The Photosphere HDR Image Browser

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Anyhere Software

Motivation

- Existing browsers are divided in two camps:
  - File browsers with no cataloging features
  - Catalogers with no file browsing features
- None of the existing browsers support HDR
  - High dynamic range imaging considered too special-interest by most software makers
- Philosophical disagreements with the status quo too numerous to mention

Goals

- Browsing High Dynamic Range Images
  - *Radiance*, TIFF, OpenEXR, JPEG-HDR formats
  - Making HDR images from bracketed exposures
- Maintaining Catalog Information
  - Subjects, keywords, albums, comments, etc.
- Tracking Image Files
  - Leave file management & modification to user

Realized Features

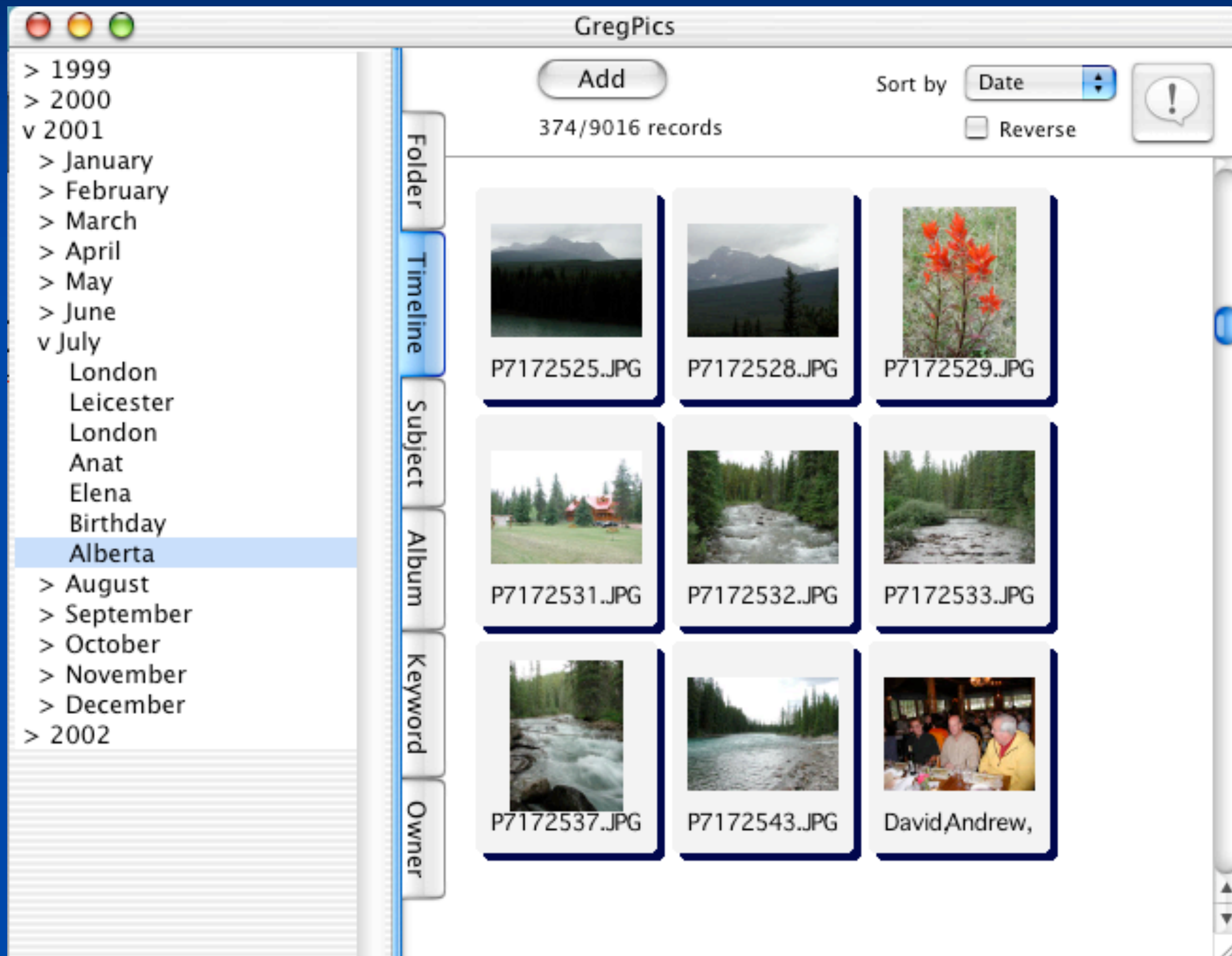
- Fast, interactive response
- Thumbnails accessible when images are not
- Interprets Exif header information
- Builds photo albums & web pages
- Displays & edits image information
- Provides drag & drop functionality
- User-defined database fields

