

# WISH Canada

## Canadian Perspective and Interests



Marcin Sawicki

WISH International Science Workshop, Marseille 2014

# WISH Canada

- who we are -



Ferrarese

Willott

Davidge

Kavelaars

McConnachie

Scott

Abraham

Doyon

Webb

Willis

Ellison

Pritchett

Barmby

Yee

Balogh

Parker

Chapman

Sawicki

# What do Canadians WISH for?

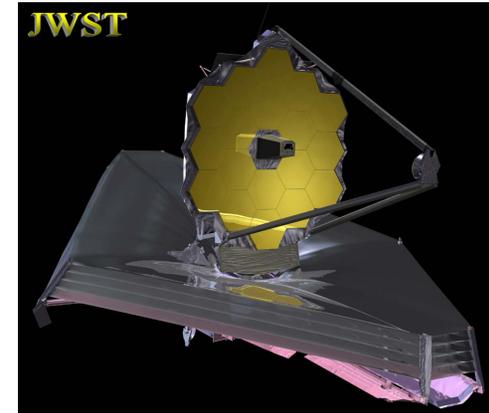
- + luminous First Light sources (*of course!*)
- + Dark Energy (CFHTLS heritage)

...but we also WISH for...

- + galaxy evolution out to  $z \sim 5$
- + galaxy clusters out to  $z \sim 2$
- + stellar populations in nearby galaxies
- + Solar System objects

# WISH in the Canadian context

**CCAT**



**JWST**



**TMT**



**ALMA**

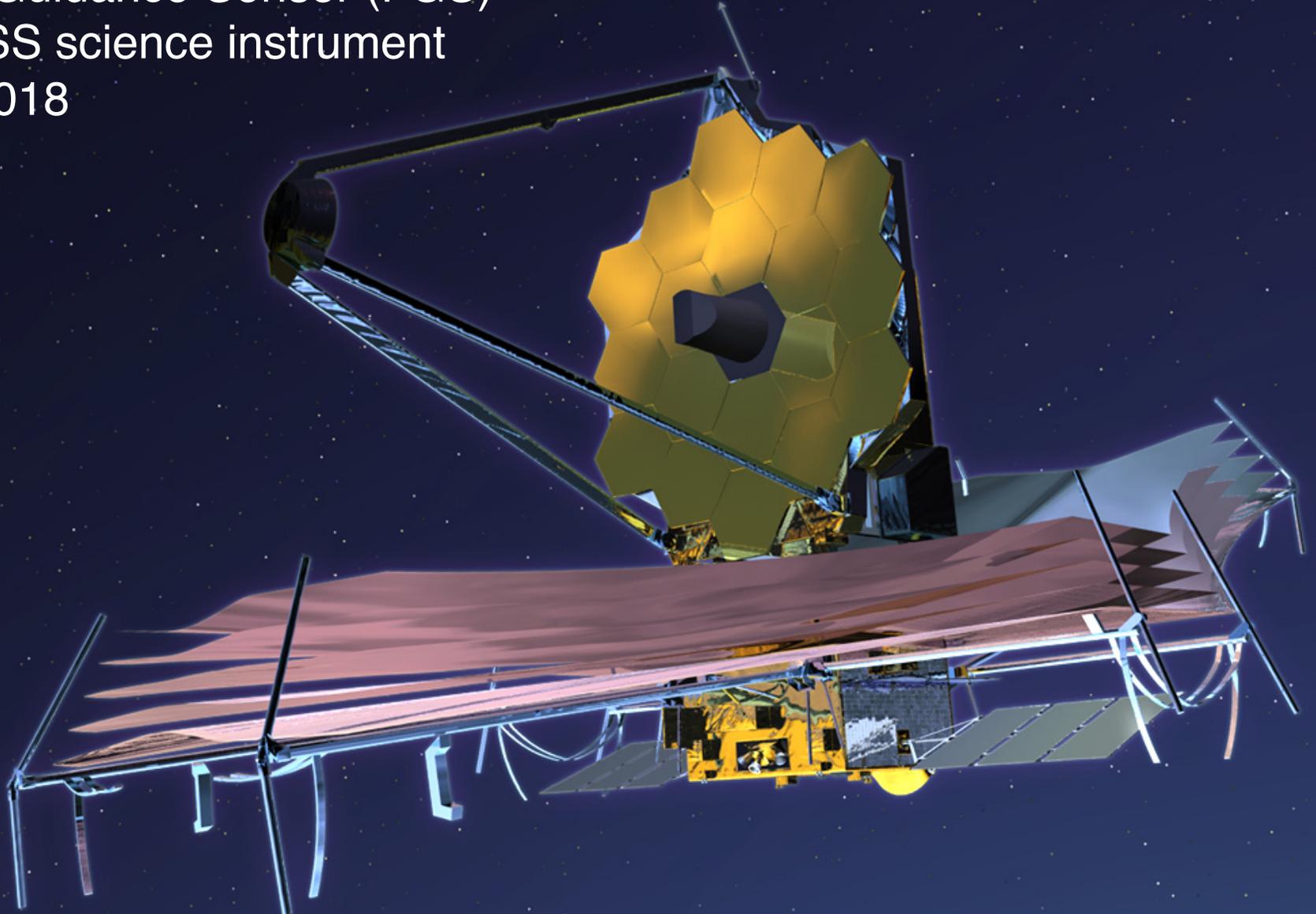
**Gemini (x2)**

**JCMT**

**CFHT**

# JWST

- Canadian Space Agency (CSA) one of the three partners
- Canada responsible for:
  - Fine Guidance Sensor (FGS)
  - NIRISS science instrument
- Launch 2018





# JWST NIRISS

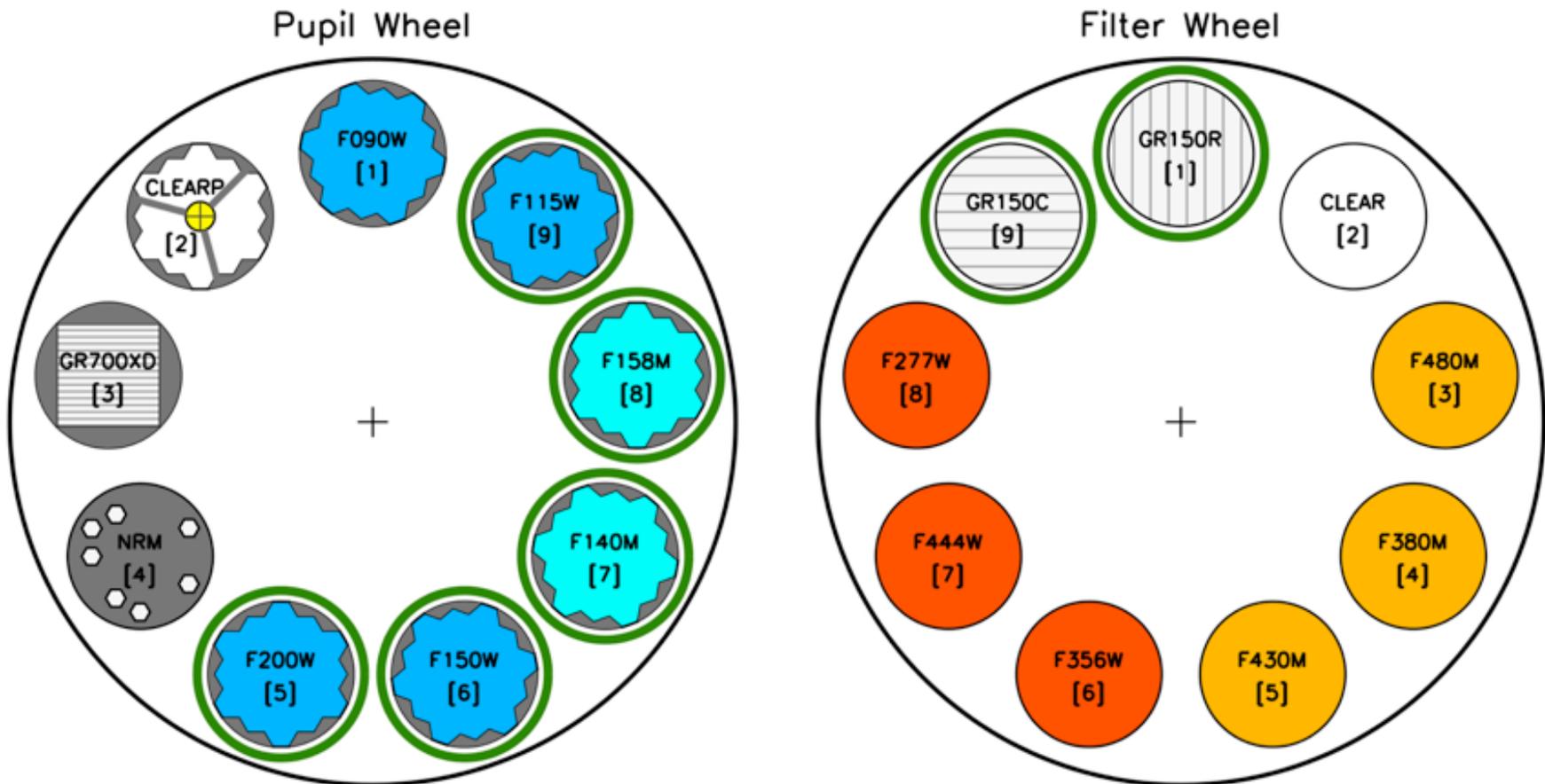
- NIRISS = Near-IR Imager and Slitless Spectrograph
- primary observing modes:
  - single-object R~700 spectroscopy (0.6-3um)
  - non-redundant mask (NRM) interferometry (3.8-4.8um)
  - wide-field R~150 grism spectroscopy (1-2.2um)



