



The Center for Astrophysical Thermonuclear Flashes

Really, Really hot flames, and
How, in My Small Way, I helped save
the universe.

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Academic Strategic Alliances Program (ASAP) Center
at The University of Chicago





What Does the Flash Center Study?



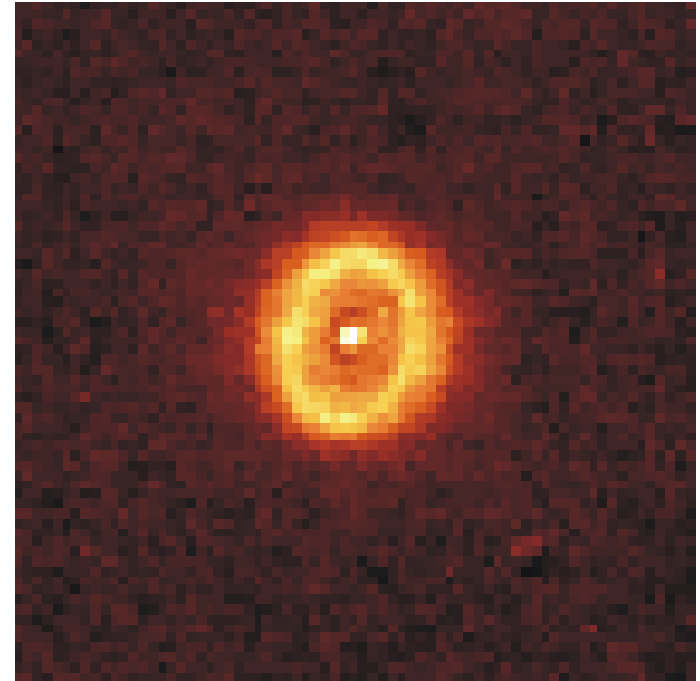
© 1992, Bill Waterson



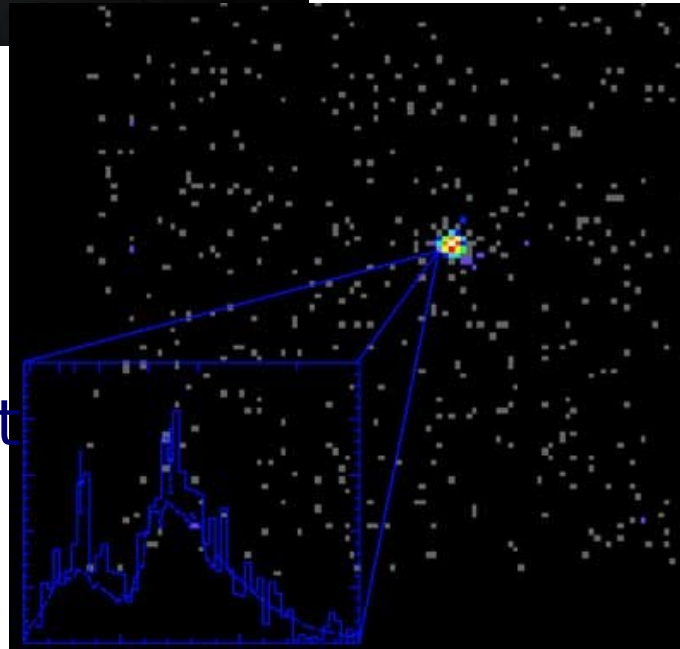
Our Three Kabloories



Supernovae Ia
Courtesy Hubble STScI



Novae
Courtesy Hubble STScI



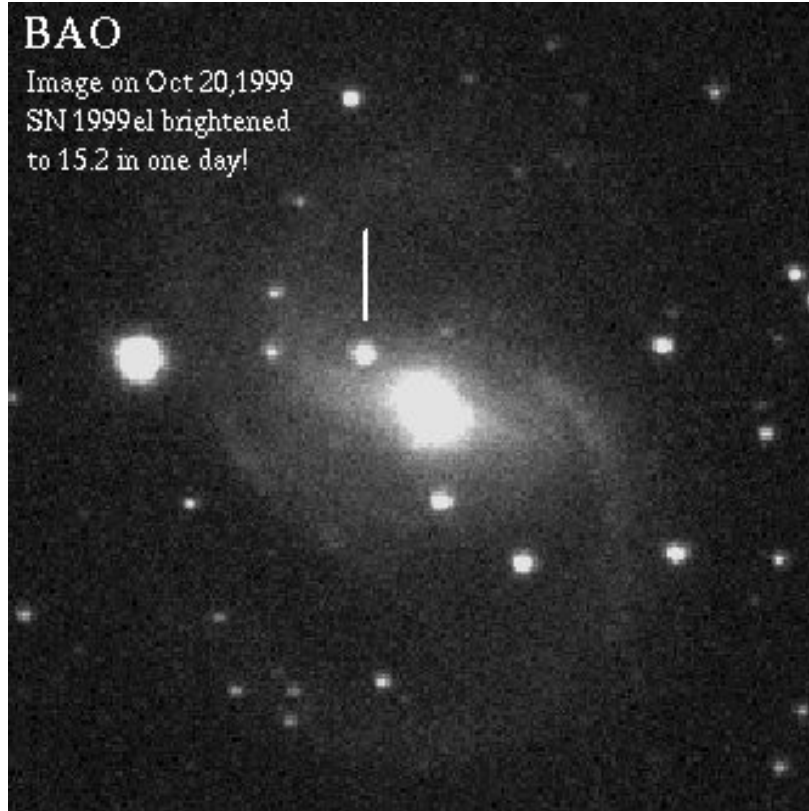
X-ray burst

Courtesy
