Bayesian Inference of Star Formation History in the Host Galaxies of Tidal Disruption Events

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Project Aims

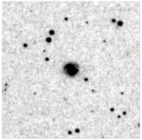


Figure: AT2019qiz Host Galaxy

- Investigate the statistical behaviour of the star formation in the host galaxies of tidal disruption events.

Motivation: XSHOOTER Targets

TDE	m	z
ASASSN-14li	15	0.0206
ASASSN-15oi	16	0.0484
AT2018fyk	17	0.06
AT2019ahk	17	0.026211
AT2019azh	15	0.022
AT2019dsg	15	0.0512
AT2019qiz	15	0.01513
iPTF16fnl	16	0.018
AT2018hyz	17	0.04573
ASASSN-14ae	17	0.0436

Table: The XSHOOTER targets on tidal disruption events.

Active Galactic Nuclei (AGN)

- Compact, highly luminous nuclear region.
- Broad spectral energy distribution.
- Strong (and sometimes broad) emission lines.
- Variability over short timescales.

Active Galactic Nuclei (AGN)

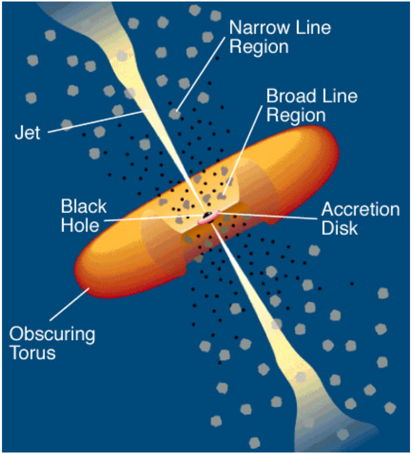


Figure: Accretion of matter onto surface of a black hole. Image adapted from Urry and Padovani 1995.

The Starburst-AGN Connection

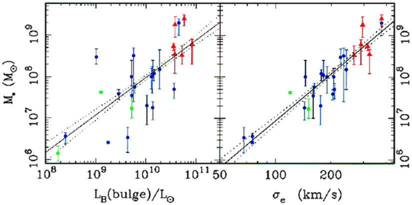


Figure: Strong relationship between star formation and black hole mass. Image adapted from Veilleux 2008.

- Cosmologically important impact on galaxy formation and evolution.

Possible mechanisms?

- Gas or radiation pressure from starbursts and/or AGN-driven wind shuts off black hole fuel supply.
- AGN is a possible source of quenching.
- Direction of causation unclear.
- Need more information...

Tidal Disruption Events

Figure: TDE impression, image credit NASA/JPL-Caltech.

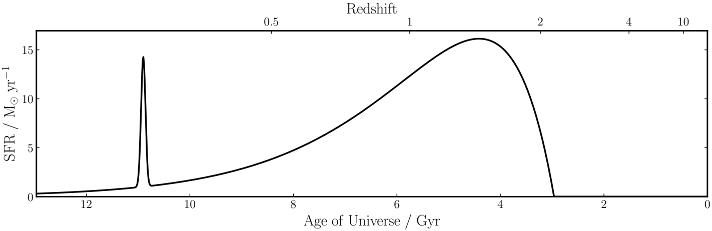
- Do TDEs exhibit the same statistical behaviour?

The BAGPIPEs Module

Bayesian Analysis of Galaxies for Physical Inference and Parameter EStimation.

- Simulation of galactic spectra from SFH.
- Fit real spectra to plausible SFH.

The BAGPIPEs Module



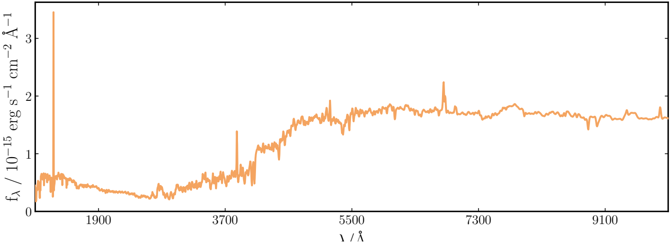


Figure: Simulated SFH and spectrum.

