Examining Accretion Disk Properties of Sgr A*

Ian Christie (Purdue University)

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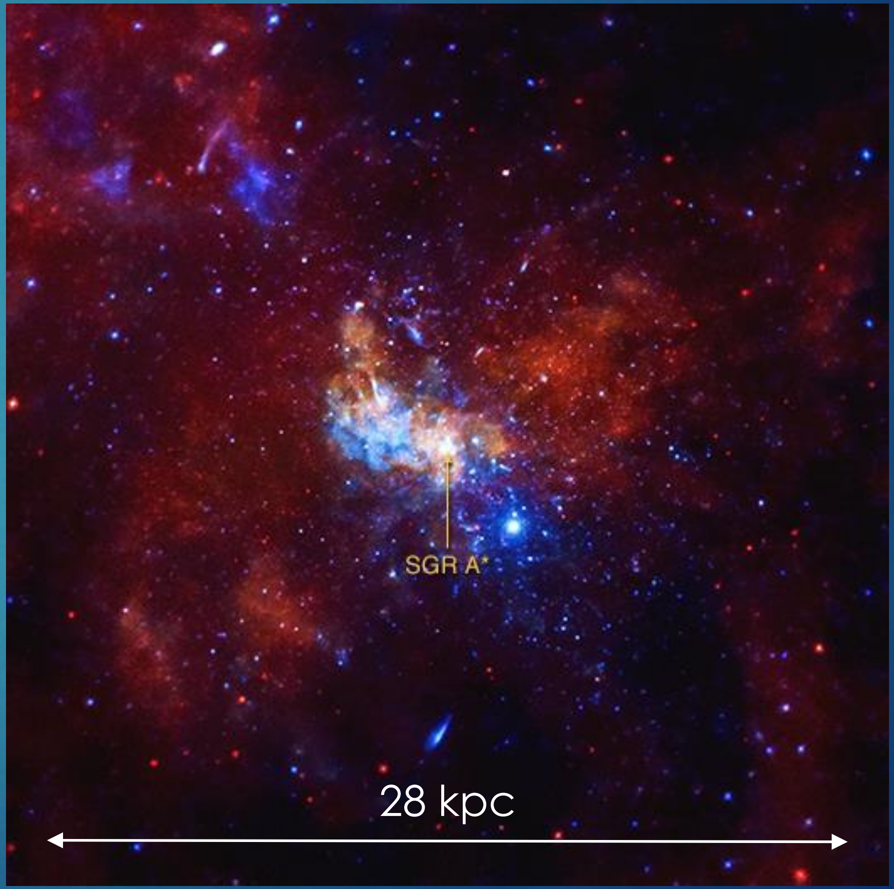
In collaboration with:

Maria Petropoulou (Purdue), Petar Mimica (Valencia), Dimitrios Giannios (Purdue)

Properties of Sgr A*

- Quiescent luminosity of . (Baganoff et al., 2003)
- Short duration X-ray flares by NuSTAR (few hours). (Barrière et al., 2014 or wait till a few presentations from now!)
- We will discuss month-long X-ray flares. (Christie et al. in prep.)



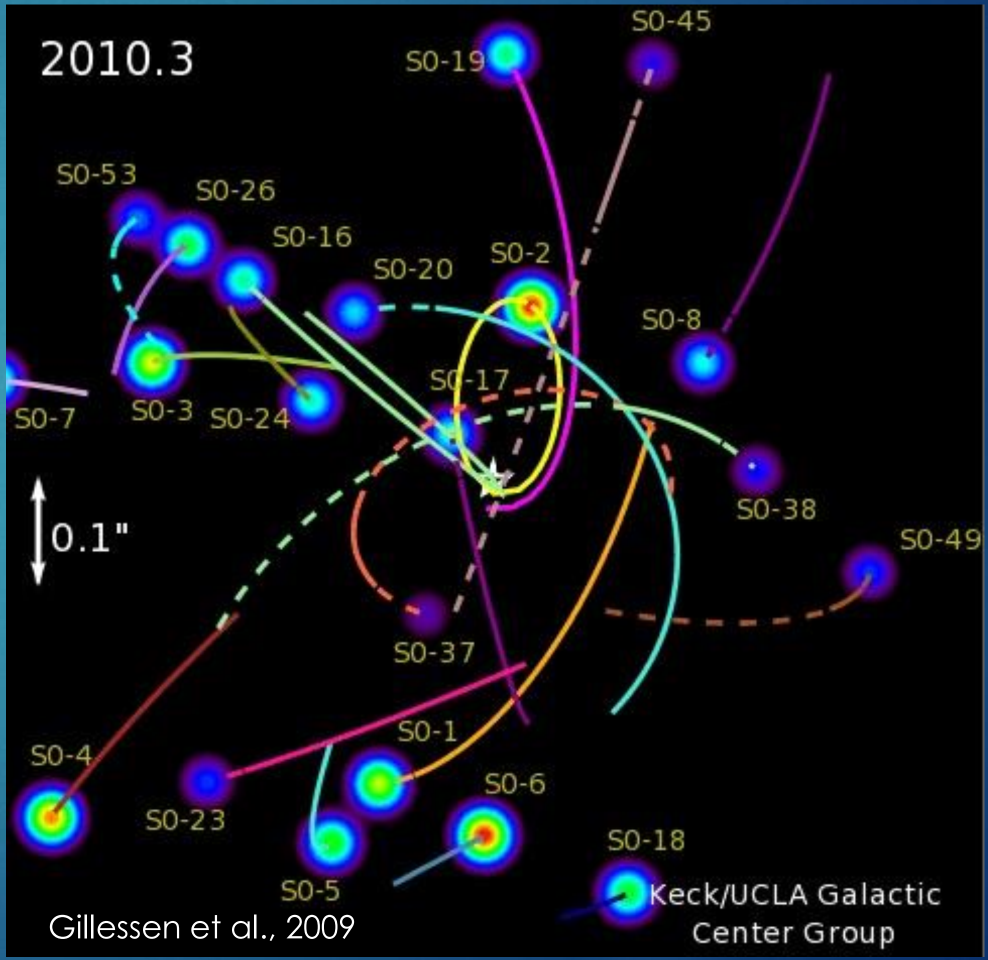
Composite X-ray image (Y.Bai. et al).

