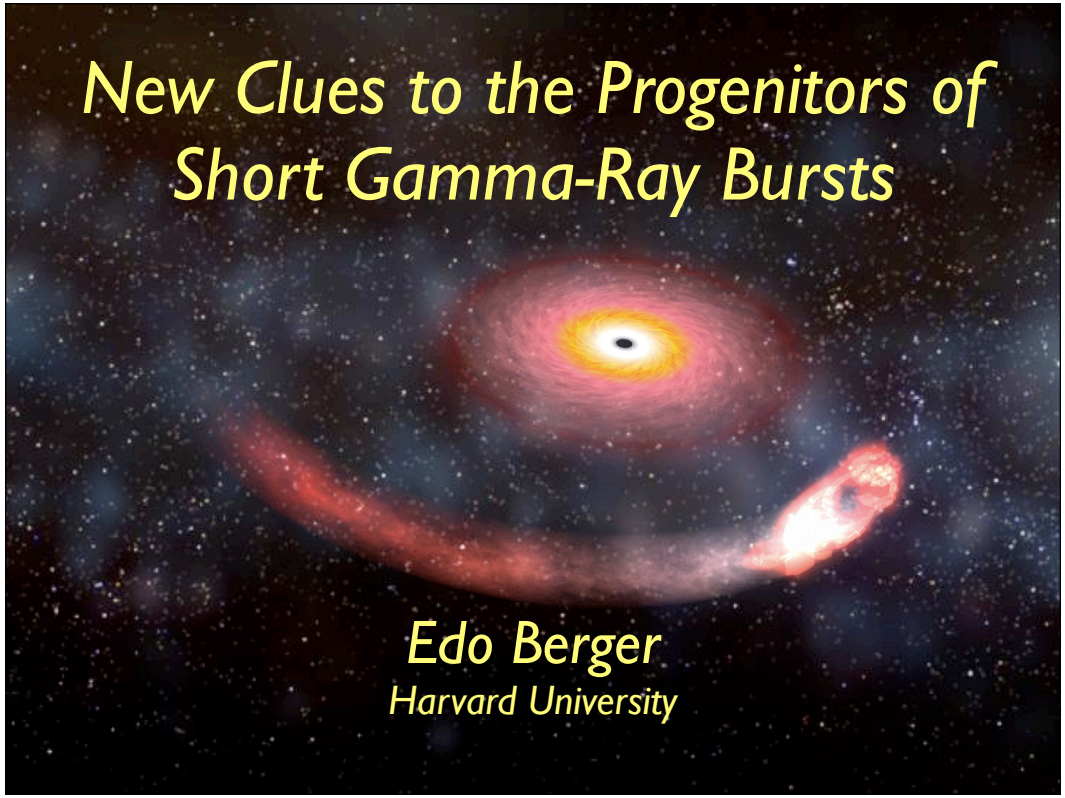

New Clues to the Progenitors of Short Gamma-Ray Bursts
Edo Berger
Harvard University

# *Short GRB Progenitor Models*

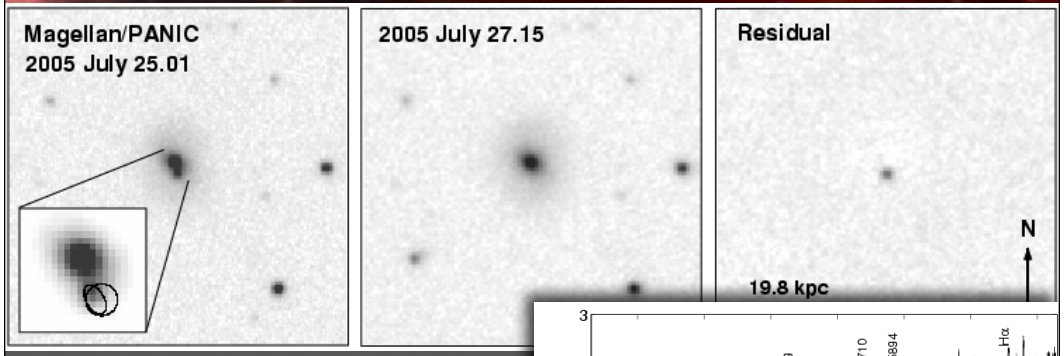
- Do short GRBs track stellar mass alone? i.e., are the progenitors older than ~1 Gyr?
- If not, what are the ages of the younger stellar populations that give rise to some short GRBs? How are they related to long GRB progenitors?
- Is there evidence for large progenitor kicks?

