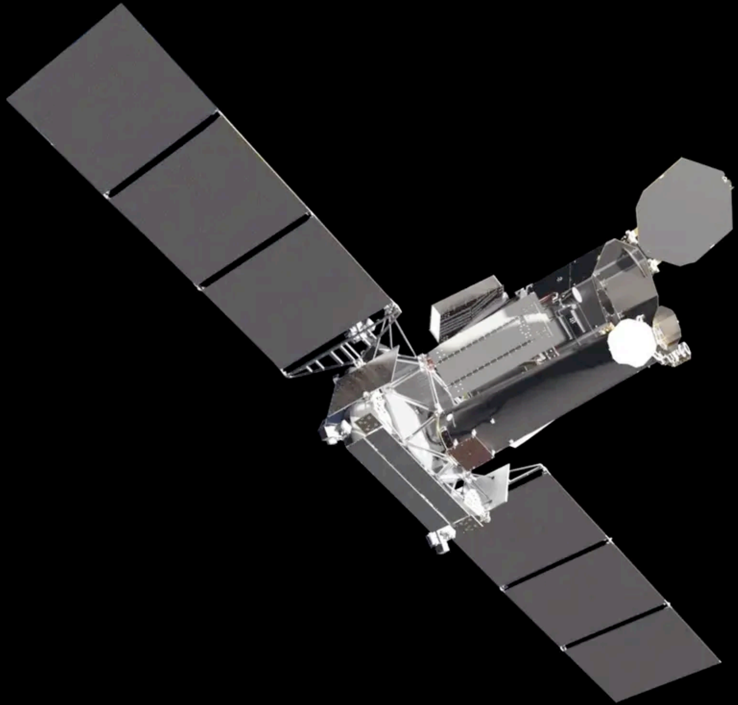


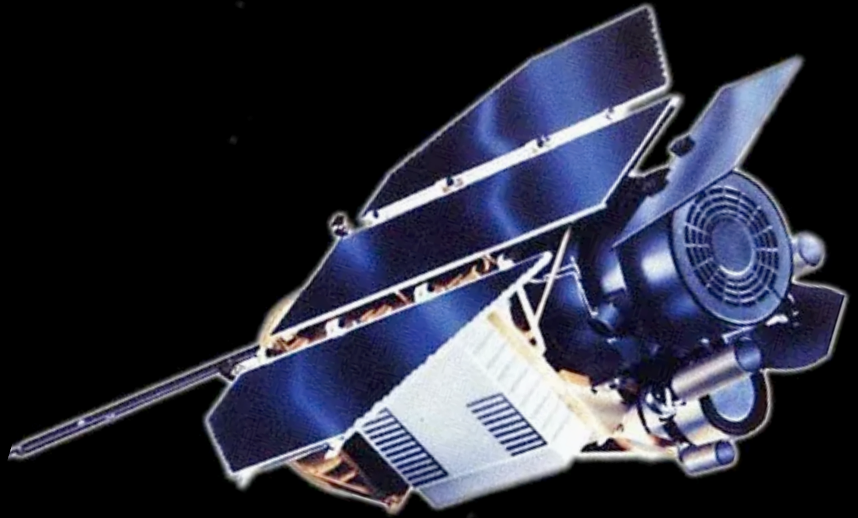
The SRG/eROSITA view of our heliosphere

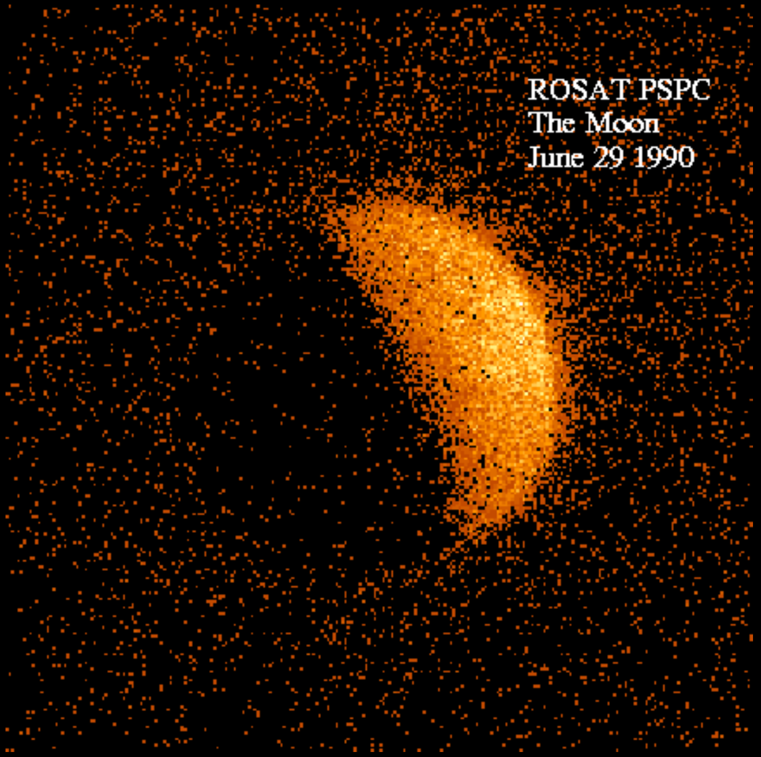
K. Dennerl[1], G. Ponti[1,2], X. Zheng[1], M. Freyberg[1], S. Friedrich[1], Th. Müller[1], M. Yeung[1]

[1] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany

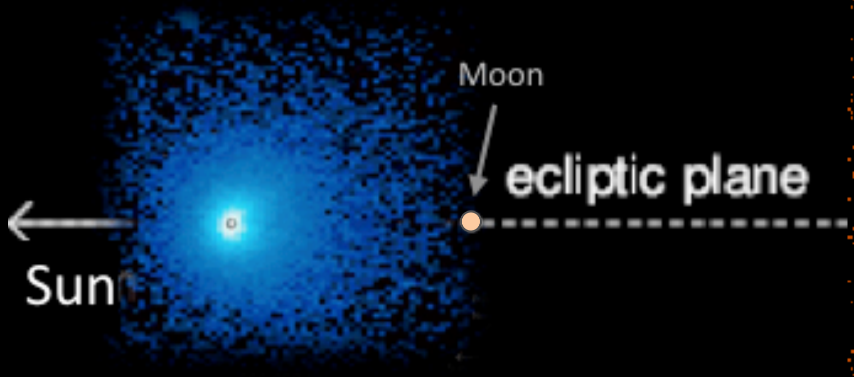
[2] INAF-Osservatorio Astronomico di Brera, Via E. Bianchi 46, 23807 Merate (LC), Italy

Geocoronal Solar Wind Charge Exchange

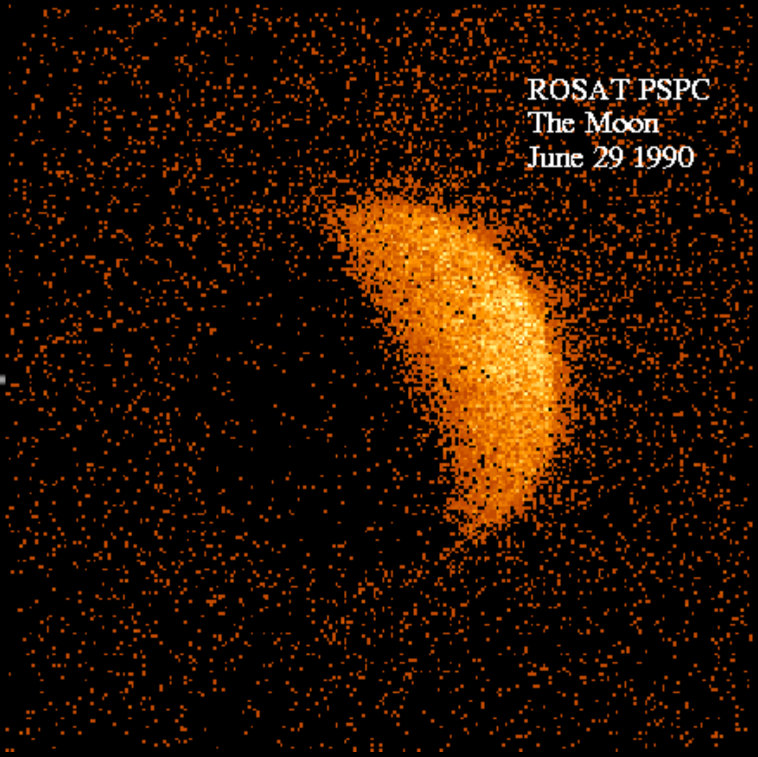




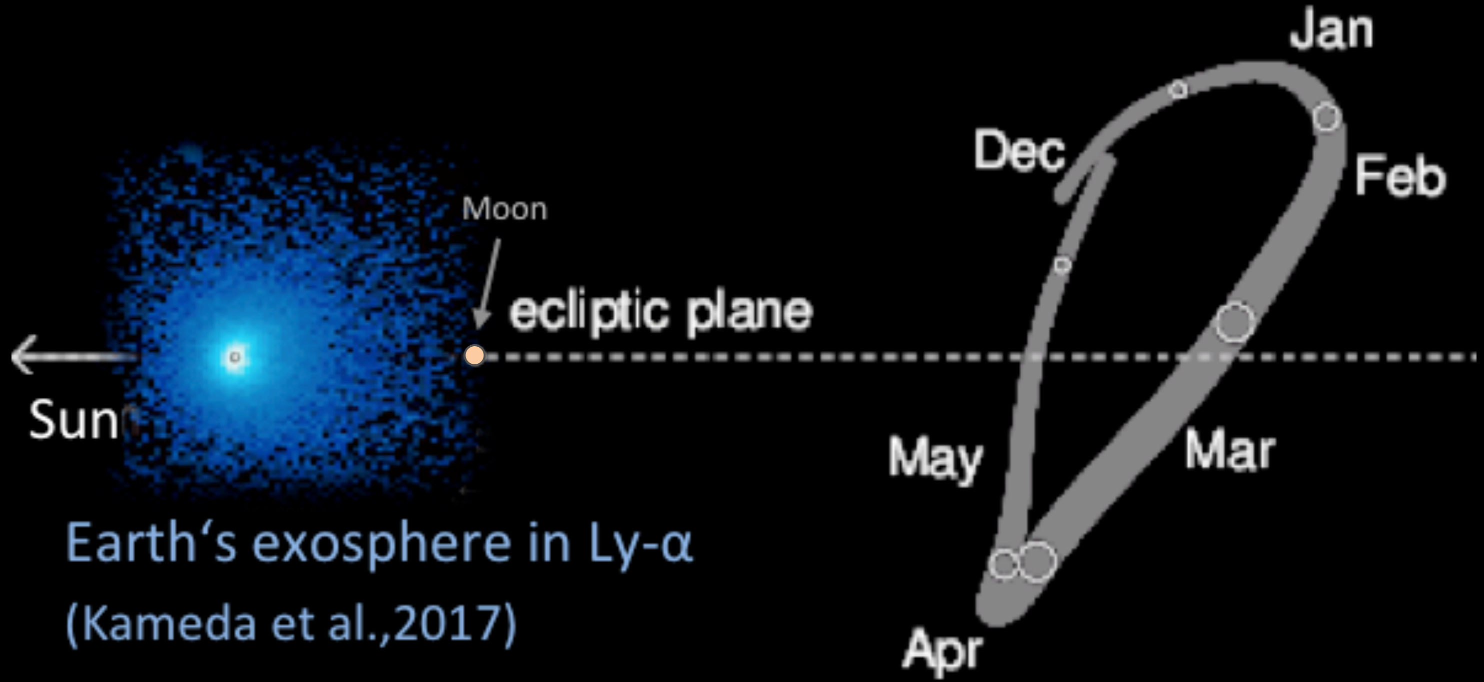
Geocoronal Solar Wind Charge Exchange and the eROSITA orbit



Earth's exosphere in Ly-α
(Kameda et al.,2017)



