EARLY SIGNATURES OF A GRAVITATIONAL WAVE BACKGROUND SEEN IN PULSAR TIMING ARRAY DATASETS!

An international team of Astronomers with the European Pulsar Timing Array and the Indian Pulsar Timing Array see an emerging signal of gravitational waves from merging black holes, several million to billion times heavier than the sun.
We used pulsars, rapidly rotating remains of dead stars as clocks to detect gravitational waves which perturb space and time using radio Telescopes for our observations.
These results were reported together with other IPTA members such as NANOGrav and the Parkes Pulsar timing Array, which see a similar signal.

More observations are needed to determine the exact nature of the signal, eventually they will let us probe the some of the oldest supermassive black holes in the universe and perhaps even shed light on some possible exotic physics such as cosmic strings and phase transitions in the early universe. A lot of new science awaits.

A new window in Graviatianal Wave astronomy has been opened.

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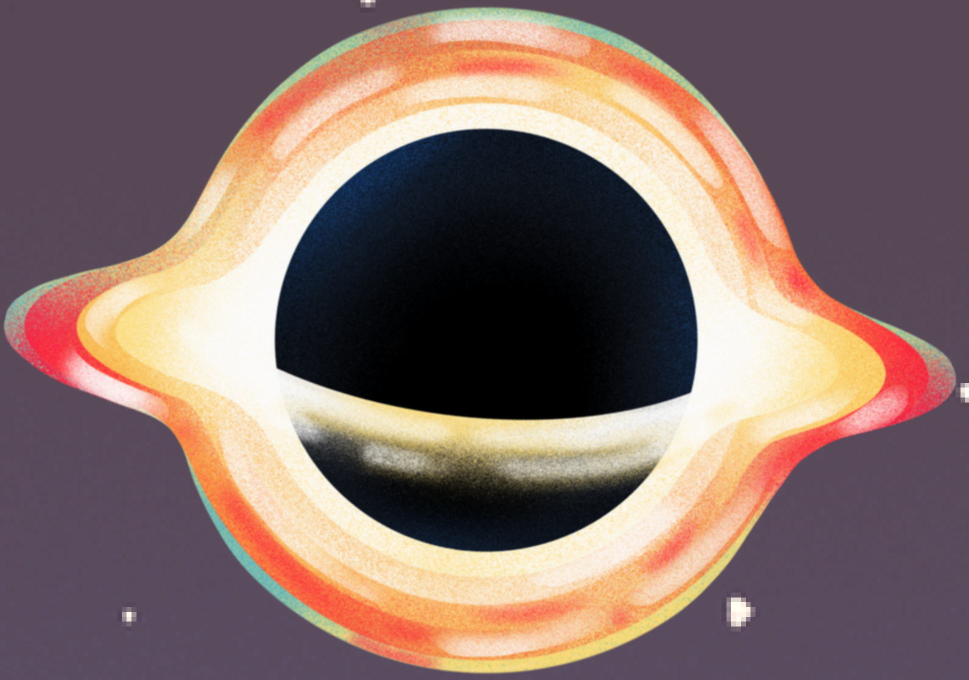
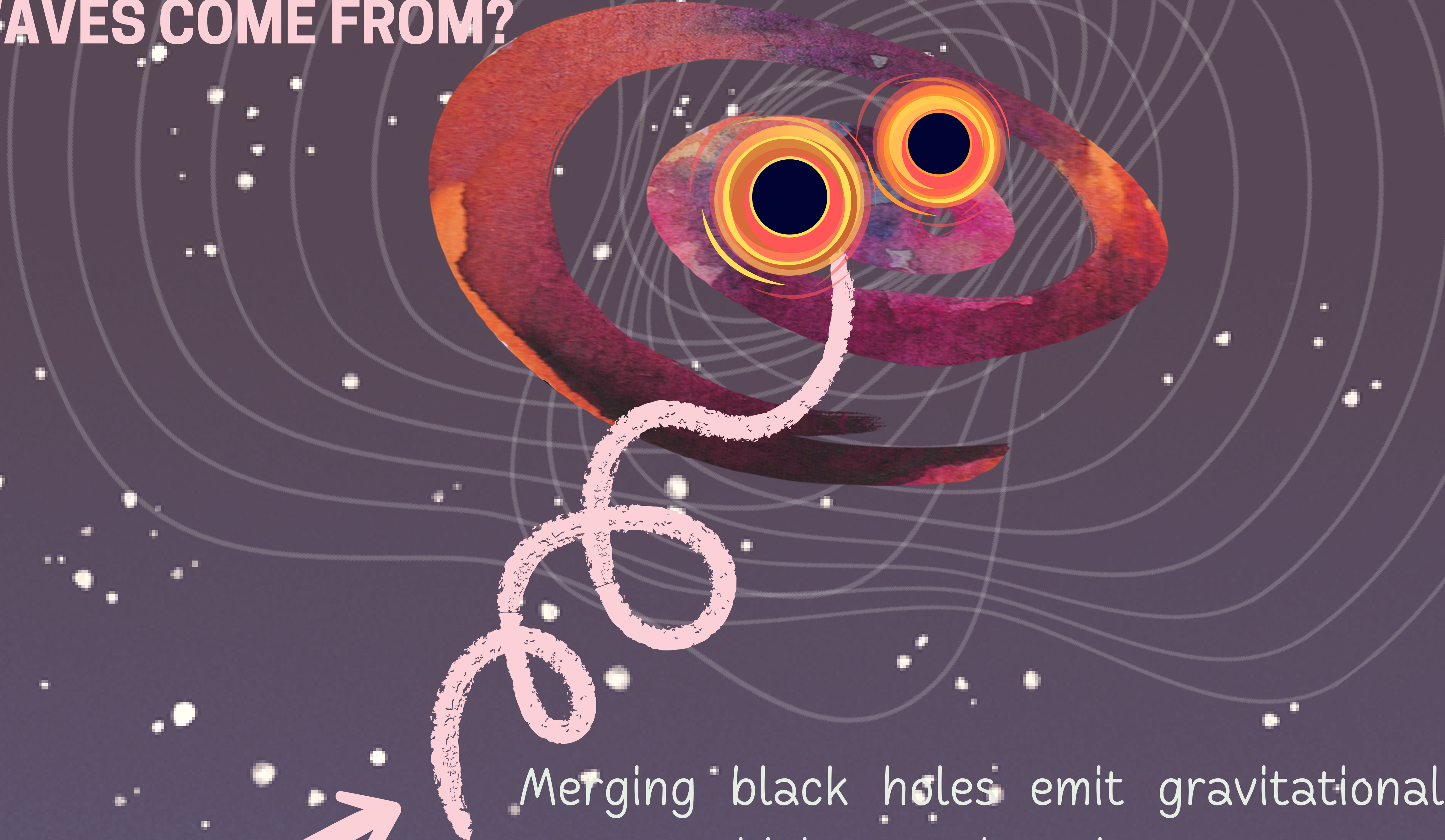
Indian Pulsar Timing Array