Berger, E. 2010, ApJ, 722, 1946

Leibler, C. & Berger, E. 2010, arXiv:1009.1147

Berger, E. 2010, New Astronomy Reviews in press

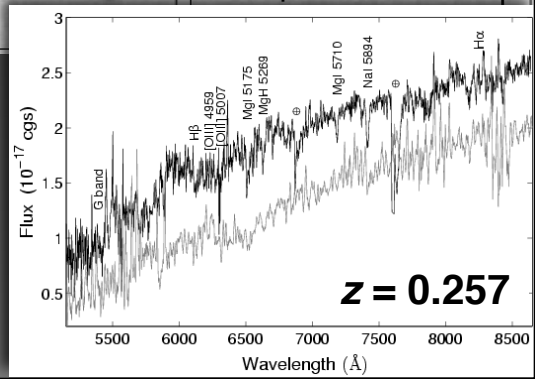
# Some Short GRBs occur in Ellipticals...




Berger et al. 2005

## GRB 050724

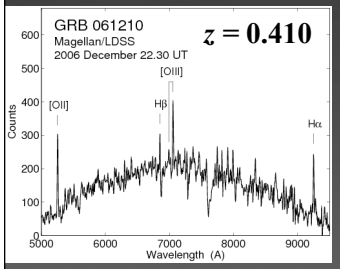
*SFR < 0.05 $M_\odot$/yr*
*Age > 1 Gyr*

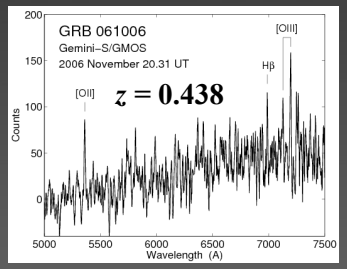


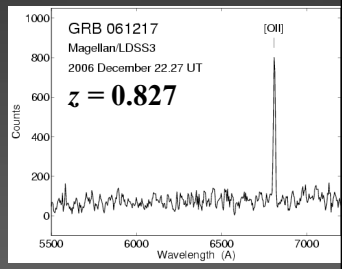
# ...But Most Occur in Late-Type Galaxies

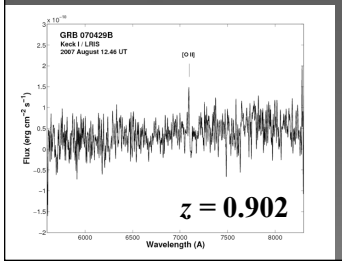
~1/2 of all short GRBs are located at z > 0.7 ⇒ ⟨age⟩≤ 7 Gyr

