Studies of high redshift galaxies with Millimetron

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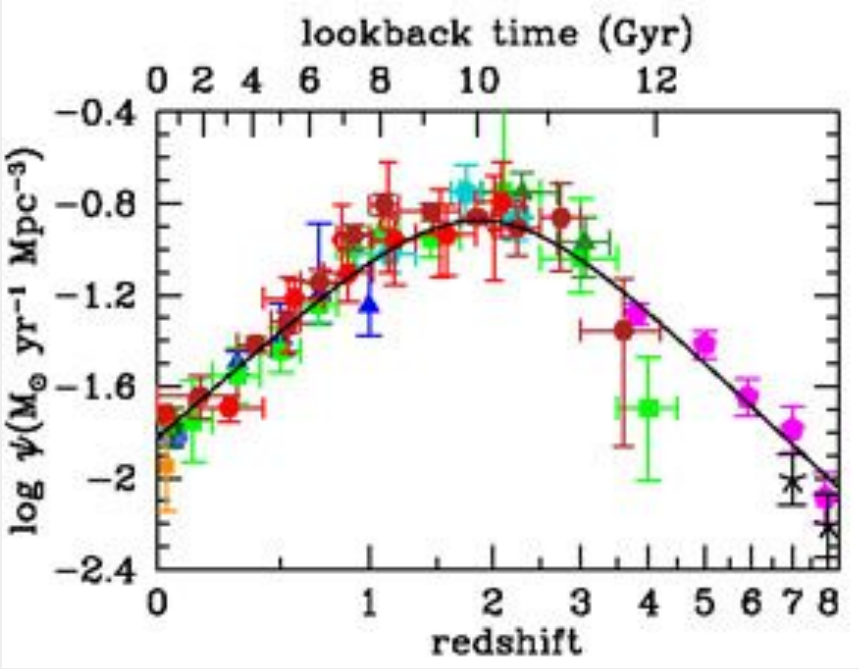
Millimetron Workshop Paris 2019

Galaxy formation: what we know and what we don't

When?