• Made by Neel Kolhe

WHERE DO THESE GRAVITATIONAL WAVES COME FROM?

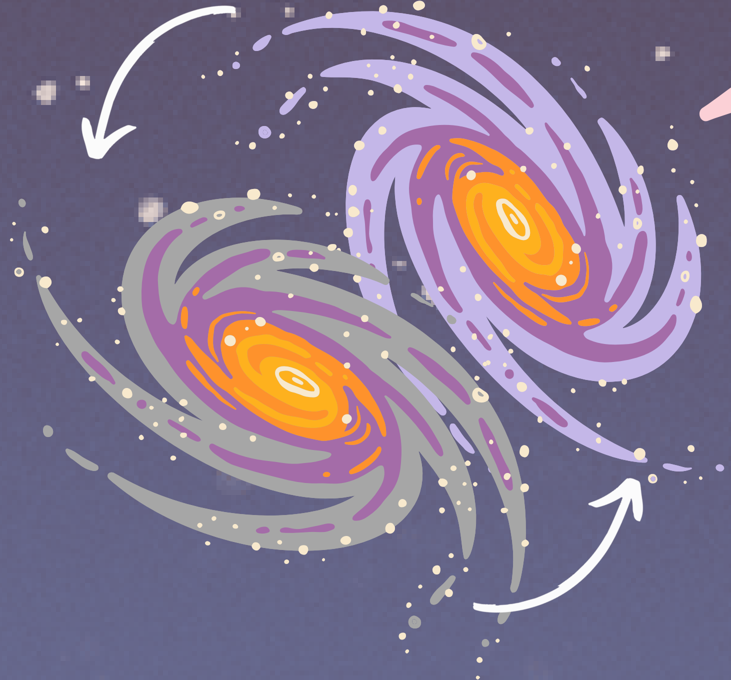


Almost all galaxies are expected to have supermassive black holes, which weigh several million to many billion times the mass of the sun, at their centers.



