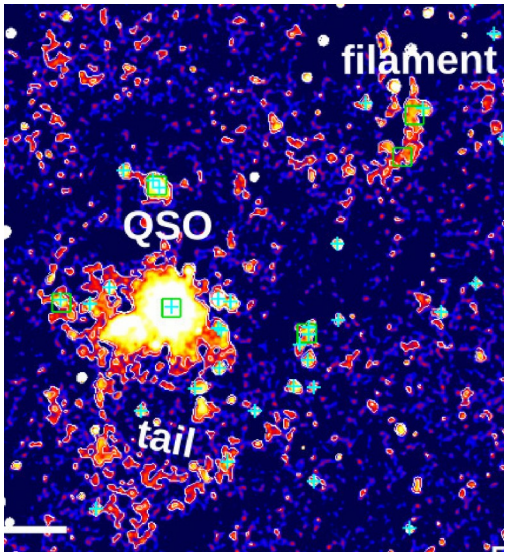
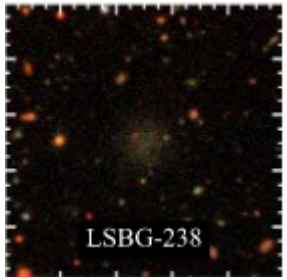
淡く広がった天体の撮像データ解析について

～ HSC での事例～



Diffuse Lyα emission around a protocluster (Kikuta+19)



Low surface brightness galaxies (Greco+18)

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「データ解析の新展開 2020 」
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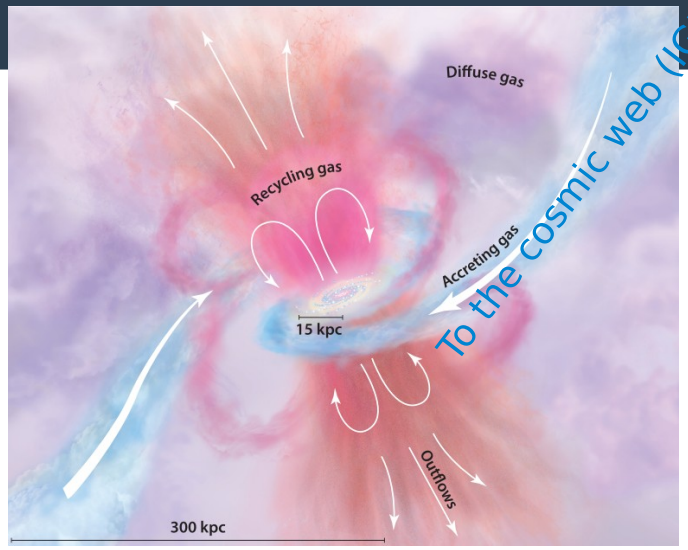
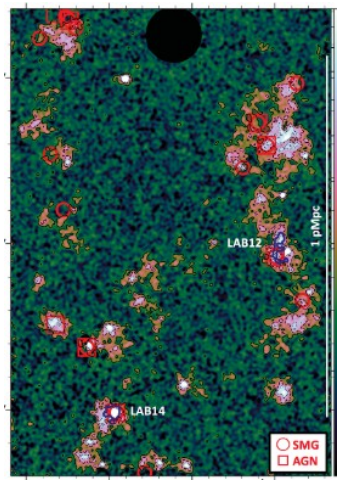
Inter/Circum-galactic medium (IGM/CGM) & Lyα emission

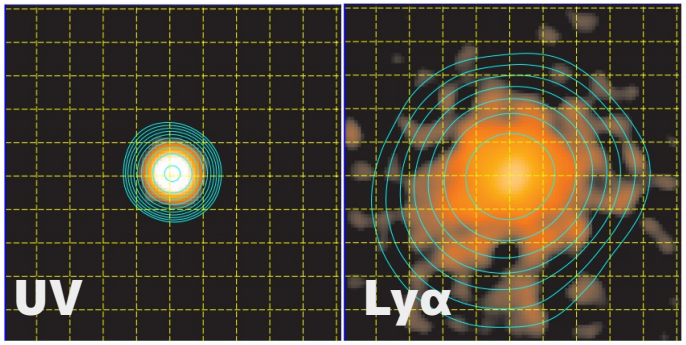
- Gas circulation between IGM/CGM is very important for galaxy evolution
- can be traced with Lyα emission at high redshift (z>2)
  - Turned out to be ubiquitous, **but very faint** (SB<10^{-18} erg/s/cm^2/arcsec^2)
  - IFU or deep NB imaging are powerful tools



