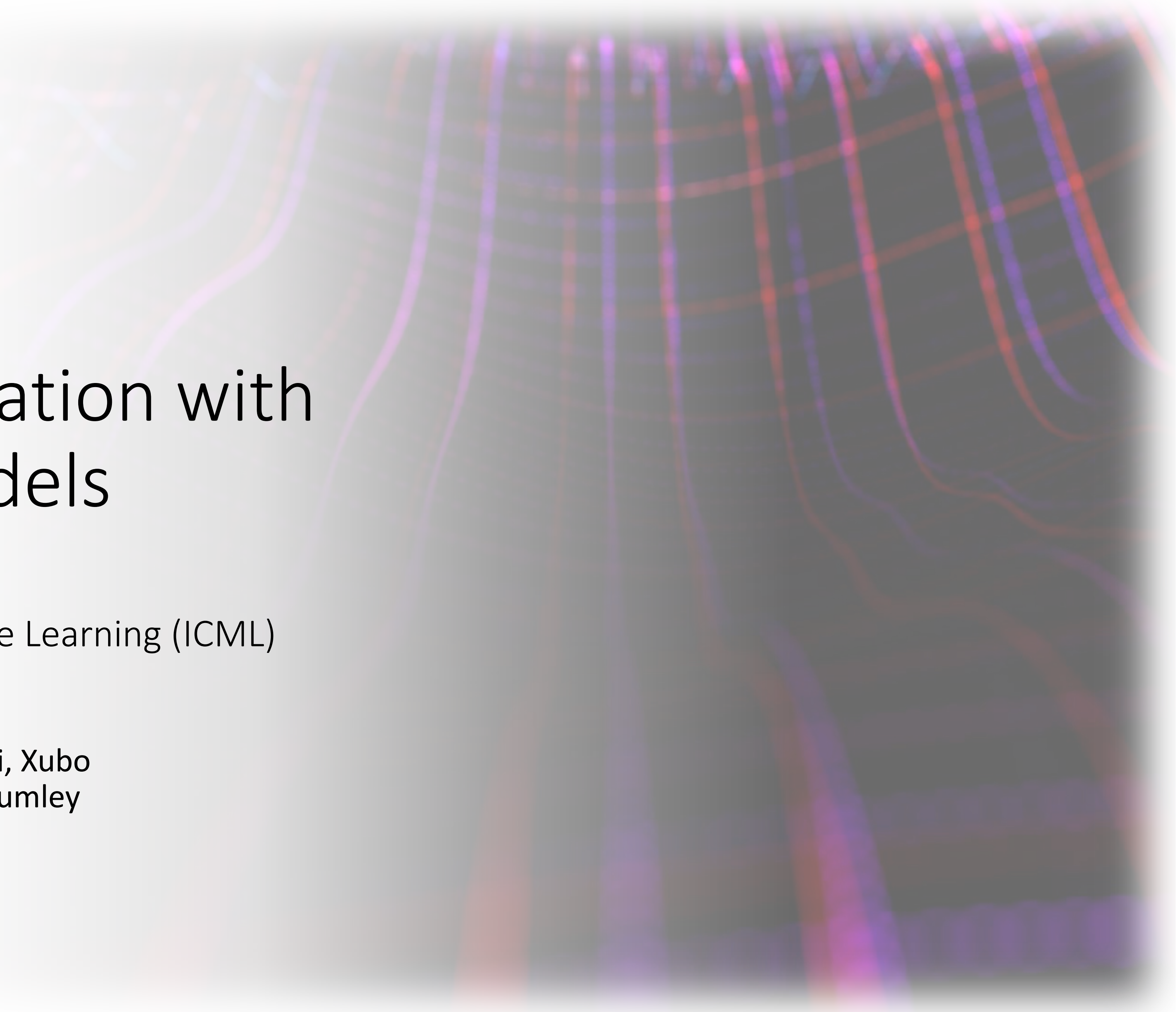

AudioLDM:
Text-to-Audio Generation with Latent Diffusion Models

The International Conference on Machine Learning (ICML)

