Searching for the turbulence/shock dominated galaxies with WFIRST's Grism at 1.8 < z < 2.0

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Basic Assumption

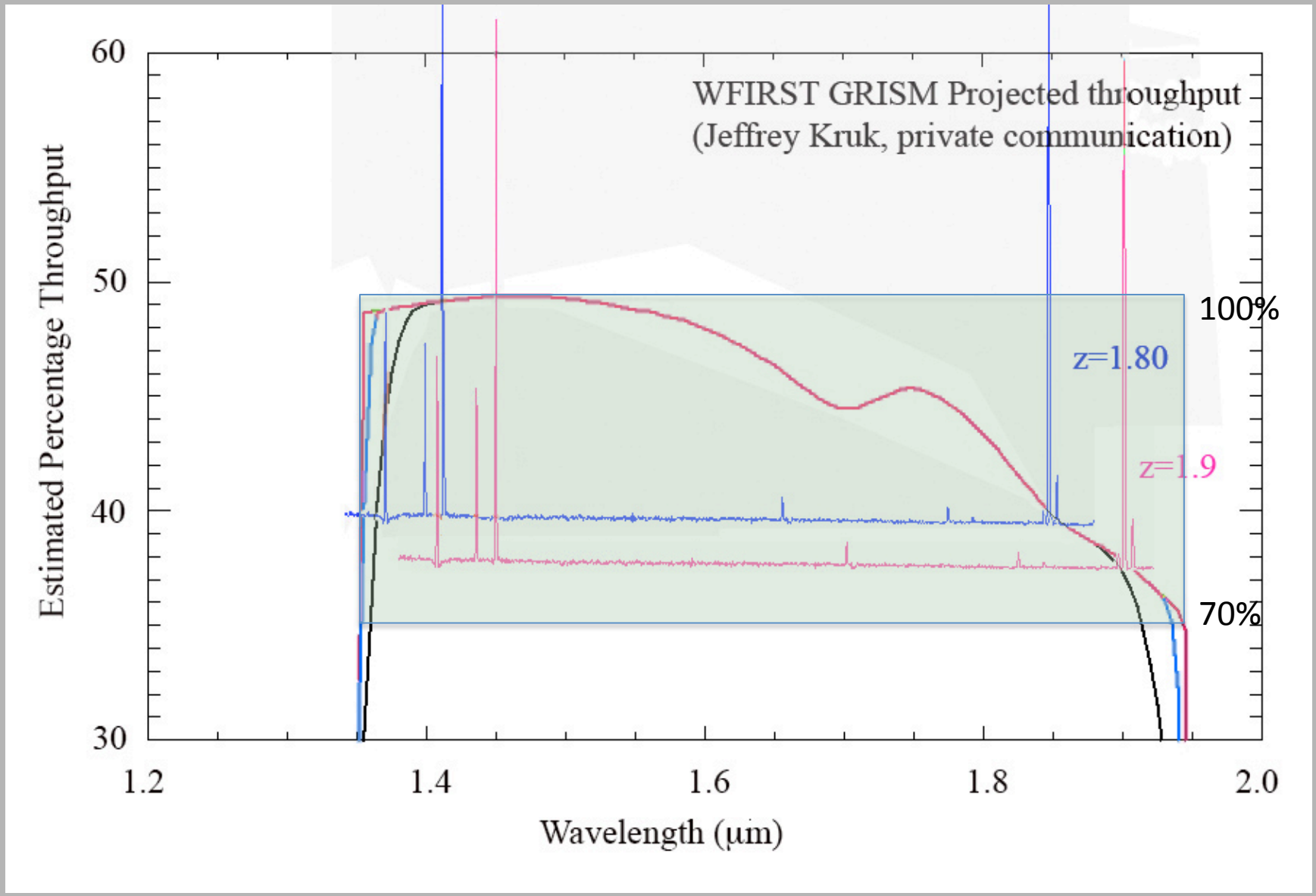
WFIRST's Grism will cover sufficient range of wavelength to span key rest-frame emission line diagnostics at $1.8 < z < 1.95$ and the Hα/[OI]6300 complexes $1.1 < z < 1.9$

Science Exploitation Example

We are studying a set of very rare galaxies at low-z that seem to be shock-dominated and may be galaxies in transition or experiencing negative feedback

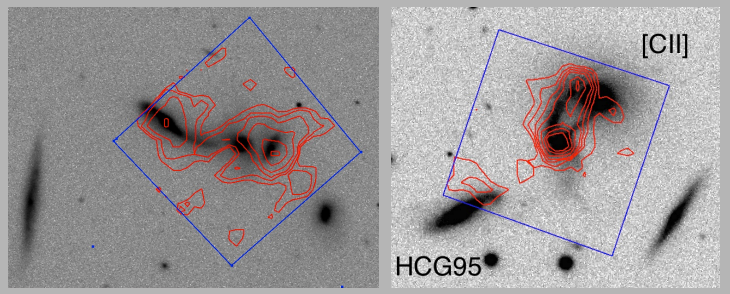
WFIRST may allow us to investigate large numbers of these rare objects at z= 1.8-1.9 where galaxy cold accretion, galaxy disk building and Proto-cluster formation is occurring

