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

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# Project Aims

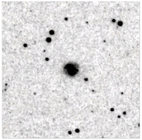

Figure: AT2019qiz Host Galaxy

- 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)

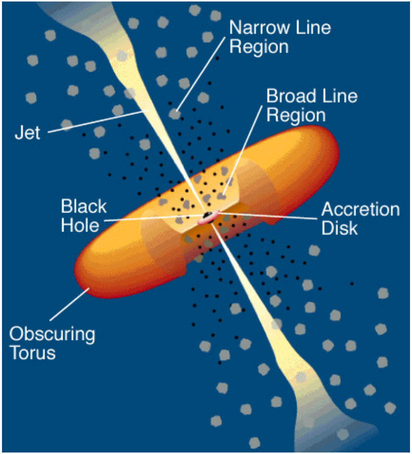


Figure: Accretion of matter onto surface of a black hole. Image adapted from Urry and Padovani 1995.

# The Starburst-AGN Connection

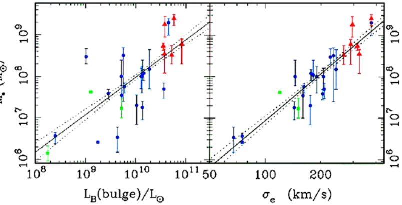


Figure: Strong relationship between star formation and black hole mass. Image adapted from Veilleux 2008.

- 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.
- Direction of causation unclear.
- AGN is a possible source of quenching.
- 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

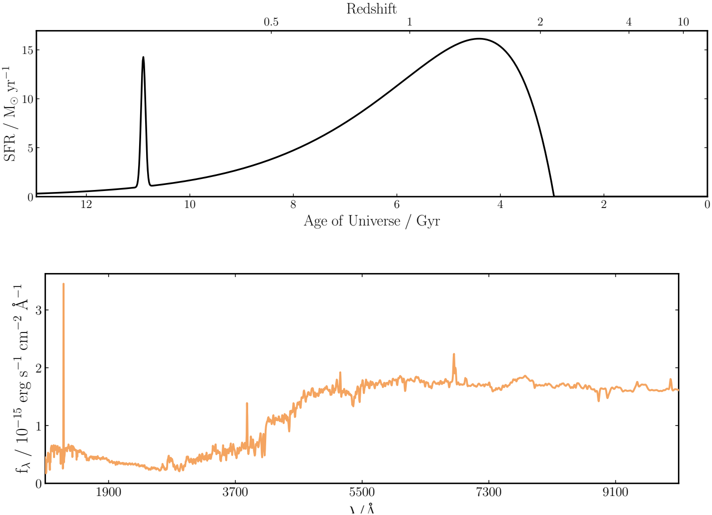


Figure: Simulated SFH and spectrum.

# The BAGPIPEs Module

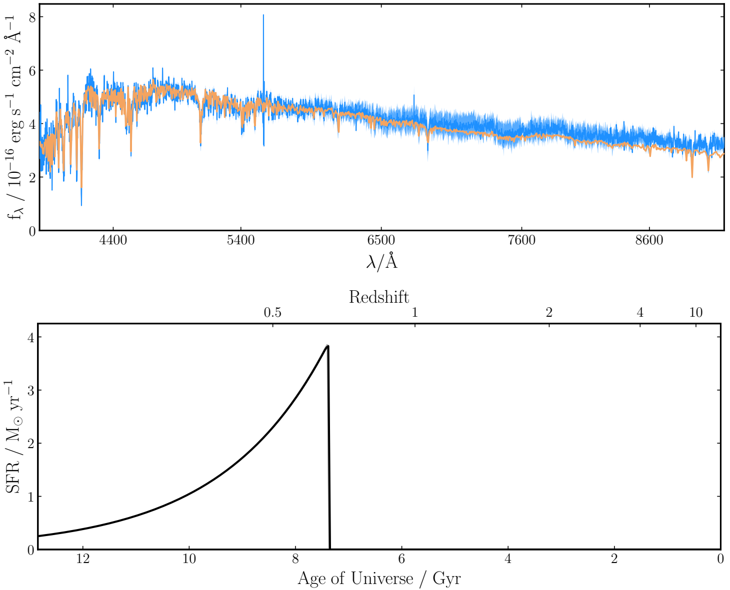


Figure: Observed and fitted spectrum, with inferred SFH.