Unrealized Features

- Plug-in interface for photo printing services
- Linux and Windows versions
- More supported image formats
  - Currently JPEG, TIFF, *Radiance*, OpenEXR, BMP

Browser Layout

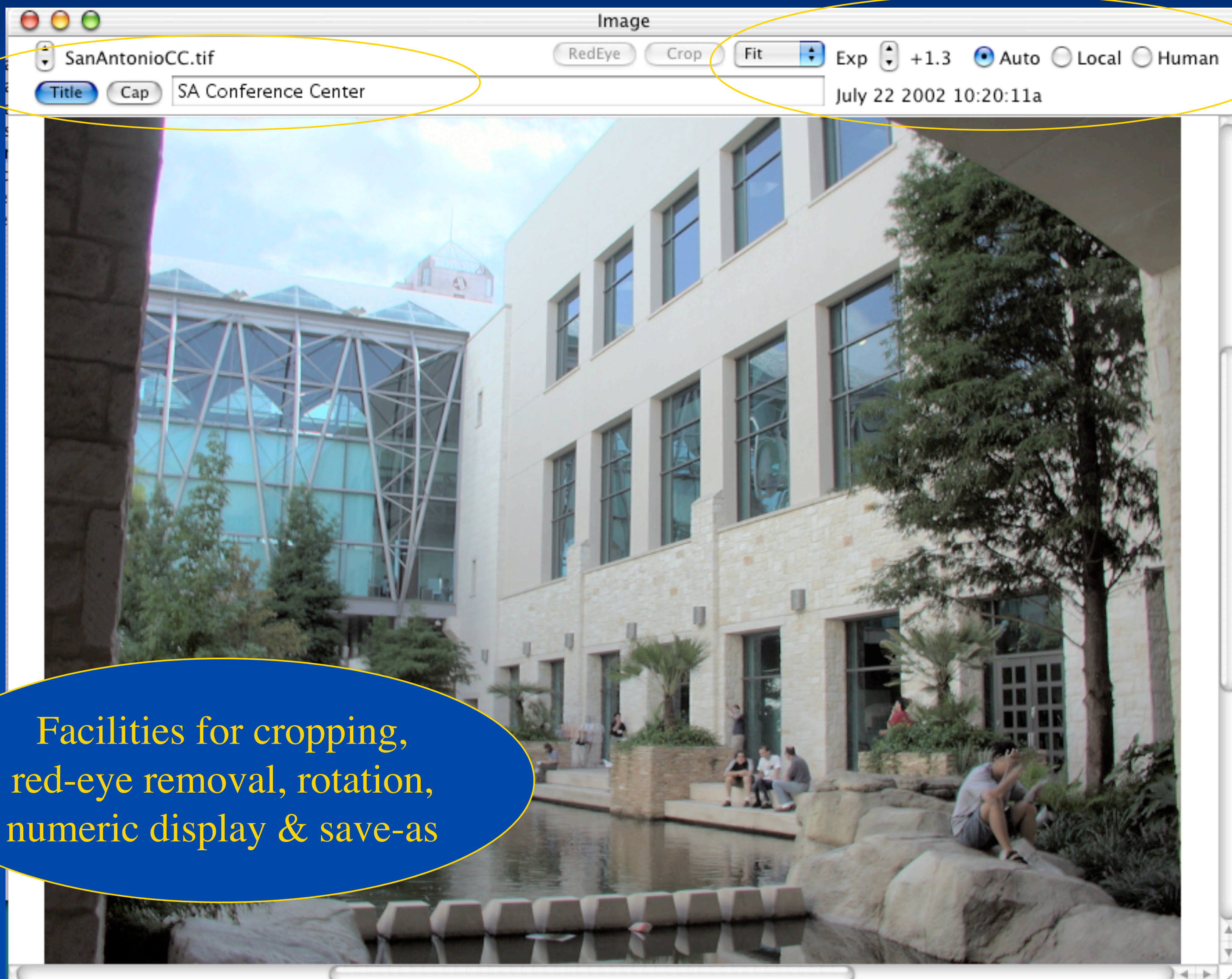
Selector Tabs permit multiple image selection from file system or catalog DB



