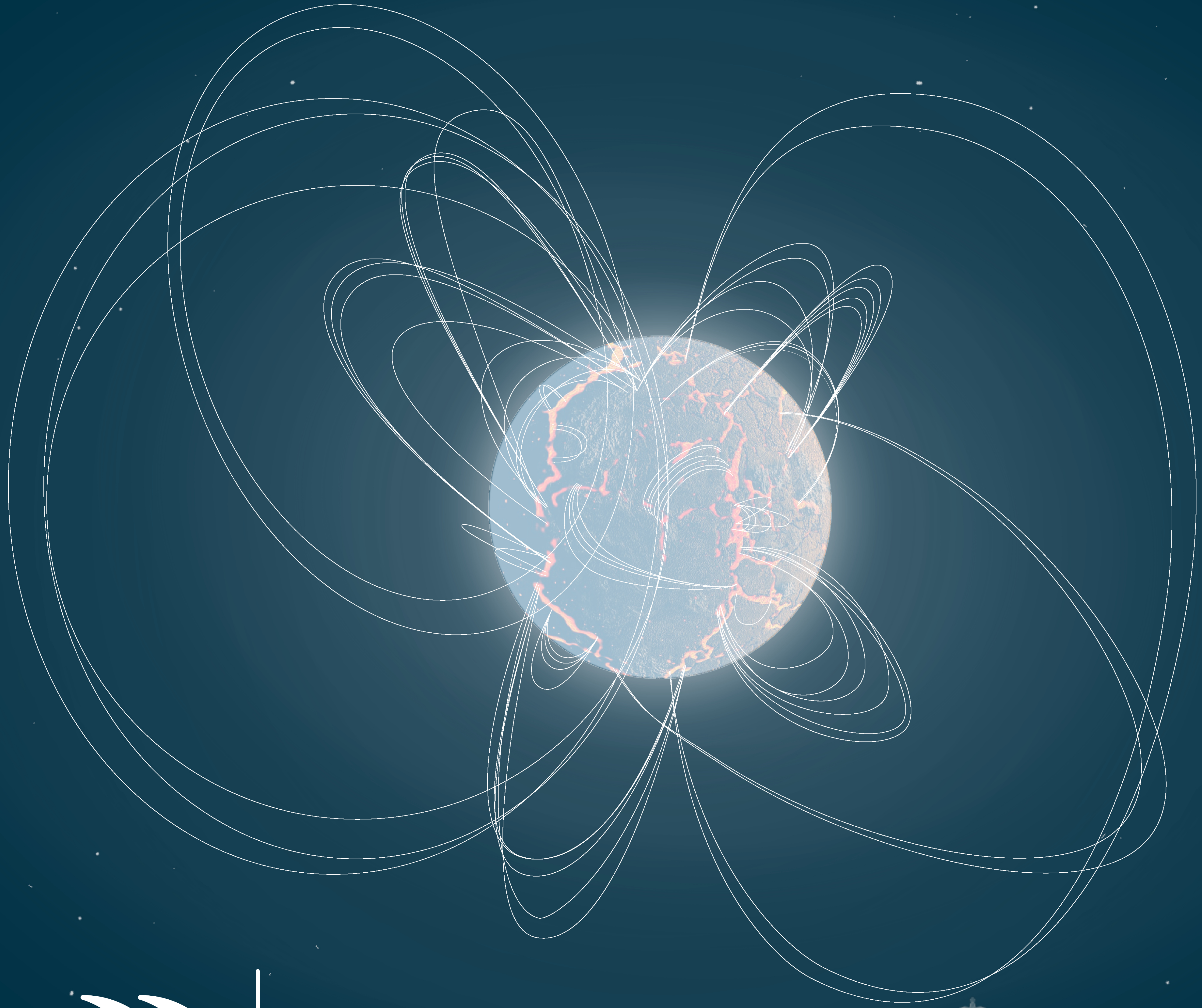
MACHINE LEARNING APPLIED TO COMPACT OBJECTS



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Barcelona, Spain

European Research Council
Established by the European Commission

MAGNESIA
MAGNETAR CENSUS
The Impact of Highly Magnetic Neutron Stars in the Explosive and Transient Universe

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Agència de Gestió d'Ajuts Universitaris i de Recerca
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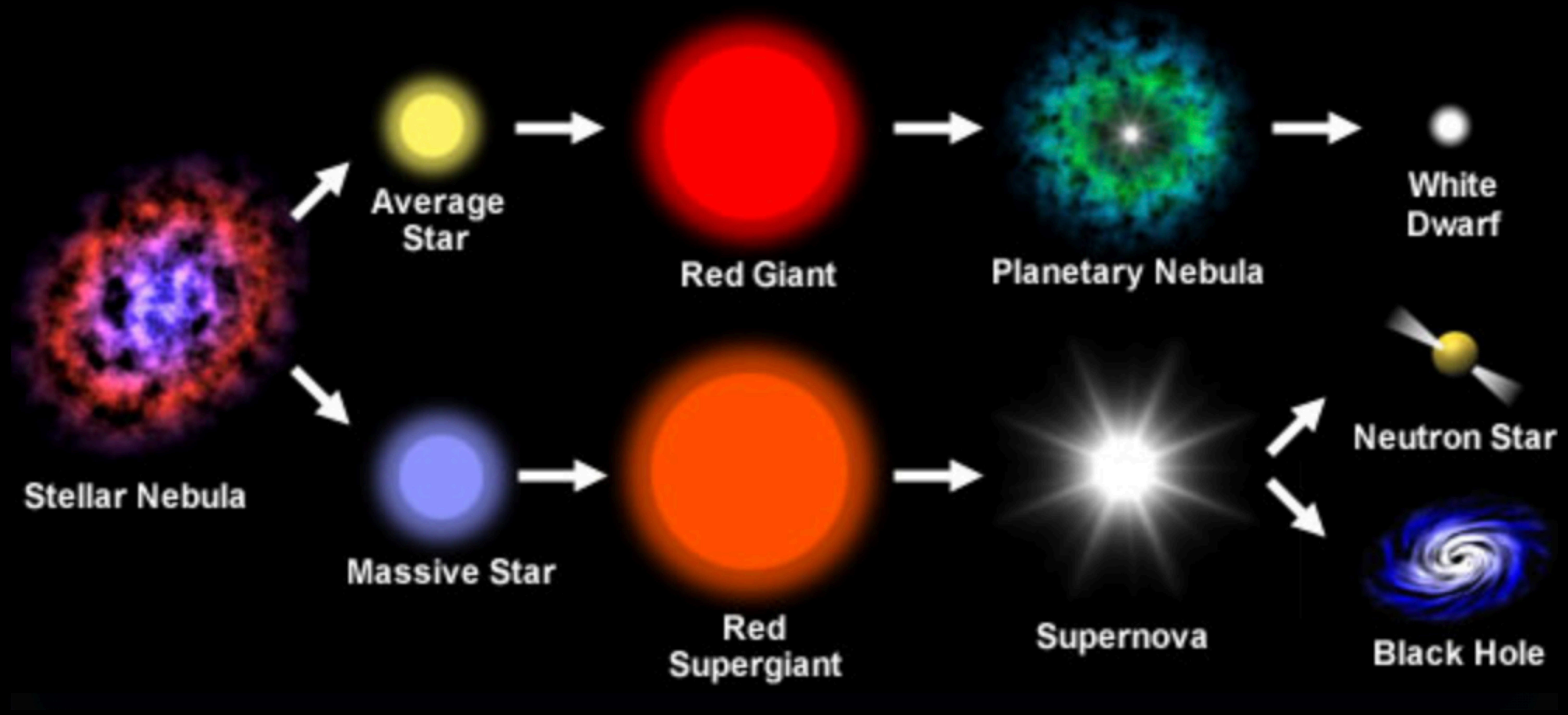
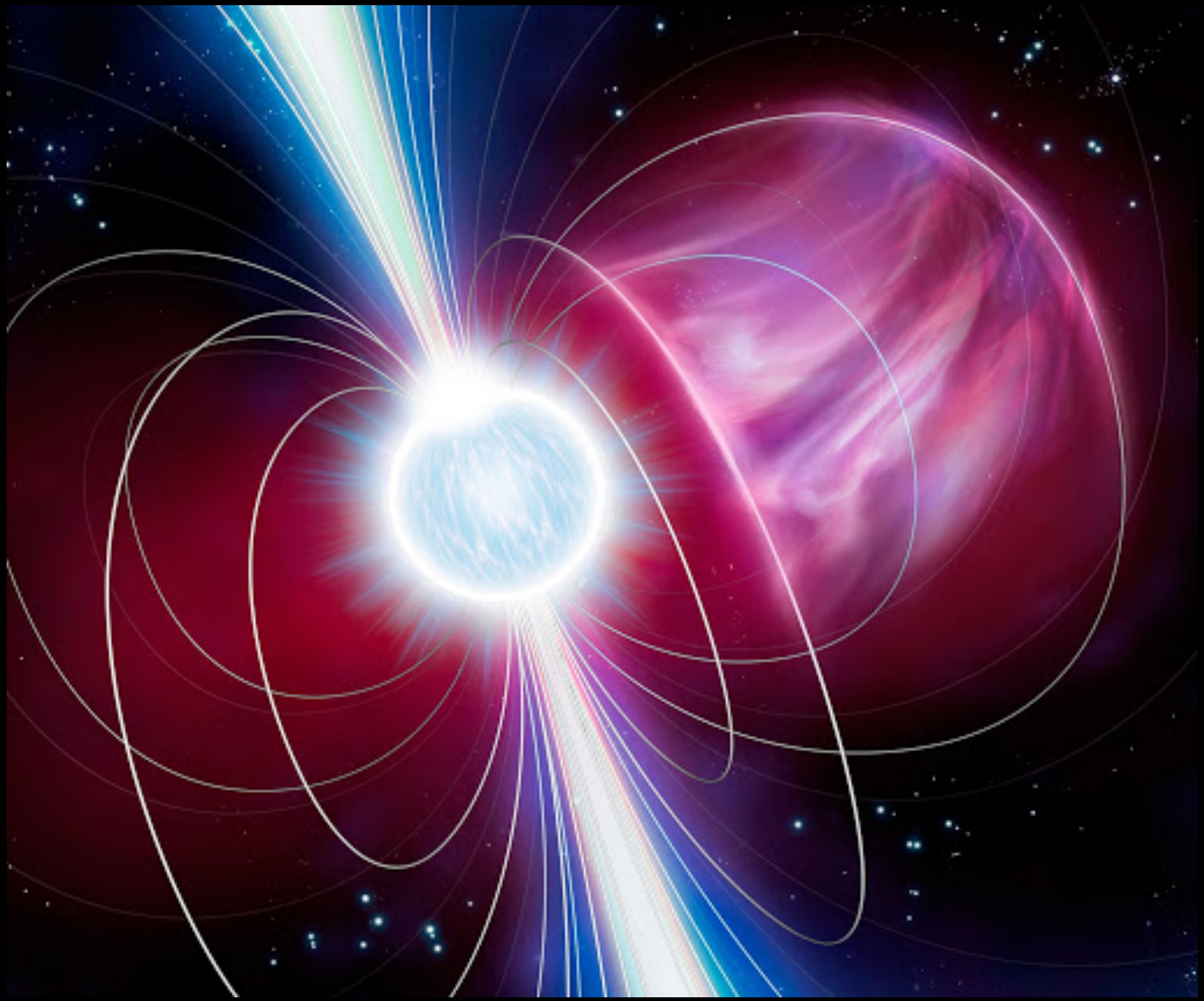
WHAT ARE THE COMPACT OBJECTS