The BAGPIPEs Module

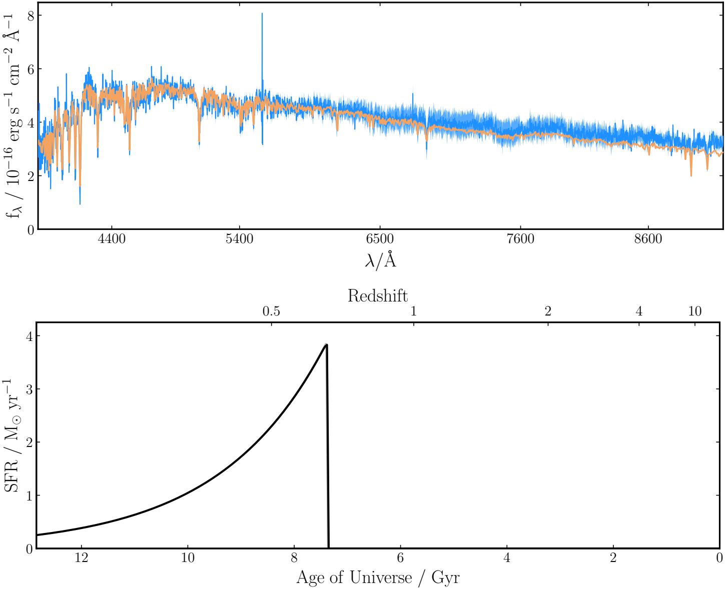


Figure: Observed and fitted spectrum, with inferred SFH.

Stellar Population Dating

Mass (solar masses)	Time (years)	Spectral type
60	3 million	O3
30	11 million	O7
10	32 million	B4
3	370 million	A5
1.5	3 billion	F5
1	10 billion	G2 (Sun)
0.1	1000s billions	M7

Figure: Stellar lifetimes and spectral type.

- Poor temporal resolution in SFR beyond 1 billion years.

Stellar Population Dating

TABLE 2

Number density in the solar neighbourhood brighter than absolute magnitude +16 by spectral type and class, per 10,000 pc^3

	Spectral type							
Class	O	B	A	F	G	K	M	Totals
Giants				0.5	1.6	4	0.25	6.3
Main sequence	0.00025	1	5	25	63	100	630	800
White dwarfs		63	100	50	50	25		250

Figure: Number density of spectral types. Table adapted from Glenn 2001.

- Poor temporal resolution beyond 1 billion years.

Stellar Population Dating

- Solution? Parameterise metallicity as well.
- How do Lyman and Balmer series lines evolve with starburst age?
- What about other metal lines?

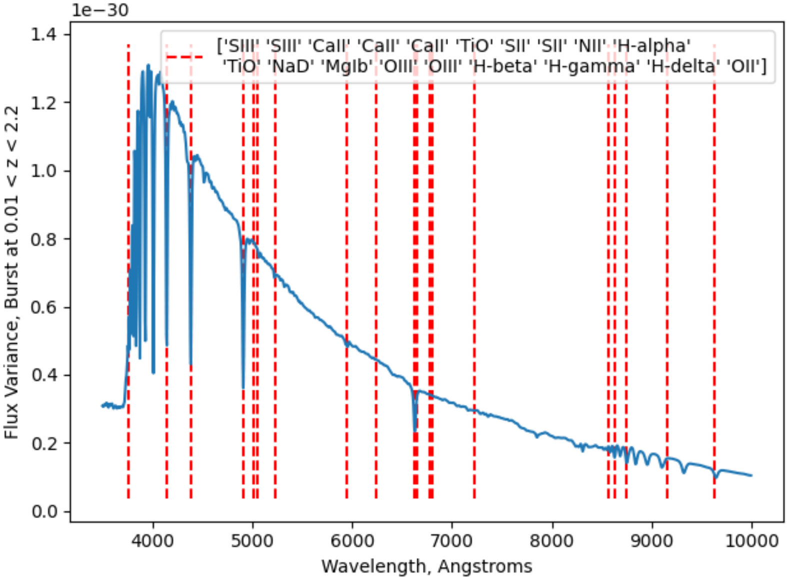


Figure: Variance in flux, over starburst evolved from z=2.2 to z=0.01.

