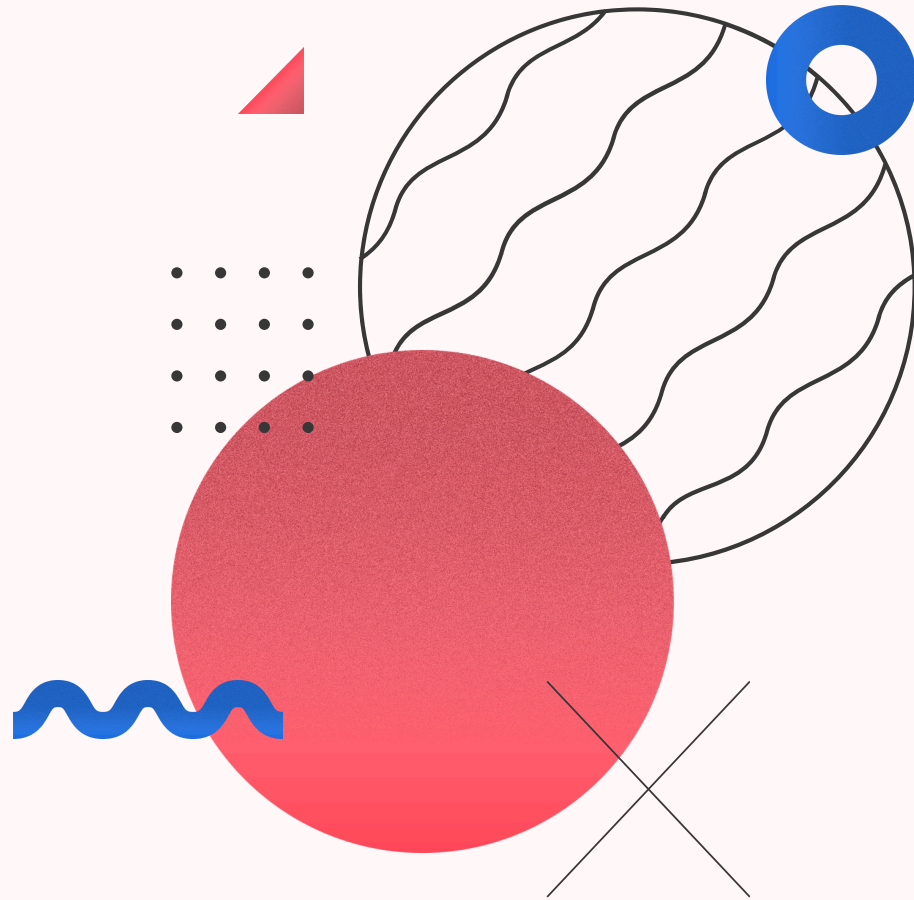


Using Pulsar Observations to Probe Solar Wind Turbulence During the 2025 Crab Conjunction

Presented by Anna(Huiyu) Xiao
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UNIVERSITY OF
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Canadian Institute for
Theoretical Astrophysics

L'institut Canadien
d'astrophysique théorique

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Wednesday, 12 August 2026 08:45 (12 minutes)

Pulsars provide a sensitive probe of heliospheric plasma through propagation-induced variations in dispersion measure (DM) (which measures the total electron column density) and scattering (which measures the scale of density perturbations perpendicular to the line of sight), particularly during solar conjunction. The Canadian Hydrogen Intensity Mapping Experiment (CHIME), together with its outrigger stations across North America, enables high-cadence, multi-baseline radio observations that are well suited for investigating these propagation effects.

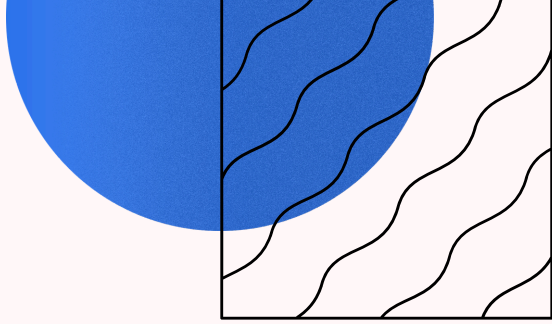
We analyze CHIME observations of the Crab Pulsar (PSR B0531+21) obtained during solar conjunction. Multi-station correlation analyses are used to characterize scattering signatures while the high sensitivity of the main station provides DM measurements. Preliminary results show enhanced dispersion measure and scattering during close solar approaches, consistent with increased plasma density and turbulence along the line of sight.