- built in Canada
- delivered to NASA in summer 2013
- now at GSFC undergoing integration and testing

# NIRISS wide-field slitless spectroscopy

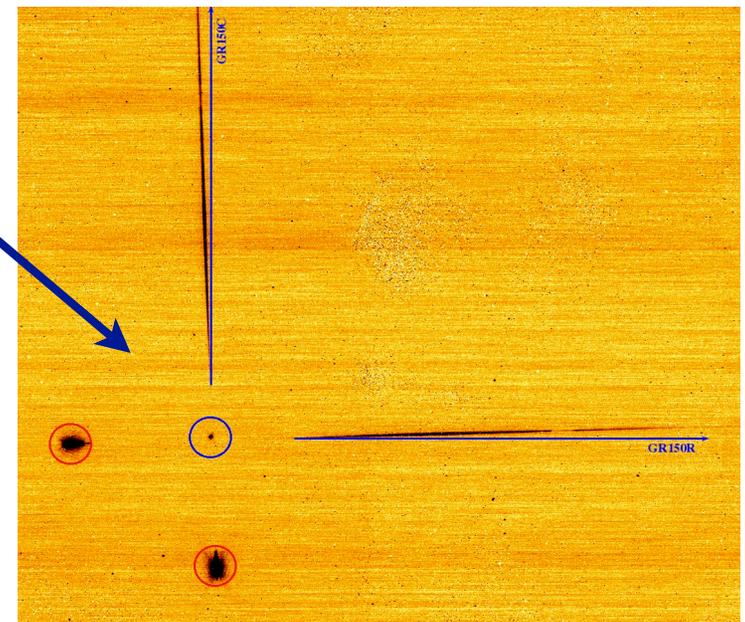
- NIRISS can do wide-field slitless spectroscopy in FOV 2.2' x 2.2'
- Two orthogonal R=150 grisms and six blocking filters from 0.9 to 2.2 microns



# NIRISS wide-field slitless spectroscopy

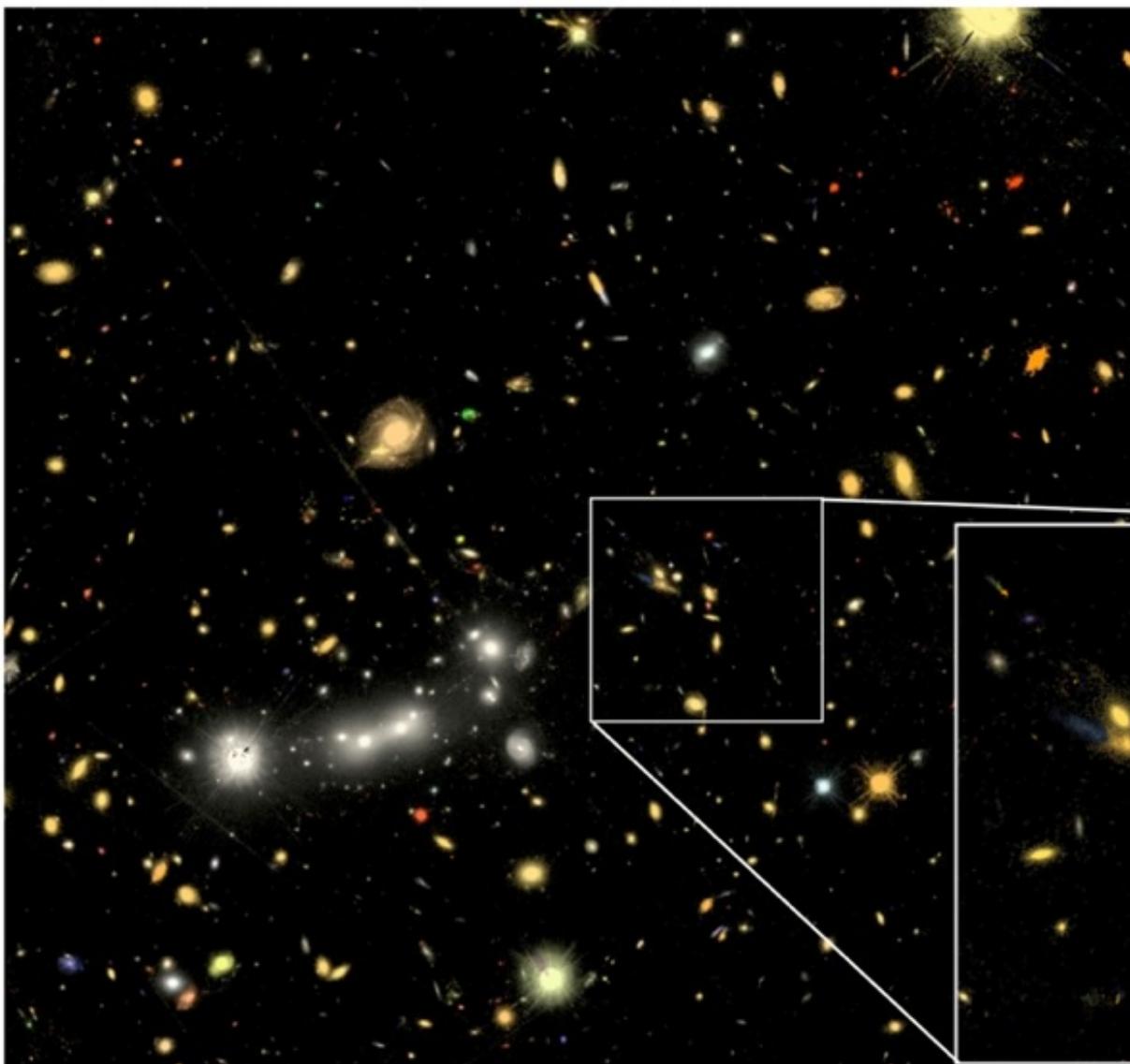


- Spectra of **all** objects in the field. In a “blank” field there are **~3000** galaxies at  $\text{mag} < 28$ .
- Almost complete **wavelength coverage** from 0.9 to 2.2 microns.
- At least one strong **emission line** from  $z=0.5$  to  $z=4.9$ . Ly $\alpha$  (if present) at  $6 < z < 17$ .
- Resolving power of 100 to 200. Most lines spectrally unresolved, so a **map of line emission**.
- **Spatial resolution** of  $0.06'' \sim 0.5$  kpc.
- **Cross-dispersed** grisms to mitigate contamination.
- **Point-and-shoot** observing - no target acquisition.
- Ideal for pure **parallels** due to simple operation.



