

An Overview of Electromagnetic Sources Associated with Black Hole Mergers

Jeremy Schnittman

Johns Hopkins University

STScI

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Observing supermassive black hole mergers will teach us about

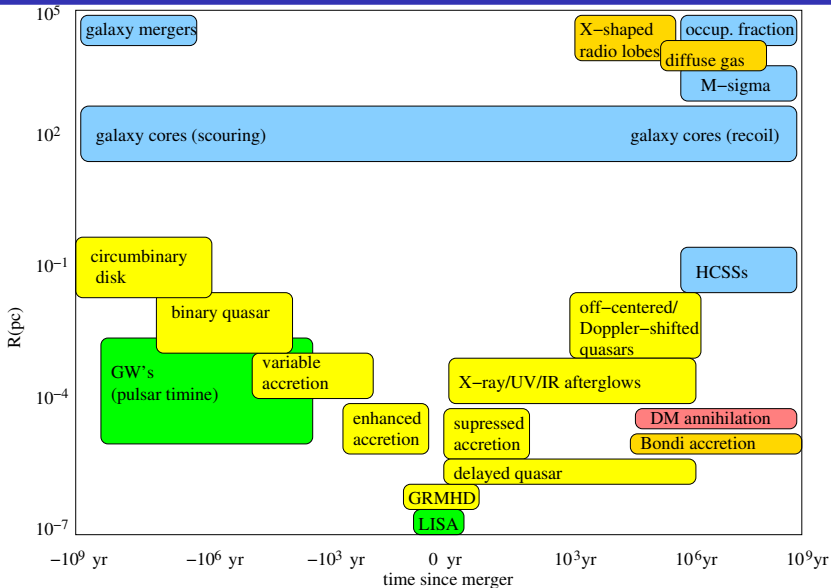
- Relativity
- High-energy Astrophysics
- Cosmology
- Galaxy Formation and Evolution
- Stellar Evolution
- Dark Matter



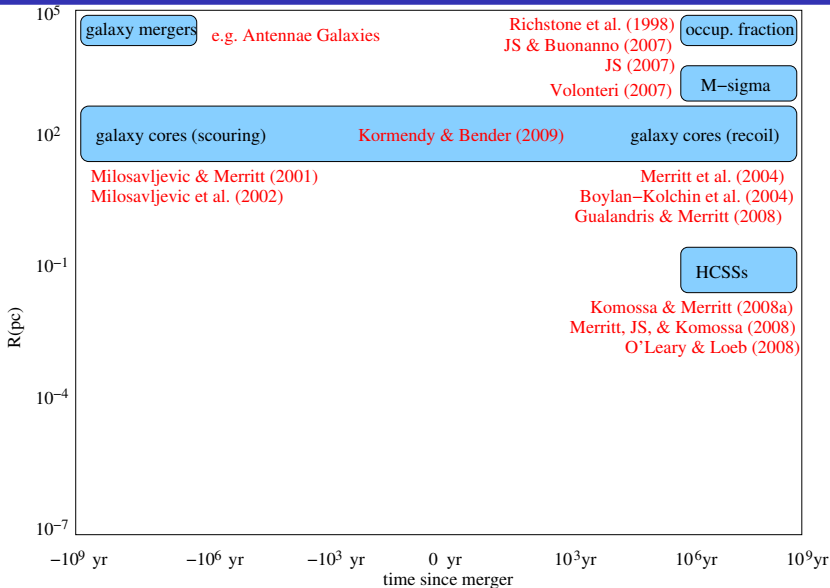
- Sources (what we have imagined so far)
- What we know
- What we don't know
 - What we need to know
 - What we will learn
 - What we will not learn
- What do we do next