We compare the measured DM variations with DM predictions derived from both an idealized Parker solar-wind density model and Parker Solar Probe (PSP) SWEAP observations. Electron density profiles are estimated from PSP measurements within time windows centered on each pulsar observation and mapped into the Earth–Crab Line of Sight (LOS) geometry to predict the corresponding solar-wind DM contribution. To better isolate the heliospheric component, we model the slowly varying interstellar DM contribution as a time-dependent trend rather than assuming a constant background.

Together, these analyses demonstrate the potential of combining multi-station pulsar observations, theoretical solar-wind models, and in-situ spacecraft measurements to quantitatively investigate the density structure and turbulence of the inner heliosphere.



**what is conjunction period and why
conjunction period?**



Conjunction Period

Definition:

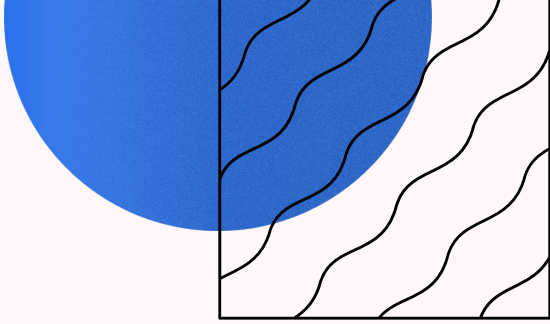
Conjunction date is the date (most of time recorded in UTC) when the sun moves closest to the LOS between Earth and the reference-----here our reference is Crab Pulsar.

Conjunction gives us the strongest interaction between the radio signal and the solar wind, so it provides the highest sensitivity to solar-wind structure.





Why using pulsar and why crab?



Pulsars emit extremely regular radio pulses, almost like highly stable natural clocks.

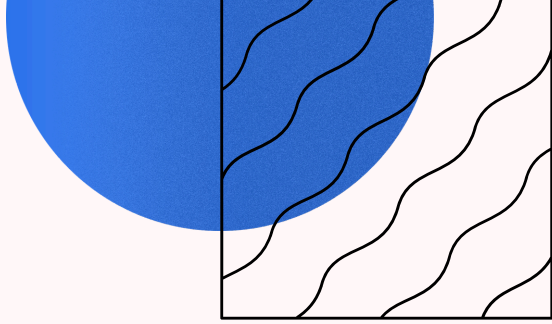
We know very precisely when the pulses should arrive, even tiny delays caused by plasma along the propagation path can be measured.

Crab Pulsar

The Crab Pulsar is one of the brightest radio pulsars and has a very high signal-to-noise ratio. It is observed regularly by CHIME, providing a dense observational data set.

Most importantly, in 2025 it underwent a favorable solar conjunction, giving us a rare opportunity to study the solar wind along that line of sight.



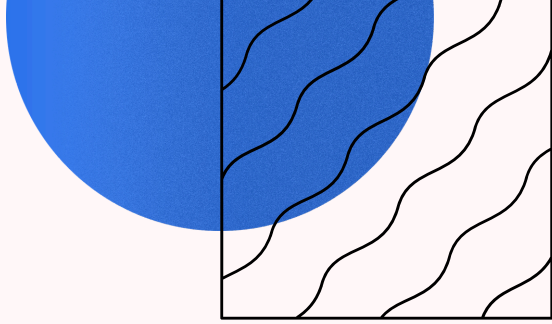


Why not another
pulsar?





**what did we do, and what kind of methods,
tools?**



computational data analysis:

- **signal-processing techniques**

Methodology

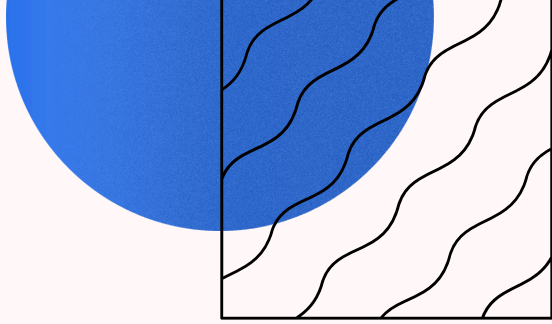
- **corrections for ionospheric and instrumental effects**

- **comparison of our observations with theoretical density models with Parker Solar Probe measurements.**





how the results we obtained related to the solar wind?

