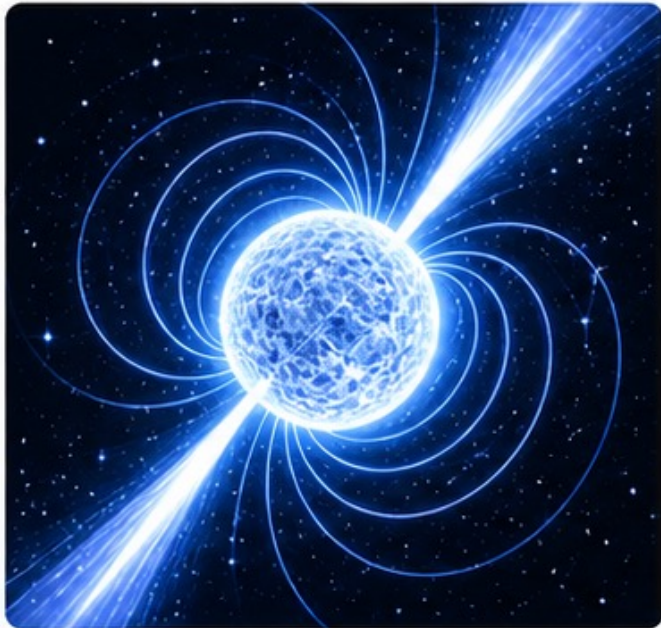


Baryakhtar et al., 2017

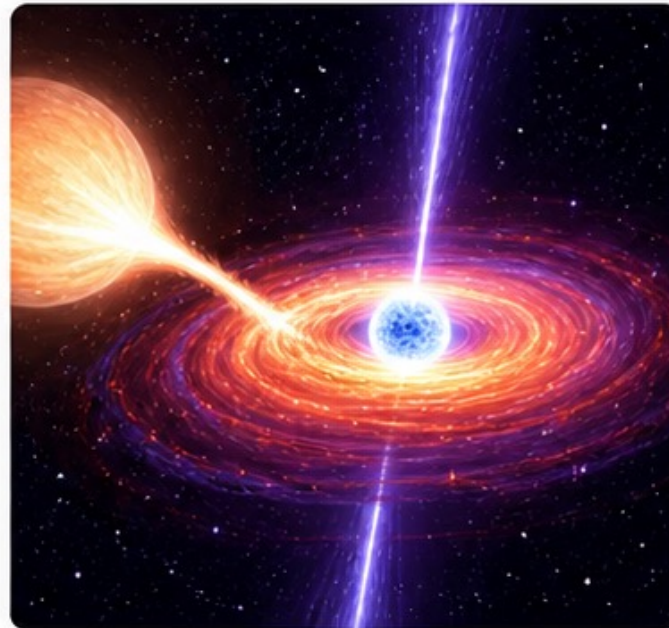
What we learn depends on which neutron stars we can actually observe