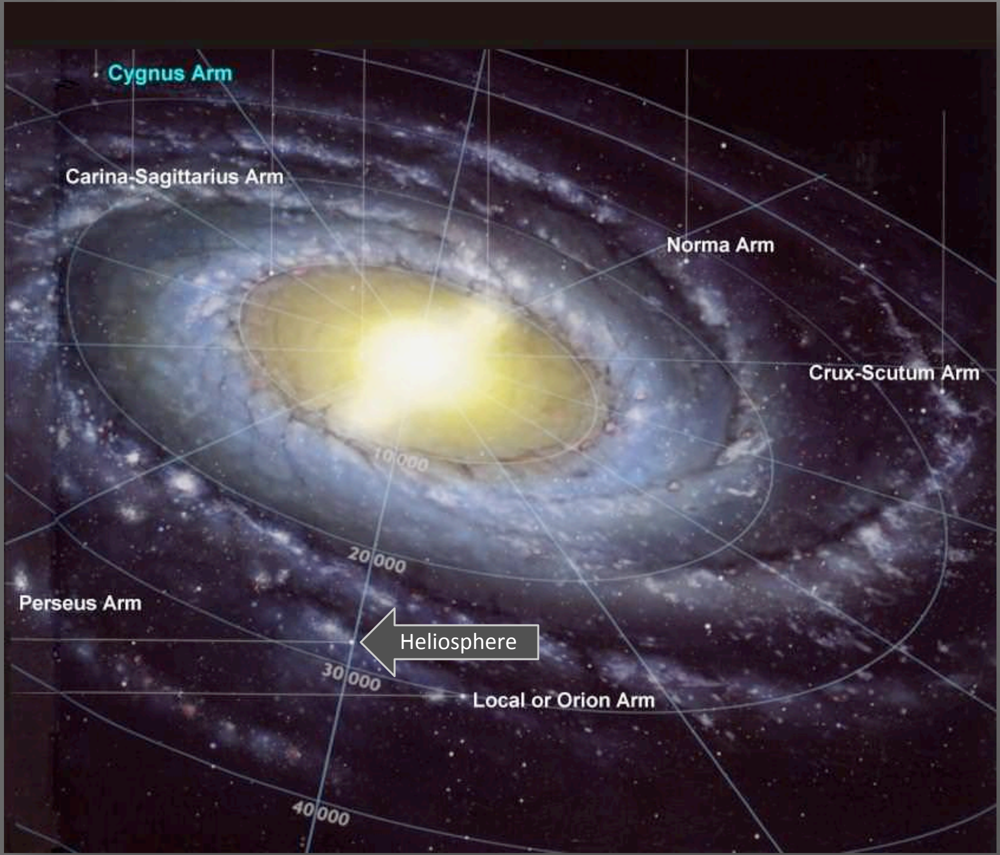
Geocoronal Solar Wind Charge Exchange and the eROSITA orbit



Earth‘s exosphere in Ly-α

(Kameda et al.,2017)

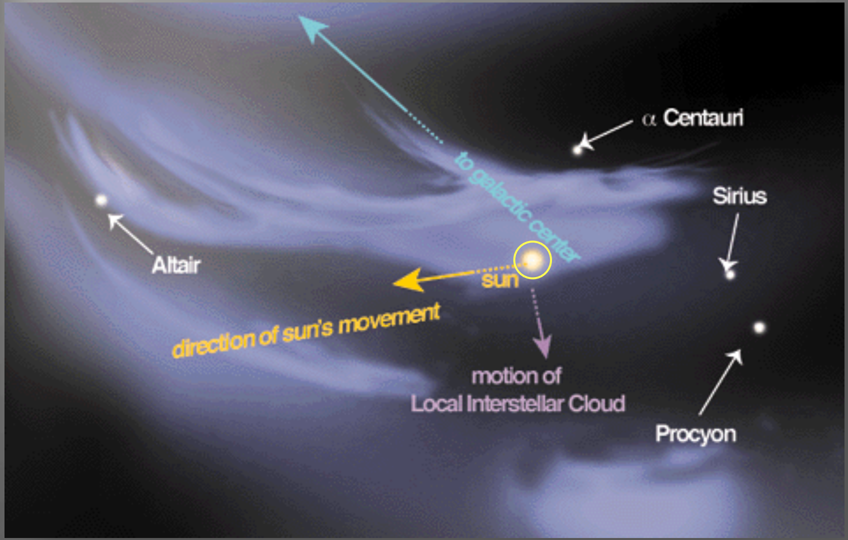
Solar Wind Charge Exchange in the Heliosphere



https://www.universetoday.com/65343/what-galaxy-is-the-earth-in/

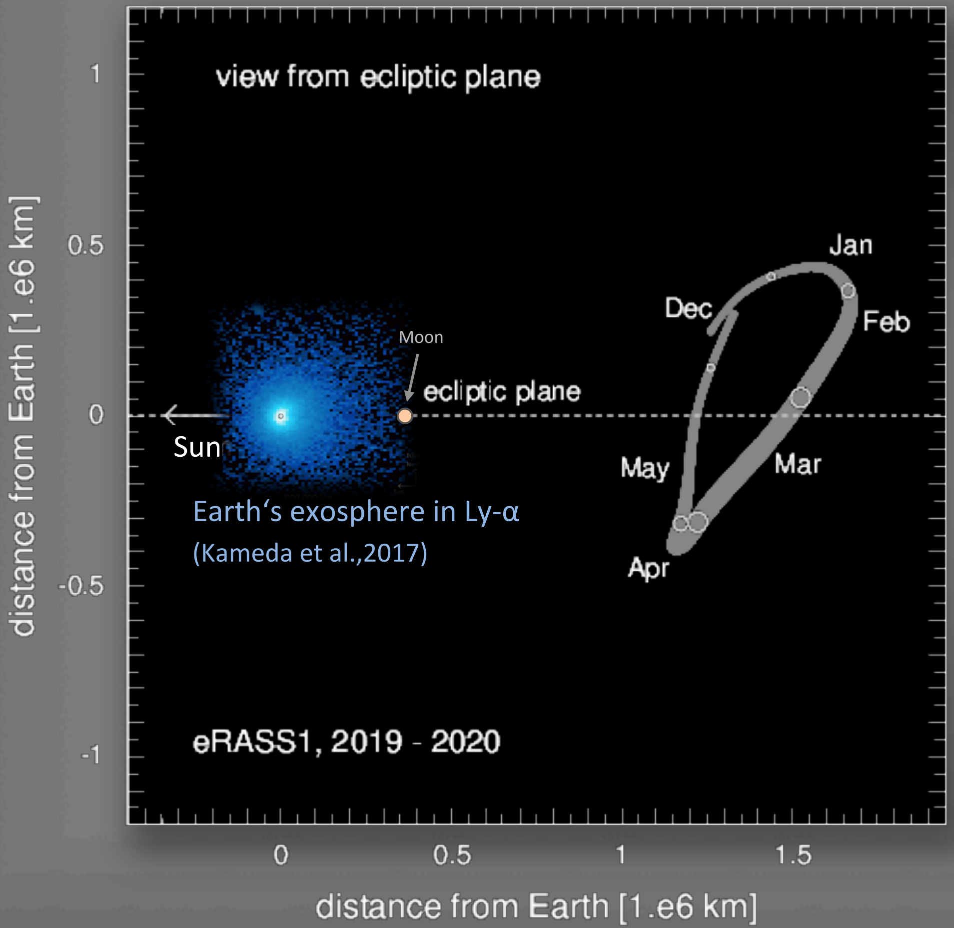
Interstellar Medium is flowing through our solar system, and we can see it with eROSITA!

(as will be shown later)



http://antwrp.gsfc.nasa.gov/apod/ap020210.html

Geocoronal Solar Wind Charge Exchange and the eROSITA orbit

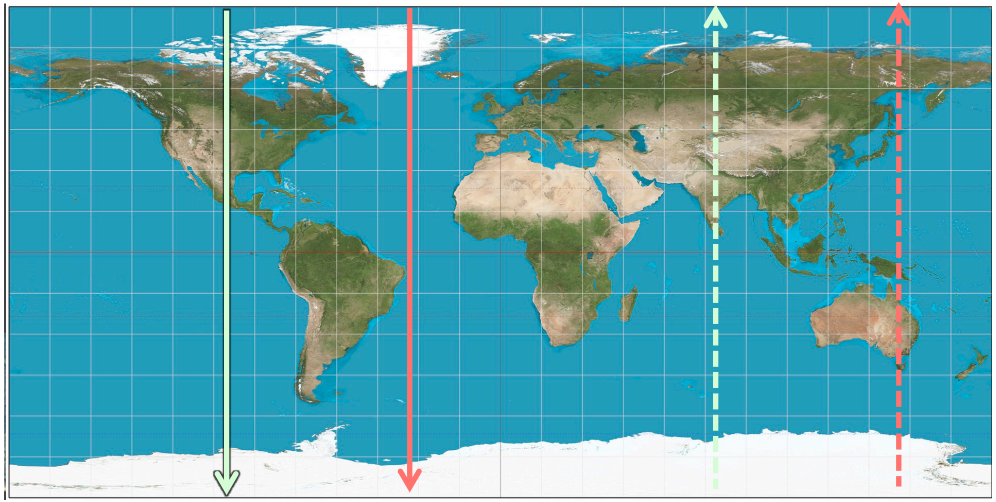


eROSITA on SRG is the first ever instrument to observe the X-ray sky from outside the Earth exosphere (!)

It has already completed four all-sky surveys (`eRASS‘), starting at solar minimum

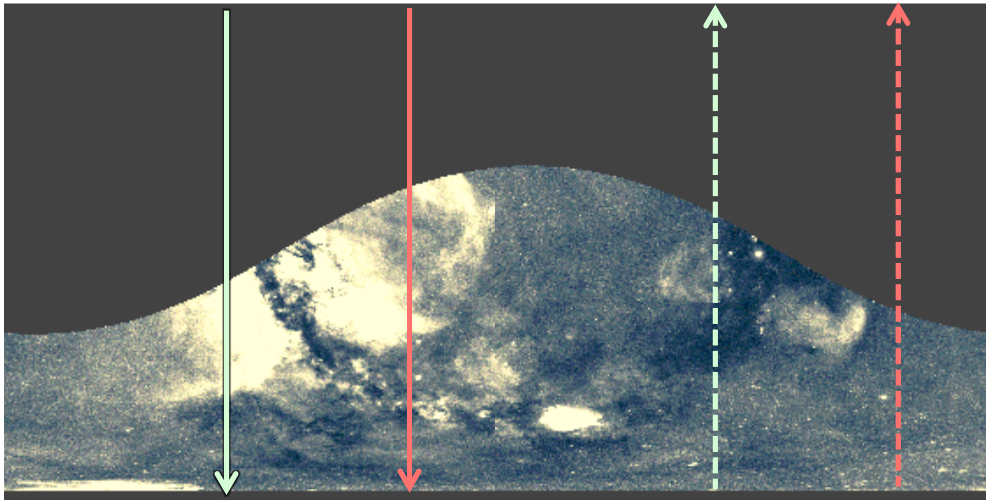
The data provide an unprecedented opportunity

1. to obtain a clear view of the sky, not affected by geocoronal X-ray emission
2. to study heliospheric X-ray emission



world map
in equirectangular (equatorial) projection
(for illustration of the projection)

eROSITA All Sky Survey (eRASS)



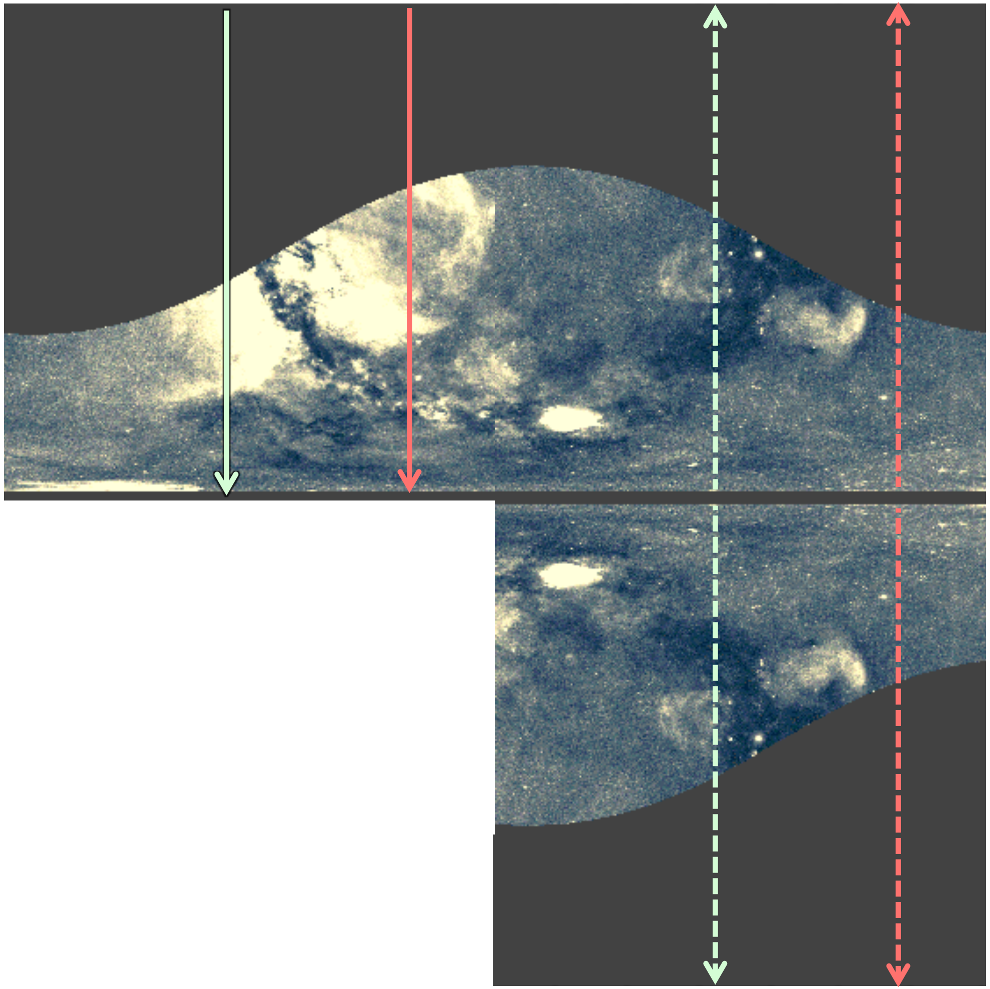
0.2 – 2.0 keV eRASS1 map
in equirectangular (ecliptic) projection
hightling low surface brightness features
(only ‚eROSITA_DE hemisphere' displayed)

all eROSITA scans go exactly over the ecliptic poles

each 360° scan takes exactly 4 hours (`eROday')

equirectangular projection:

- all scans exactly along y axis
- constant speed along y axis



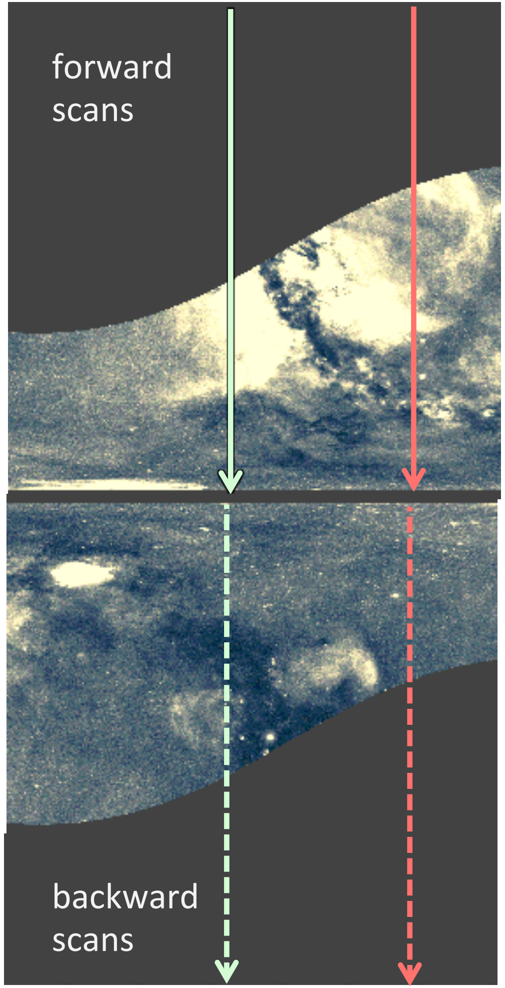
eROSITA All-Sky Survey (eRASS)

all eROSITA scans go exactly over the ecliptic poles

each 360° scan takes exactly 4 hours (`eROday')

equirectangular projection:

- all scans exactly along y axis
- constant speed along y axis



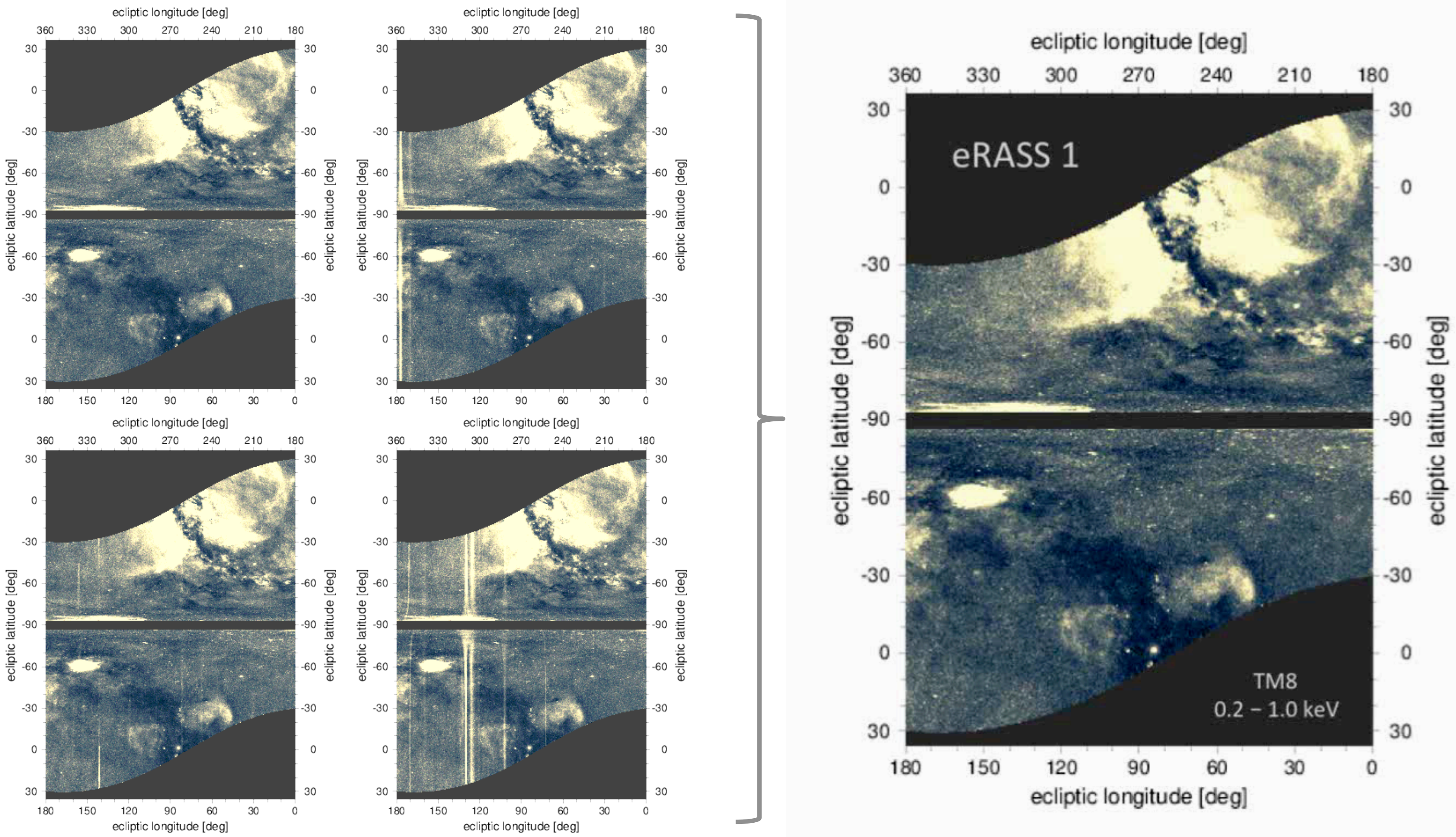
eROSITA **A**ll-**S**ky **S**urvey (eRASS)

all eROSITA scans go exactly over the ecliptic poles

each 360° scan takes exactly 4 hours (`eROday‘)

equirectangular projection:

- all scans exactly along y axis
- constant speed along y axis


ecliptic longitude [deg]
ecliptic latitude [deg]
eRASS 1
TM8
0.2 – 1.0 keV

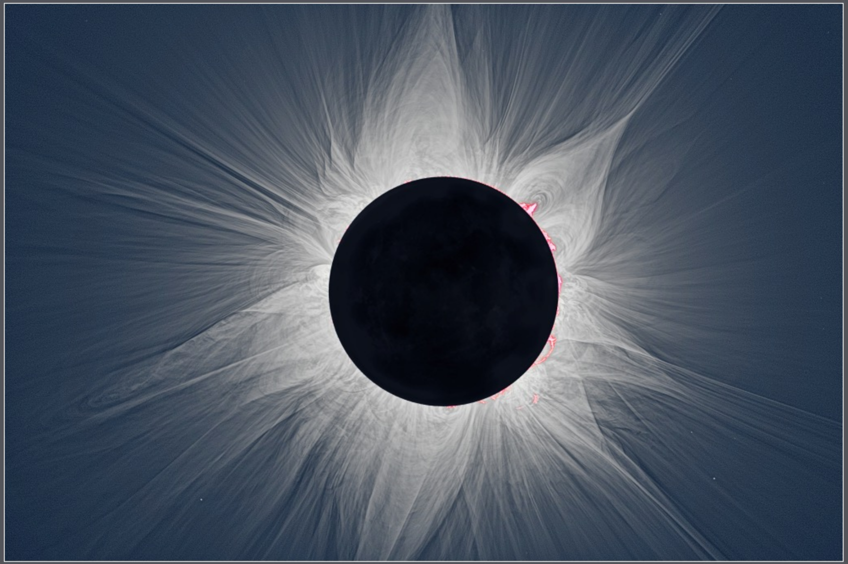
Solar Wind Properties

2019 Jul 02

Total Solar Eclipse 2019 © 2019 Miloslav Druckmüller, Peter Aniol

near solar minimum

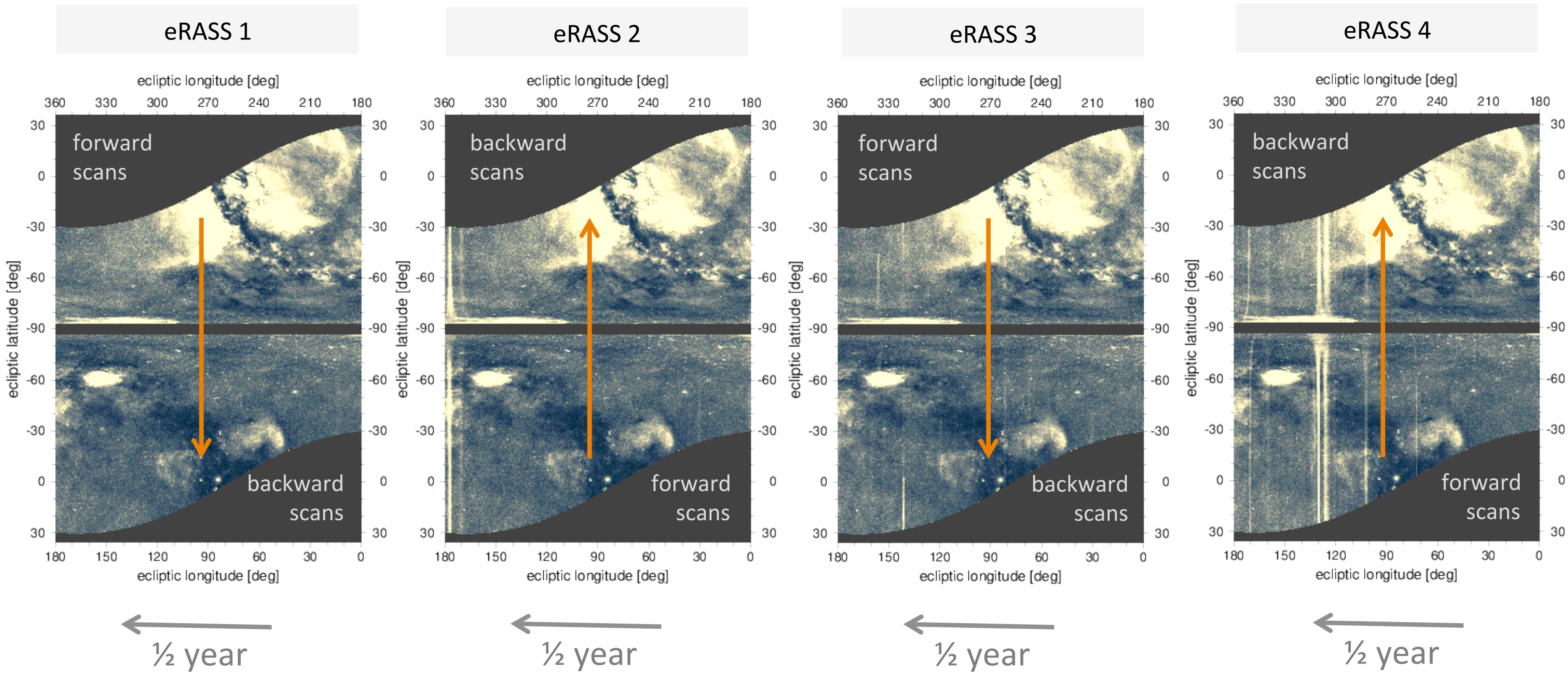
2023 Apr 20

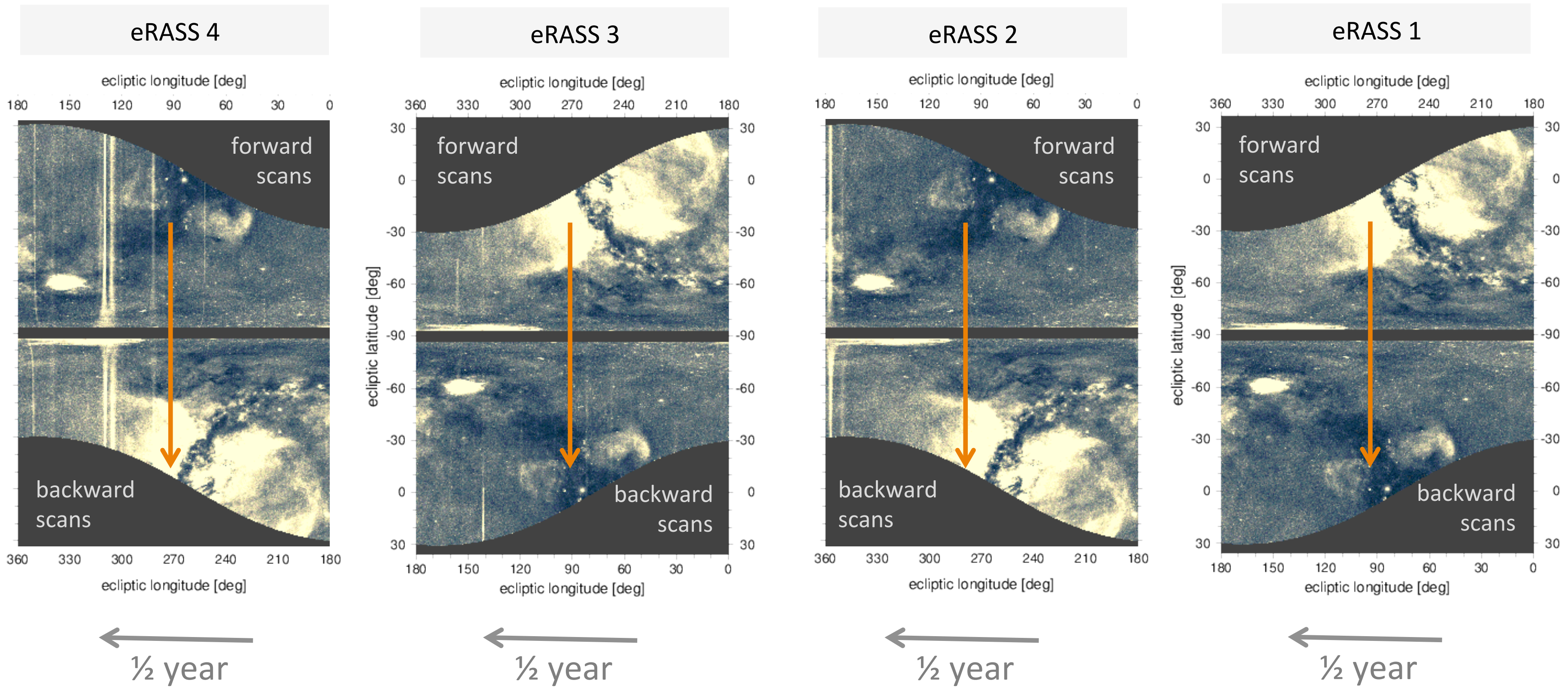


Total Solar Eclipse 2023 © 2023 Pavel Štarha, Shadia Habbal, Miloslav Druckmüller

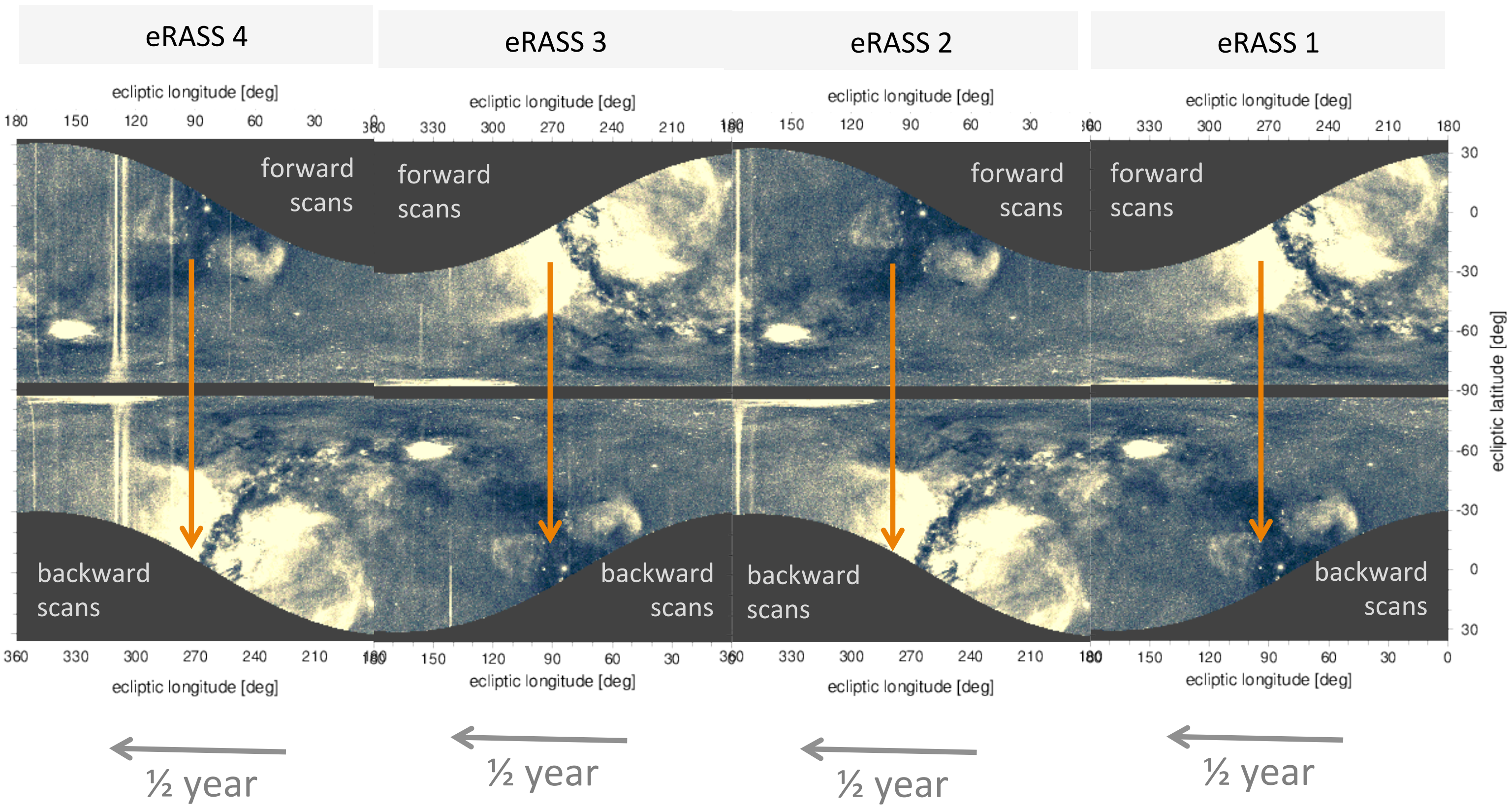
near solar maximum

Druckmüller et al., http://www.zam.fme.vutbr.cz/~druck/eclipse/


eRASS 1
eRASS 2
eRASS 3
eRASS 4
ecliptic longitude [deg]
ecliptic latitude [deg]
forward scans
backward scans
backward scans
forward scans
forward scans
backward scans
backward scans
forward scans
360 330 300 270 240 210 180
180 150 120 90 60 30 0
30 0 -30 -60 -90 -60 -30 0 30
½ year
½ year
½ year
½ year

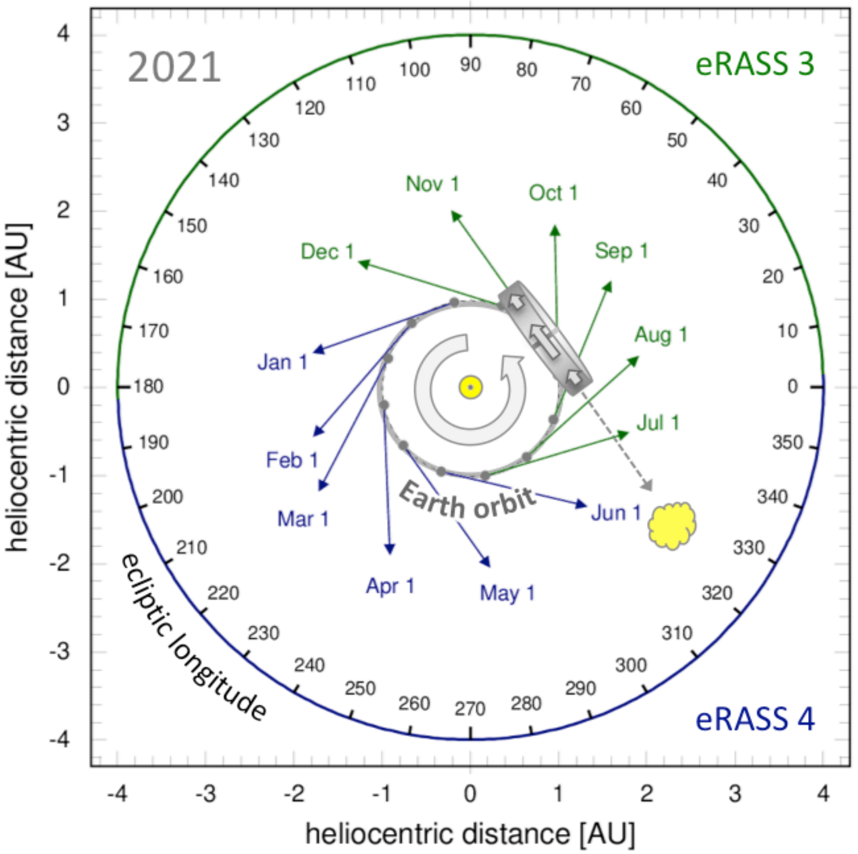


eRASS 4
eRASS 3
eRASS 2
eRASS 1
ecliptic longitude [deg]
ecliptic latitude [deg]
forward scans
backward scans
½ year
½ year
½ year
½ year



eRASS 4
eRASS 3
eRASS 2
eRASS 1
ecliptic longitude [deg]
ecliptic latitude [deg]
forward scans
backward scans
½ year

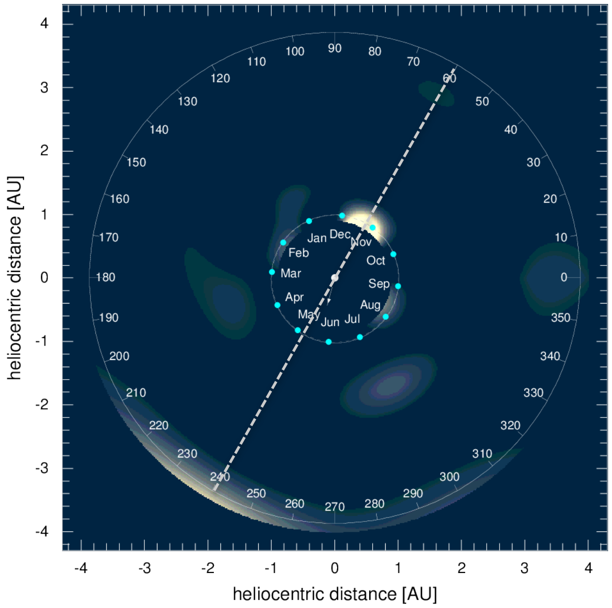
A novel method: X-ray triangulation



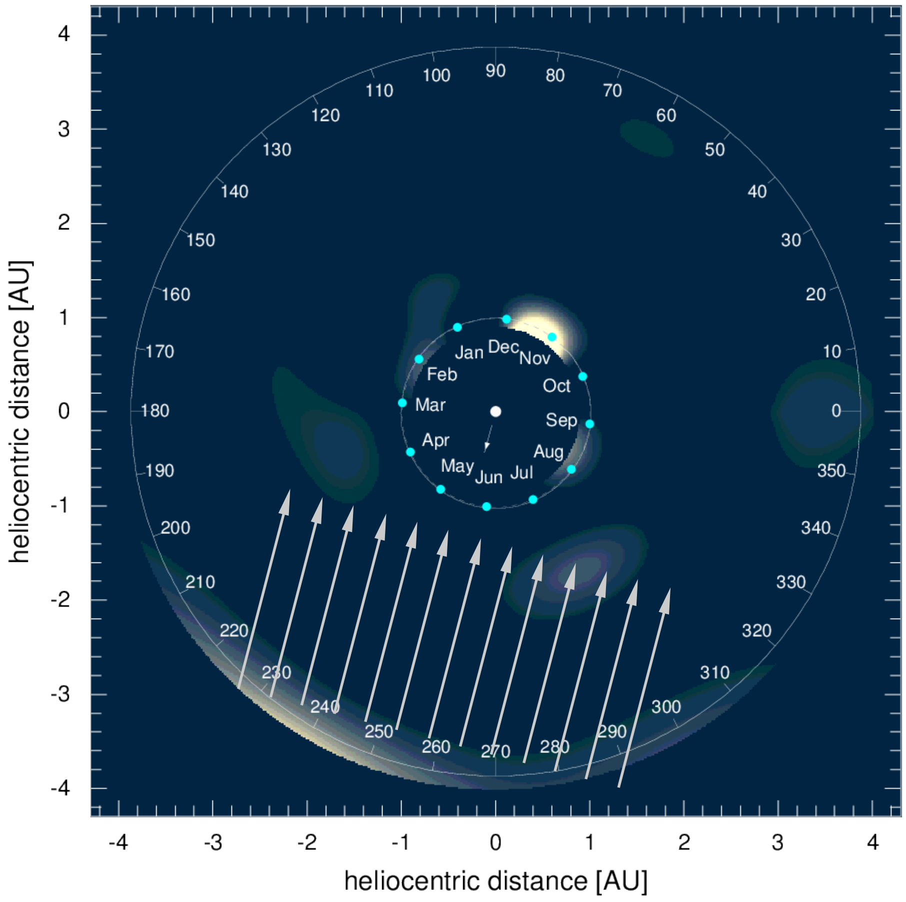
Localization of stationary emission regions by X-ray triangulation