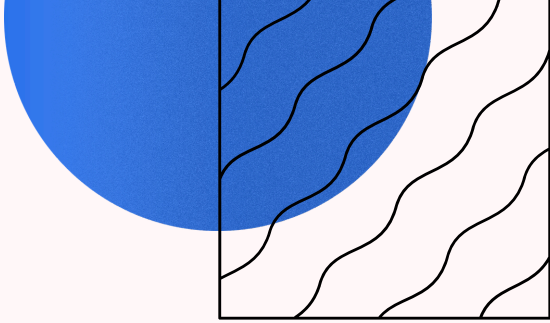


Solar Wind

- Dispersion measure tells us about the integrated electron density along the line of sight.
- Scattering tells us about density fluctuations and turbulence in the solar wind.

Together, they provide complementary information about both the large-scale plasma distribution and the smaller-scale turbulent structures.





Dispersion vs Scattering

Dispersion:

frequency



different frequencies
arrive at different times

SHIFT

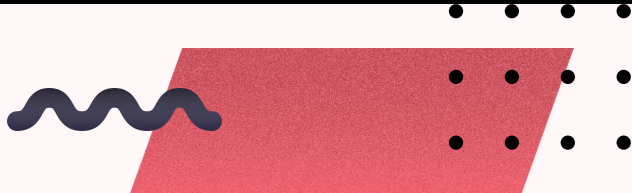
Scattering:

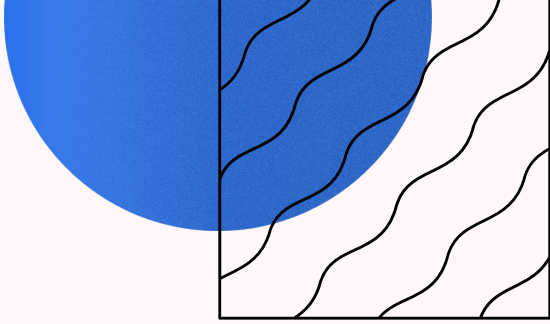
intensity



pulse gets broadened
+ develops a tail

BROADEN





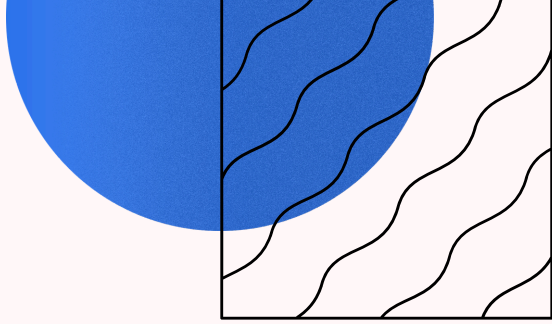
Dispersion vs Scattering

Dispersion produces a frequency-dependent arrival-time delay, whereas **scattering** produces pulse broadening and an extended tail.





what are the findings, what we learned?



Conclusions we draw:

- the propagation effects change systematically as the pulsar approaches and moves away from conjunction, reflecting changes in the solar-wind plasma along the line of sight.
- Combining remote observations from pulsars with in-situ measurements from Parker Solar Probe provides a much more complete picture of the solar wind than either approach alone.
- More broadly, the project demonstrates that astronomical observations can be used as powerful probes of heliospheric plasma.