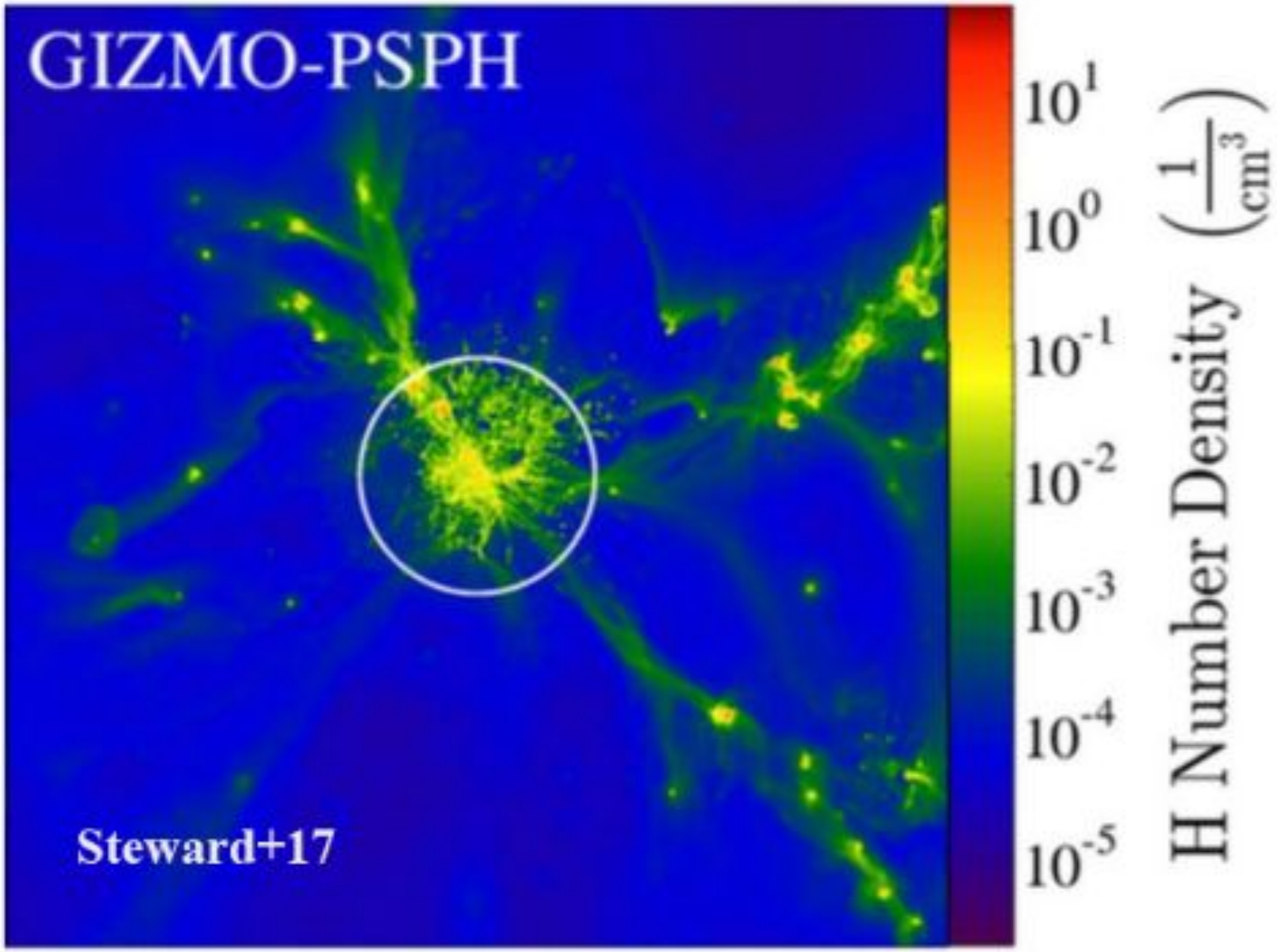


Madau & Dickinson 2014

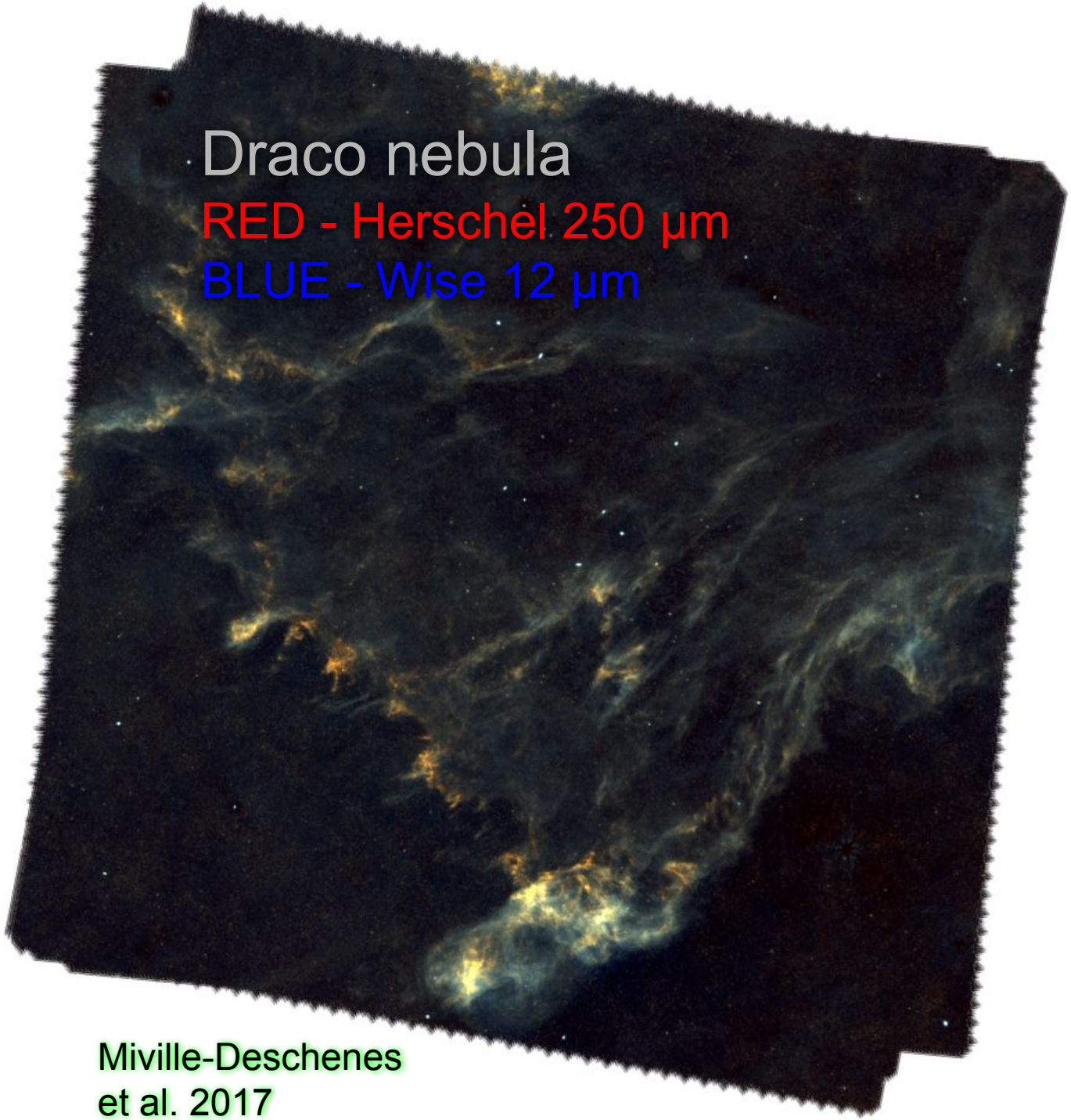
How?

