Analysis of Synthetic Flux Rope in ICME Simulation Using Unpolarized and Polarized White-Light Signal and In-Situ Data

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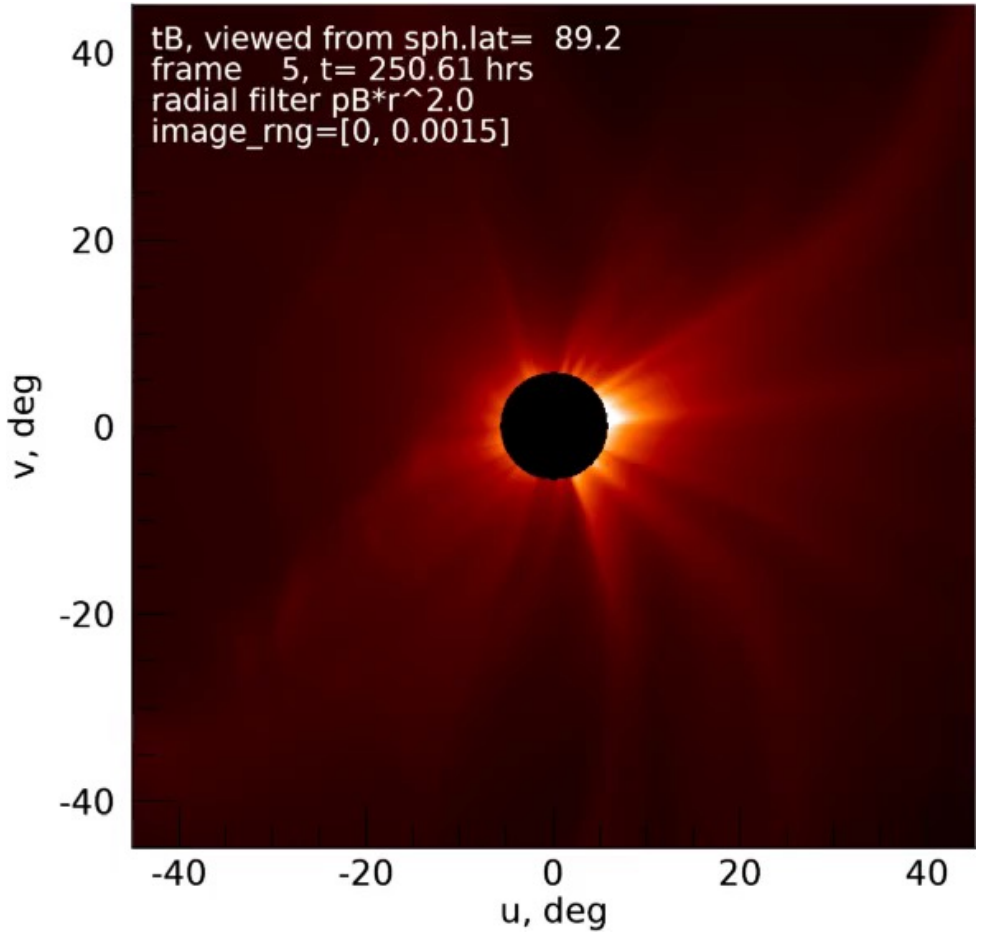
Simulated PUNCH data

GAMERA simulation, PUNCH field of view

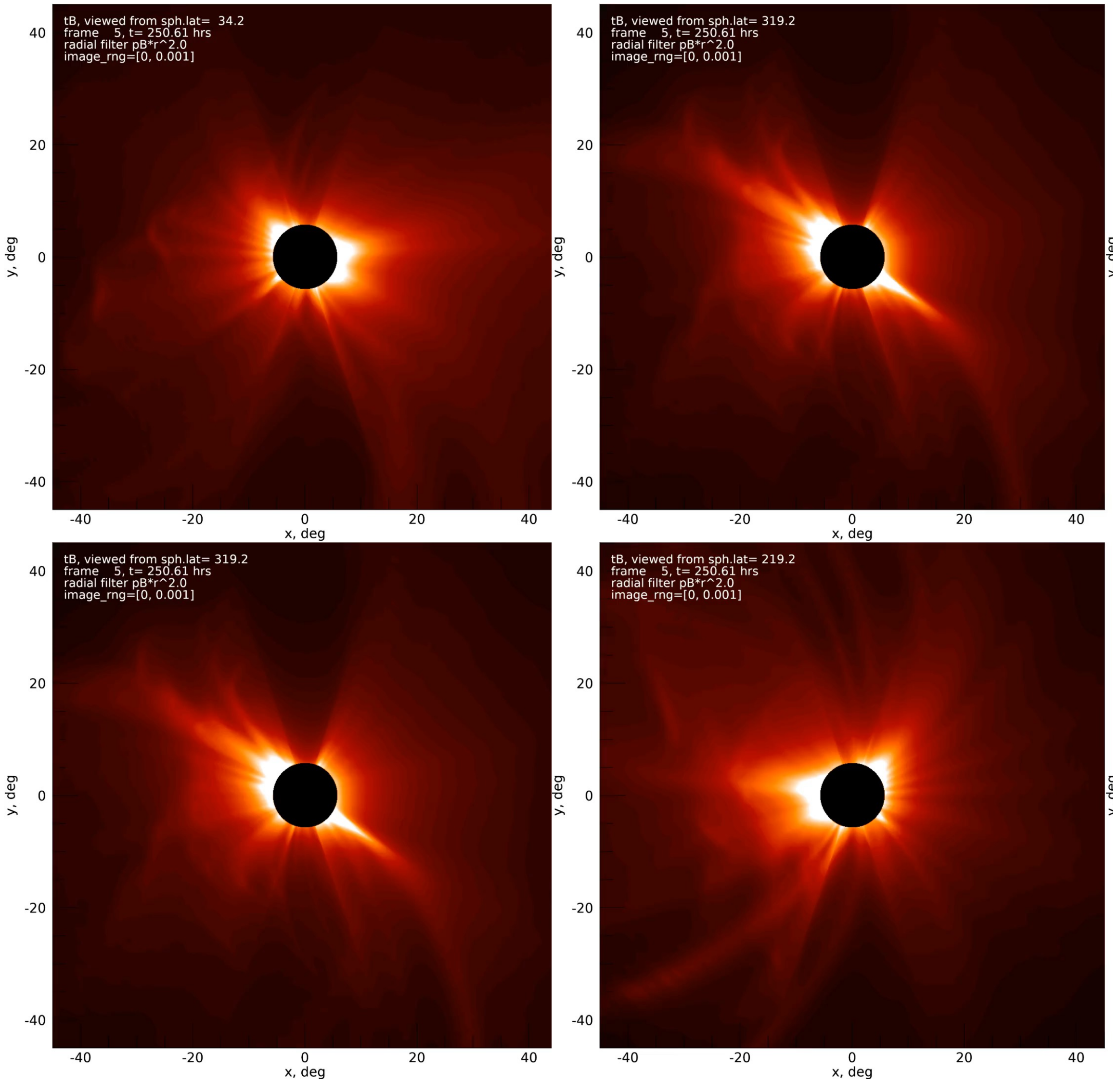


Agenda:

- "CME challenge" v2.0
- Thomson scattering: what we have vs what we want
- Density along the line of sight ("hunters and pheasants")

CME Challenge v2.0

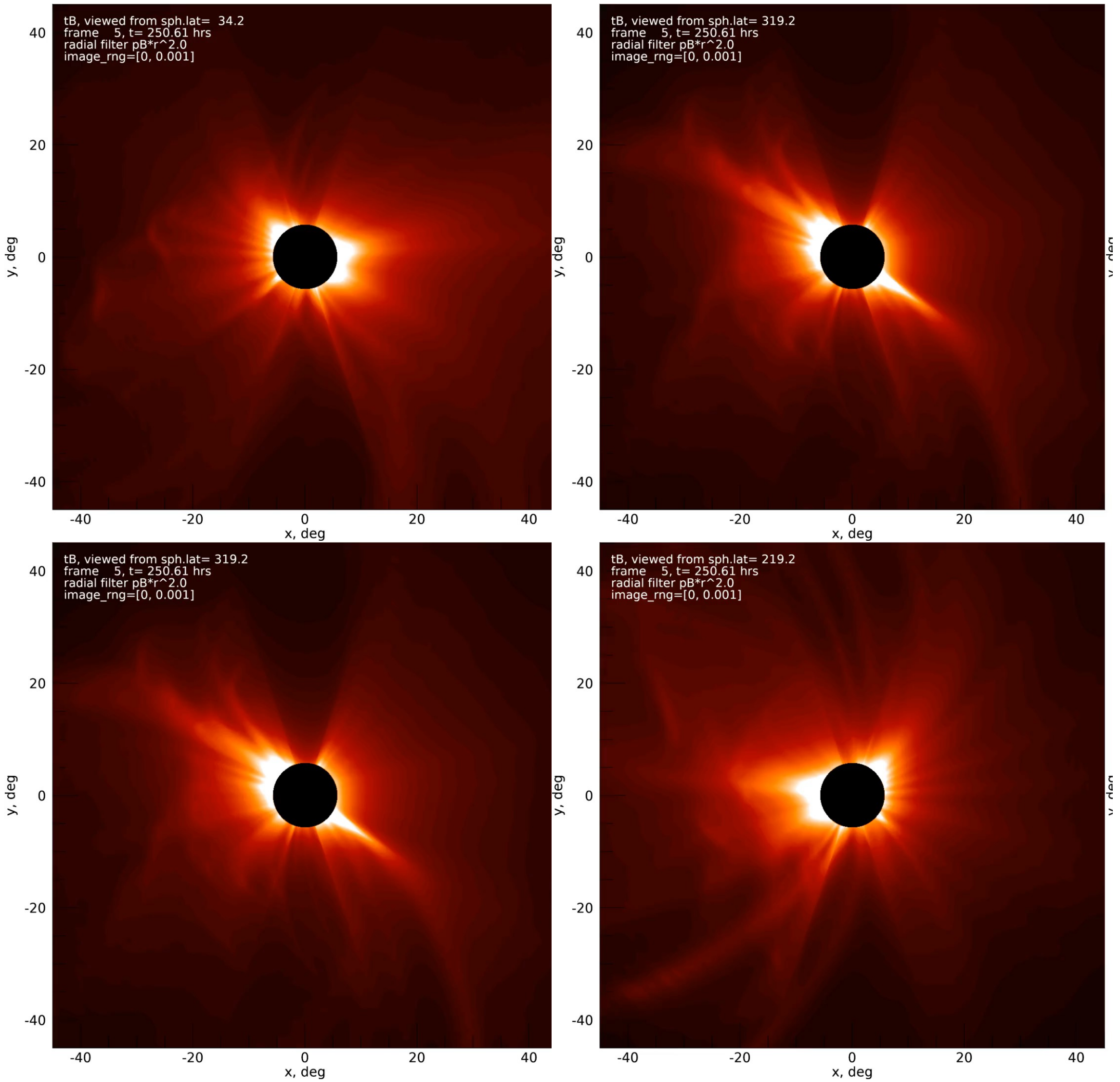
- Open dataset, ready to use!
- Based on GAMERA simulation with WSA background and Gibson&Low flux rope
- Both tB and pB, PUNCH-like field of view and projection



https://download.hao.ucar.edu/pub/punch/cme_challenge_v2/

CME Challenge v2.0

- Four CMEs with different properties
- One CME is reference (open parameters), three for validation (parameters disclosed upon request)