WFIRST GRISM
Low-R but huge surveys possible



Shocks and Turbulence in dense environments in the Local Universe

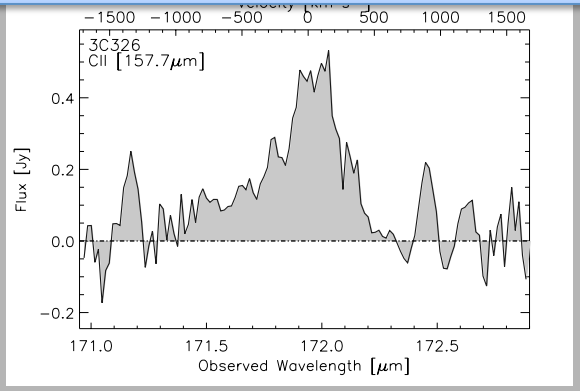
Stephan's Quintet
Contain > 10^9 M_{sun}
warm molecular gas
group-wide which
Is shock-heated by
dissipation of energy
from collision:
mid-IR rotational H_2
and C+ very powerful



Spitzer and Herschel studies
of more compact groups are
revealing evidence of shocked diffuse gas
Shocked systems have distinct IR colors
suggesting a transitional population
Cluver+2013

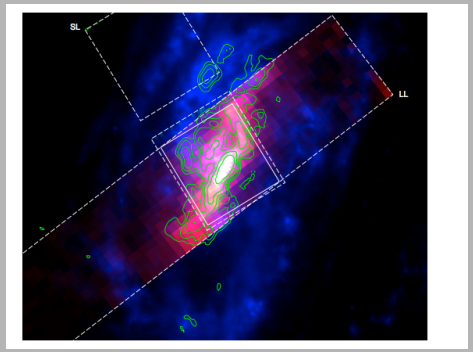
Appleton+2006,2013,Cluver+2010, Guillard+2009,2010,2012

Shocked/turbulent gas in Radio Galaxies



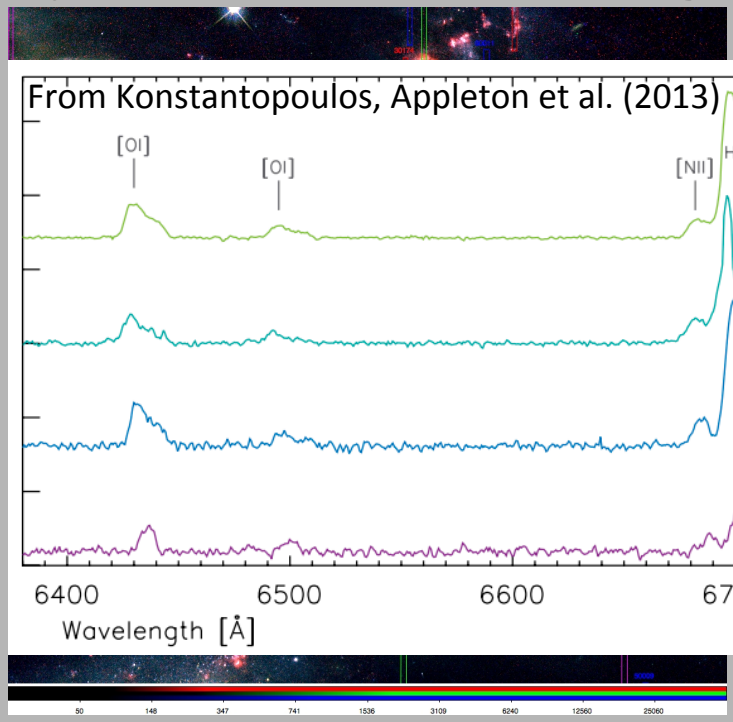
Powerful warm H_2 and C+ in 3C326
Guillard et al. 2014

Shocked H_2 gas
In the anomalous
arms of NGC 4258

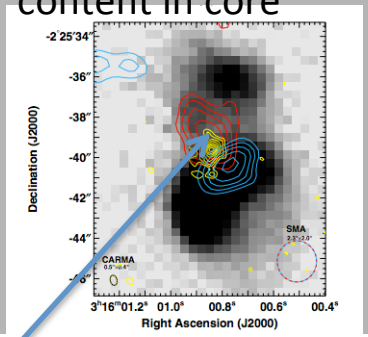


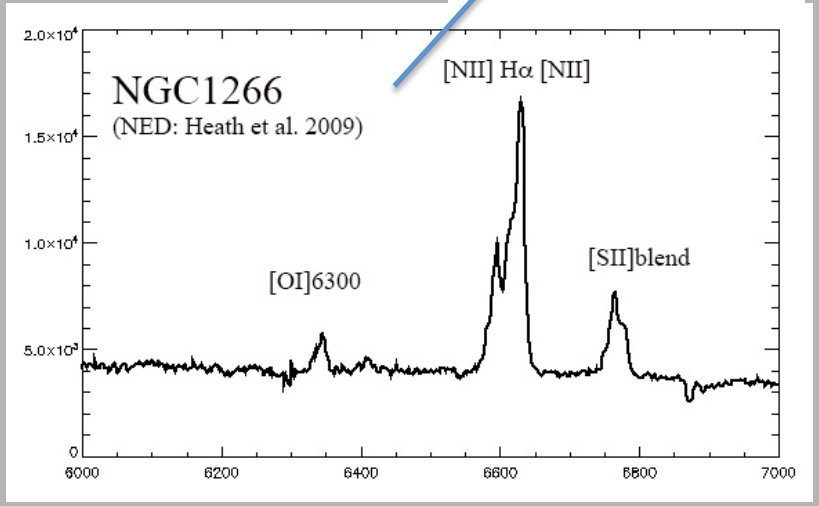
Ogle, Lanz & Appleton, 2014

Stephan's Quintet: the archetypal collisionally induced shocked system, but AGN outflows can also shock large quantities of the ISM in galaxies