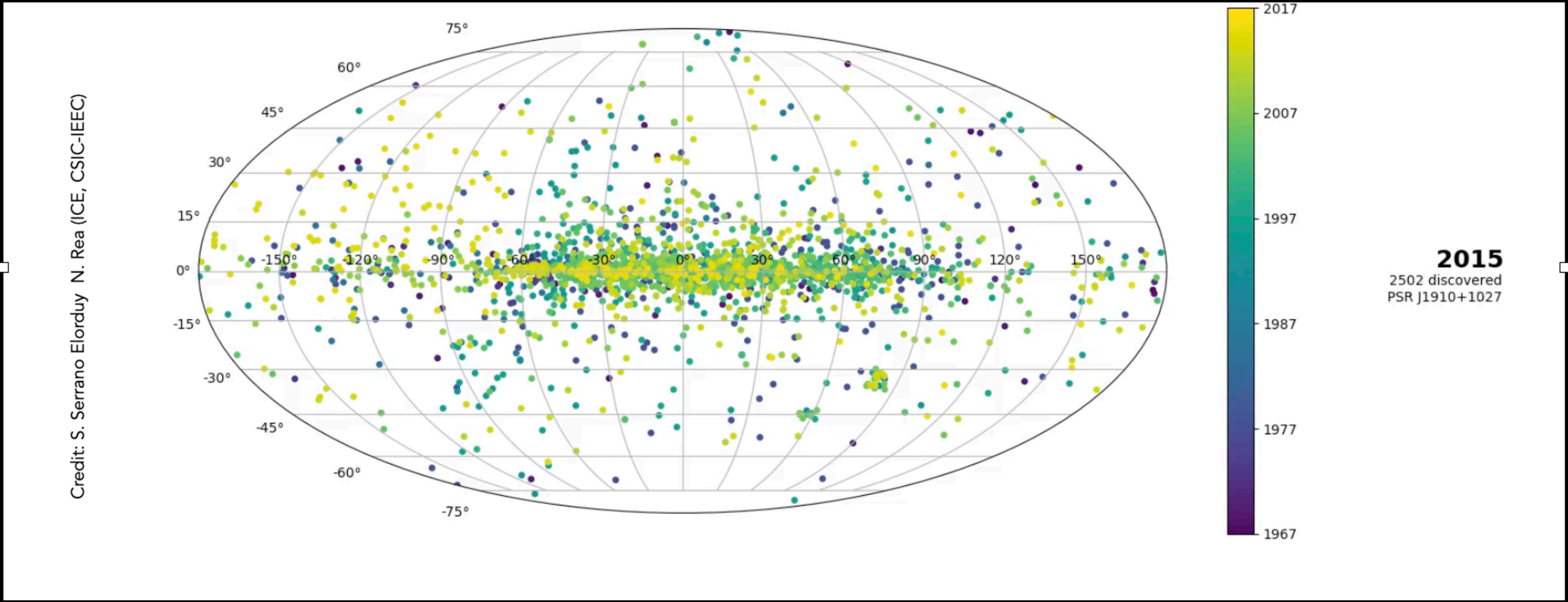
WHY NEUTRON STARS ARE IMPORTANT?



…AND THEY KEEP BUSY NUCLEAR PHYSICISTS, ASTROPHYSICISTS, THEORETICAL PHYSICISTS, PARTICLE PHYSICISTS AND SPACE ENGINEERS

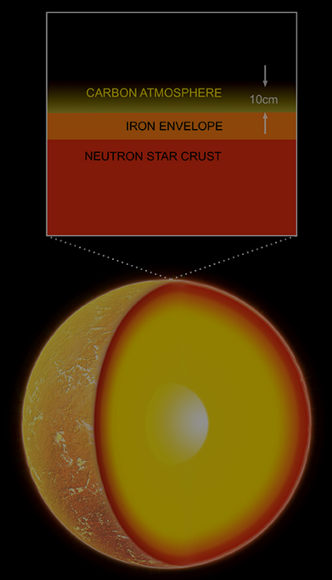
~50 YEARS OF NEUTRON STARS

PSR J1921+2153, discovered in **1967**, became the first astronomical object discovered as a pulsar, a rotating neutron star



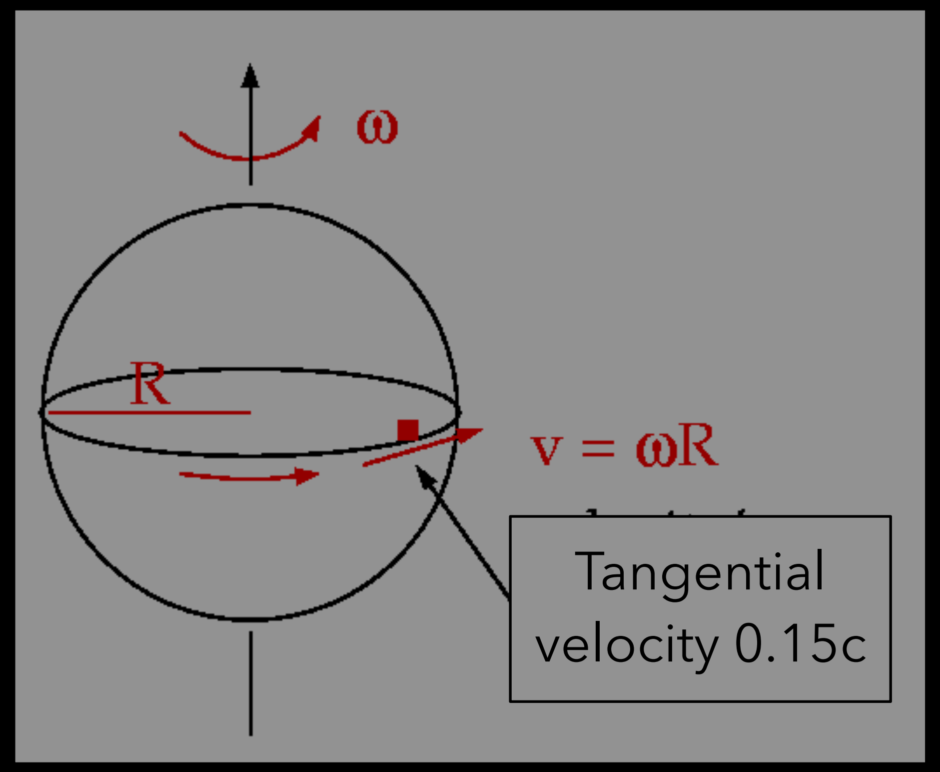
Rea 2017, Nature Astronomy, Vol. 1 p 827