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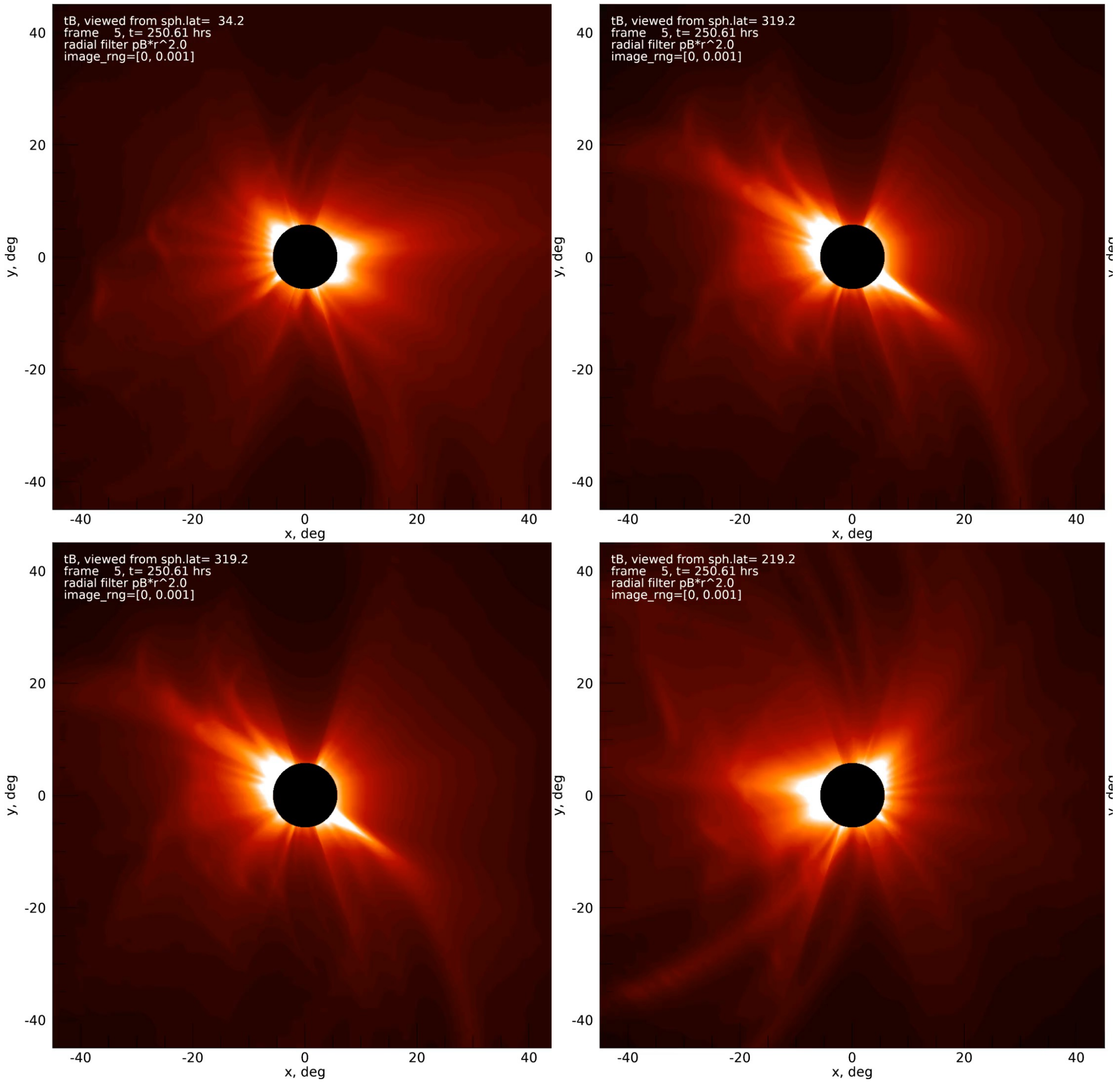
CME Challenge v2.0

- Two types of products:
  - "Challenge": observer at 1AU on solar equator, at 4 different angles w.r.t. the CME
  - "4π" – for one event only, observer at 1AU on 4π orbit



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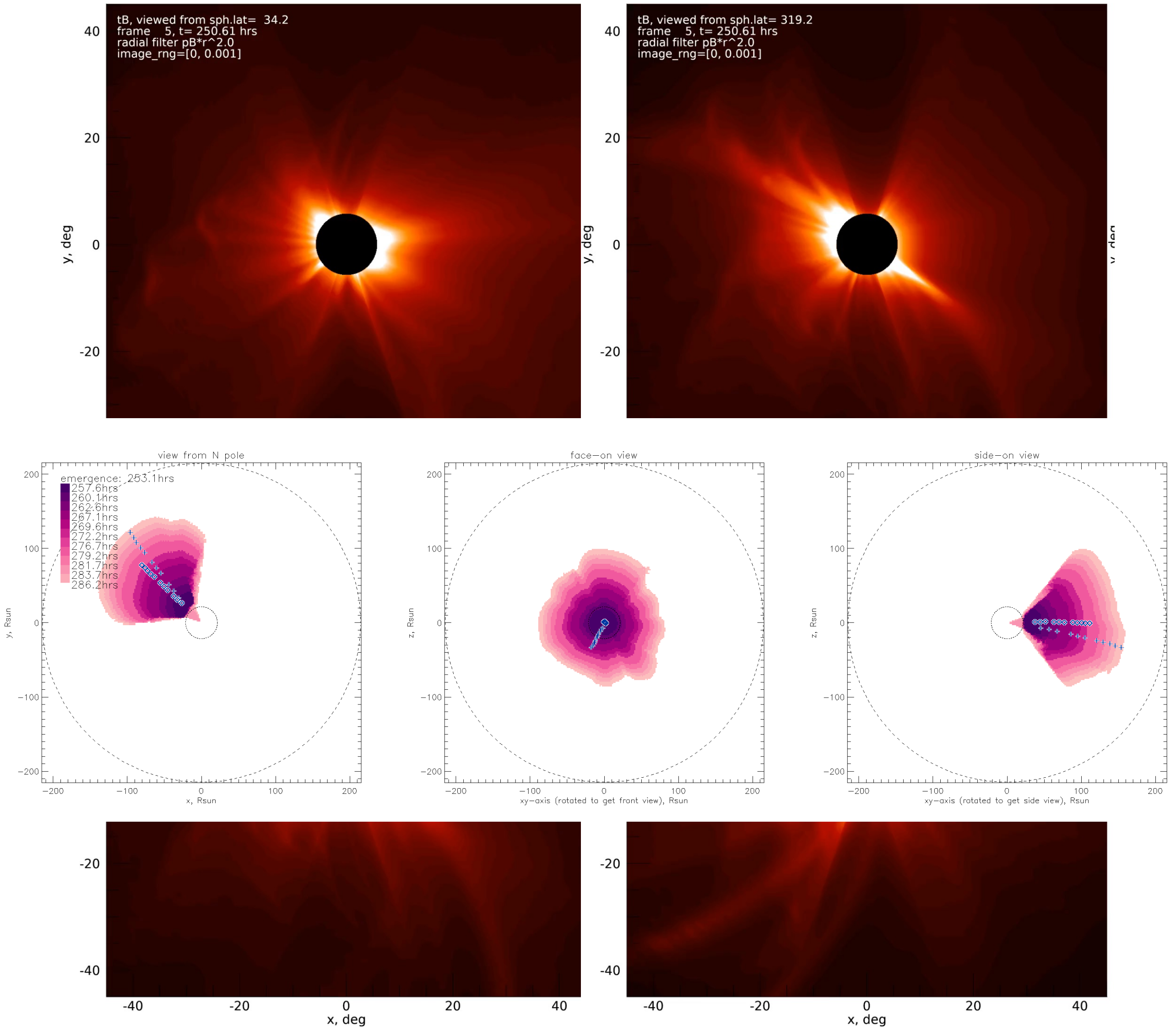
CME Challenge v2.0

- Properties are known:
  - Simulation parameters (e.g., size, launch location, etc)
  - “Ground truth” data: analyzed 3D data, identified CME, properties measured (e.g. deceleration, trajectory, etc)



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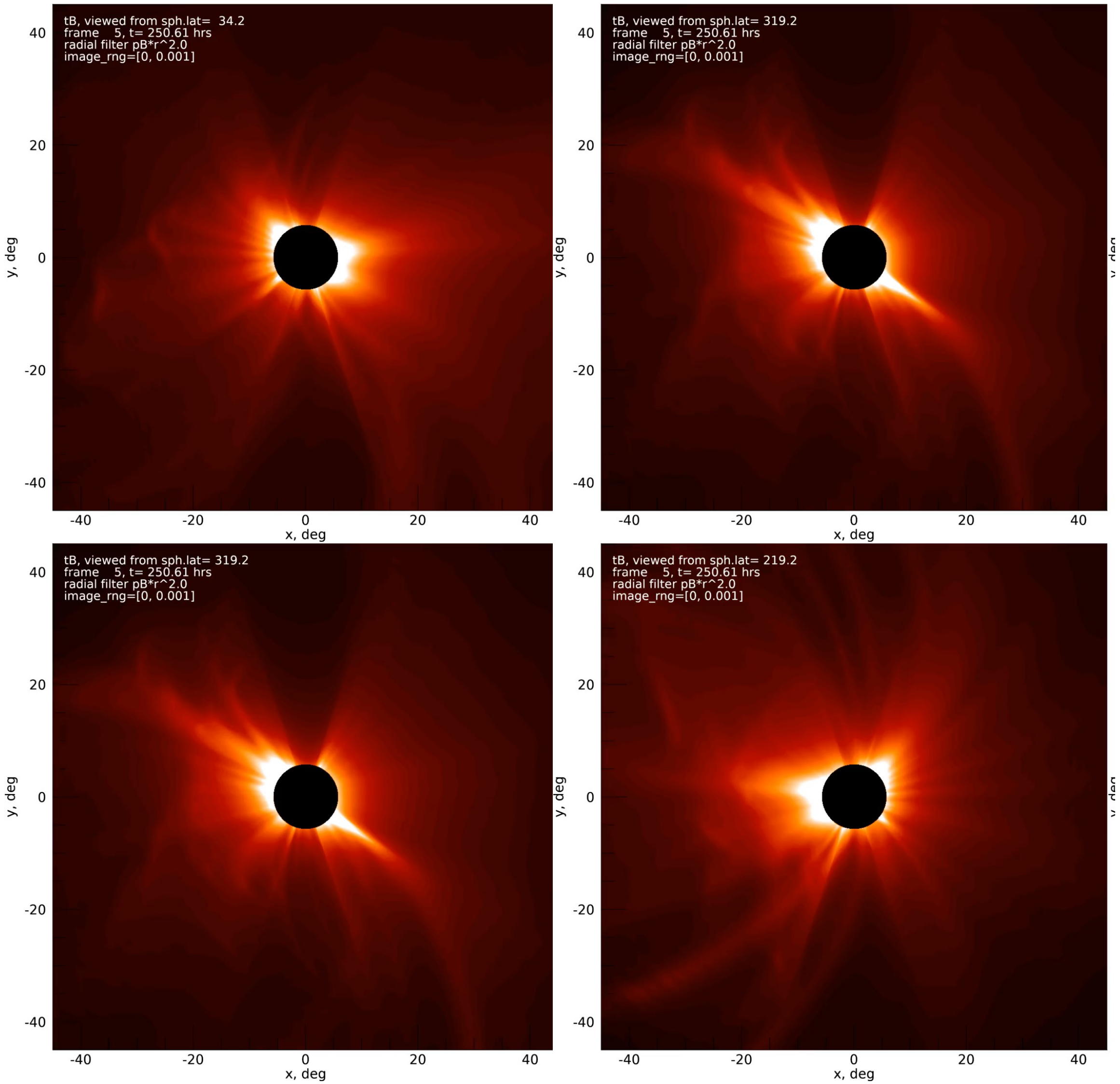
CME Challenge v2.0