Haohe Liu*, Zehua Chen***,** Yi Yuan, Xinhao Mei, Xubo Liu, Danilo Mandic, Wenwu Wang, Mark D. Plumley

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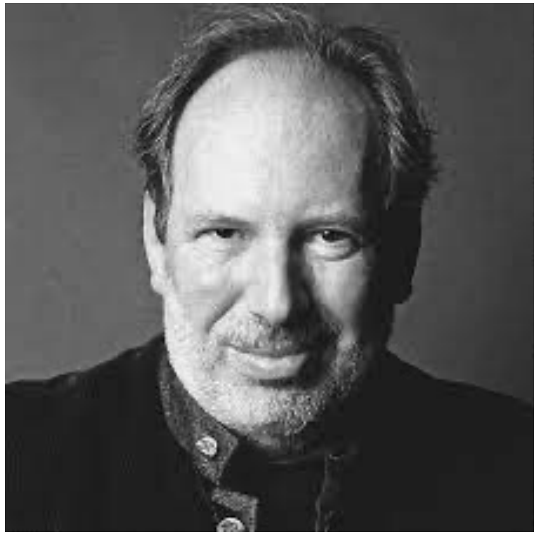
Audio Generation

- **The creation of sound through various ways**
- **The targets include:**
  - *Sound Effect* (Natural, Human-made objects, Animal, etc.)
  - *Speech* (Emotion, Pace, Gender, etc.)
  - *Music* (Genre, Rhythm, Instruments, etc.)
  - *Other* (Imaginary sound, compositional sound)

Text-to-Audio Generation Usage Cases

- Computational “foley artist”: (e.g., https://www.thefoleybarn.com)
  - *Game developer: e.g., A ghost is haunting a house.*
  - *Audio producer: e.g., high heels hitting metal ground.*
  - *Movie producer: e.g., the laser sound from a laser gun.*
  - …
- Automatic content creation (> 60 startups[1])
  - Endless music
  - Audiobook with ambient noises
  - White noise for meditation
  - …
- In the Academia



Sound is often the unsung hero of the movie world
- Hans zimmer

[1] https://github.com/csteinmetz1/ai-audio-startups

Related works

- **Label-to-Audio Generation**
  - Acoustic Scene (Kong et al., 2019), Sound event (Liu et al., 2019), FootStep (Comunit et al. 2019), …
- **Text-to-Audio Generation**
  - DiffSound (Yang et al., 2022), AudioGen (Kreuk et al., 2022), Make-an-Audio (Huang et al., 2023)
- **Text-to-Music Generation**
  - MusicLM (Andrea et al., 2023)
  - Moûsai (Flavio et al., 2023)
  - Noise2Music (Huang et al., 2023)
- **Others**
  - JukeBox (Dhariwal et al., 2020), AudioLM (Borsos et al., 2022), SingSong (Donahue et al., 2023),…

Comparison with previous studies

- Previous audio generation studies:
  - Requires large-scale audio-text pairs
    - Prev: Text → Audio → Loss → Backprop
    - Our: Audio → Audio → Loss → Backprop
  - High computational cost
    - Prev: 64 or 32 V100 GPUs (AudioGen, DiffSound)
    - Our: 1 GPUs
  - Limited generation quality and diversity.
  - Discrete latent space may limit model performance

Previous works:
10+ datasets, 800K audio-text pairs
(**still not enough**).

Self-supervised Learning
for Audio Generation!