# NIRISS wide-field slitless spectroscopy

Simulated NIRISS imaging observation of MACS0647 cluster



Full NIRISS FOV = 2.2' x 2.2'

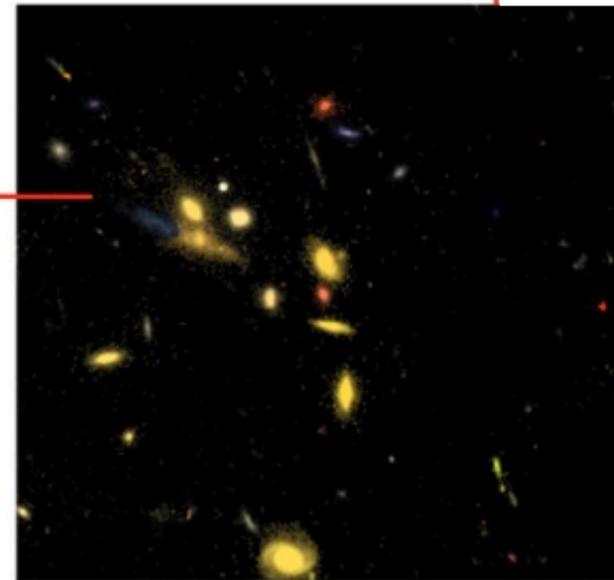
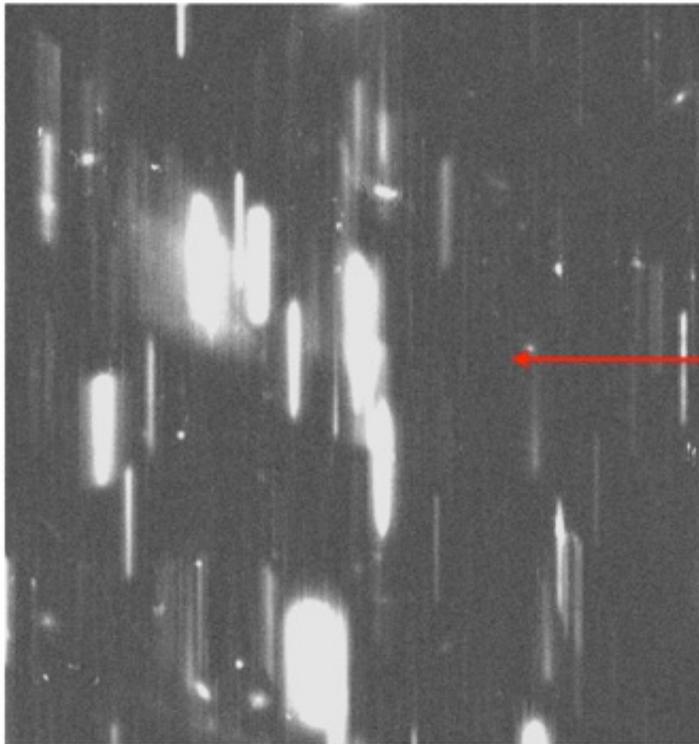
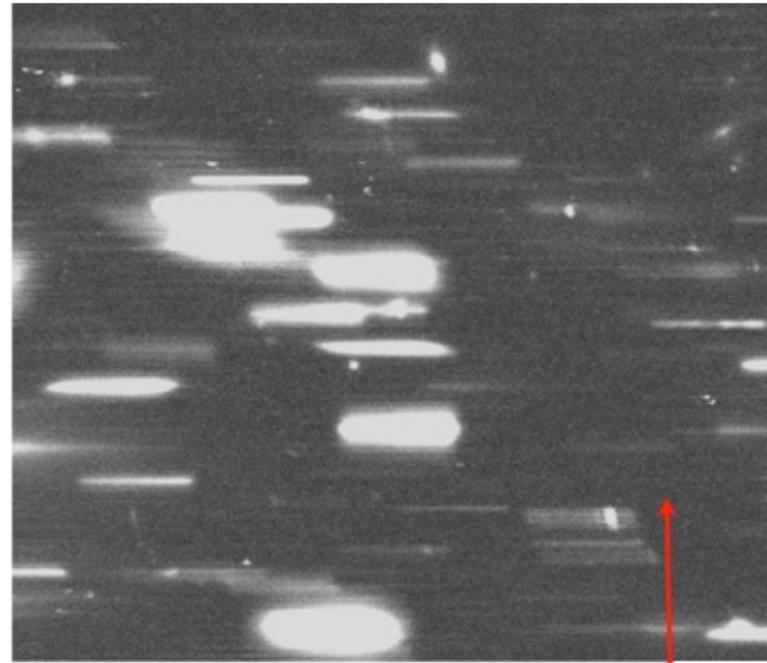
Zoom in to part of field

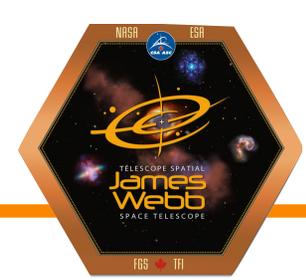
# NIRISS wide-field slitless spectroscopy

NIRISS Simulation

Orthogonal grism data  
for this part of field.

Lots of emission lines

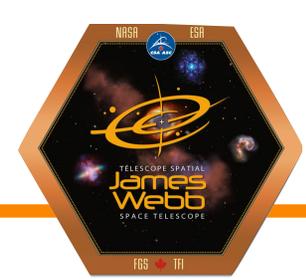




# NIRISS wide-field slitless spectroscopy

“First Light” science aims:

- Confirm redshifts for LBG candidates
- Discover high-EW Lyman- $\alpha$  galaxies not selected as LBGs
- Measure galaxy spectral slopes,  $\beta$ , for stellar pops, dust.
- Lyman- $\alpha$  EW as a function of redshift and luminosity - reionization
- Spatial distribution of Lyman- $\alpha$  emission, especially when lensed
- Signatures of AGN (e.g. H $\alpha$ , C IV, C III]) or Pop III (H $\alpha$ )
- Physical associations, e.g. groups, clusters



# NIRISS wide-field slitless spectroscopy

“Galaxy Assembly”,  $z < 5$ , slitless grism science is exciting:  
A low-resolution spectrum for every object in the field!

- Much better than photo-z's:

redshift catalogs good enough to, e.g., assign galaxies to local environment

- Total line fluxes and line ratios:

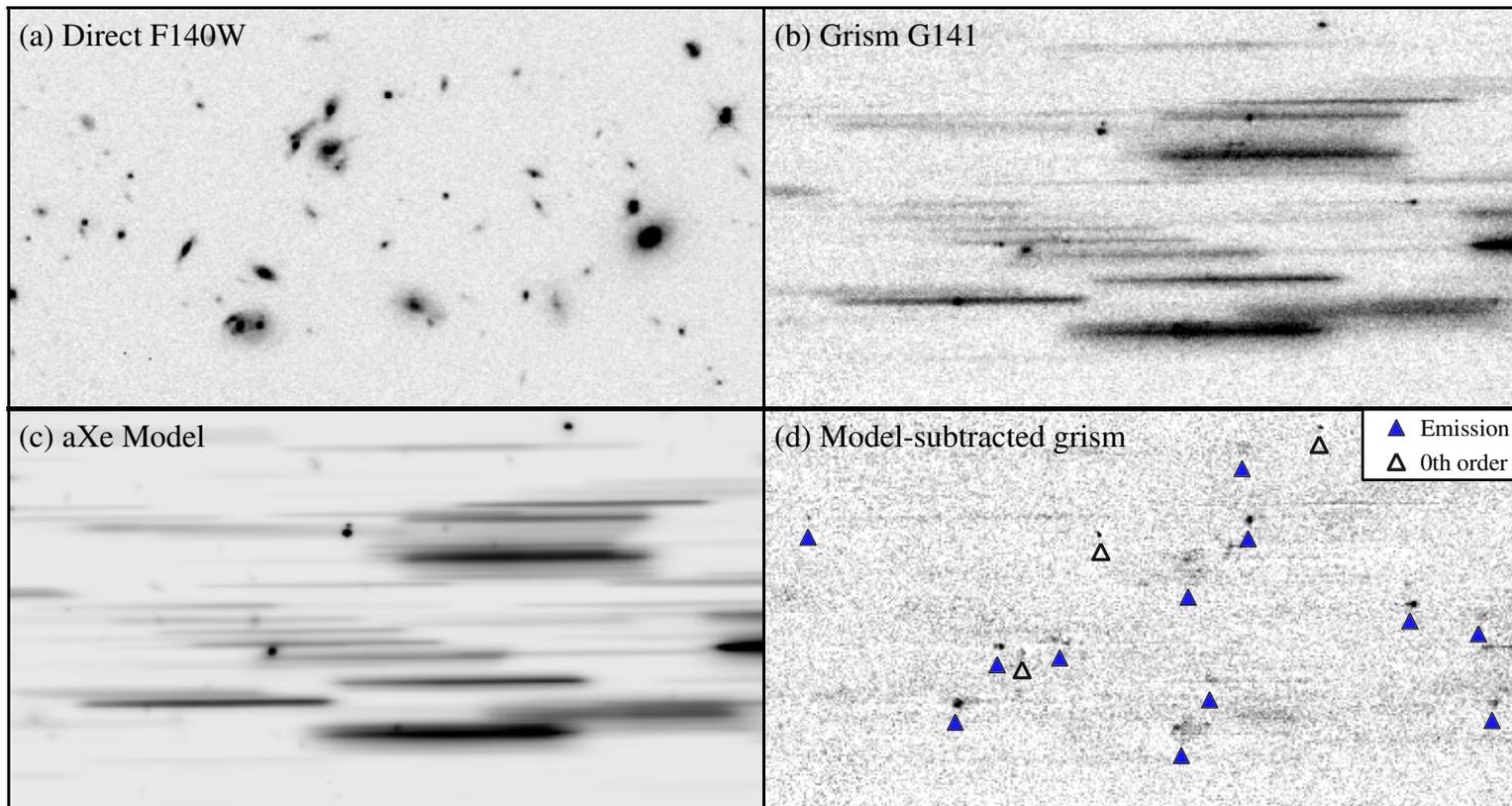
SFRs, extinction, metallicity as function of time, galaxy type, stellar mass

- Spatial distributions of line emission:

where in a galaxy do stars form as function of epoch, galaxy's mass?  
spatial distributions of stellar populations, metallicities

# NIRISS wide-field slitless spectroscopy

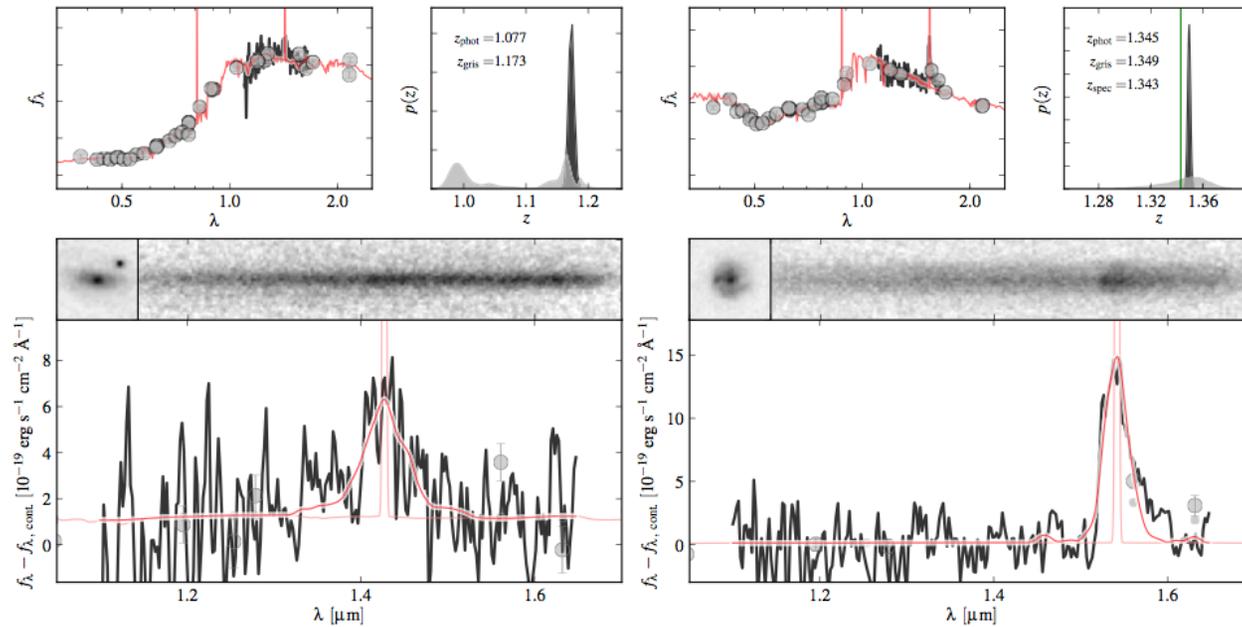
The 3D-HST survey with WFC3-IR has highlighted capabilities of space-based near-IR grisms



Brammer et al. 2012

# NIRISS wide-field slitless spectroscopy

## 3D-HST: good redshifts for every object in the field:



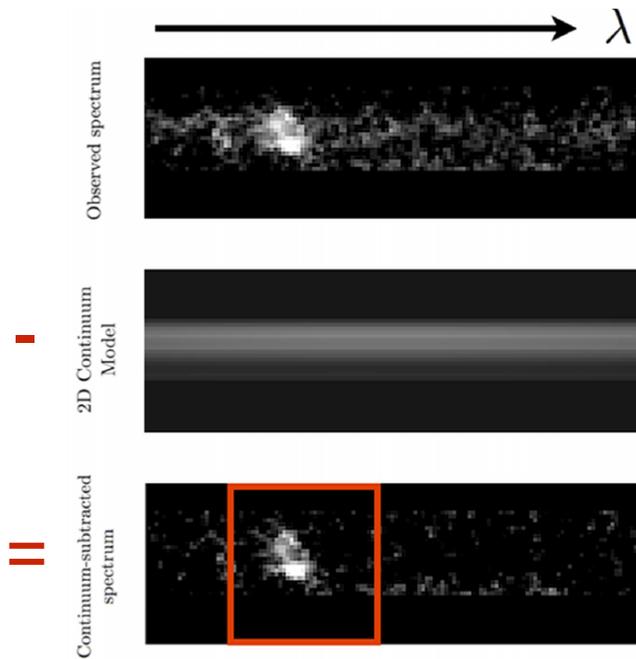
Brammer + 2012

- standard  $\delta z_{\text{phot}}$  too big for ID'ing environment (local density), true galaxy pairs
- but with grism  $\delta z_{\text{grism}} \sim 10\times$  better than  $\delta z_{\text{phot}}$ .
- This is particularly powerful when combining  $z_{\text{grism}}$  &  $z_{\text{phot}}$

