



# Headroom Adaptive Gain Curve (HAGC)

## Unified HDR headroom management for Stills and Videos

Ronan Boitard - ICC Experts Day - 21st September 2026 - Gjøvik, Norway

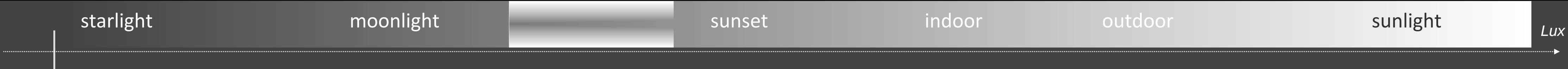
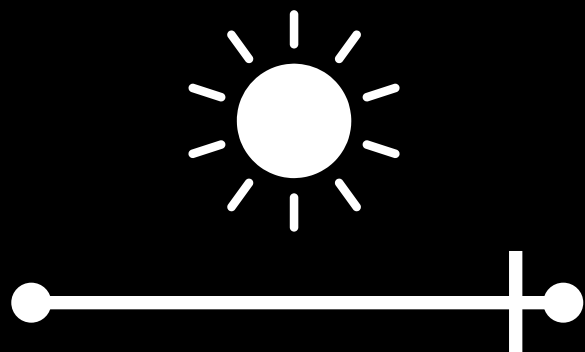
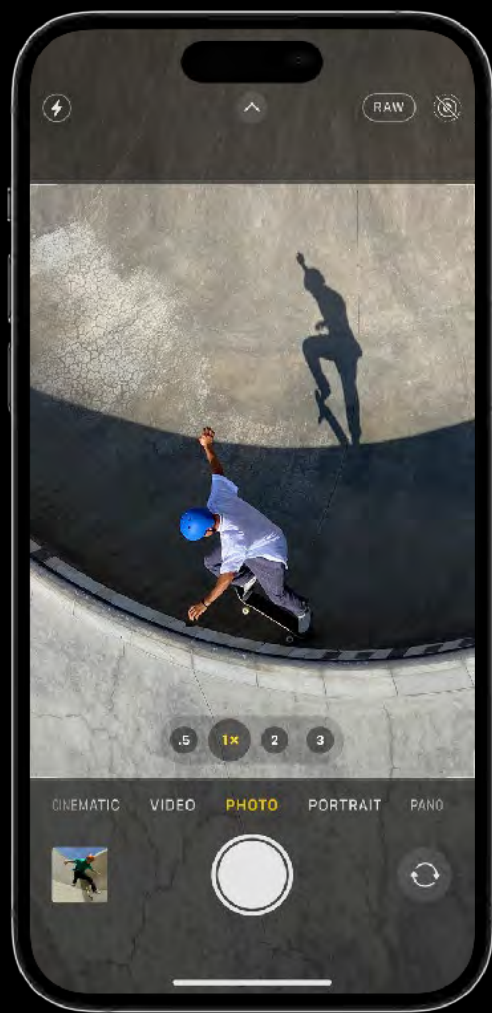
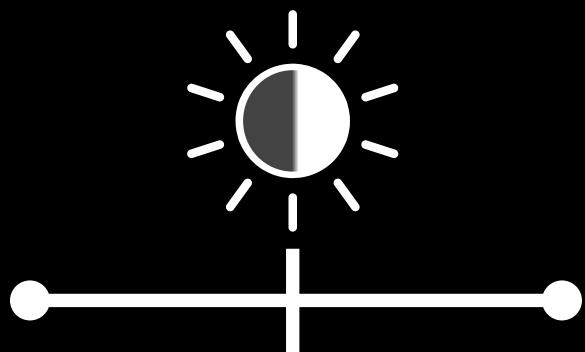
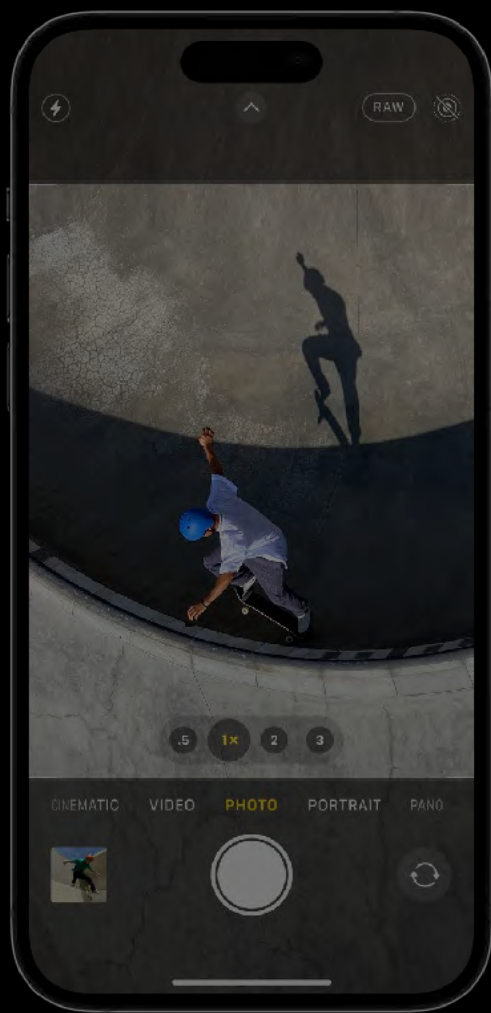
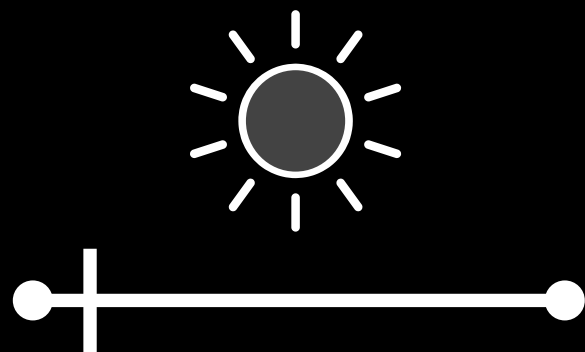
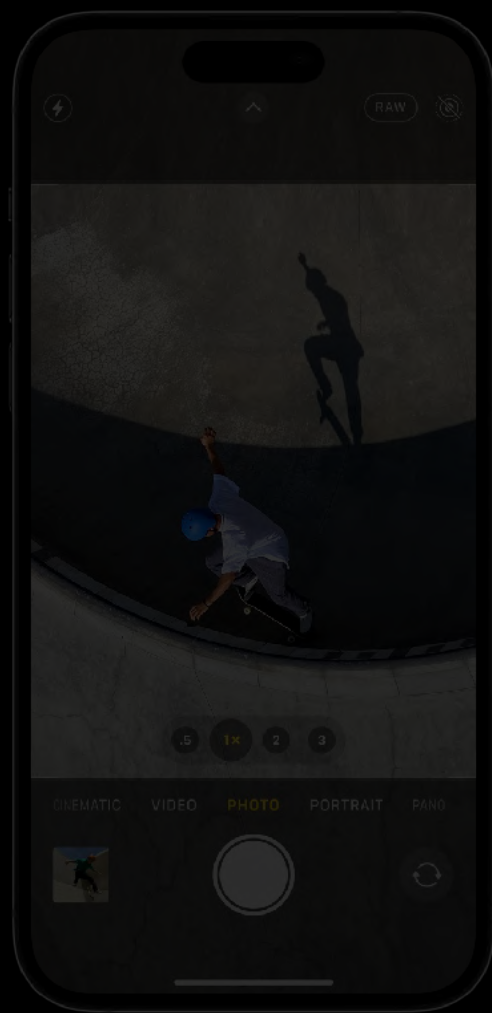
# Outline