Tumlinson et al., 2017



←Lyα emission from the cosmic web connecting galaxies (Umehata+19)

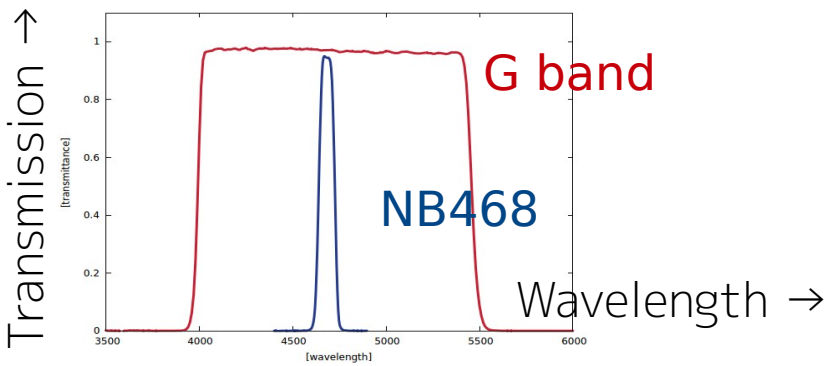


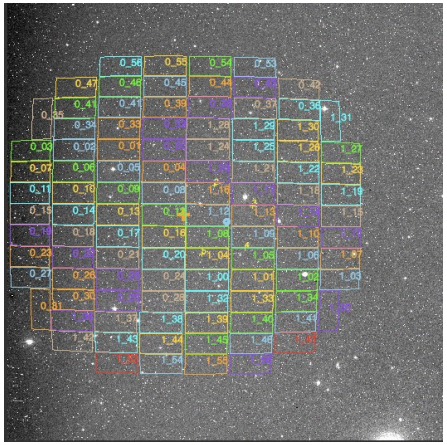
↑**Stacked** UV(left) and Lyα(right) image of **LBG** @ z=2.65 (Steidel+11)

Deep HSC imaging for diffuse emission

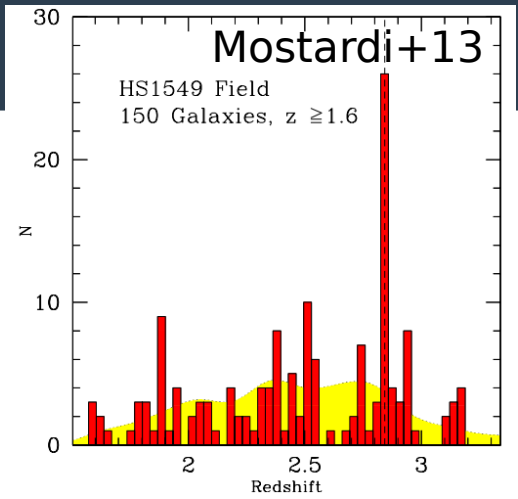
- Target: Field around a hyperlumious QSO at z=2.84 (HS1549+1919)
  - reside in massive overdensity (proto-cluster)
  - Deep Keck imaging & spectroscopic data available at the center
- Observed with Subaru/HSC (S16A-110, PI: Yuichi Matsuda)

  G 2.2 hr (20s ×389 shots) → 27.4 mag (5σ, 1.5” aperture~2×seeing 0.77”)
  NB468 6.3 hr (300s ×113 shots) → 26.6 mag (5σ, 1.5” aperture)

