

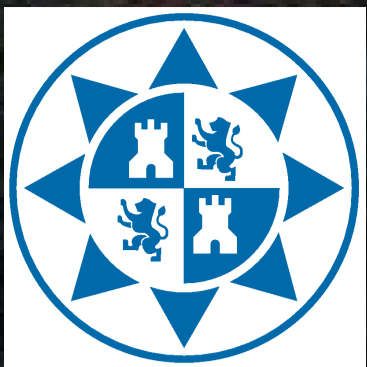
Discovery of a lensed ultrabright submillimeter galaxy at $z = 2.0439$

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Abstract

We report an ultra-bright lensed submillimeter galaxy (SMG) at $z = 2.0439$, *WISE* J132934.18+224327.3, identified as a result of a full-sky cross-correlation of the *AllWISE* and *Planck* compact source catalogs aimed to search for bright analogs of the submillimeter galaxy SMMJ2135, the Cosmic Eyelash. Inspection of archival SCUBA-2 observations of the candidates revealed a source with fluxes ($S_{850\mu\text{m}} = 130$ mJy) consistent with the *Planck* measurements. The centroid of the SCUBA-2 source coincides within 1 arcsec with the position of the *AllWISE* mid-IR source, and, remarkably, with an arc shaped lensed galaxy in *HST* images at visible wavelengths. Low-resolution rest-frame UV-optical spectroscopy of this lensed galaxy obtained with 10.4 m GTC reveals the typical absorption lines of a starburst galaxy. Gemini-N near-IR spectroscopy provided a clear detection of $H\alpha$ emission. The lensed source appears to be gravitationally magnified by a massive foreground galaxy cluster lens at $z = 0.44$, modeling with Lenstool indicates a lensing amplification factor of 11 ± 2 . We determine an intrinsic rest-frame 8-1000- μm luminosity, L_{IR} , of $(1.3 \pm 0.1) \times 10^{13} L_{\odot}$, and a likely star-formation rate (SFR) of $\sim 500 - 2000 M_{\odot} \text{yr}^{-1}$. The SED shows a remarkable similarity with the Cosmic Eyelash from optical-mid/IR to sub-millimeter/radio, albeit at higher fluxes.

The Search

In order to find bright lensed SMGs in the full-sky, we carried out a cross-matching between the *AllWISE* and *Planck* full-sky compact source catalogs. As a reference we adopted the SED of the Cosmic Eyelash, from the MIR to the submillimeter. Our aim was to identify candidates in these catalogs with MIR colors similar to the Cosmic Eyelash and strong submillimeter fluxes. First we built a full-sky selection of galaxies verifying the color criteria $W1 - W2 > 0.8$, $W2 - W3 < 2.4$, $W3 - W4 > 3.5$ and detection at $S/N > 3$ in the four bands of the *AllWISE* catalog, we limited the sample to galactic latitude $b \geq 20^{\circ}$. Then, we requested the selected objects to have a *Planck* source detected within 5 arcmin with submillimeter flux ratios consistent with those expected for SMGs at $z = 2 - 3$.