## Brightness Setting, Reference White and Headroom

ISO HDR Image File Format

Headroom Adaptive Gain Curve (HAGC)

# Displays adapt dynamically to environment

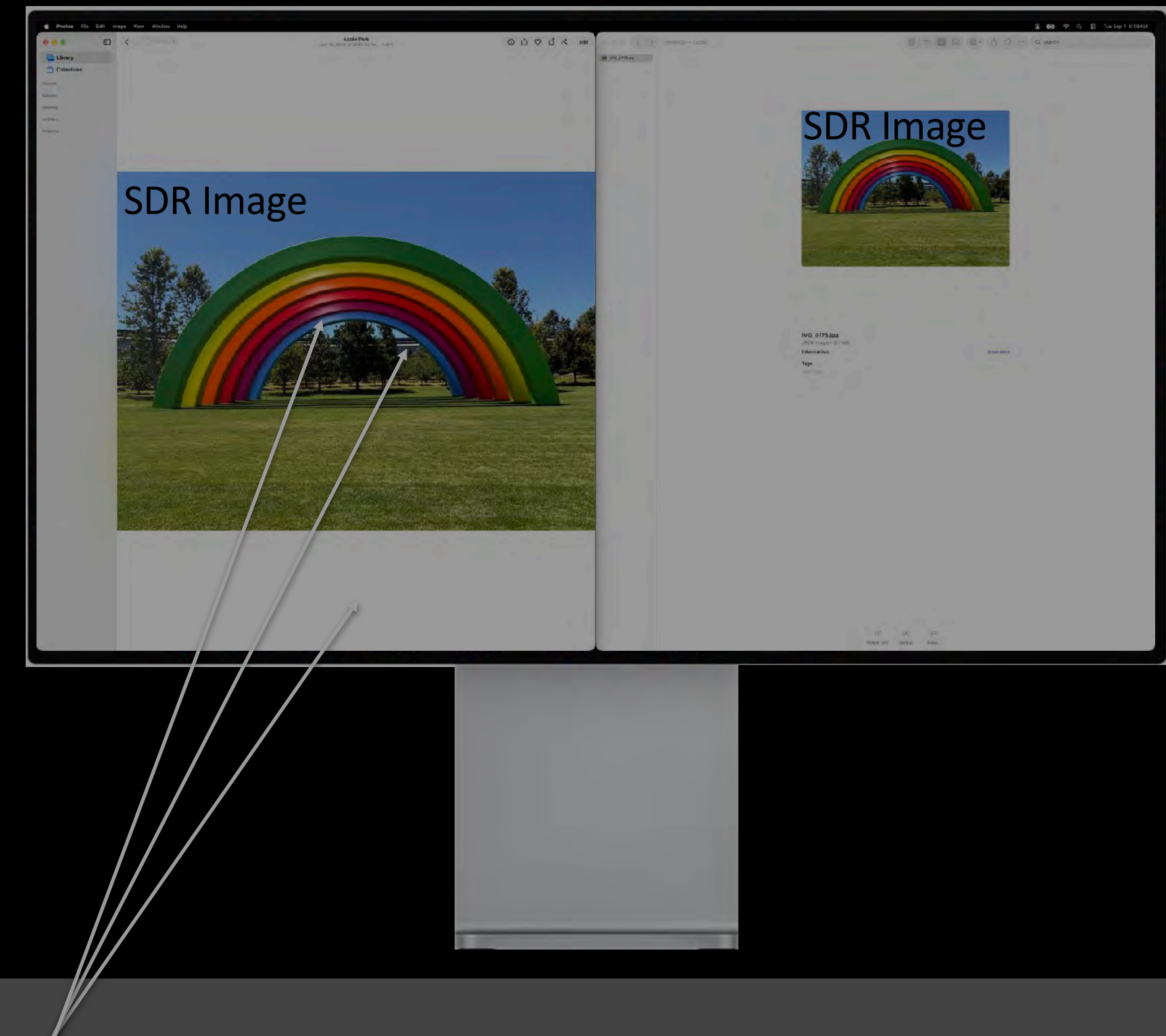


# Brightness Setting and Display Reference White

## Brightness setting set Display Reference White

- UI White
- Diffuse white surfaces

Media/content anchored around that value (reference white)