- Properties are known:
  - Simulation parameters (e.g., size, launch location, etc)
  - “Ground truth” data: analyzed 3D data, identified CME, properties measured (e.g. deceleration, trajectory, etc)
  - Can calculate other characteristics, e.g., in *situ data*, etc – we have all MHD variables in the volume vs time



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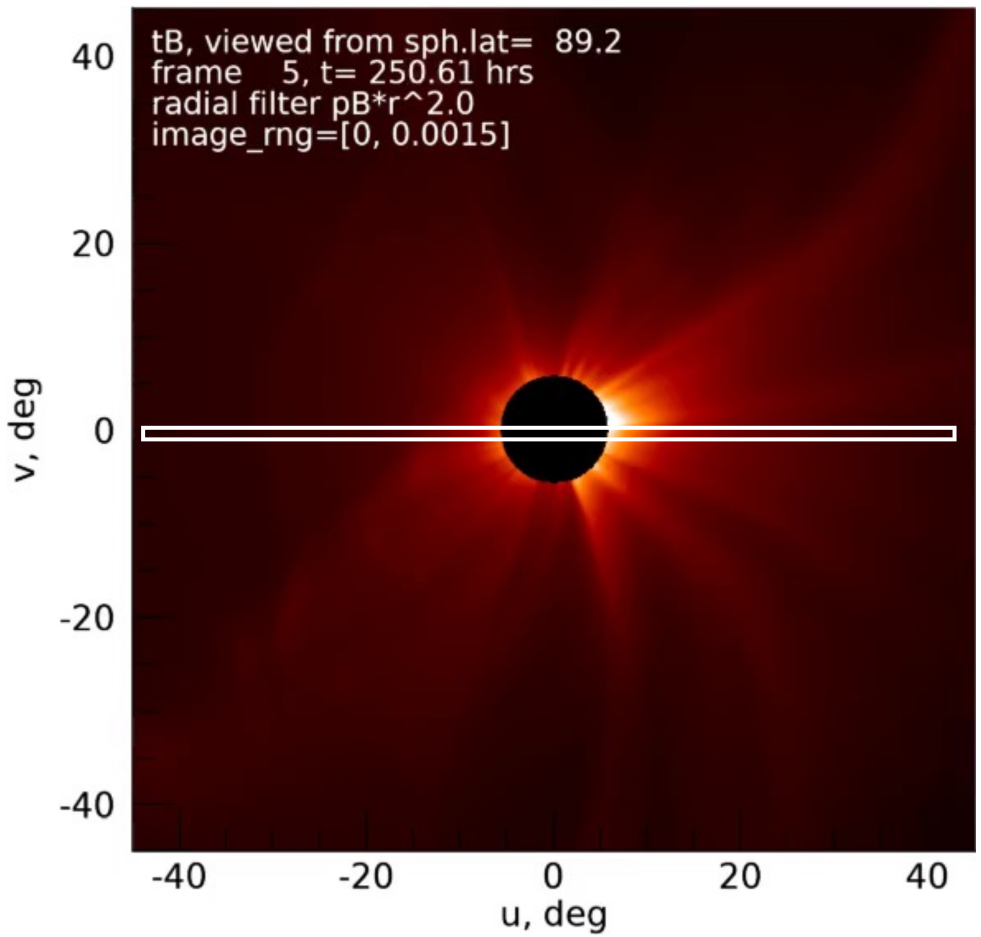
Projections

- PUNCH will have a *very* wide field of view



Projections

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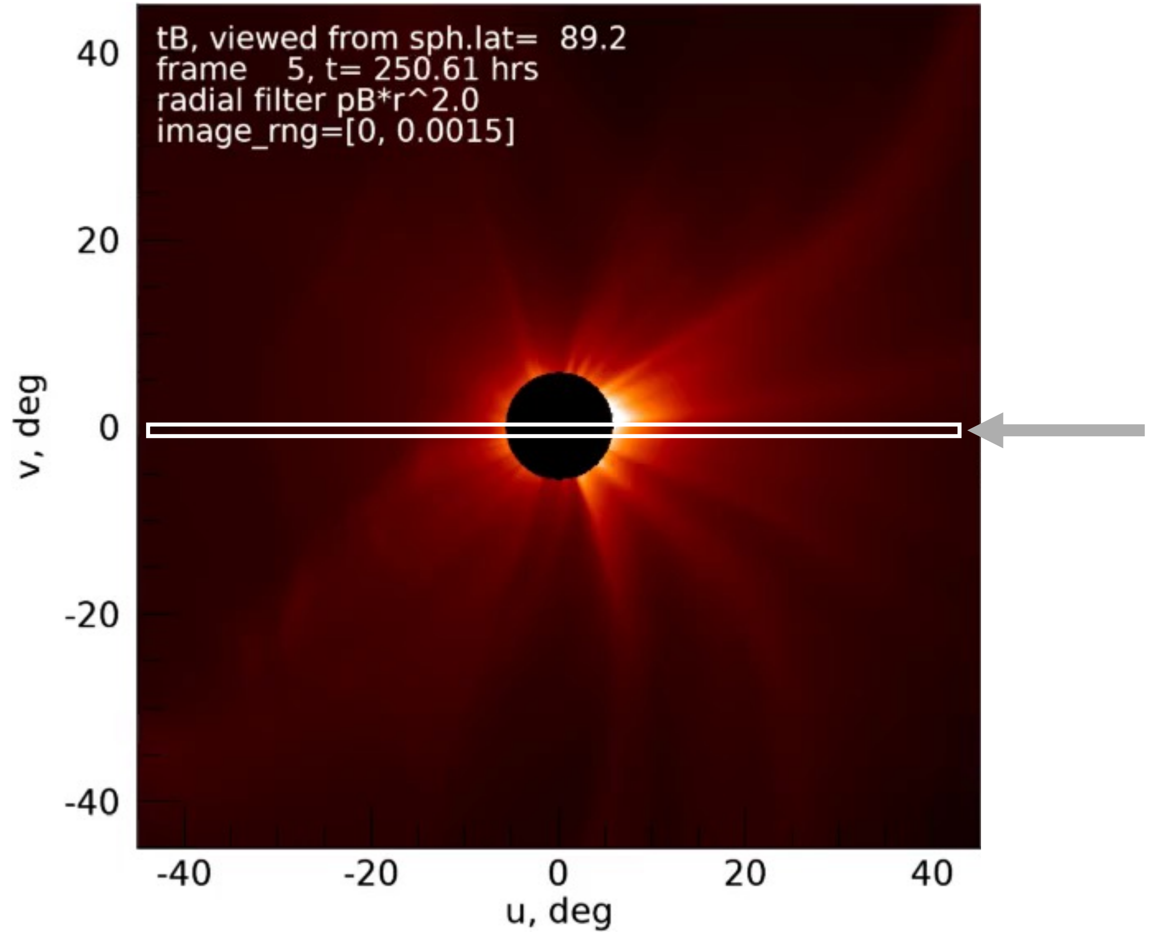
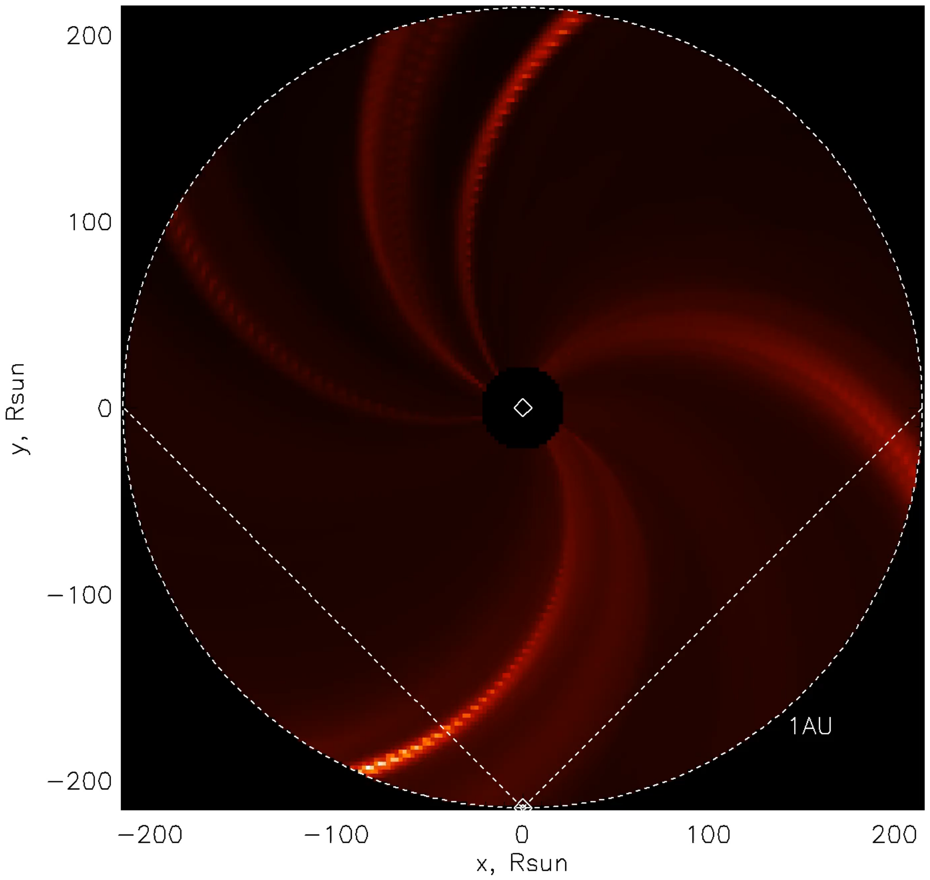
- So, it'll have a somewhat unusual projection (for heliospheric obs.)



density *slice* at equator (vignette: r^2)



