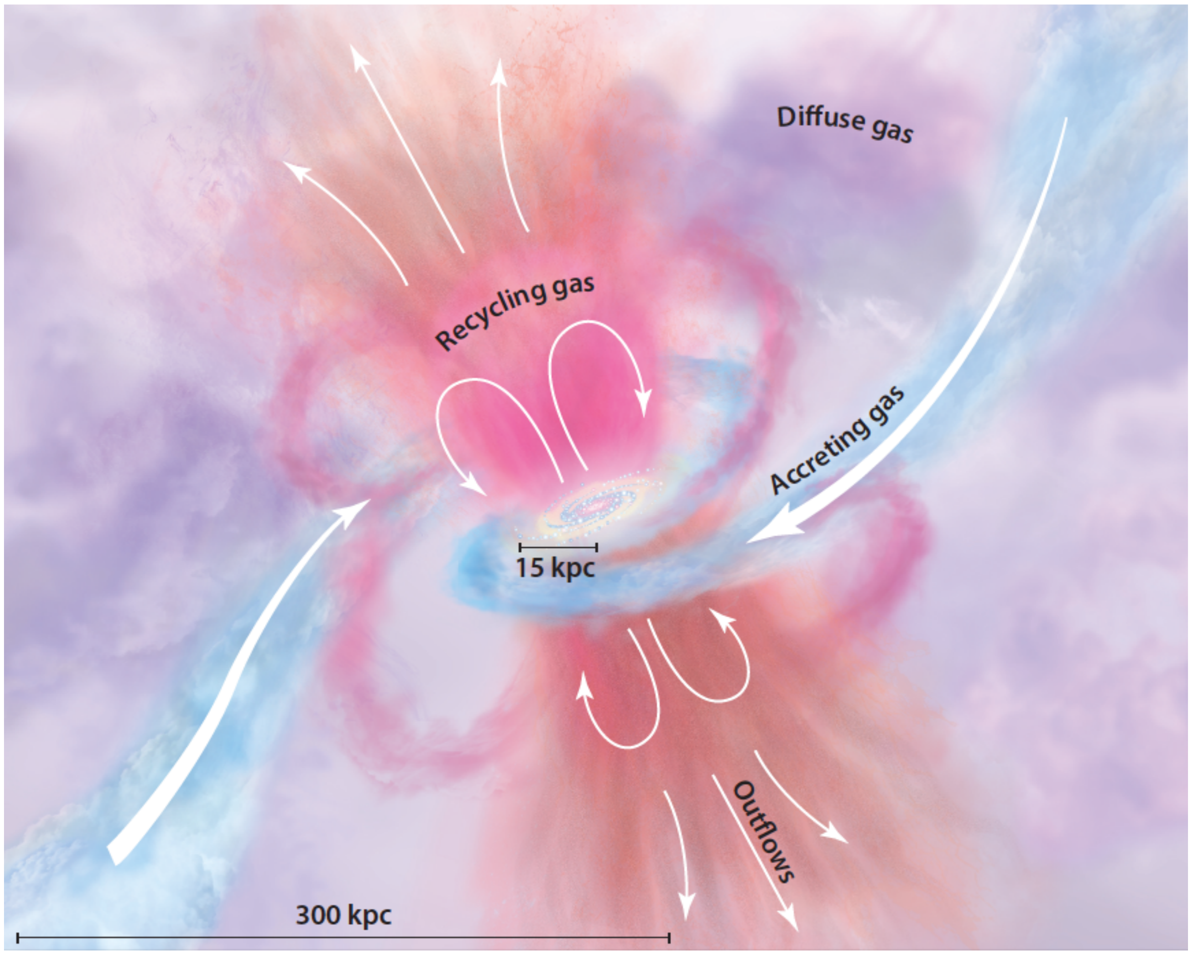
The History of Metal Production and Ejection in M31

Grace Telford

Jessica Werk, Julianne Dalcanton, Benjamin Williams

Astrophysical Frontiers in the Next Decade and Beyond
June 27, 2018 — Portland, OR

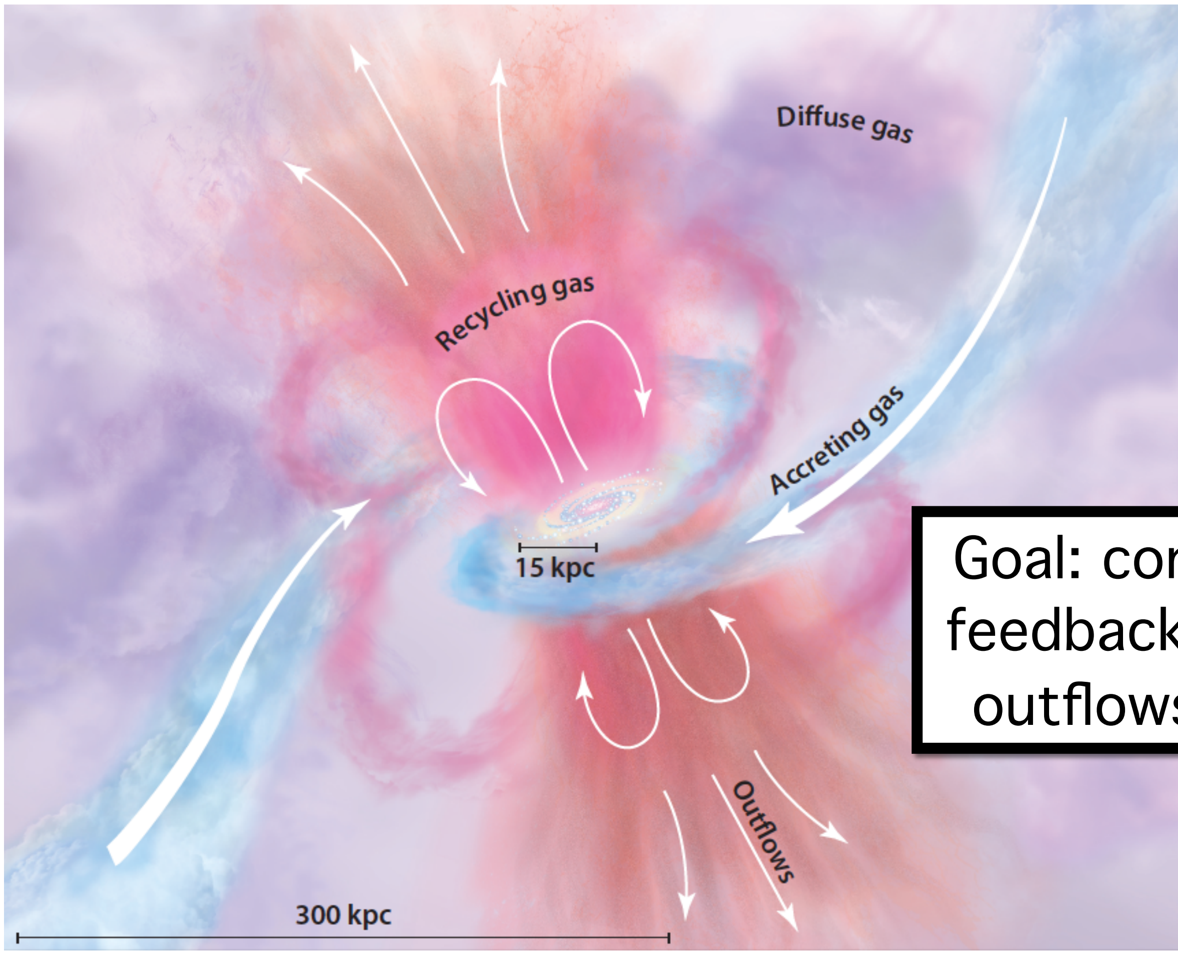
How is gas ejected from galaxies?