*Display Reference White*

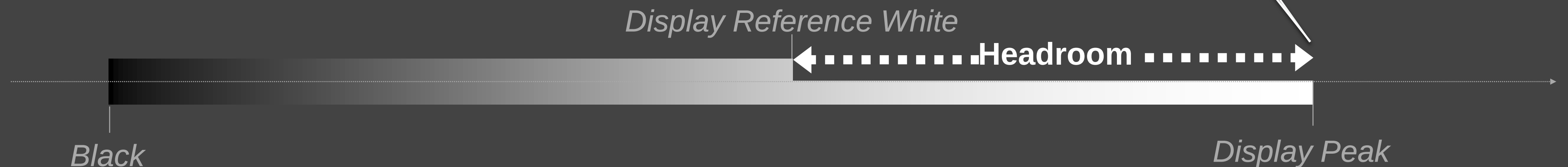
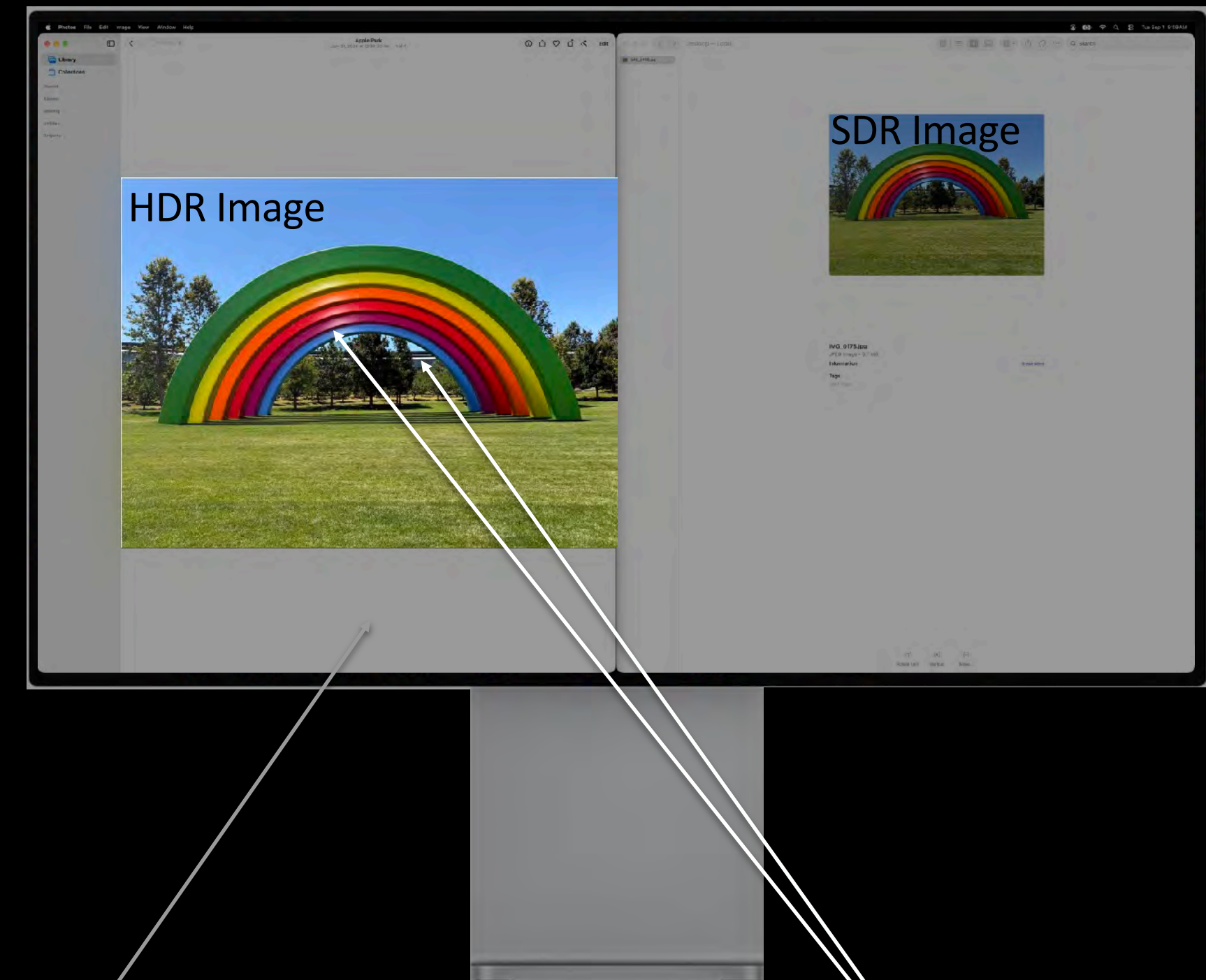
*Black*

*Display Peak*

# Displays can show more than Reference White

## Display Peak > Reference White

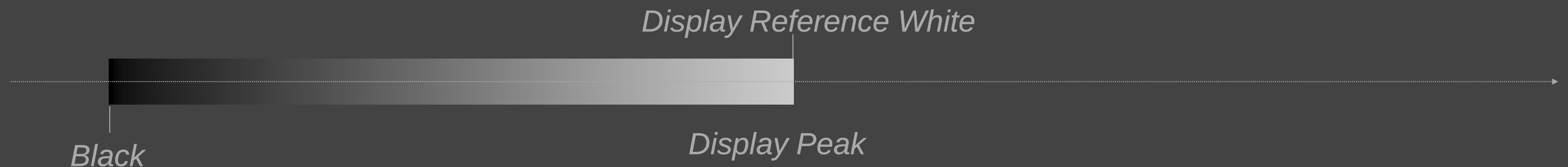
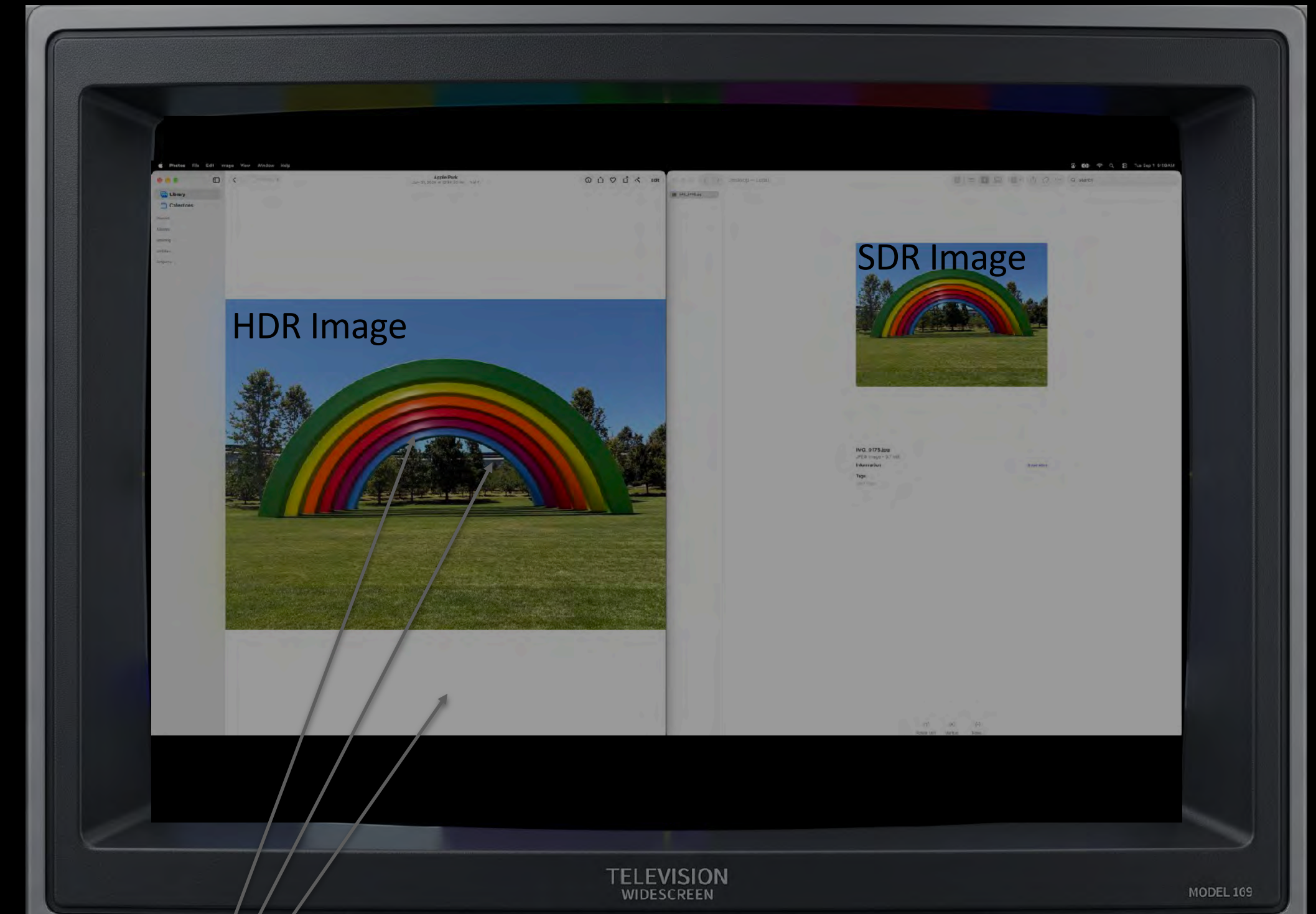
- Display has “headroom” to show highlights above UI White
- HDR content can use headroom to go beyond UI White