  - Large dithering (N_{dith}=5, R_{dith}=10’) + PA rotation (30°×N)
- 



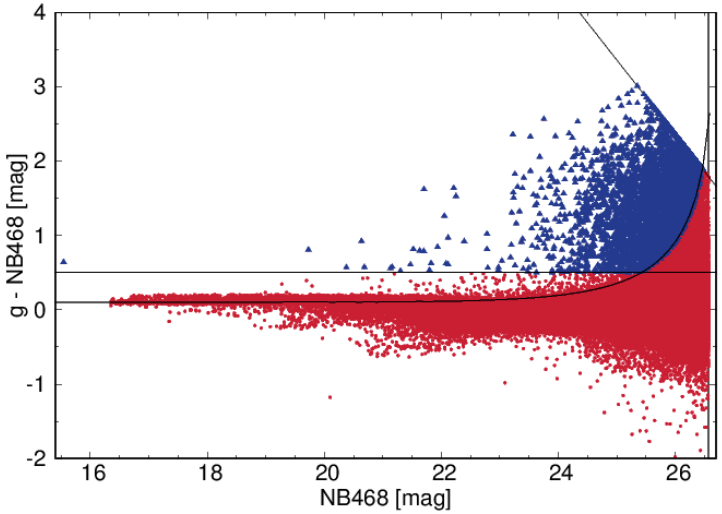
LAE/LAB Detection



Target: the HS1549 protocluster @ z=2.84)
hyperluminous QSO HS1549+1919 is at its center
(e.g., Steidel+11, Mostardi+13)

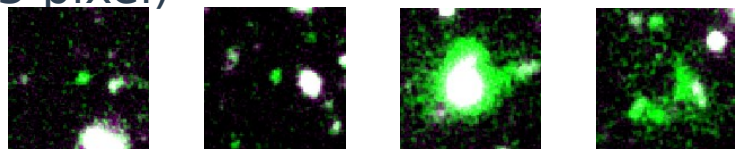
Observed with **Subaru/HSC**, g(2.2hr) and NB468(6.3hr)
→ Data reduced with HSC pipeline (hscPipe 4.0.5)

Source detection & photometry with Source Extractor (Bertin & Arnouts 96)



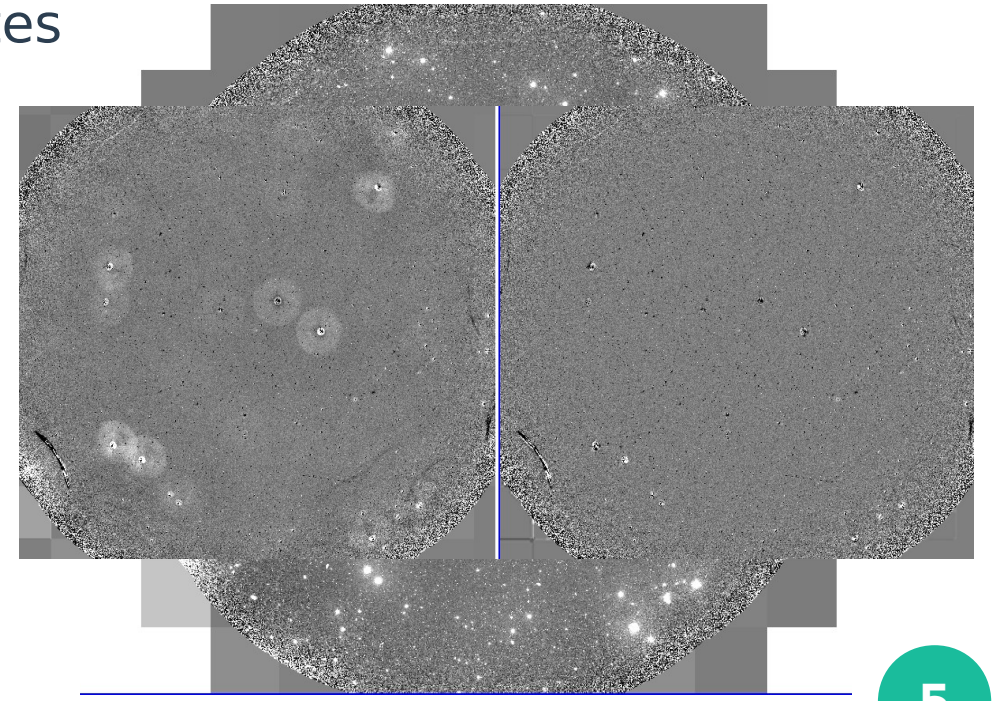
- **LAE selection criteria (2.815<z<2.887):**
  - NB < 26.57(5σ)
  - G – NB > max{0.5, 0.1+4σ(G-NB)}
    (rest $EW_{Ly\alpha}$ >12Å)
- **LAB (Lyα blob)selection criteria:**
  - criteria above(in isophotal mag) + Lyα 2σ isophotal area>16 arcsec² in the smoothed Lyα image (gaussian with σ=3 pixel)