Merging black holes emit gravitational waves, which stretch and squeeze space and time as they propagate!

Galaxies merge with each other, and the black holes at their centers are also expected to merge after a long spiral dance.



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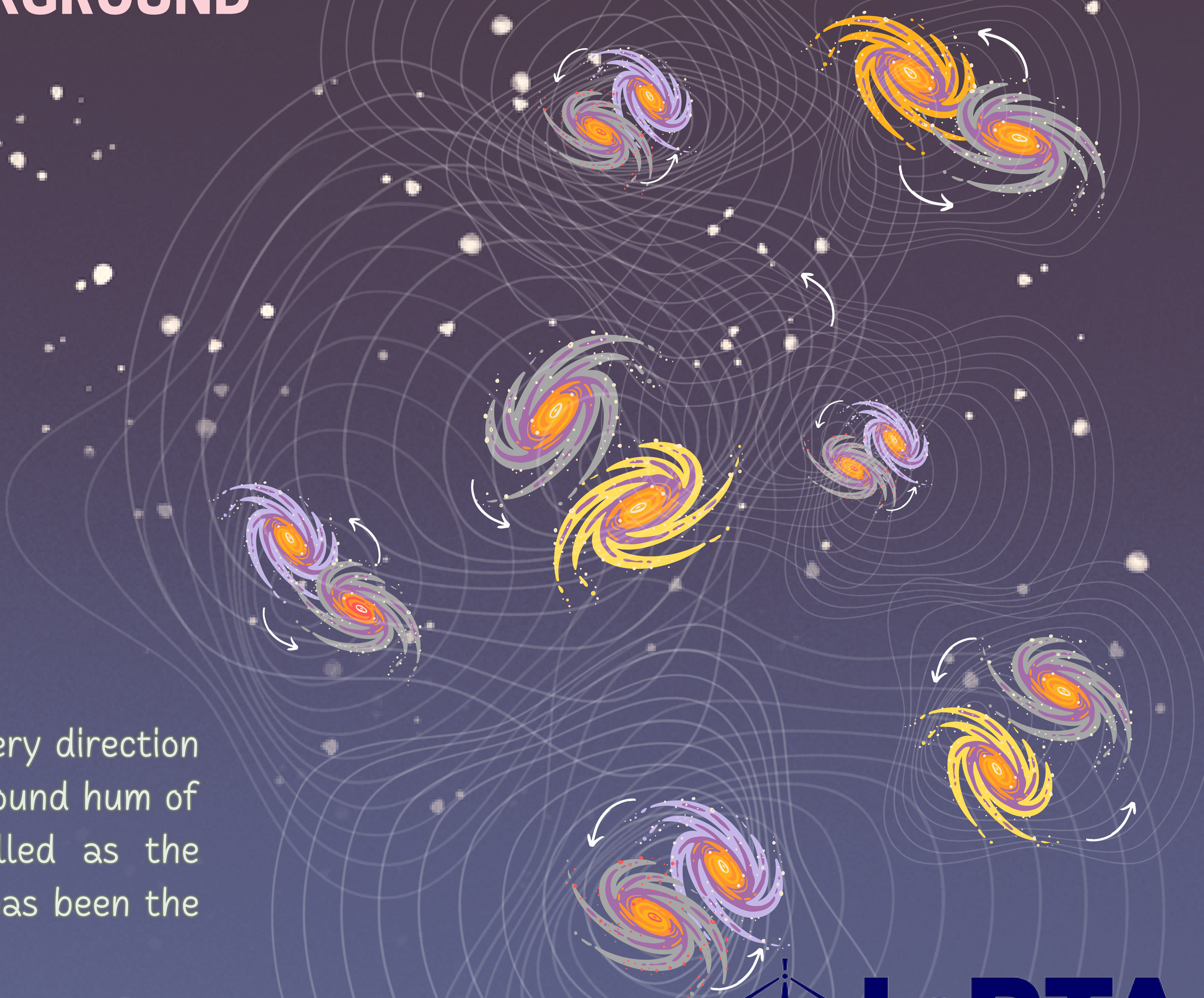
THE GRAVITATIONAL WAVE BACKGROUND