RECORD GUINNESES



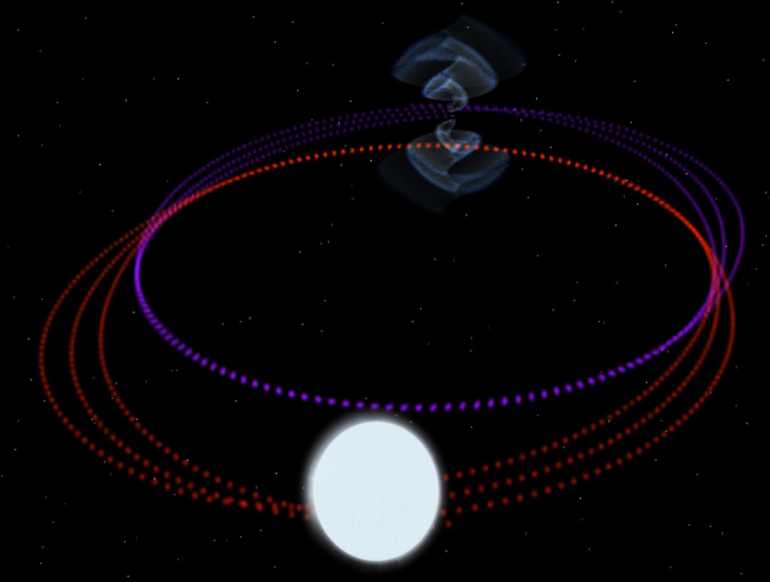
The densest rigid body known to date:

As dense as a nucleus, with a central pressure 10^{25} times the atmospheric pressure on Earth.



The fastest known rotating body in the Universe:

1.3955467744700354+/-0.0000000000000003ms



The roundest known circle in the Universe:

Is the orbit of the pulsar PSR J1909-3744 around a normal star. It is round to 5micron (1/10 of a human hair) to 567000km.

RECORD GUINNESES

The most stable clocks in the Universe:

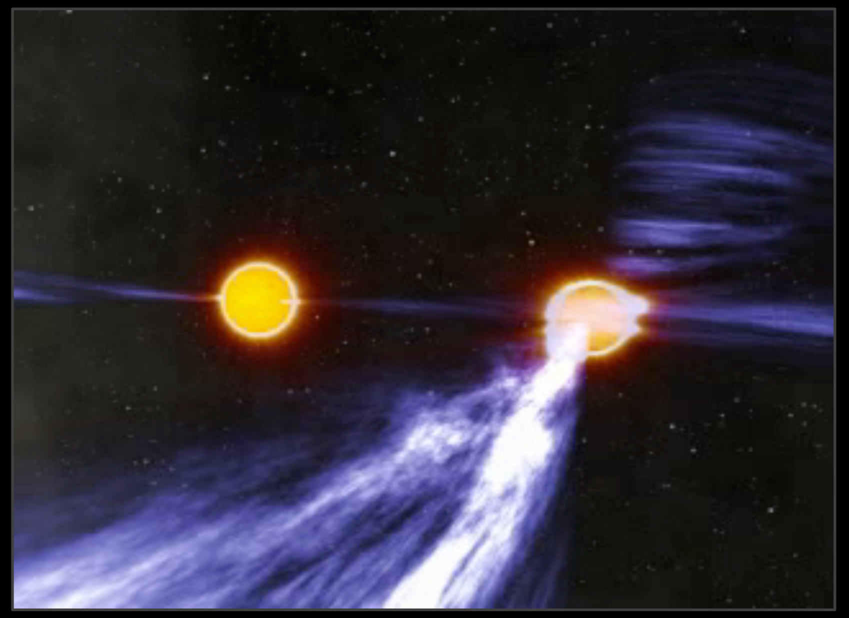
Pulsar arrivals are so precise and stable that beats atomic and quantum optical clocks.

The most magnetic objects in the Universe:

The magnetar SGR 1806-20 has a magnetic field of $\sim 10^{15}$ G, about 10^{8} times larger than the highest B-field we can produce on Earth.

The most precise tests of General Relativity:

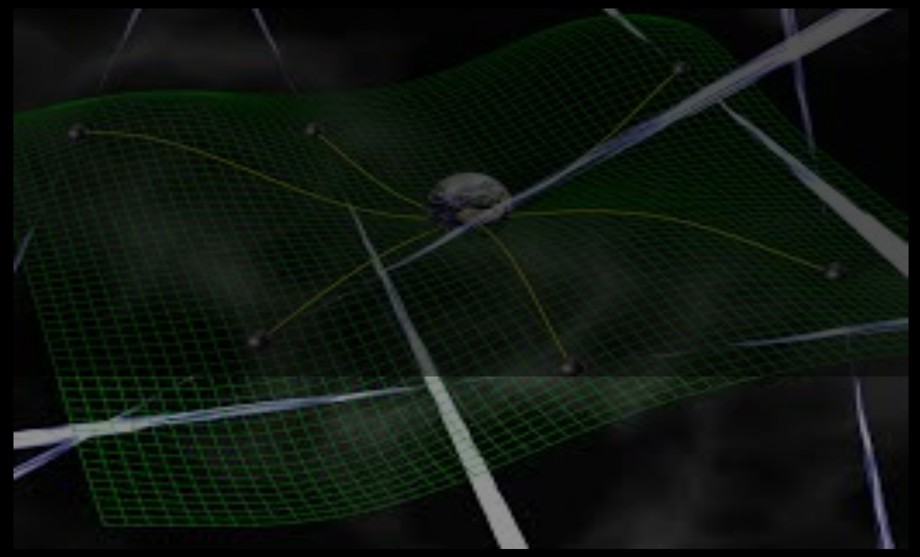
Binary pulsar systems holds the Guinness for having tested GR at 0.02% confidence level. Einstein is right so far…



RECORD GUINNESES

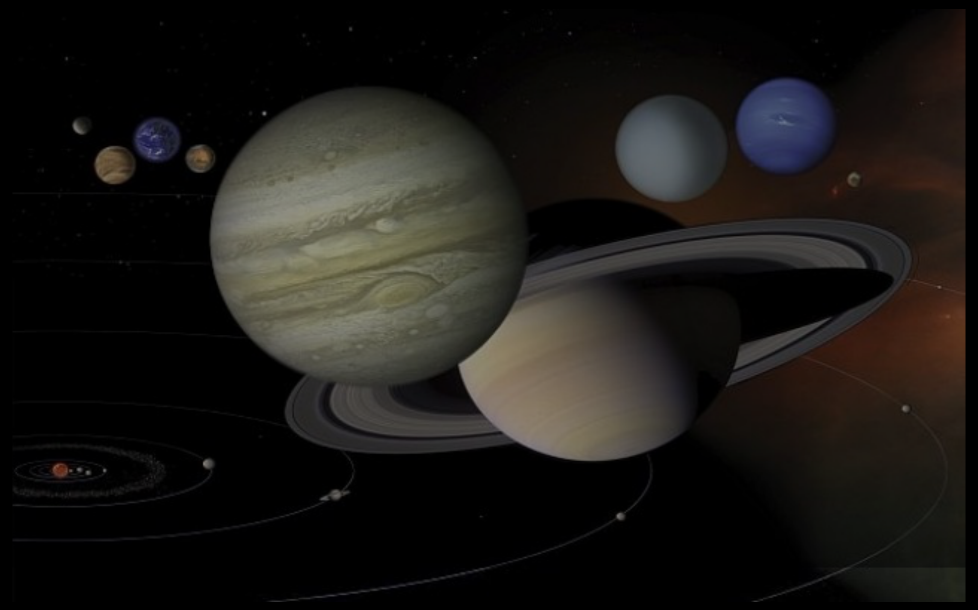
A natural Gravitation Waves detector:

Observing regularly millisecond pulsars we might detect GWs (International Pulsar Timing Array).



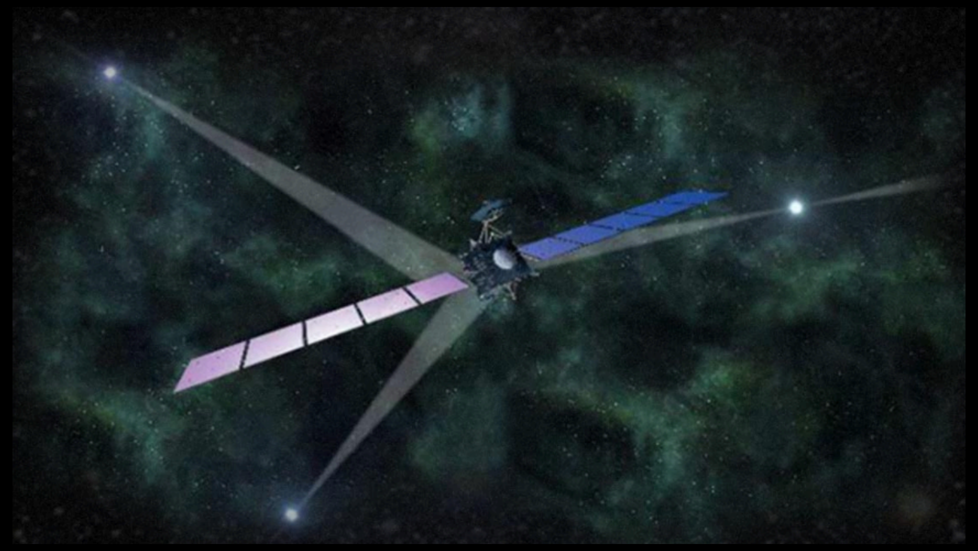
The least expensive Solar System planet mass determination:

Observing pulsars systematically planet masses are measured as precisely as dedicated satellites.