- Accretion
- Cooling
- Feedback
- Mergers

Accretion

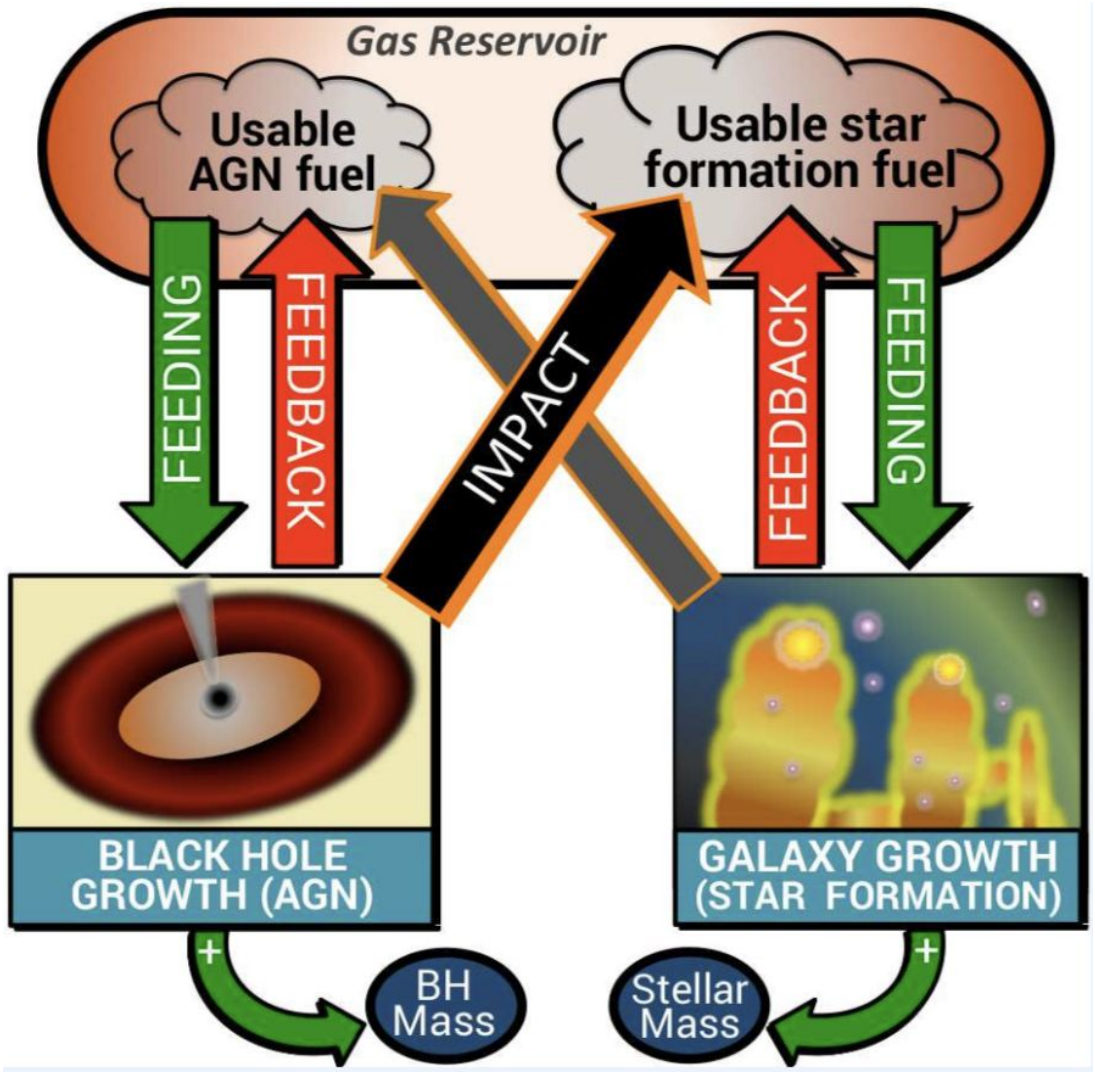

GIZMO-PSPH
Steward+17
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
H Number Density $\left(\frac{1}{cm^3}\right)$