# SDR Displays have no headroom

Display Peak = Reference White

- Headroom=0
- HDR content need to be tone mapped to SDR



# Key take-away

- Display Reference White (via brightness slider) adapt to display conditions
- Display Reference White and Peak can be measured (cd/m<sup>2</sup> or nits)
- Display Headroom is the ratio between Display Peak and Reference White

$$Headroom = \log_2 \left( \frac{Peak}{ReferenceWhite} \right)$$

**Display headroom changes with display conditions**

# Outline

Brightness Setting, Reference White and Headroom

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# ISO 22028-5

Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

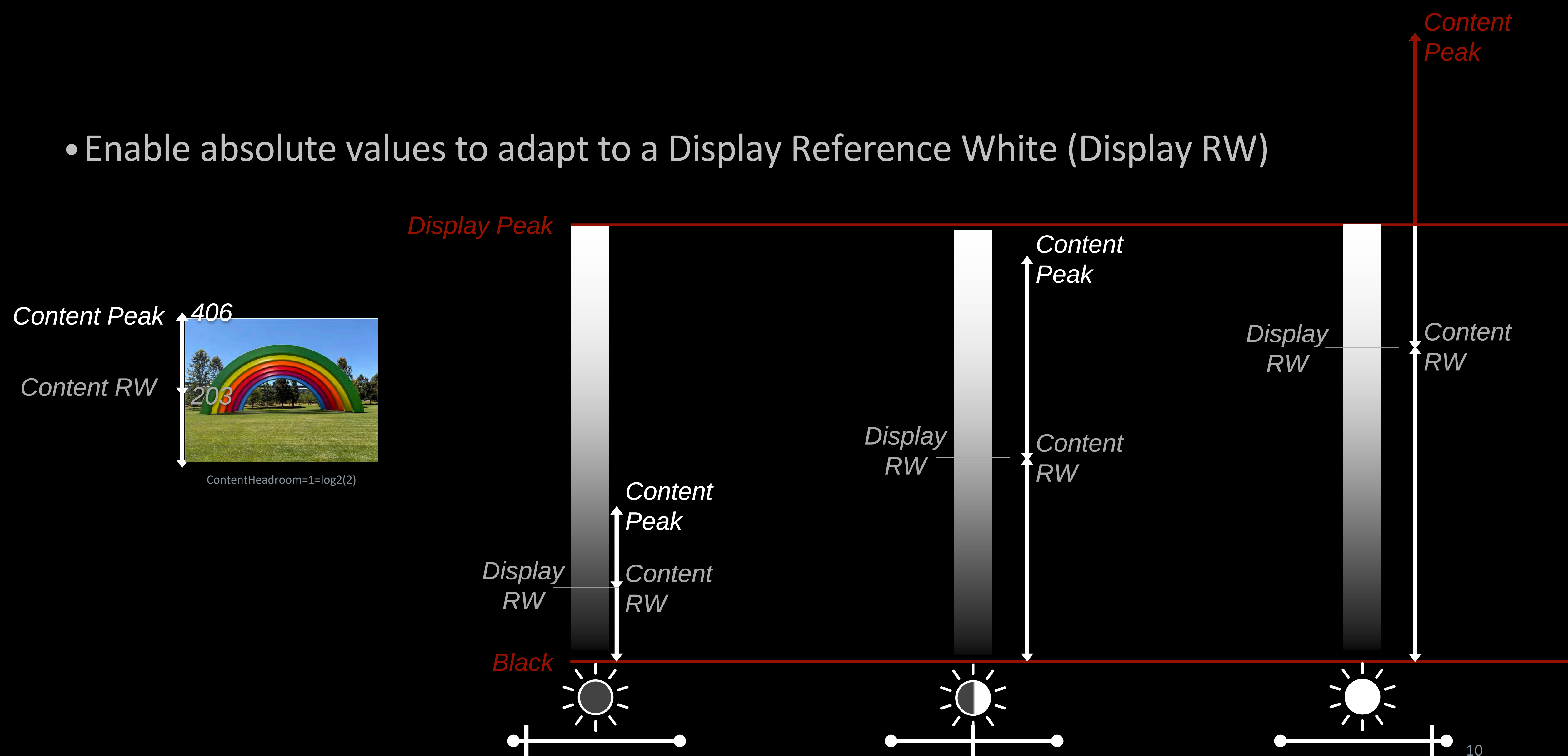
Part 5:  
High dynamic range and wide colour gamut encoding for still images (HDR/WCG)

- Designed for headroom management and compatibility with video workflows
- BT.2100 HDR image (PQ/HLG-BT.2020) with HDR metadata
  - HDR Reference White
  - Content Peak Light Level (MDCV/CLL metadata)
- Content Headroom can be computed:

$$\textit{Headroom} = \log_2 \left( \frac{\textit{Peak}}{\textit{ReferenceWhite}} \right)$$

# ISO 22028-5: HDR Reference White

- Enable absolute values to adapt to a Display Reference White (Display RW)



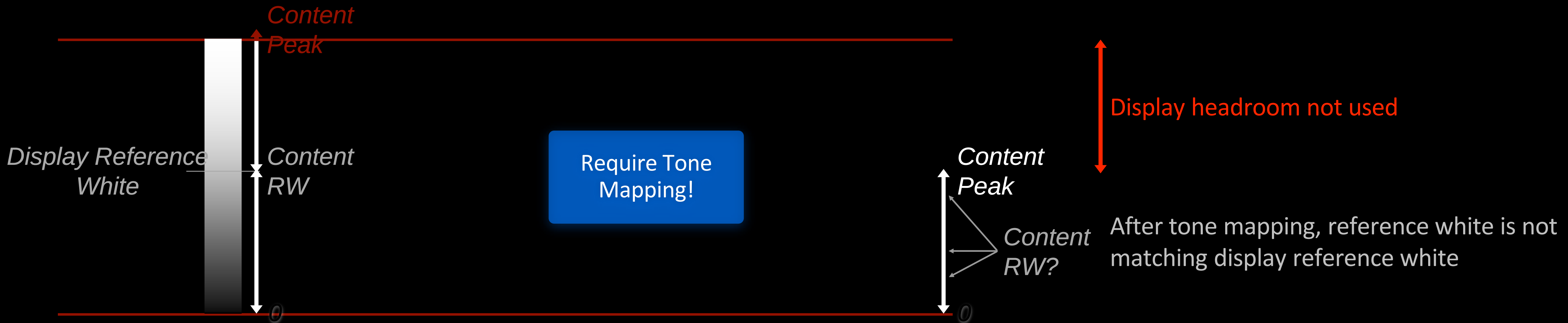
# ISO 22028-5: Tone Mapping

ISO 22028-5:2026(en)