Our future GPS in space:

Pulsar clocks are so precise that will be our unique GPS system when travelling in space with no connection with Earth.

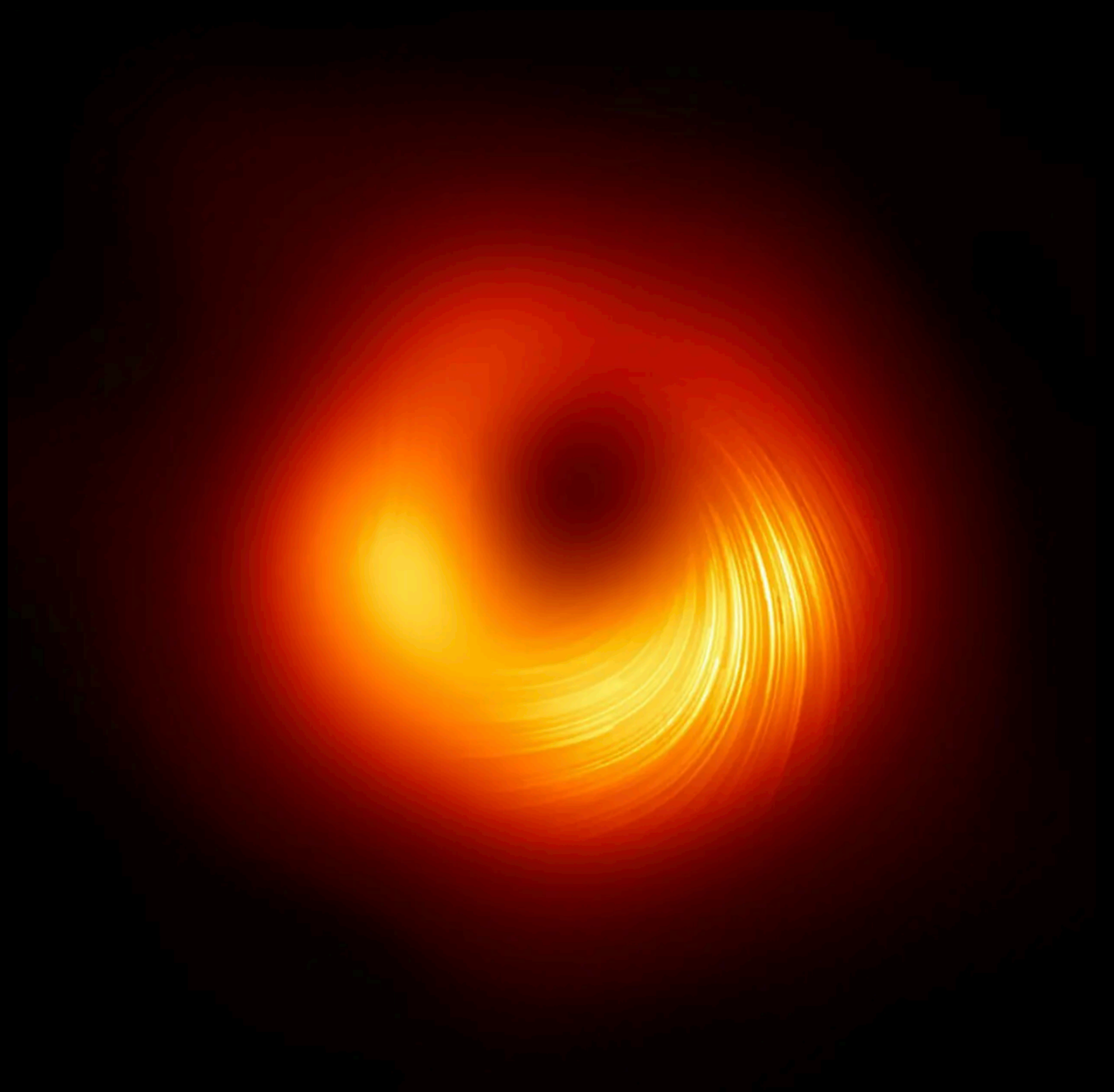


WHY BLACK HOLES ARE IMPORTANT?

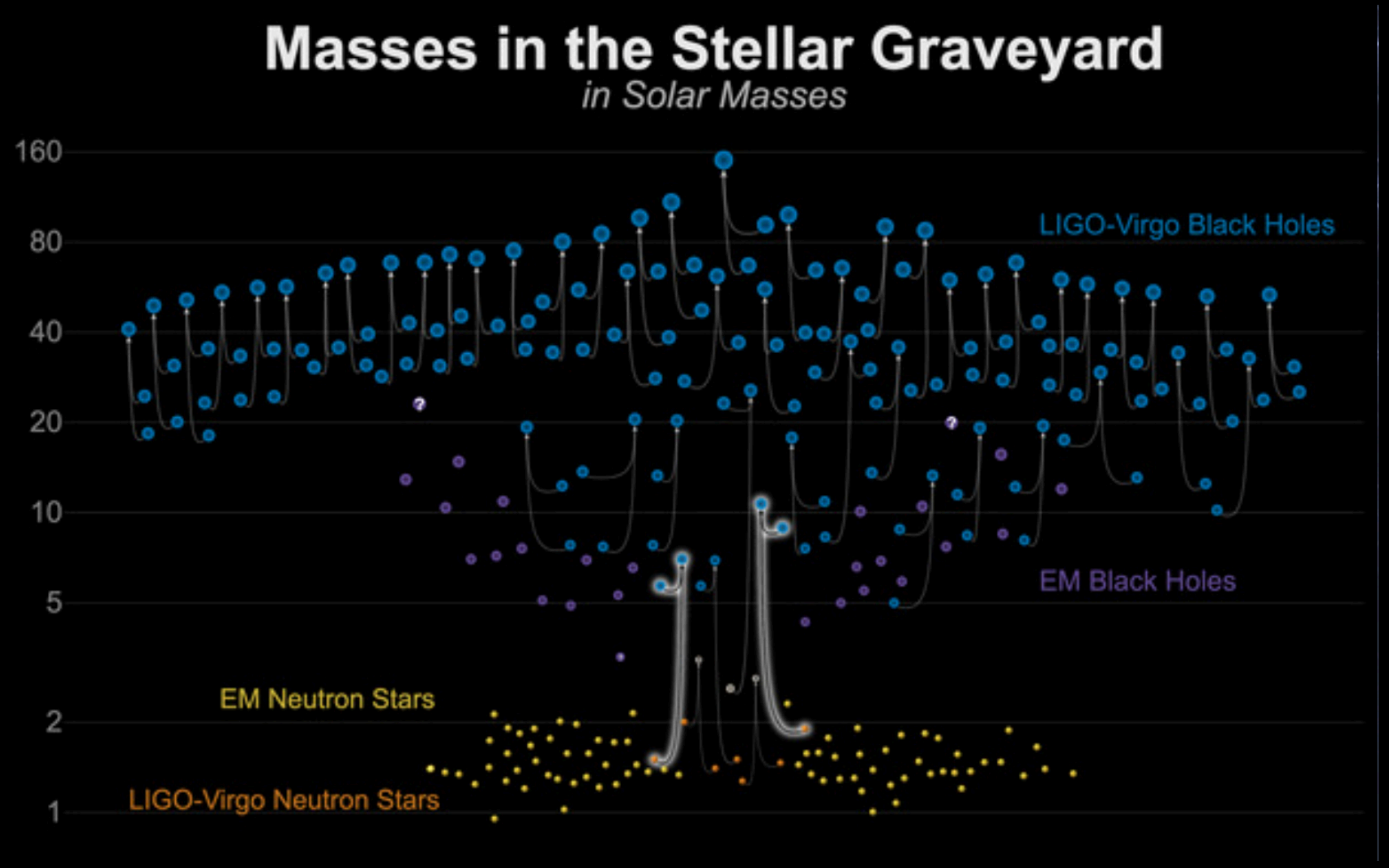
…AND THEY KEEP BUSY COSMOLOGIST, ASTROPHYSICISTS, THEORETICAL PHYSICISTS, AND PARTICLE PHYSICISTS

~50 YEARS OF BLACK HOLES

Cygnus X-1, a galactic X-ray source discovered in **1964**, became the first astronomical object commonly accepted to be a black hole