→ 3490 LAEs and 76 LABs found



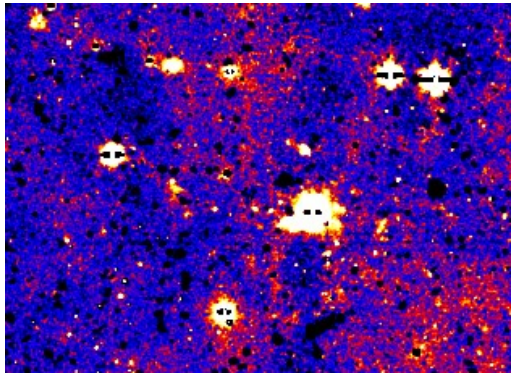
Data Reduction

- Data reduced using HSC pipeline (hscPipe 4.0.5)
  - With **global sky subtraction** + ghost mask package +addtional mask by myself
    - https://hsc.mtk.nao.ac.jp/pipedoc/pipedoc_4/j_tips/skysub.html#global-sky
    - https://hsc.mtk.nao.ac.jp/pipedoc/pipedoc_4/j_tips/ghost.html
  - Global sky subtraction estimates the sky on scales ~17’
- For further analysis, we subtract the sky with SExtractor with arbitrary sky mesh size
  - For point source detection, we used 64 pixel
  - For extended source analyses, we used 176 pixel (=30”)