Alatalo+11,+12,+14
Bipolar outflow
Strongly Suppressed SF, Huge molecular content in core





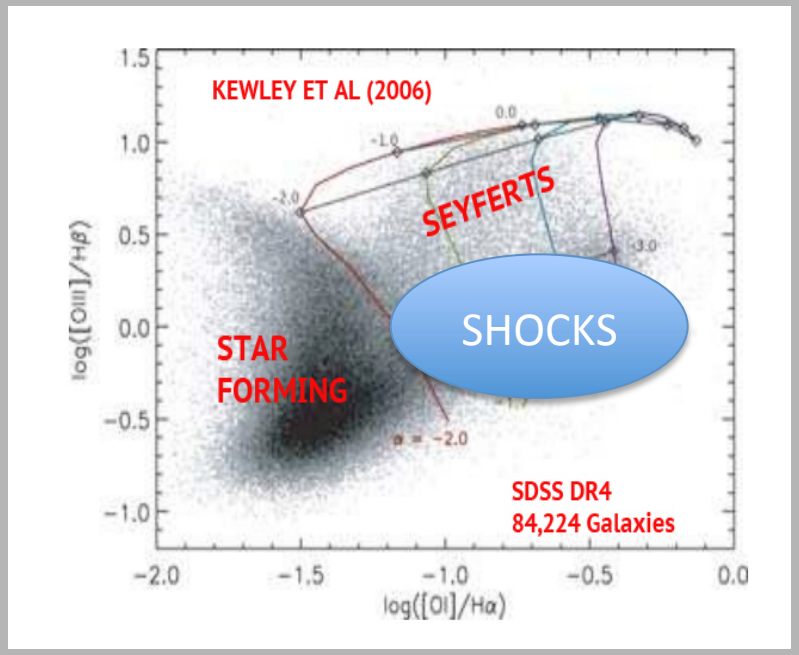
Optical Shock Signature:
High [OI]6300/Hα ratio
Very broad lines often asymmetric

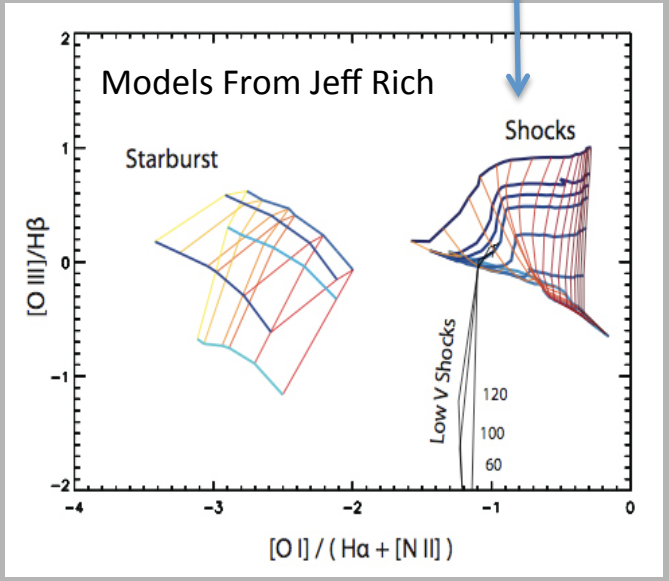
SPOGS

Post-starburst galaxies with evidence of large scale-shocked gas

Shocked ISM has well-determined spectral diagnostics based on both observation and theory

Katie Alatalo initiated the SPOGS project to define SPOGS in the VO/BPT diagnostic ratios