Chandra X-Ray
Observatory

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Supernovae are my Favorite

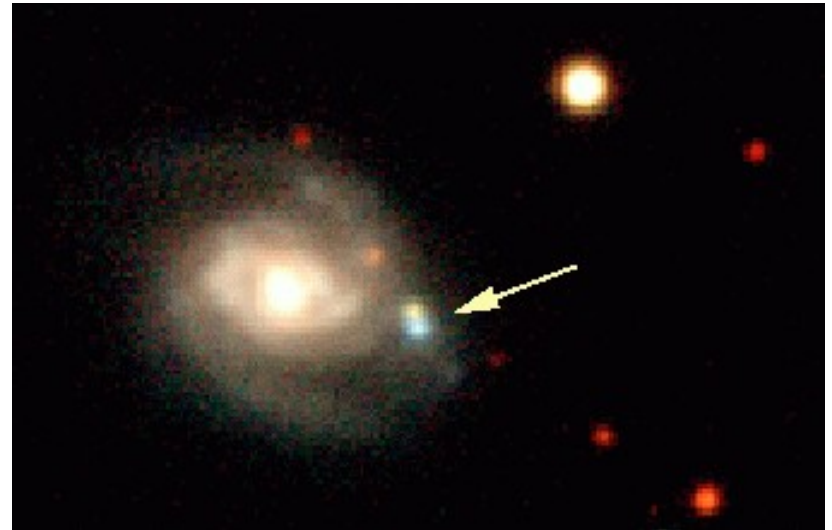


- ❑ Pretty common
- ❑ Cosmologically interesting
- ❑ No one knows how they actually explode



Supernovae are my favourite

- ❑ Can't explode with a simple detonation.
- ❑ Can't explode with a simple flame.
- ❑ 1d models can reproduce real supernovae pretty well by adding imaginary physics:
 - ❑ Flame reaches 1/3 flame speed (from 10^{-4} or so)
 - ❑ Flame reaches 1/30 of flame speed, then magically becomes detonation (DDT)