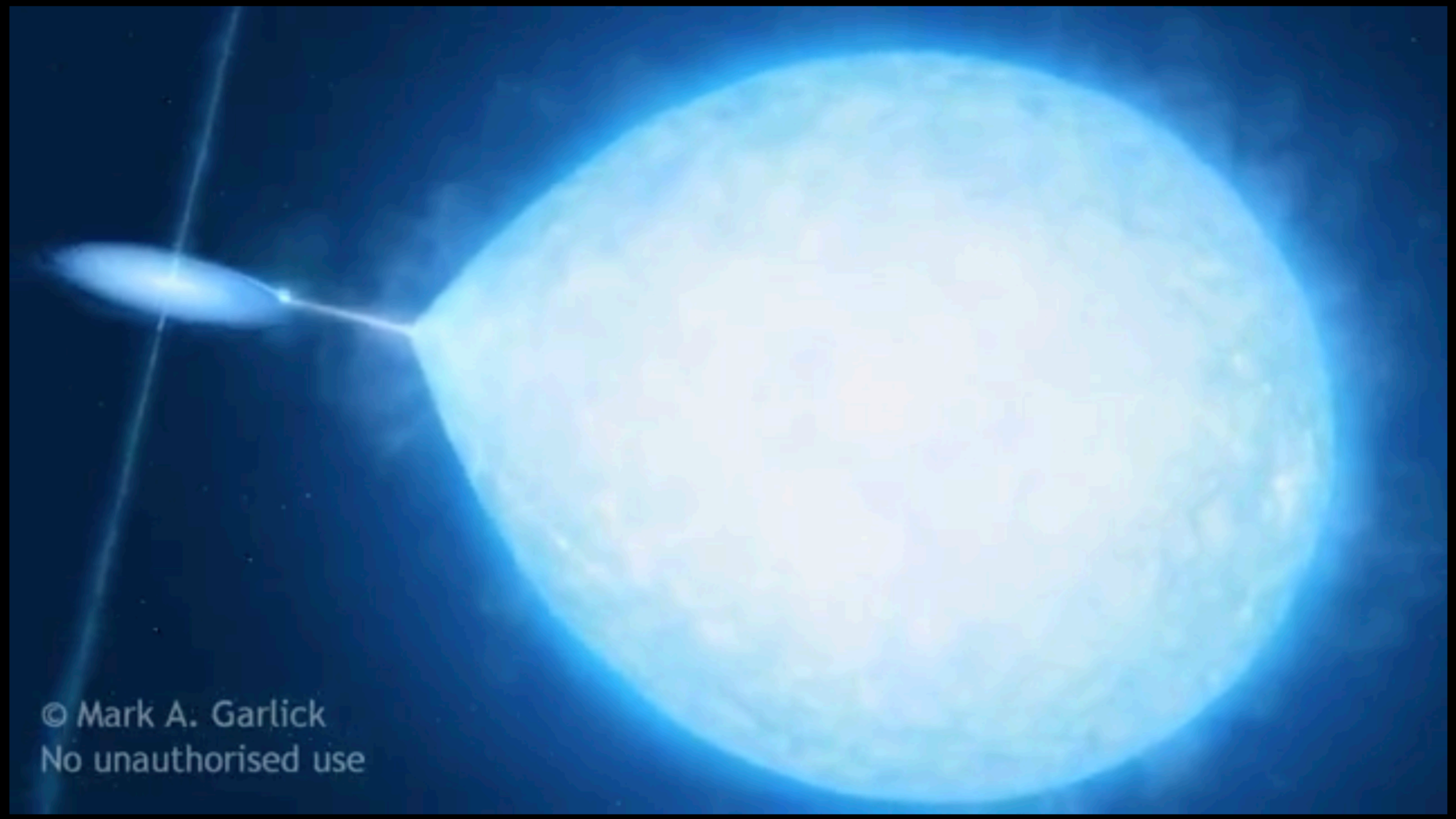


EHT Collaboration 2020

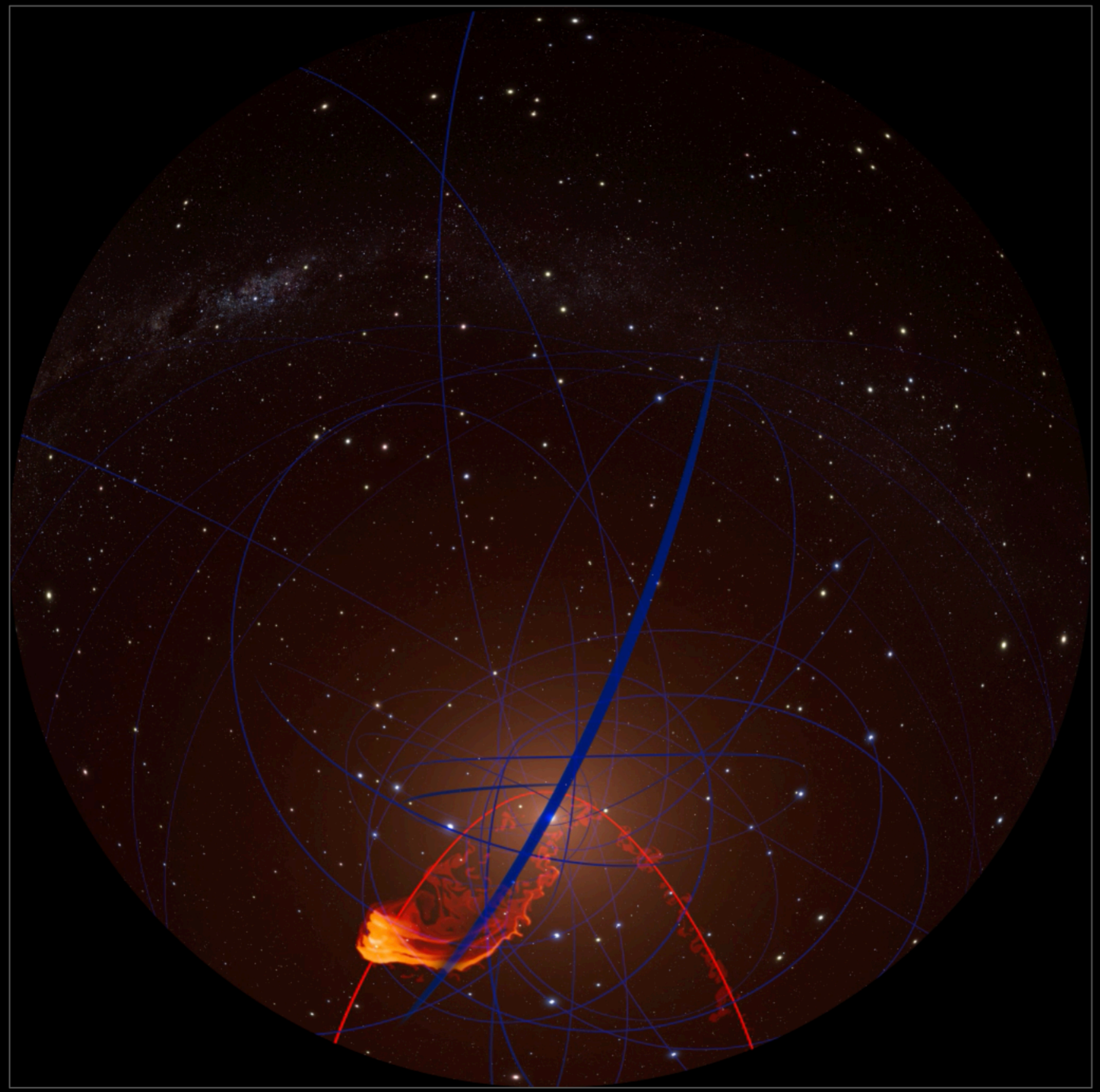


LIGO-Virgo Collaboration 2021

HOW DO WE OBSERVE BLACK HOLES



Stellar Mass Black Holes in binary systems

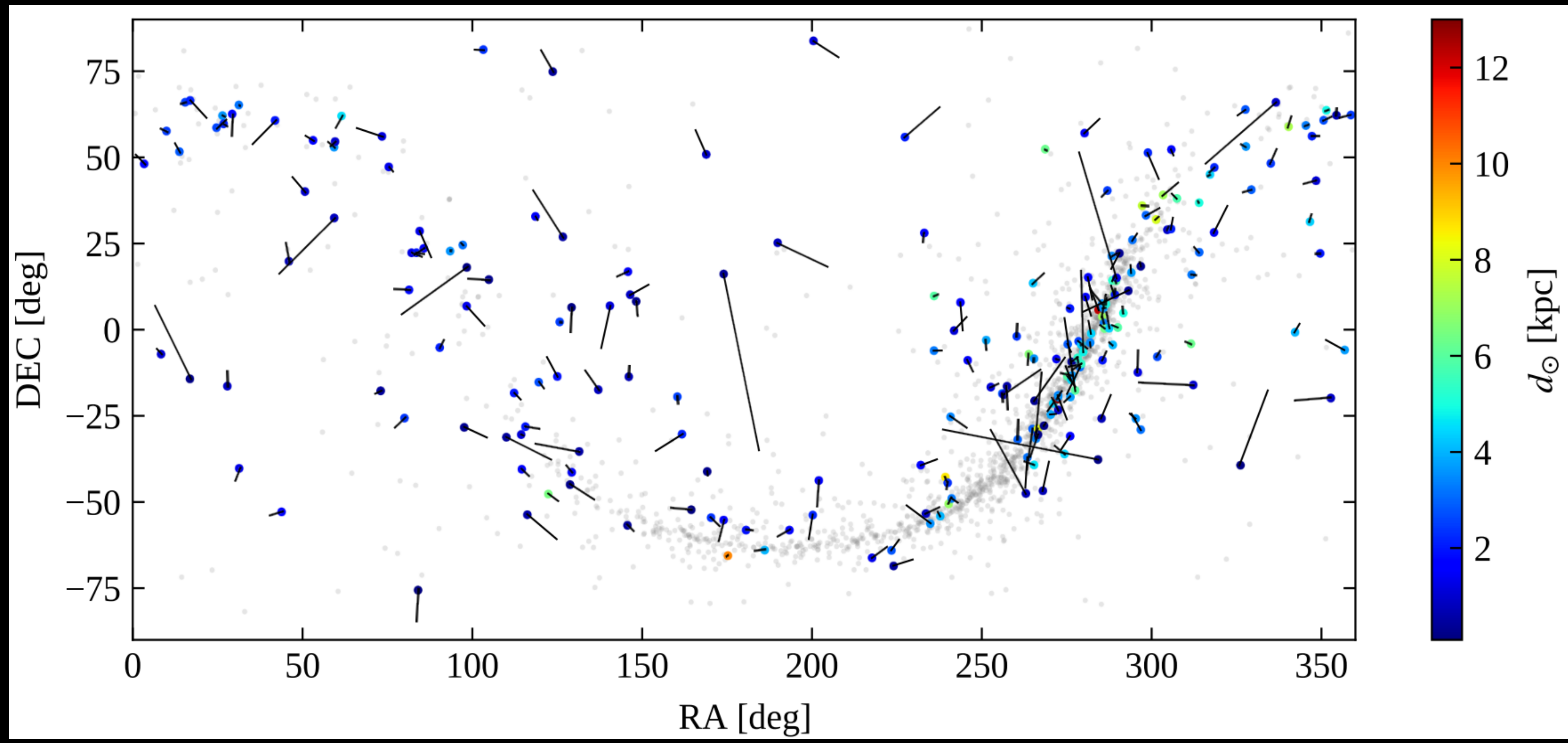


Active Galactic Nuclei: SgrA*

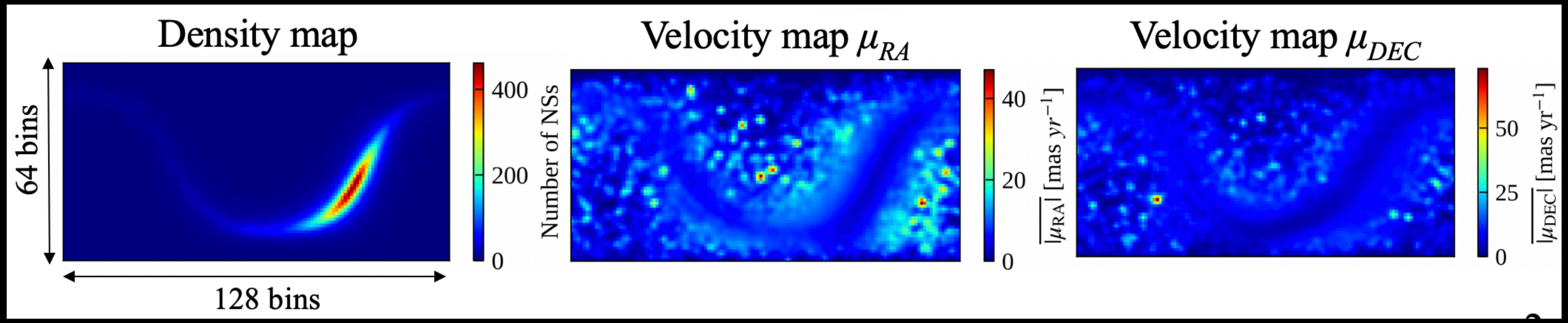
Tidal Disruption Events