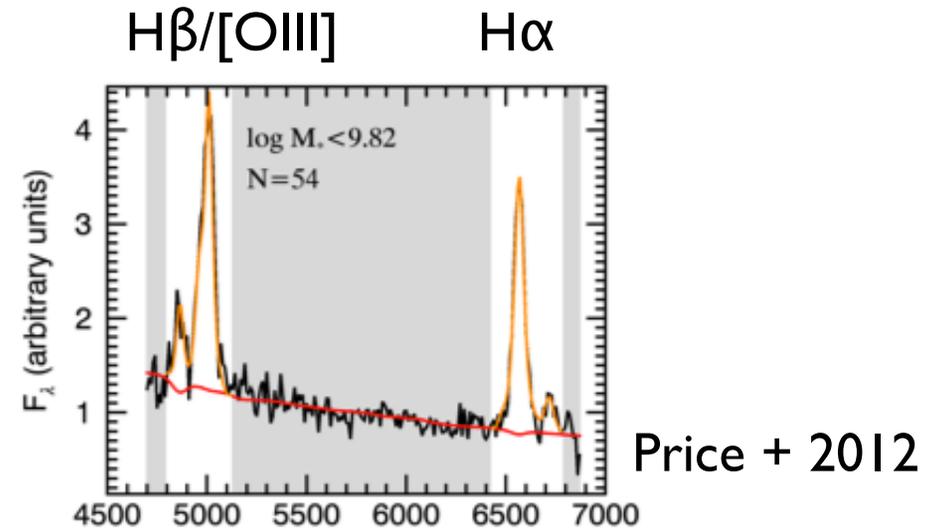
# NIRISS wide-field slitless spectroscopy



## 3D-HST: line fluxes and line ratios:



Schmidt + 2013

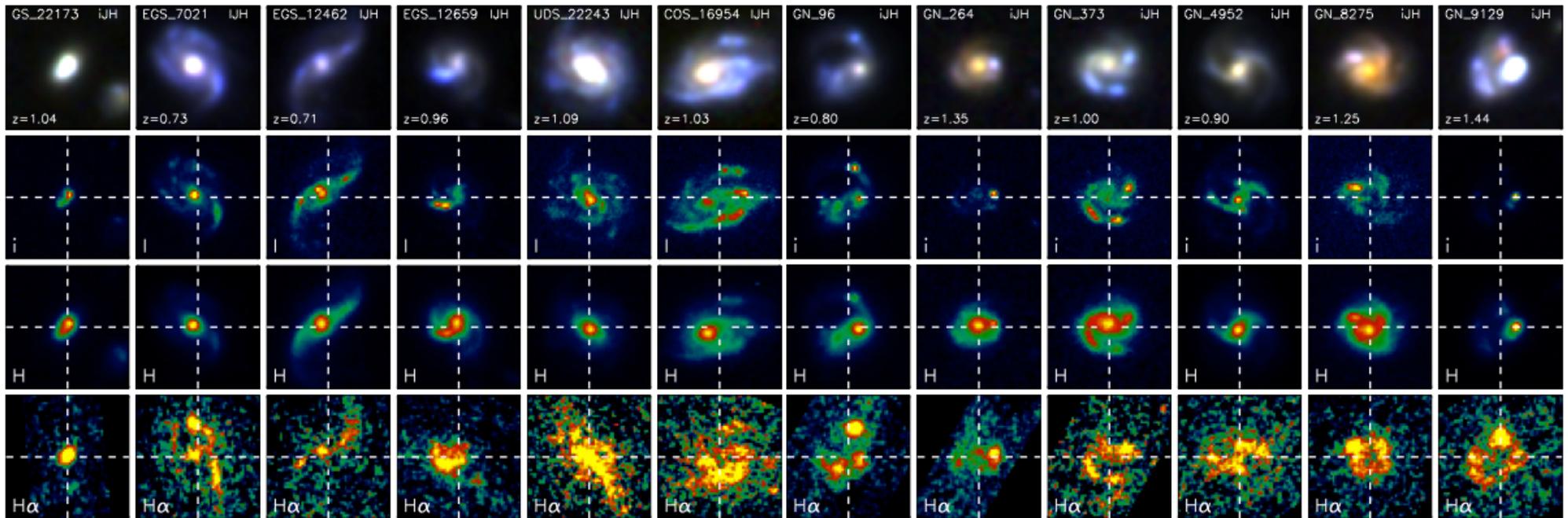


- Total fluxes. No slit losses, no NB wavelength uncertainty.
- Emission line luminosity:
  - ➔ star formation rate, extinction, metallicity
- Absorption line strength:
  - ➔ age - more difficult, can be done if bright or by stacking

# NIRISS wide-field slitless spectroscopy

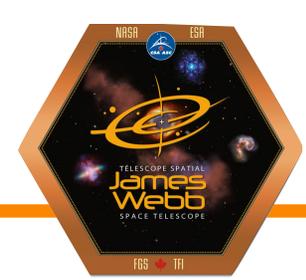


## 3D-HST: spatial distribution of line emission



Wuyts + 2014

- Line map  $\rightarrow$  star formation map
- Line ratios  $\rightarrow$  metallicity, reddening, AGN signatures, stellar population gradients

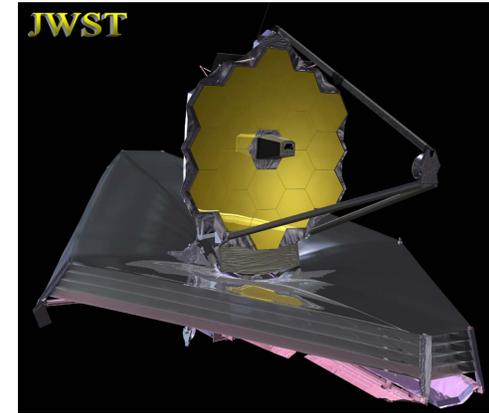


# JWST

- We are very excited about JWST in Canada
- great for First Light science
- fantastic for “Epoch of Galaxy Assembly” at  $z=1-5$
- NIRISS science team plans to spend  $\sim 1/2$  its GTO time (200hrs) in the wide-field slitless spectroscopy mode
  
- But: JWST has a small FoV:  
    NIRCam =  $10 \square'$ ; NIRISS =  $5 \square'$
- JWST will have a hard time finding rare, luminous objects that (a) probe extreme of physical parameter space and (b) can be followed-up in detail even with ELTs

# WISH in the Canadian context

**CCAT**



**JWST**



**TMT**

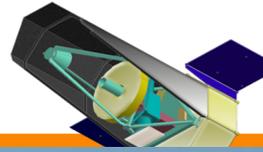
**ALMA**

**Gemini (x2)**

**JCMT**

**CFHT**

# Synergy with TMT

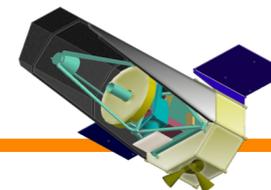


- Canada one of the first partners
- Canada responsible for:
  - enclosure
  - NFIRAOS AO system
- \$300M (planned Canadian share)





# Synergy with TMT



Most JWST very-high-z objects will be too faint for spectroscopy with ELTs  
...but...

TMT will be able to study the rare, luminous objects that WISH finds.

## WISH Ultra Deep Survey:

(100deg<sup>2</sup>, 28AB, 1-4um 15h integration)

e.g.: z = 11-12 galaxies

~26.5AB  
~5/deg<sup>2</sup>

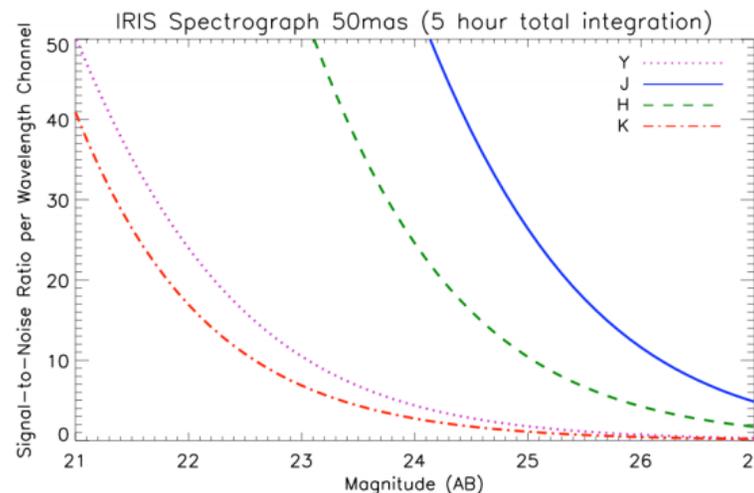
~27AB  
~20/deg<sup>2</sup>

## TMT/IRIS:

0.1" aperture AO-assisted

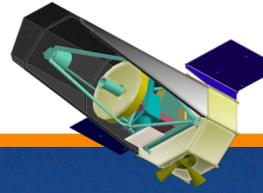
Continuum H-band, 5hrs, S/N= 2-3

26-27 AB (R~4000 resolution unit)