Projections: azimuthal equidistant projection

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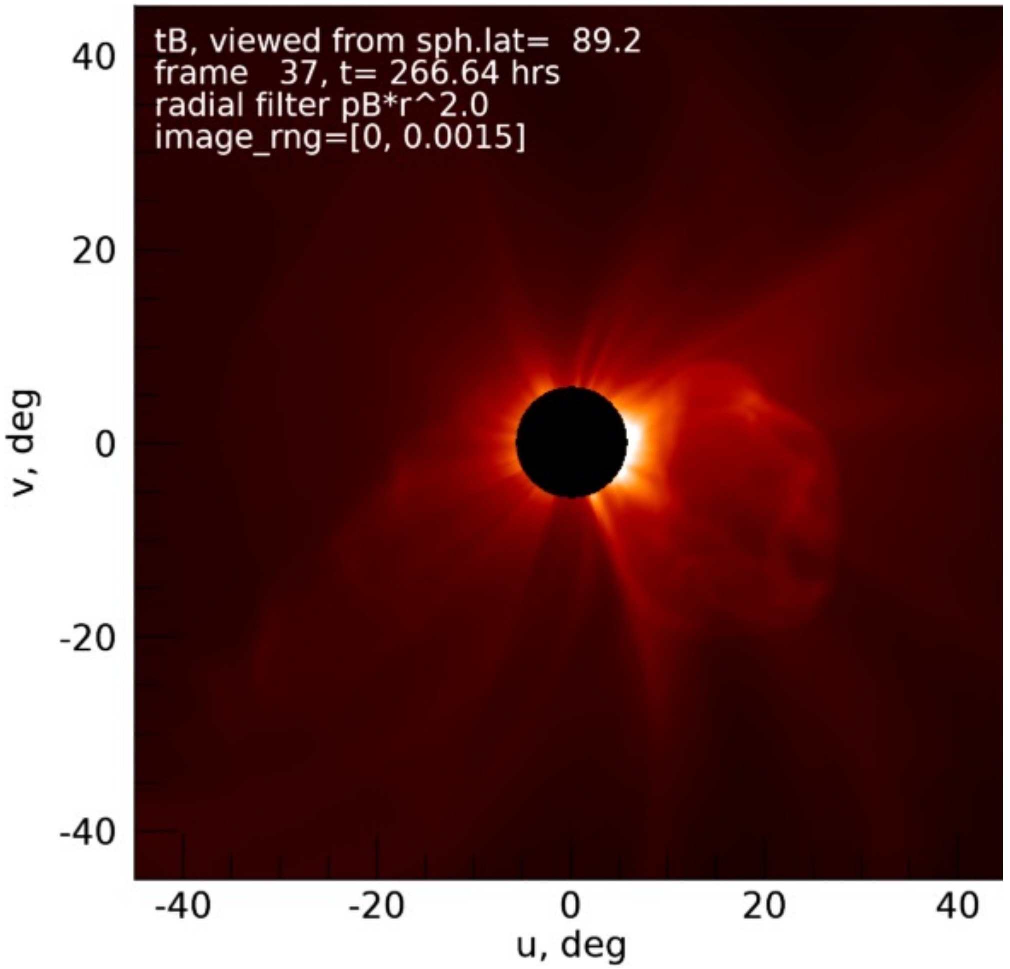

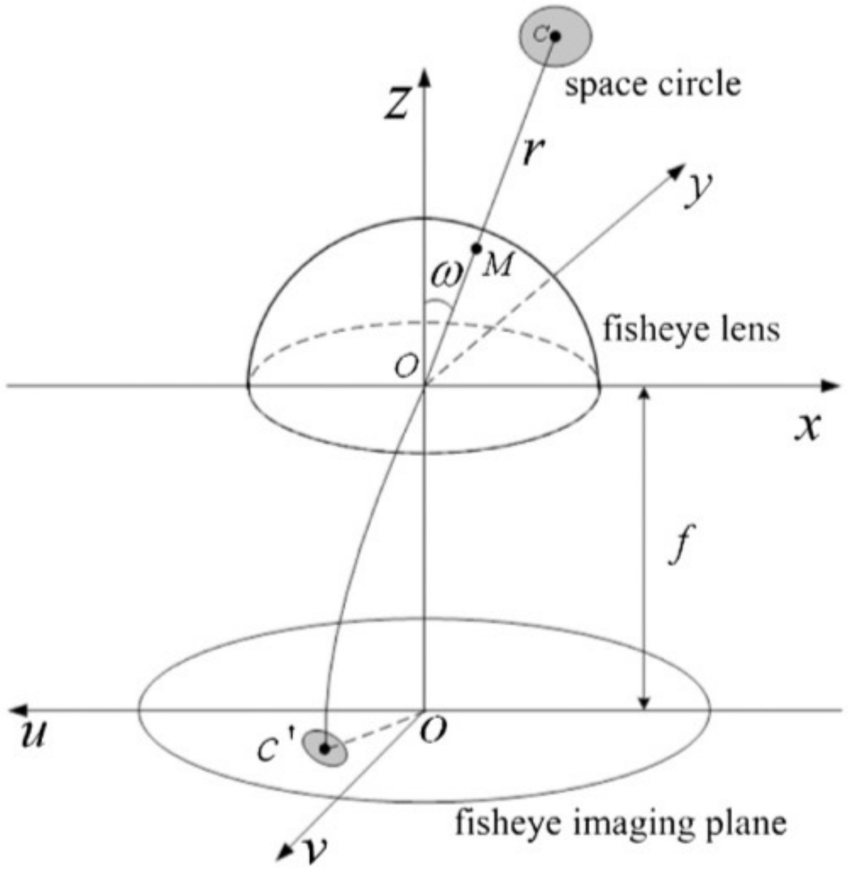

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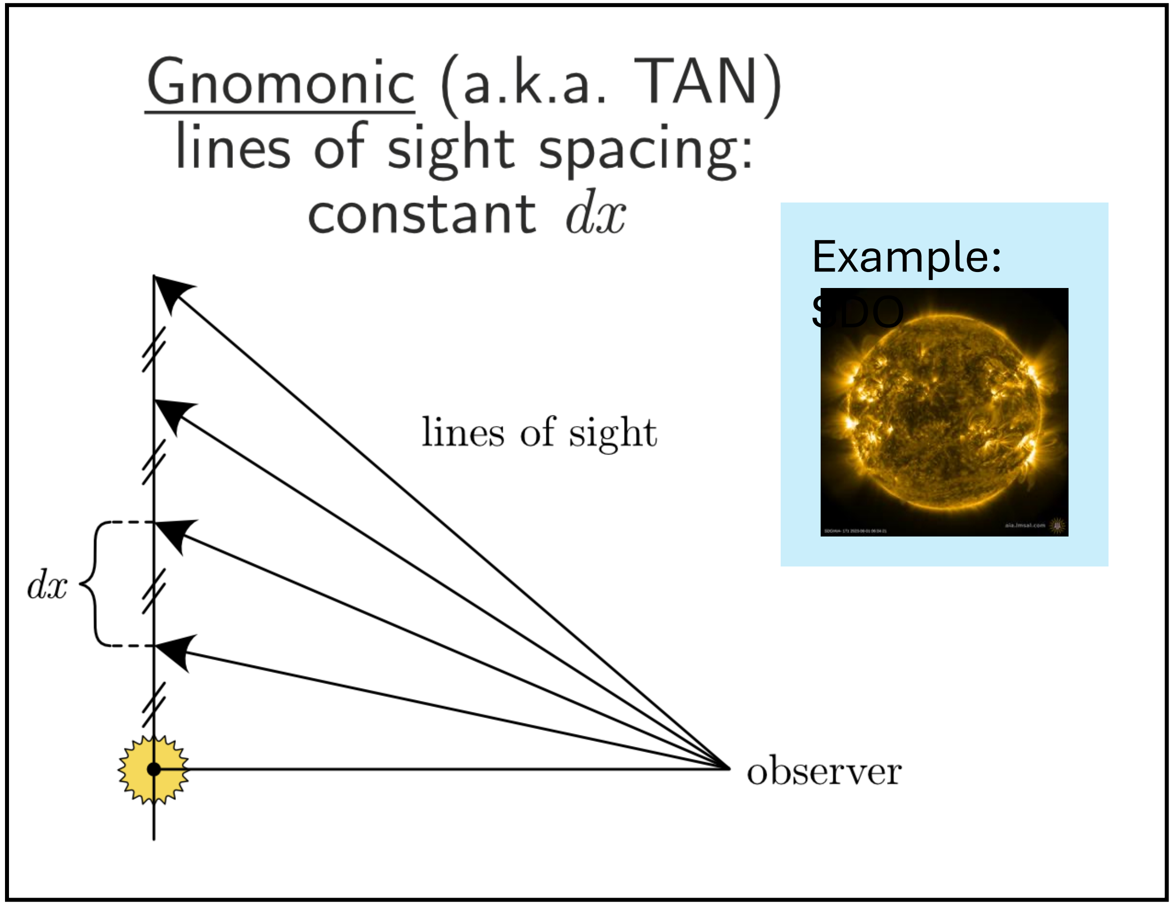
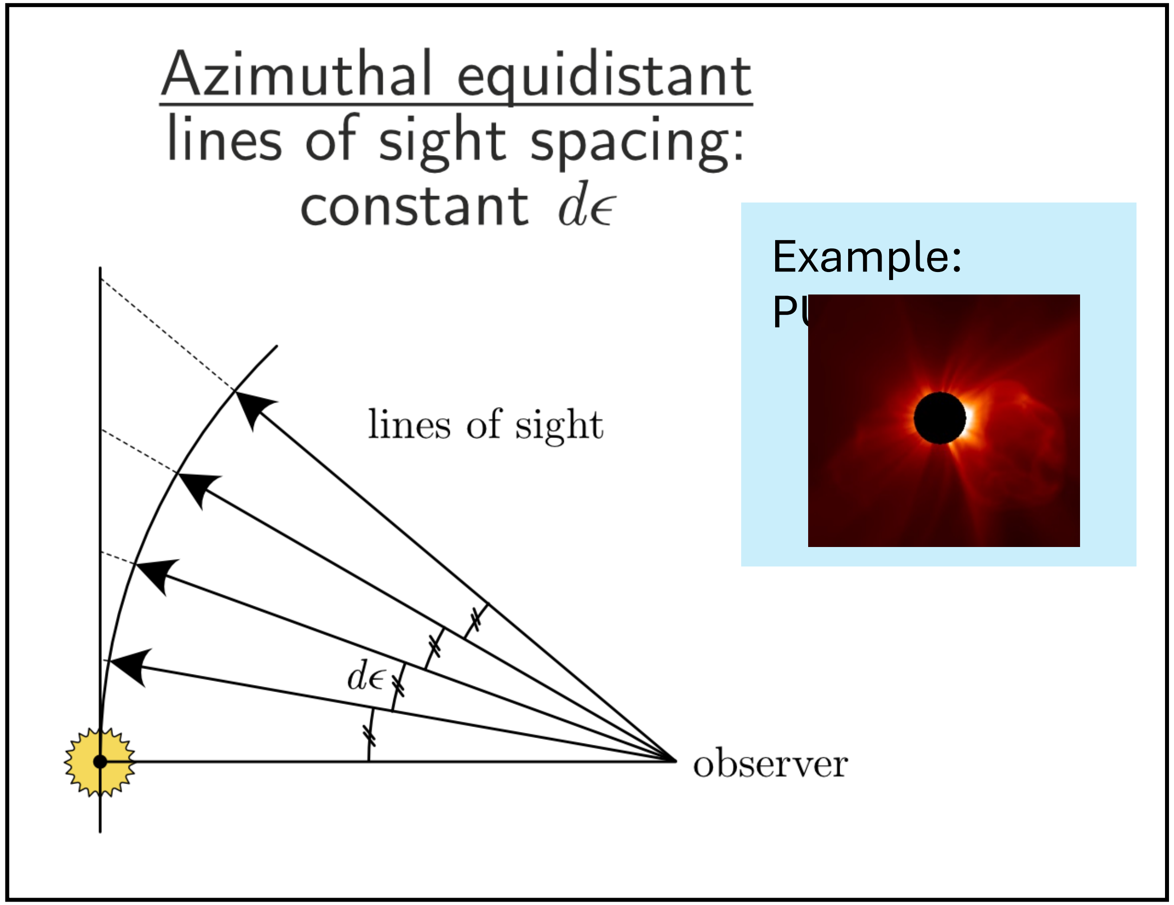
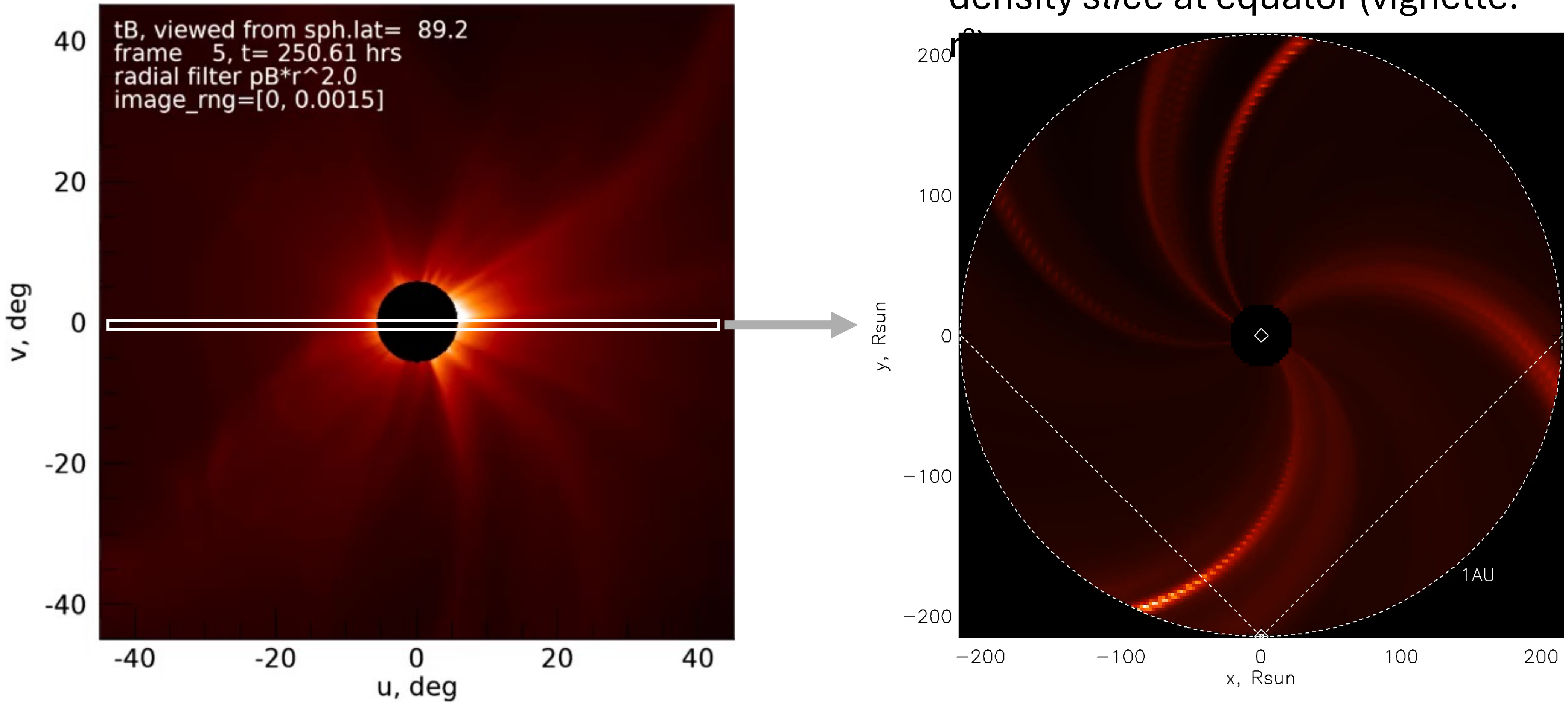