Gas Density around Sgr A*

- Sgr A* is an ideal place to study quiescent accretion and properties of geometrically thick disk.
- At Bondi Radius (~10^5 R_g), Chandra resolves X-ray, thermally emitting gas with density . (Baganoff et al. 2003)
- Very close to the black hole (~), Faraday rotation constrains mass-loss rate at M_w. (Marrone et al. 2007, Mos´cibrodzka et al. 2009)
- We aim to study properties of the disk between two boundaries.

Stars in Galactic Center: The S-Cluster

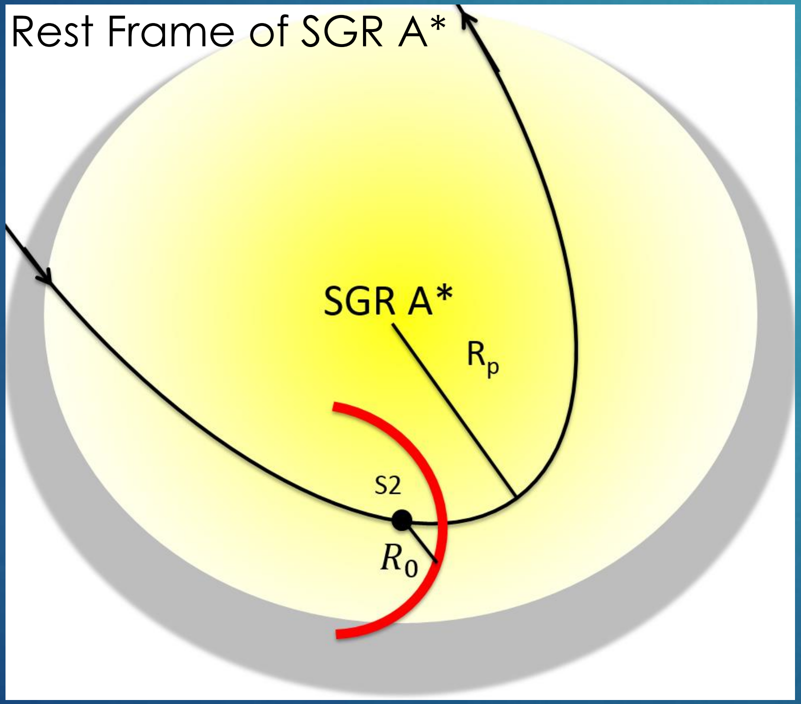
- Massive, B-dwarf stars with powerful winds of .
- The brightest star, S2, is characterized by a close pericenter passage of ~3000 R_g and mass loss rate M_w. (Martins et al., 2008)
- These stars, specifically S2, are good probes of the accretion disk. (Giannios & Sironi, 2013)