These waves stretch along for many light years, and cannot be detected by experiments such as LIGO, VIRGO or KAGRA, which have been detecting gravitational waves from merging black holes only 10s of times the mass of the sun



As black holes merge all across the universe, in every direction in the sky, these waves overlap and form a background hum of gravitational waves. This thrumming hum is called as the stochastic gravitational wave background, and it has been the ongoing goal of PTA experiments to detect it.

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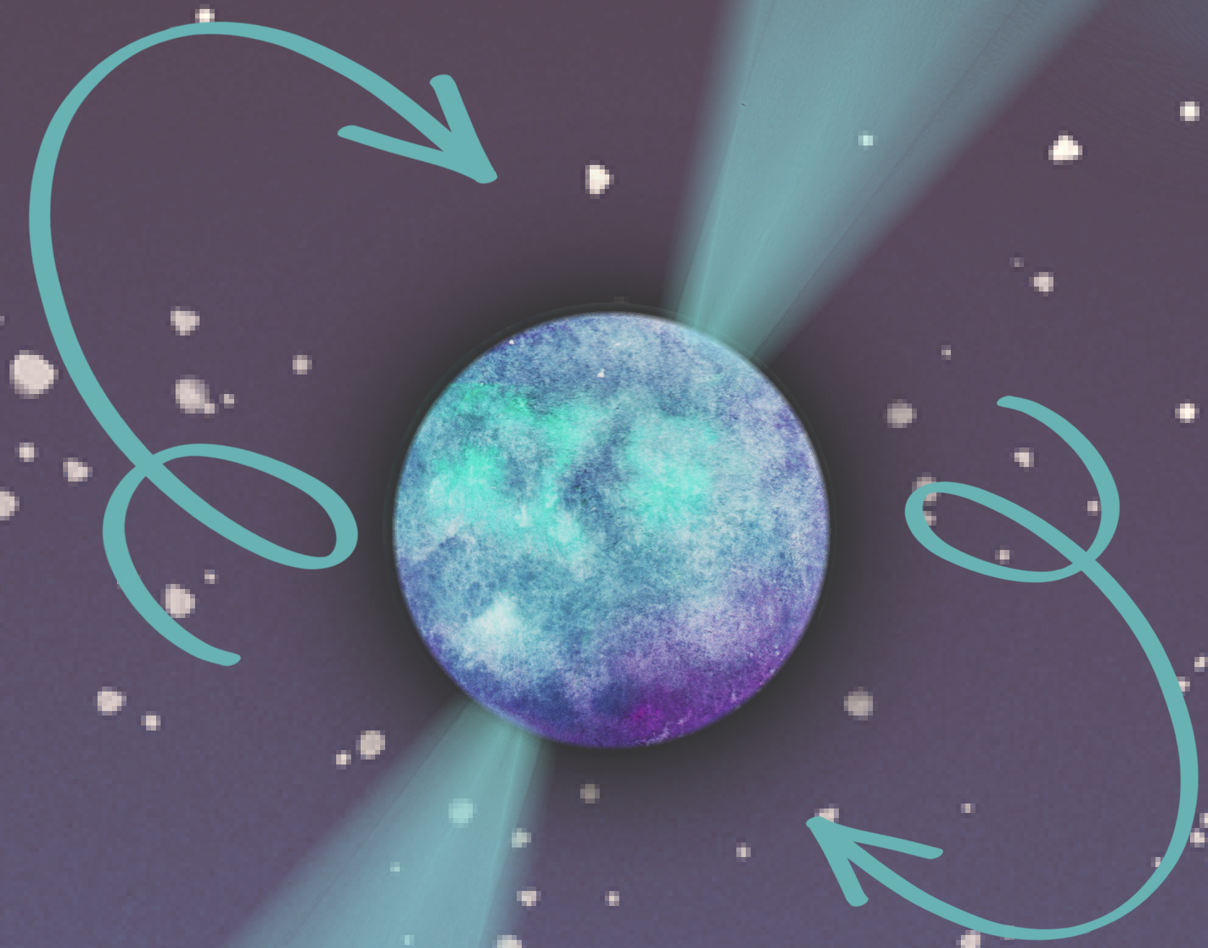
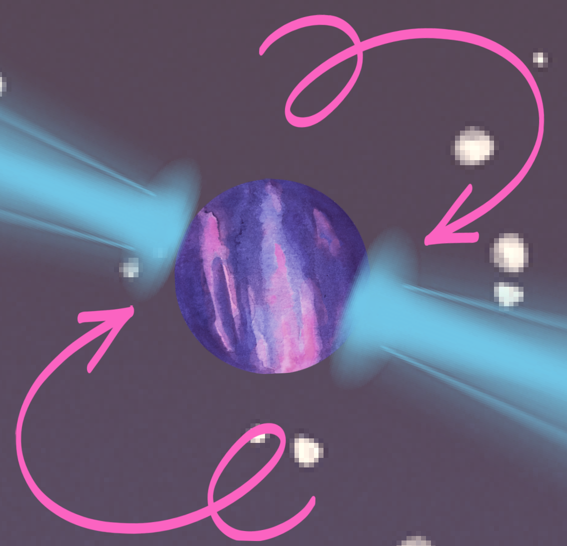
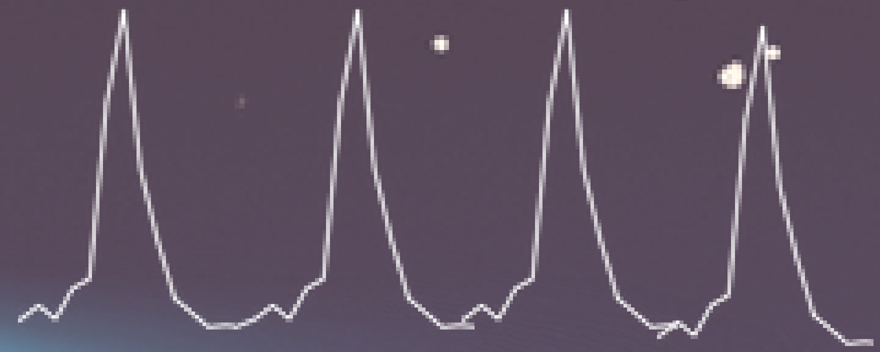
ENTER: PULSARS!