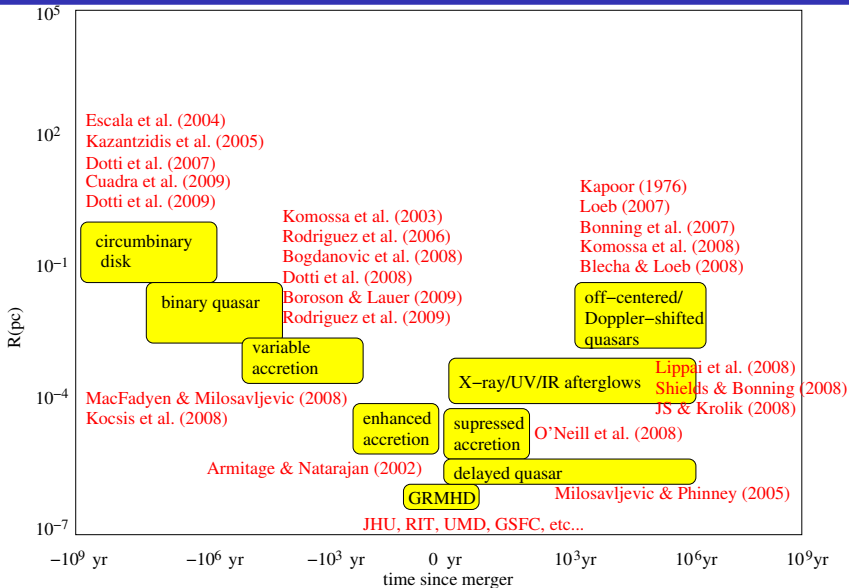
Diversity of Sources



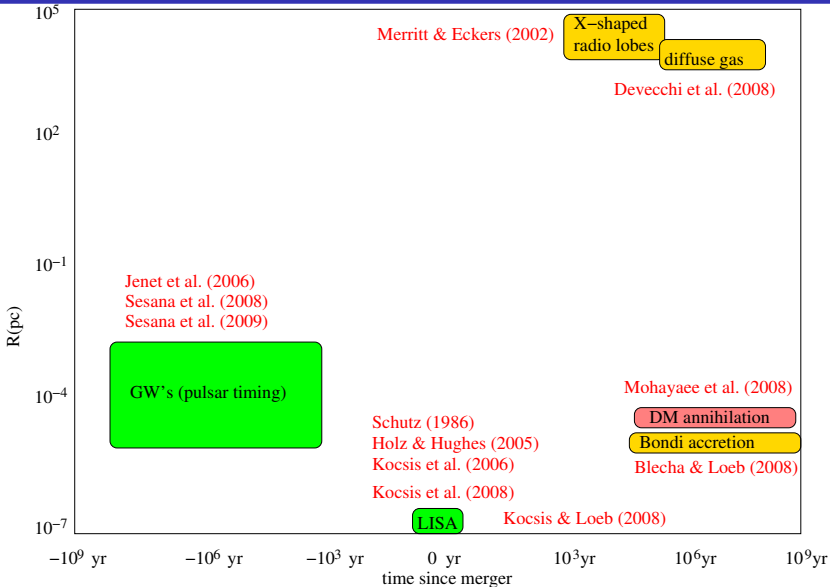
Stellar signatures



Gas/disk signatures



Other signatures



What do we know?

- galaxy mergers + ubiquitous SMBHs
- remarkably few AGN pairs
- phases of BHB evolution
 - stellar dynamical friction
 - gas dynamical friction
 - (final parsec?)
 - GW loss
- post-Newtonian + numerical relativity



What do we need to know?

- galaxy merger rates
- BH parameters
 - BH masses
 - BH spins: amplitude and orientation
- BH environment prior to merger
 - quantity and quality of gas
 - stellar distribution and age/metallicity
 - properties of circumbinary disk



What we will learn

- LISA: merger rates, masses, spins, but only for $M \lesssim 10^{6-7} M_{\odot}$
- L_D vs z out to $z \sim 1$
- galaxy environs: gas vs stars
- high-velocity end of kick distribution
- time delay between galaxy, BH merger



What we will not learn

- BH mass function for $M \gtrsim 10^7 M_\odot$
- L_D vs z for $z > 1$
- low-velocity end of kick distribution
- anything about extra-solar planets (probably)



What do we do next—theory

- full NR+MHD
- good initial conditions for circumbinary disk
- grid-based code vs. geodesics/SPH
- high-resolution N-body simulations of galactic nuclei
- cosmological N-body plus hydro



What do we do next—observations

- binary AGN: SDSS + long-term spectroscopic followups
- LISA counterparts/precursors: wide-field time domain surveys
- pulsar timing: more pulsars, ~ 10 ns resolution
- afterglows: wide-field multi-band surveys
- cores/star clusters: HST imaging + hires spectra



EM signatures of BH mergers are valuable as:

- Probes of strong-field GR (mass loss, kicks)
- Probes of accretion disk properties
- Cosmological observations
 - SMBH growth (mergers vs. accretion)
 - mass/spin distribution functions
 - M_{BH} , M_{bulge} , σ_{bulge} relationships
- LISA counterparts
 - distance ladder in a single step
 - luminosity-redshift to $\lesssim 1\%$