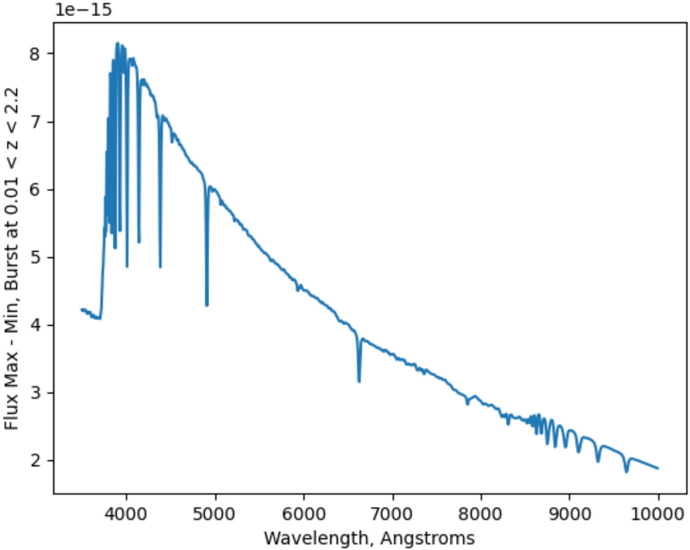


Figure: Deltas in flux, over starburst evolved from z=2.2 to z=0.01.

SFH Inference - What is possible?

- Blind fitting of spectra with known priors.
- Fitting multiple SFH forms.
- Iterative fitting.

Exploring the SFH Parameter Space

R1: Entire Parameter Space with Two Components

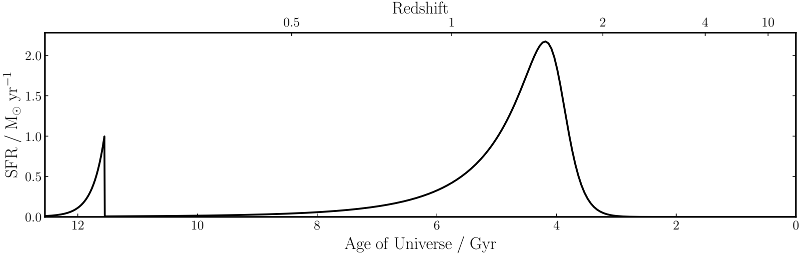


Figure: Example SFH.

- Constrain z to be less than or equal to the TDE targets
- Assume separate bulk formation and burst events

Exploring the SFH Parameter Space

R2 & R3: Iterative Fitting

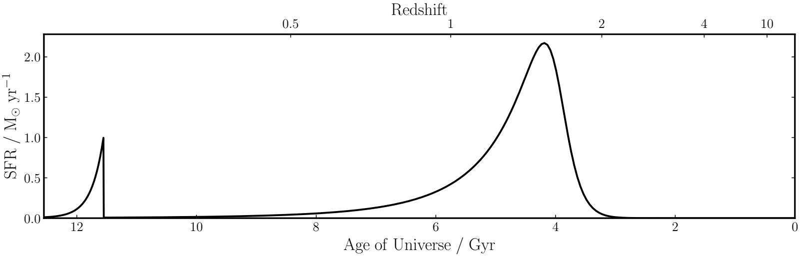


Figure: Example SFH.