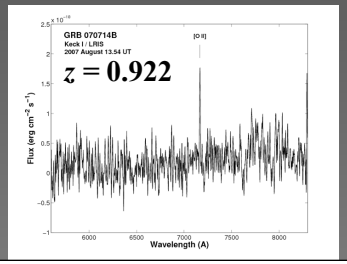
Berger et al. 2007; Berger 2009

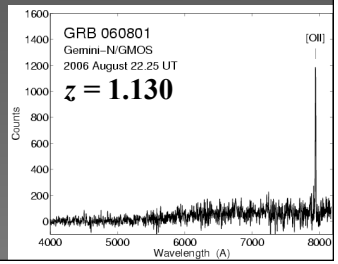


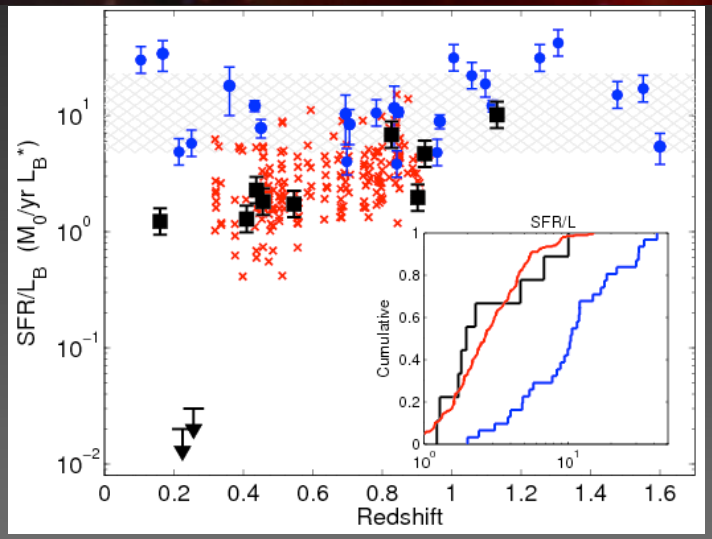



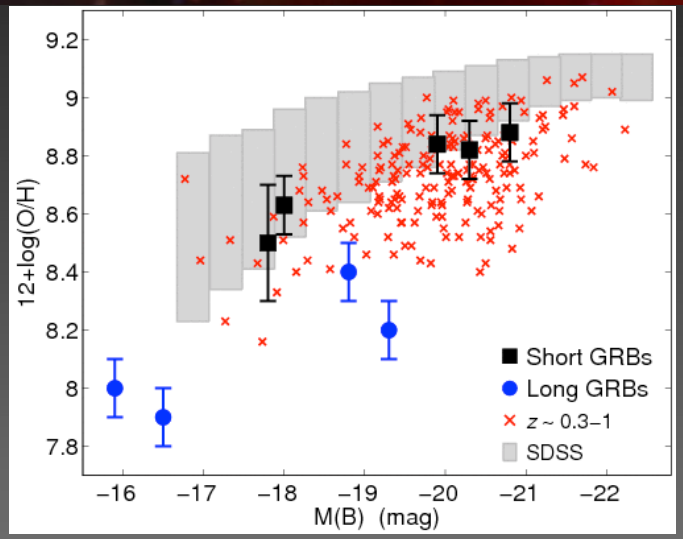
# Star Formation Rates




Berger 2009

Short GRB hosts have lower specific star formation rates than long GRB hosts; they trace the general galaxy population