Going to need some Flame Physics

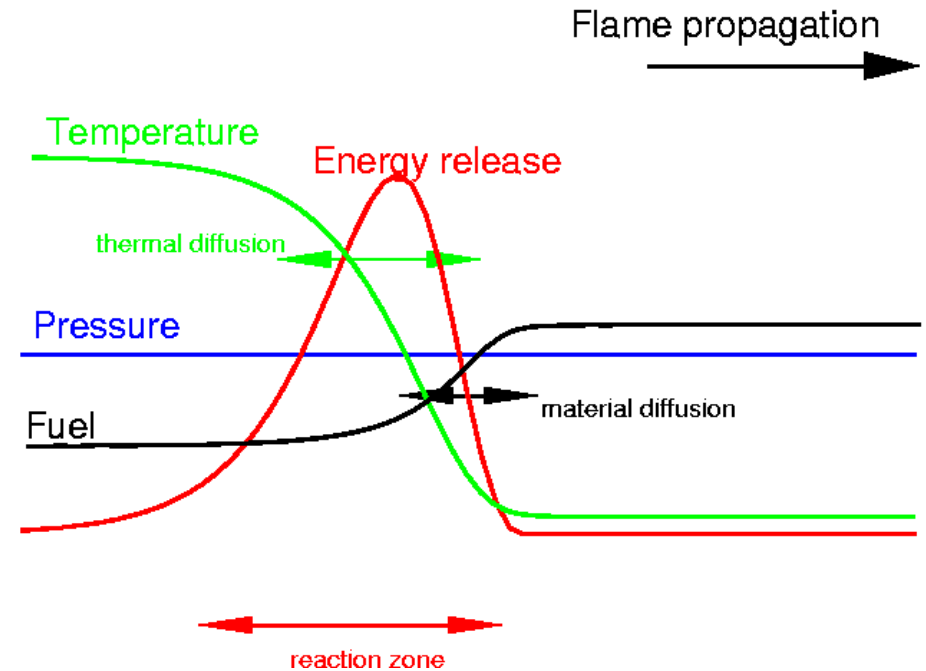


- ❑ How to accelerate flame that fast?
- ❑ Wrinkling by flow or by flame instabilities
 - ❑ Increased surface area --- increased burning
- ❑ Thermonuclear flames are similar enough to learn from chemical flames, but different enough must be studied separately.