Tumlinson, Peeples & Werk 2017

Grace Telford

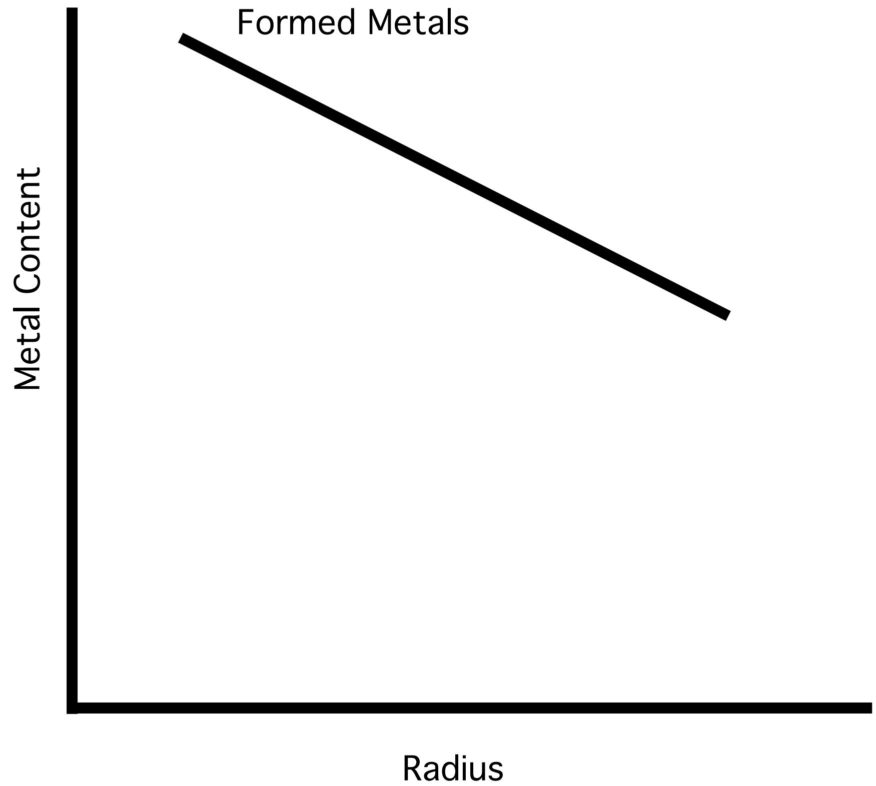
How is gas ejected from galaxies?