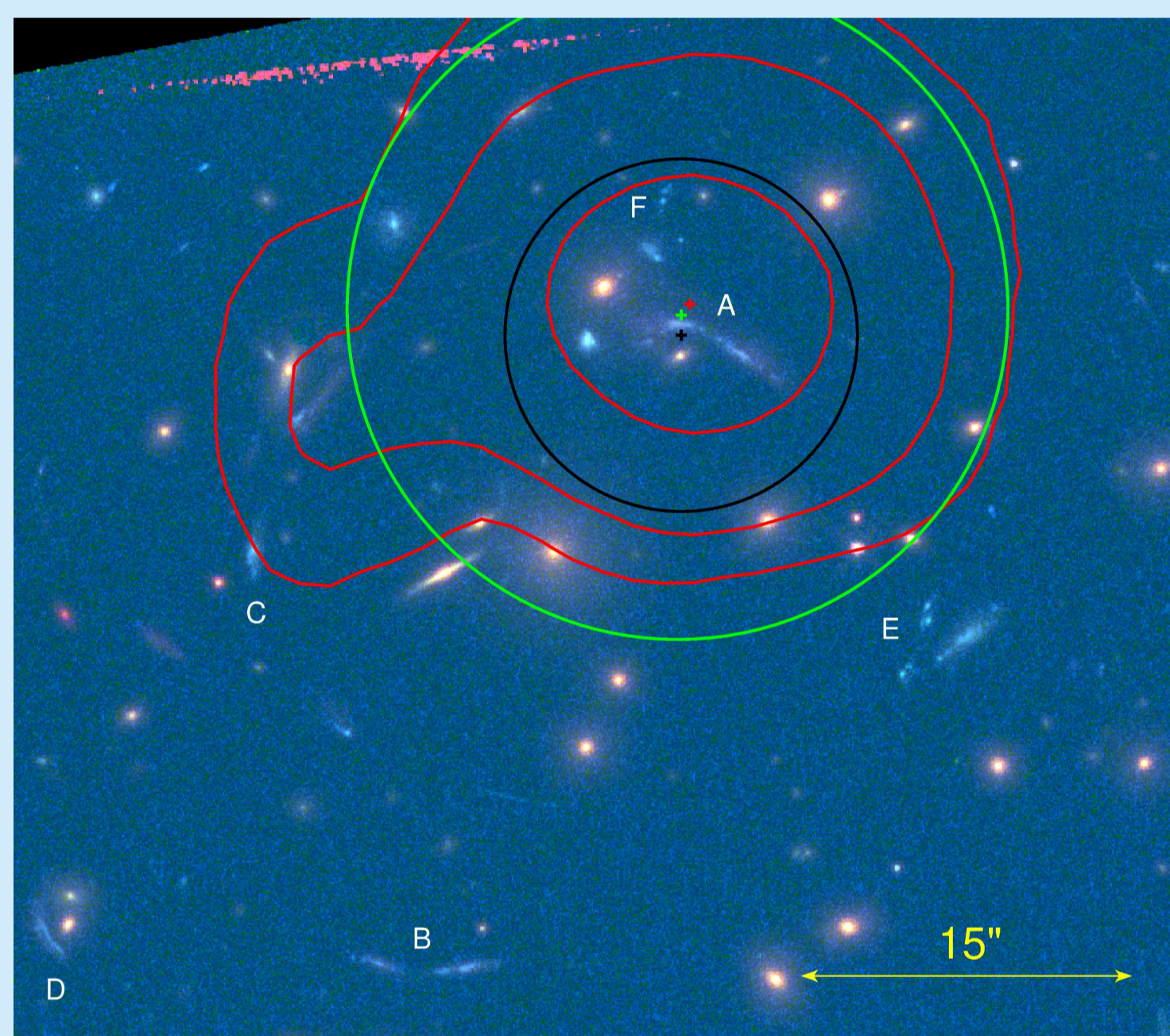