The eROSITA data indicate that

- there are well localized emission regions in the solar system which **do not orbit the Sun**
- they are distributed symmetrically to a line passing through the Sun and exhibit a strong concentration



Localization of stationary emission regions by X-ray triangulation

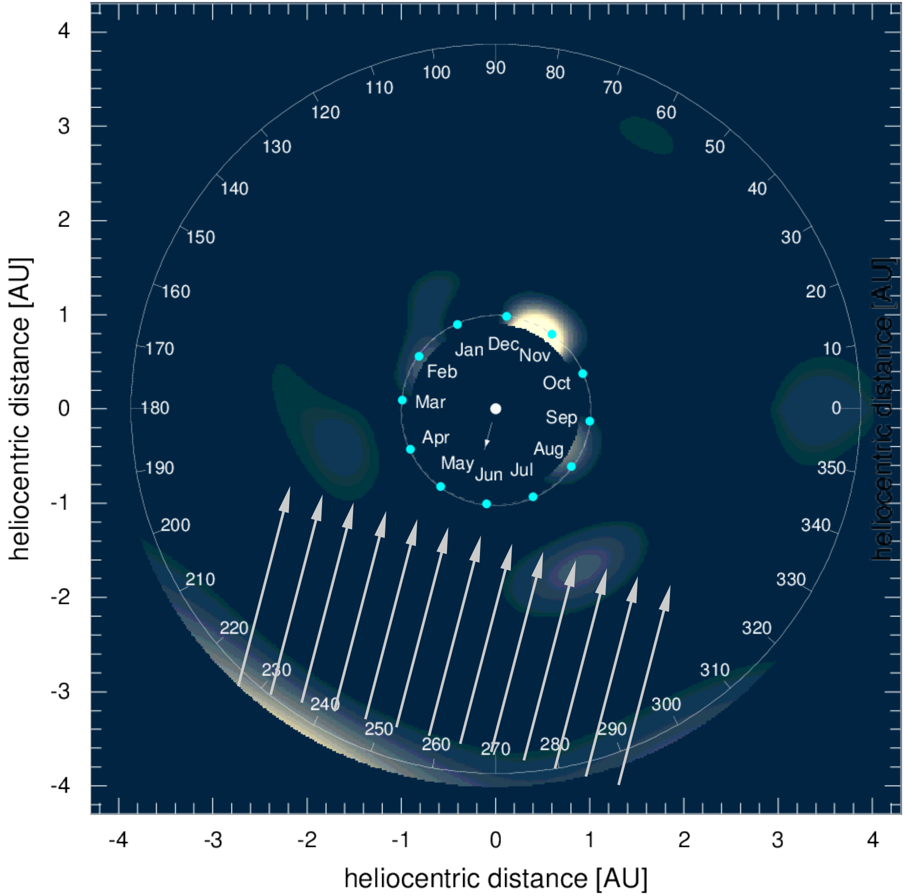


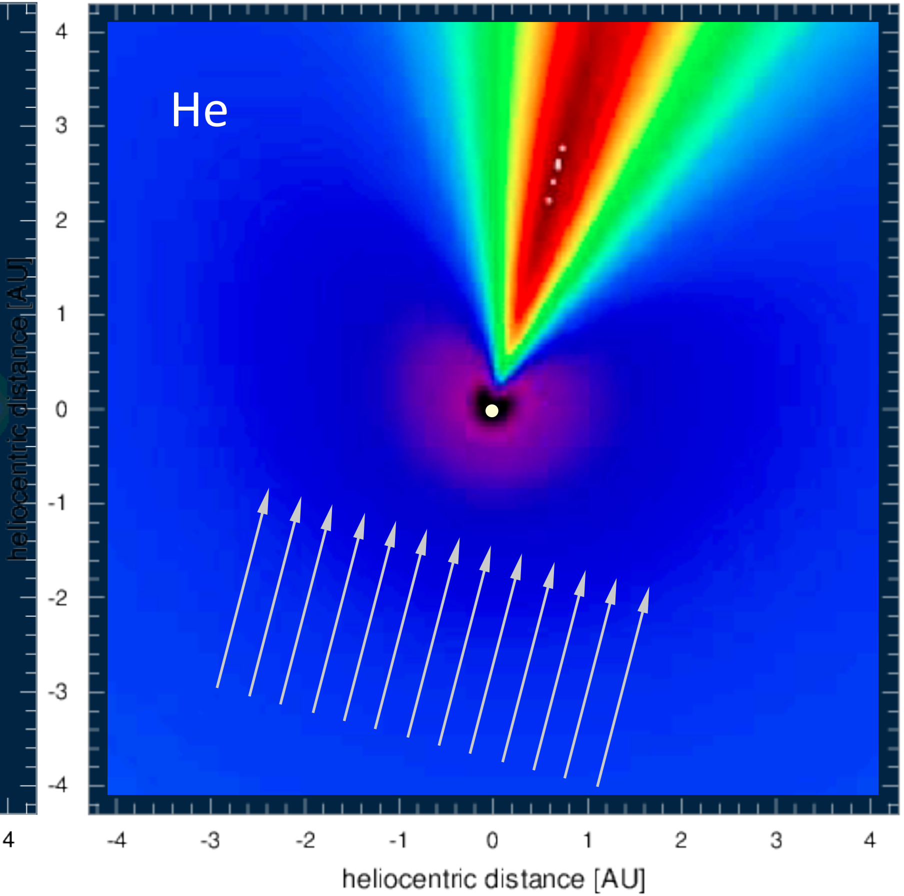
X-ray signal from the „Helium focusing cone“!

→ it would have been possible to discover the Helium focusing cone with only the eROSITA data!

Distribution of local interstellar Helium

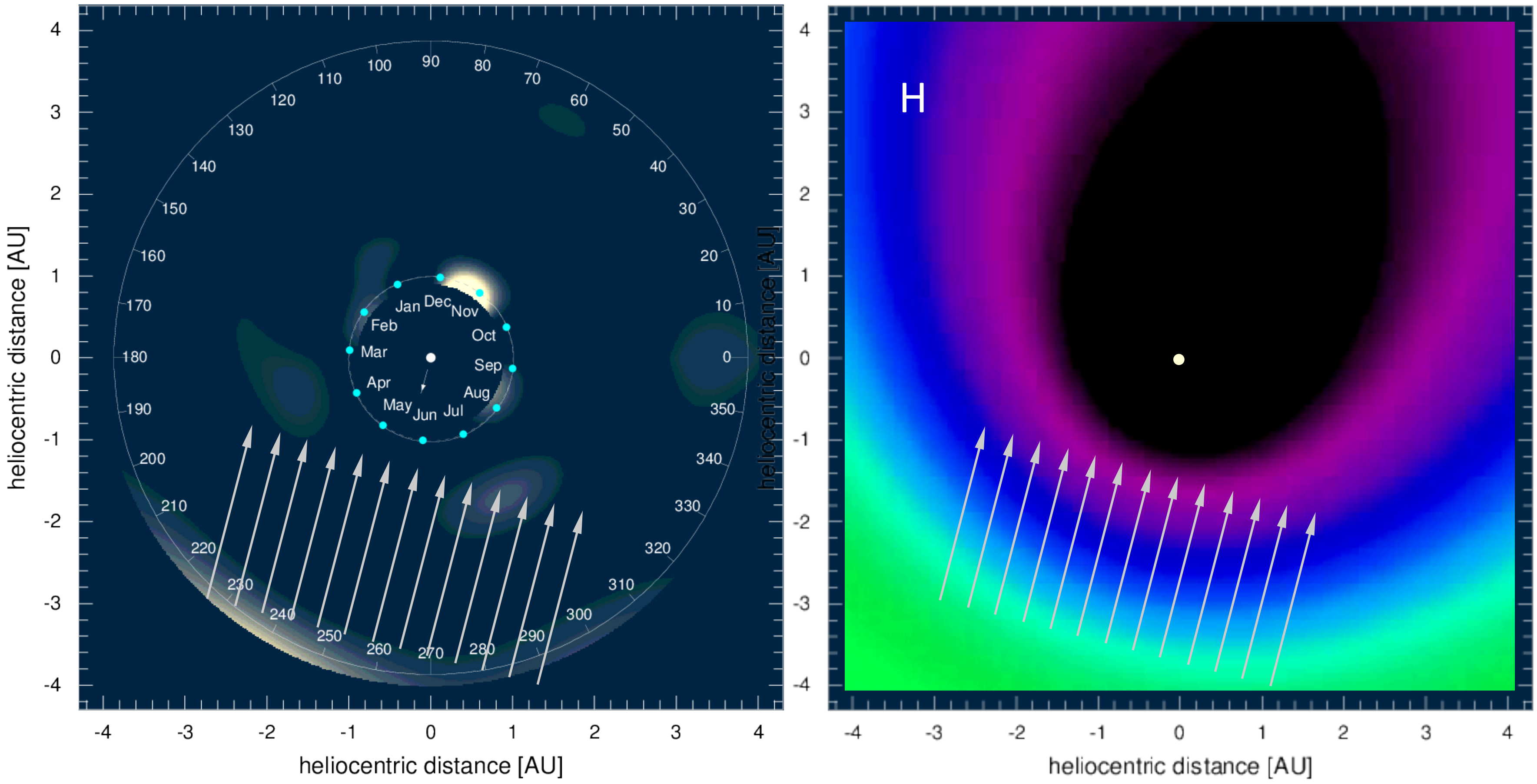
Ringuette et al. 2021





Distribution of local interstellar Hydrogen

Ringuette et al. 2021



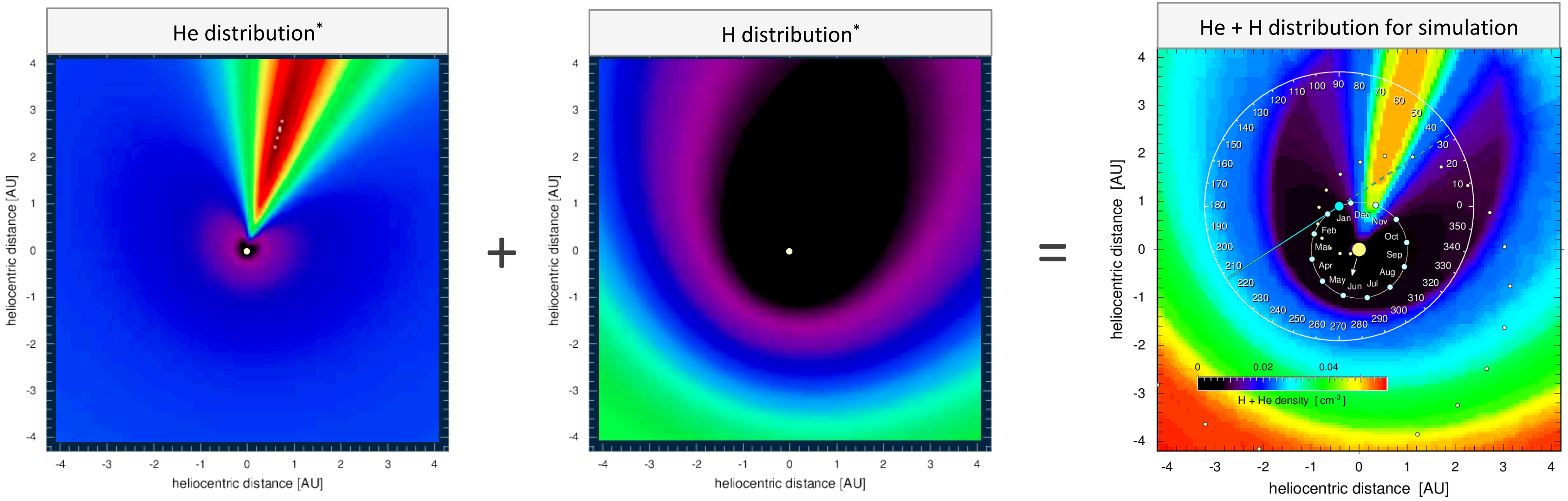
Simulating heliospheric X-ray emission for 2020 – 2021 (eRASS 3 & eRASS 4)

Caveats:

- Local Interstellar Medium (H + He):
  distribution assumed to be valid for 2020-2021

- Solar Wind
  - almost no data on solar wind ions available for eRASS 3
    - **proton density and velocity taken as a rough(!) proxy**
  - only measurements from one location (SOHO) used
    - persistent solar wind flow for one solar rotation assumed
    - ecliptic plane used as symmetry plane (7.25° tilt of solar rotation axis neglected)
    - latitudinal dependence only estimated ($\cos^6 b$)