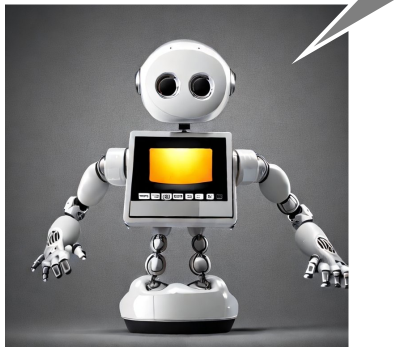
Self-supervised Audio Generation

Step 1

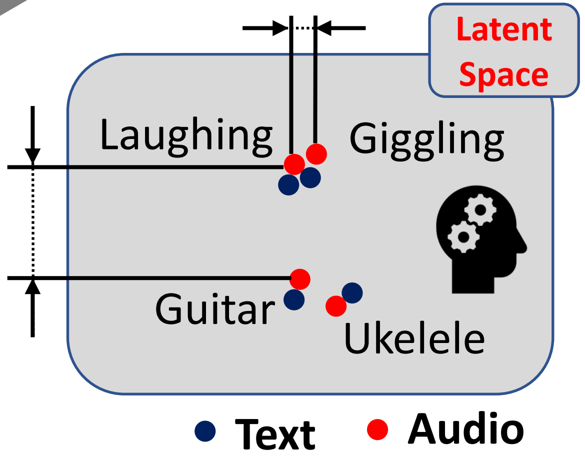
Audio ⇆ Text

Human Developer :
Here are some audio-text pair,
try to figure out their relation!

AI



OK Got it

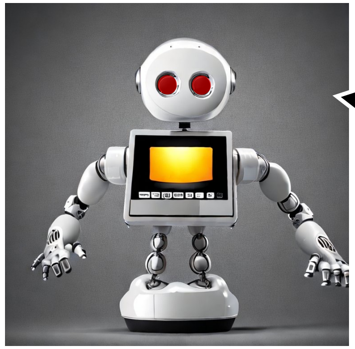


Step 2

Audio

Human Developer:
Here are more audio data,
Try to figure out how to generate them
using your knowledge!

AI



Nobody knows audio better than me!!!

Tell me what you want!

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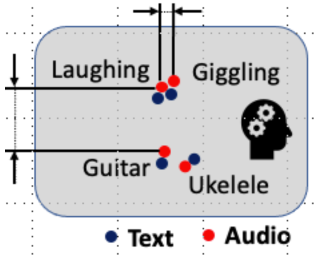
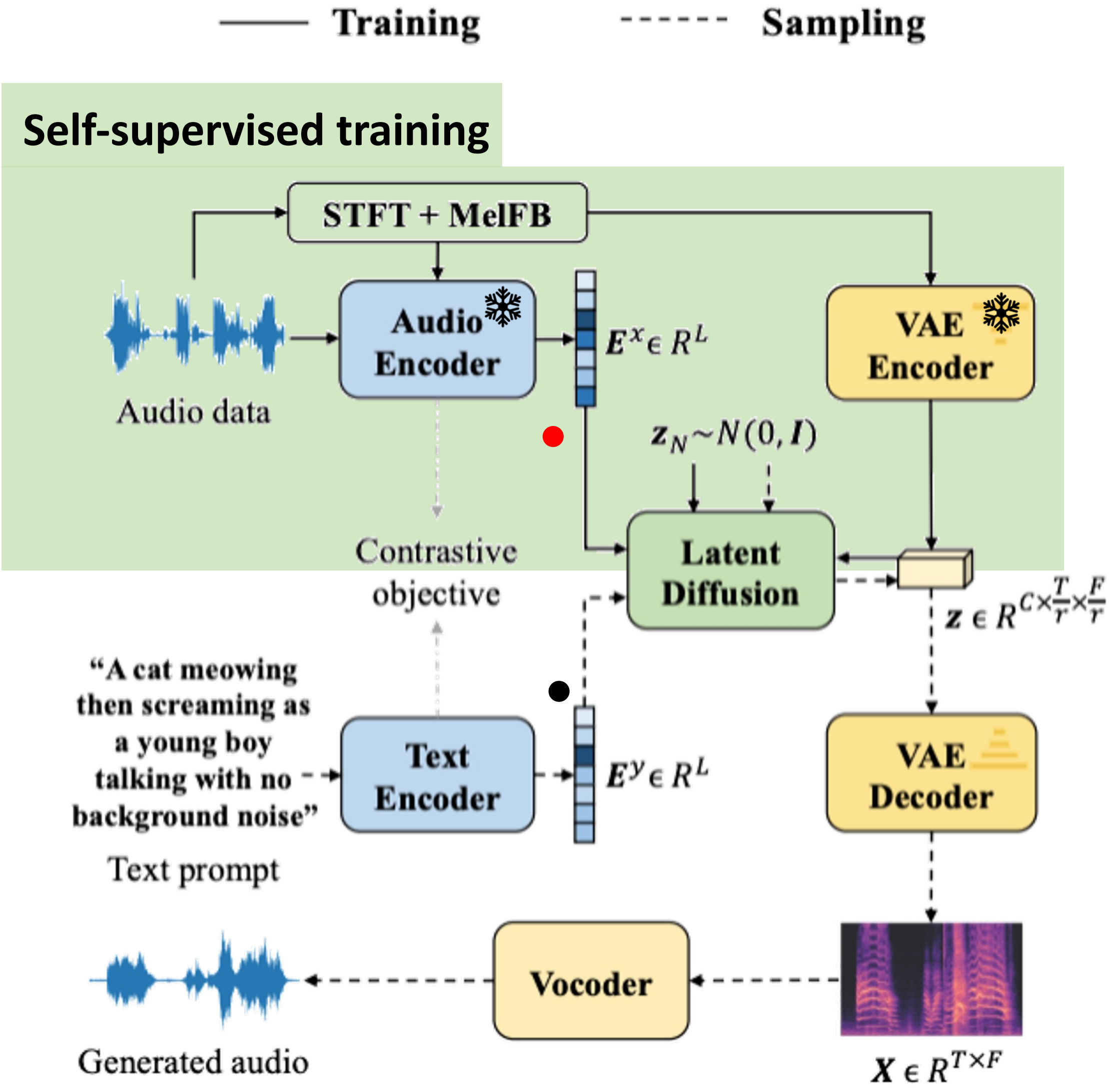
AudioLDM