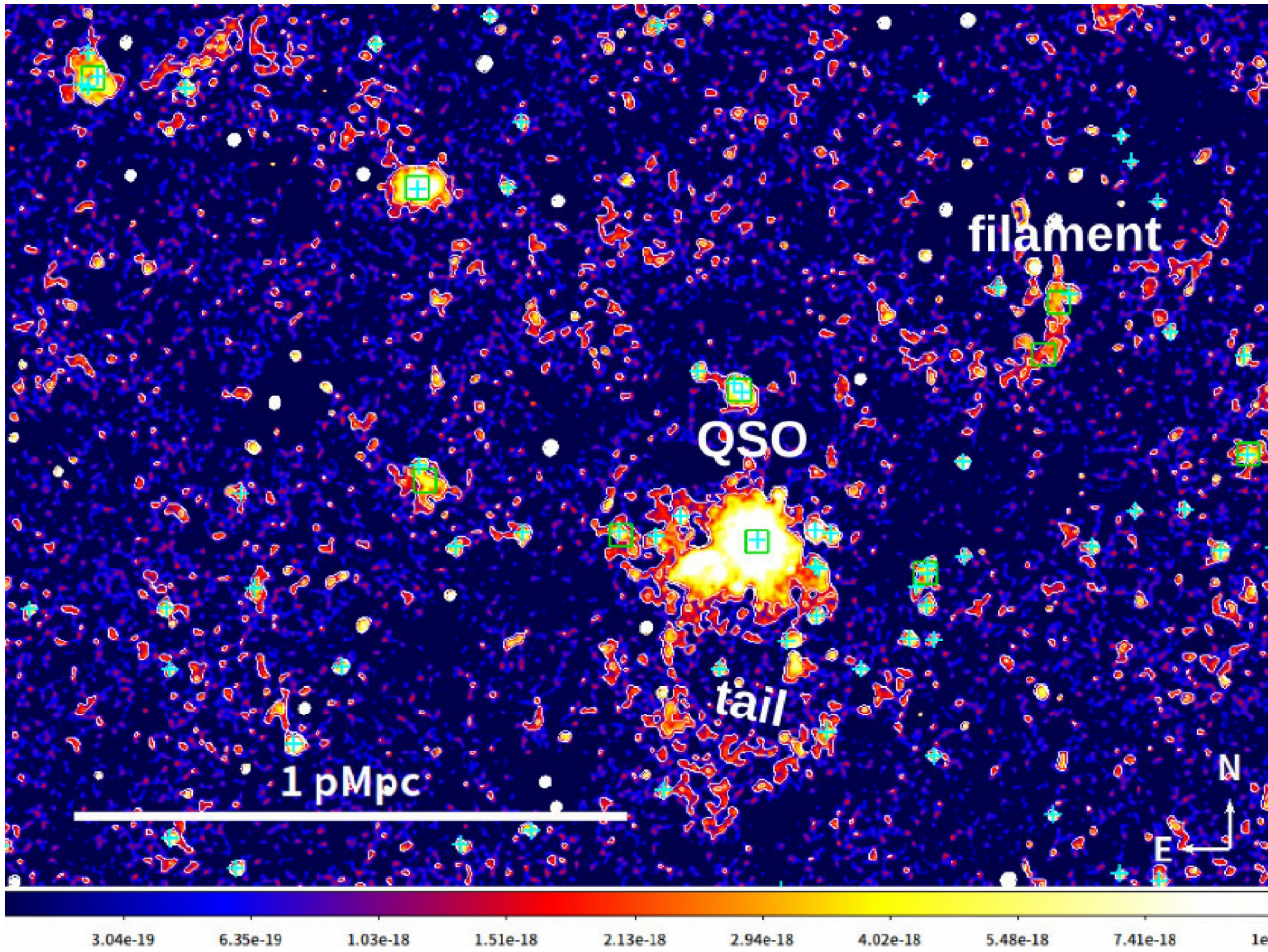


Diffuse Lyα emission from protocluster core

Diffuse emission down to 1e-18 erg/s/cm^2/arcsec^2 (white contour)