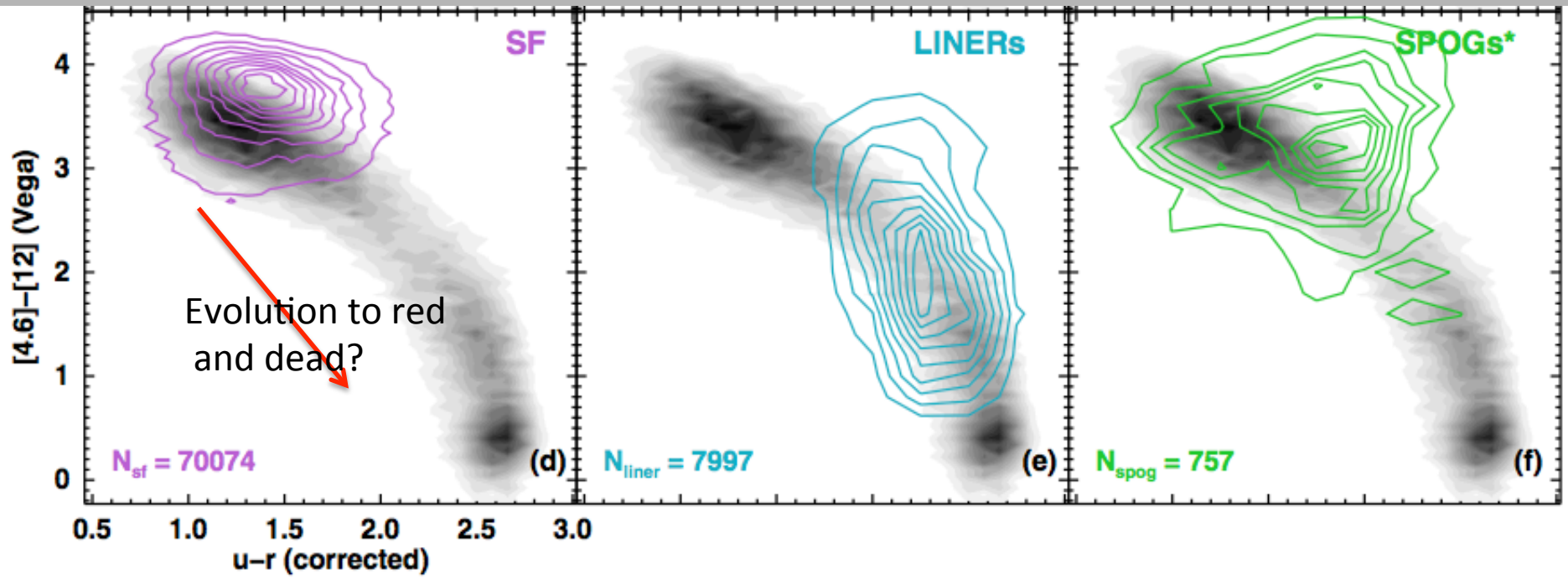


Models suggest shocks have distinctive line ratios in various emission-line diagnostic diagrams

WISE/OPTICAL COLORS OF GALAXIES SHOW MAJOR BIFURCATION

SPOGS may represent a rapidly transitioning population perhaps dominated by shocks? **(Alatalo+14)**

Shocked post-starbursts and LINERS seem to dominate the zone between Blue and red galaxies—Perhaps shocks may play a role in transitioning galaxies

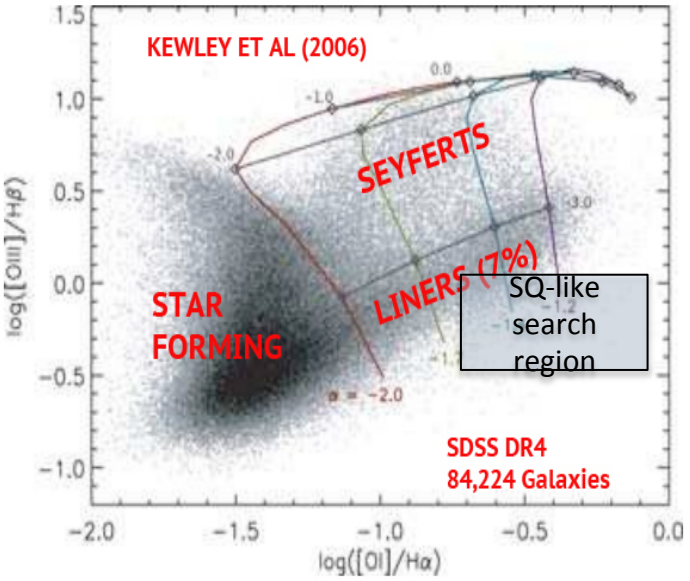


SPOGS and other LINERS occupy an interesting region in galaxy evolutionary phase

space—they are worth investigating further

Can we find more shocked systems?
Here I present an initial sampling of spectra from SPOGS+LINER sample derived from the Oh+2011 sample (OSSY) designed to find potentially shocked systems

Scaled up versions of these may exist at high-z



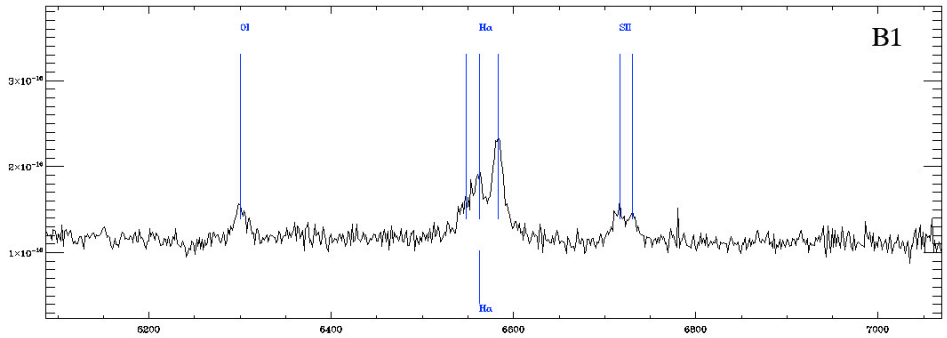
These objects represent < 0.5% of the SDSS galaxies

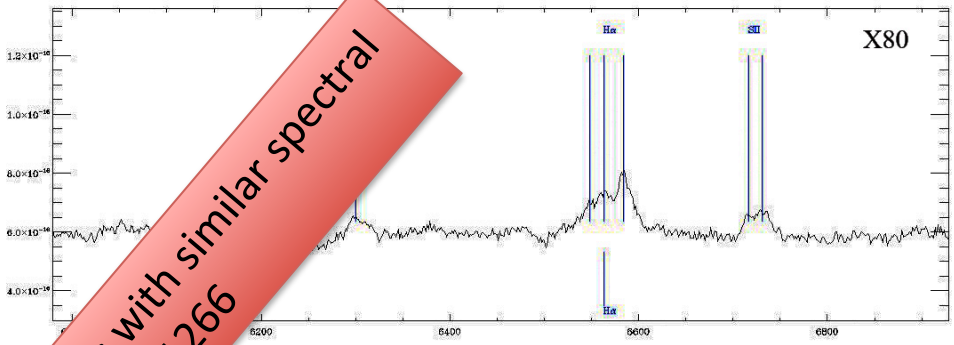
IN THE LOCAL UNIVERSE THEY ARE RARE!