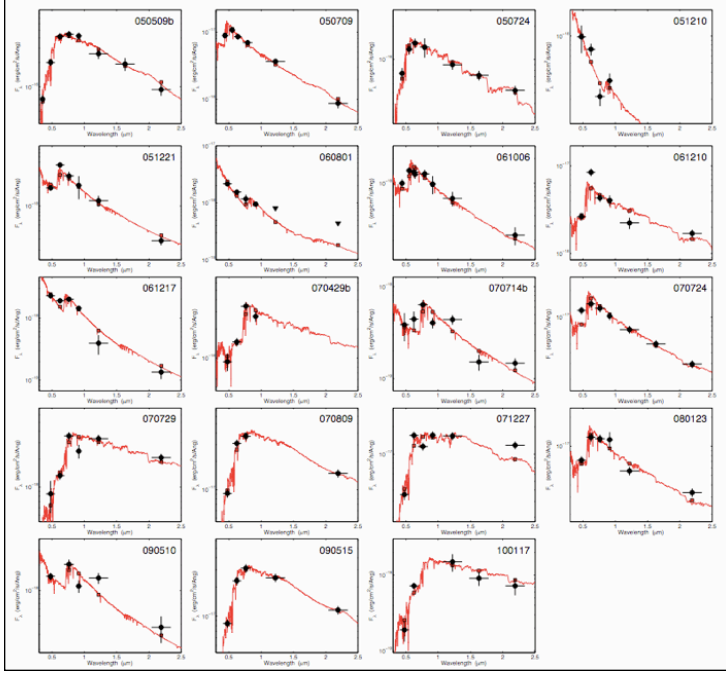
# Metallicities




Berger 2009

Short GRB hosts have higher metallicities than long GRB hosts; they trace the general galaxy population