# 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?

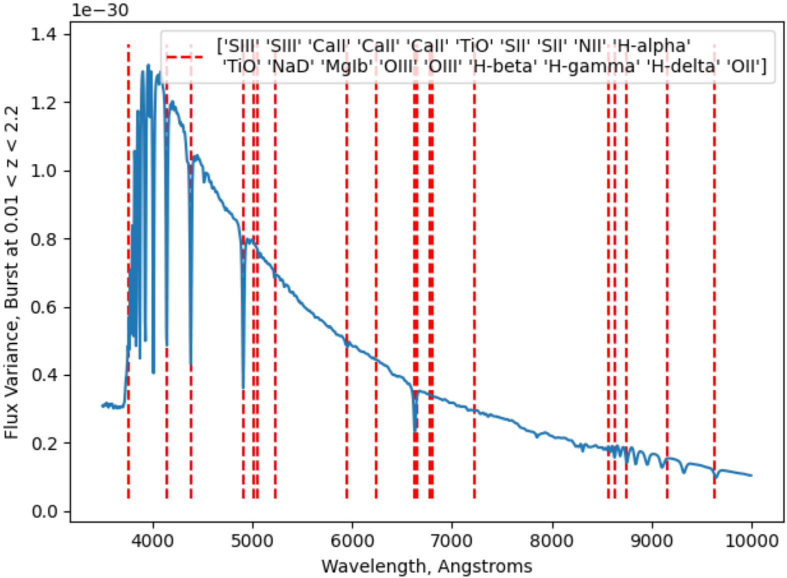


Figure: Variance in flux, over starburst evolved from z=2.2 to z=0.01.

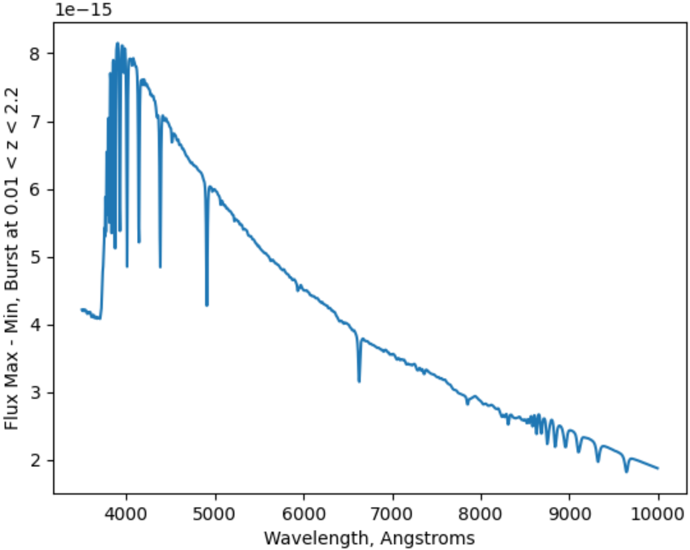


Figure: Deltas in flux, over starburst evolved from z=2.2 to z=0.01.

# 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

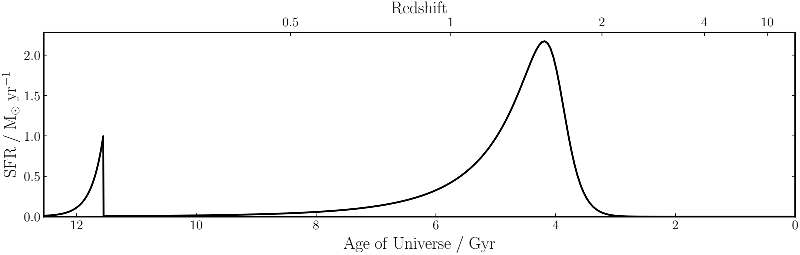


Figure: Example SFH.