Pulsars are rapidly rotating compact dead stars, which emit bright beams of radio light from their poles



Radio telescopes, such as the upgraded Giant Meterwave Radio Telescope (uGMRT) used by InPTA pick up these radio beams as timely pulses as they sweep the earth!





Some pulsars rotate ~ 100 times a second without missing a beat, hence called millisecond pulsars, and are the ones observed by PTAs

Due to the regularity of these pulses, we can use them as extremely accurate clocks, correct up to a nanosecond!

This ability to keep time precisely is what PTAs exploit to detect gravitational waves.

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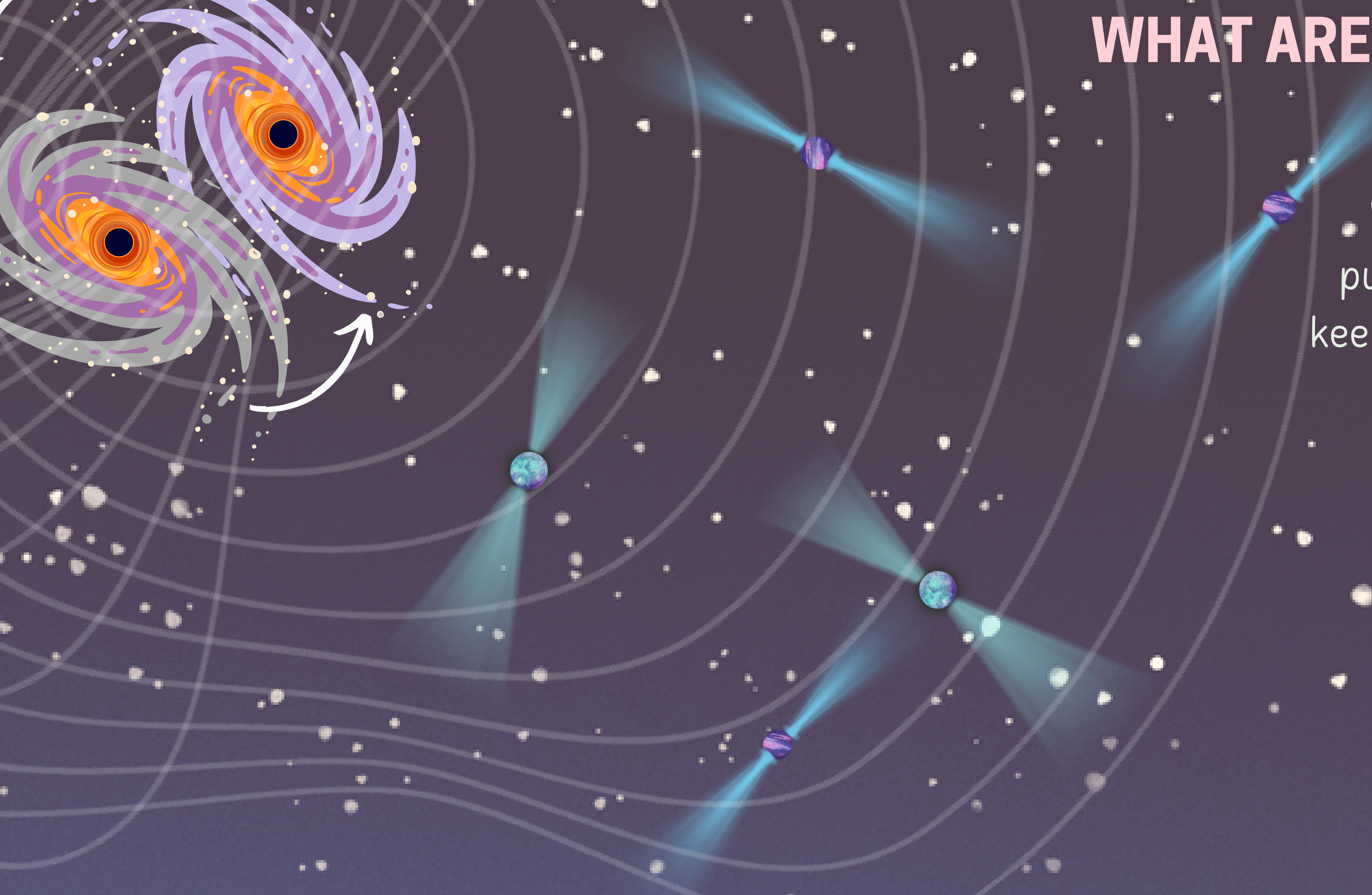
WHAT ARE PULSAR TIMING ARRAYS?



We observe an array of millisecond pulsars, distributed all over the sky to keep accurate time, hence the expeirment is called a "Pulsar Timing Array"

The Gravitational waves interact with the pulsars, stretching and squeezing space-time, which causes changes in the time of arrival of the pulses to earth, and as we very accurately have been keeping time, this change can be noted over many years of observation, hence detecting the presence of the Gravitvational Waves!