CURRENT STUDIES APPLYING MACHINE LEARNING TO GALACTIC NEUTRON STARS AND BLACK HOLES

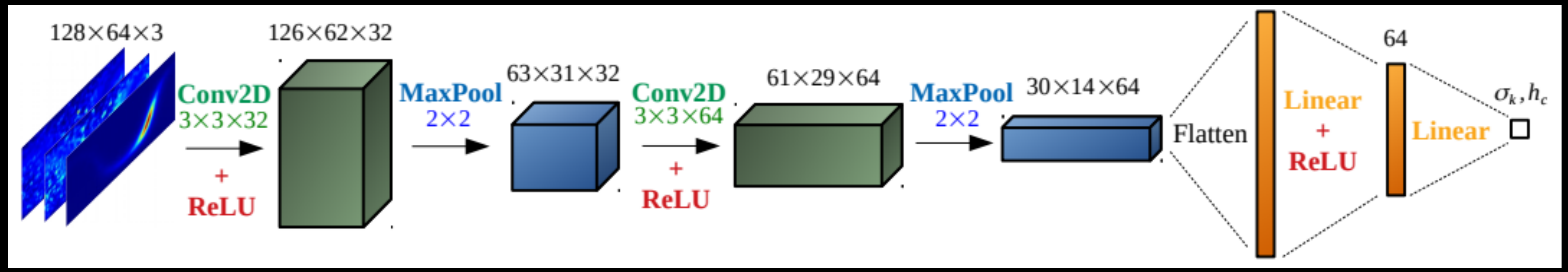
MACHINE LEARNING APPLIED TO THE PULSAR POPULATION



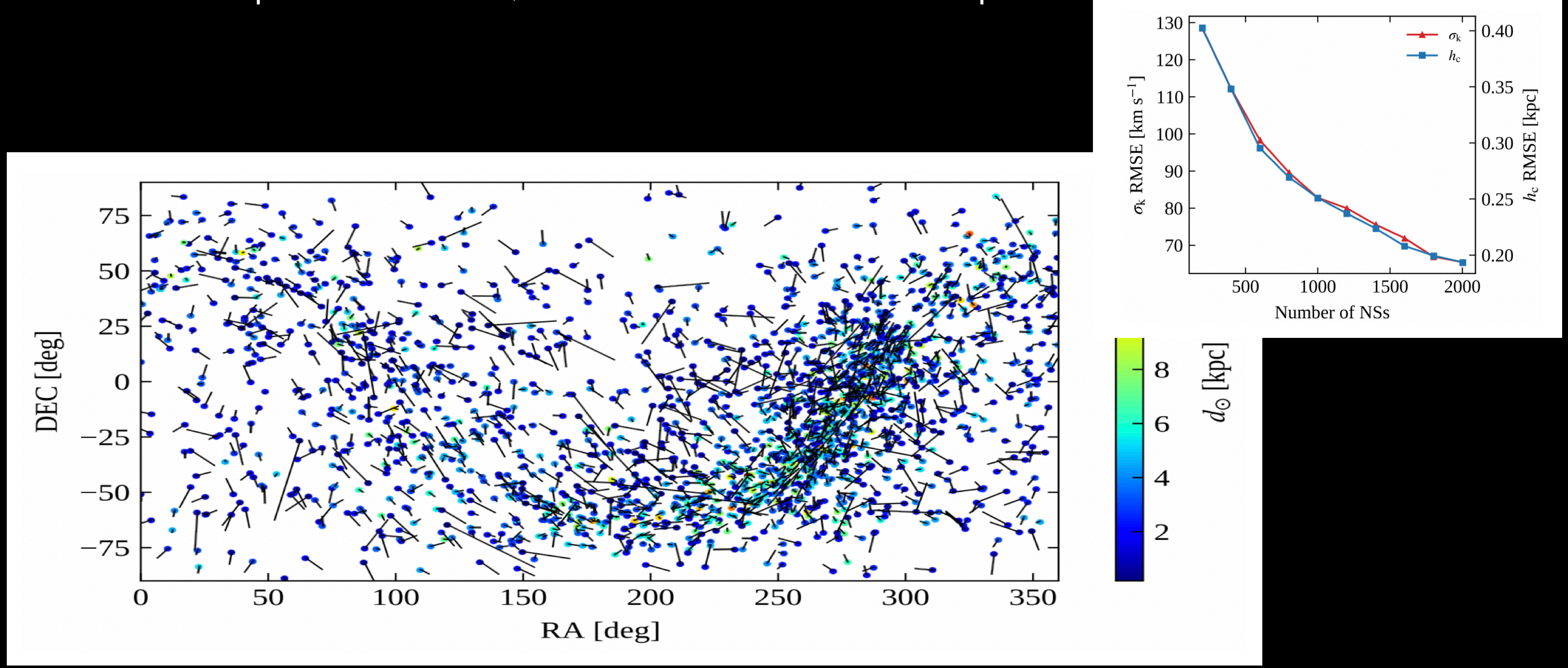
1) Distribution and velocities of the observed pulsar population



2) Given certain physical inputs (kick velocity distribution, Galactic gravitation potential, birth position, etc.) we construct three maps.