- 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

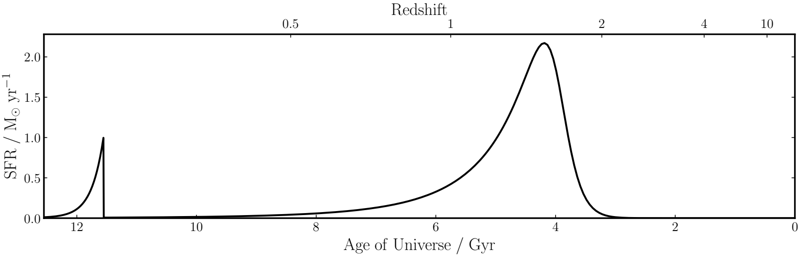


Figure: Example SFH.

- Insist burst component is younger than the bulk formation

# Exploring the SFH Parameter Space

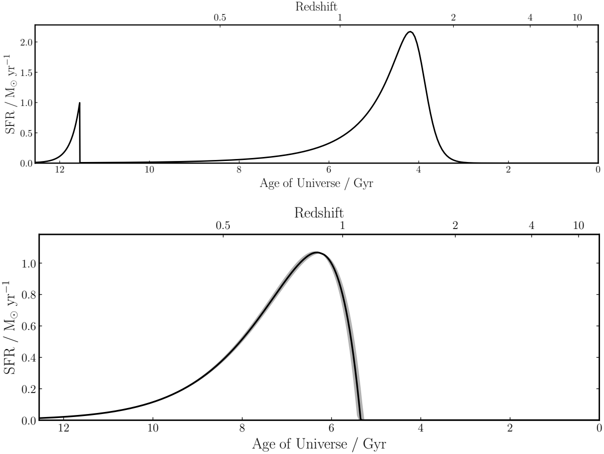


Figure: Prior and posterior SFH.

- "Best" fits favour single component star formation.

# Selecting Physically Reasonable Priors

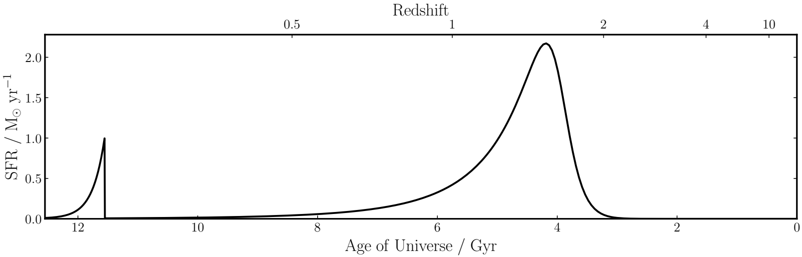


Figure: Example SFH.

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

# Selecting Physically Reasonable Priors

**R4: Fixed Old Component, Free Burst Component**

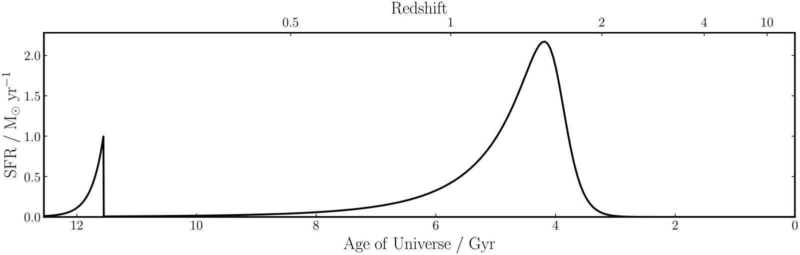


Figure: Example SFH.

