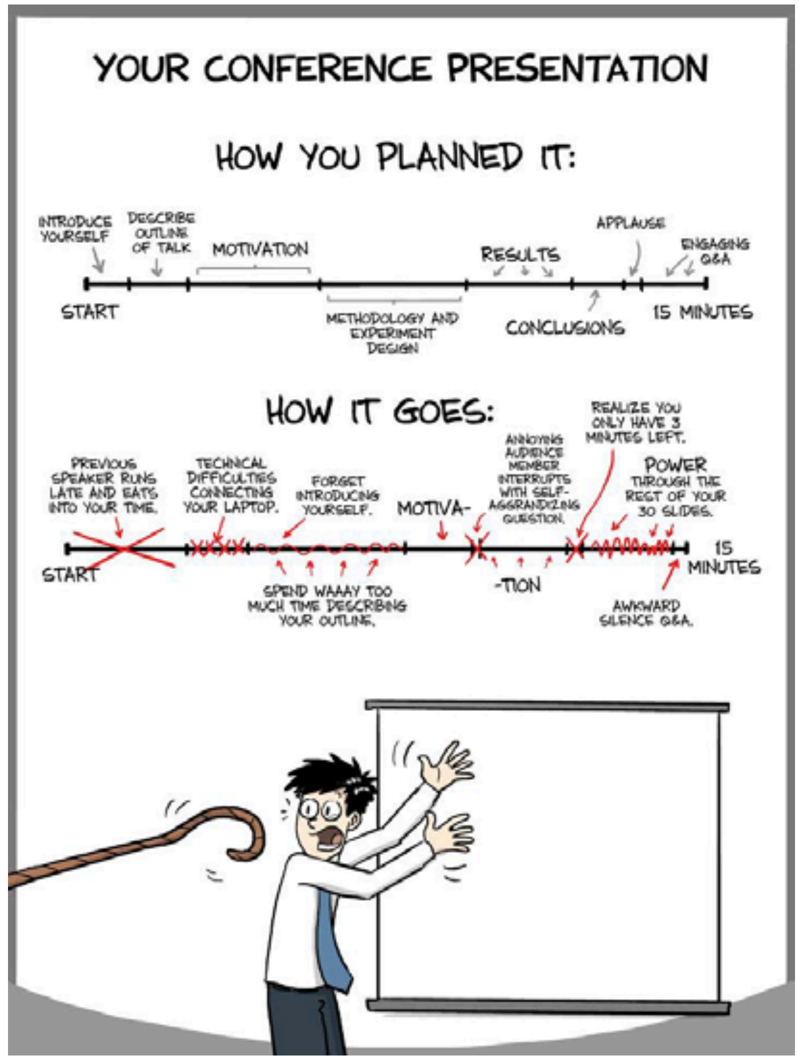
Penn State Gravitational-Wave Astronomy Group

Gravitational Waves and the Final Parsec Problem



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Work in collaboration with X. Deng

There is no satisfying understanding of how $M > 10^8 M_\odot$ binaries coalescence from $a \sim 1$ pc in $t < t_H$

Post-merger, dynamical friction drives merger until separation reaches ~ 1 pc

Dynamical Friction: SMBH passing through stellar field leaves over-dense wake, whose gravity acts to slow SMBH

Dynamical friction turns-off when mass enclosed becomes less than ~twice the binary mass: $a \sim 1$ pc

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Gravitational wave radiation reaction can drive black holes to coalescence in $t < t_H$ once $a \lesssim 0.2$ pc for a $M = 10^9 + 10^8\ M_\odot$ binary

$$\Delta T \lesssim 1 \times 10^{10}\,\mathrm{yr} \left(\frac{a}{0.2\,\mathrm{pc}}\right)^4 \left(\frac{10^9\,\mathrm{M}_\odot}{M}\right)^3 \left(\frac{1/10}{\eta}\right)$$

$m_1 m_2 / M^2$

Suggestions for spanning the last pc include sling-shot ejection of individual stars & gas dynamical processes (may increase eccentricity)

*Whatever drives the last pc of coalescence must act **much** more rapidly than gravitational wave radiation reaction*

Few year PTA gravitational wave observation can measure driver action over ~ $3\times10^2 - 3\times10^3$ yrs!

Some PTA binaries are being driven by unknown decay mechanism

$$f_{\rm GW} \simeq 8\,{\rm y}\left(\frac{a}{0.1\,{\rm pc}}\right)^{3/2}\left(\frac{10^9\,{\rm M}_\odot}{M}\right)^{1/2}$$

Timing residual amplitude in a given array pulsar depends on binary decay driver

pulsar distance

wave propagation direction

pulsar direction

$$\tau_{\rm GW}(t) \simeq \omega^{-1}\left\{h[t] - h[t - L(1+\hat{k}\cdot\hat{n})]\right\}$$

$$\simeq \omega^{-1} e^{i(\Phi+\Delta\Phi/2)}\sin\frac{\Delta\Phi}{2}$$

$\Delta\Phi/2$ = Change in binary phase over interval $L(1+\hat{k}\cdot\hat{n})$

Different pulsars, different distances, different projection angles, different $\Delta\Phi \bmod 2\pi$

Posterior probability distribution binary parameters includes binary period rate

Measurement requires distance to (some) timing pulsars (more better)

SKA can be expected to measure distances to 20 MSPs @0.5-1 kpc with better than 1 ly uncertainty

Smits et al. 2011. A&A **528**; priv. comm.

Measurement requires resolvable sources

If you believe in an SMBHB “stochastic background” then you also believe these exist (and, in significant number)

Measurement will capture mechanism acting near transition to gravitational wave driver

Can’t have everything ;)