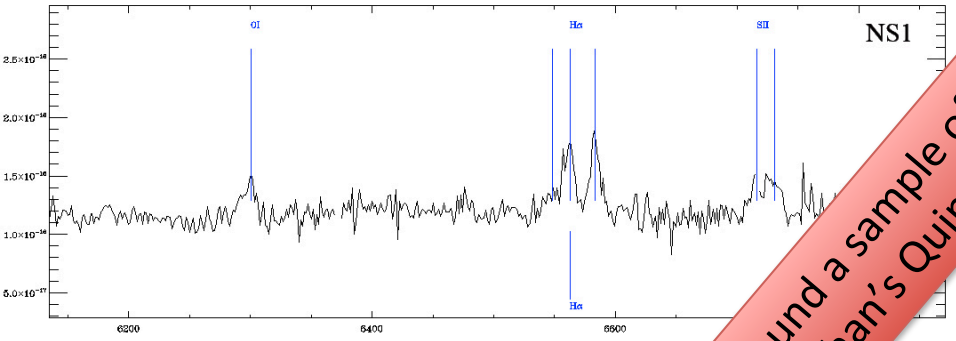
DO SIMILAR OBJECTS EXIST AT HIGH Z—

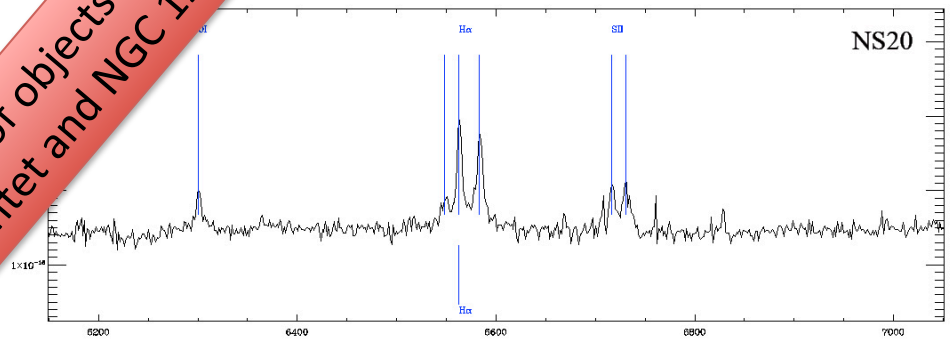
BIG SURVEYS WOULD BE REQUIRED

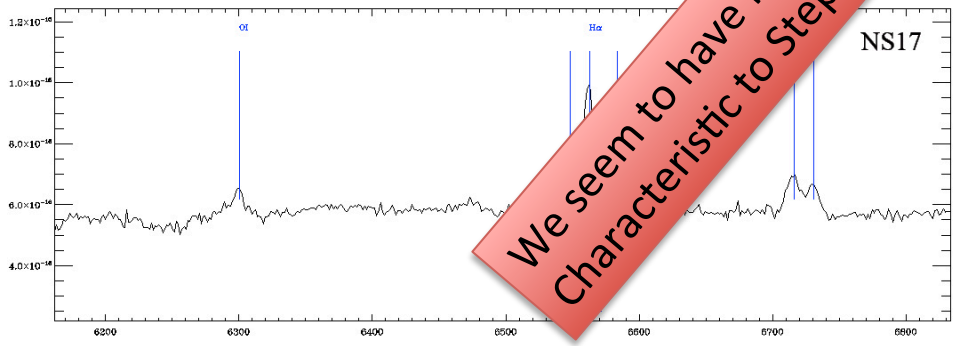
Rogues spectral-gallery of potentially shock-excited galaxies [OIII]/Hβ < 0.1, -0.7< [OI]/Hα < 0