# Stellar Masses & Ages



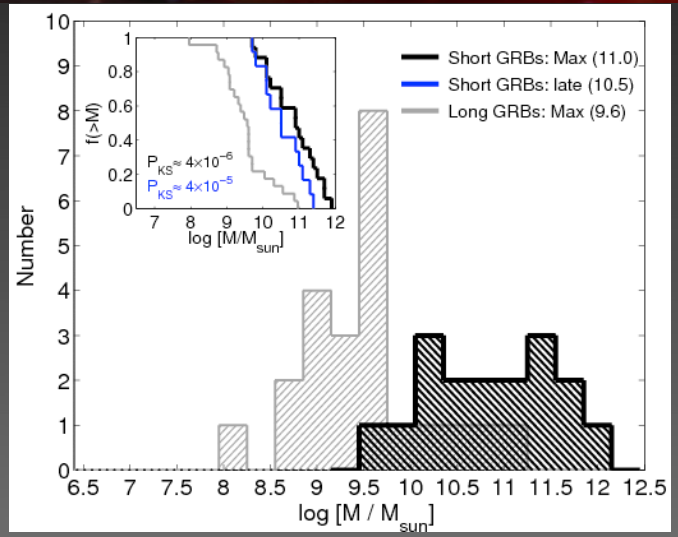

Leibler & Berger 2010

$\log(M_*) \sim 8.8-11.6$

$\log(M_{max}) \sim 9.7-12$

$\tau_* \sim 0.03-4.4$ Gyr

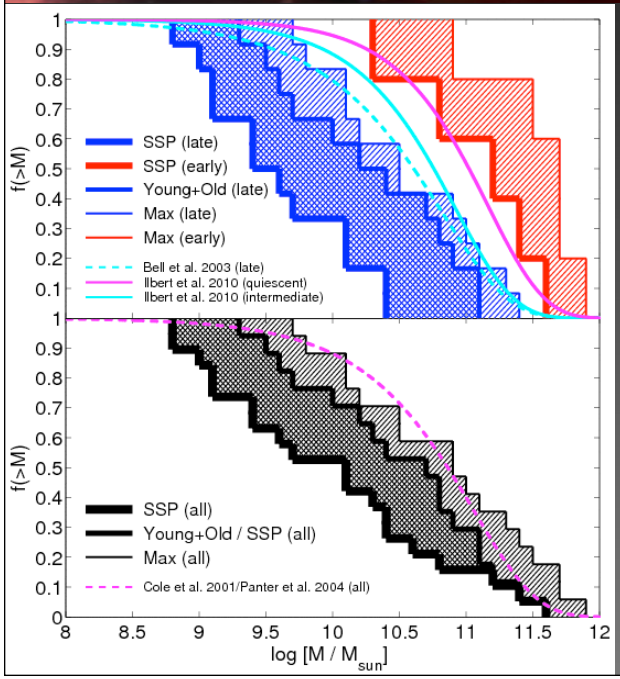
# Stellar Masses




Leibler & Berger 2010

Short GRB hosts (including late-types) have higher masses than long GRB hosts

# Stellar Masses vs. Galaxy Mass Function



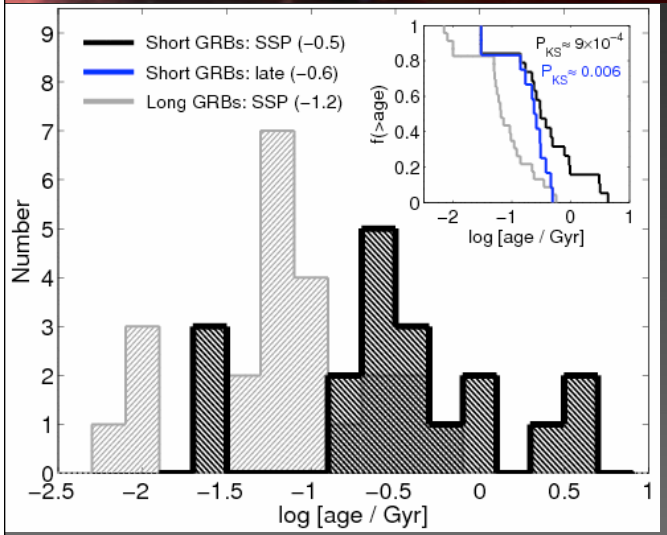

Leibler & Berger 2010

- Short GRBs in early-type hosts track stellar mass
- Late-type hosts have lower masses than expected
- This is supported by the dominant fraction of late-type hosts (1:1 expected)

$R_{ell} \sim 6\times10^{-12}$ per $M_\odot$

$R_{sp} \sim 2\times10^{-11}$ per $M_\odot$

# Stellar Population Ages




Leibler & Berger 2010

$\tau_{short,sp}$ ~ 0.3 Gyr

$\tau_{short,ell}$ ~ 3 Gyr

$\tau_{long}$ ~ 60 Myr

Short GRB hosts (including late-types) have older ages than long GRB hosts

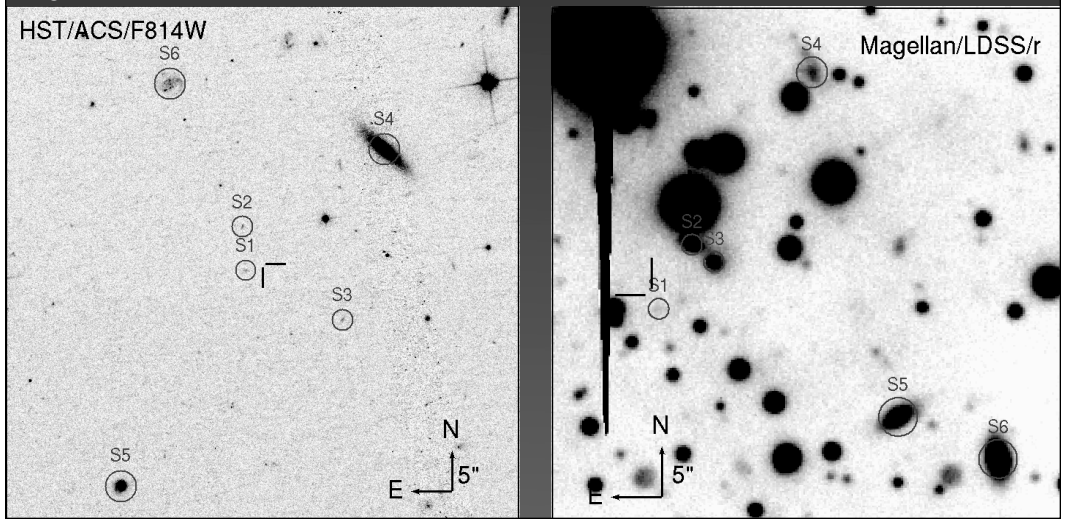
# *Implications I*

- Short GRBs do not select galaxies just by stellar mass; star formation appears to play a role
- Short GRB progenitors in ellipticals have ages of ~few Gyr; if the progenitors in spirals track star formation their ages are ~0.3 Gyr
- Even if short GRBs in spirals track star formation, their progenitors are much older than long GRB progenitors (with $\tau$~0.05 Gyr)
- We should not trivially reclassify GRBs into Type I and II for events that do not and do track star formation