Goal: constraints on the feedback physics driving outflows from galaxies

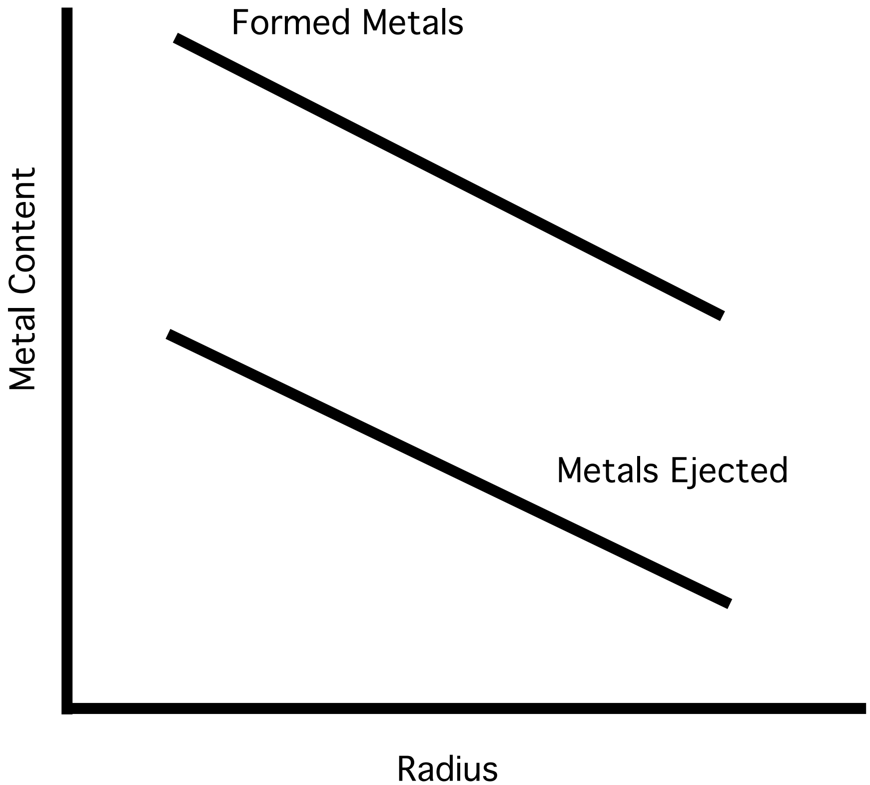
Tumlinson, Peeples & Werk 2017

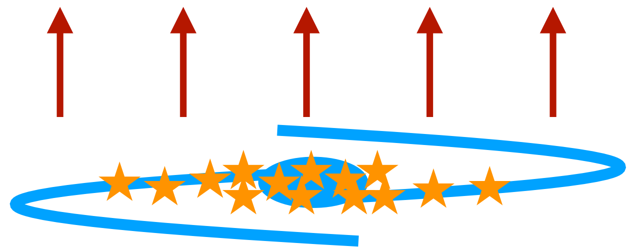
Metals as Tracers of Past Gas Flows



Grace Telford

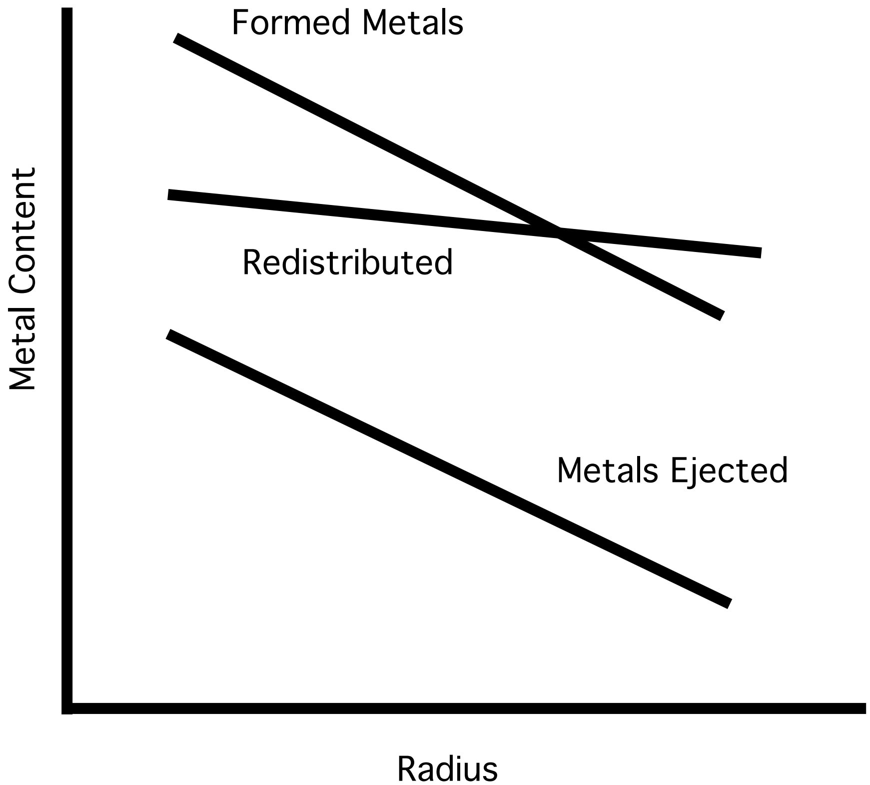
Metals as Tracers of Past Gas Flows

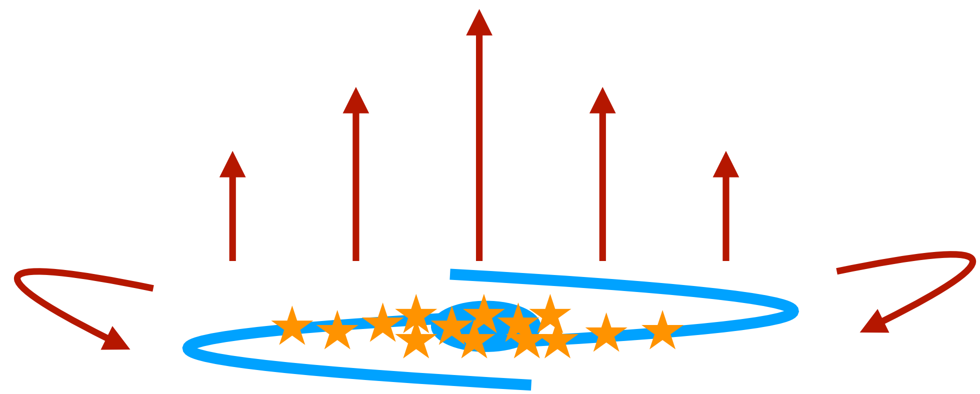




Grace Telford

Metals as Tracers of Past Gas Flows





The difference between the distribution of metals present vs. formed tells us where metals have been ejected/accreted

Grace Telford

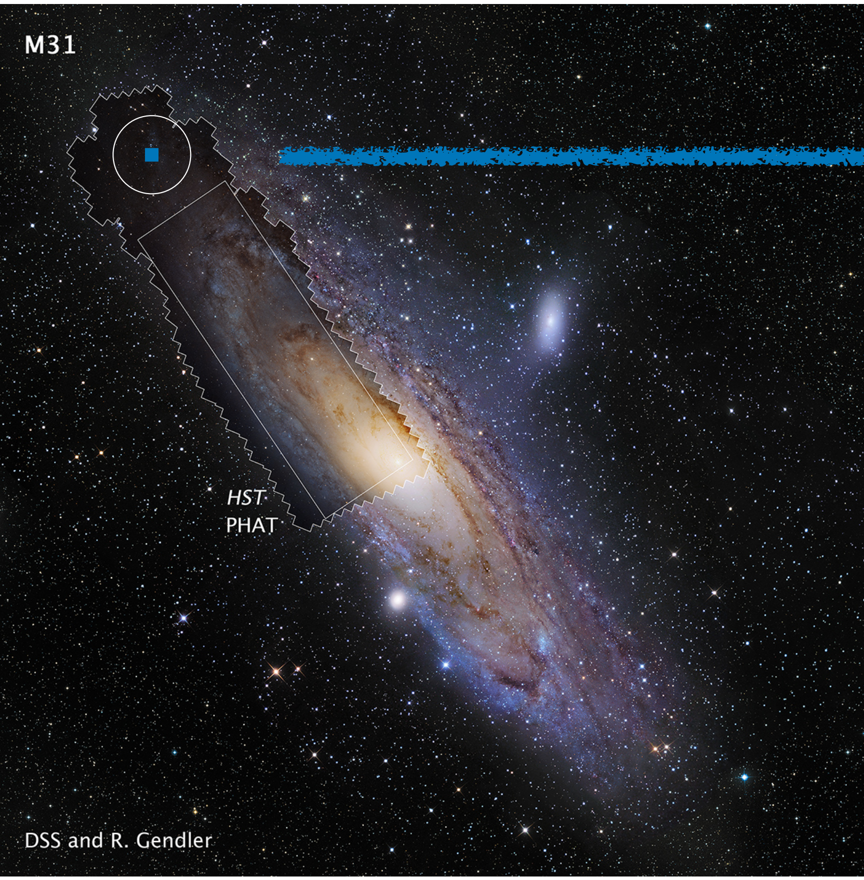
Spatially Resolved Metal Production Histories in M31

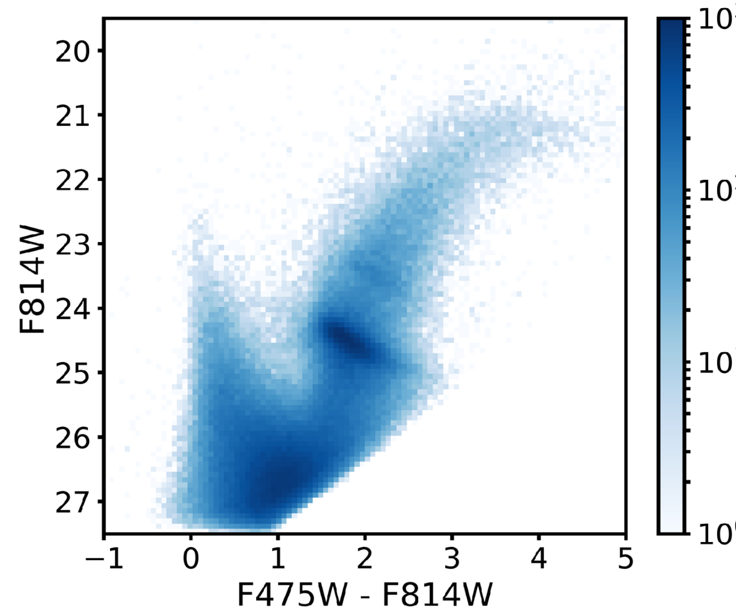
Star Formation Histories in M31 from PHAT