# We mostly find neutron stars when they are 'loud'

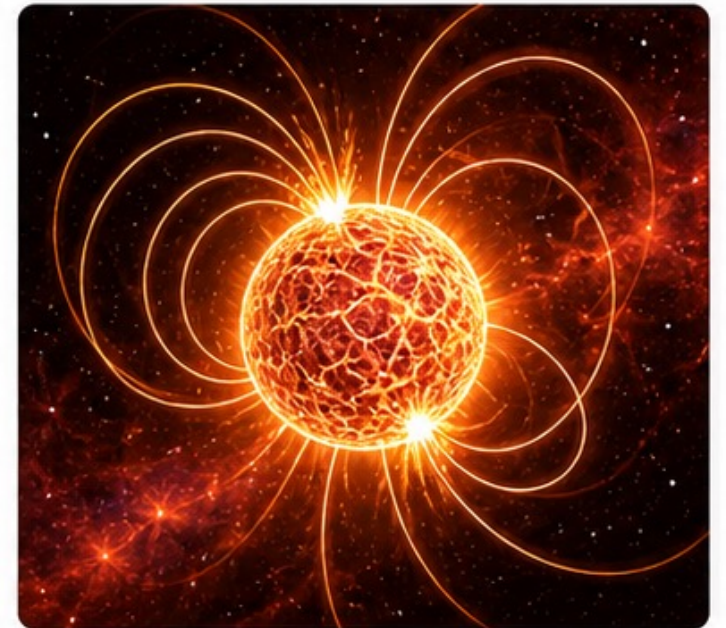
Pulsars



Accreting NSs



Magnetars



We have observed ~ 3000 such systems

# The quiet sample is tiny: the Magnificent Seven

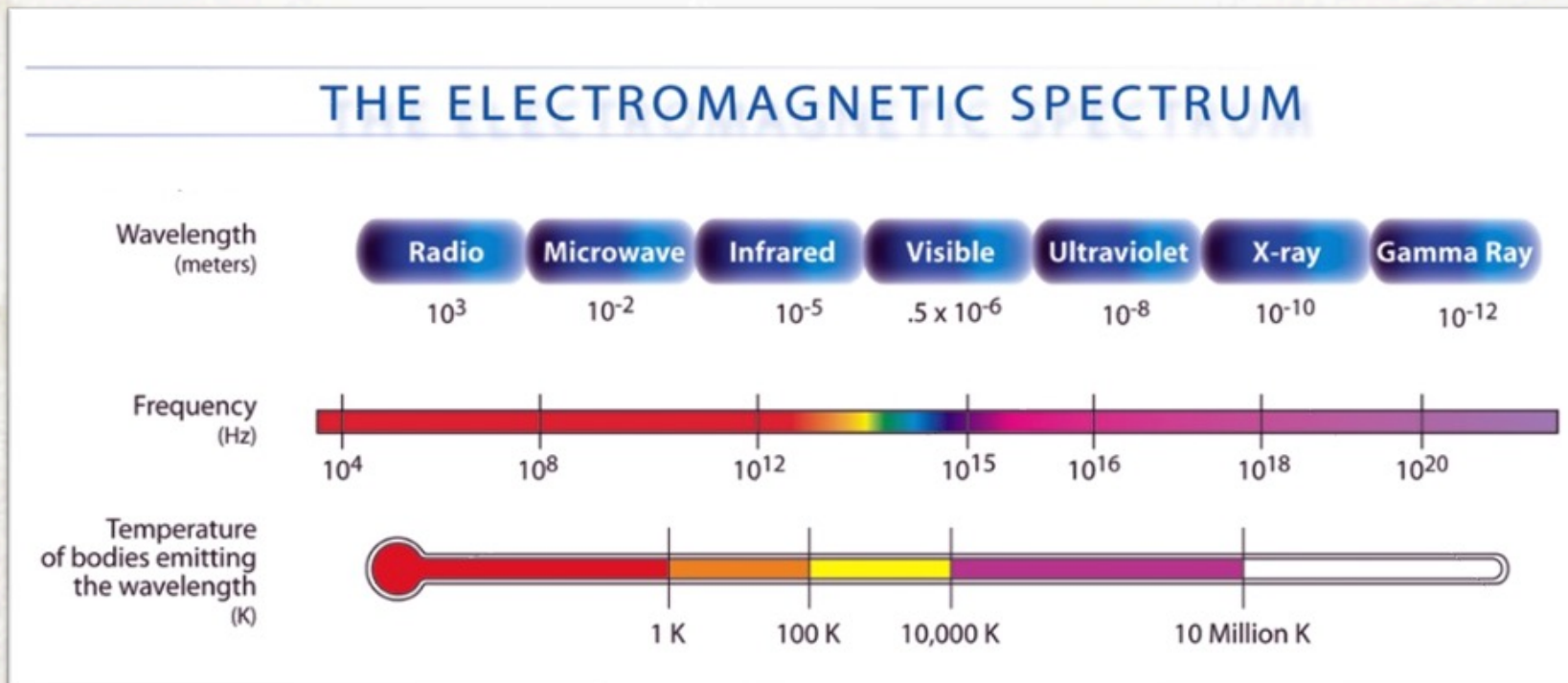
## Quiet isolated NSs



- 7 confirmed systems
- Thermally emitting
- Discovered in an X-ray survey
- Faint

How can we find more  
isolated neutron stars?