Annex G  
(informative)

Tone mapping to SDR display

- Annex G defines a recommended HDR to SDR tone mapping (RWTMO)
  - Single solution for each content headroom



- Adapts to the content headroom but not to the display headroom

# ISO 21496-1

International Standard

ISO 21496-1:2025(en)

Digital photography — Gain map metadata for image conversion —

Part 1:  
Dynamic range conversion

- Defines two independent grading (e.g. SDR and HDR) using a gain map
  - Gain Map Stores the difference between the two grades
  - Adapt to any Display Headroom by scaling the gain map



SDR



Gain Map

Adaptive HDR metadata  
• AlternateHeadroom



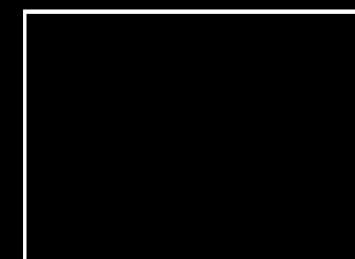
DisplayHeadroom=0



DisplayHeadroom=0.5\*  
AlternateHeadroom



DisplayHeadroom= AlternateHeadroom



Scaled Gain Map



Scaled Gain Map



Scaled Gain Map

# Key take-aways

- ISO 21496-1:
  - Full artistic control in all headroom conditions
  - Not compatible with video
- ISO 22028-5:
  - Designed to enable content headroom management and compatible with videos
  - Lack of metadata to enable artistic control in limited headroom scenario

**Desire for consistent artistic control between photo and videos**

# What would we need?

- Required
  - File format independent (can be used with any video or image file)
  - Creative control on tone mapping to any display headroom
  - Low file size overhead
  - Prescriptive -> headroom adaptation fully defined
- Extras
  - User-friendly customization/editing

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# HDR metadata for Videos and Images

- Defined in SMPTE and ICC

|          | Video                                                                                                                                          | Photo                                                                                                          |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Standard |  <b>SMPTE</b><br>ST 2094-50                                | <br>ICC Specification v4.4 |
| Storage  | ITU T.35 : <ul style="list-style-type: none"><li>Elementary stream (e.g. SEI in H.265)</li><li>Container level Timed-Metadata tracks</li></ul> | <ul style="list-style-type: none"><li>headroomAdaptiveGainCurveType (HAGC) tag</li></ul>                       |
| Status   | Published<br><a href="https://pub.smpte.org/doc/st2094-50/20260824-pub/">https://pub.smpte.org/doc/st2094-50/20260824-pub/</a>                 | Under Review                                                                                                   |

# High Level Metadata

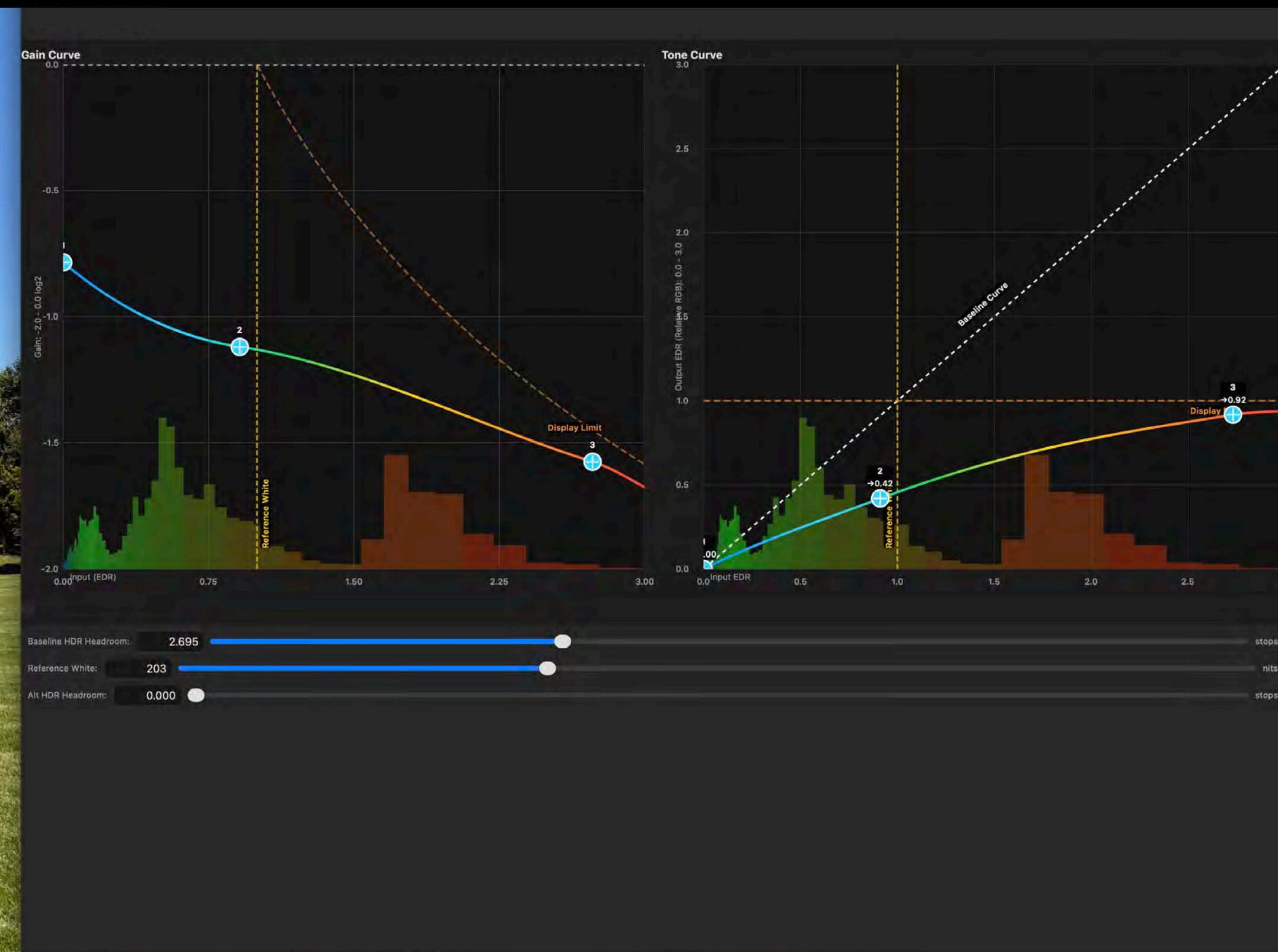
| Metadata Name                     |                               | Description                                                                            |
|-----------------------------------|-------------------------------|----------------------------------------------------------------------------------------|
| HDR Reference White               |                               | Maps HDR signal to Display reference white                                             |
| Headroom-Adaptive<br>Tone Mapping | Baseline Headroom             | Indicate when to tone map<br>Target headroom < Baseline Headroom, require tone mapping |
|                                   | Gain Application Space        | Color Space in which to apply the tone mapping                                         |
|                                   | Alternate Images<br>(up to 4) | Specify tone mapping to a specific target headroom                                     |