Grace Telford

Dalcanton+2012, Williams+2012

Star Formation Histories in M31 from PHAT

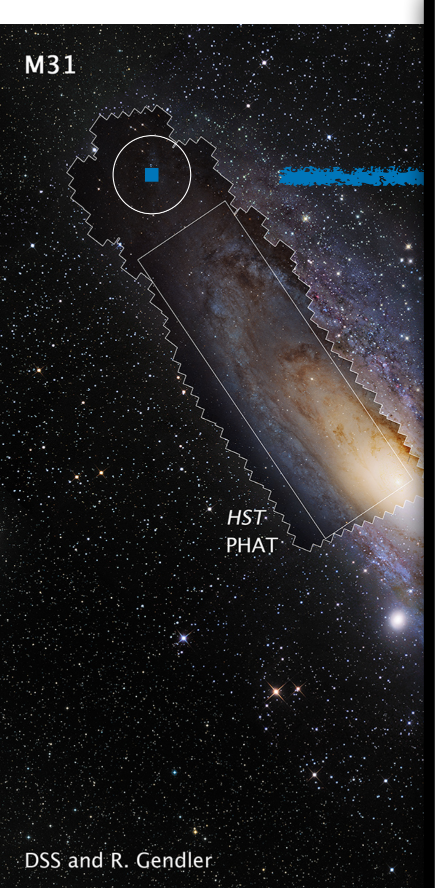


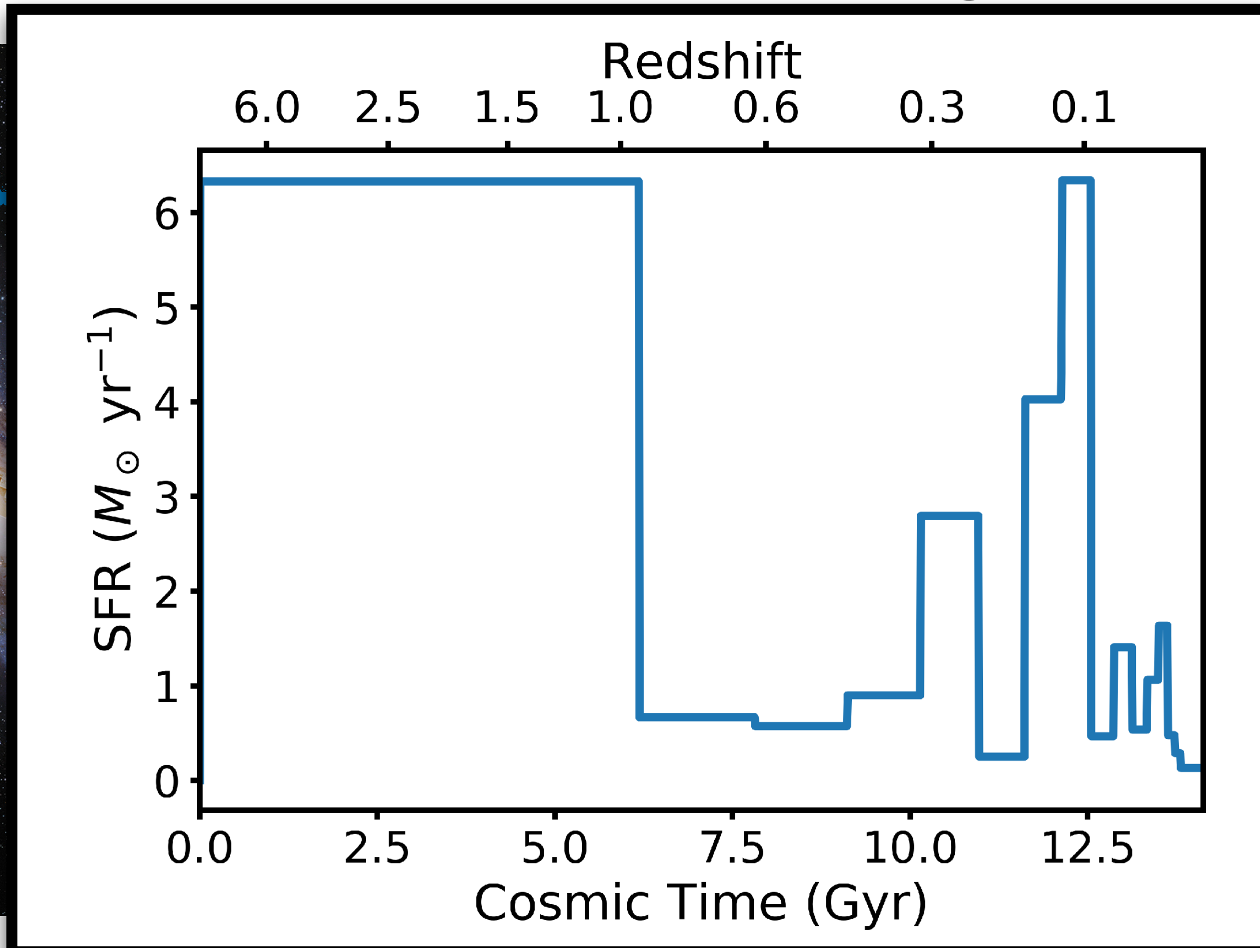


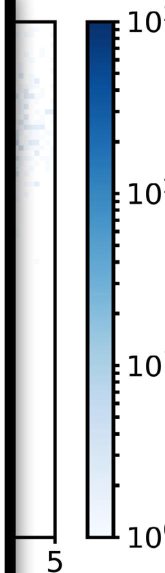
Williams+2017 modeled optical+NIR color-magnitude diagrams (CMDs) to derive histories of metal enrichment and star formation