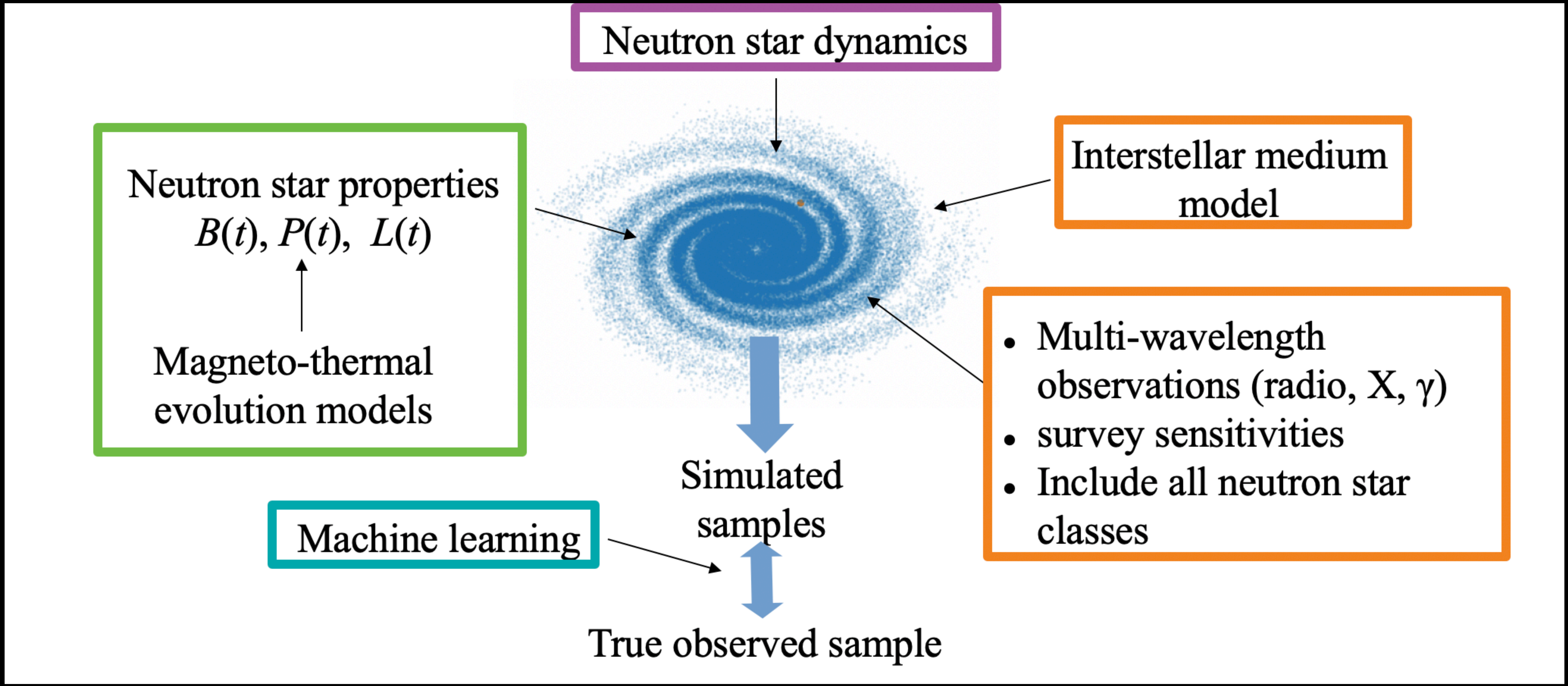
3) Train convolutional neural network (supervised learning)



4) We can predict how we will observe the population with future instruments and predict how many NS proper motion measurements we need to constrain the distribution of birth properties.

(Ronchi, Graber, García, Rea & Pons 2021, ApJ; Graber, Ronchi, Pardo, Rea & Pons 2022 in prep)