# Alternate Image Details

| Metadata Name       |                  | Description                                                                                  |
|---------------------|------------------|----------------------------------------------------------------------------------------------|
| Alternate Headroom  |                  | Headroom resulting from applying the associated Color Gain Function                          |
| Color Gain Function | Component Mixing | Parametrize tone mapping across color volume (uses Min, Max, Red, Green, Blue and Component) |
|                     | Gain Curve       | Piece-wise Cubic Hermite splines with up to 32 points                                        |

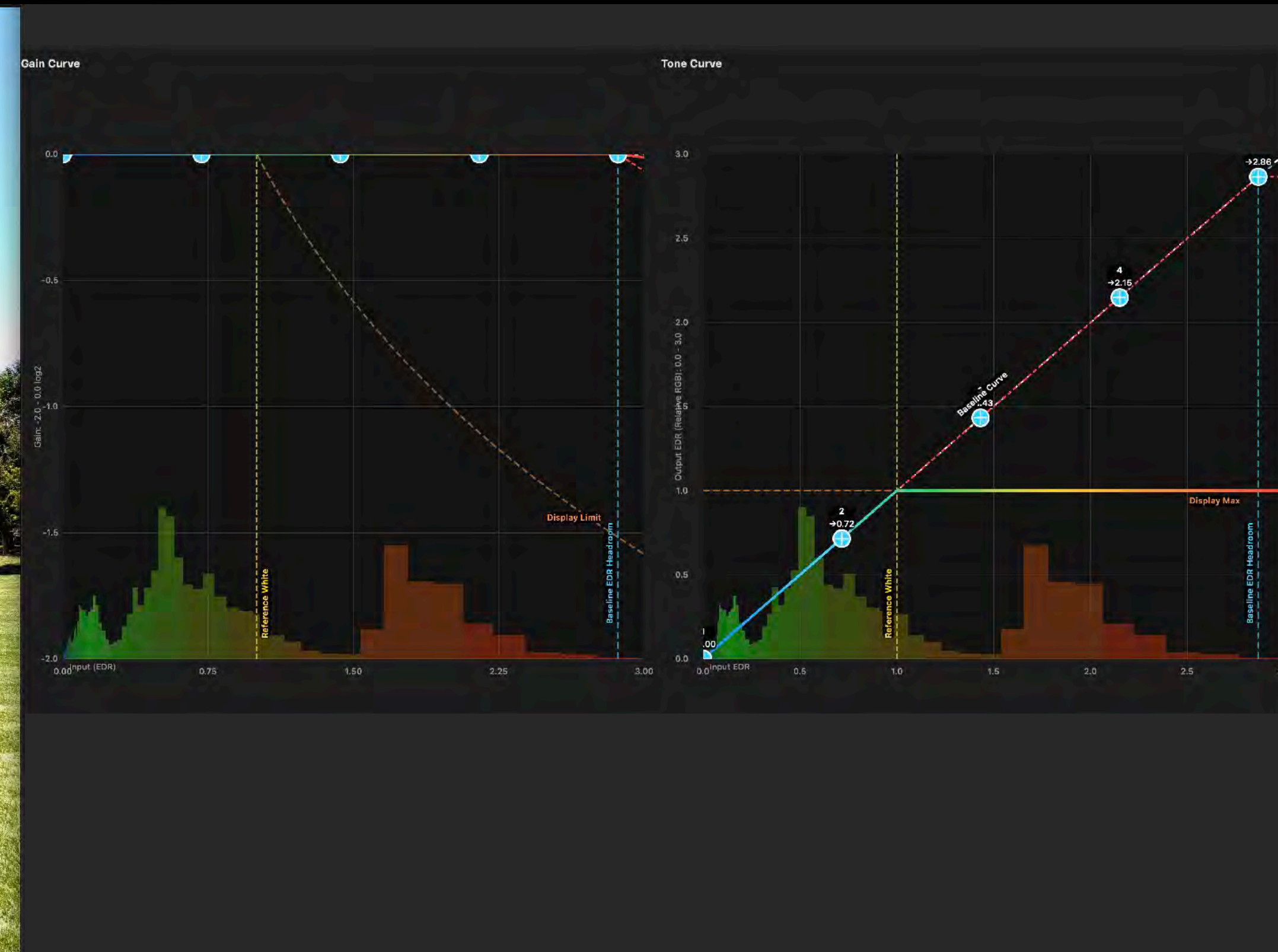
# Gain Curve Examples (1/4)

- 3-point gain curve with progressive soft-clip



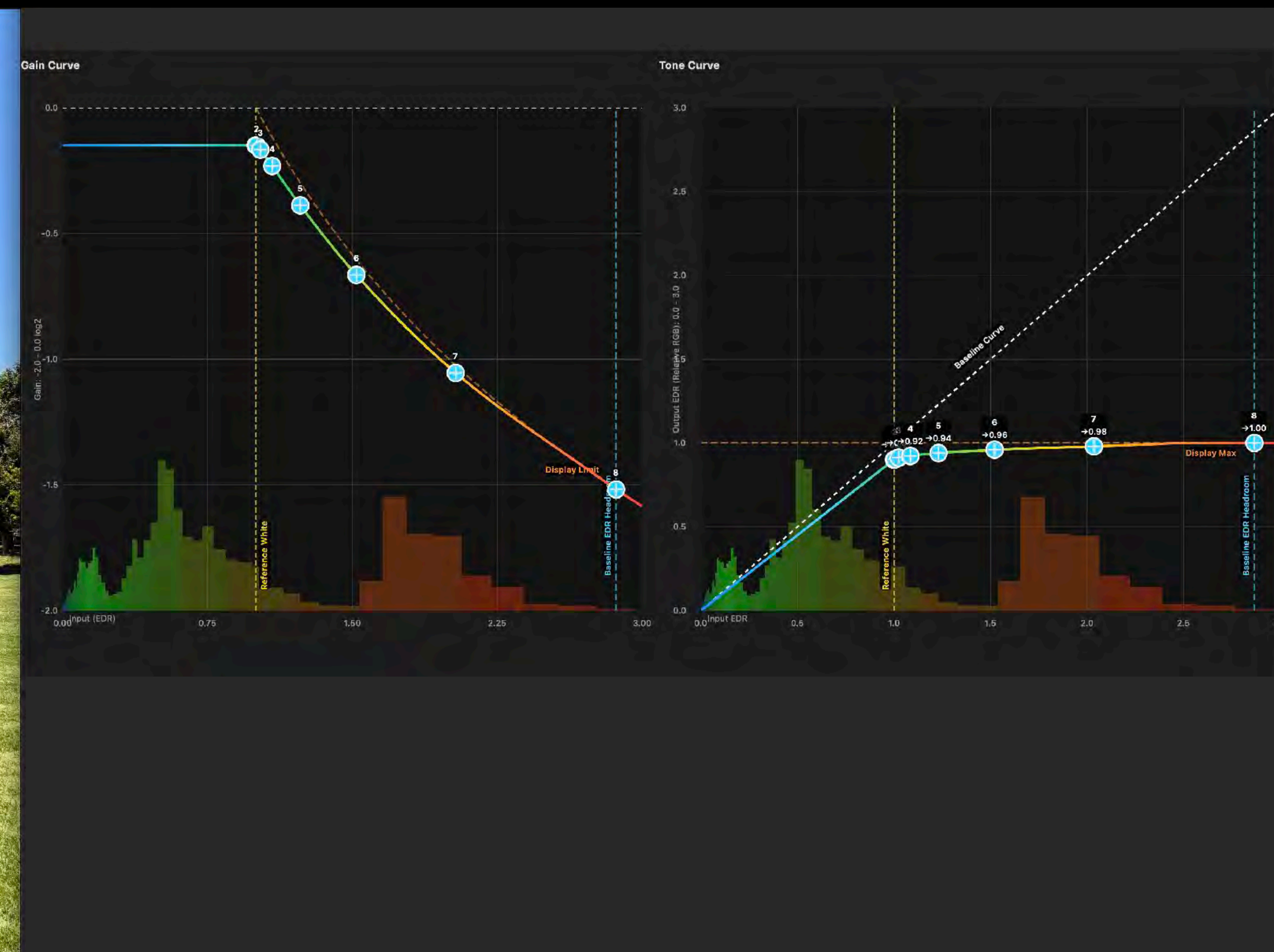
# Gain Curve Examples (2/4)