Dalcanton+2012, Williams+2012

Star Formation Histories in M31 from PHAT



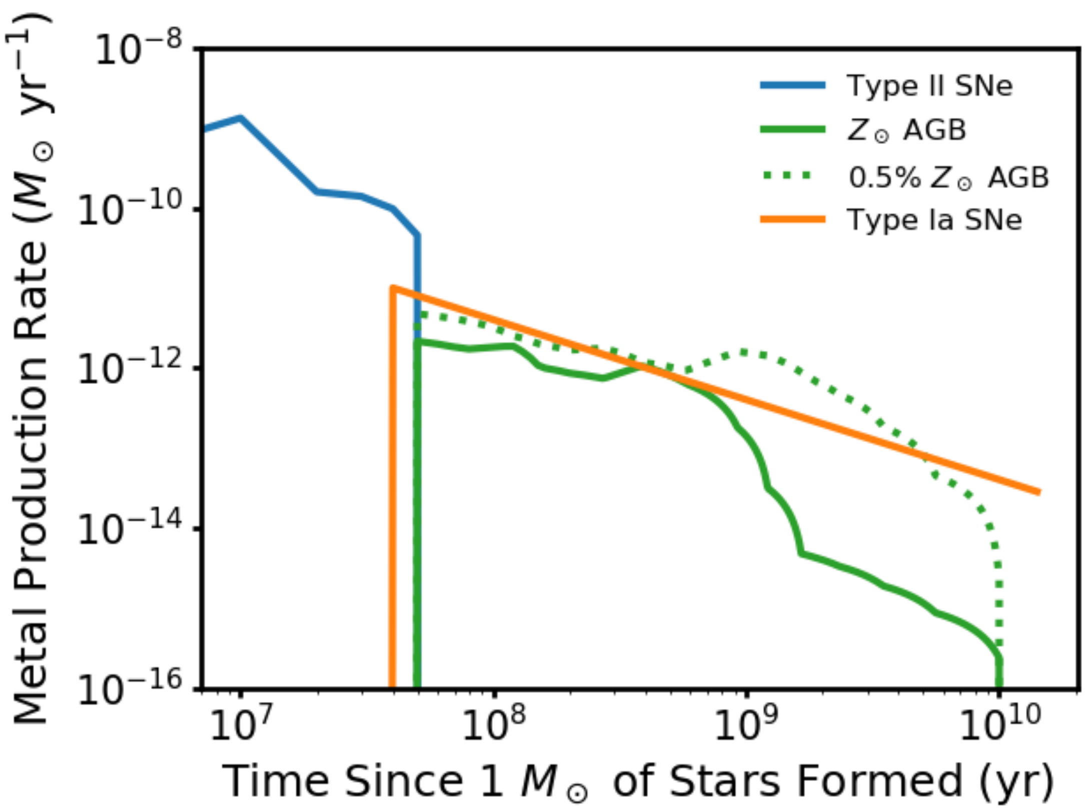




cal+NIR color-
derive histories
ar formation

Dalcanton+2012, Williams+2012

Modeling Metal Production Following a Star Formation Burst



Type II SNe

Yields from Nomoto+2013, 8-40 $M_\odot$

AGB Stars

Yields from Karakas 2010, 1-8 $M_\odot$

Type Ia SNe

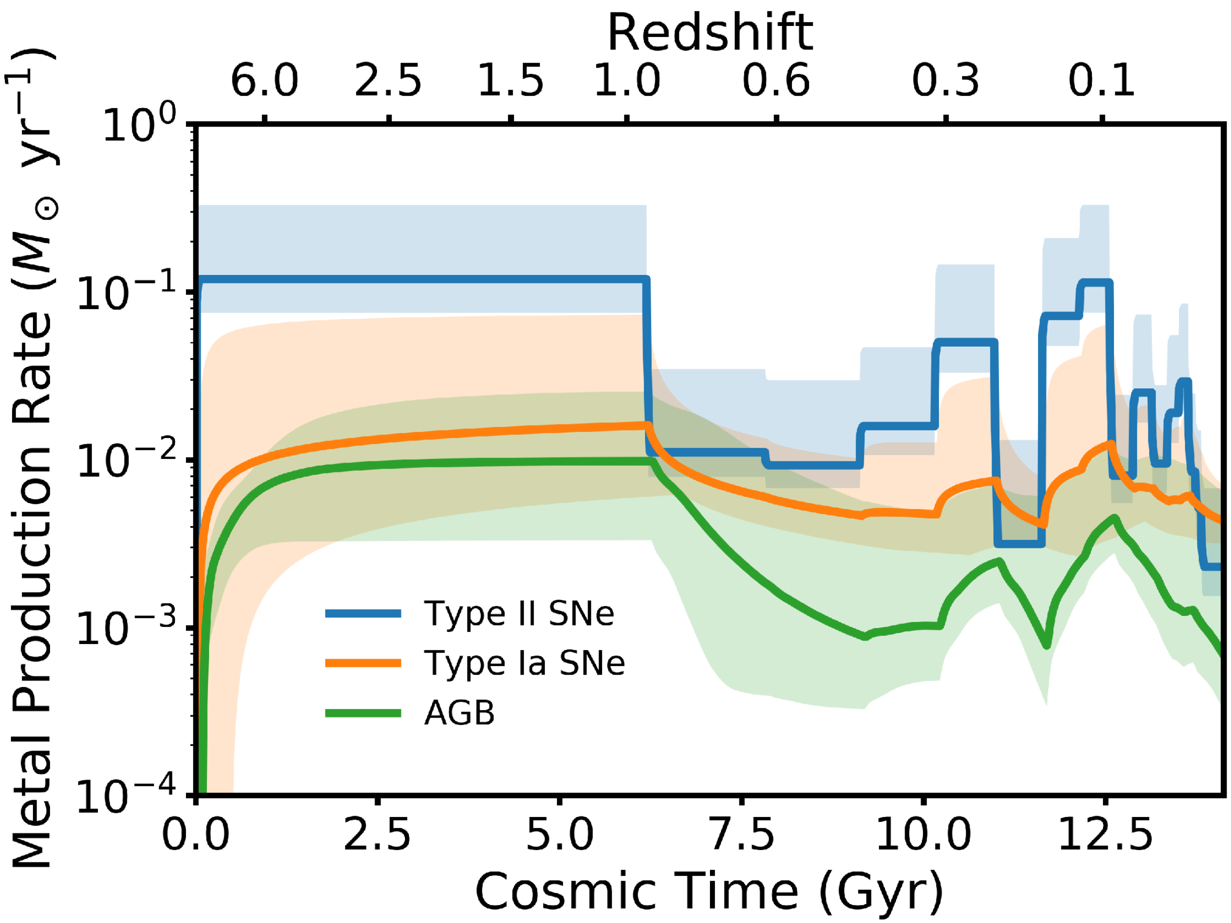
Yields from Tsujimoto+1995

Assume WD mergers, progenitors ~3-8 $M_\odot$

Power-law delay time distribution

Grace Telford

Convolve with SFH to Find History of Metal Production



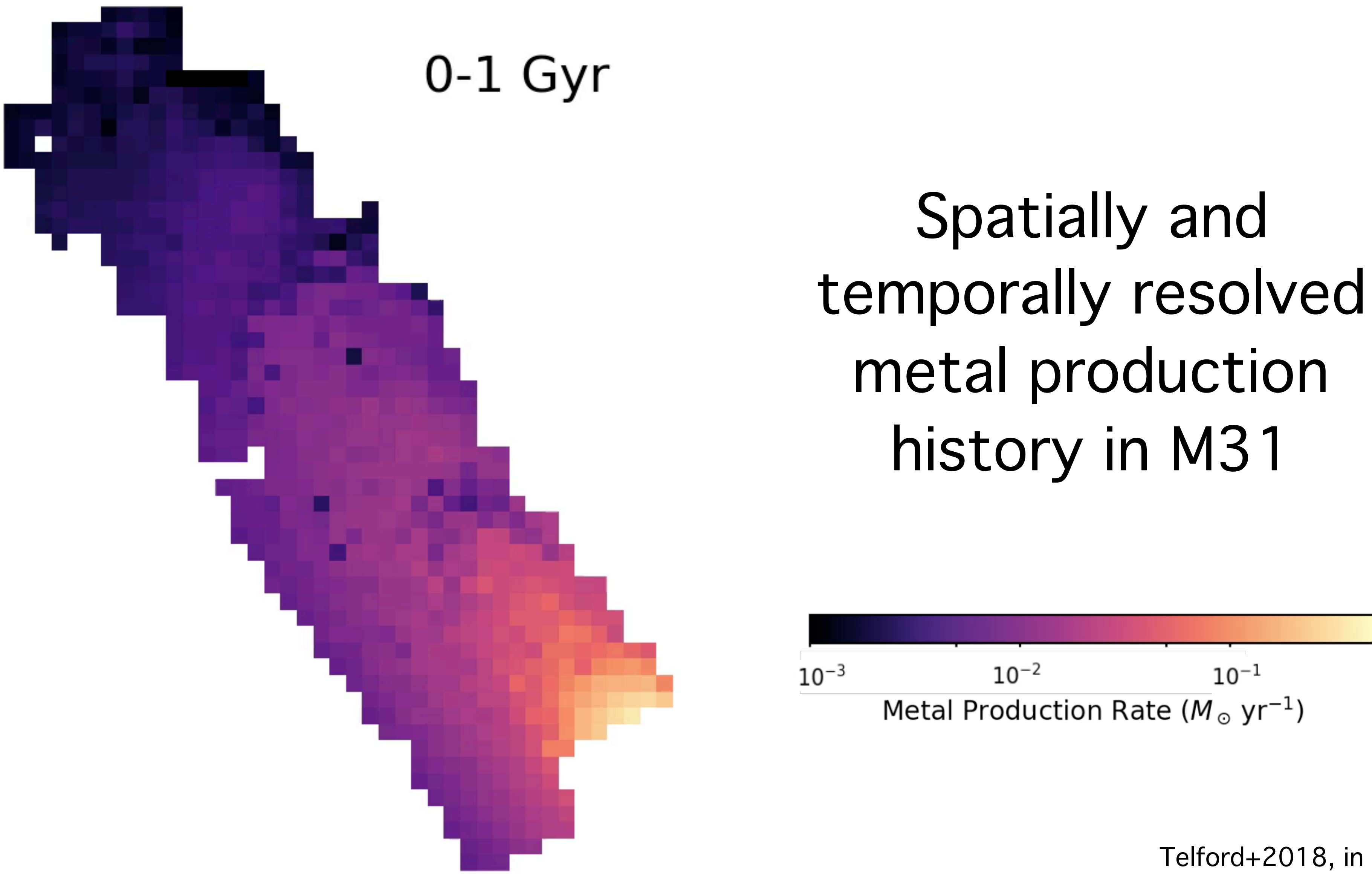
Relative production of elements changes over time:

Type II: O, Si, Mg (alpha elements)

Type Ia: Fe

AGB: C, N

Telford+2018, in prep.