Accretion



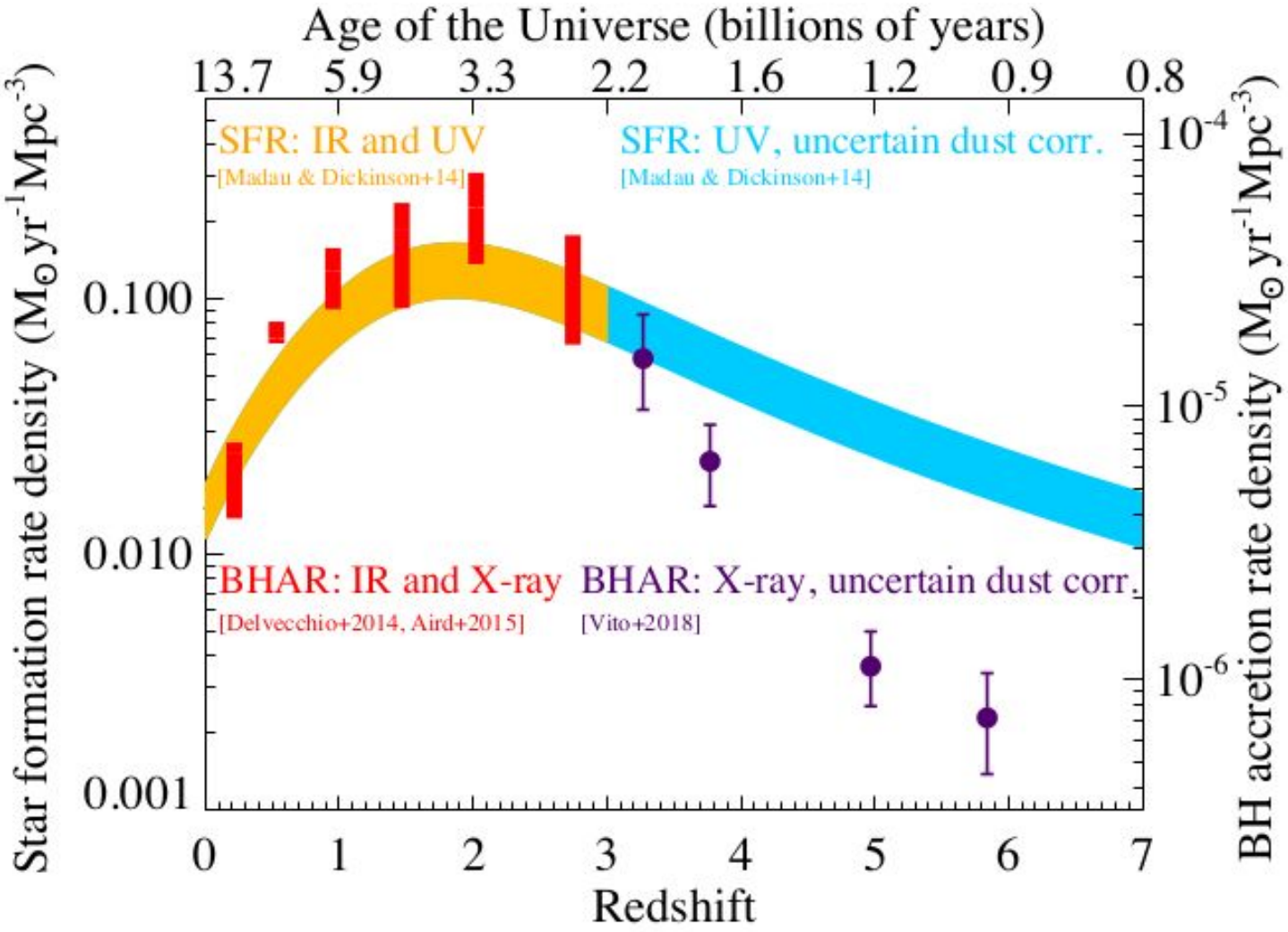
Miville-Deschenes
et al. 2017

Feedback



Harrison 2017

SMBH - Bulge co-evolution



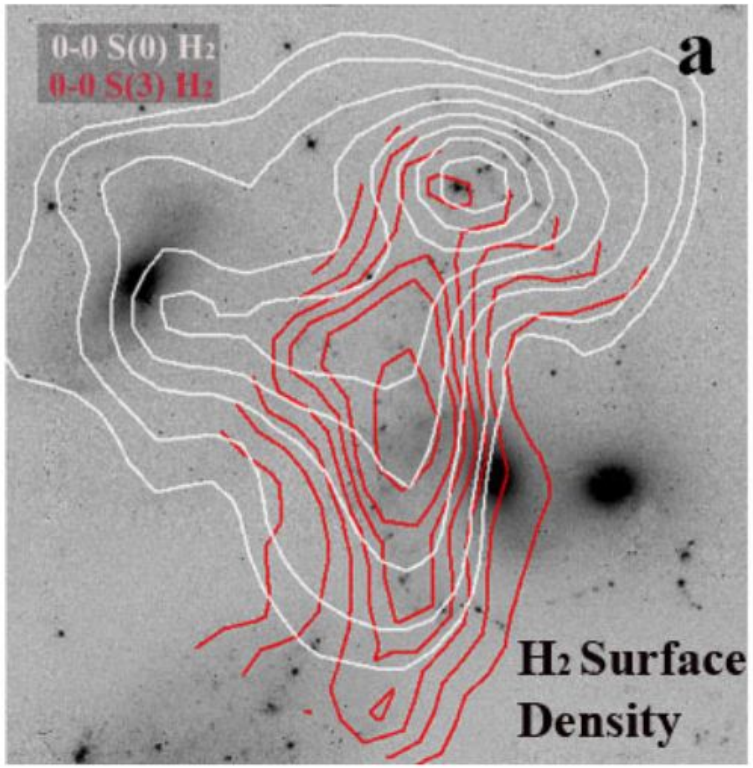
Questions

- Accretion: where do shocks occur?
  - At virial radius
  - Close to the center
- Feedback:
  - What are the gas reservoirs?
  - AGN power
  - Outflow rates
- How SMBH and bulges co-evolve?

H_2 lines

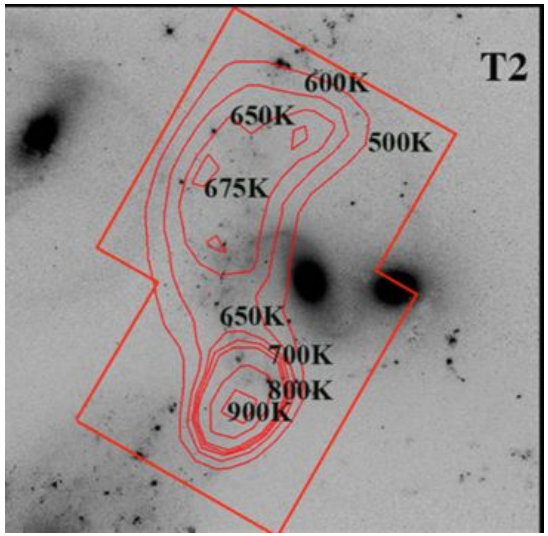
Transition	Wavelength
0-0 S(0)	28.2
0-0 S(1)	17.0
0-0 S(2)	12.3
0-0 S(3)	9.7
0-0 S(4)	8.0

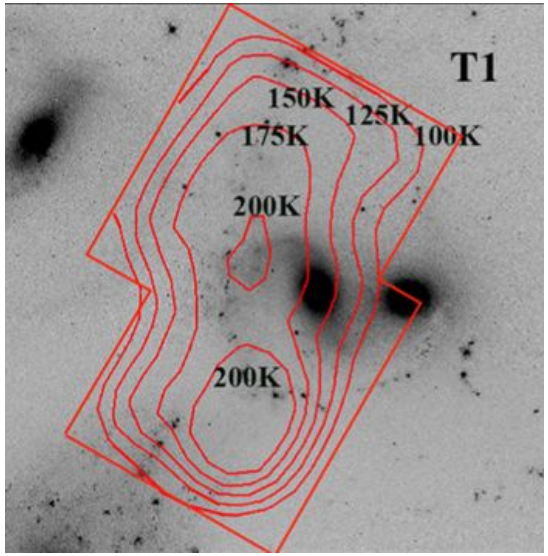
- ★ Warm gas
- ★ Turbulence
- ★ MHD shocks