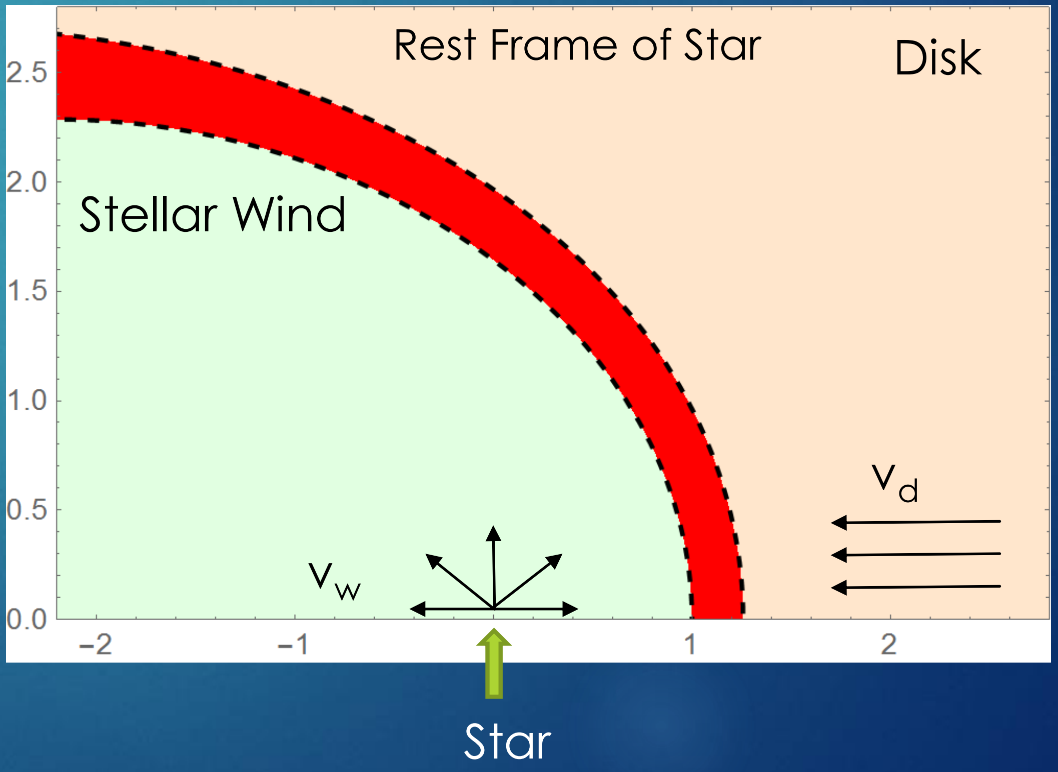


Gillessen et al., 2009

Stellar Wind – Accretion Disk Interactions

- Interactions cause the formation of a bow shock in stellar wind of star.





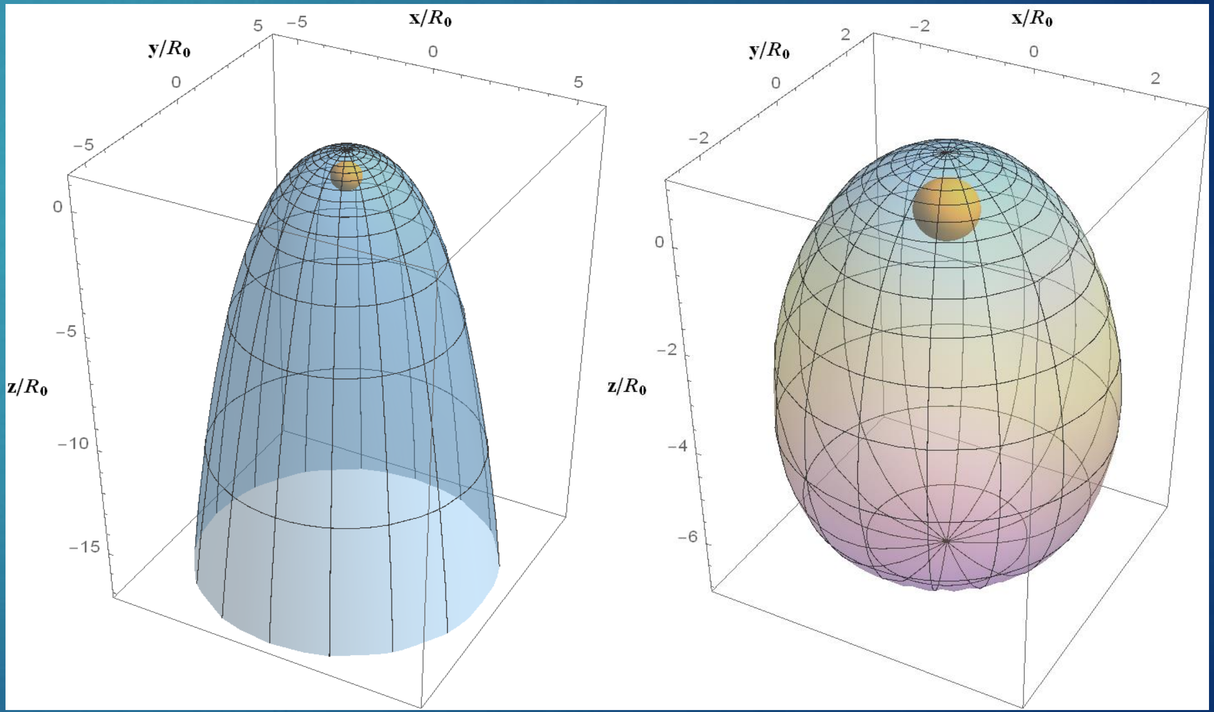
Determining Shape of Termination Shock

- Assumptions for semi-analytical model:
  i) The system has reached a steady state.
  ii) The shocked wind region falls within the thin shell limit.