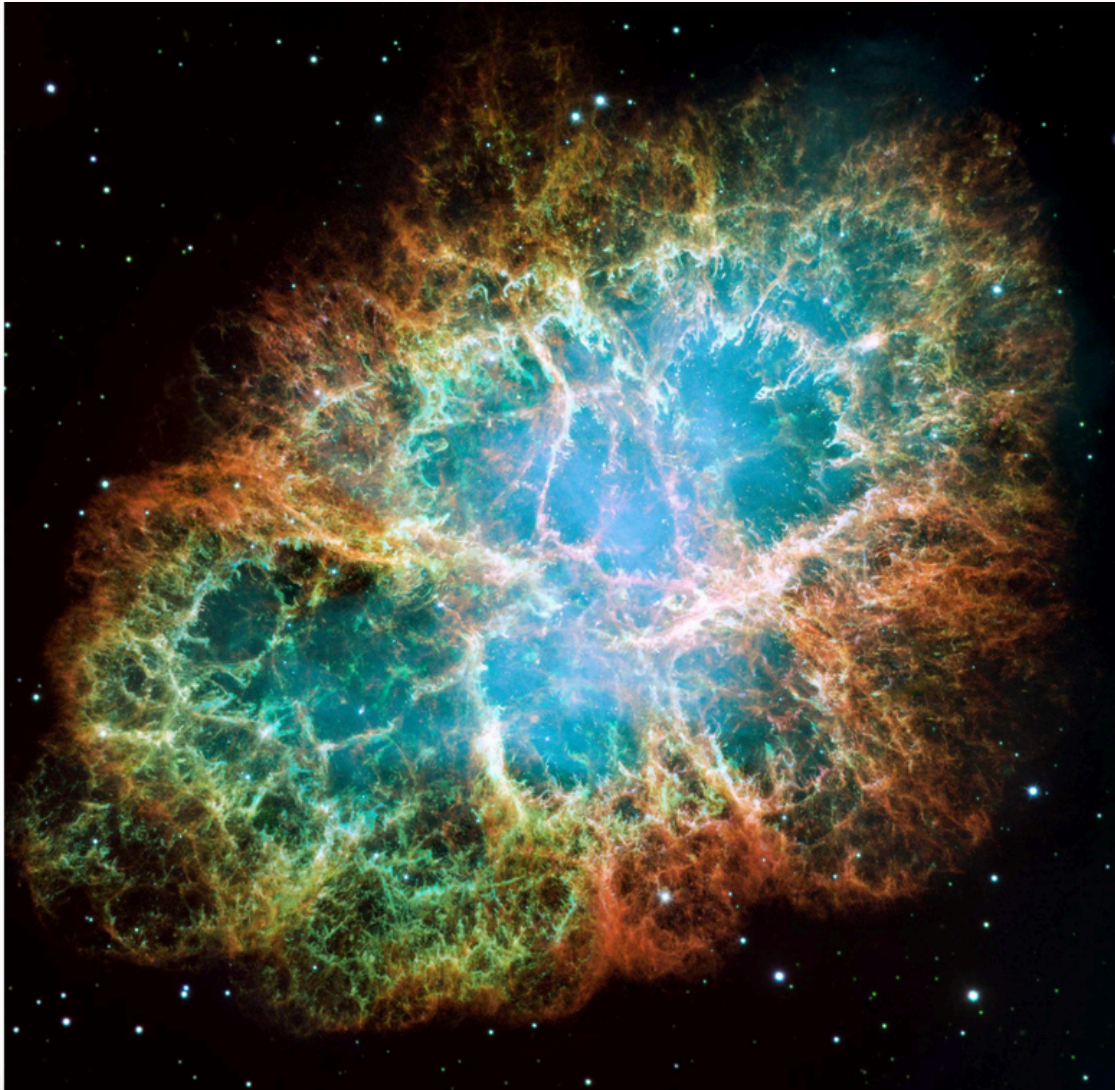
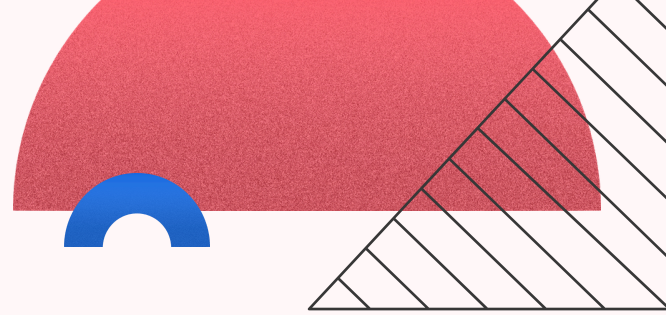