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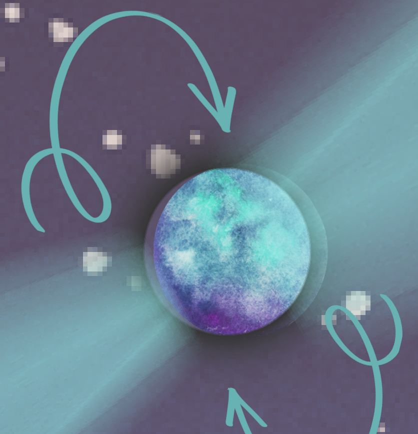
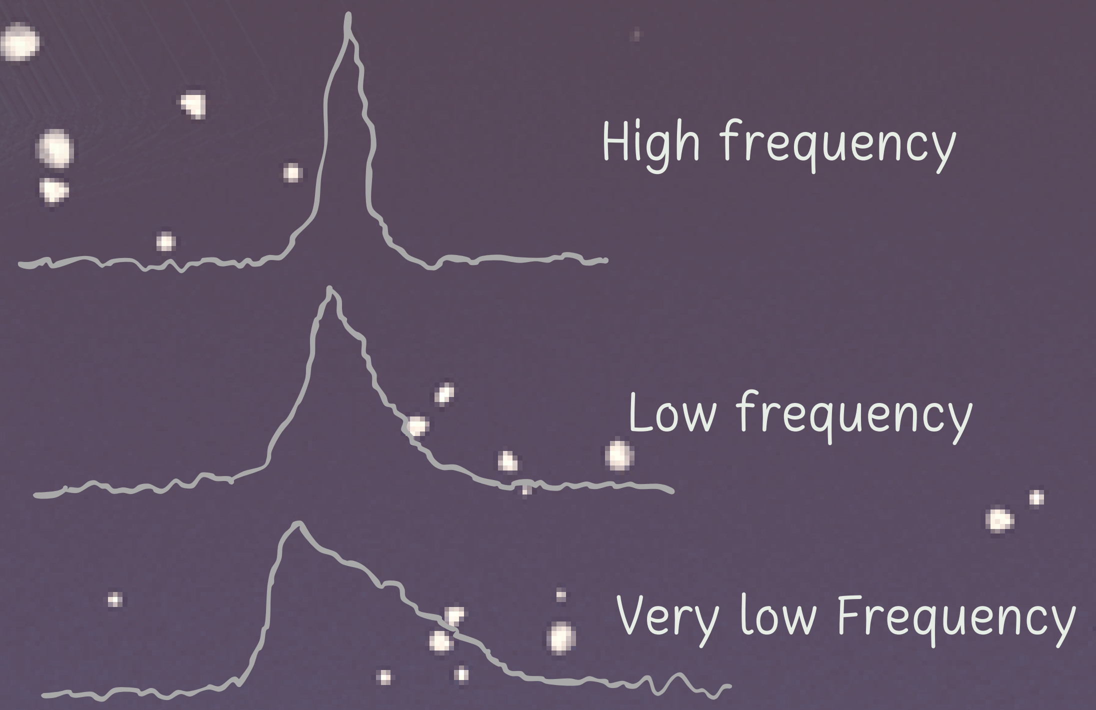
THE UNIQUE FEATURE OF THE INDIAN PULSAR TIMING ARRAY



Outer space isn't truly empty! There are free electrons, protons and other material between us and the pulsars we observe. Lower frequency radio light interacts differently with this medium than light at higher frequencies.

The same pulse at various radio frequencies



InPTA observes pulsars at both a higher frequency and a lower frequency simultaneously due to a unique feature of the uGMRT which let's us split the telescope dishes into two sets, this lets us study the medium between us and the pulsar exquisitely and also helps us correct our pulsar 'clocks' better, thus helping PTAs improve their precision.