- Follow an analysis of momentum supported bow shocks. (Wilkin,1996)

- Include thermal pressure of disk: P_{therm}.

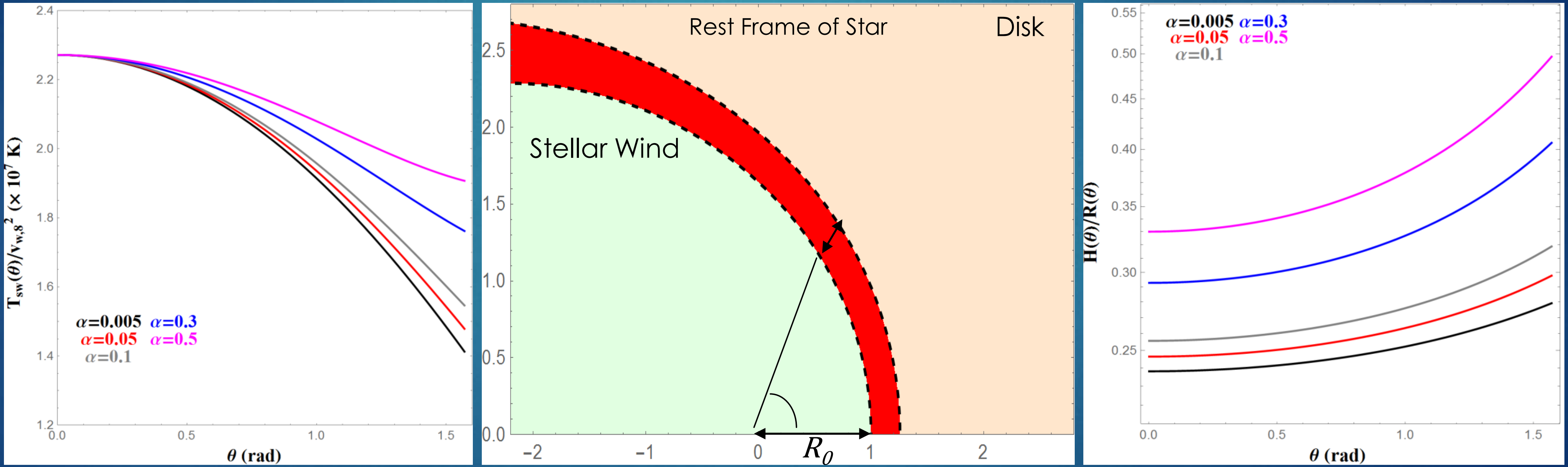
Shape of Termination Shock



Christie et al. in prep.

Properties of Shocked Stellar Wind

- Using Rankine-Hugoniot conditions → derivations of T_{sw} → thermal bremsstrahlung power



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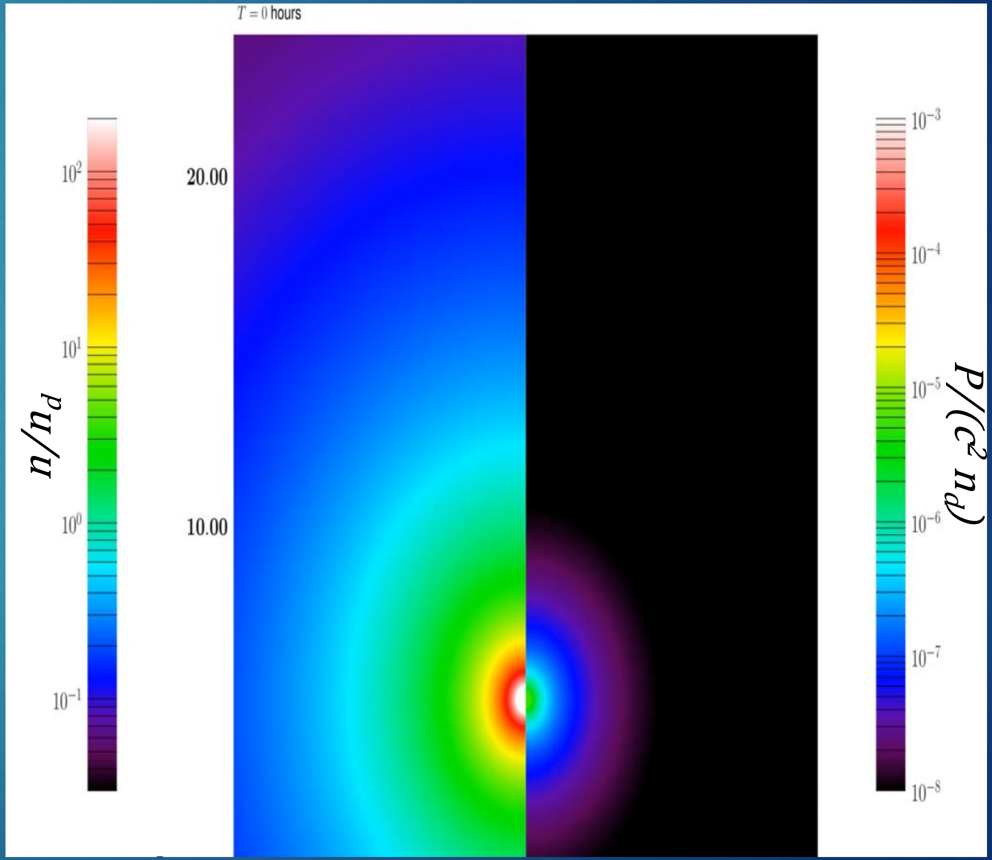
Testing Our Model Through Hydro-Simulations