Thomson scattering

- ...so, lines of sight.
  What do we integrate along the lines of sight?

density *slice* at equator (vignette: r^2)



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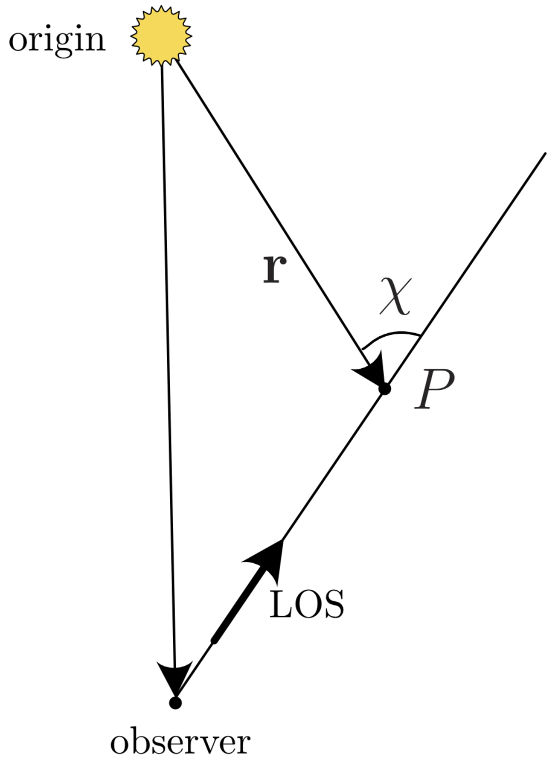

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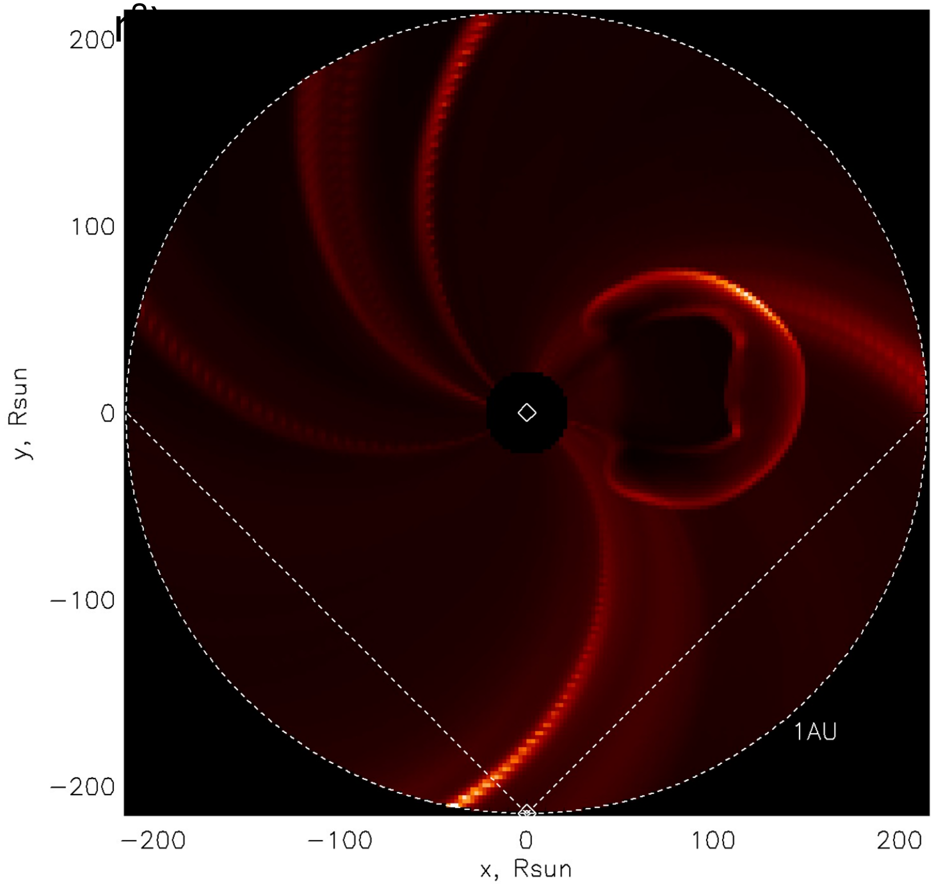

Thomson scattering

Useful papers: Billings (1966) Chapter 6; Vourlidas&Howard (2005); Howard&Tapping (2009); Howard&DeForest (2012)

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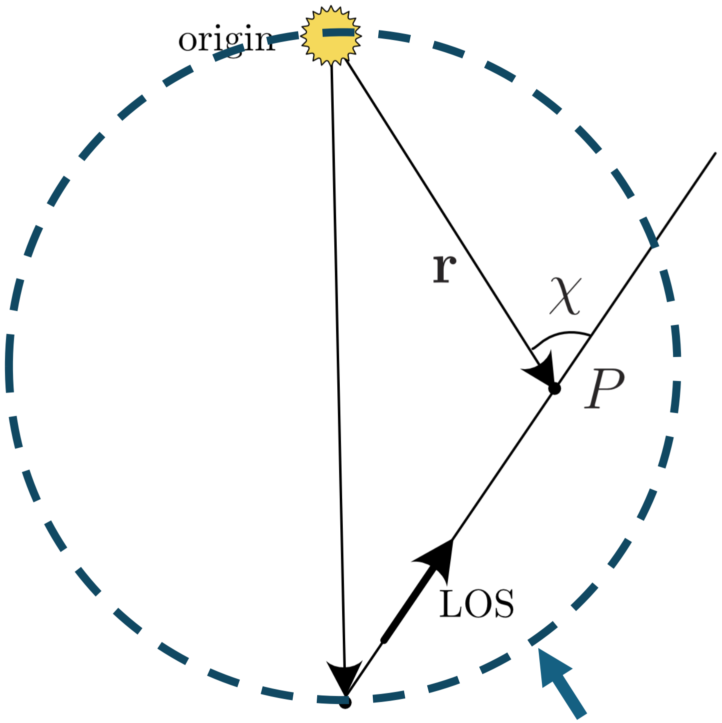

$$tB = C_0 \int_0^\infty N(l) \left[2\left[(1-u)C + uD\right] - \sin^2\chi \left[(1-u)A + uB\right]\right] dl$$

$$pB = C_0 \int_0^\infty N(l) \sin^2\chi \left[(1-u)A + uB\right] dl$$

$N(l)$ – density

A,B,C,D – functions of r , not the observer (aka “van de Hulst coefficients”)