Wright et al. 2010  
0.1" aperture / point source  
0.05"/pix

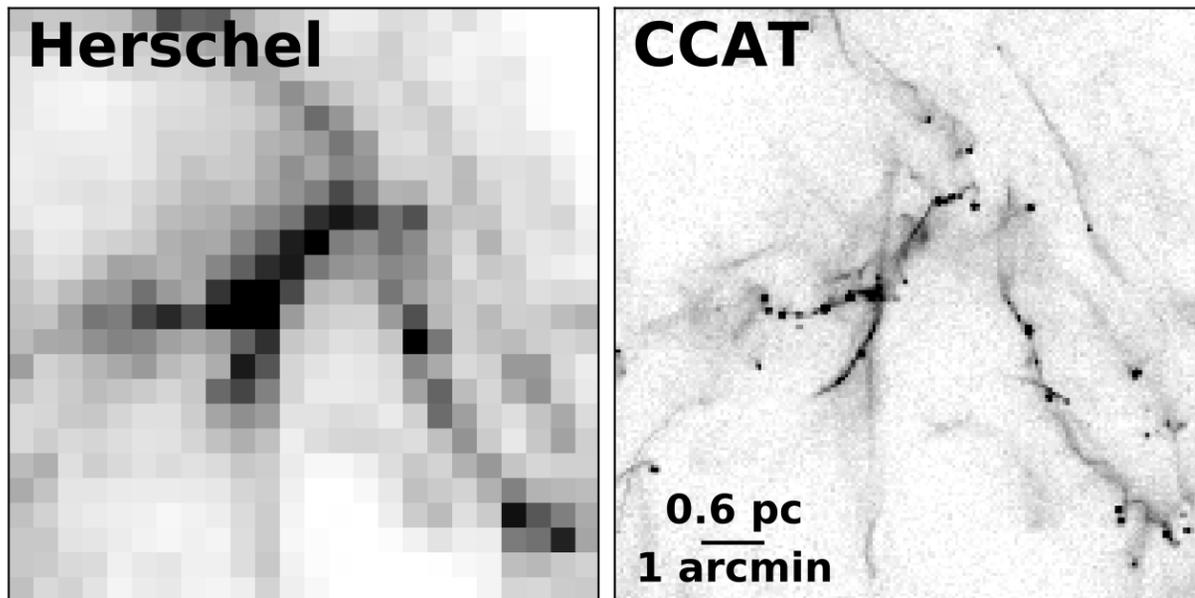
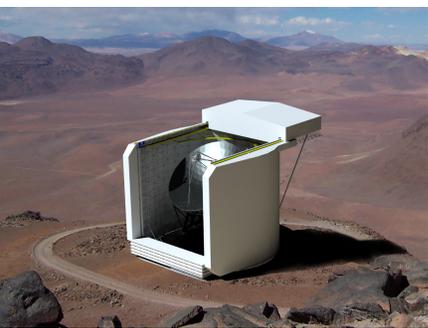
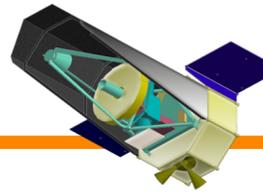
# Synergy with CCAT



- proposed 25m sub-mm telescope in the high Atacama
- 1000x faster mapping speed than SCUBA2
- consortium of US, German, and (10) Canadian institutions
- first light ~2020



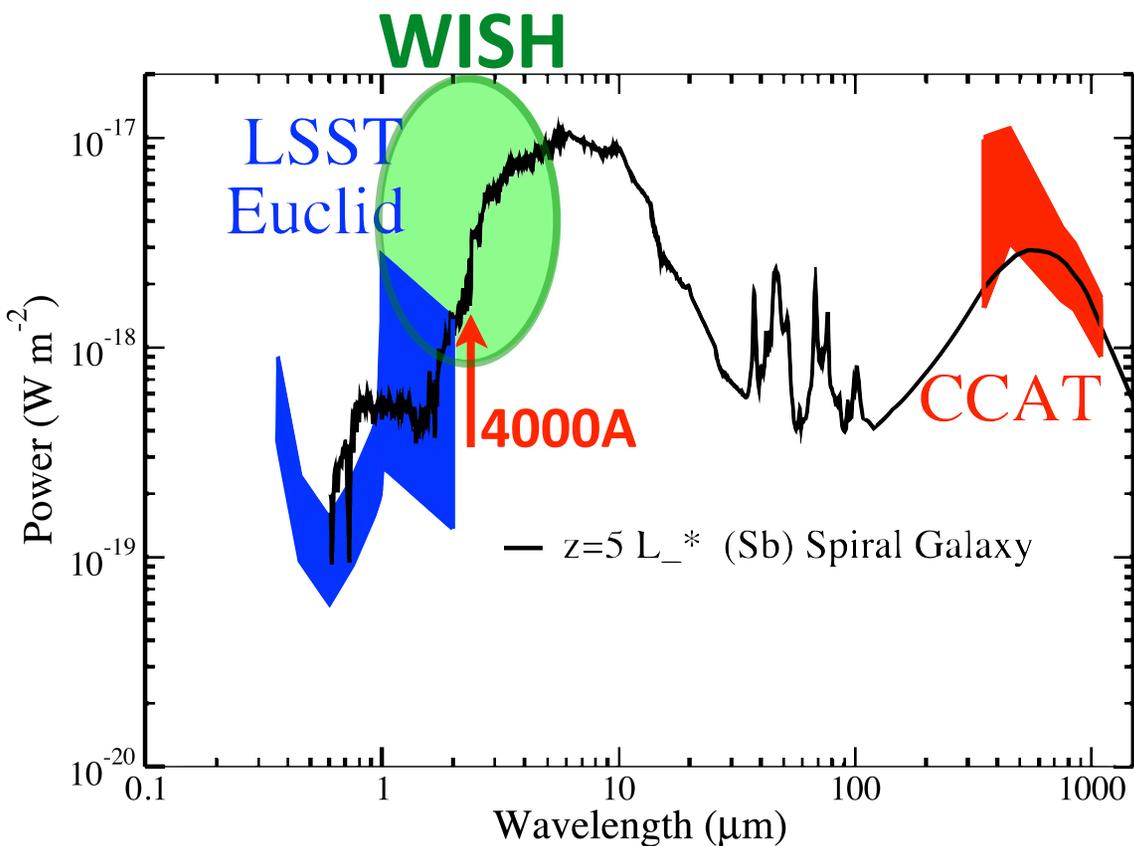
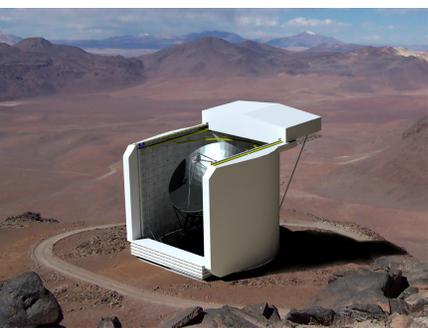
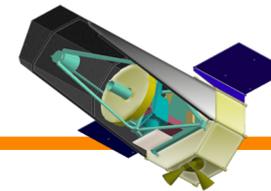
# Synergy with CCAT



Herschel vs CCAT at 350um: a simulated image of a molecular cloud

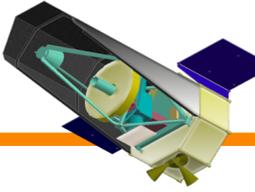
- CCAT designed for large surveys and large statistical samples
- CCAT will survey  $>100 \text{ deg}^2$  at 350, 450, 850um: i.e., the very dusty universe
- WISH will sample around 4000A at  $z \sim 5$ , => measure stellar masses etc. of CCAT objects