- Used to make comparisons of:
  - Our estimates of the termination shock and contact discontinuity.
  - Thermal bremsstrahlung power produced from the shell.

- Large back region beyond termination shock is dominated by Kelvin-Helmholtz instabilities.



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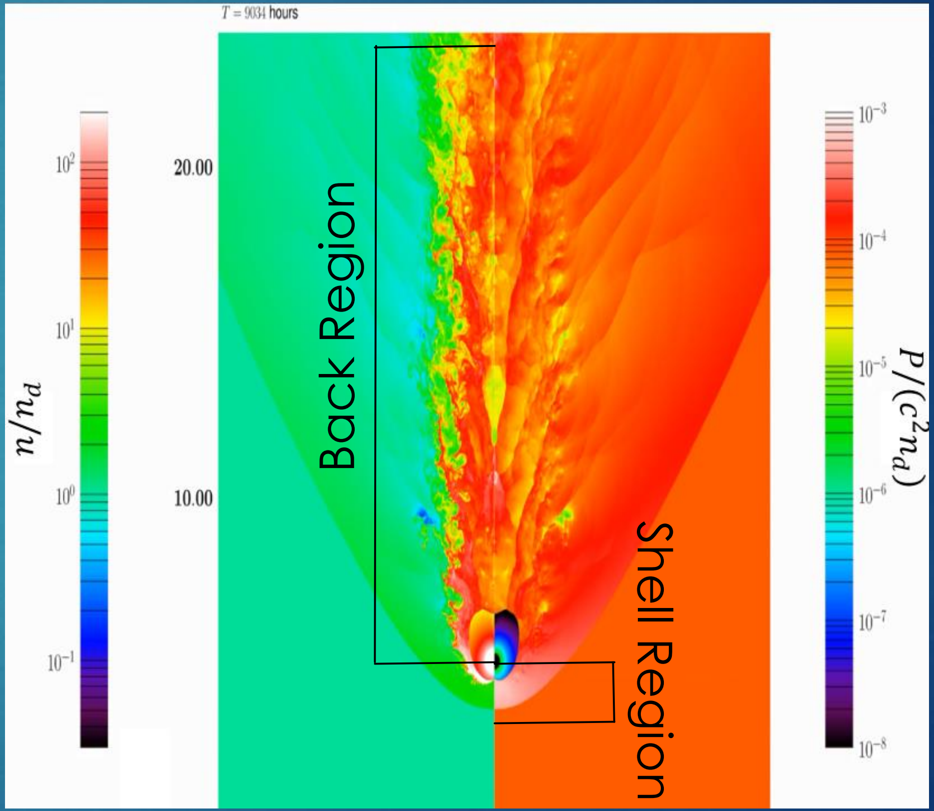
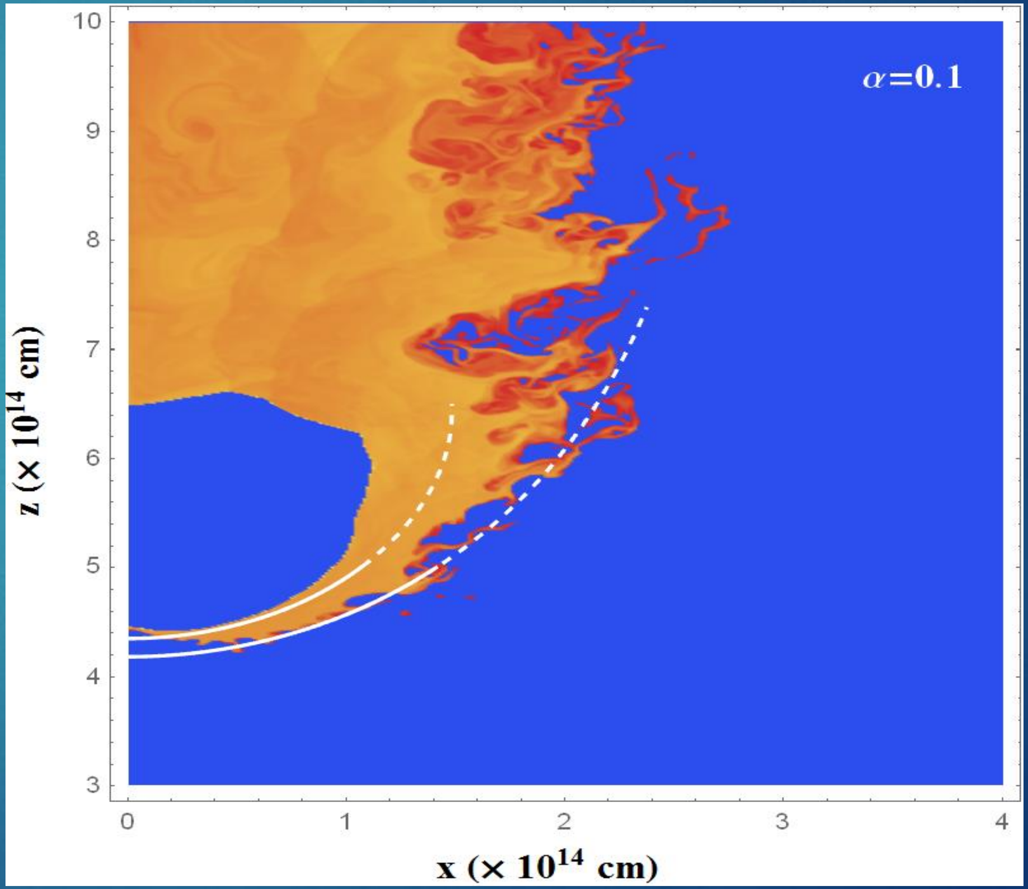