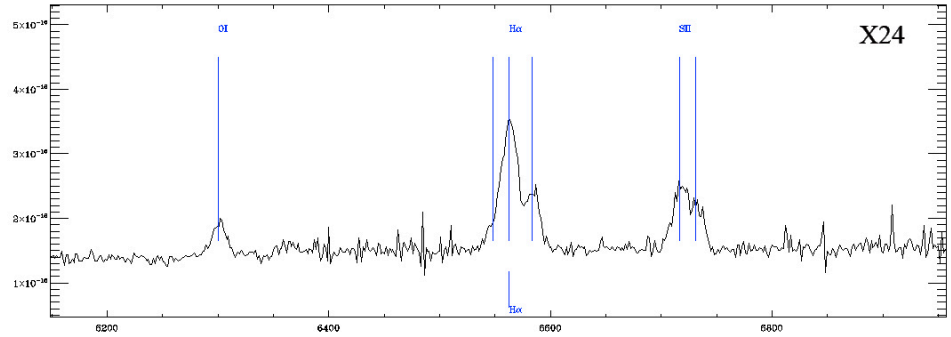












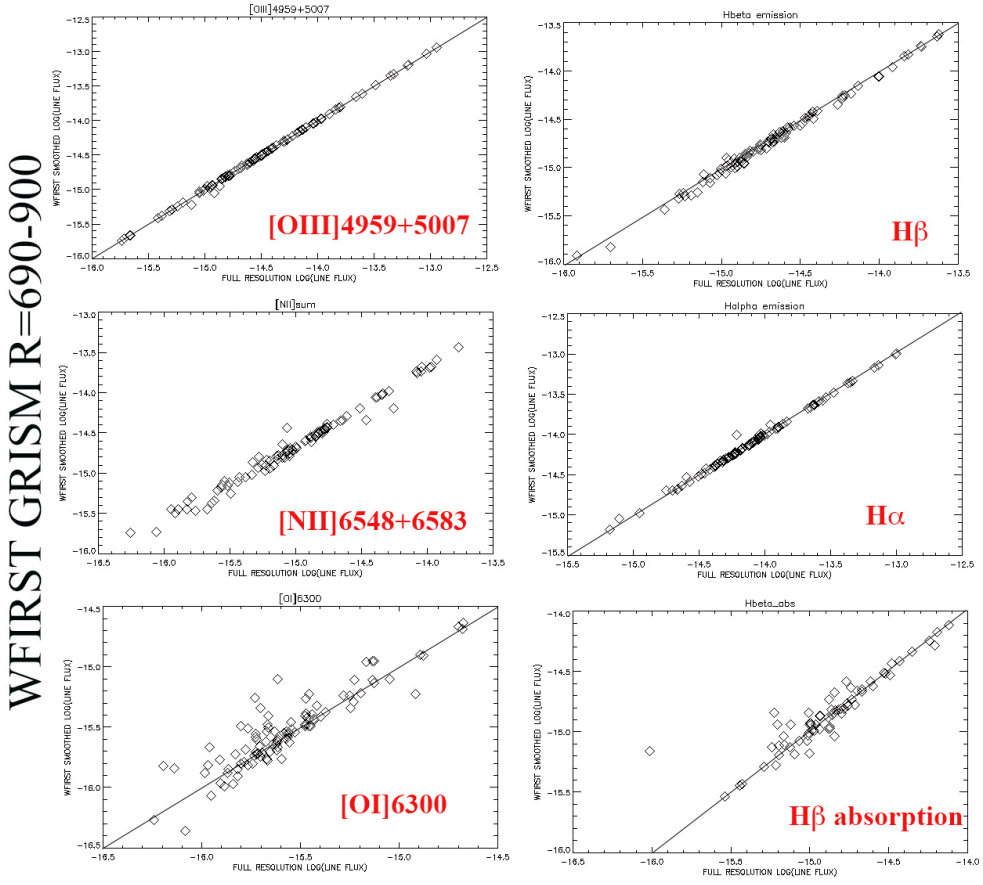
We seem to have found a sample of objects with similar spectral Characteristic to Stephan's Quintet and NGC 1266

Effects of lower resolution on line ratios? (WFIRST-AFTA GRISM 690< R < 900)

- We examined 140 (mainly SF dominated) spectra of galaxies from our SDSS sample and convolved to the resolution to WFIRST/GRISM
- Extracted line fluxes of principal lines
- Compared results
- The preliminary study does not take into account detailed aspects of the planned GRISM but just explores the degradation of resolution—More work will be needed

Effects of Resolution on measured lines?

Flux comparison from SDSS spectra
compared with spectra degraded to GRISM resol.



SDSS Resolution R = 1850–2200

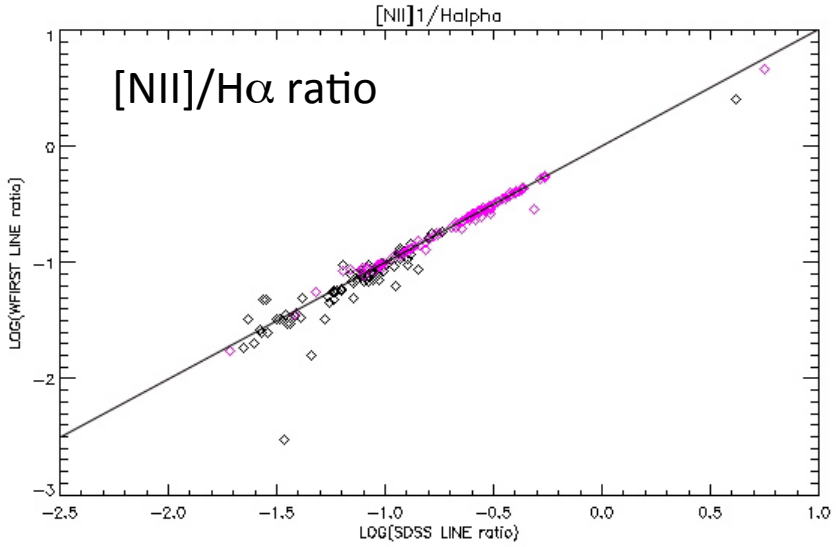
Isolated strong lines
have no obvious issues
in this limited study