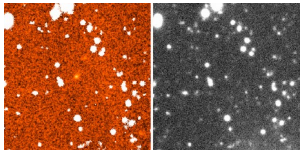


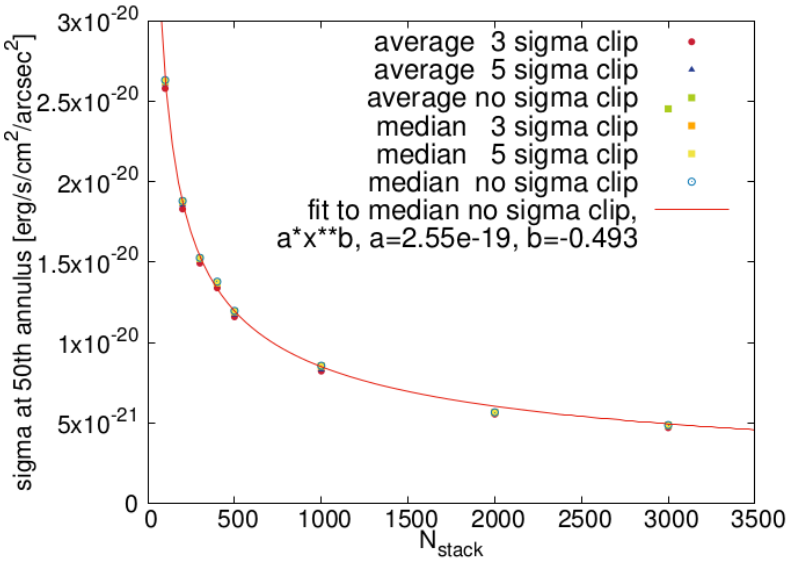
Lya image from Keck

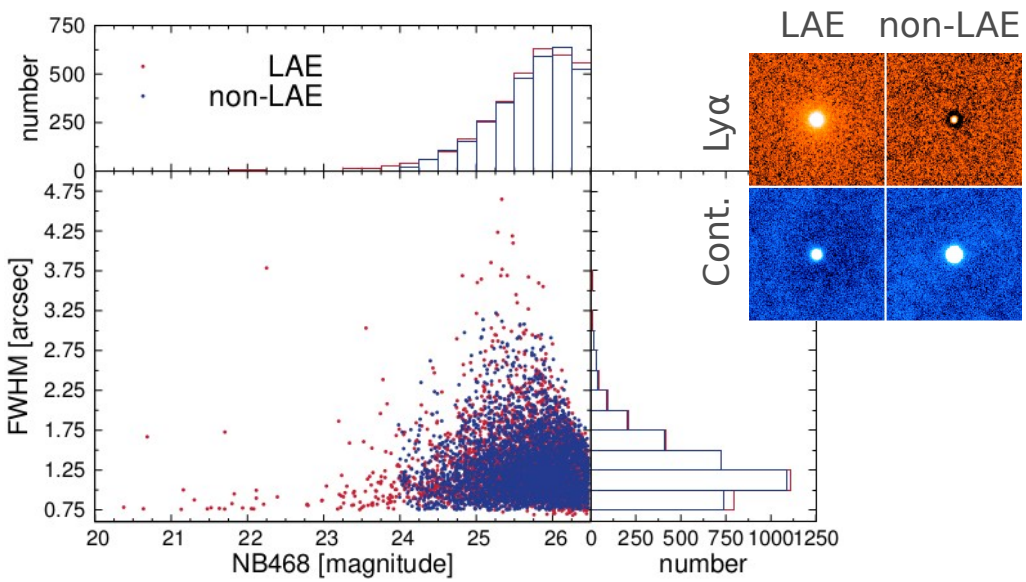


Stacking Analyses

- Use cutout Lyα images of LAEs (sky mesh size=30”) with continuum sources masked
- Stack Lyα & continuum images with IRAF imcombine (median, no clipping)
- Sky noise is estimated with “sky cutouts”; behaves well ($\propto \sim N^{-1/2}$)
- “Non-LAE” sample is constructed to check total systematics (see Momose+14)