Termination Shock & Contact Discontinuity

- These surfaces are quickly prone to instabilities.
- Estimates for these interfaces valid up to $\frac{\pi}{2}$.



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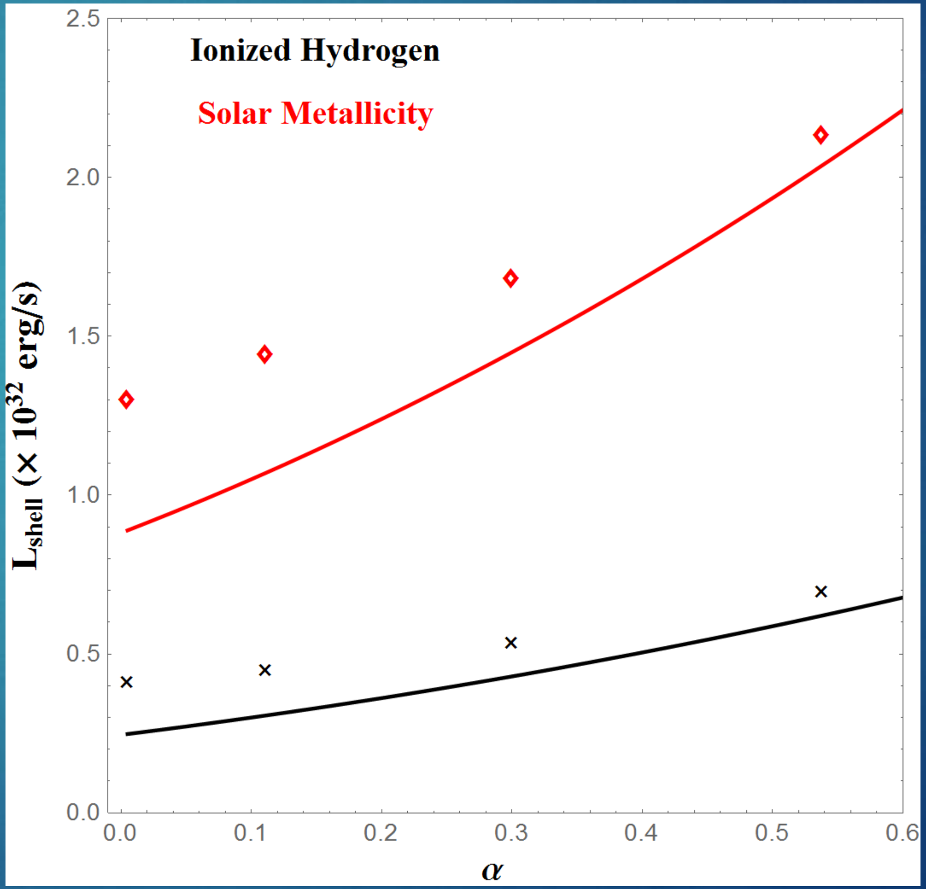
Bremsstrahlung Emission from Shell