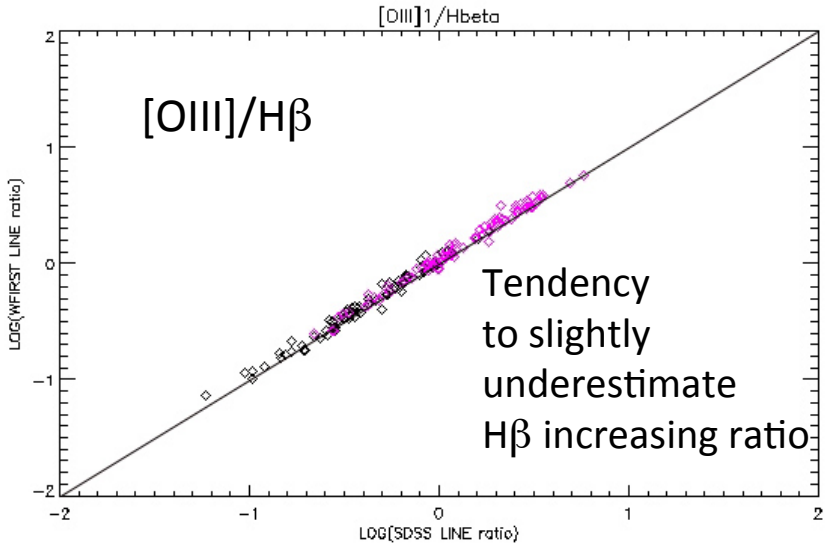
In particular at WFIRST-AFTA
GRISM resolution, we can recover
The Hβ narrow lines quite
well despite the presence of
Hβ absorption in many cases

Note—this is NOT a proper
simulation with WFIRST/GRISM
Spectral sampling and effects of
Confusion from nearby sources

More work is needed.

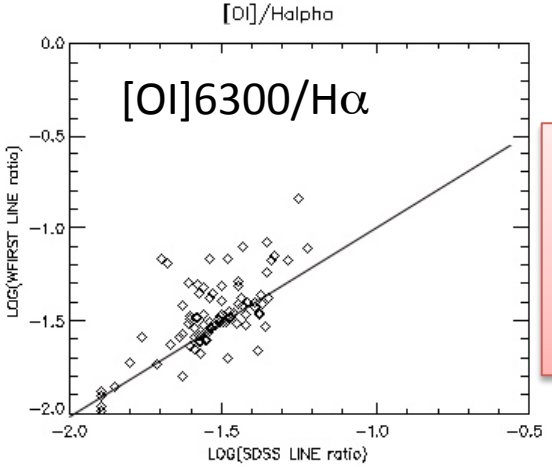
Assumed resolution from Interim
Report R= 690-900





How do the key diagnostic ratios do with the low-R spectra?

EFFECT OF RESOLUTION ONLY

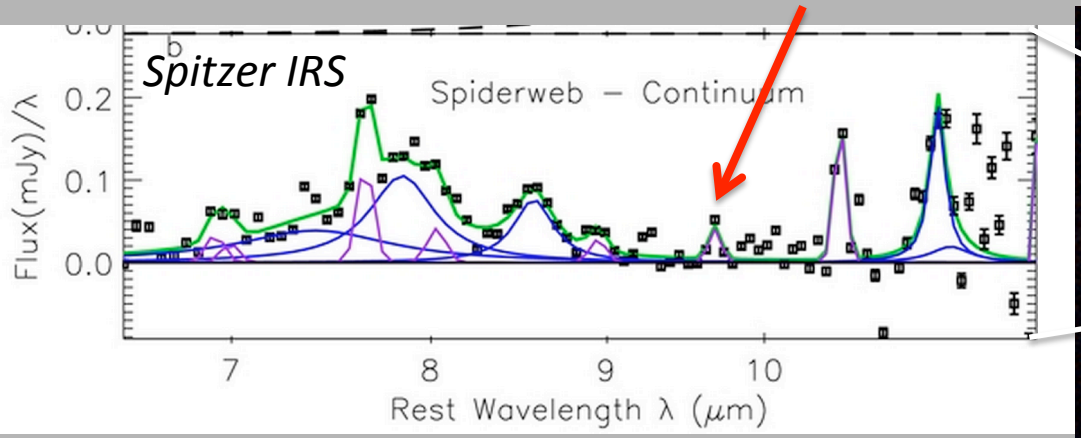


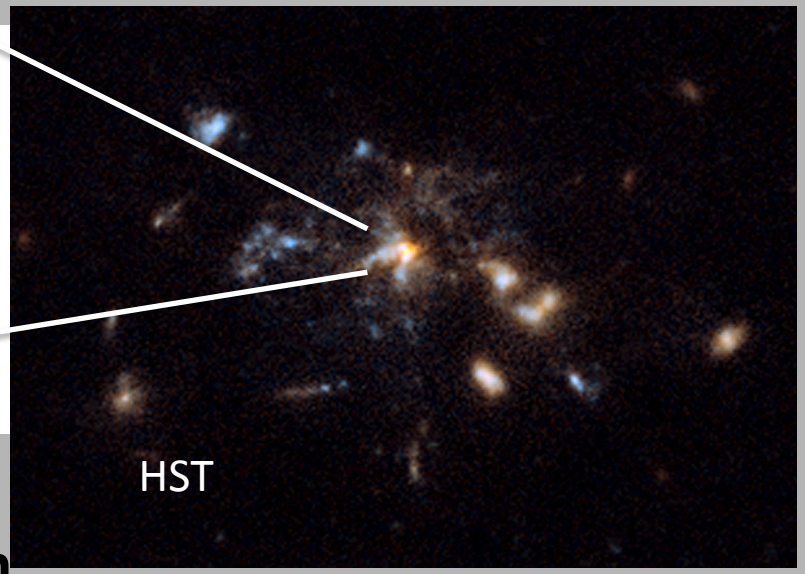
[OI]6300 feature
is often overestimated
in the smoothed spectra
when compared with Hα

Scaling up from Stephan's Quintet the Spiderweb Radio Galaxy z = 2.16?