- Insist burst component is younger than the bulk formation

Exploring the SFH Parameter Space

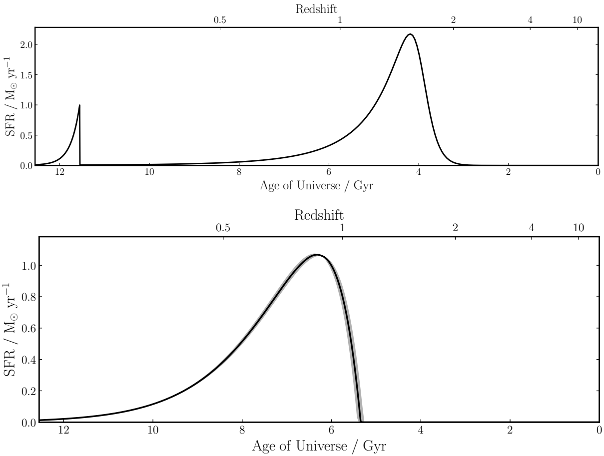


Figure: Prior and posterior SFH.

- "Best" fits favour single component star formation.

Selecting Physically Reasonable Priors

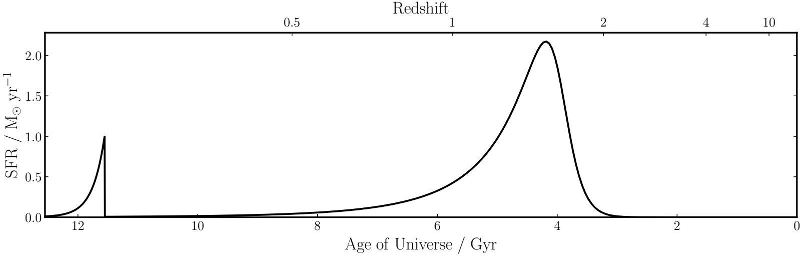


Figure: Example SFH.

- SPS limits burst detection.
- Precise form of old formation is unimportant.

Selecting Physically Reasonable Priors

R4: Fixed Old Component, Free Burst Component

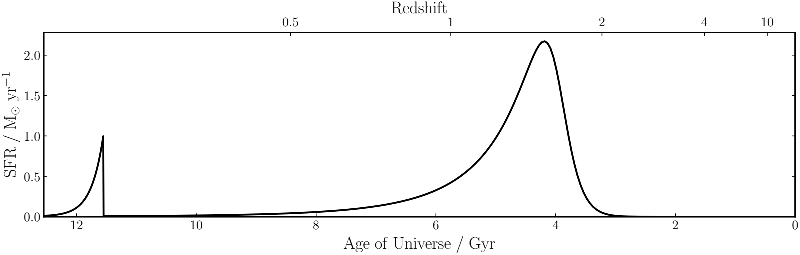


Figure: Example SFH.

Conclusion:

- Impose a lower limit on bulk formation age and mass.
- Impose an upper limit on burst age, but let mass vary freely.

Selecting Physically Reasonable Priors

R4: Fixed Old Component, Free Burst Component

Other refined priors:

- Velocity dispersion, σ_v
- Birth cloud lifetime, τ_{BC}
- Metallicity, Z
- Extinction, A_V
- Nebular ionisation, U