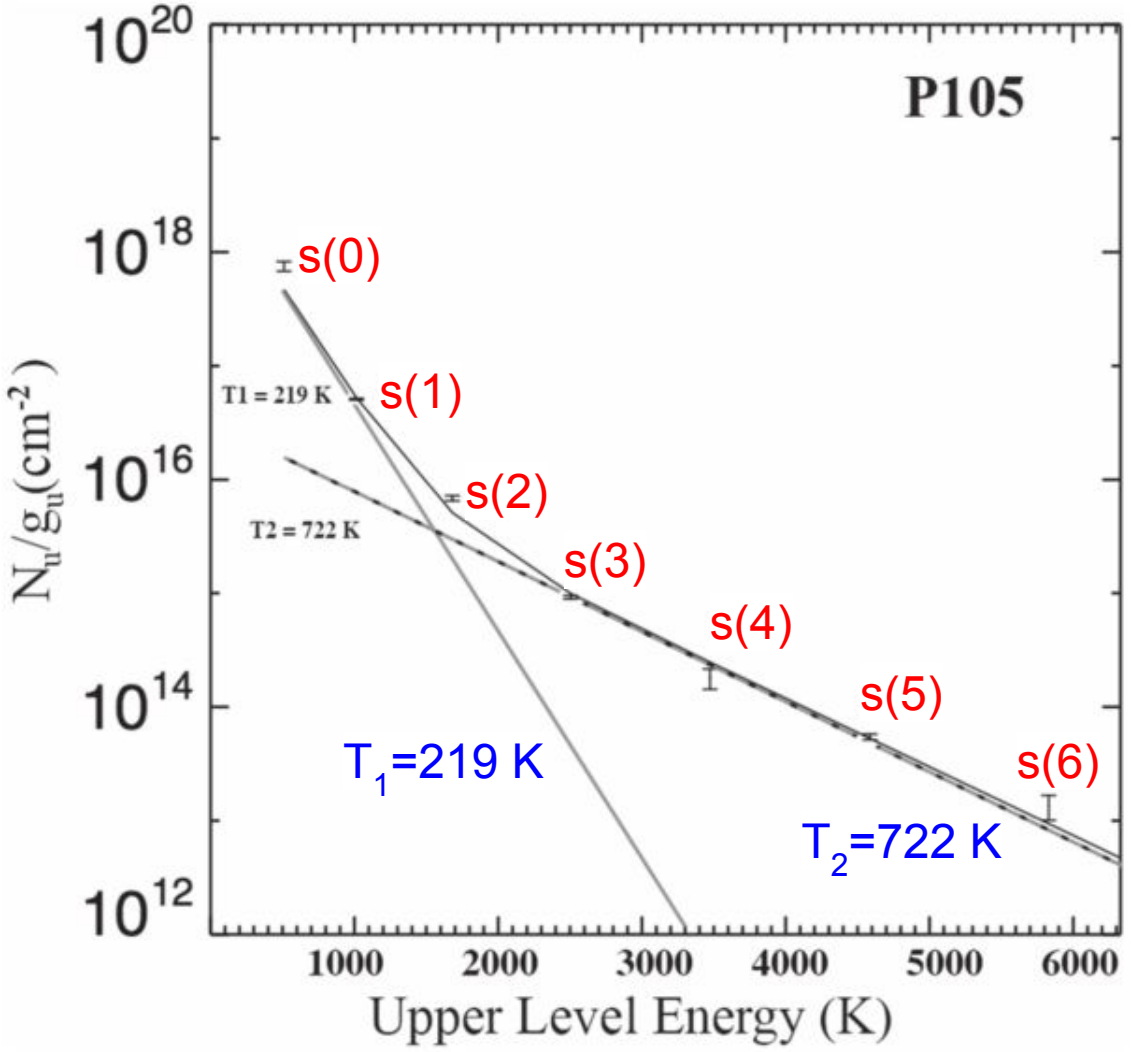


Appleton et al. 2017
"Stepah's Quintet"