1. **Contrastive Language-Audio Learning (CLAP) Encoders**
   - Align audio and text in one space.
2. **Latent Diffusion Models**
   - Learn to generate VAE latent conditioned on CLAP embedding
3. **Mel-spectrogram Autoencoder**
   - Learn latent representations.
4. **Mel-to-Waveform Vocoder**
   - Reverse Mel back to waveform



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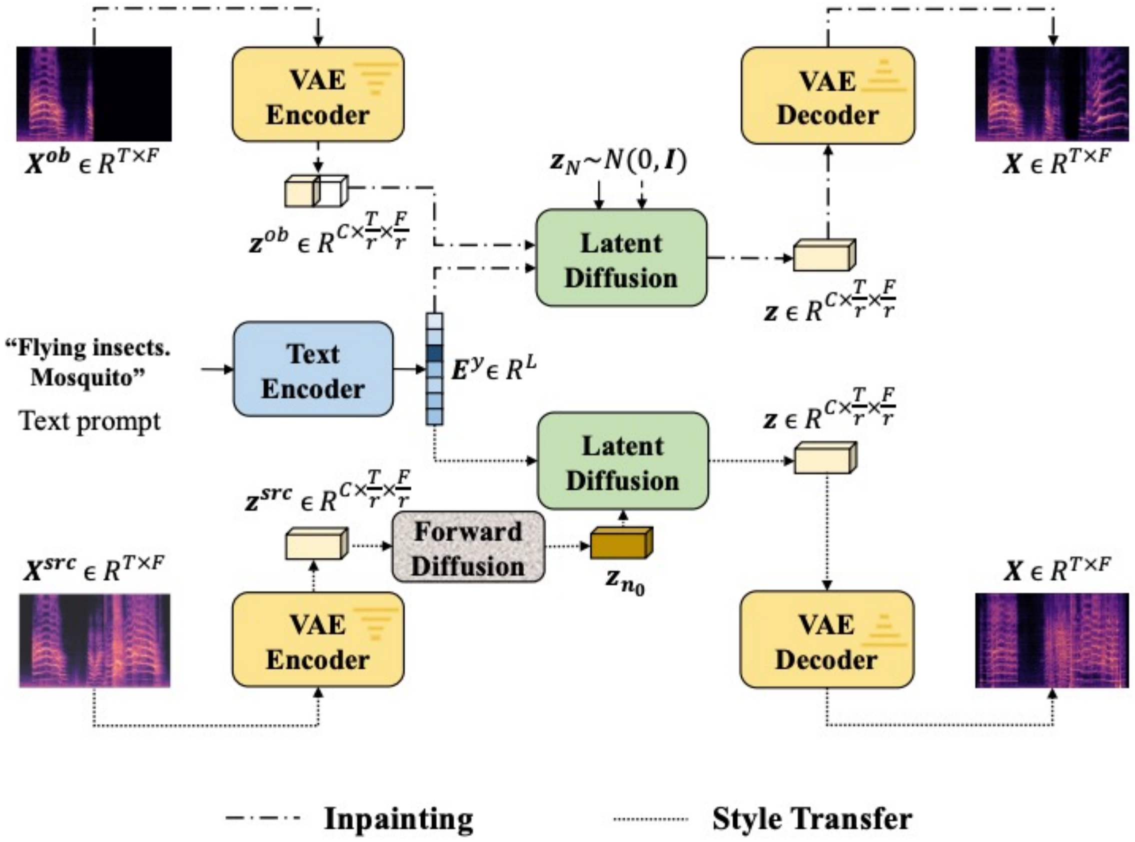
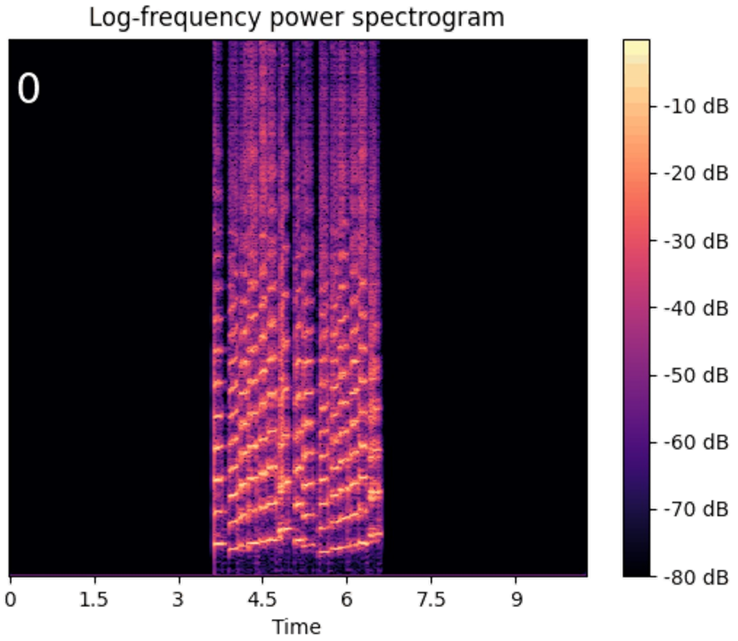
Zero-shot down stream tasks

- Audio style transfers
  - Corrupt -> Reverse Diffusion
- Audio inpainting
  - Provide temporal hint during sampling.
- Audio super-resolutions
  - Provide frequency hint during sampling.