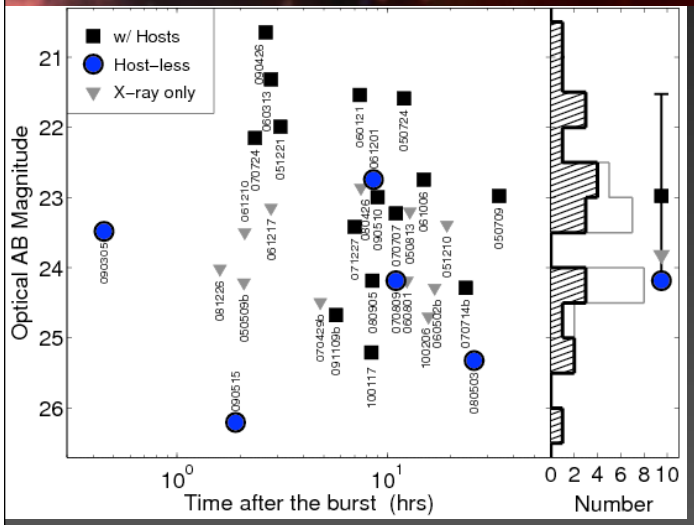
# *Robust Evidence for Large Kicks?*

In the sample of 20 short GRBs with optical positions, 5 events have no coincident host galaxies to >26 mag

Berger 2010



# *Is there Evidence for Kicks?*




Berger 2010

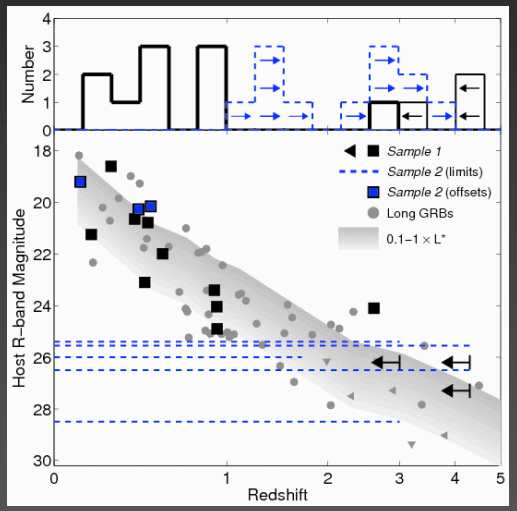
*Option 1:*

Underlying hosts >26 mag (high redshift)

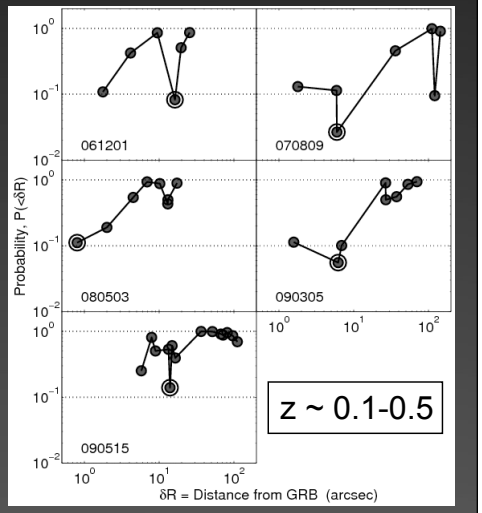
*Option 2:*

Offsets due to kicks / GCs (low density)