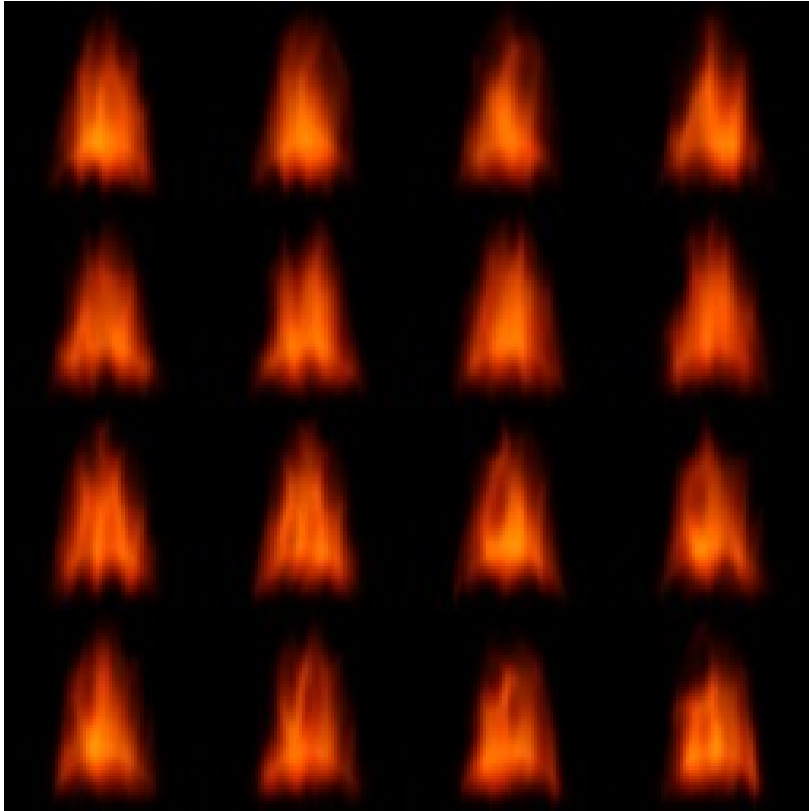
Flame Basics

- A mode of burning; self-propagating subsonic wave
- Propagates by thermal conduction outward, fuel diffusion inward
- Reactions occur in fairly narrow region
- Astrophysical flame:
 - material doesn't diffuse
 - very high energies
 - Degenerate





Flame Basics



- Fluid affects flame:
 - Energy release rate depends on local properties
 - Flame front transported by flow
- Flame affects fluid:
 - Adds energy to fluid, generating fluid motions
- Back-reactions:
 - Fluid motions generated by flame will change local properties and transport the flame



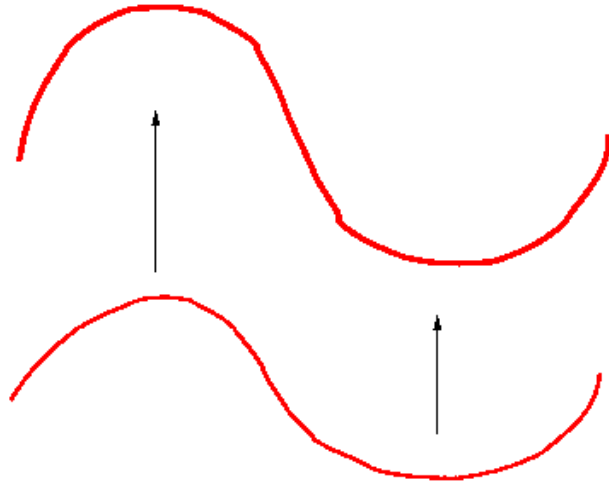
Flame Basics

- Astrophysical flame will never occur in a stationary fluid:
 - Stratification
 - Turbulence
 - Rotation
- If flame were a passive interface, would just advect with the fluid velocity plus its own laminar propagation velocity.
- However:
 - Stretch
 - Curvature
 - Back-reactions





Interaction Ex: Simple Landau-Darrieu

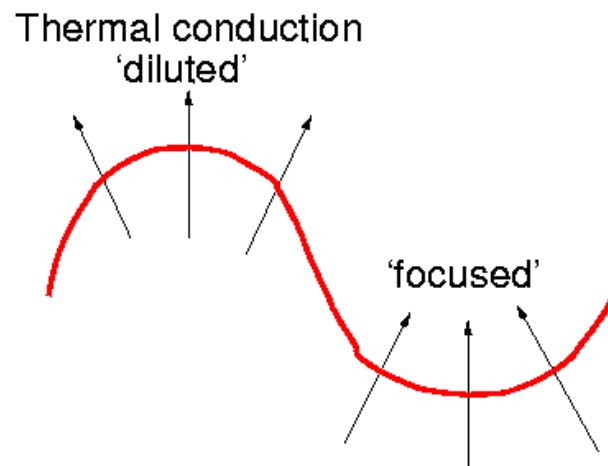


- Semi-passive interface
- Flame generates volume behind front
- More volume generated behind leading 'peak' than 'trough'; any mode grows
- Purely hydrodynamic --- depends on density contrast



Interaction Ex: Complex Landau-Darrieus

- Astrophysical flame: material diffusion unimportant, thermal conduction important
- Curvature `focuses' heat transport
 - Faster/Slower flame propagation
- Suppresses growth on diffusion scales
- Depends on curvature, Lewis Number Le (ratio of thermal/material diffusion)





FLASH Code!