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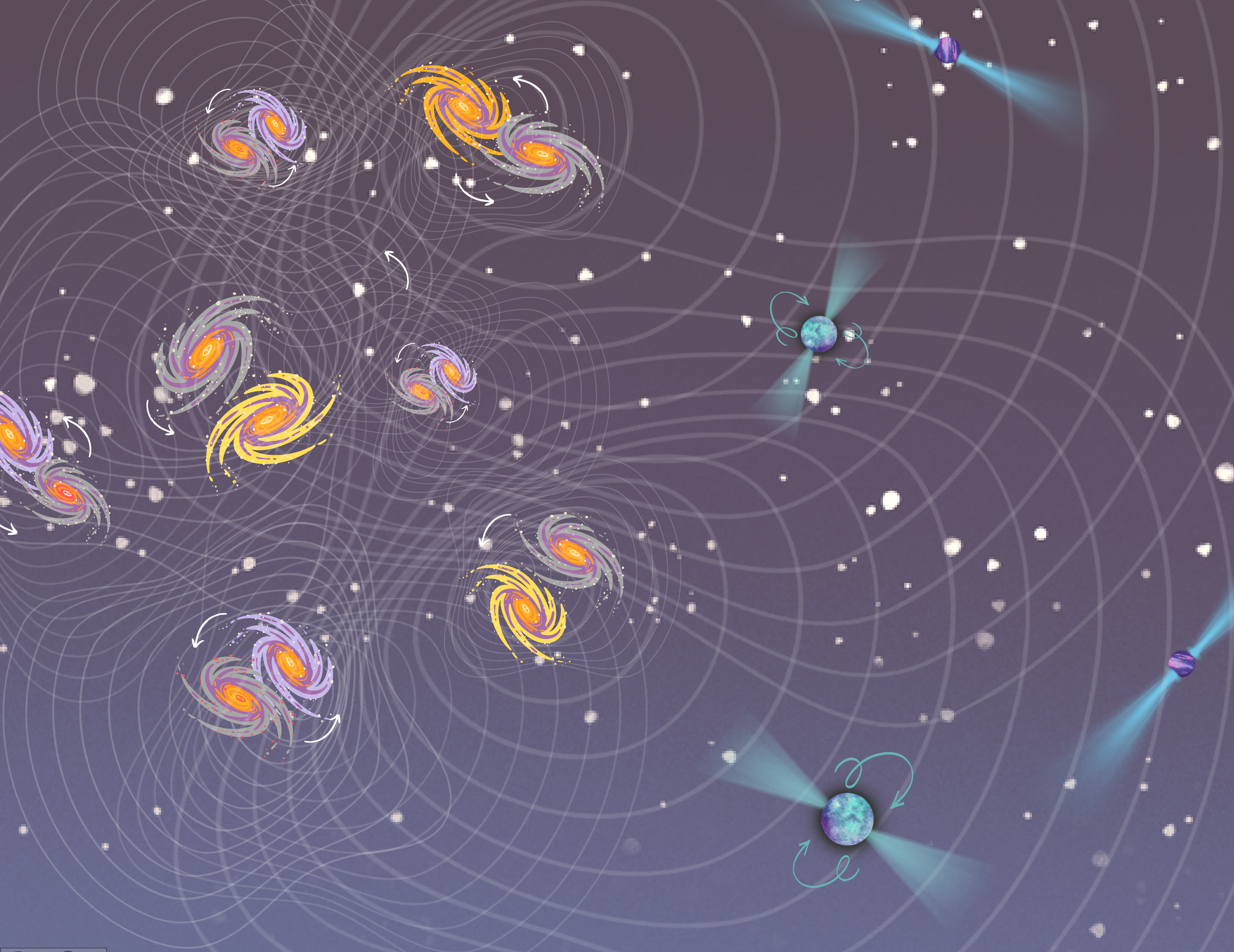
DETECTING GRAVITATIONAL WAVES USING PULSARS



As the Gravitational Wave Background should affect all the pulsars we observe in a similar way, we should see common effects in pairs of them, this gives rise to a unique signature:

InPTA teamed up with the European Pulsar Timing Array (EPTA) and we combined our data, to generate a more sensitive dataset.
Us, along with other PTAs such as NANOGrav and PPTA now see tantalizing hints of this unique signature.

A global effort deemed the International Pulsar Timing Array (IPTA) is afoot to chase these elusive waves

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A truly global venture, some of whose constituents have been operational for decades, the IPTA exemplifies the international spirit of science, bringing scientists from all walks of life together for a cosmic goal with more PTAs such as the African PTA and Chinese PTA joining in every year.

WHAT COMES NEXT?

OBTAIN A STRONGER SIGNAL AND UNDERSTAND THE GWB

PTAs get more sensitive, the longer they observe a larger number of pulsars, over the next few years we'll probe the nature of the current signal much deeper.

SHOOT FOR INDIVIDUAL BINARIES, WORK WITH VLBI NETWORKS

The stochastic background is a mish-mash of gravitational wave signals from all over the sky, PTAs expect to detect individual merging binaries at the cores of galactic nuclei, finding and studying candidates with VLBI experiments such as the EHT, EVN, VLBA will be crucial.

MULTIMESSENGER ASTRONOMY AND COSMOLOGICAL DISTANCES

With the detection of individual binaries, we will be able distances to these mergers, and predict the expansion rate of the universe at an early epoch. Merging black hole's circumbinary disks are also potential candidates for neutrino detections.

PULSAR TIMING ARRAYS ARE STRONGER TOGETHER!

With PTAs such as the chinese pulsar timing array and the african pulsar timing array joining the international effort and with telescopes such as the SKA and the extended GMRT on the horizon, pooling in data and searching for all of the above together shall be a fruitful effort!

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A NEW WINDOW IN GRAVTITIONAL WAVE ASTRONOMY IS NOW OPEN!