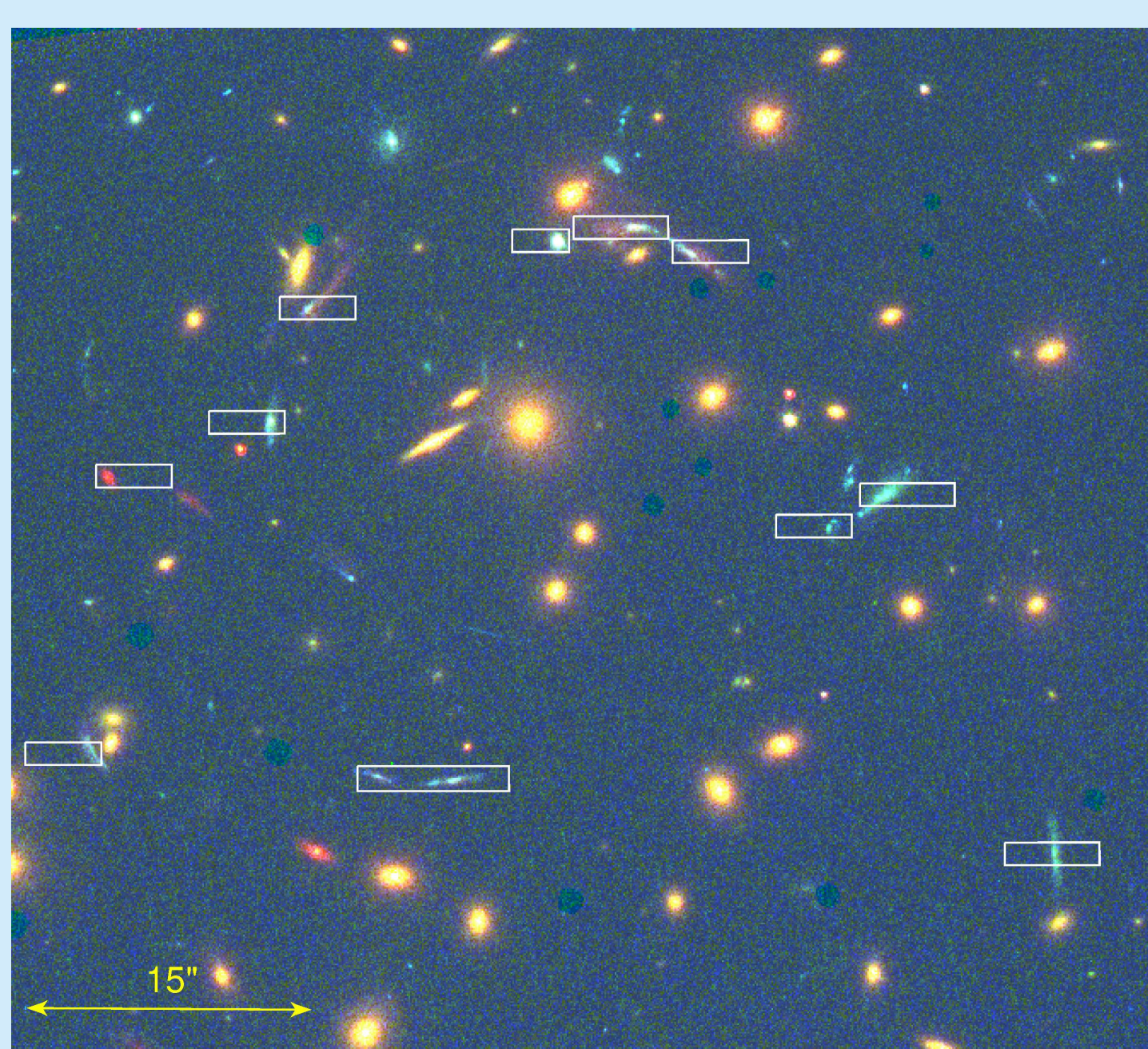