PKS 1138-26 Ogle et al. (2012)

3.7 x 10^{10} $L_{\odot}$ in 0-0 S(3) line alone!





Mid-IR signal from molecular hydrogen shows likely huge quantities of shocked molecular hydrogen– a super-stephans quintet?

If ionized gas scales with amount of warm H_2 then shocked systems may be detectable with WFIRST at z = 1.8

Summary

- Assuming approximately 2000-3000 galaxies/sq degree for WFIRST detectable > 10^{-16} ergs/s/cm^2, and for the larger surveys planned 2000-3000 sq degrees/yr, even if only 0.5% of galaxies are are dominated by shocks—we should find thousands of shocked galaxies

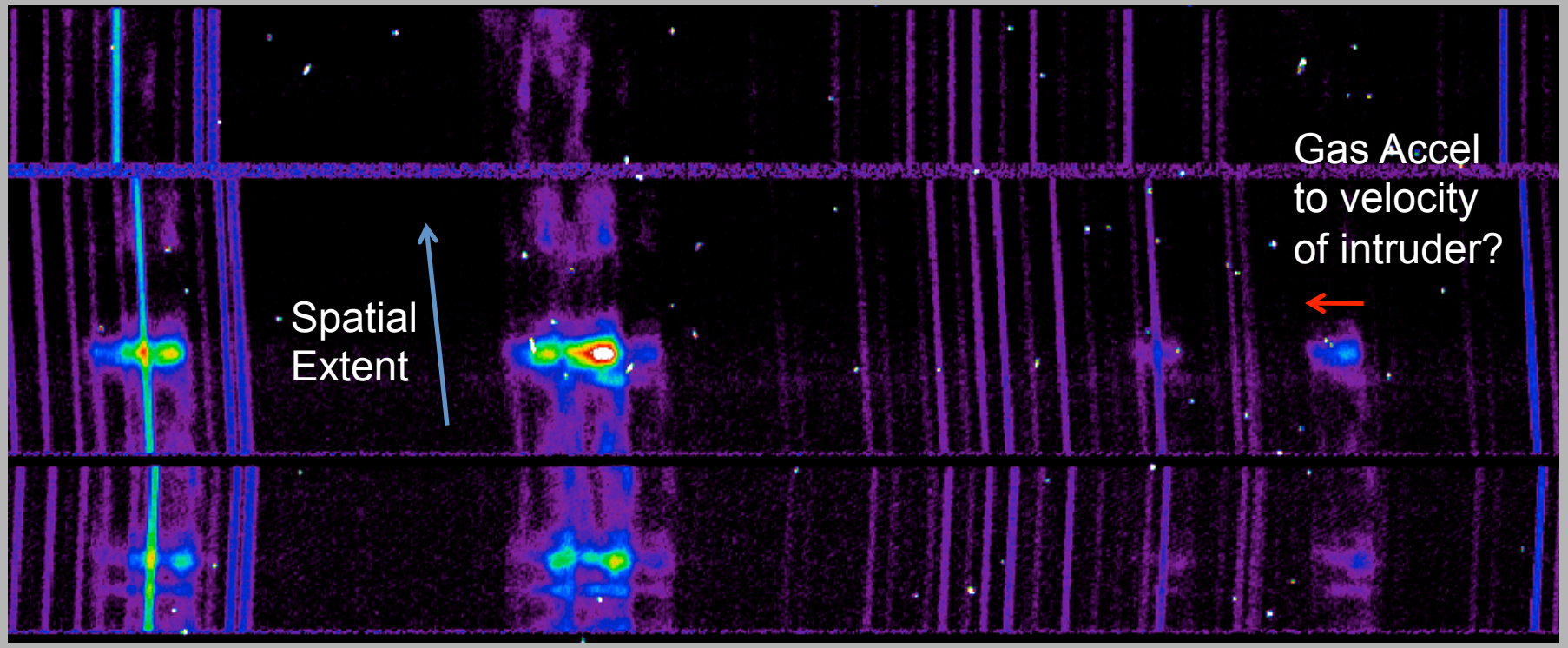
- Emission-line diagnostics will be doable for the brighter galaxies at z=1.8-1.9 (covering Hβ to Hα) with the current GRISM bandwidth, and could be larger if extended to longer wavelengths >1.95 μm. The resolution is only ~3x poorer than SDSS, and at this z would cover a huge volume. With R=625-900 basic diagnostic line measurements are possible.

- Scaled-up versions of local shocked systems may be detectable. If these galaxies are associated with quenching of star formation, it would provide a window into the universe at a time when disks are being built and cold-flows are potentially important. Follow-up with JWST 0-0S(3-5) line H_2?

- Radio galaxies and dense proto-clusters may be worth targeting with deep observations exploiting targets from micro-Jy all-sky radio surveys (SKA and precursors, and eVLA). Dense environments may contain more shocked gas (e. g. as in the Hickson Compact groups—Cluver et al. 2013)

Extras

GEMINI Visble SPECTRA of Stephan's Quintet show high degree of turbulence!



SHOW BROAD FAINT EMISSION WITH LOOPS AND BUBBLES OF GAS

Extending over 500-1000 km/s range

EXCITATION IS THAT OF SHOCK excitation (Xu et al. 2003—Shocks e. g. Rich et al. 2012).