# How can we find more isolated neutron stars?

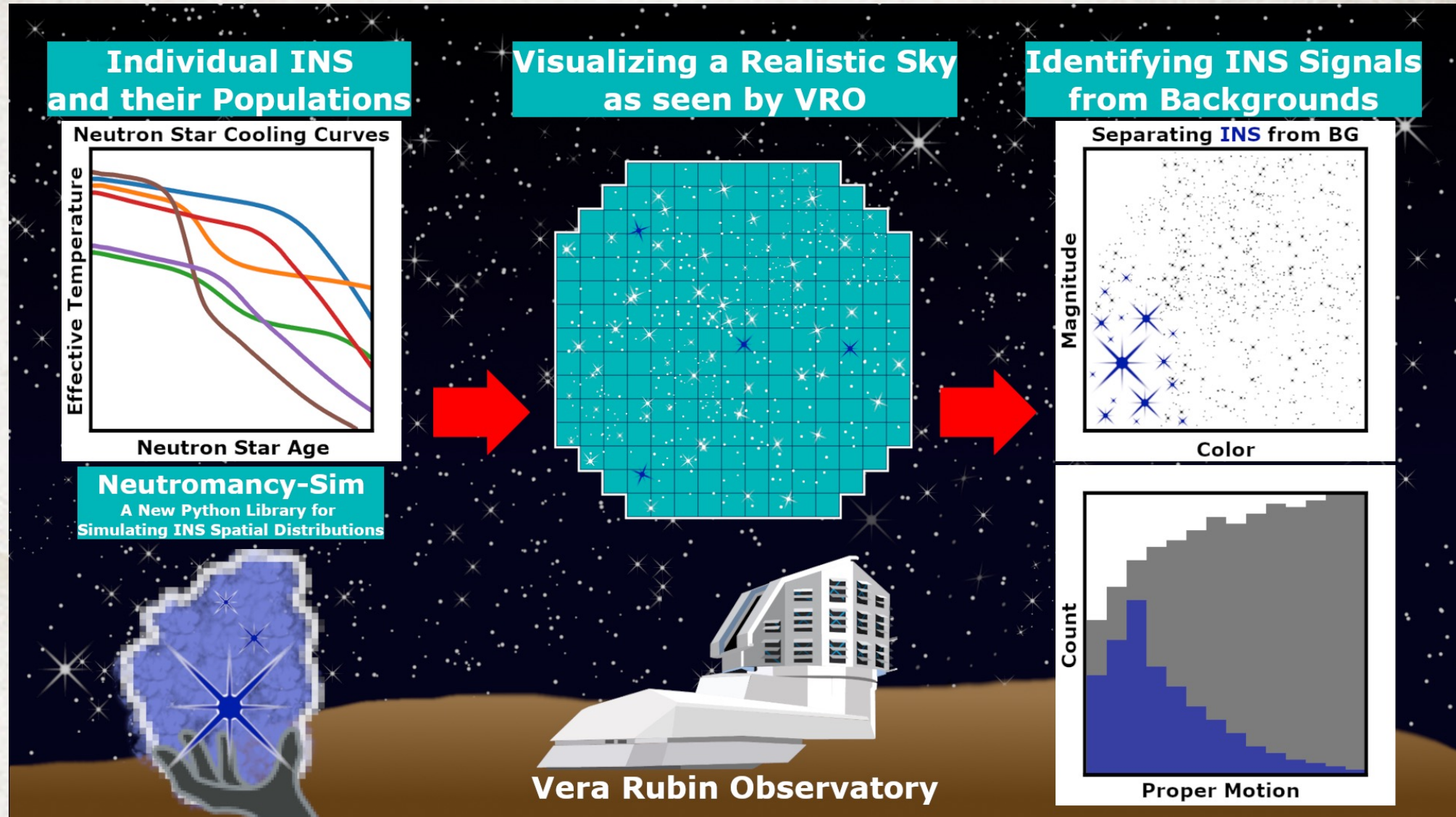


# Optical surveys provide the right discovery channel