Image credit: NASA, ESA, J. Hester
and A. Loll (Arizona State
University)

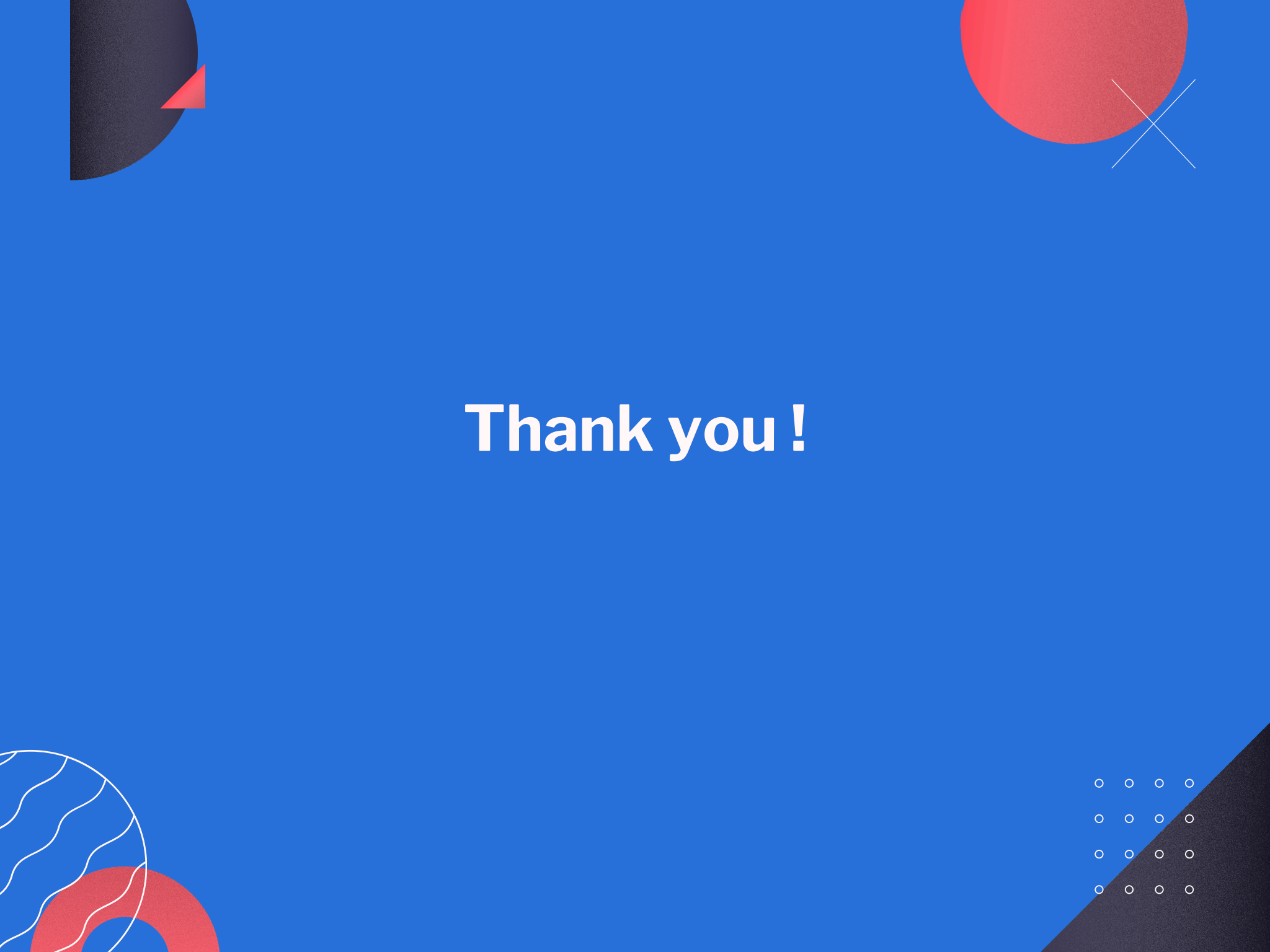


References and helpful links:

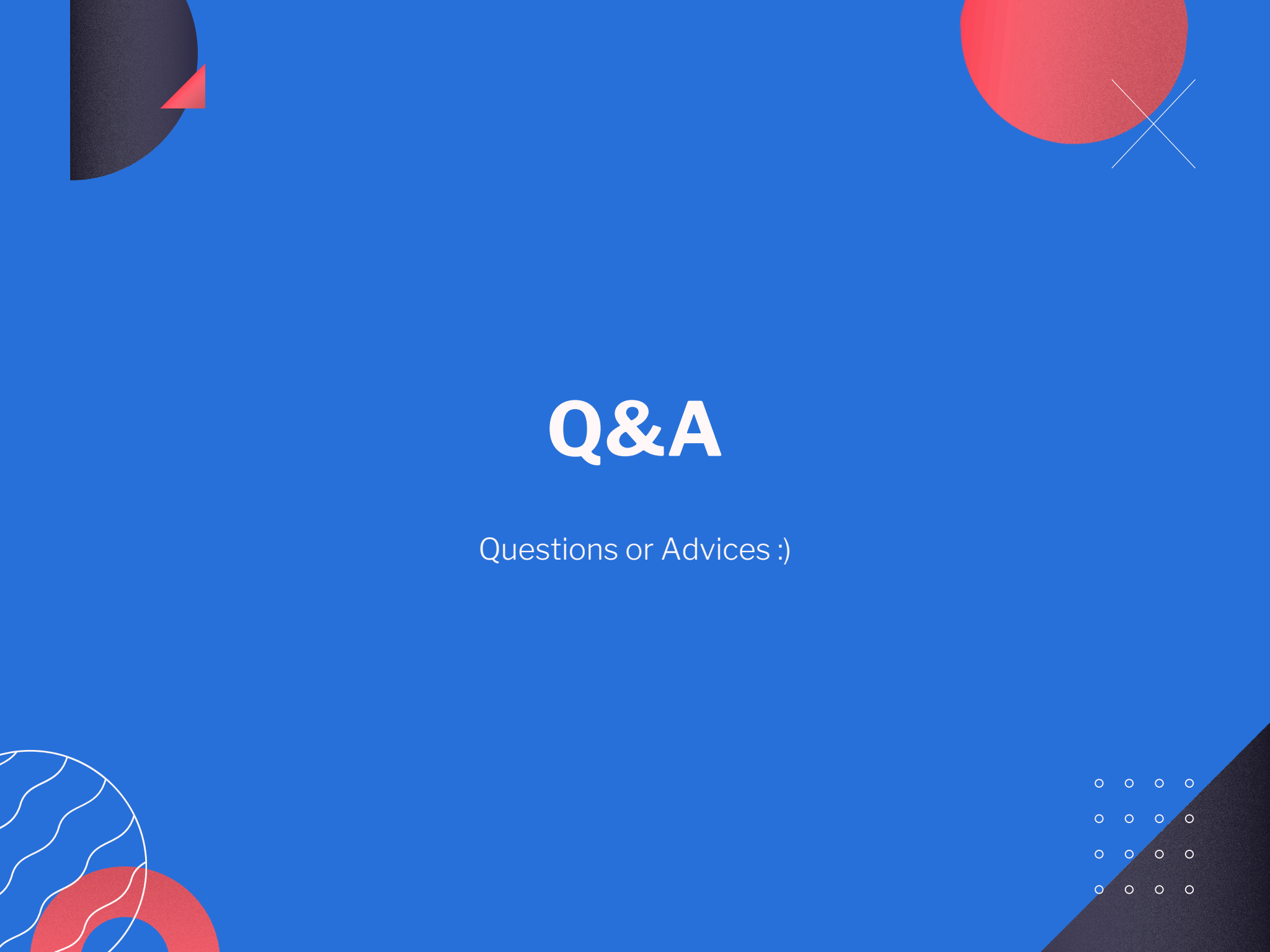
·Crab Nebula (Messier 1). NASA, ESA, J. Hester and A. Loll (Arizona State University). Retrieved from [Presentations are communication tools that can be used as demonstrations, lectures, speeches, reports, and more.](#)

·Parker Solar Probe Data:
<https://sweap.cfa.harvard.edu/pub/data/sci/sweap/>





Thank you !



Q&A

Questions or Advices :)