Blind Fitting Results with R4 Priors

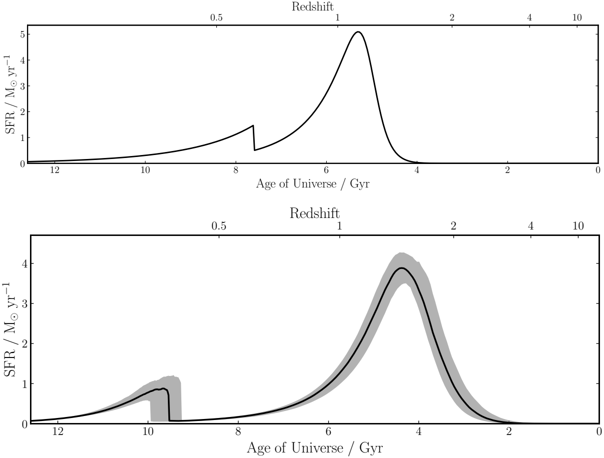
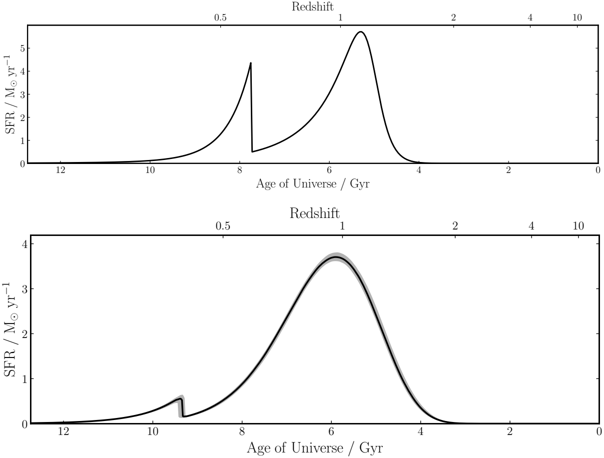


Figure: Prior and posterior SFH.

Blind Fitting Results with R4 Priors



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Blind Fitting Results with R4 Priors

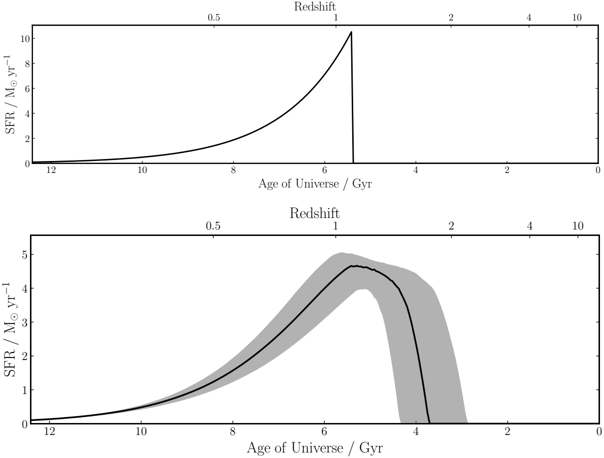
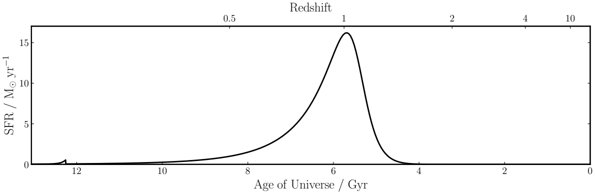


Figure: Prior and posterior SFH.

Blind Fitting Results with R4 Priors



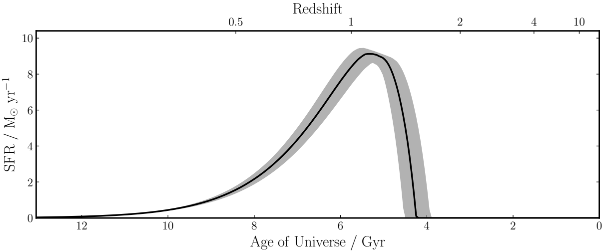


Figure: Prior and posterior SFH.