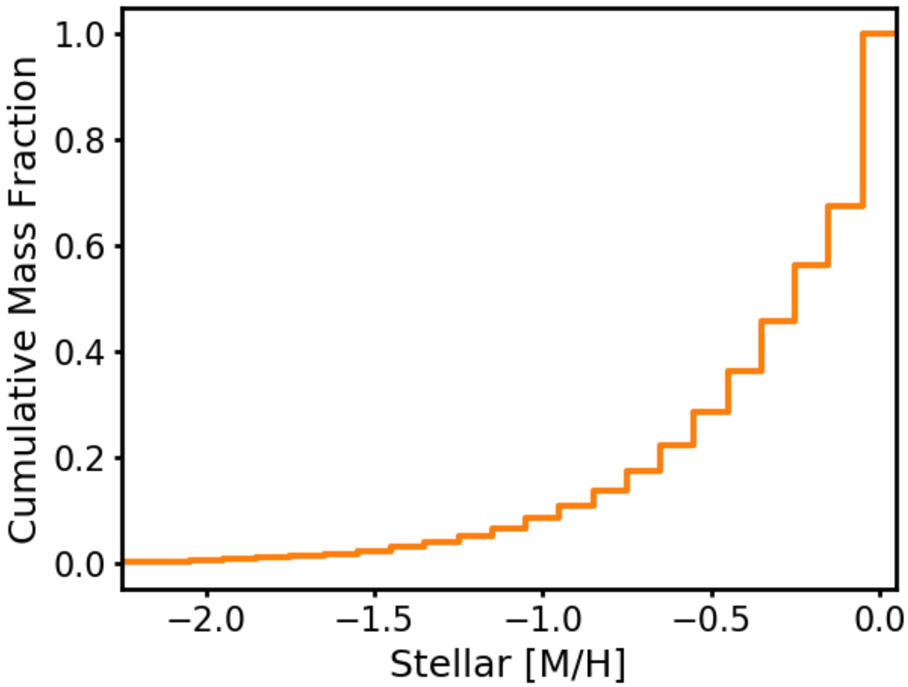
Spatially and temporally resolved metal production history in M31

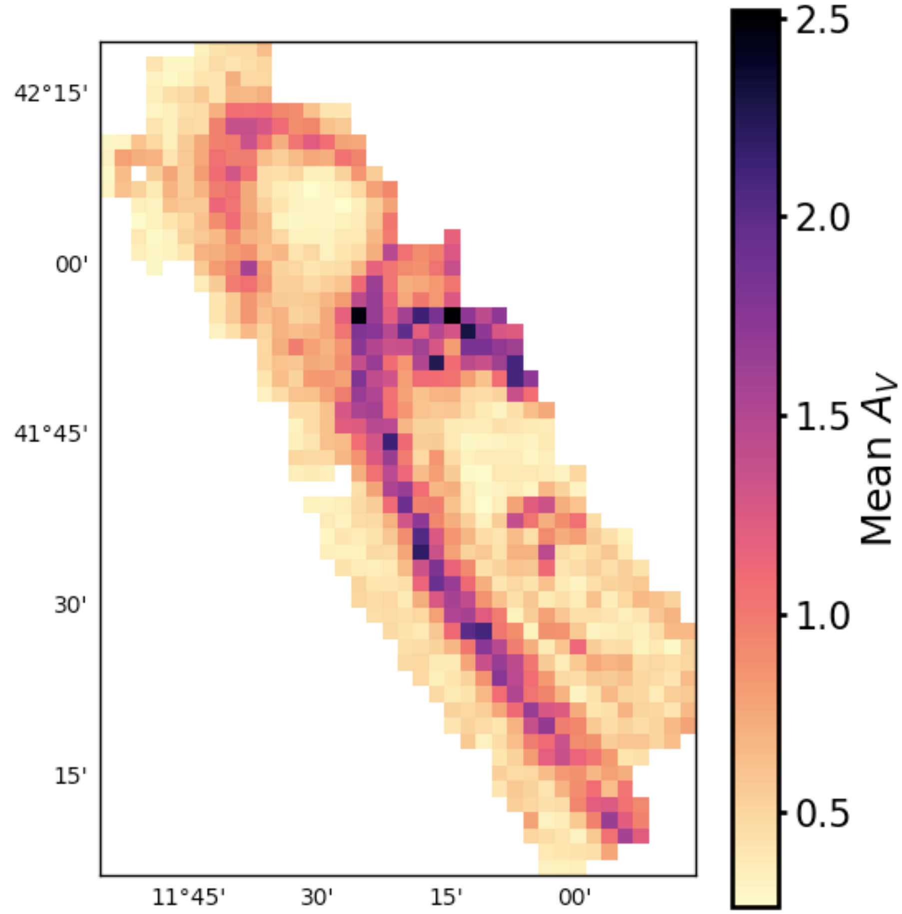
Telford+2018, in prep.

Census of Metals Currently Present in M31

Stellar [M/H] and Dust from PHAT CMD Modeling

Have a measurement of the metallicity distribution function in each ~1 kpc region at each age