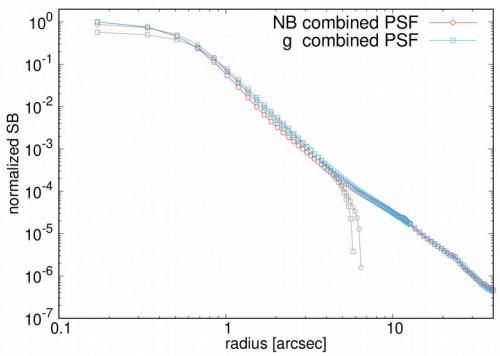




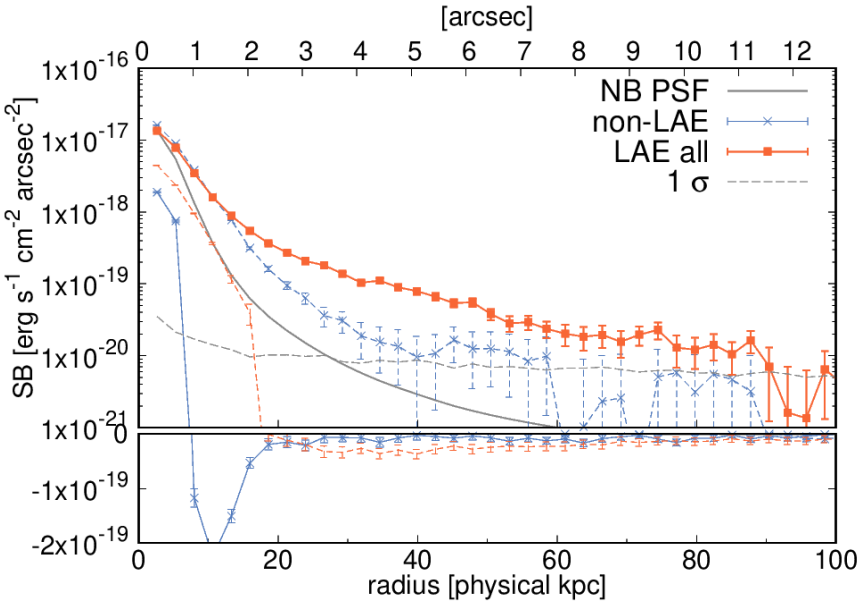


Stacking Analyses

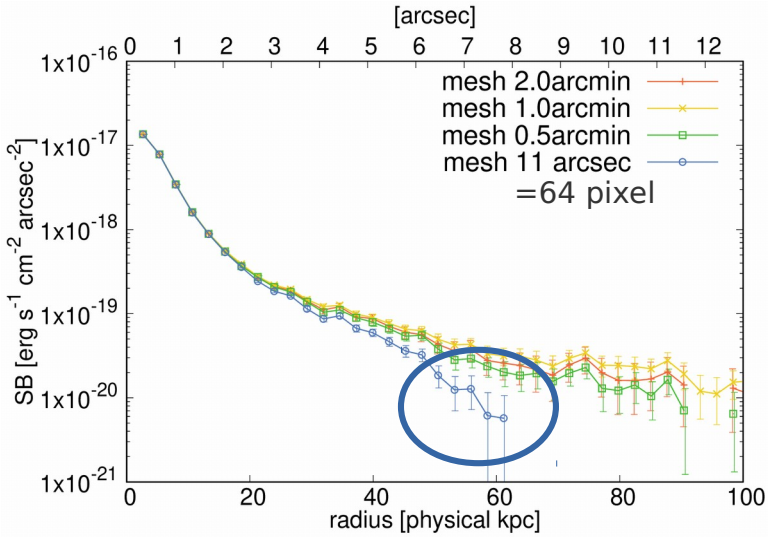
- PSFs of NB/g-band images are measured with bright point sources
  - Central part: objects with CLASS_STAR> 0.95 and 18 < g < 22
  - Outer part: stars with 13 < g_{SDSS} < 15 from SDSS DR14 catalog
  - These are connected at r = 20 pixels following a method described in Infante-Sainz et al. (2019)



- **Detect diffuse Lyα emission down to ~10^{-20} erg/s/cm²/arcsec²**



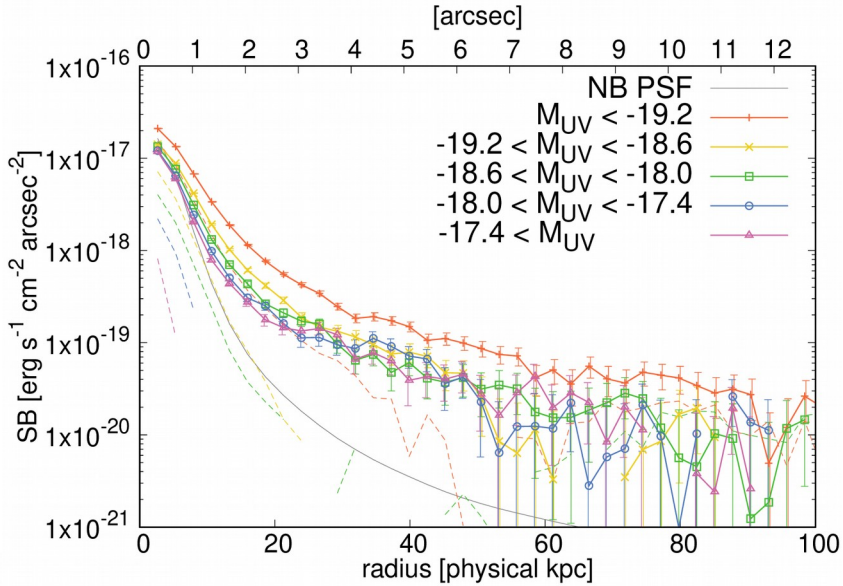
solid: Lyα, dashed: Cont.