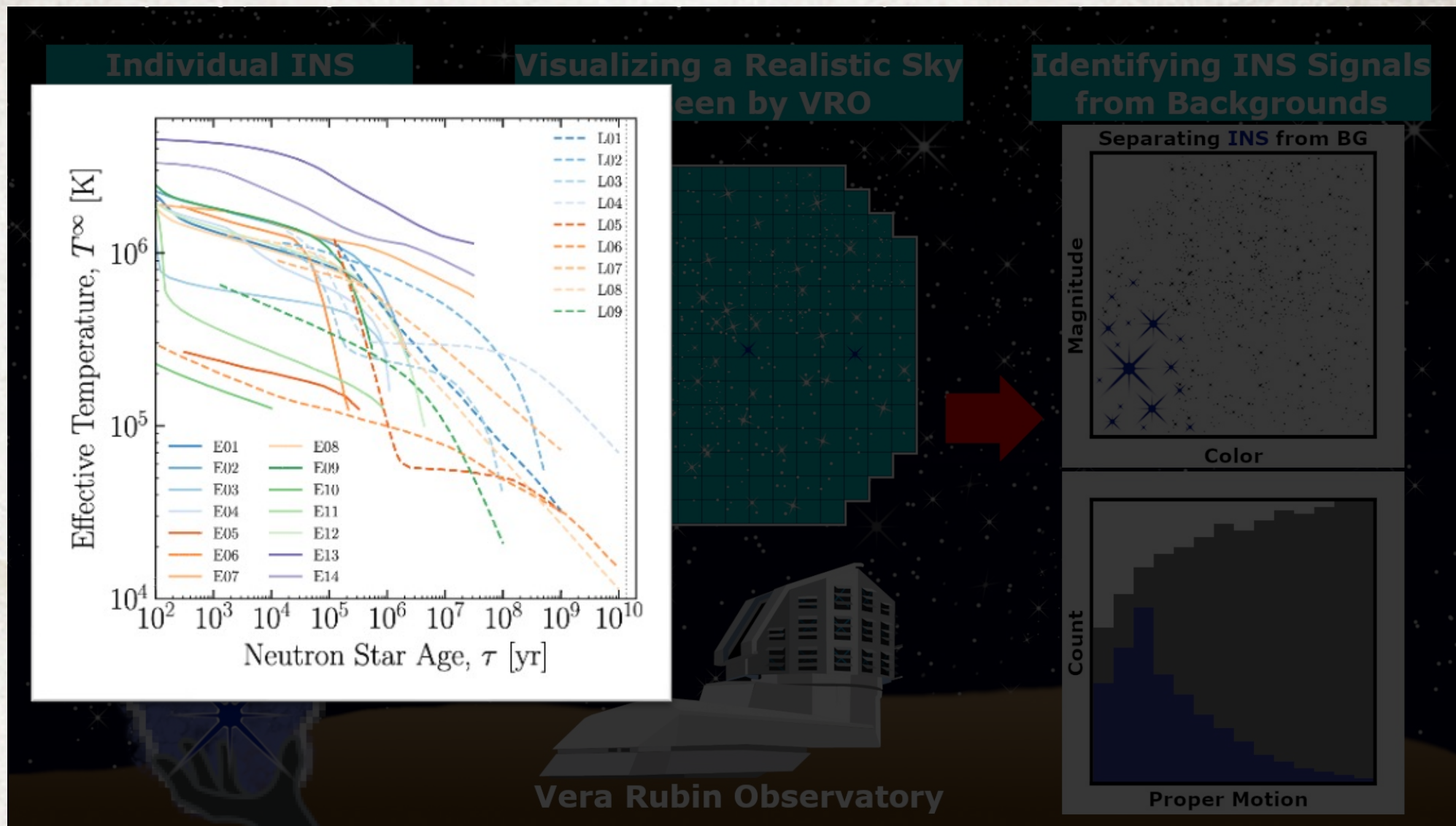
- Wide field
- Deep imaging
- Sensitive to colder neutron stars that are X-ray dim
- Repeated observations → proper motion