# Synergy with CCAT



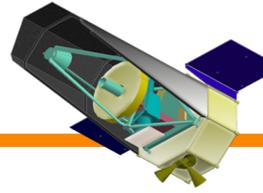
- Strong case for pushing the studies of sub-mm galaxies in early cosmic epochs,  $z \sim 5$
- WISH will sample around 4000A at  $z \sim 5$ , => measure stellar masses etc.
- WISH an excellent follow-up instrument for characterizing high- $z$  very dusty galaxy

# WISH and the assembly of galaxies ( $z=1-5$ )



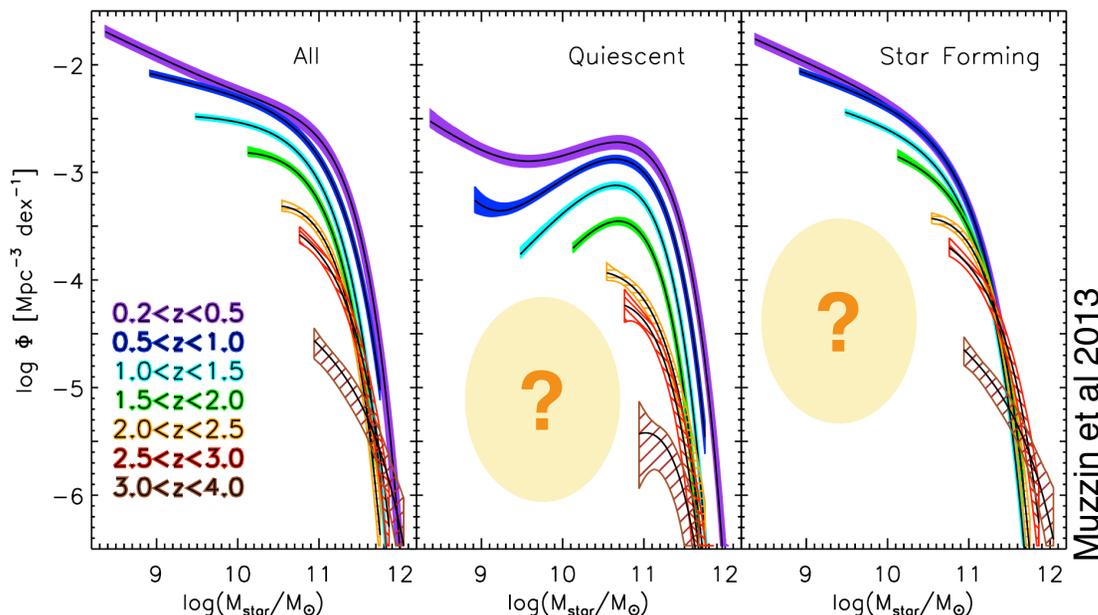
- WISH will be great for “first light” science
- it will be even better for the “epoch of galaxy assembly” at  $z \sim 1-5$

# WISH and the assembly of galaxies ( $z=1-5$ )



- $z = 5 \rightarrow 1$  is where much of galaxy-building takes place
- We still have much to learn at these epochs:
  - how much stellar mass has been assembled?
  - how important is environment?
  - how do galaxies go from star-forming to quenched?
  - what role do interactions and AGN play?

One example of our ignorance:



- Current surveys barely resolve the peak in galaxy formation efficiency at  $1 < z < 3$
- Evolution of galaxies with  $M < 10^{10}$  is largely unconstrained.
- WISH will reach  $10^9 M_{\odot}$  for quiescent galaxies and  $10^8 M_{\odot}$  for star-forming galaxies at  $z \sim 3$

# WISH and the assembly of galaxies ( $z=1-5$ )

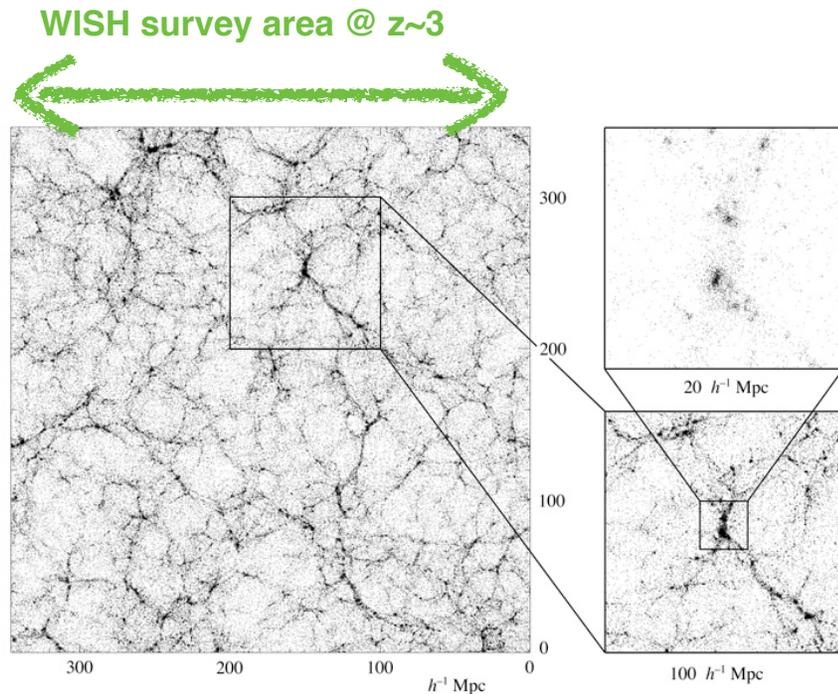
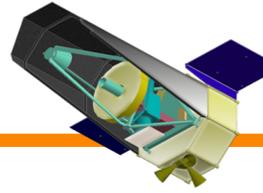
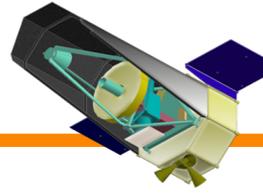


Fig 8.16 (D. Weinberg) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

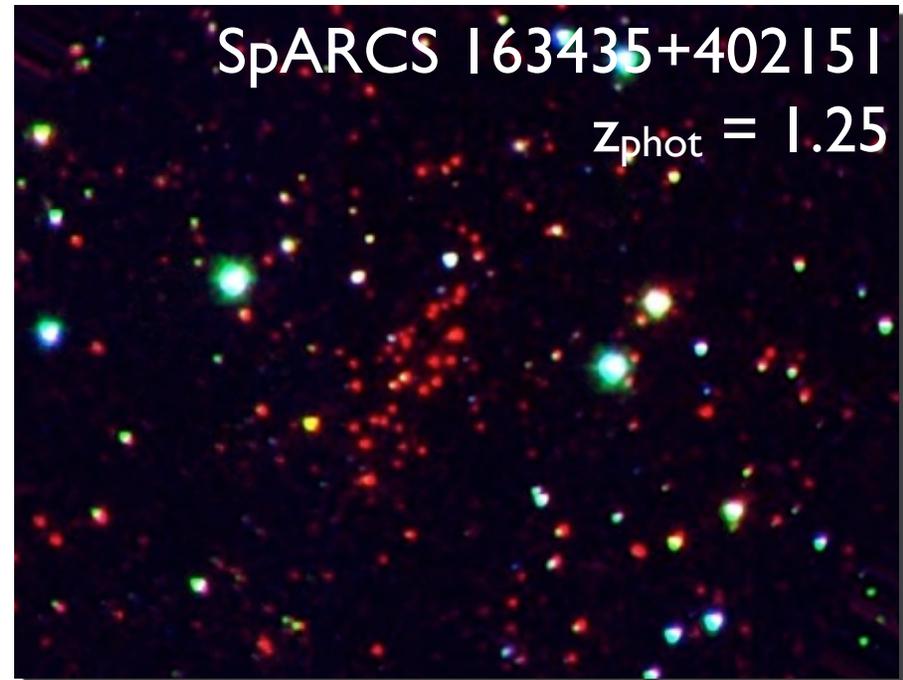
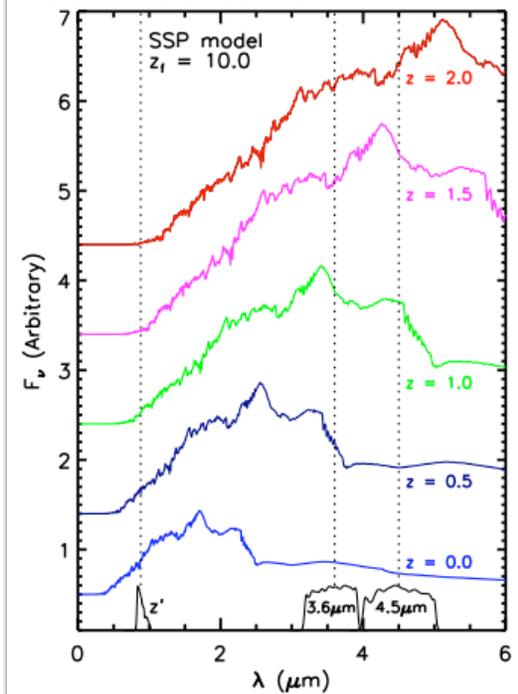
- Galaxy evolution at  $z\sim 0$  seems to depend on local environment (e.g., Peng et al. 2010)
- This may also be the case at high redshift!
- $\rightarrow$  we need large galaxy samples across a range of environments
- $\rightarrow$  WISH