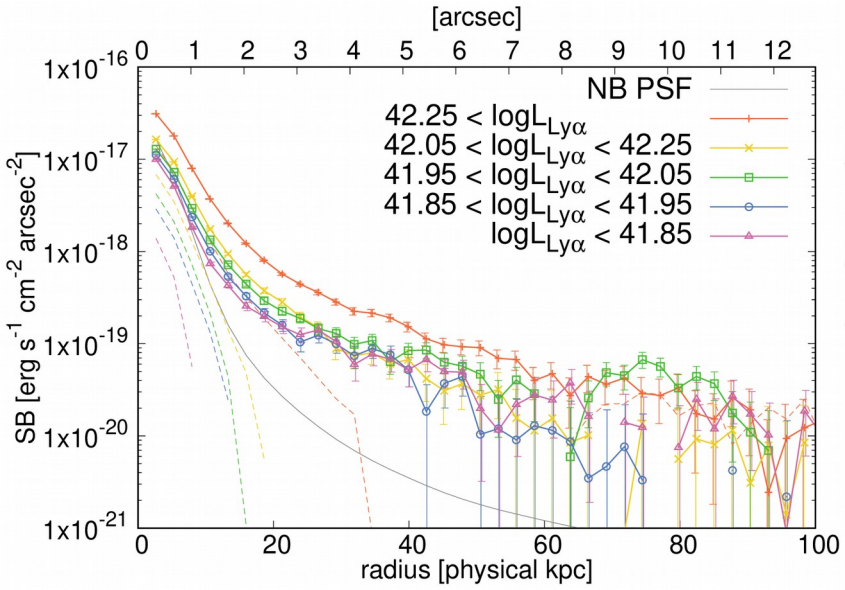


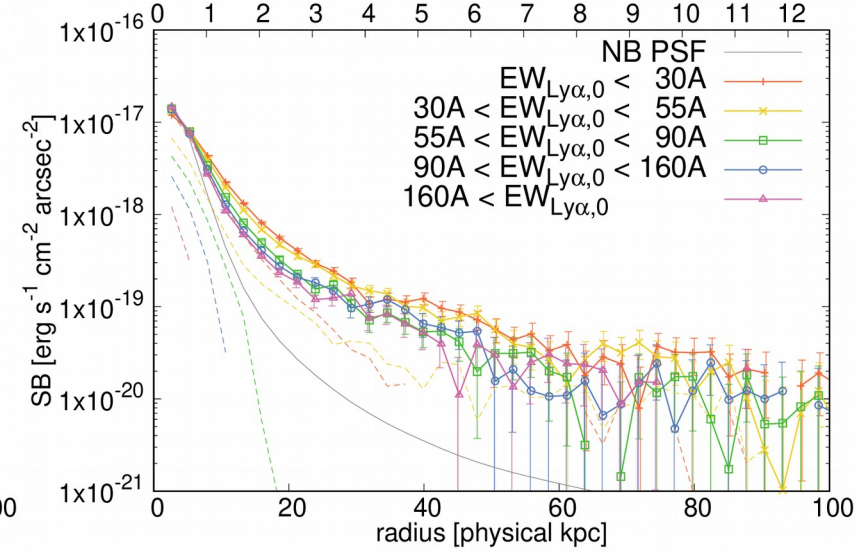
Sufficiently large sky mesh size is crucial!!

Results of Stacking: UV, $L_{Ly\alpha}$, EW

- LAHs are detected for all subsamples
- Bright/low-EW LAEs tend to have larger LAHs
  - Consistent with [CII] halo at higher-z (though mass range is different)







まとめと提案

- **サイエンスによって best なスカイ引き法は異なる**
  - Point sources vs Extended diffuse sources
- **HSC 画像の質は極めて高く、 diffuse な成分の解析にも耐えうる**
- **多様なニーズに応えるため、アーカイブでもユーザーが選べることが理想**
  - 現実的には、 conservative な global sky subtraction 済みの画像から始められればよい？
  - HSC は PDR2 以降 global sky subtraction がデフォルト (Aihara+19, ~2.8’)
- **Diffuse object の検出・カタロギング・測光では目的によりパラメータが多岐にわたり試行錯誤が必要となる**
  - すべてのユーザの需要を満たすのは難しい

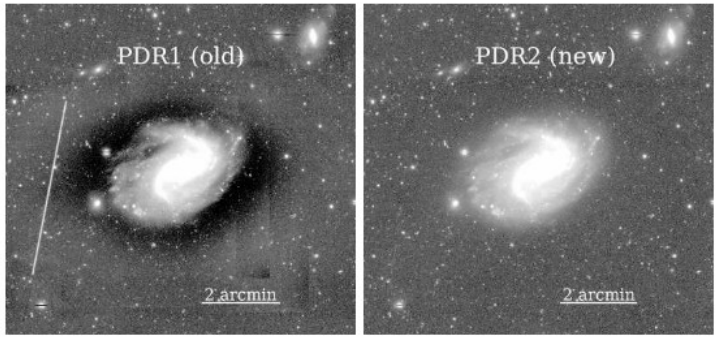


Fig. 5. Left: coadd image of a nearby galaxy in the i-band from PDR1. **Right:** same image but constructed using the new sky subtraction algorithm. The images are stretched to the same level for a fair comparison.