Excitation diagrams

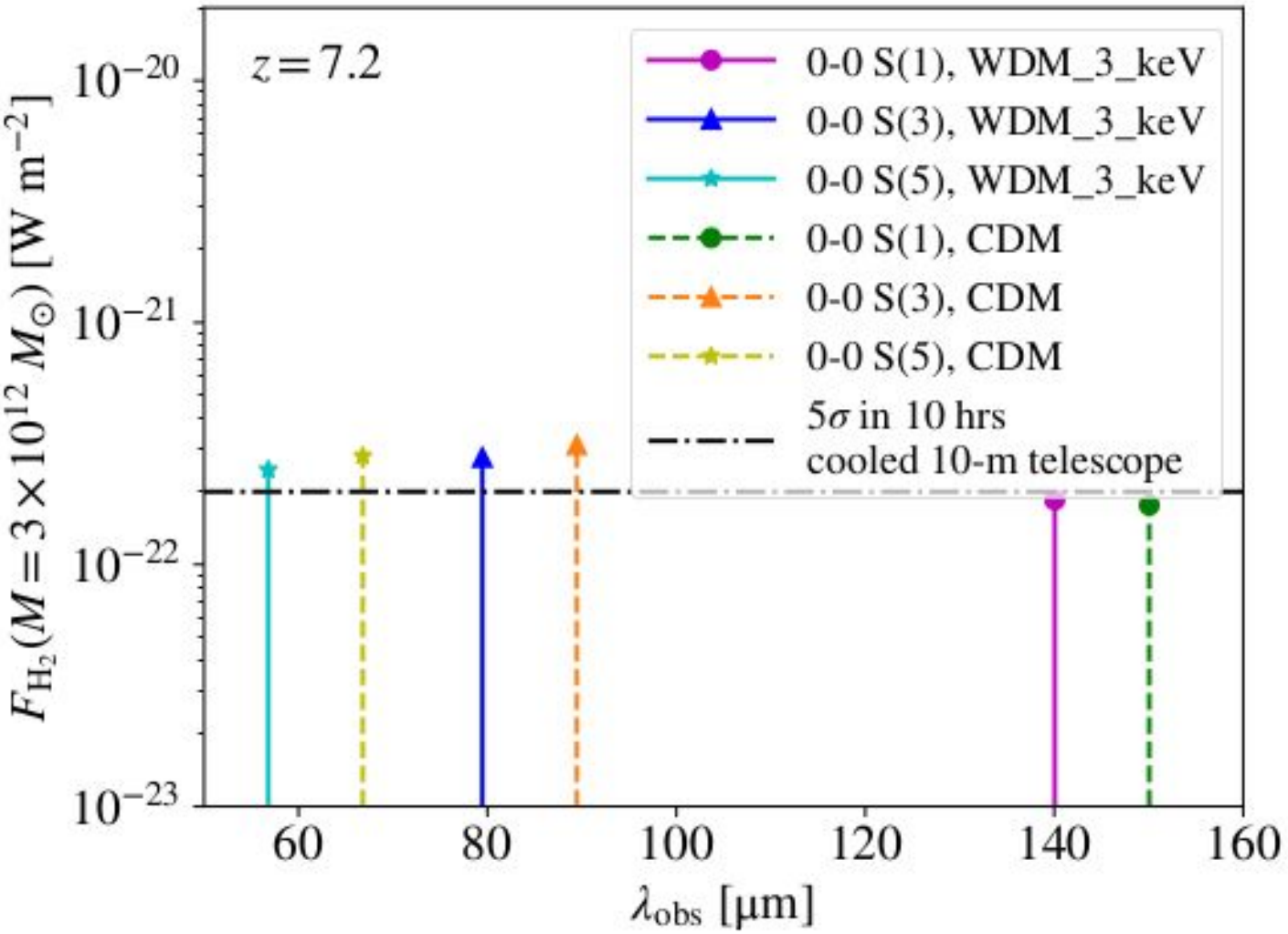






Appleton et al. 2017

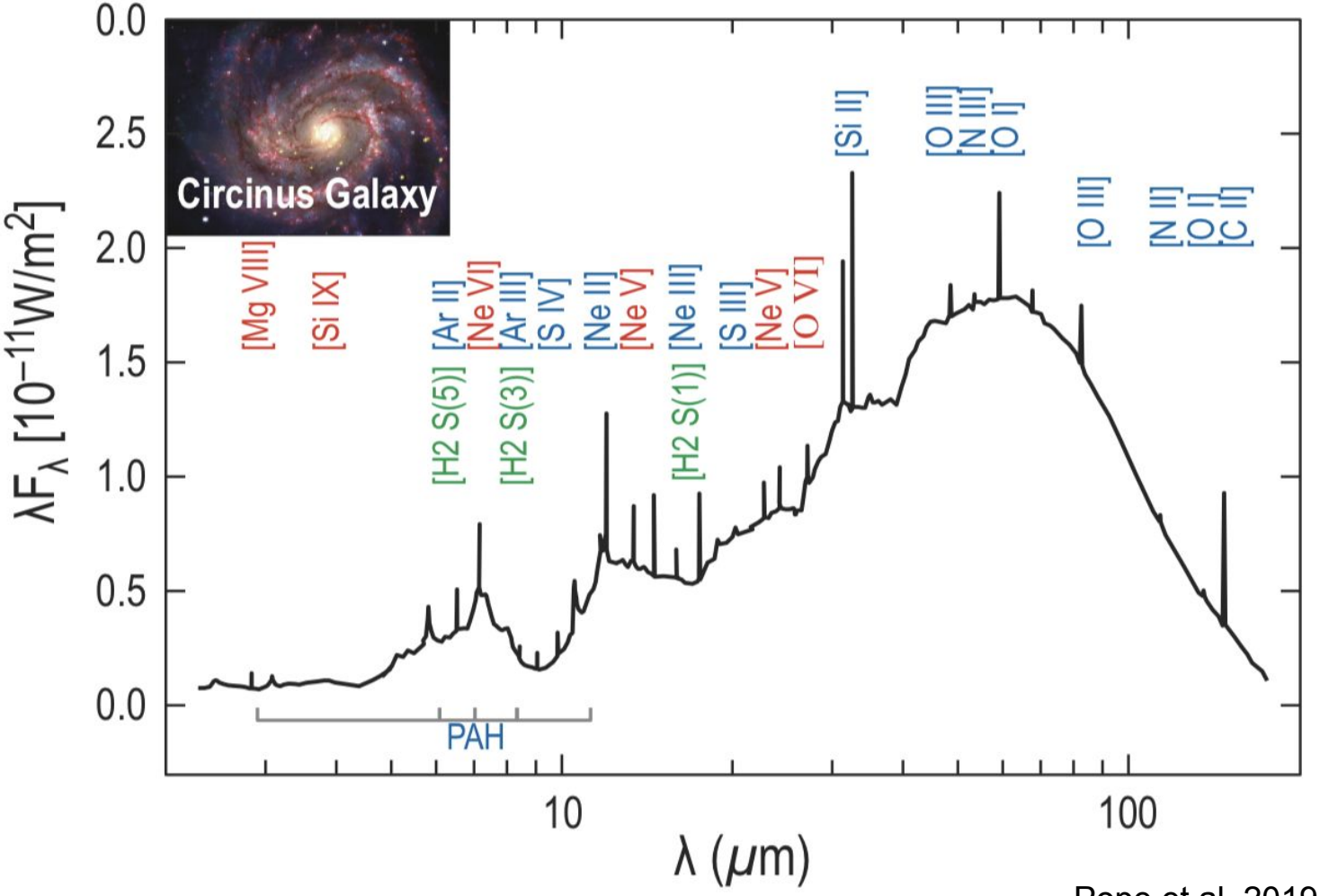
Cosmic Dawn?