- ❑ FLASH!!!!
- ❑ Ahhh-aaaahhhh...
- ❑ Saviour of the Universe!



Saviour of the Universe



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FLASH Code!

- ❑ FLASH!!!!
- ❑ Ahhh-aaaahhhh...
- ❑ He *[ed: `he' presumably refers to one of the FLASH developers]* saved every one of us!!!!

Source: F. Mercury *et al.*, (1980)



Day-to-Day FLASH Code developing



Ignorance of basic physical phenomena (personified)

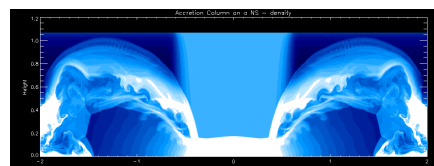
Me (note previous hair colour)



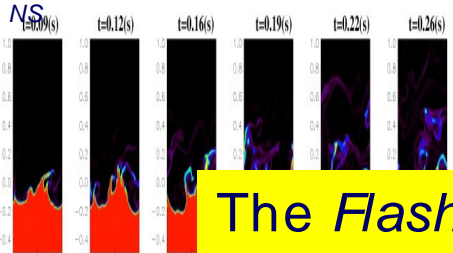
Flame



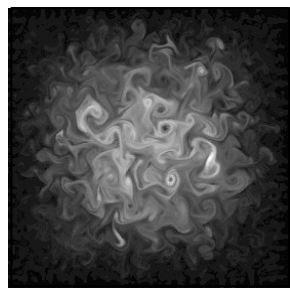
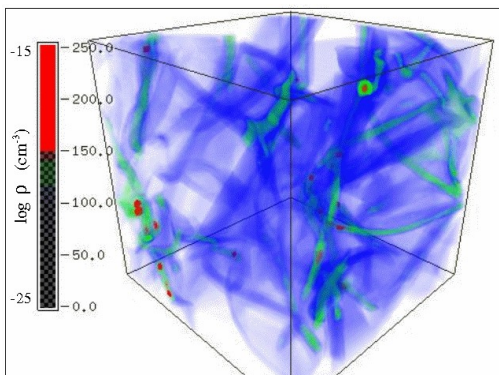
The Flash Code



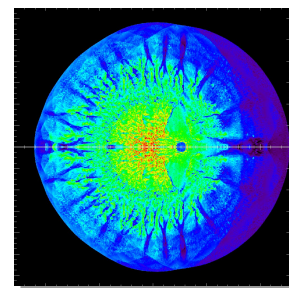
Shortly: Relativistic accretion onto NS



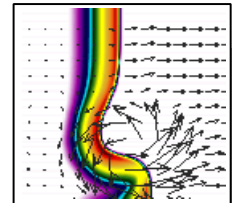
Wave breaking



Compressed turbulence



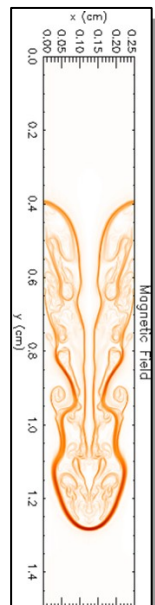
Type Ia Supernova



Flame-vortex interactions

The *Flash* code

- Is modular
- Has a modern CS-influenced architecture
- Can solve a broad range of (astro)physics problems
- Is highly portable
 - Runs on most available massively-parallel systems
 - Runs on my laptop
- Scales and performs well
- Carefully tested and validated
- Is available on the web: <http://flash.uchicago.edu>