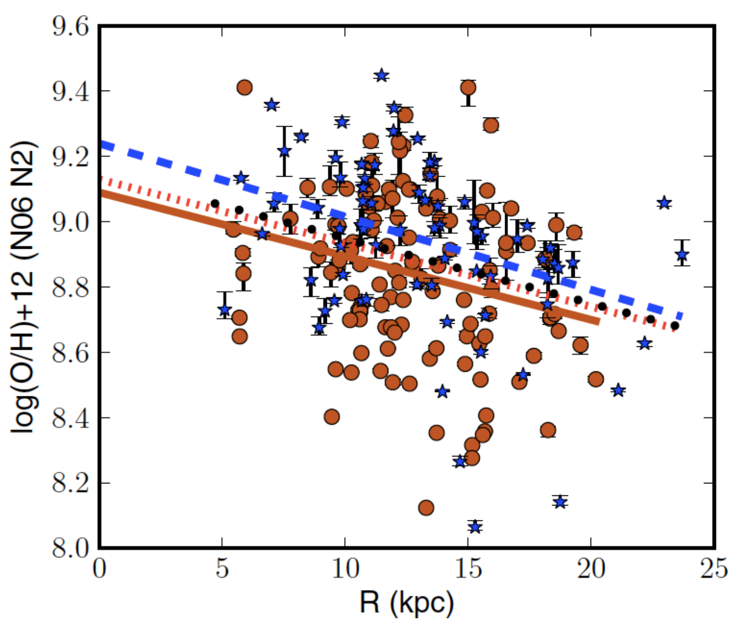




Grace Telford

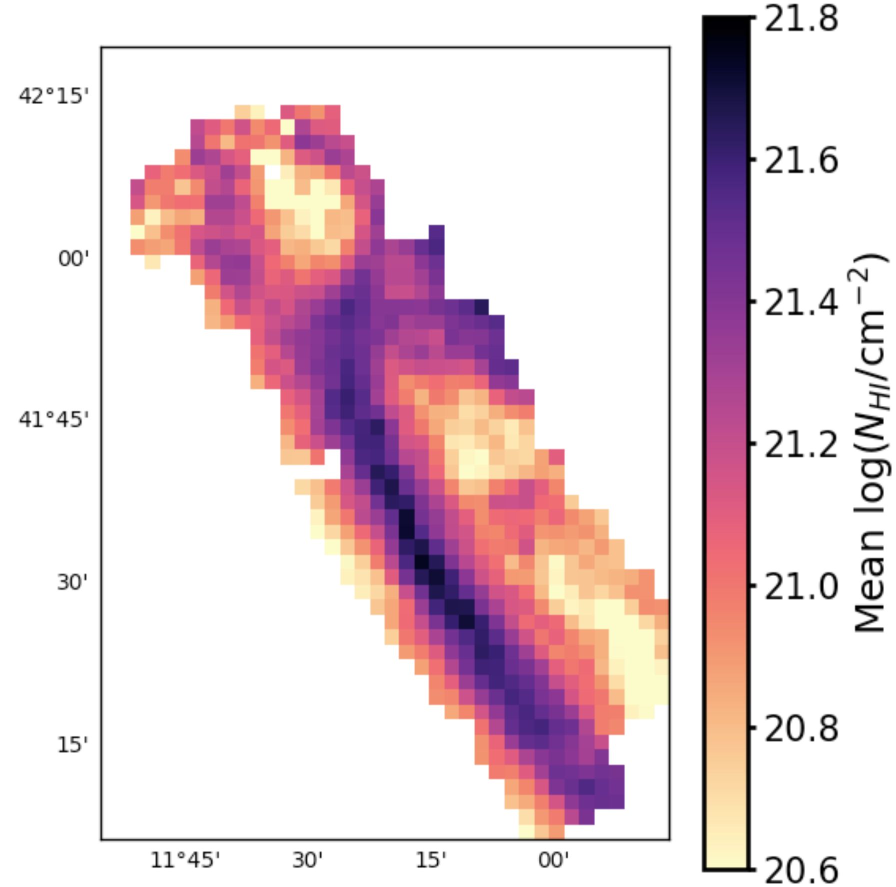
Williams+2017, Dalcanton+2015

Gas-Phase Metallicity Gradient + HI Column Density



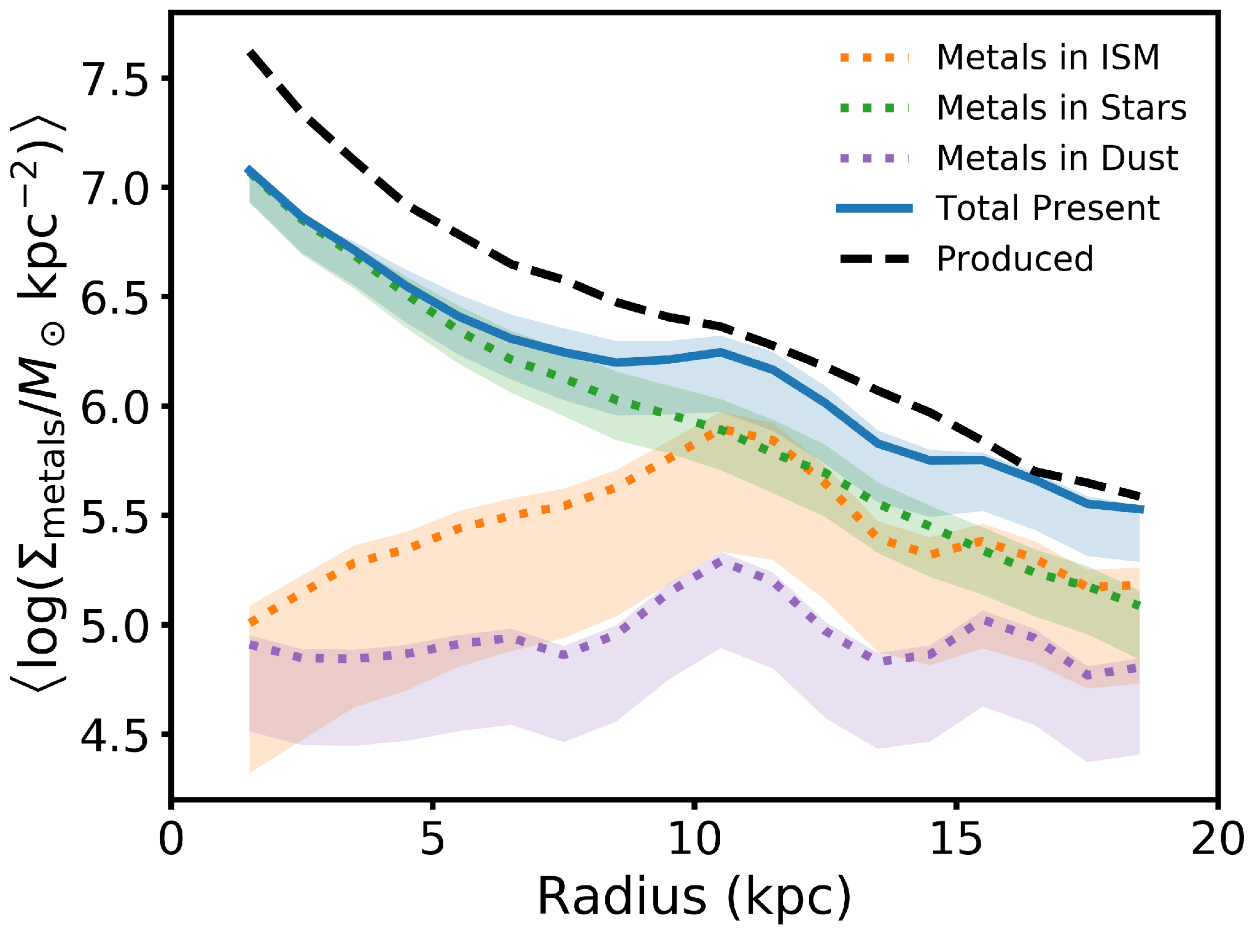
Metal rich, shallow gradient: -0.02 dex/kpc

Little gas near center of M31, highest column density near star-forming ring



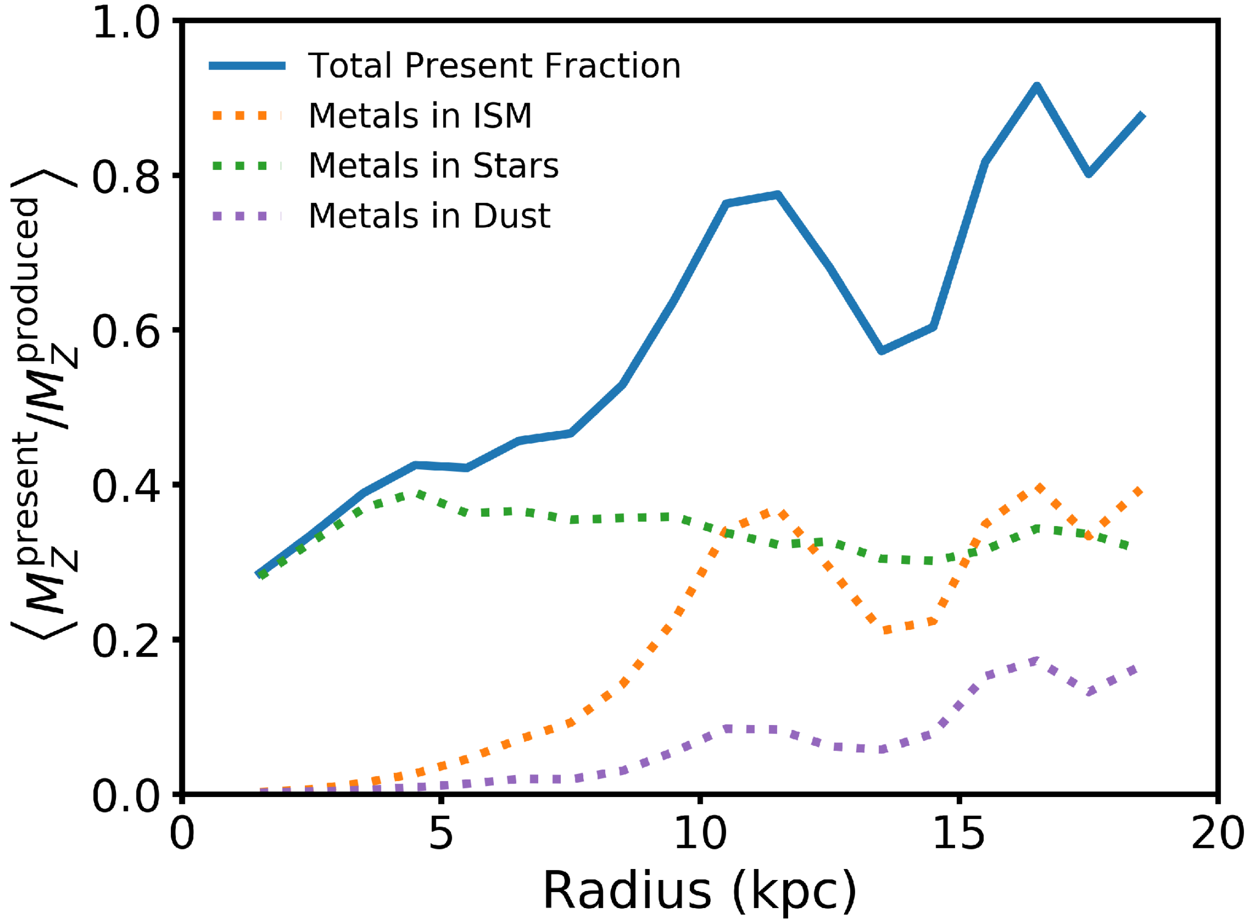
Sanders+2012 , Brinks & Shane 1984

Metals Present in M31



Telford+2018, in prep.