$\sin^2\chi$ – function of scattering angle, depends on observer

$\sin^2\chi$ is the biggest at Thomson sphere

Thomson scattering

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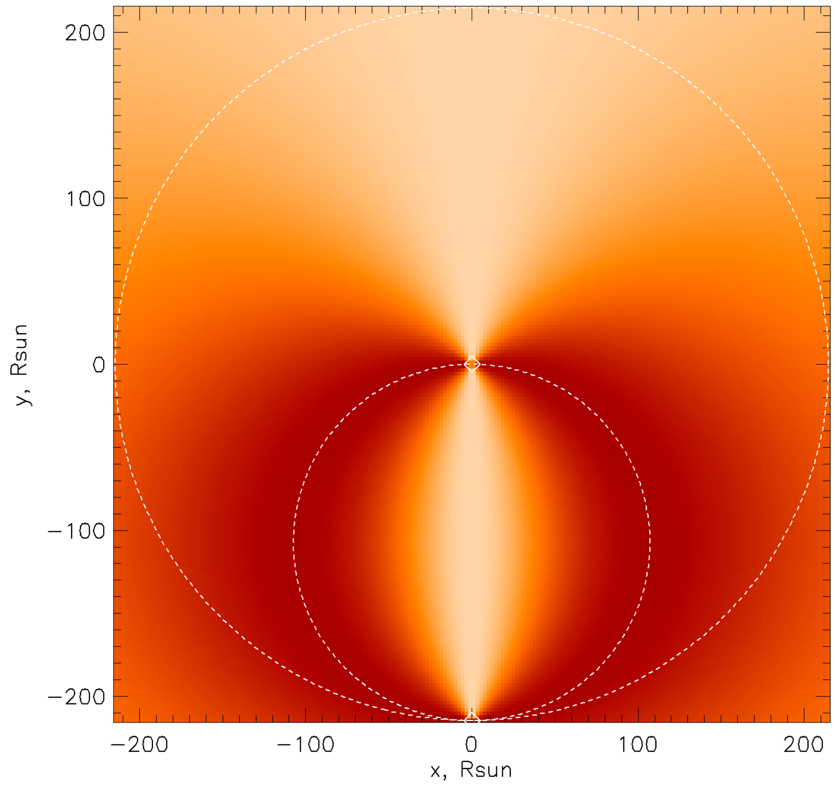

$$pB = C_0 \int_0^\infty N(l) f_2(r) \sin^2 \chi \, dl$$

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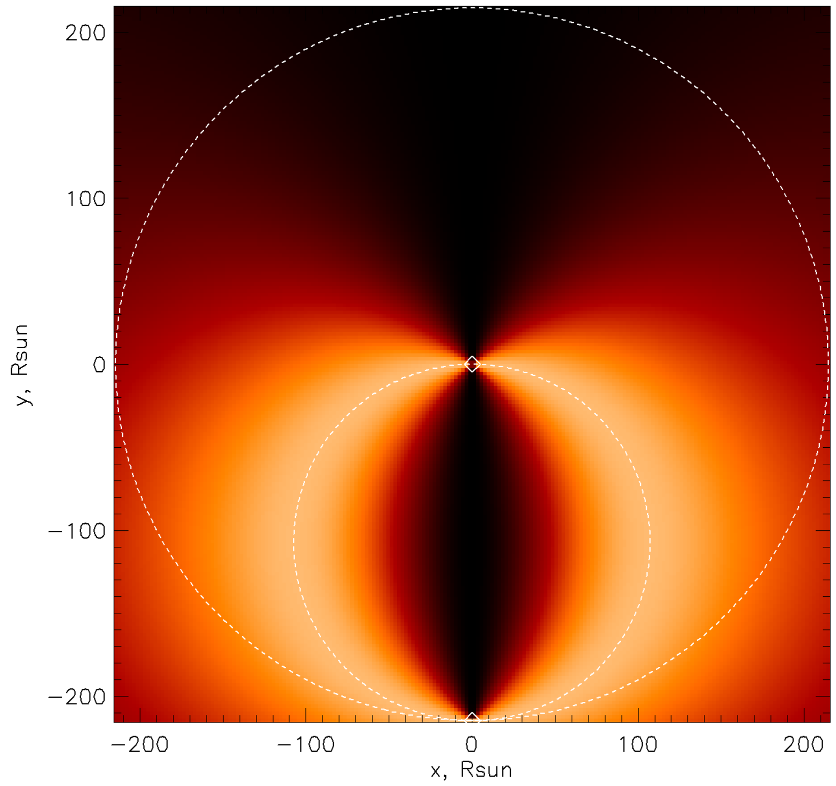

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- We have to integrate density along the line of sight *times* some geometric factors:

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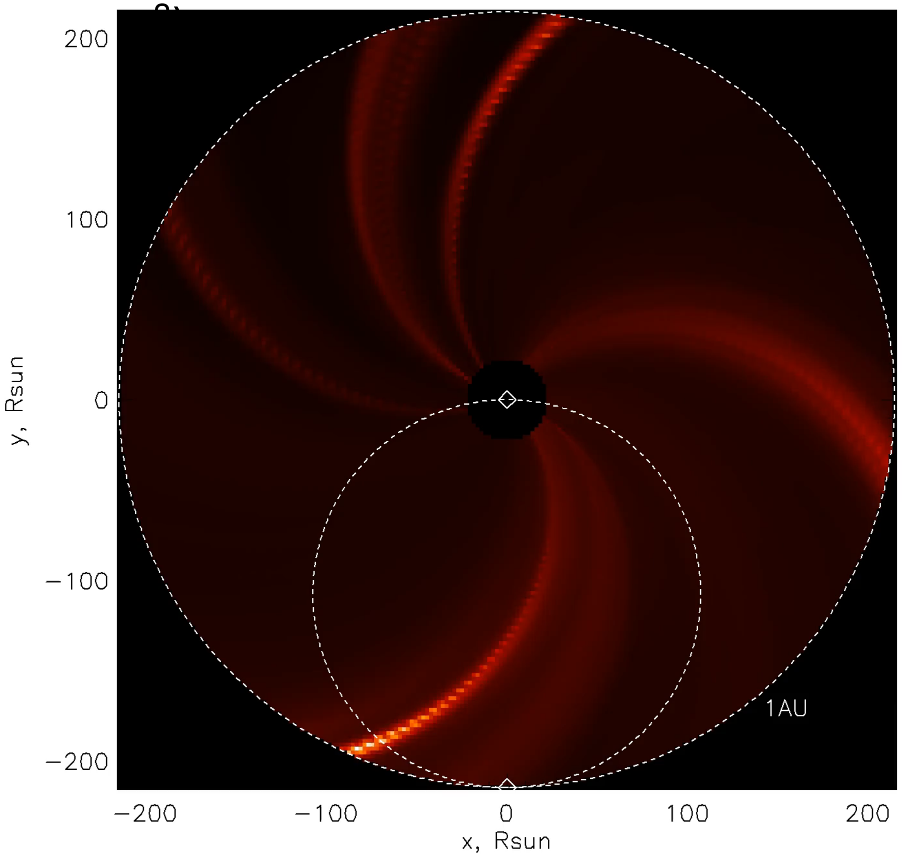
density *slice* at equator (vignette:



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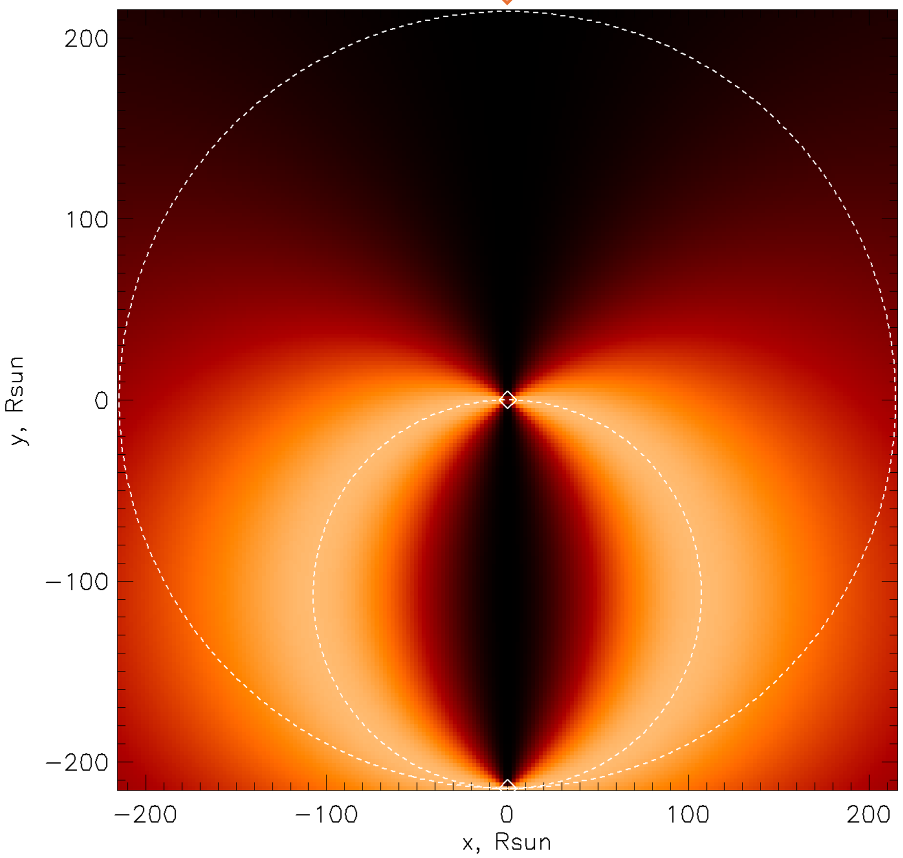