# *Is there Evidence for Kicks?*

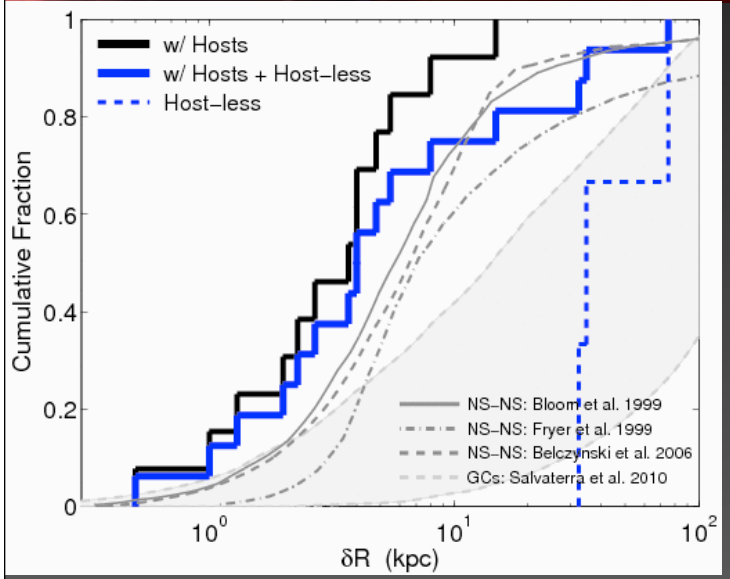



<u>high-z:</u> if they are the same galaxies
⇒ bimodal redshift distribution




<u>Offsets:</u> galaxies w/ low chance coincidence probability at ~10”

# Kicks? GCs?




Berger 2010

Extension to large offsets consistent with NS-NS kicks or ~20% subset in globular clusters

# *Implications II*

- Short GRBs with optical afterglows and no coincident hosts are likely due to kicks/GCs; alternatively, a bimodal redshift distribution

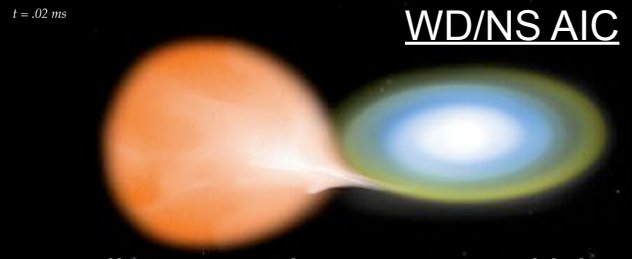
The preponderance of evidence points to NS-NS/NS-BH binaries as the progenitors of most short GRBs.

# *Short GRB Progenitor Models*

<u>NS-NS / NS-BH</u>

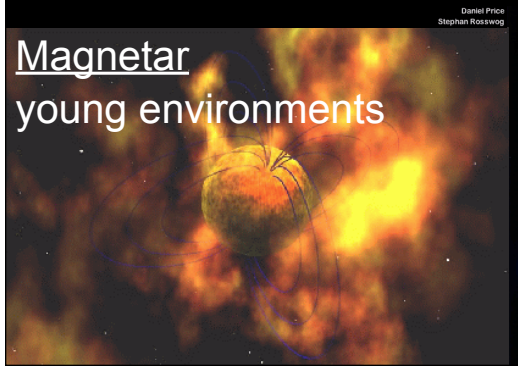
diverse environments

"kicks"



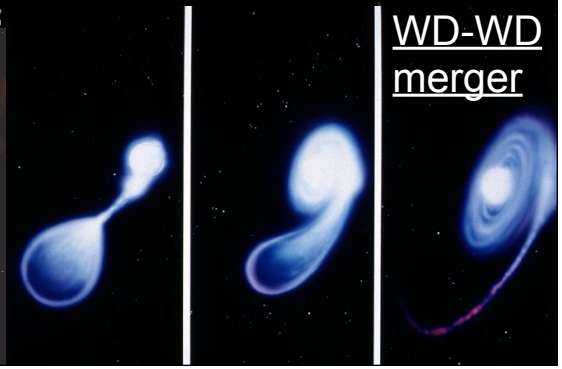

<u>WD/NS AIC</u>

diverse environments; no kicks




<u>Magnetar</u>

young environments



<u>WD-WD merger</u>