Liu et al. 2019

Ions & atoms

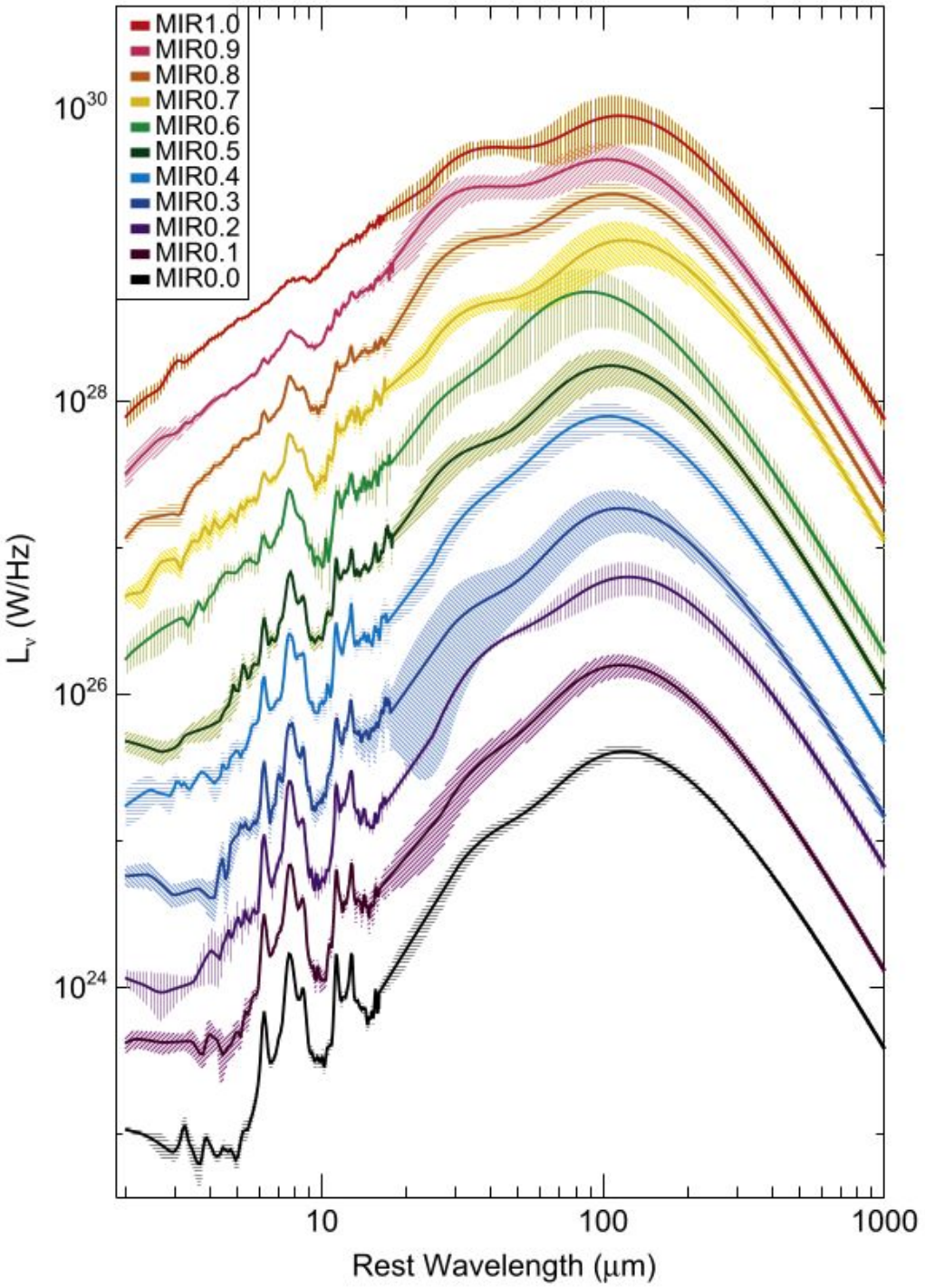
Blue = star formation
Red = AGN



Pope et al. 2019

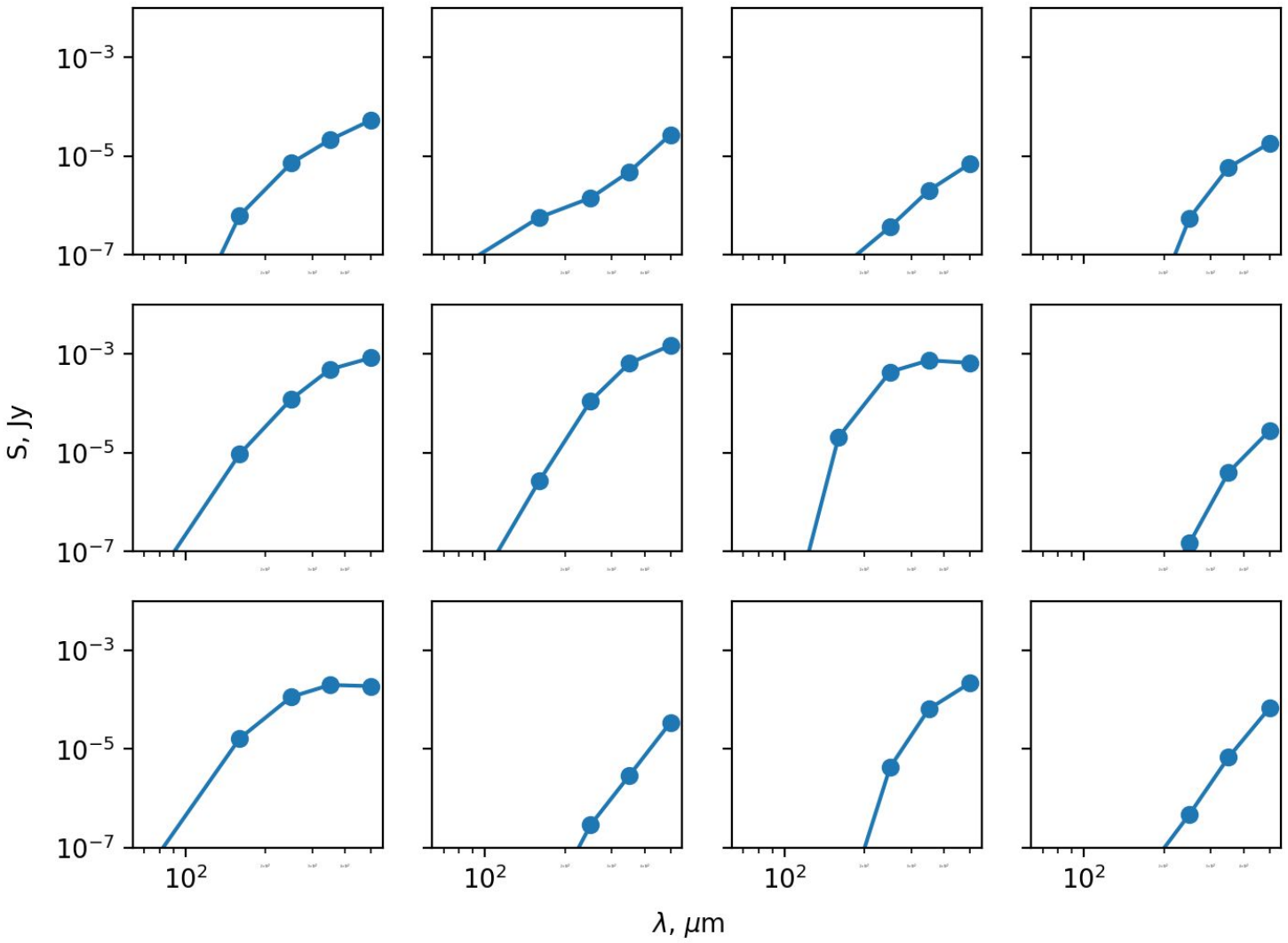
Dust continuum

SED templates
from Kirkpatrick et al. 2015

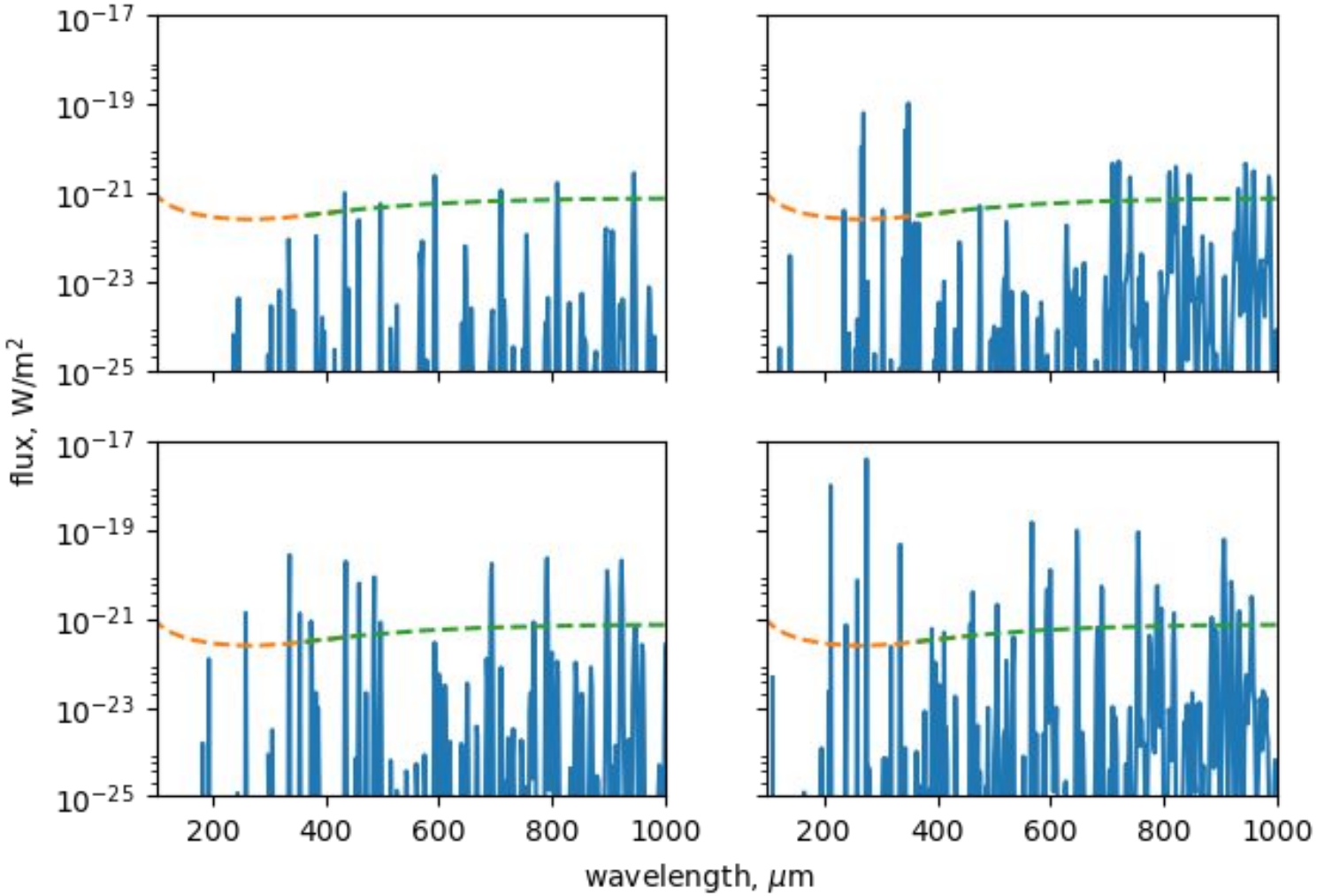



FIR background

SEDs of random pixels on the sky...



Spectral lines at random pixels



[OI] 63 microns, [NII] 122 microns, [CII] 158 microns

Is it possible without Millimetron?

- Warm gas (H_2) - in absorption, but very limited
- AGN
  - Problems with obscured AGN
  - We need properties of gas usable for SFR anyway
  - We need to measure SF

Preliminary Millimetron requirements
for studies of accretion, feedback and SF-SMBH correlation at z>3

- Short wavelengths, 50 μm or less
- Spectroscopy, R~1000
- Wide spectral coverage
- Time to detect few sources with ~10^{-22} W/m^2

What do we need in the nearest future?

- Check that we really cannot do this w/o FIR space observatory
- Can we survive with >80 μm?
- How many objects do we need to observe?
  - Blind survey?
  - Known objects?
- What will we do with the CIB?
  - Models and tests