- Computation of bremsstrahlung emission produced from the shell is permitted up to with M_w
- Consider wind compositions of hydrogen and solar metallicities.
- $L_{Hydrogen}{}^{3/2}\, n_d{}^{1/2}\, v_w{}^{-1/2}$



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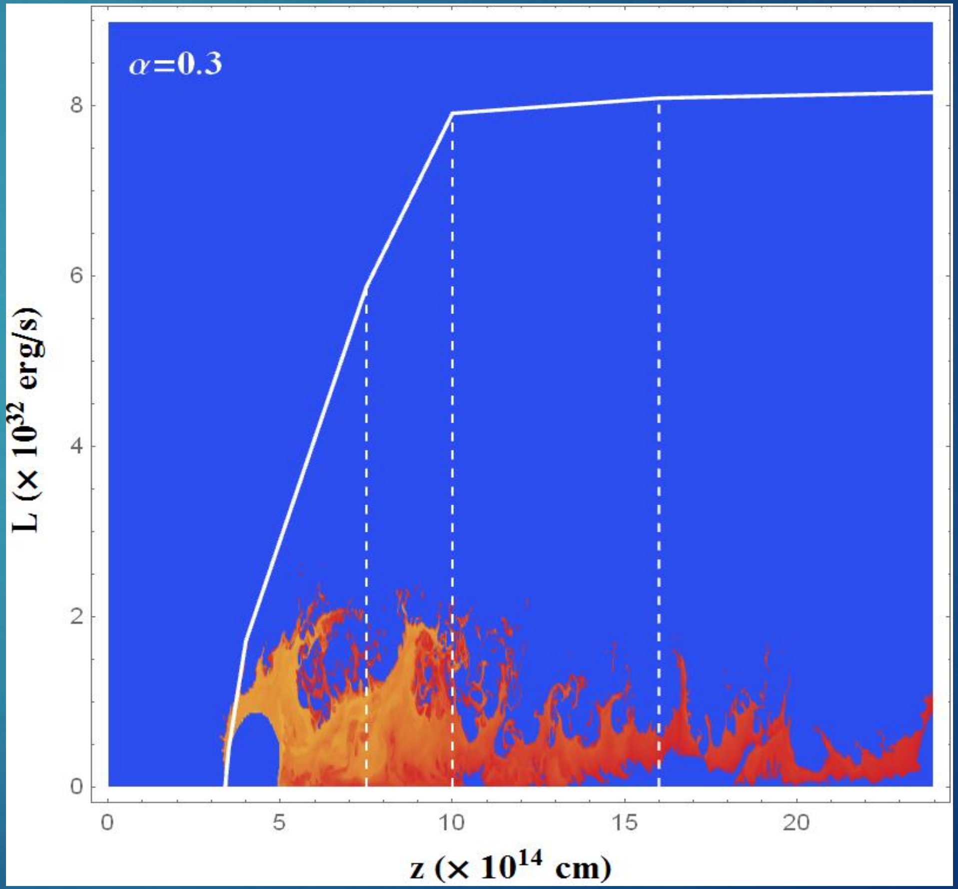
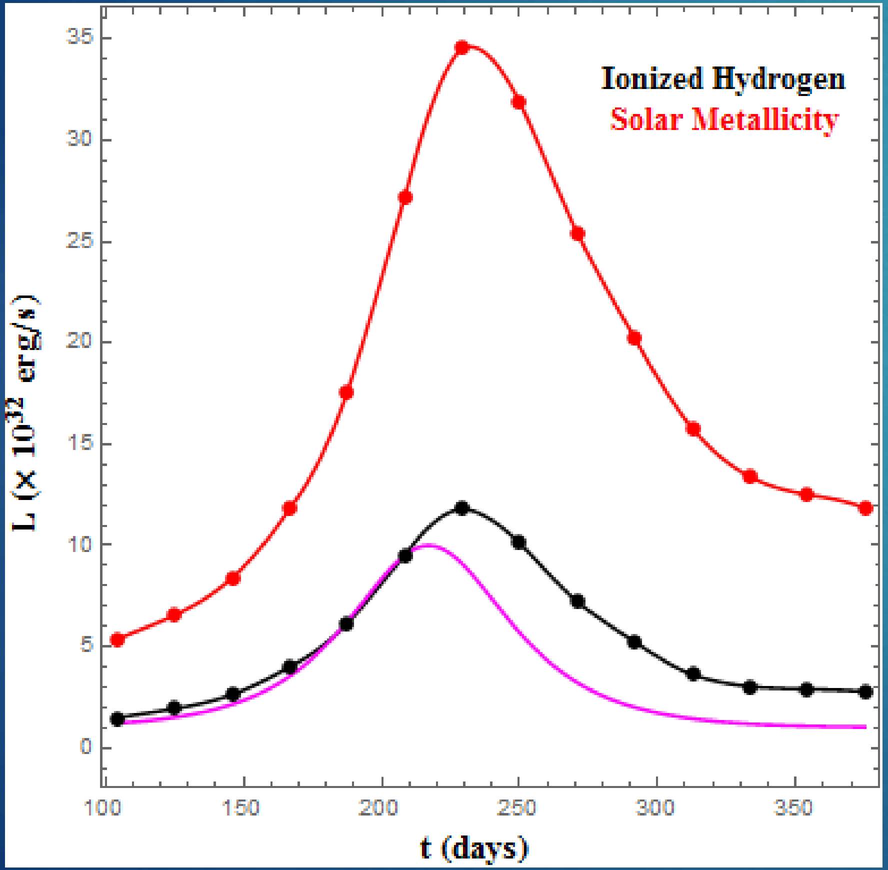
Contributions from Back Region