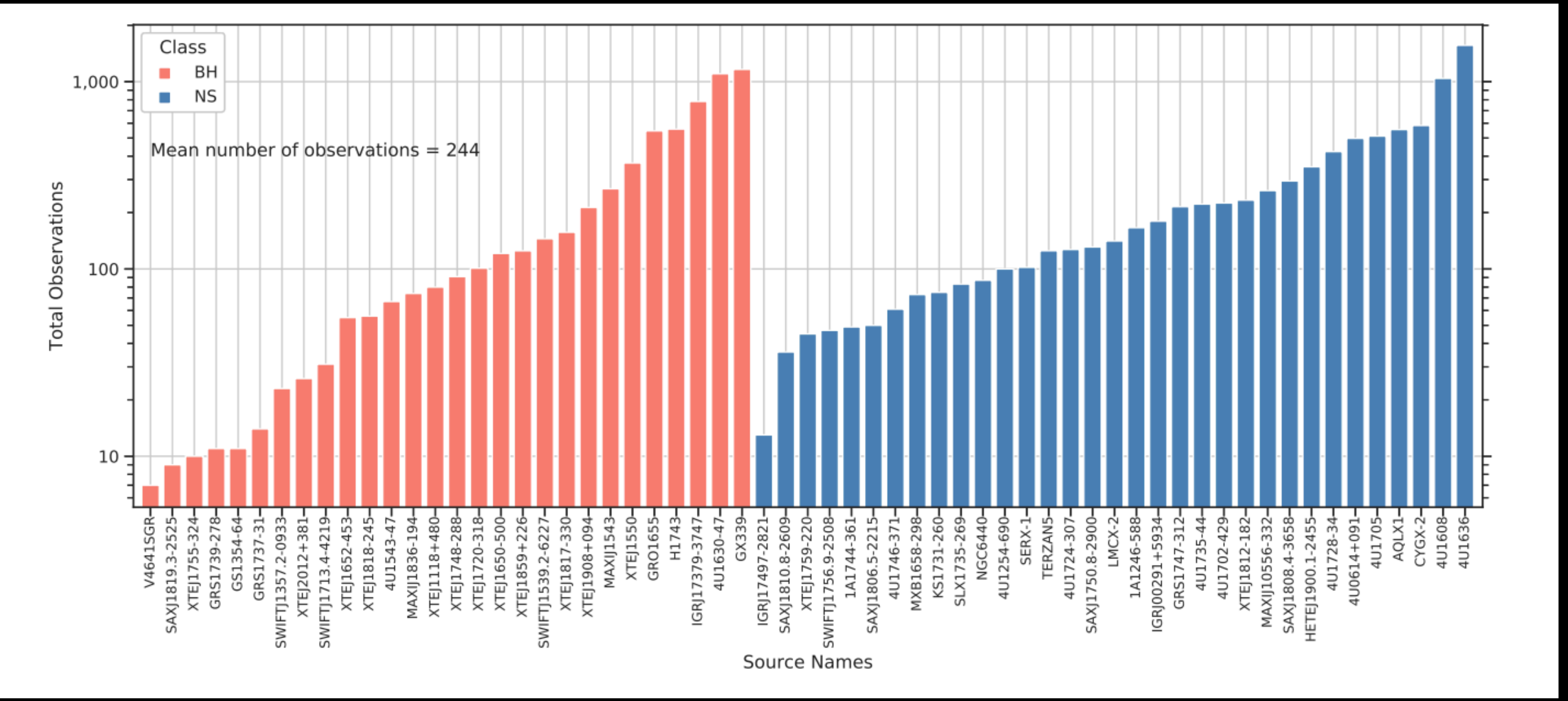
MACHINE LEARNING APPLIED TO THE PULSAR POPULATION

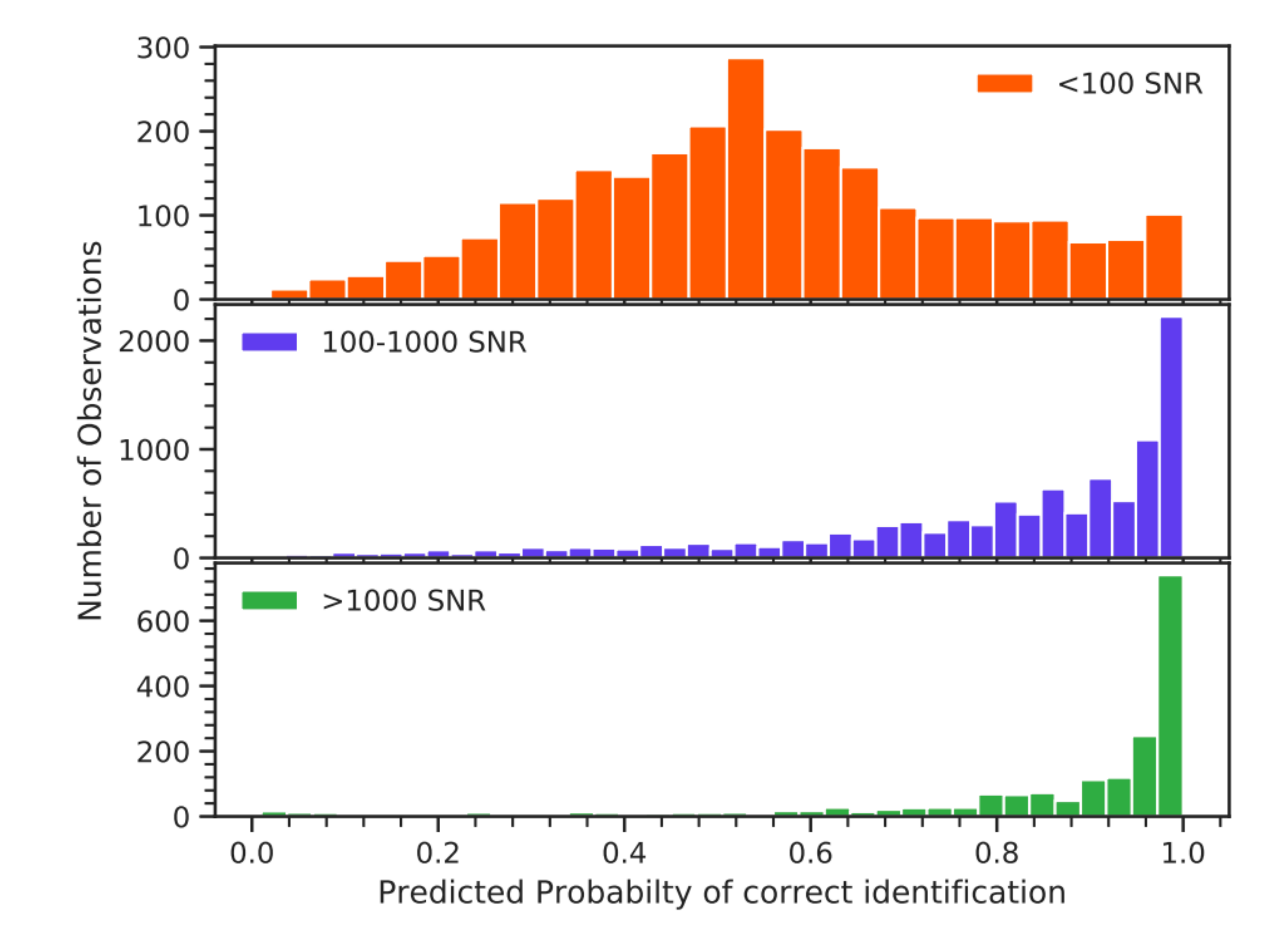


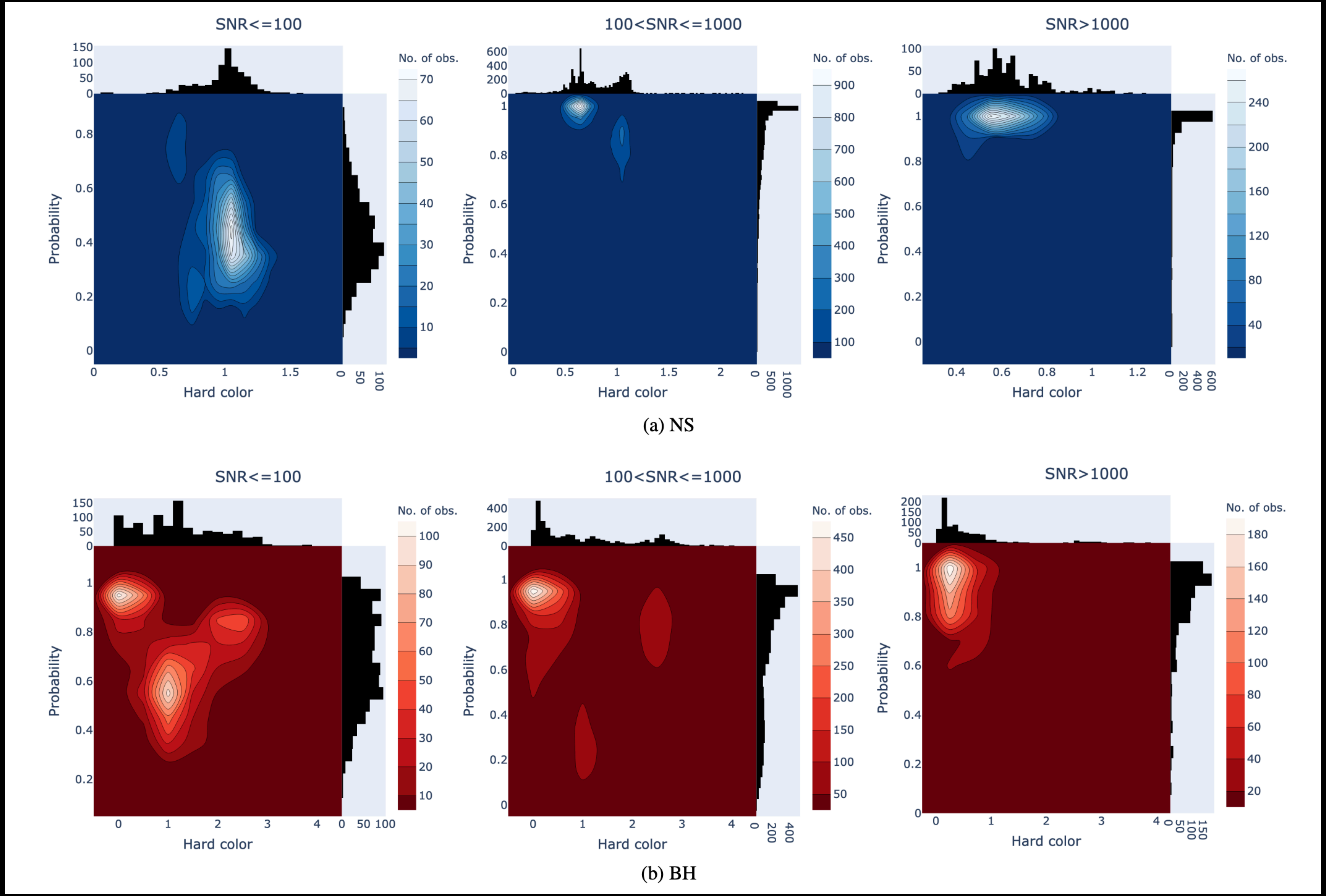
FUTURE: multi-parameter training of the neural network → predict the birth distribution of magnetic fields and spin periods.

(Ronchi, Graber, García, Rea & Pons 2021, ApJ; Graber, Ronchi, Pardo, Rea & Pons 2022 in prep)

MACHINE LEARNING TO CLASSIFY NS/BH BINARIES







Training a random forest classifier to identify the type of compact object using the energy spectrum in the energy range 5-25 keV obtained from the Rossi Xray Timing Explorer archive. This method has an average accuracy of 87±13% in classifying the spectra of LMXB sources.

(Pattnaik, Sharma, Alabarta et al. 2020, MNRAS)

THANKS!

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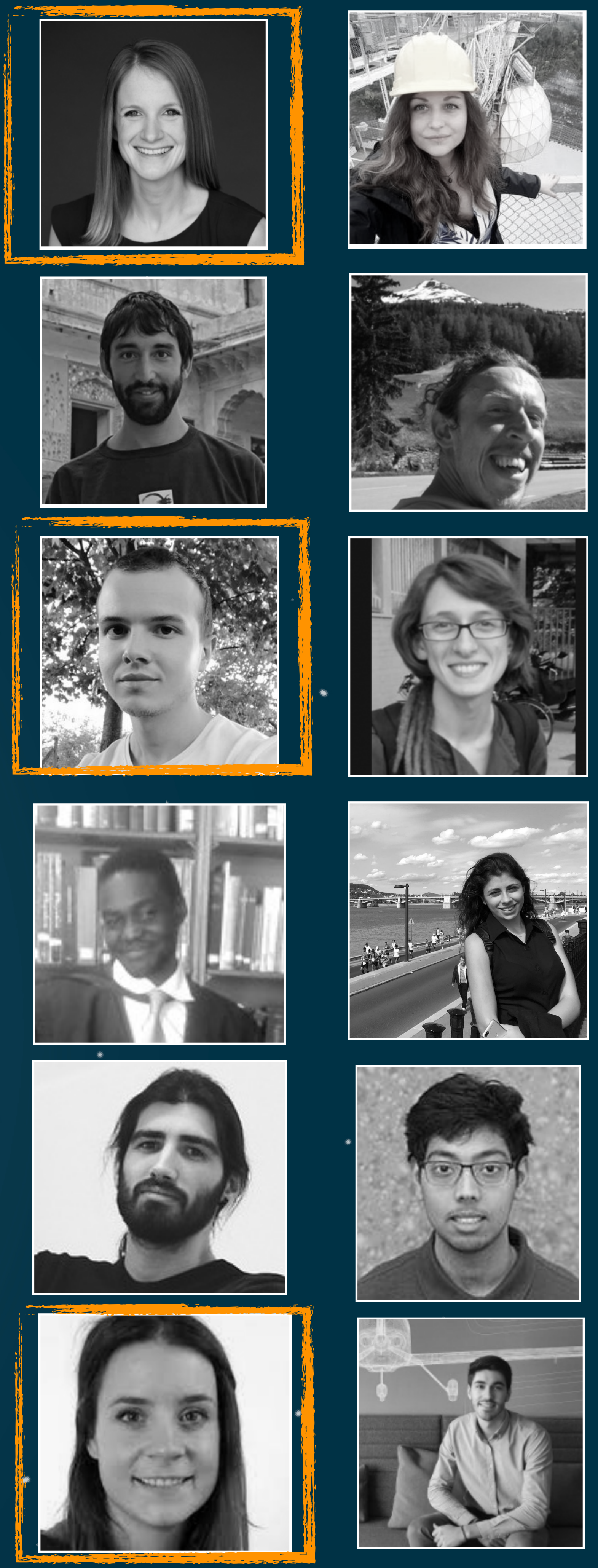
Mr. Abubakr Ibrahim
Dr. Stefano Ascenzi
Dr. Rajath Sathyaprakash
Mr. Celsa Pardo
Mr. Albert Herrando



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