**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, $\sigma_v$
- Birth cloud lifetime, $\tau_{BC}$
- Metallicity, $Z$
- Extinction, $A_V$
- Nebular ionisation, $U$

# Blind Fitting Results with R4 Priors

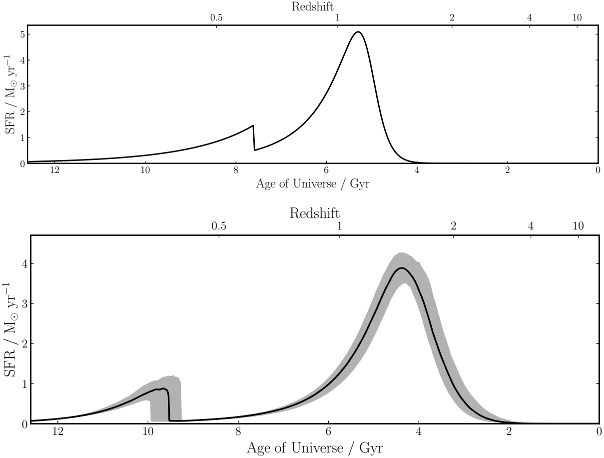


Figure: Prior and posterior SFH.

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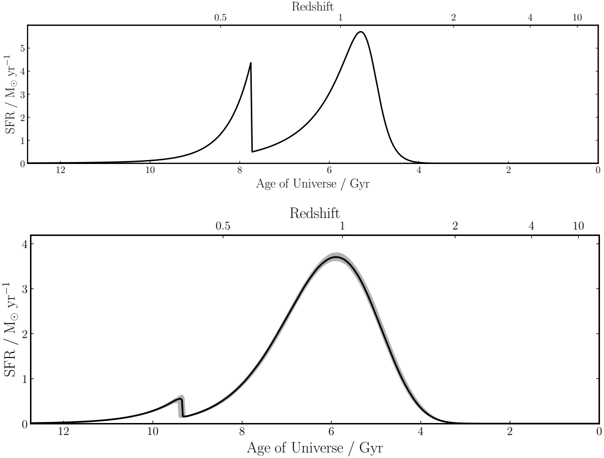


Figure: Prior and posterior SFH.

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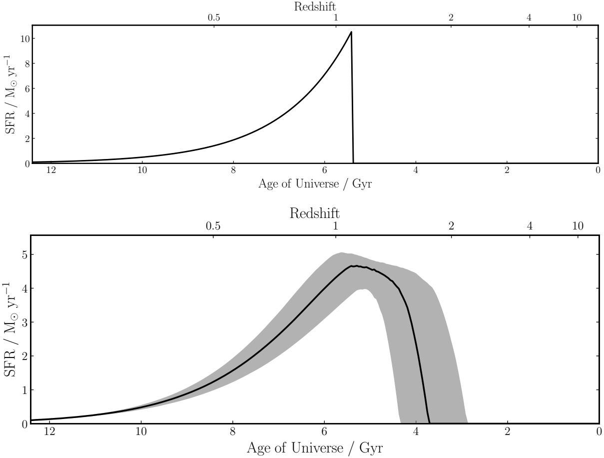


Figure: Prior and posterior SFH.

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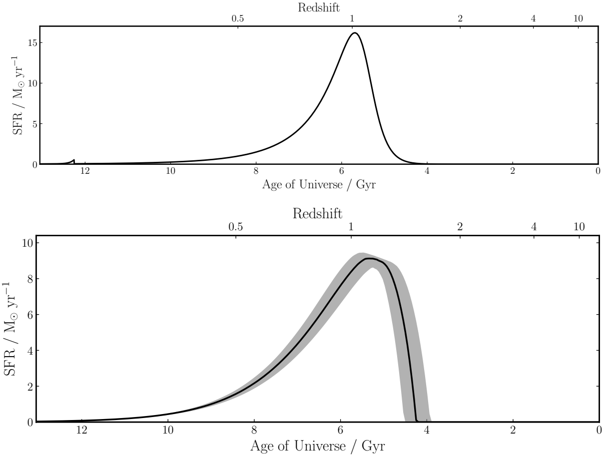


Figure: Prior and posterior SFH.