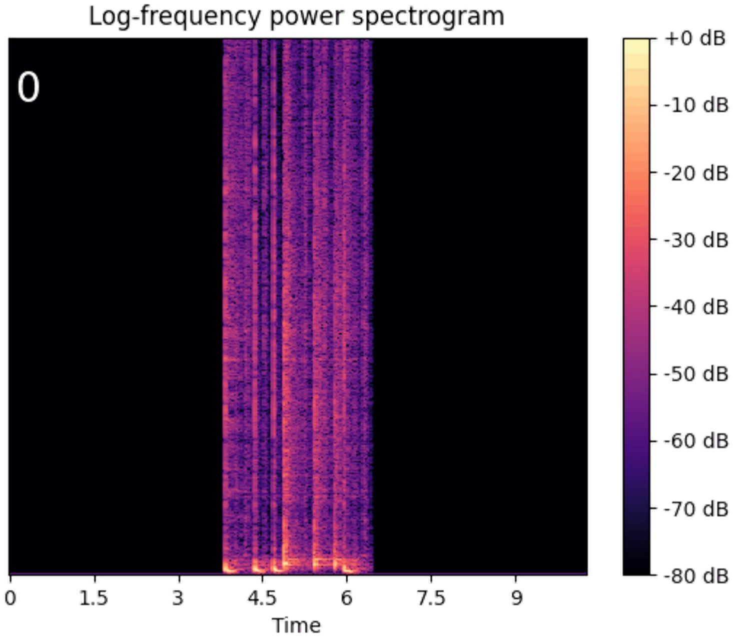


$X^{ob} \in R^{T\times F}$
VAE Encoder
$z^{ob} \in R^{C\times\frac{T}{r}\times\frac{F}{r}}$
$z_N \sim N(0, I)$
Latent Diffusion
VAE Decoder
$X \in R^{T\times F}$
$z \in R^{C\times\frac{T}{r}\times\frac{F}{r}}$
"Flying insects. Mosquito"
Text prompt
Text Encoder
$E^y \in R^L$
Latent Diffusion
$z \in R^{C\times\frac{T}{r}\times\frac{F}{r}}$
$z^{src} \in R^{C\times\frac{T}{r}\times\frac{F}{r}}$
Forward Diffusion
z_{n_0}
$X^{src} \in R^{T\times F}$
VAE Encoder
VAE Decoder
$X \in R^{T\times F}$
Inpainting
Style Transfer