- Unity gain curve -> Preserve SDR range and clip HDR



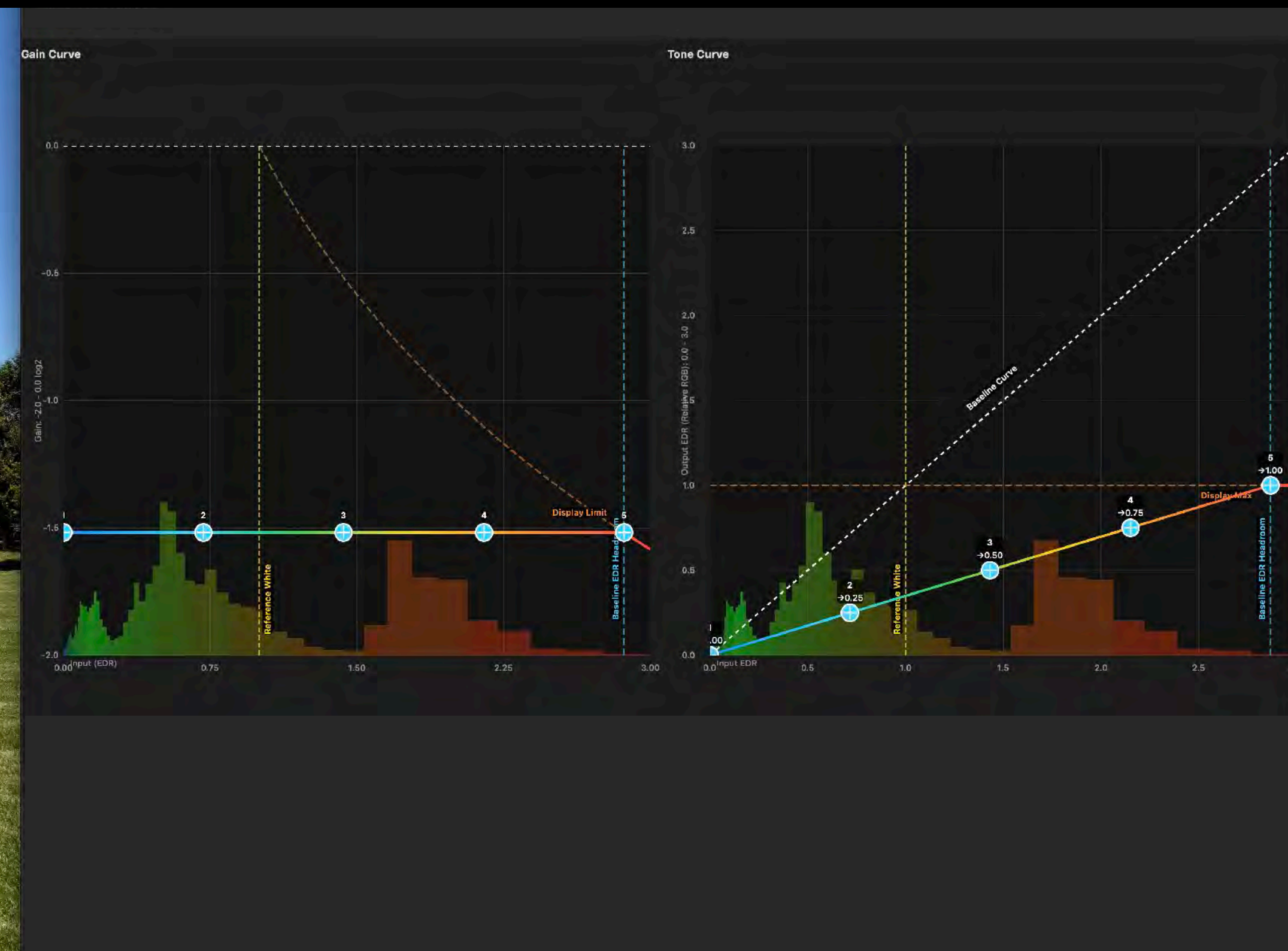
# Gain Curve Examples (3/4)