# Clusters at $z=1-2$

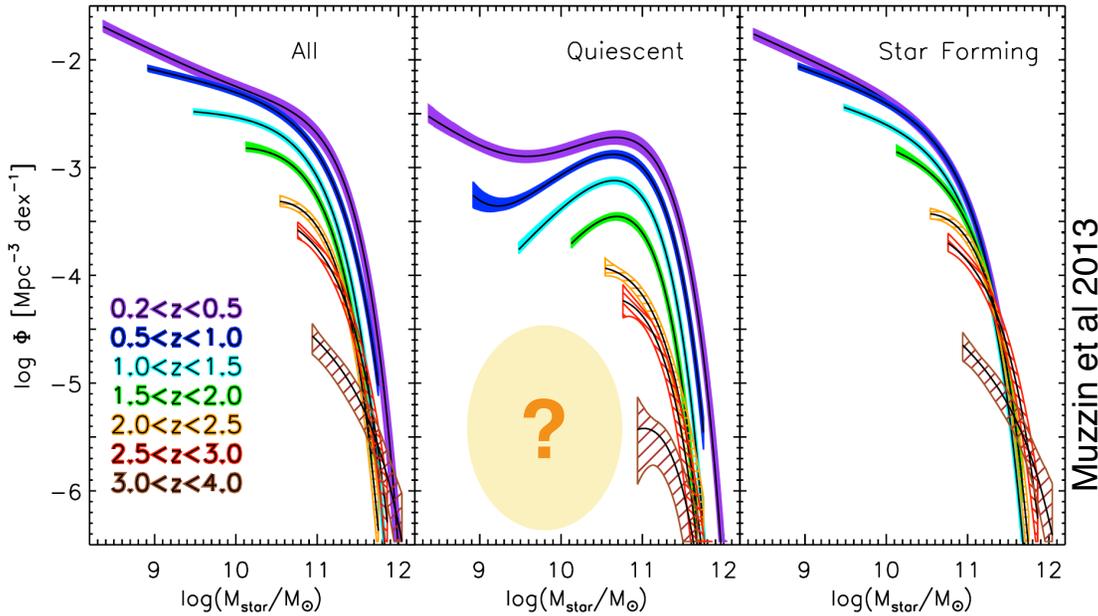
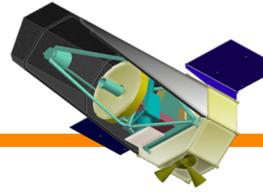


- Galaxy evolution in dense environments
- Growth of structures  $\rightarrow$  measurement of cosmological parameters
  - independent of geometric methods (SN, CMB, BAO)
  - on of very few ways to test GR on very large scales
- These goals require large samples (=large areas) at high redshifts

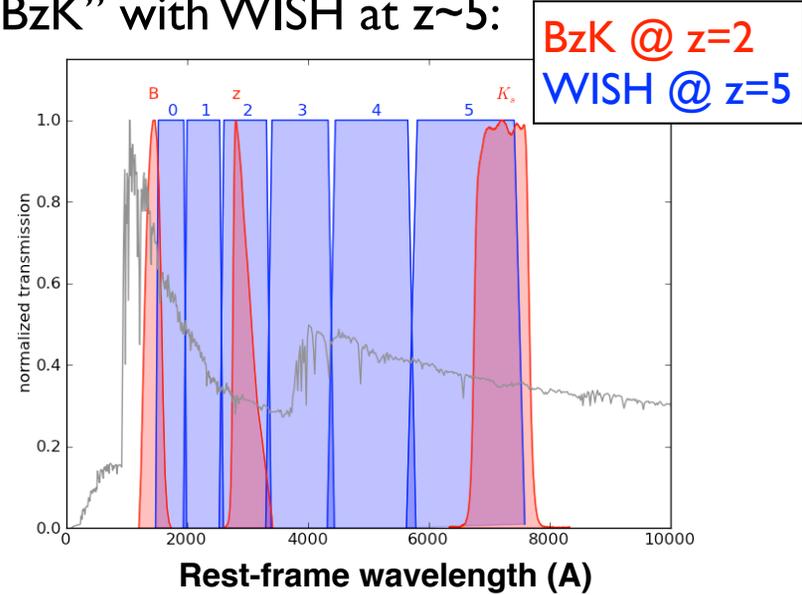
*Color selection in the IR:*



# Fossil record of first light galaxies



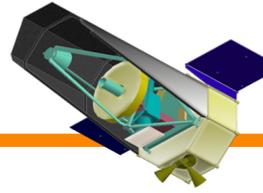
“BzK” with WISH at  $z \sim 5$ :



## Quiescent galaxies at $z \sim 5$ :

- fossils of  $z \geq 10$  star-forming galaxies
  - this is another way to study the First Light objects!!
- detectable to  $M \sim 10^{10} M_{\odot}$  with WISH W5 filter (26AB)
- even their numbers are unconstrained:  $\sim 1-100/\text{sq deg}/\Delta\text{mag} ??$ 
  - $\Rightarrow$  need  $\sim 100$  sq deg  $\Rightarrow$  WISH

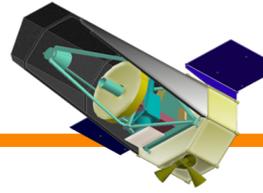
# $z < 5$ summary



- Characterizing the growth of galaxies
- Study dependence on environment, which seems to be key
- Large samples of  $z > 1$  clusters: for galaxy evolution and for cosmology
- Characterization of ultra-dusty CCAT galaxies out to  $z \sim 5$
- $z \sim 5$  red-and-dead galaxies: another way to study First Light objects

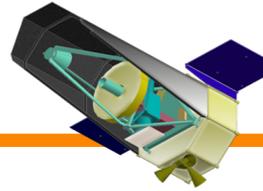
***$z=1-5$  is as exciting as First Light!***

# Canadian perspective in conclusion



- Strong scientific interest in Canada, spanning a wide range of science
- I would say  $z \sim 1-5$  as exciting (or even more exciting) than First Light science, given the vast range of possible programs at  $z < 5$
- WISH is very complementary to other Canadian projects (JWST, TMT, CCAT)

# Canadian perspective in conclusion



- We have identified the WISH filter exchange unit (FEU) as matching Canadian capabilities and interests. This is the potential Canadian contribution to the project.
- Canadian Space Agency (CSA) does not have a system of regular proposals: no clear mechanism to propose for funding
- We hope upcoming proposal submissions in Japan and US will spur the CSA to action