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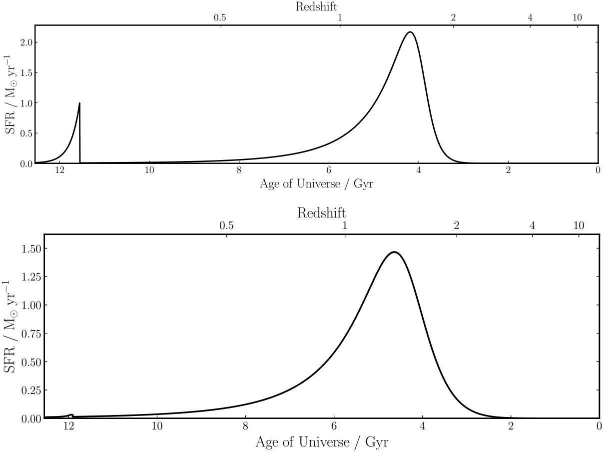
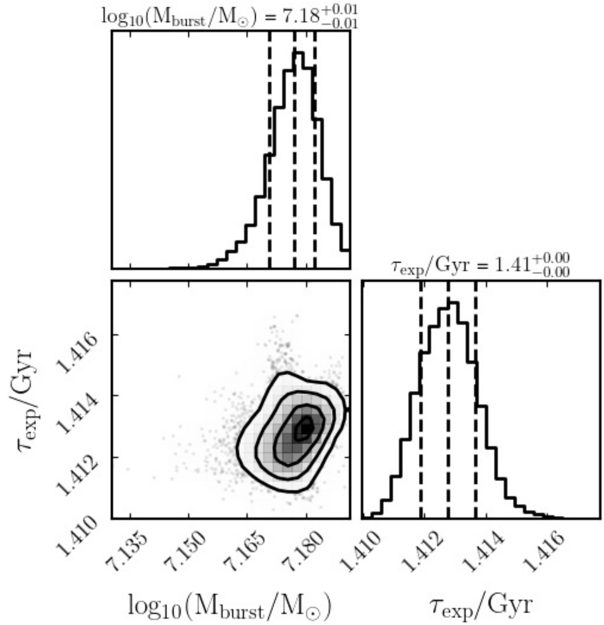



Figure: Prior and posterior SFH.

# Correlated Parameters



# Application to XSHOOTER Data

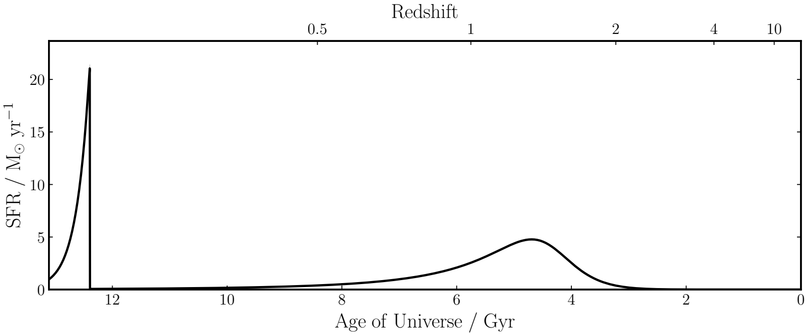



Figure: Posterior SFH for AT2019ahk.

# Application to XSHOOTER Data

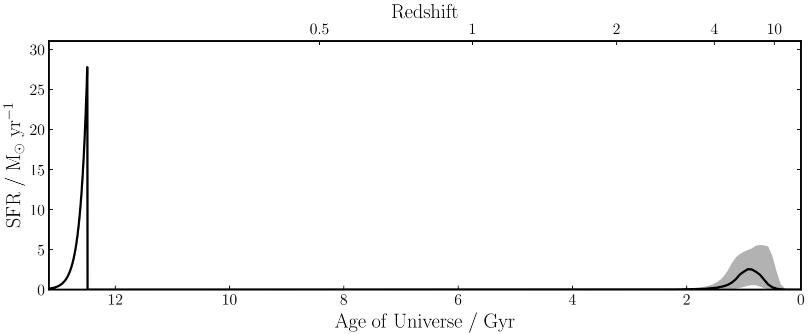



Figure: Posterior SFH for AT2019azh.