Figure 1. HST-image of Cosmic Eyebrow with the *HST/WFC3* filters. Red contours are *WISE* channel 4 and black (green) circles represent SCUBA-2 450 ($850 \mu\text{m}$) detections. Crosses are the centroids of the *WISE* and SCUBA-2 detections and they are within 1 arcsec from the *HST* main source of the arc. Capital letters indicate the six families of multiply lensed background galaxies used to perform a mass reconstruction of the foreground galaxy cluster. When modeling the lensing with Lenstool, the mean amplification factors for each family with $z_{\text{LTM}} = 2.044$ are A $\sim 11 \pm 2$, B $\sim 7 \pm 2$, C $\sim 14 \pm 2$, E $\sim 7 \pm 2$, and for the other two families the mean amplification factors are D $\sim 4 \pm 2$ ($z_{\text{LTM}} \sim 2.9$) and F $\sim 5 \pm 2$ ($z_{\text{LTM}} \sim 1.0$).

GTC/MOS proposal



Spectral Energy Distribution (SED)

We calculate the rest-frame 8-1000- μm luminosity, L_{IR} , from direct integration of the data fit, and obtain an intrinsic luminosity for our galaxy $L = (1.3 \pm 0.1) \times 10^{13} L_{\odot}$, indicating a SFR of $\sim 2000 M_{\odot} \text{yr}^{-1}$, which assumes a Salpeter IMF, assuming a Chabrier IMF would possibly be a factor of ~ 1.8 lower.

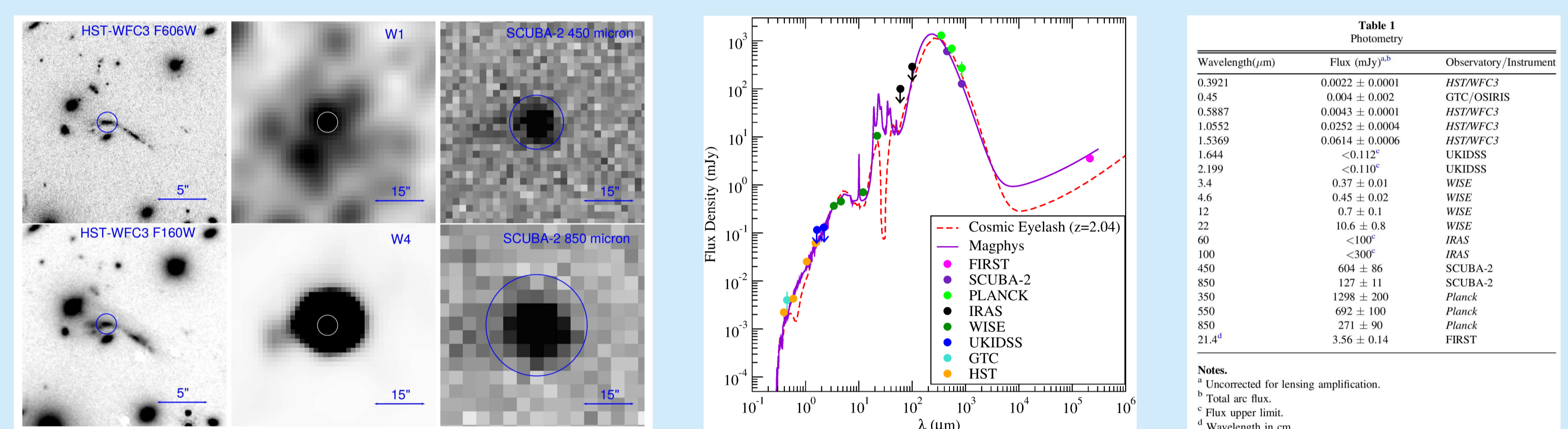


Figure 2. Multi-wavelength spectral energy distribution of Cosmic Eyebrow. The SED of Cosmic Eyelash shifted to $z = 2.044$ is consistent with the measurements of the galaxy at all frequencies from the optical to the radio.