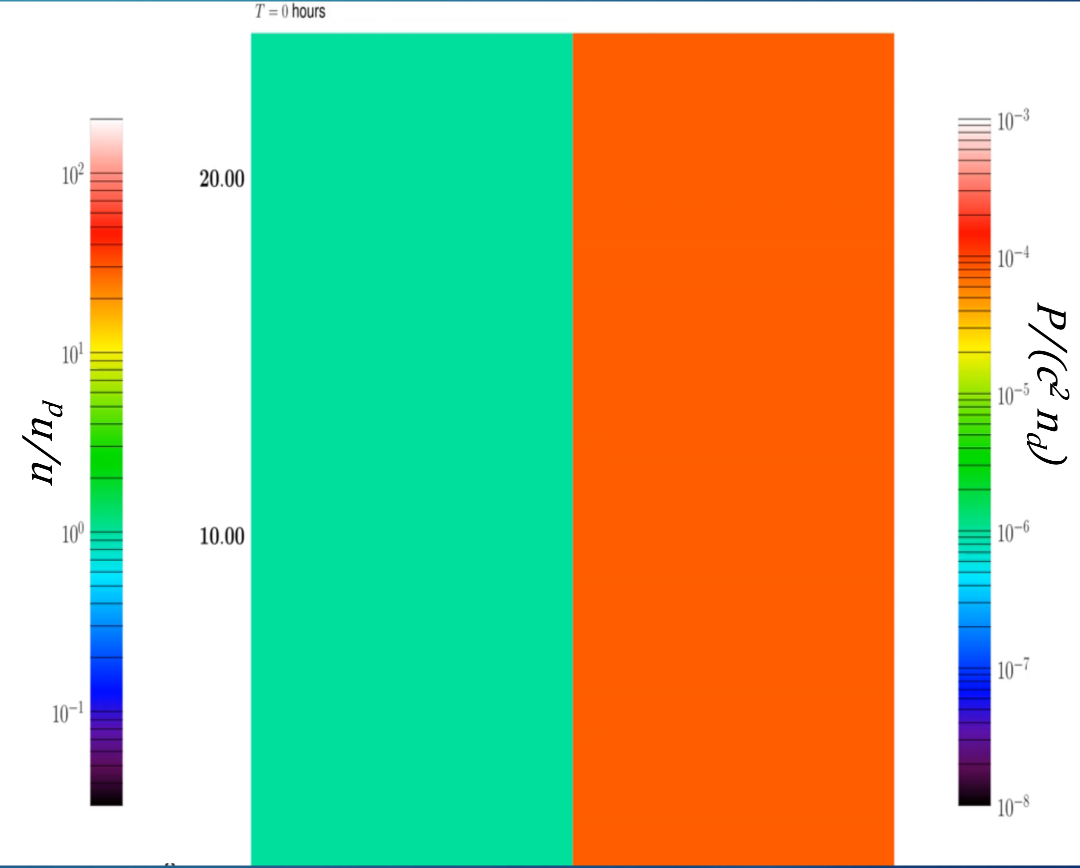
- Bremsstrahlung emission produced by all shocked wind computed as a function of both α and z.
- Back region contributes large fraction to total luminosity (~10 times that produced from the shell).



Evolution of Back Region

- Time dependent density used to model transit through pericenter and observe evolution of "mixing" region.





Christie et al. in prep

Summary

- Thermal pressure of the accretion disk substantially affects the emission.

- Radiation from tail of bow shock structure dominates emission.

- The passage of a star through the accretion disk of Sgr A* produces a bow shock while an observable, month-long X-ray flare may be expected with luminosities

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Simulation Setup

- Performed using hydrodynamic code MRGENESIS (Mimica et al. 2009)
- 3^{rd} order Runge-Kutta scheme for time integration.
- Piecewise-parabolic method for spatial interpolation (Colella & Woodward 1984).
- Reflective boundary conditions along symmetry axis.