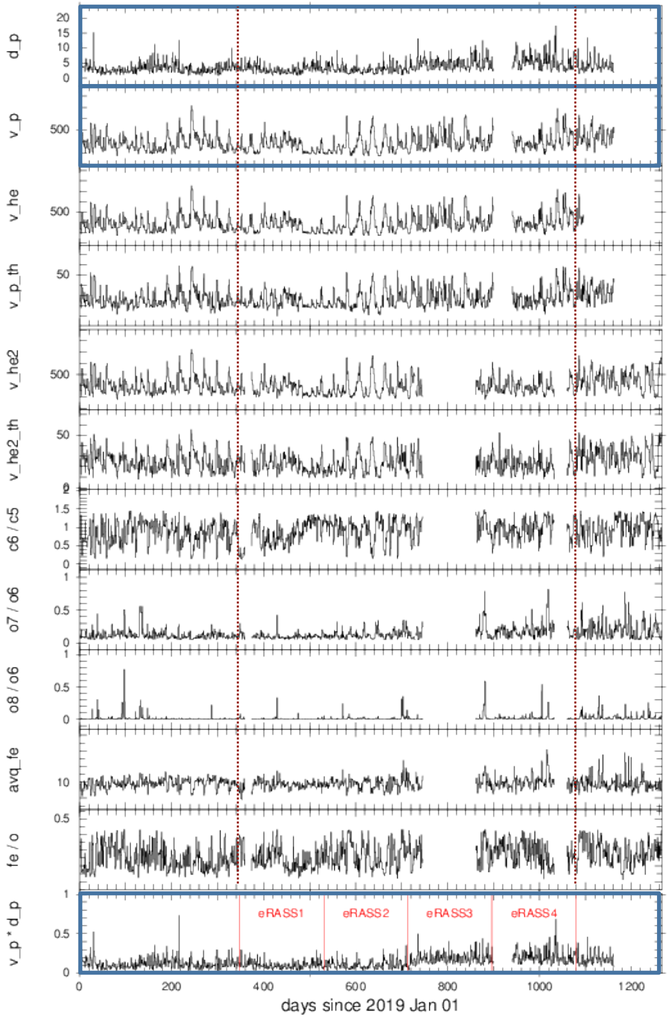
Distribution of interstellar He and H



*Ringuette et al. 2021

distribution changes with solar activity (not considered in the simulation)

symmetry line tilted by -5.6° to ecliptic plane (considered in the simulation)



proton density [cm^{-3}]

proton velocity [$km\ s^{-1}$]

He velocity [$km\ s^{-1}$]

proton thermal velocity [$km\ s^{-1}$]

He^{++} velocity [$km\ s^{-1}$]

He^{++} thermal velocity [$km\ s^{-1}$]

C^{6+}/C^{5+} charge state ratio

O^{7+}/O^{6+} charge state ratio

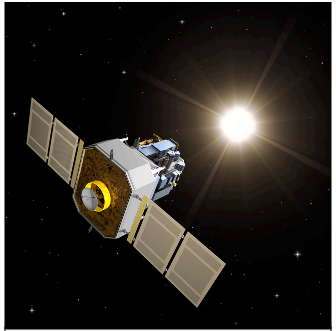
O^{8+}/O^{6+} charge state ratio

$Fe^{(6\text{-}10)}$ average charge state

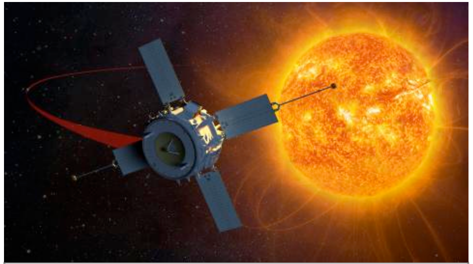
Fe/O element ratio

p density * velocity [$10^9\ cm^{-2}\ s^{-1}$]

(displayed with 1 day time bins)

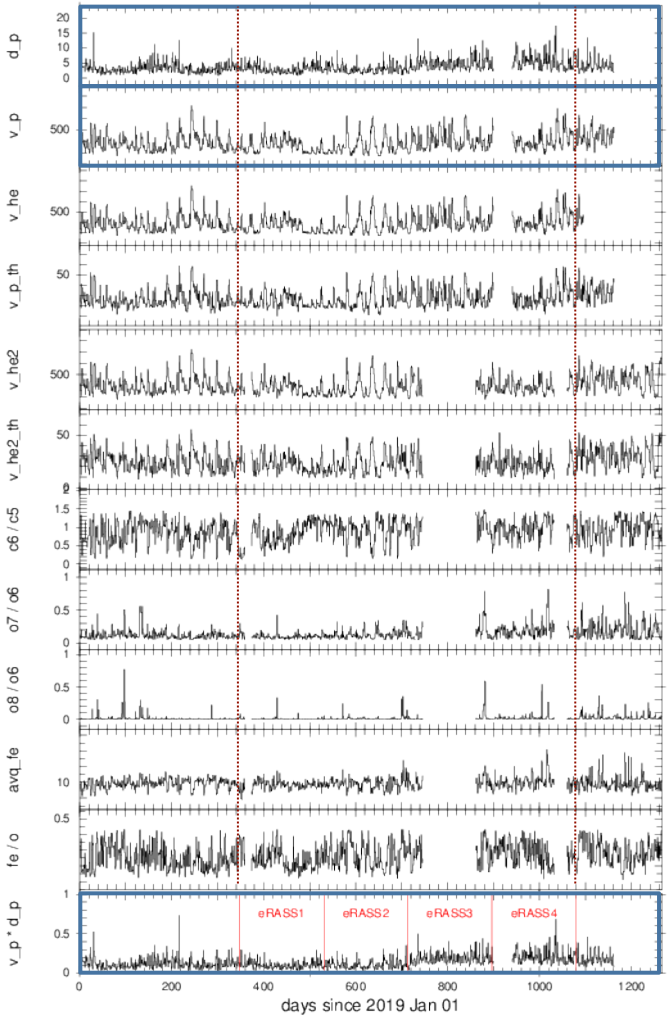


SOHO/CELIAS/MTOF

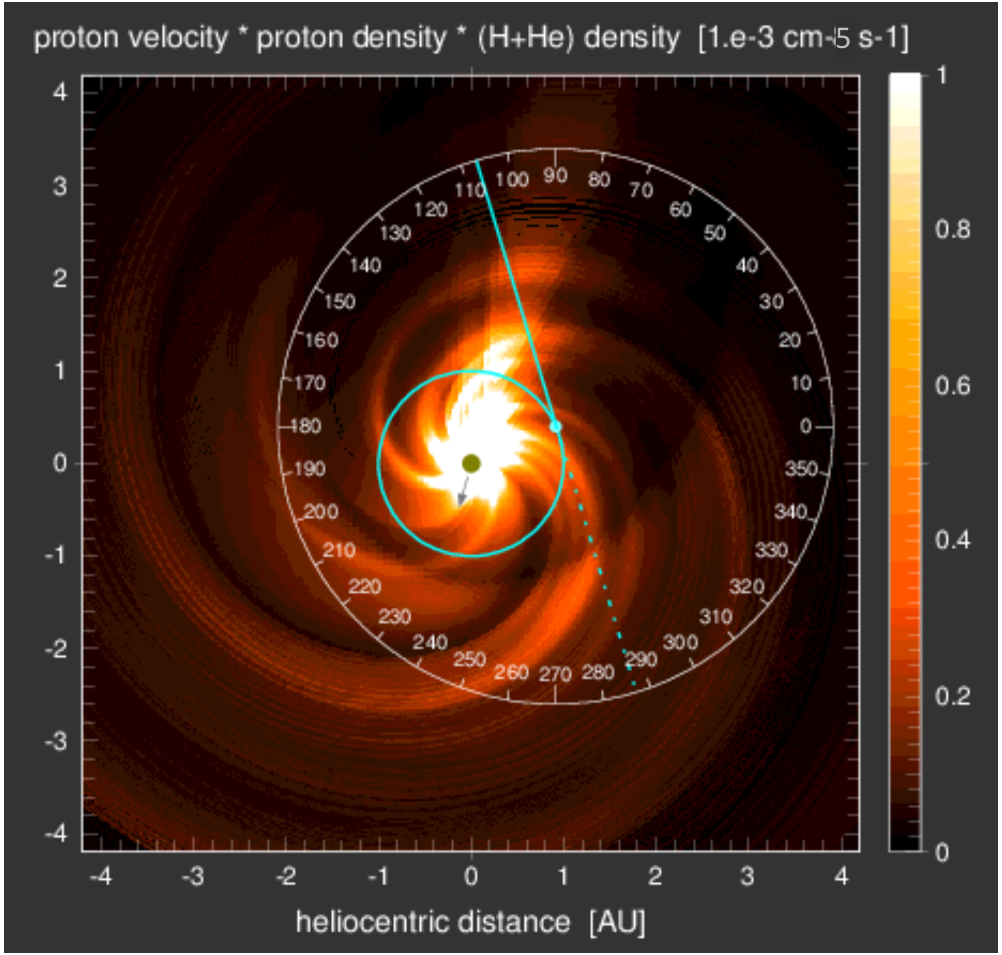


ACE/SWICS/SWIMS

Solar Wind Measurements



d_p
v_p
v_he
v_p_th
v_he2
v_he2_th
c6 / c5
o7 / o6
o8 / o6
avq_fe
fe / o
v_p * d_p
eRASS1
eRASS2
eRASS3
eRASS4
days since 2019 Jan 01

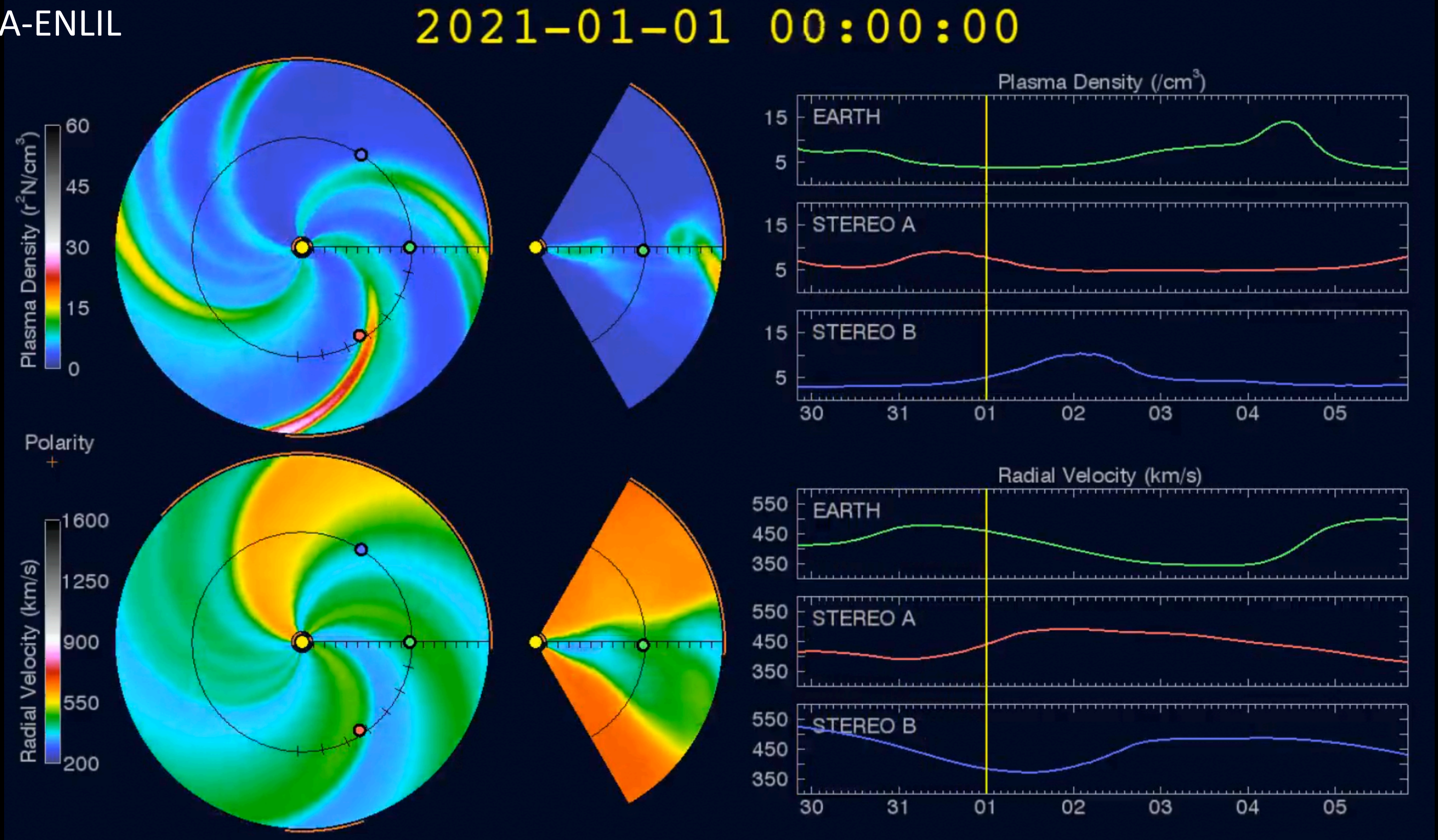


proton velocity * proton density * (H+He) density [1.e-3 cm-5 s-1]
heliocentric distance [AU]

WSA-ENLIL SOLAR WIND PREDICTION

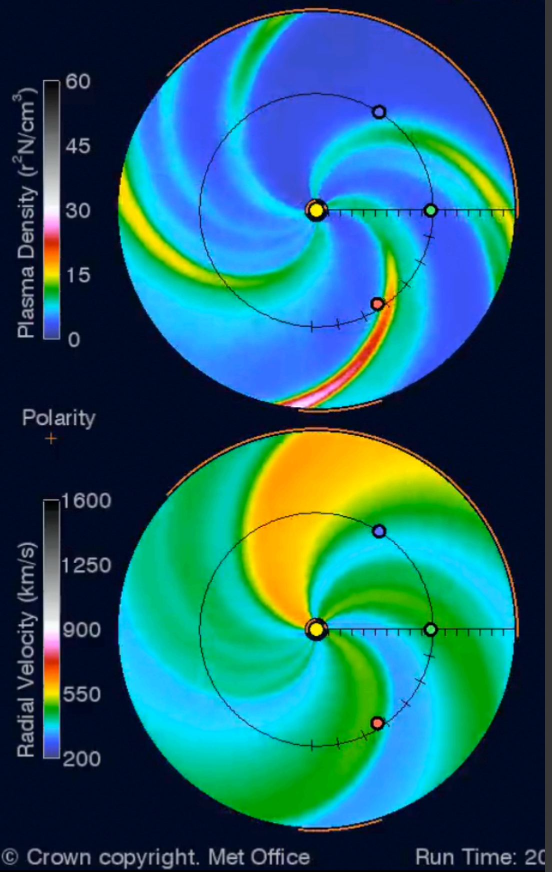
The modeling system consists of two main parts: 1) a semi-empirical near-Sun module that approximates the outflow at the base of the solar wind; and 2) a sophisticated 3-D magnetohydrodynamic numerical model that simulates the resulting flow evolution out to Earth. The former module is driven by observations of the solar surface magnetic field, as taken over a solar rotation and composited into a synoptic map; this input is used to drive a parameterized near-Sun expansion of the solar corona, which is subsequently input into the second, interplanetary module to compute the quasi-steady (ambient) solar wind outflow. Finally, when an Earth-directed CME is detected, coronagraph images from NASA spacecraft are used to characterize the basic properties of the CME, including timing, location, direction, and speed. This input (the "cone" model) is injected into the pre-existing ambient conditions, and the subsequent transient evolution forms the basis for the prediction of the CME arrival time at Earth, its intensity, and its duration.