# Application to XSHOOTER Data

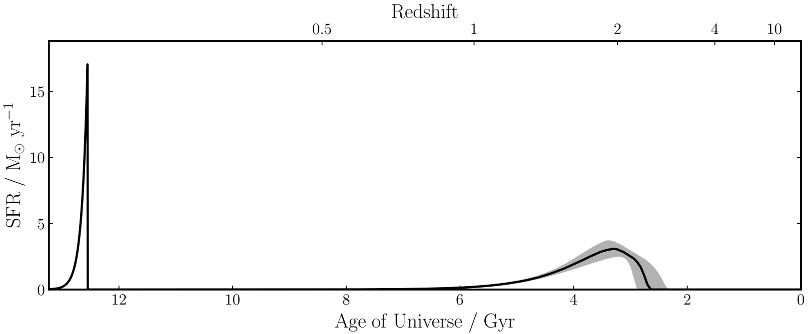



Figure: Posterior SFH for iPTF16fnl.

# Application to XSHOOTER Data

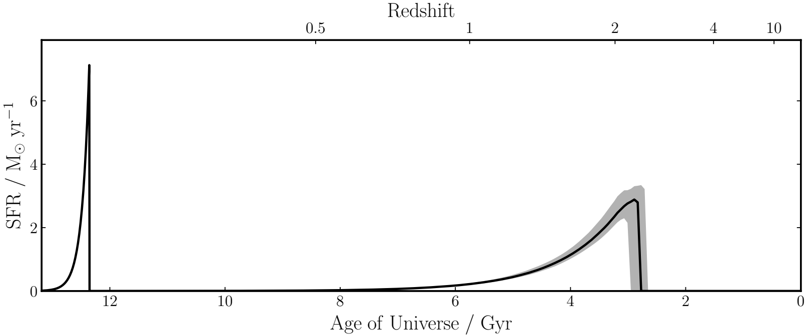



Figure: Posterior SFH for ASASSN14li.

# Application to XSHOOTER Data

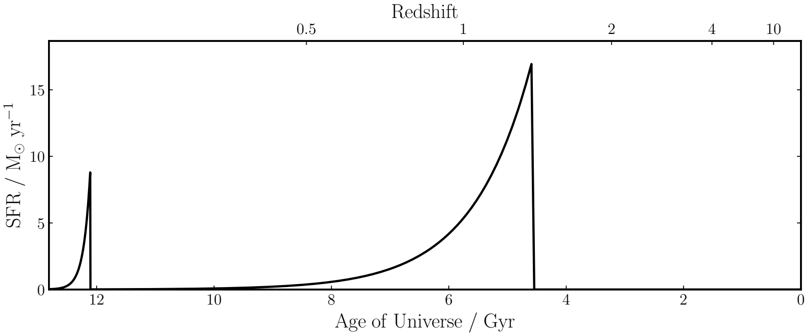



Figure: Posterior SFH for ASASSN15oi.

# Application to XSHOOTER Data

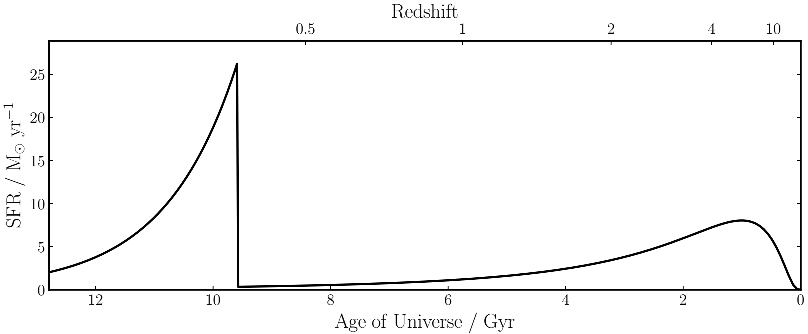



Figure: Posterior SFH for AT2019dsg.

# 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.