Magnetic Rayleigh-Taylor

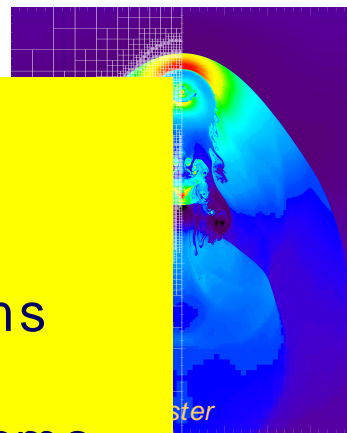
Cellular detonation

Helium burning on neutron stars

Orzag/ Tang MHD vortex

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Richtmyer-Meshkov instability



Making FLASH `do' flames



- ❑ FLASH was a code originally put together for detonation problems.
- ❑ Subsonic boundary conditions very hard, but done
- ❑ Modified solver to keep hydrostatic equilibrium for long times (Zingale, Dursi et al, 2002)
- ❑ Need new solver for multi-d flames (RSN), but ok for 1d flames for time being.

``Let him debug the code. He knows what he's doing.''

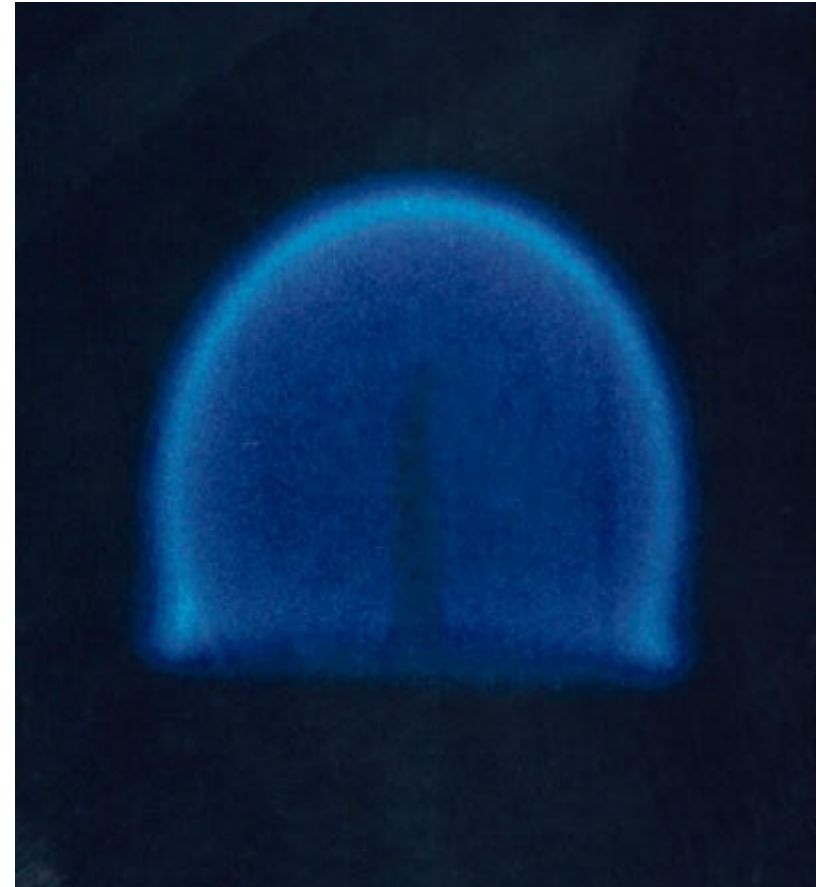
``But it's too dangerous!''

``Yes... but it's our only hope.''



What to simulate

- First step: Investigate flame reaction to curvature
- Simulate outgoing and ingoing spherical flames
 - At each time, experiences different strain/curvature
 - Can `read off' flame speed, structure as a function of radius (=curvature)
- Model flames, astrophysical flames.





Conclusions

- ❑ Flash code has been used to
 - ❑ Study astrophysical flames
 - ❑ Slay Space Lizards
- ❑ Can predict how an astrophysical flame will react to curvature
 - ❑ Influences stability, ease of wrinkling
 - ❑ Makes it harder (damn!)
- ❑ Next step: incorporate into model and simulate larger scales