WSA-ENLIL

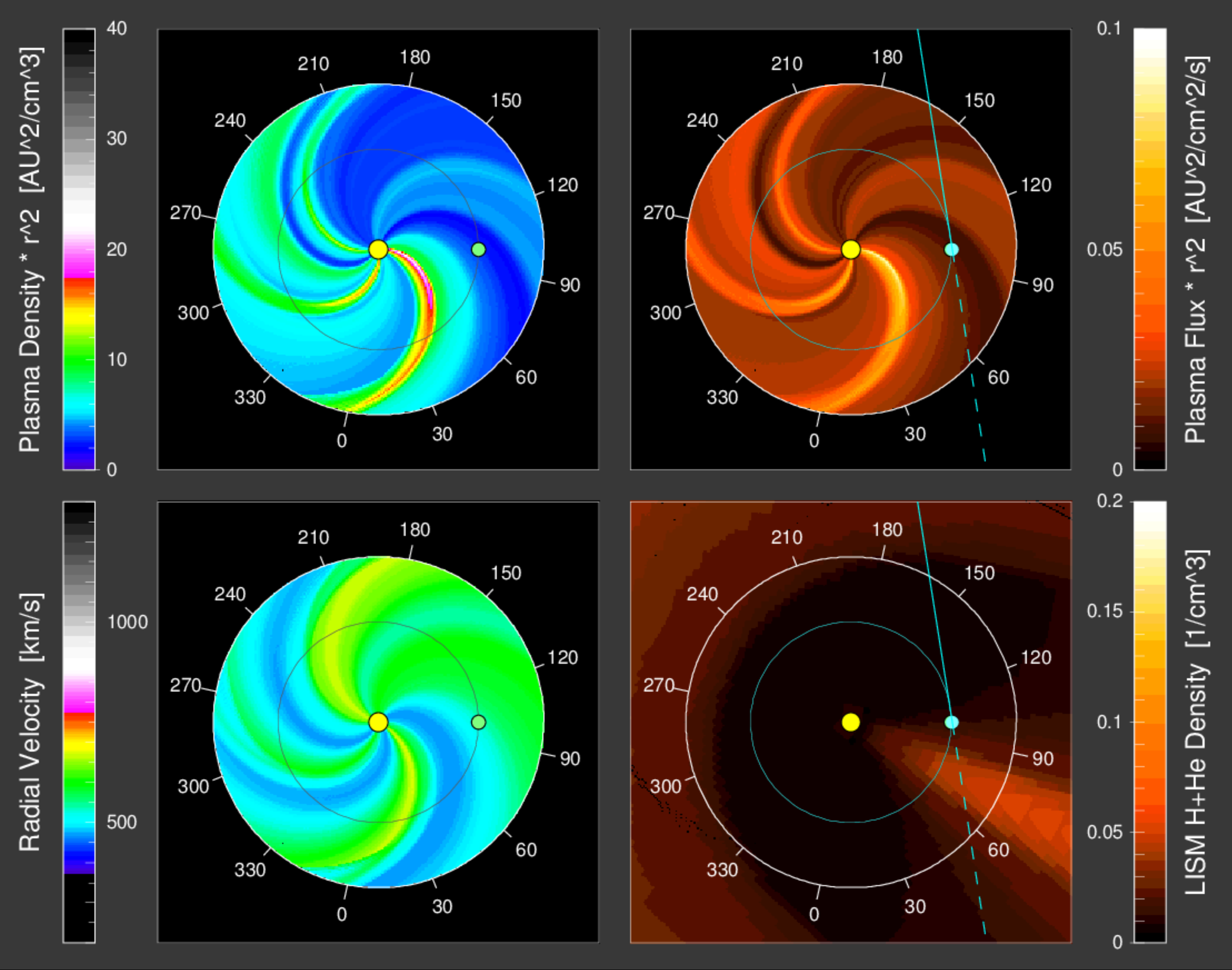


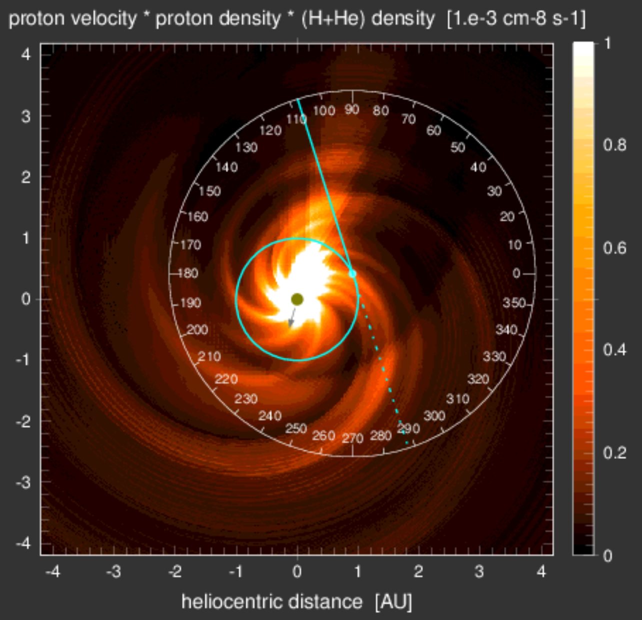
Run Time: 2020-12-31 20:00 UT Mode: CME
Image Created: 2020-12-31 23:55 UT