Metal Retention in M31

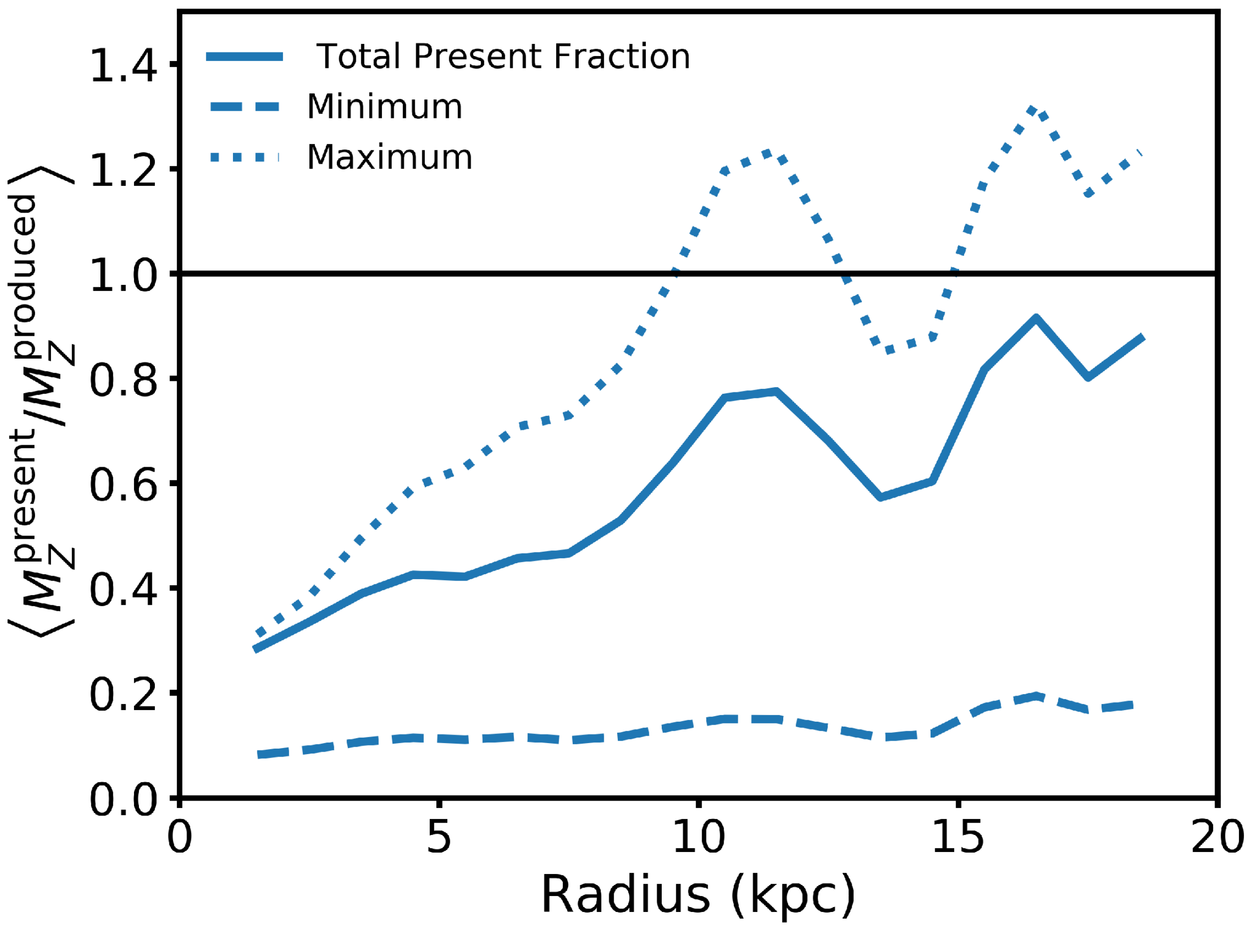


Just ~40% of metal mass is retained in the inner region of the disk

Outside 10 kpc, stars and gas are equally important reservoirs of metals — account for 60-90% of metals produced

Telford+2018, in prep.

Conservative Systematic Uncertainties

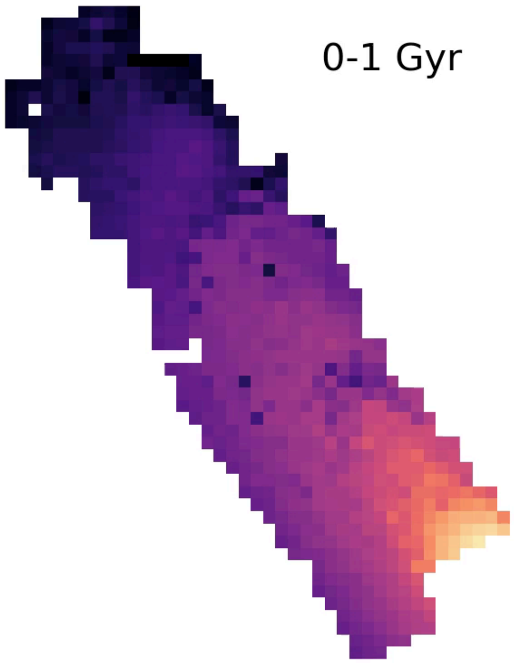


Regardless of assumptions:

- always a radial gradient
- missing metals inside ~10 kpc
  - By z=1, ~70% of metals had formed, so early outflows & metal ejection is <u>required</u>

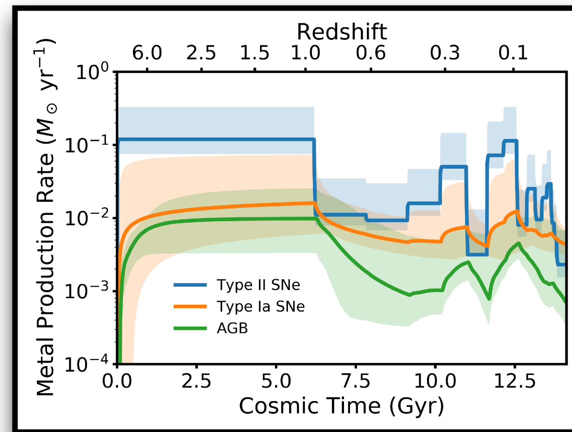
Possible that there is more metal mass beyond 10 kpc than was produced there.

Telford+2018, in prep.

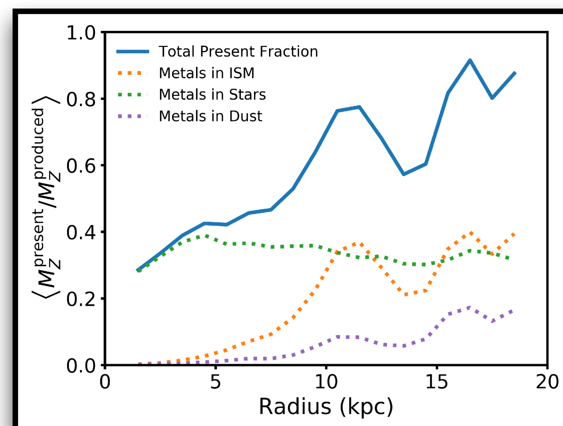


Takeaways

We have performed a detailed calculation of when and where different elements formed in the M31 disk.



~60% of metals are missing in the center and metal ejection must have occurred at z >1, within conservative systematic uncertainties.



Grace Telford - otelford@uw.edu - PhD Student, University of Washington