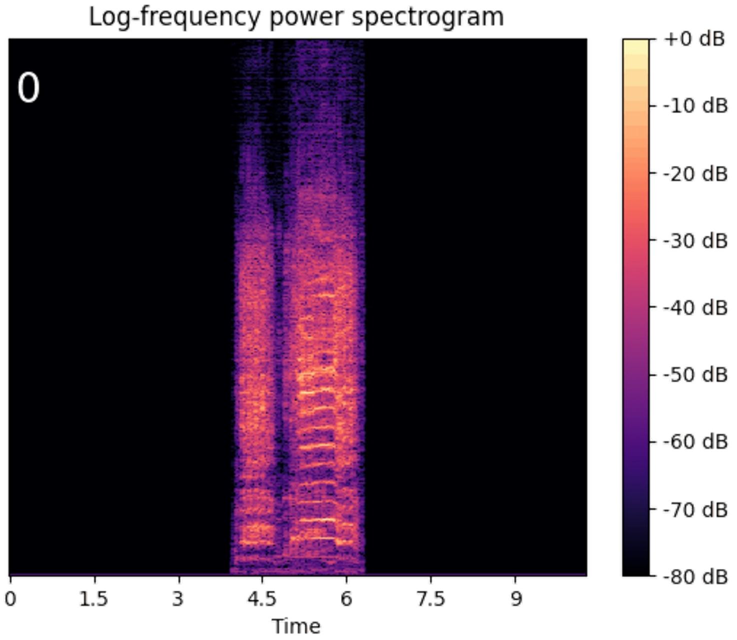
Audio Style Transfer



Trumpet
→ Children Singing

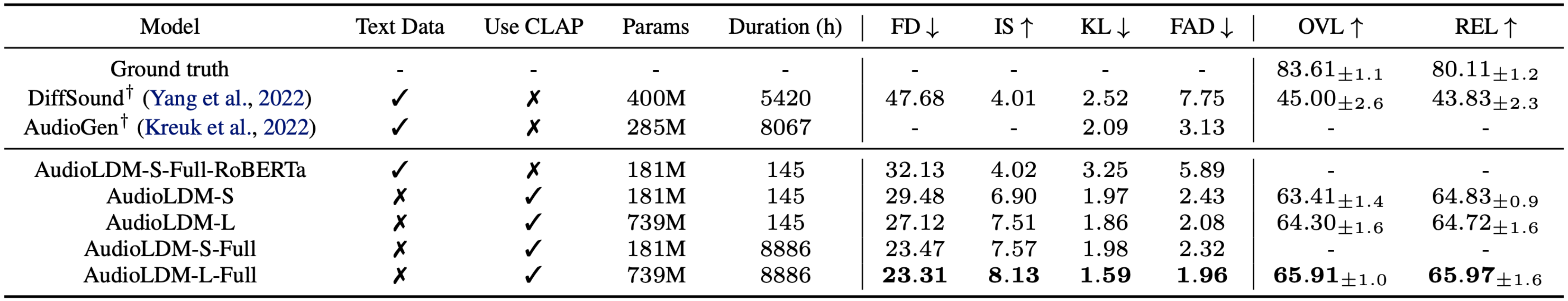


Drum beats
→ Ambient Music

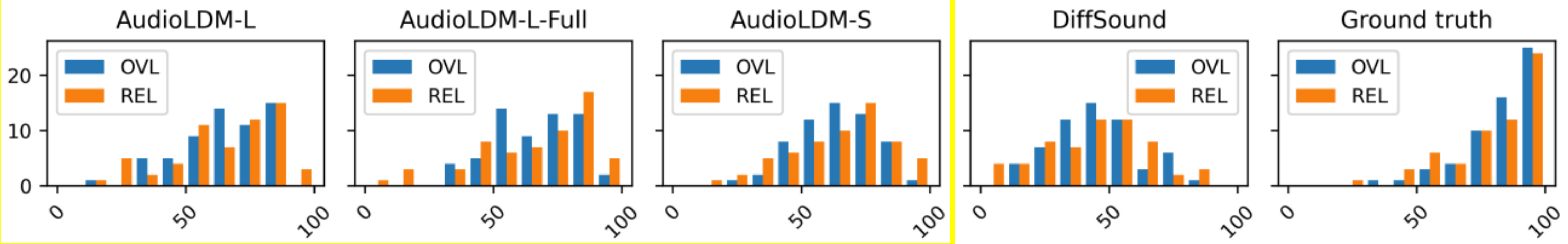


Sheep vocalization
→ Narration, monologue

Result – SOTA comparison



Model	Text Data	Use CLAP	Params	Duration (h)	FD ↓	IS ↑	KL ↓	FAD ↓	OVL ↑	REL ↑
Ground truth	-	-	-	-	-	-	-	-	$83.61_{\pm 1.1}$	$80.11_{\pm 1.2}$
DiffSound† (Yang et al., 2022)	✓	✗	400M	5420	47.68	4.01	2.52	7.75	$45.00_{\pm 2.6}$	$43.83_{\pm 2.3}$
AudioGen† (Kreuk et al., 2022)	✓	✗	285M	8067	-	-	2.09	3.13	-	-
AudioLDM-S-Full-RoBERTa	✓	✗	181M	145	32.13	4.02	3.25	5.89	-	-
AudioLDM-S	✗	✓	181M	145	29.48	6.90	1.97	2.43	$63.41_{\pm 1.4}$	$64.83_{\pm 0.9}$
AudioLDM-L	✗	✓	739M	145	27.12	7.51	1.86	2.08	$64.30_{\pm 1.6}$	$64.72_{\pm 1.6}$
AudioLDM-S-Full	✗	✓	181M	8886	23.47	7.57	1.98	2.32	-	-
AudioLDM-L-Full	✗	✓	739M	8886	**23.31**	**8.13**	**1.59**	**1.96**	$\mathbf{65.91}_{\pm 1.0}$	$\mathbf{65.97}_{\pm 1.6}$



Trained on a single 3090 or A100 GPU!

A few take aways here, thanks!

- Project Page: https://audioldm.github.io/
- Hugging Face Space (Listen to the samples contributed by the community!):
  - https://huggingface.co/spaces/haoheliu/audioldm-text-to-audio-generation
- Github:
  - Pretrained model: https://github.com/haoheliu/AudioLDM
  - Evaluation tools: https://github.com/haoheliu/audioldm_eval
- Interesting demo website:
  - https://www.latent.store/albums