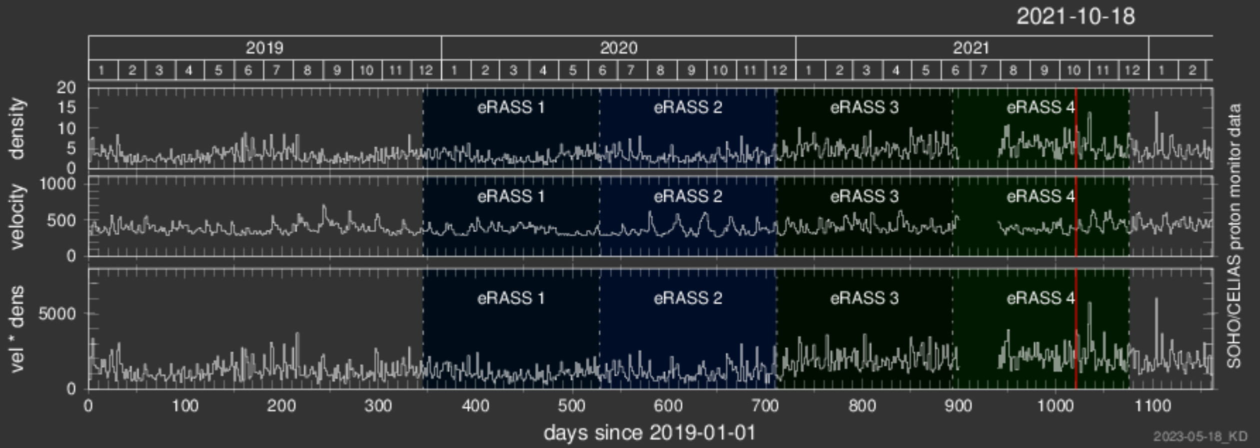
WSA-ENLIL

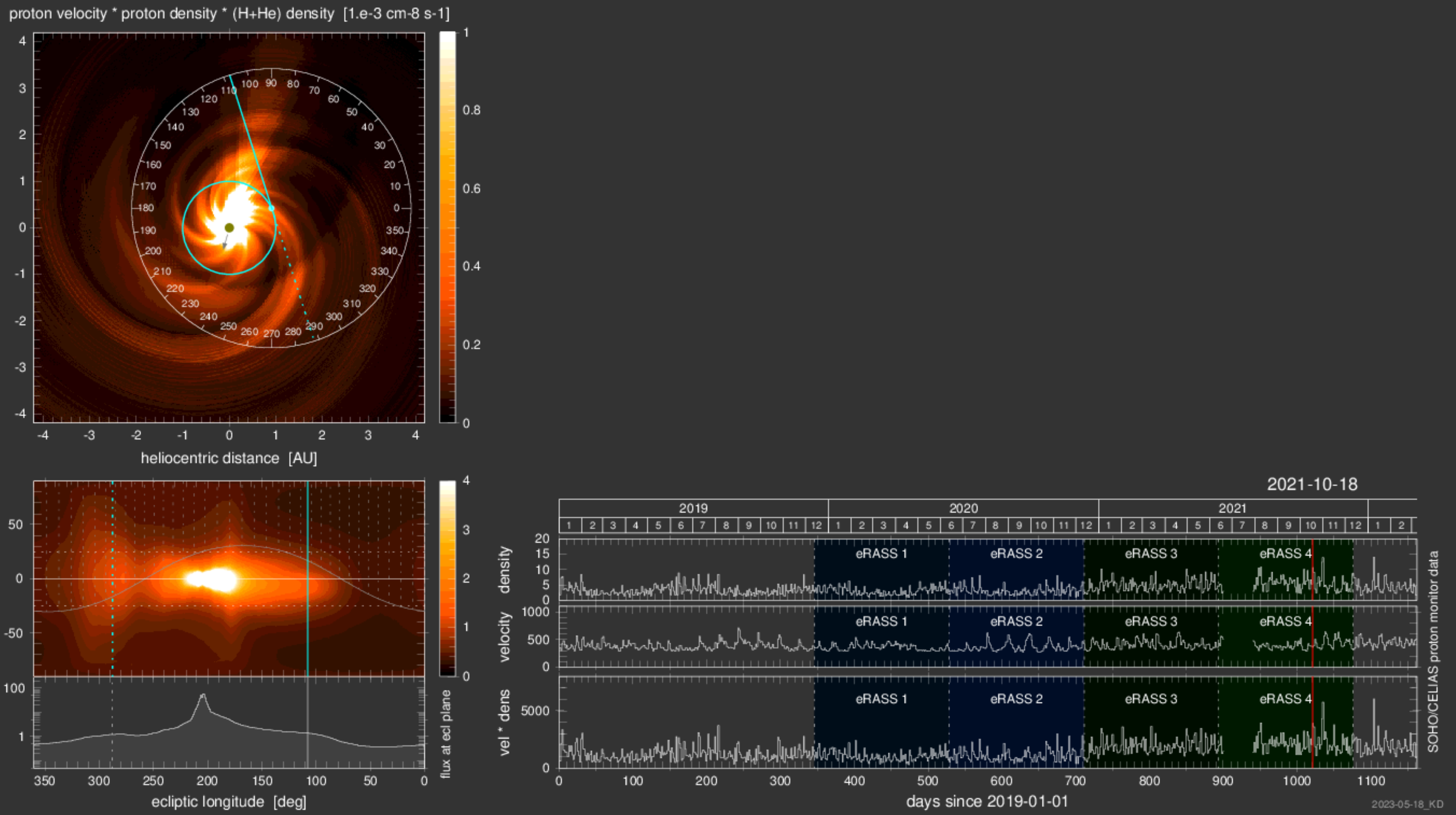


own calculations

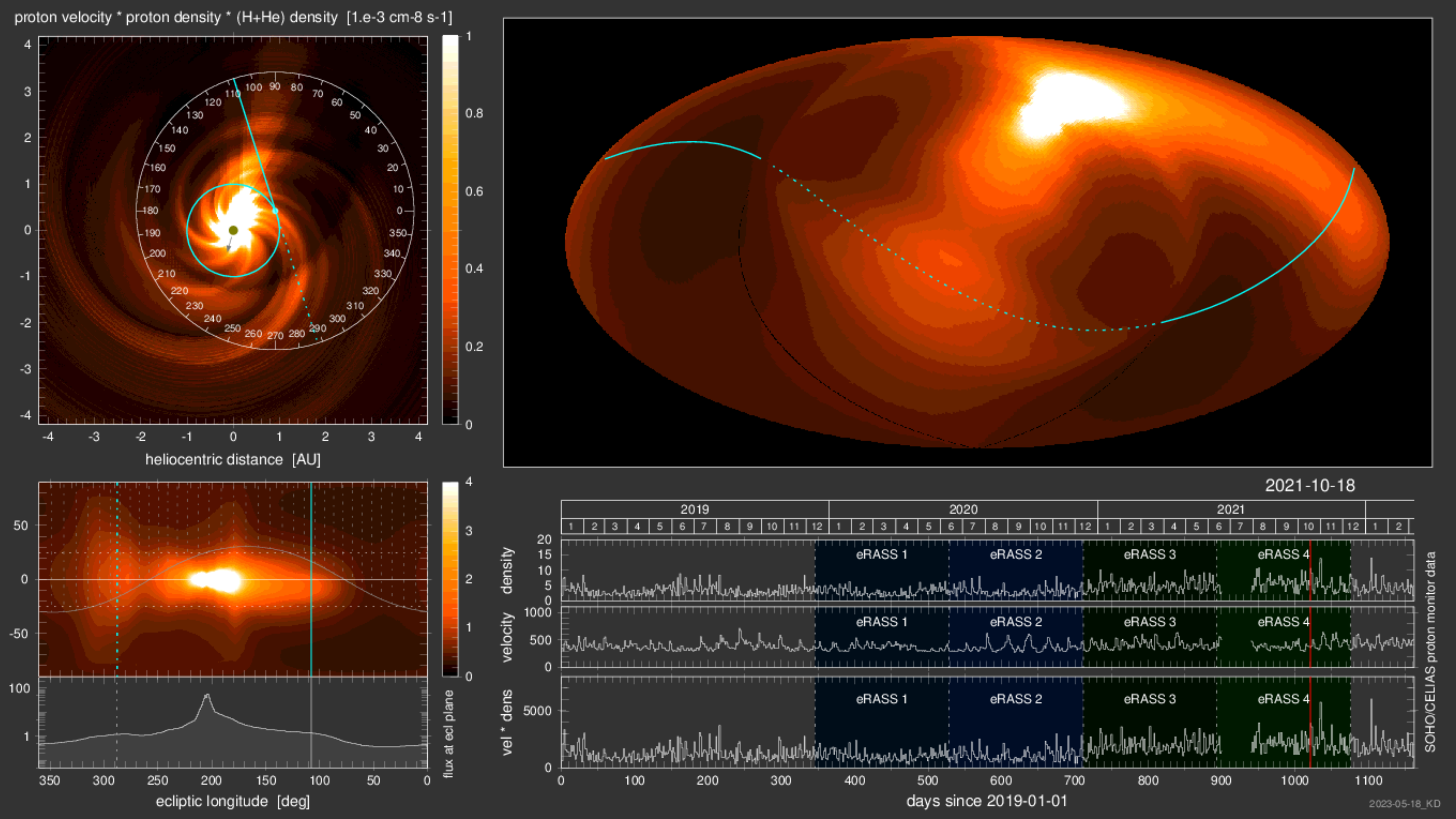



proton velocity * proton density * (H+He) density [1.e-3 cm-8 s-1]
heliocentric distance [AU]

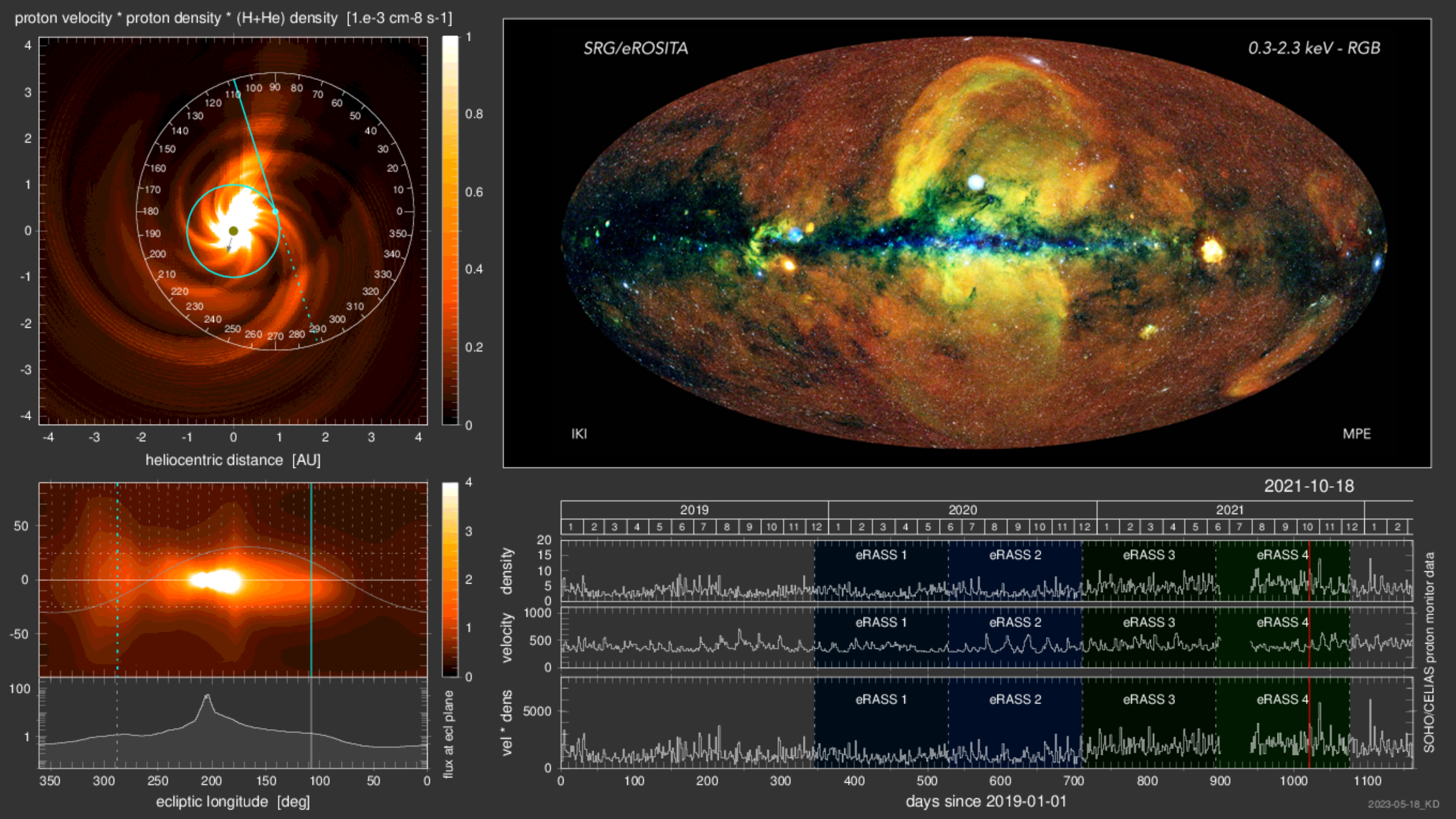

2021-10-18
2019
2020
2021
density
velocity
vel * dens
eRASS 1
eRASS 2
eRASS 3
eRASS 4
days since 2019-01-01
SOHO/CELIAS proton monitor data
2023-05-18_KD

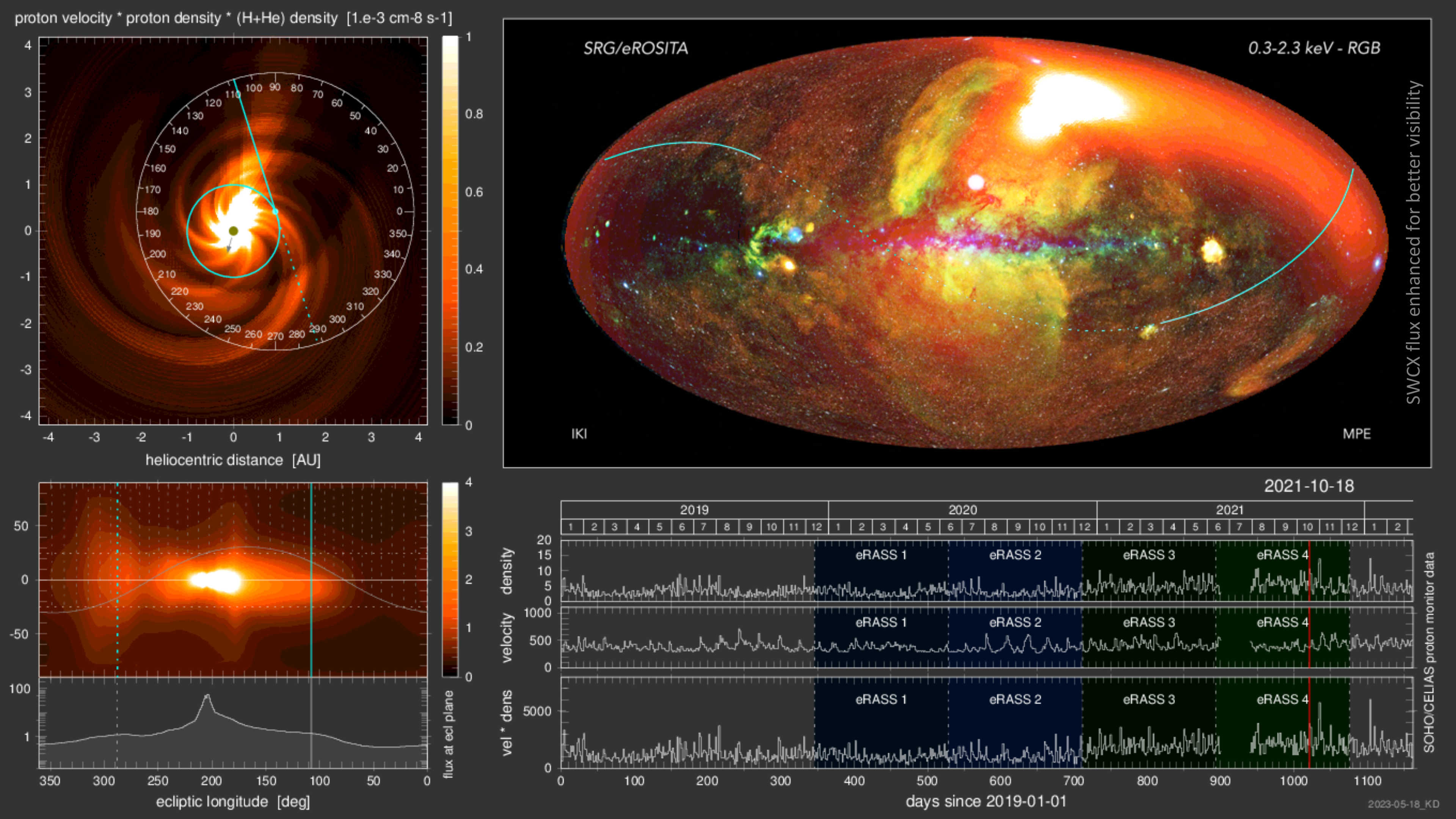


proton velocity * proton density * (H+He) density [1.e-3 cm-8 s-1]
heliocentric distance [AU]
ecliptic longitude [deg]
flux at ecl plane
2021-10-18
2019
2020
2021
density
velocity
vel * dens
eRASS 1
eRASS 2
eRASS 3
eRASS 4
days since 2019-01-01
SOHO/CELIAS proton monitor data
2023-05-18_KD



proton velocity * proton density * (H+He) density [1.e-3 cm-8 s-1]
heliocentric distance [AU]
2021-10-18
2019
2020
2021
density
velocity
vel * dens
eRASS 1
eRASS 2
eRASS 3
eRASS 4
SOHO/CELIAS proton monitor data
days since 2019-01-01
ecliptic longitude [deg]
flux at ecl plane
2023-05-18_KD


proton velocity * proton density * (H+He) density [1.e-3 cm-8 s-1]
heliocentric distance [AU]
SRG/eROSITA
0.3-2.3 keV - RGB
IKI
MPE
2021-10-18
2019
2020
2021
eRASS 1
eRASS 2
eRASS 3
eRASS 4
density
velocity
vel * dens
SOHO/CELIAS proton monitor data
days since 2019-01-01
flux at ecl plane
ecliptic longitude [deg]
2023-05-18_KD


proton velocity * proton density * (H+He) density [1.e-3 cm-8 s-1]
heliocentric distance [AU]
SRG/eROSITA
0.3-2.3 keV - RGB
SWCX flux enhanced for better visibility
IKI
MPE
flux at ecl plane
ecliptic longitude [deg]
2021-10-18
2019
2020
2021
eRASS 1
eRASS 2
eRASS 3
eRASS 4
density
velocity
vel * dens
SOHO/CELIAS proton monitor data
days since 2019-01-01
2023-05-18_KD