Blind Fitting Results with R4 Priors

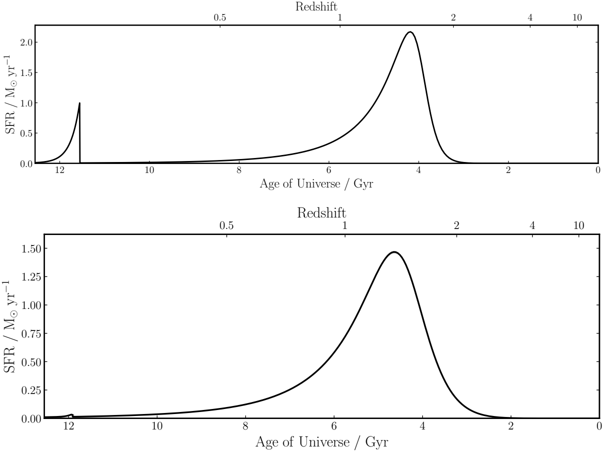
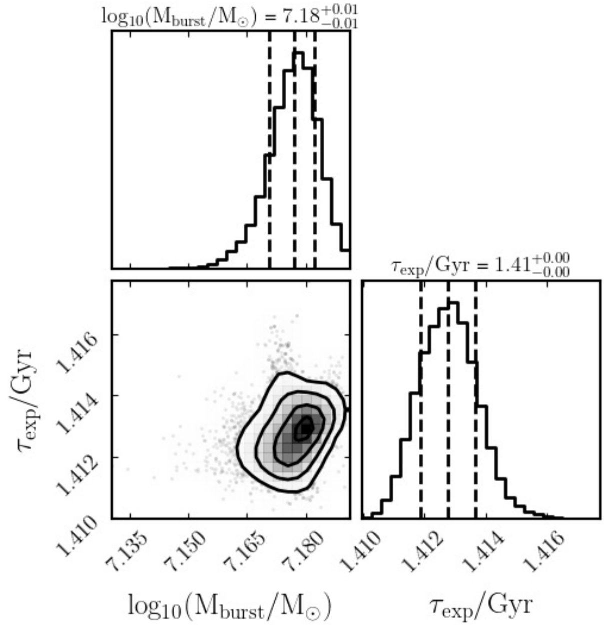


Figure: Prior and posterior SFH.

Correlated Parameters



Application to XSHOOTER Data

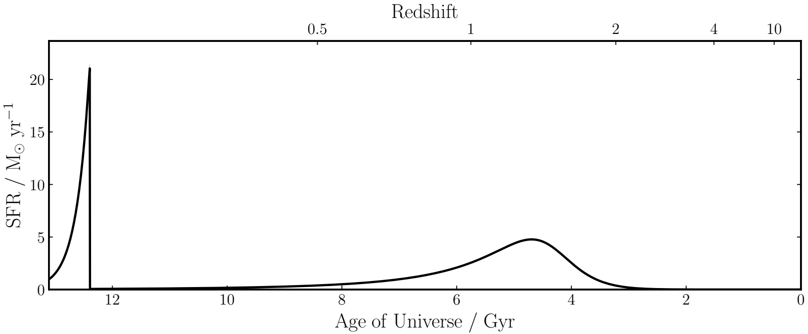


Figure: Posterior SFH for AT2019ahk.

Application to XSHOOTER Data

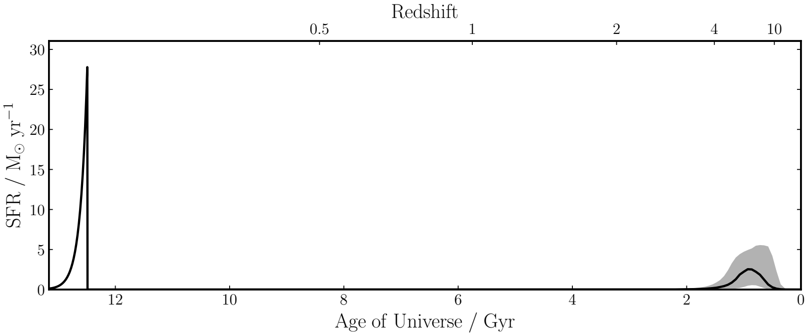


Figure: Posterior SFH for AT2019azh.