Spectroscopy

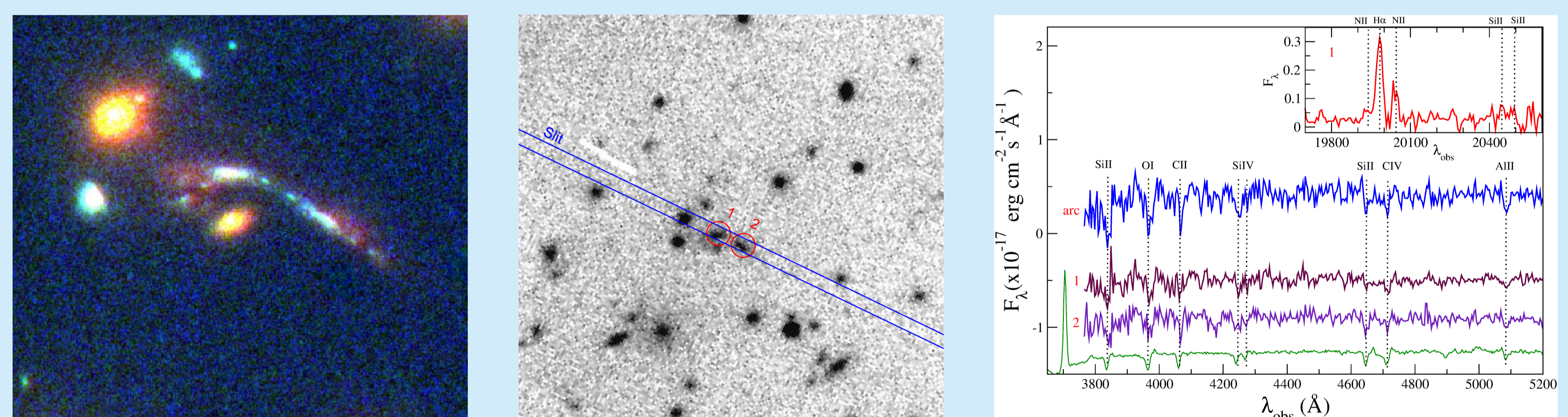


Figure 3. Left side, HST-image. Center, GTC *g*-band image with the orientation of the long-slit. Right side, GTC/OSIRIS spectra of the two regions (up) and for the each individual regions (both down shifted for clarity). We mark the positions of the absorption features identified in the spectra. For comparison, we show the composite spectrum of LBGs. We also show in the inset the Gemini spectrum for region 1 and mark the emission lines we identify, the $H\alpha$ emission line yields a redshift for the source of $z = 2.0439$.

Molecular gas observations with NOEMA

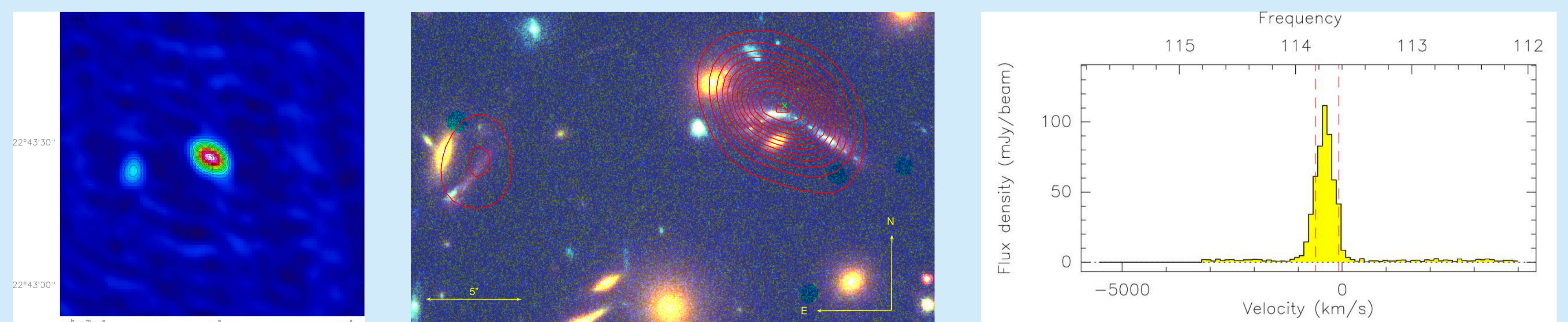


Figure 4. Left side, velocity-averaged map of the CO(3-2) emission from the Cosmic Eyebrow. Center, HST-image, superimposed are velocity-averaged map of the CO(3-2) (red contours) and the detection in the radio band found in FIRST (green cross). Right side, CO(3-2) spectrum at $z = 2.0401$ of the Cosmic Eyebrow taken with NOEMA. Dashed-red line indicates the range for the velocity-averaged map (Dannerbauer et al. in preparation).

References

- Díaz-Sánchez, A., Iglesias-Groth, S., Rebolo, R., & Dannerbauer, H., 2017, ApJL, 843, 22
- Iglesias-Groth, S., Díaz-Sánchez, A., Rebolo, R., & Dannerbauer, H., 2017, MNRAS, 467, 330
- Dannerbauer, H., et al., in preparation