- Gain curve prioritizing SDR with aggressive highlight roll-off

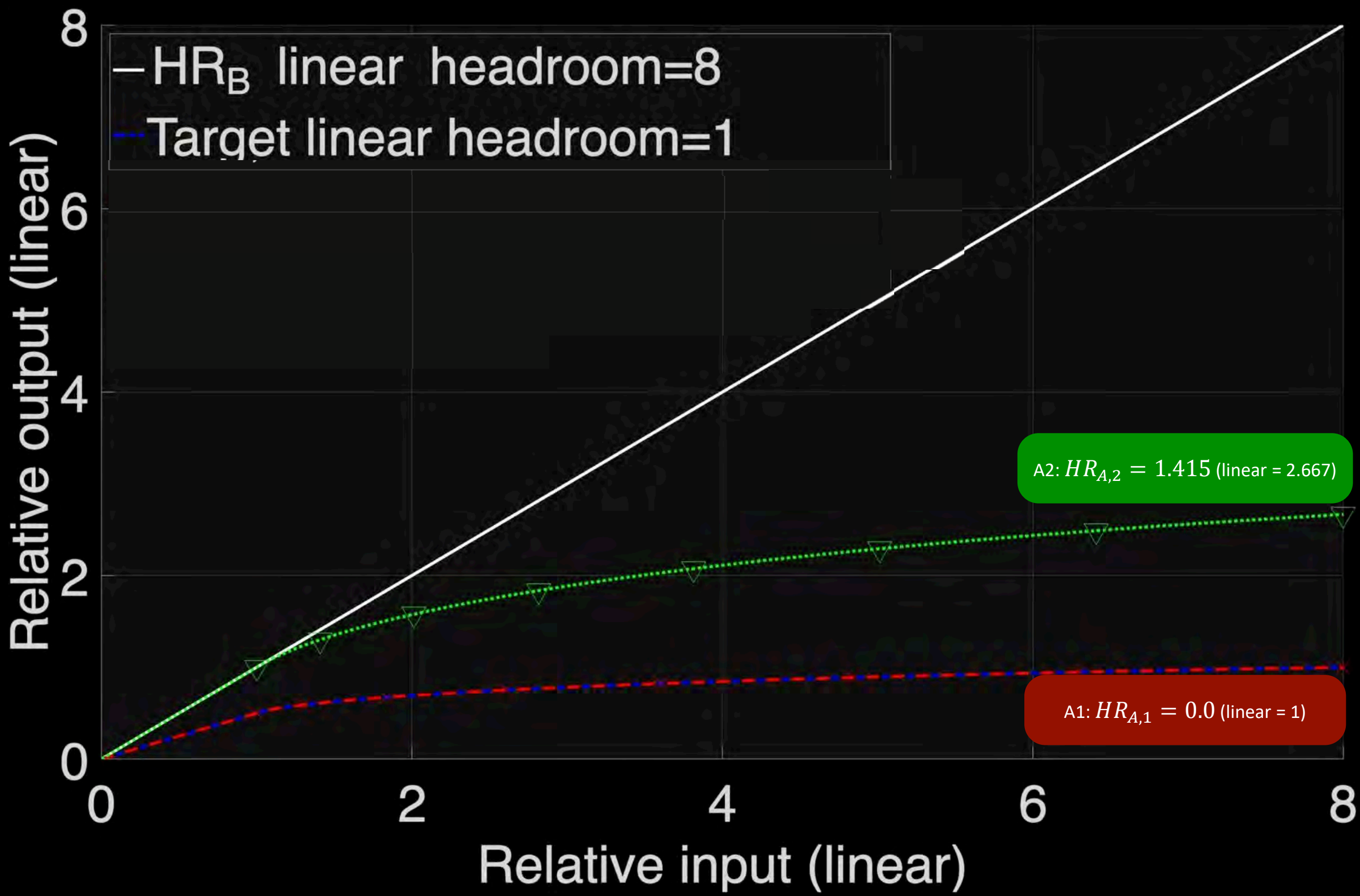
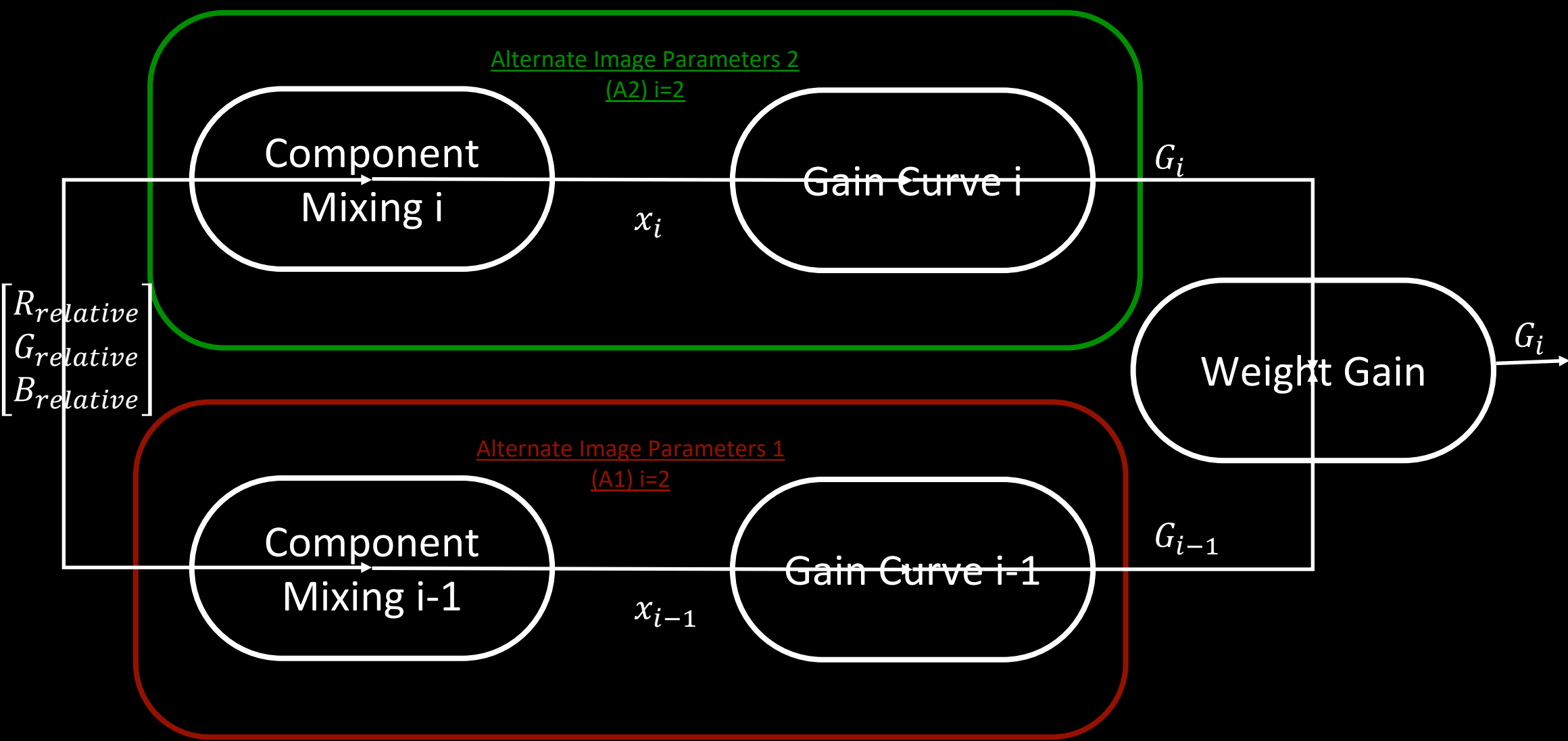


# Gain Curve Examples (4/4)

- Constant gain (linear scaling)



# Computing to any Headroom



# Headroom Adaptive Gain Curve

## Key take-aways

- HAGC enables:
  - Consistent metadata across video/images
  - Intuitive creative control with minimum impact (file size, rendering performance)
  - Consistent reproduction across systems where playback is supported
  - Evolves seamlessly across any display headroom (animation, display changes)
  - Reverts to identify if no tone mapping required
  - Enable up (expand) and down (compress) tone mapping

# Links

- SMPTE ST 2094-50:
  - <https://pub.smpte.org/doc/st2094-50/20260824-pub/>
- Documentation:
  - <https://developer.apple.com/documentation/coloursync/headroom-adaptive-gain-curve>
- Adding ITU-T T.35 message to videos
  - [https://github.com/MPEGGroup/isobmff/tree/t35\\_tool](https://github.com/MPEGGroup/isobmff/tree/t35_tool)