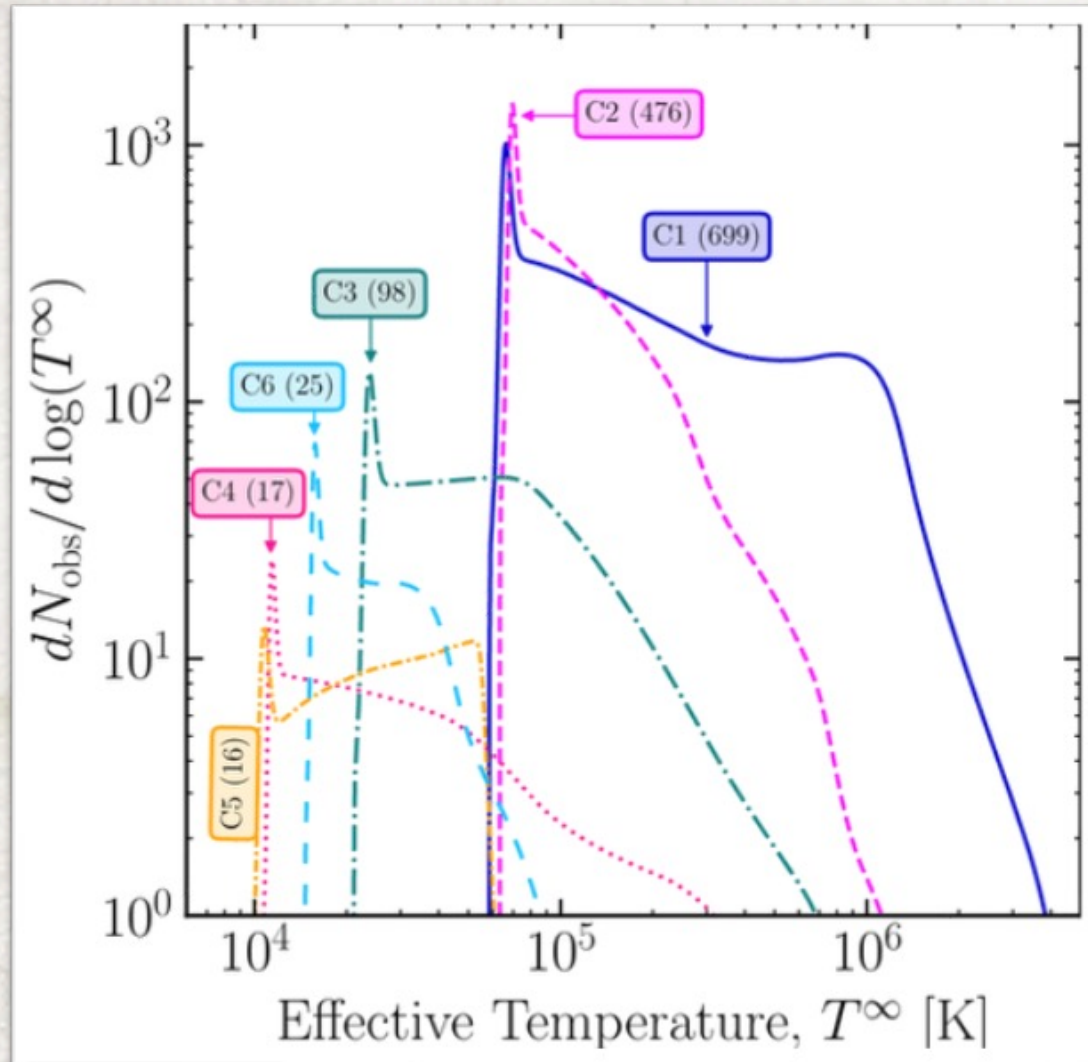
# Our calculation pipeline



# Our calculation pipeline



# Result: Rubin should greatly expand the sample

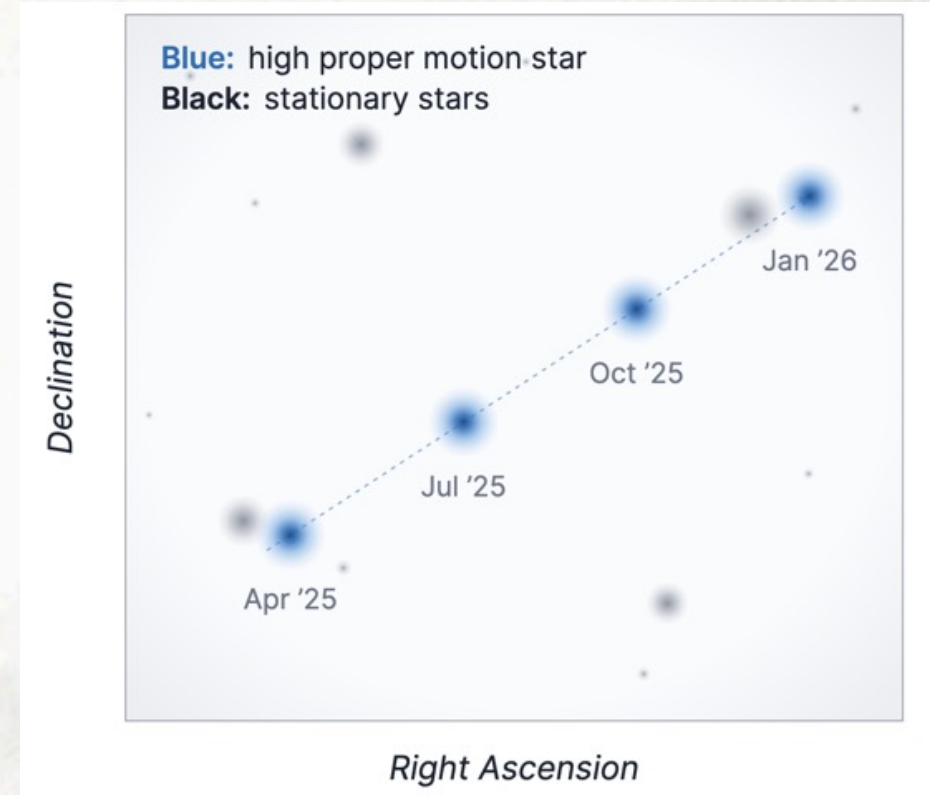
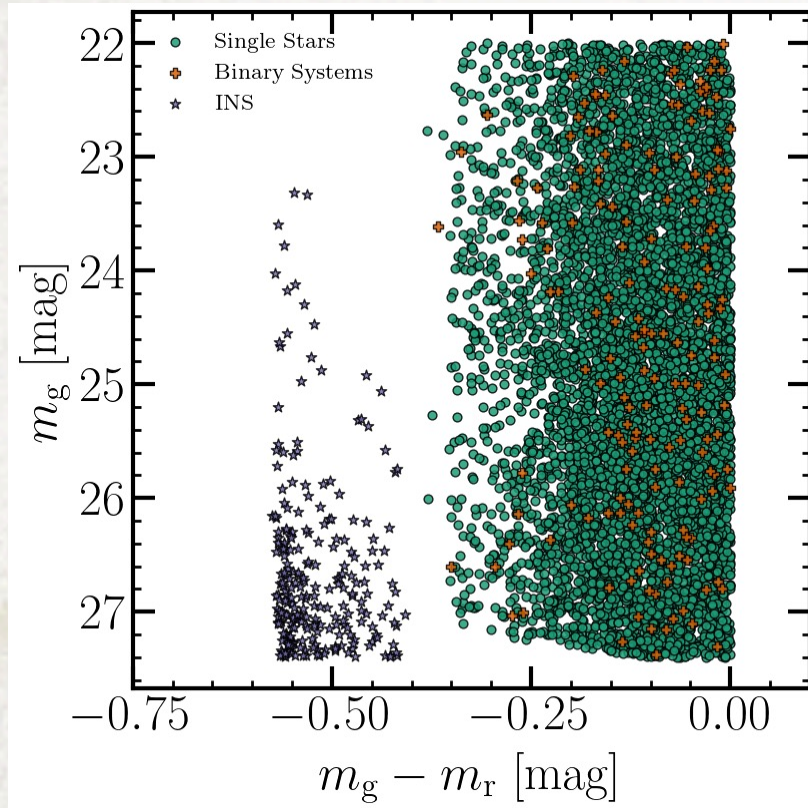


Rubin forecasts: tens to hundreds, depending on assumptions

The largest theory uncertainty: neutron star cooling curve

# The practical challenge

## Separating signal from background



Color identifies promising candidates;  
proper motion helps make the search credible.

# Conclusions

1. Too few observed isolated neutron stars
2. Rubin provides a new search channel: wide, deep, time-domain optical data
3. A discovery sample would enable population studies of old neutron stars and BSM searches
4. Even a null result would constrain neutron star cooling models