Application to XSHOOTER Data

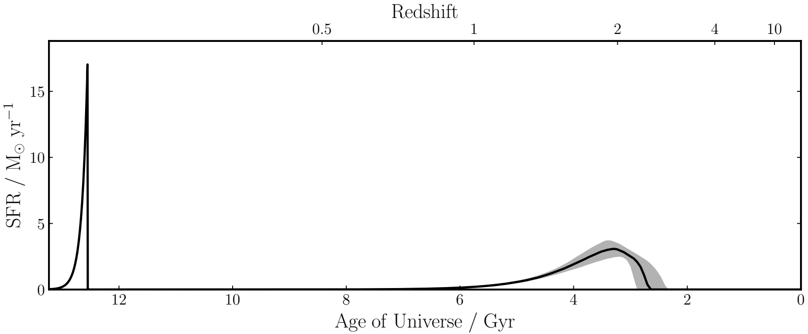


Figure: Posterior SFH for iPTF16fnl.

Application to XSHOOTER Data

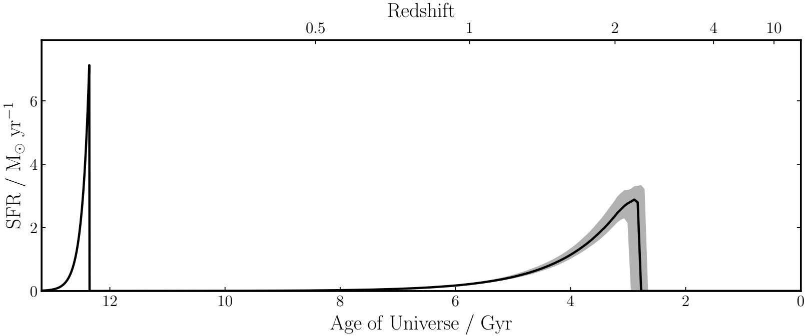


Figure: Posterior SFH for ASASSN14li.

Application to XSHOOTER Data

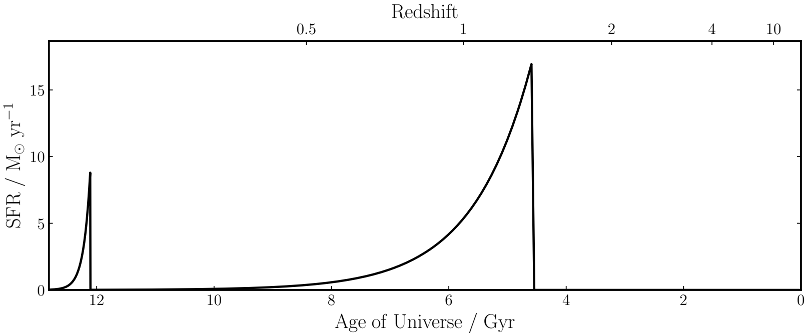


Figure: Posterior SFH for ASASSN15oi.

Application to XSHOOTER Data

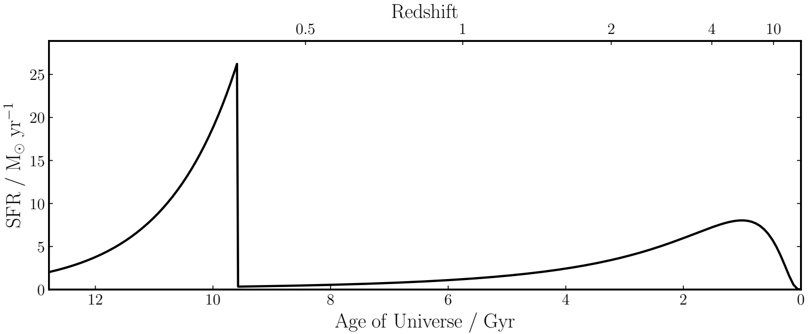


Figure: Posterior SFH for AT2019dsg.

Conclusions

Figure: TDE impression, image credit NASA/JPL-Caltech.

- Starbursts are detectable **IF** recent
- Assumptions about host SFH history must be made
- TDE hosts exhibit strong starburst features

Future Applications

- Larger sample size.
- Tailor priors to host morphology.
- Compare with Hubble analogues, and Seyferts.

Questions?