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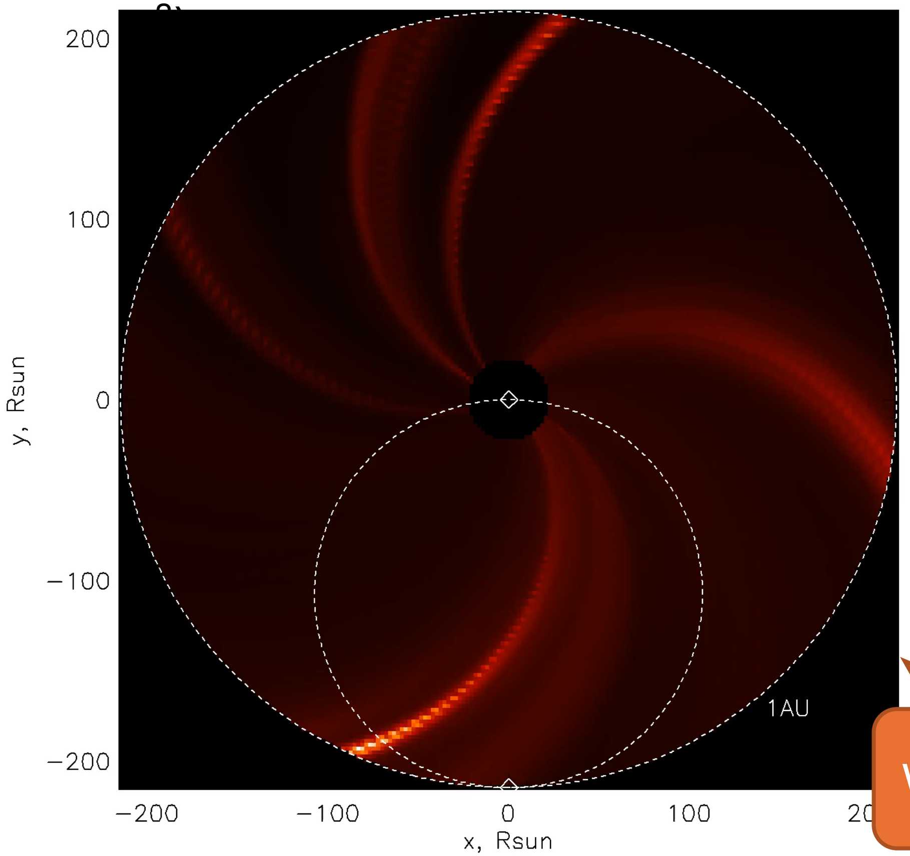
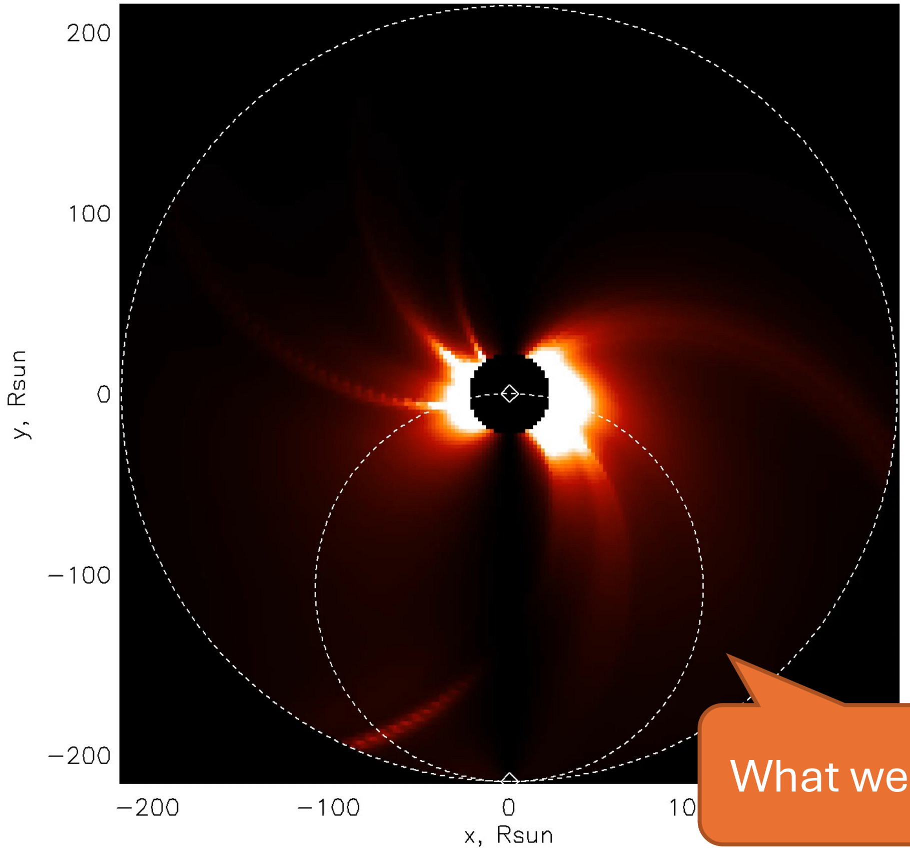


What we want

(vignette: r^2)

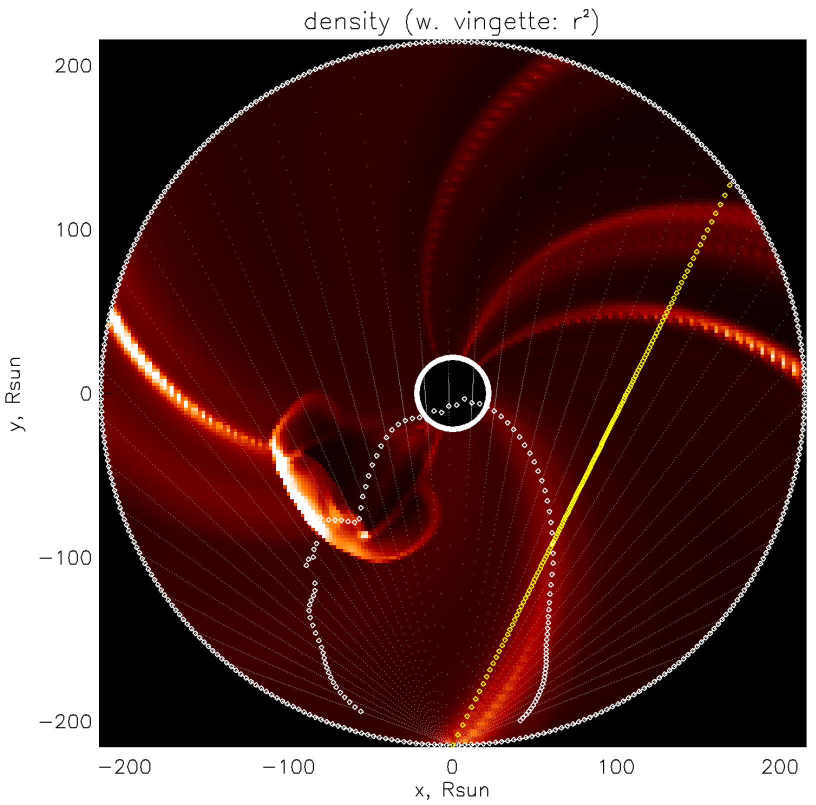


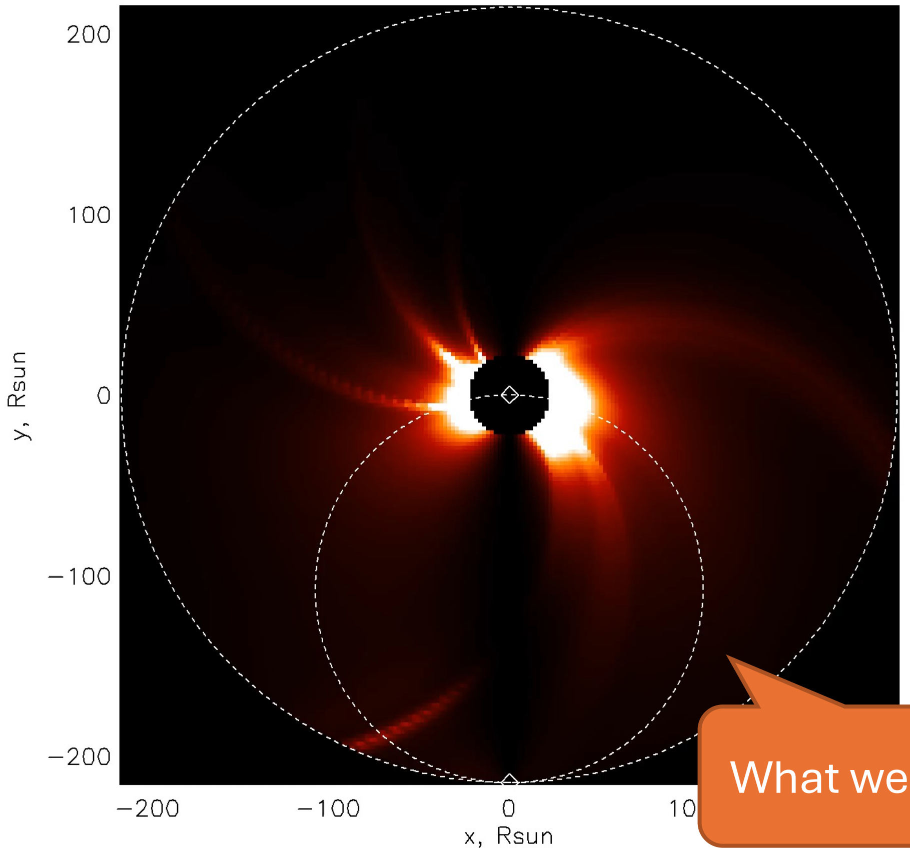
What we have

What do we do?

- Since pB and tB depend on scattering angle in a different way, we can get the angle from their ratio => position along the ling of sight
- But it only works for a compact mass
- And for distributed mass, do we get center of mass?

(vignette: r^2)





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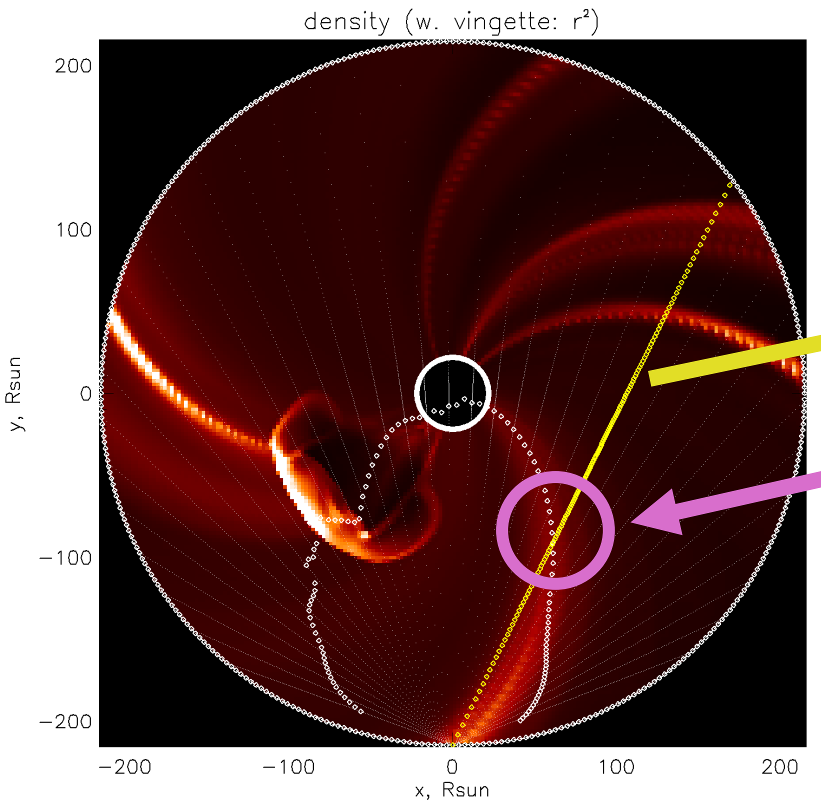

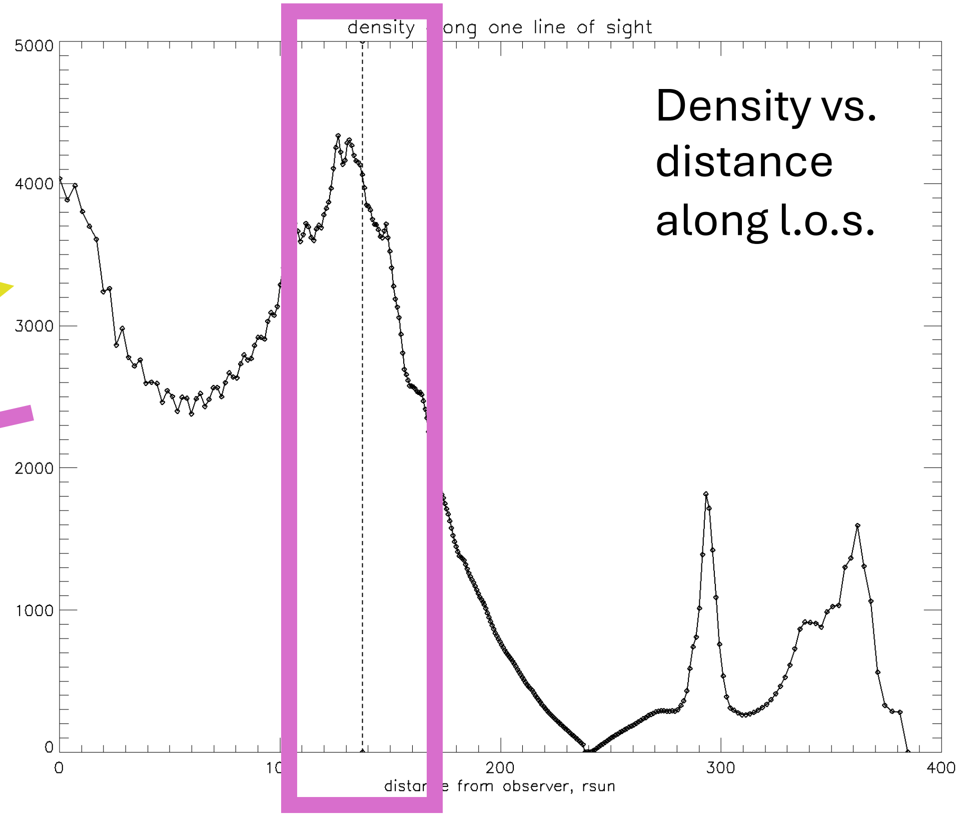

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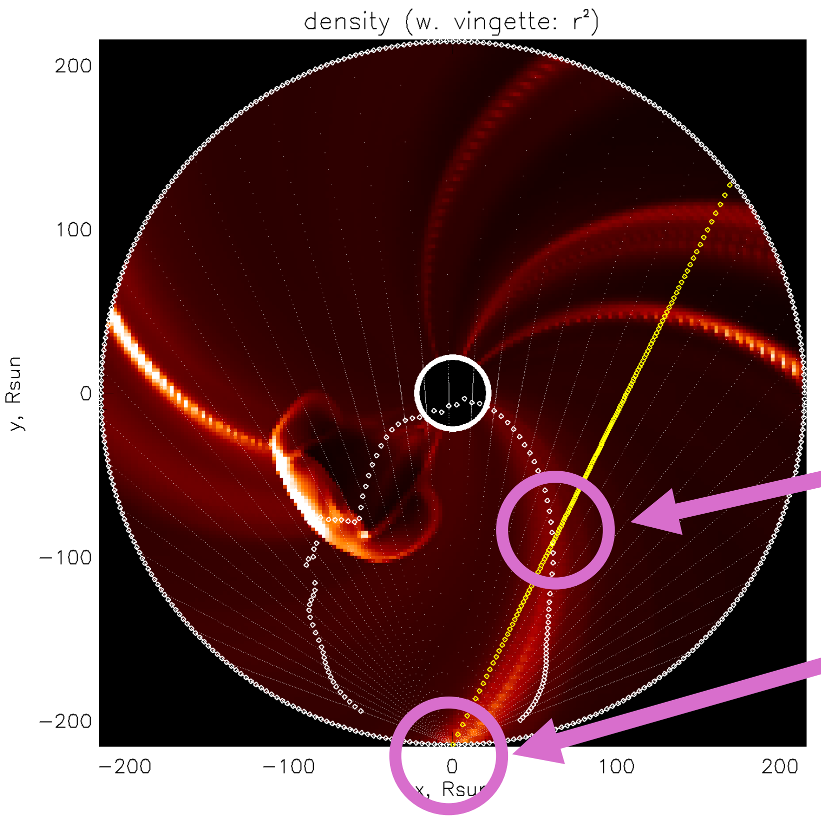
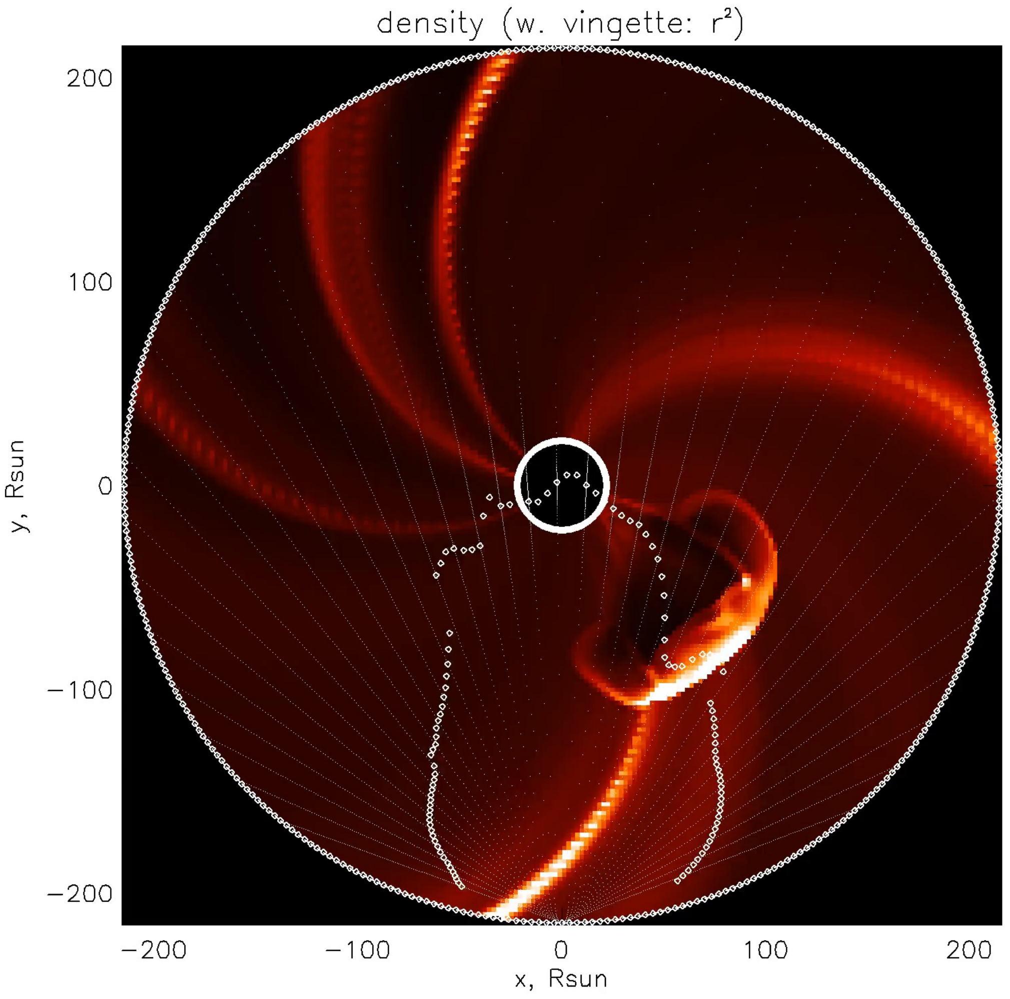
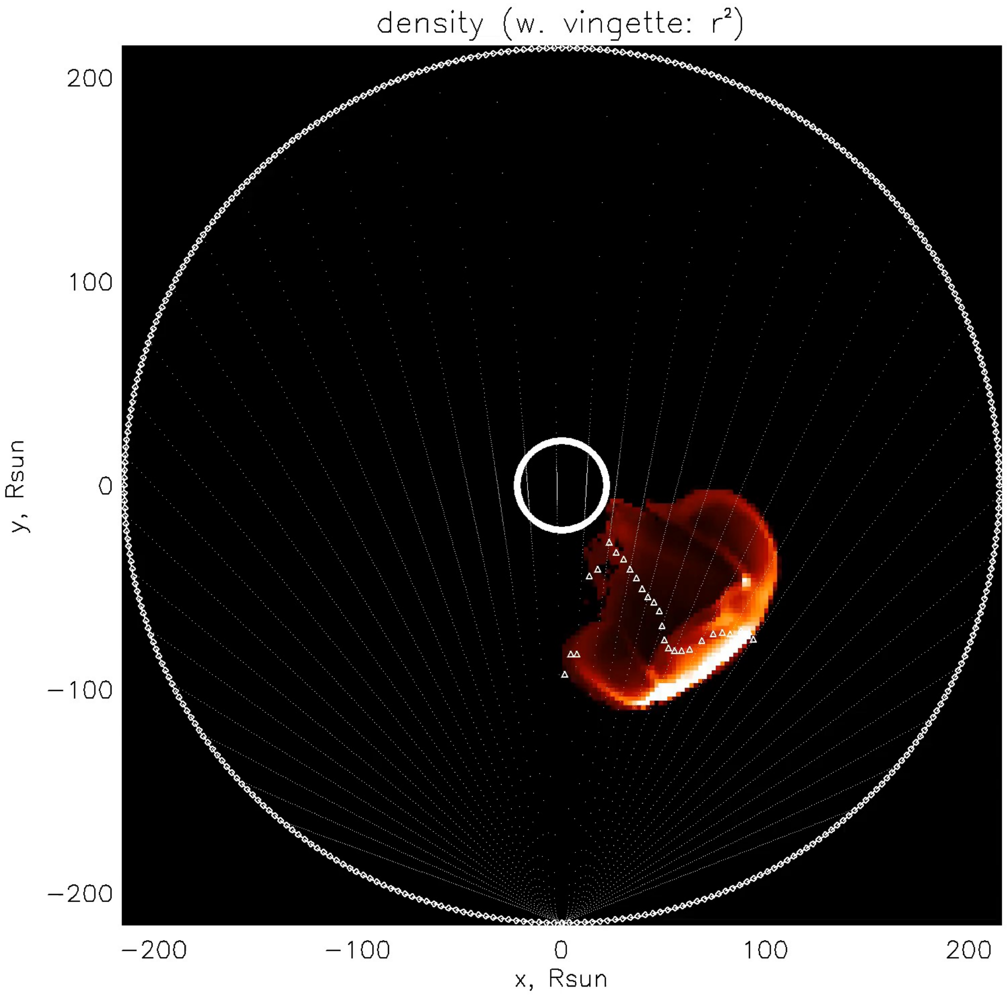


“Every hunter wants to know where sits the pheasant”

What do we do?

- What should the center of mass look like? Derived from simulation:





What do we do?

- (preliminary!) derived from tB/pB ratio (two solutions shown with blue an orange; true center of mass with white)