Thumbnail sizes up to 320-pixel resolution preview

Viewer Layout

Handy settings of title & caption



Facilities for cropping, red-eye removal, rotation, numeric display & save-as

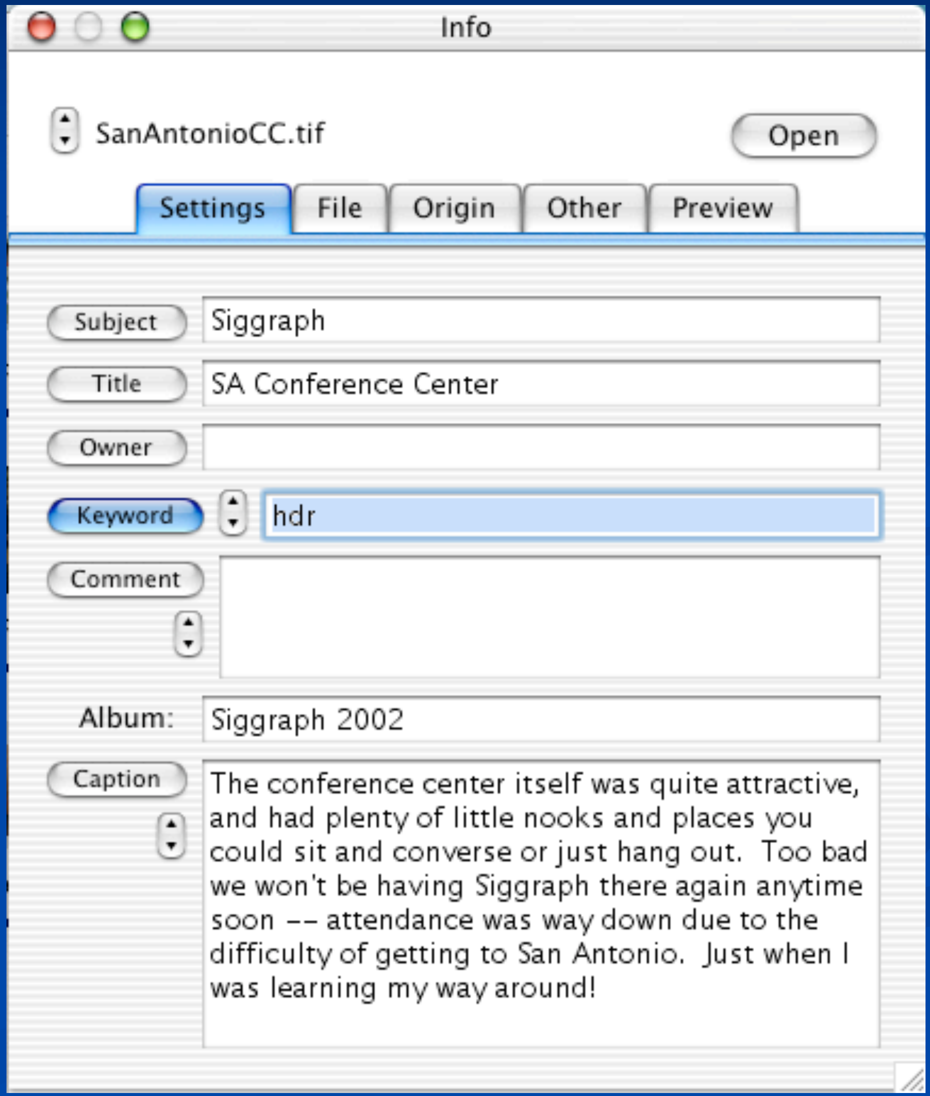
Controls for display size and tone-mapping

Info Window Layout

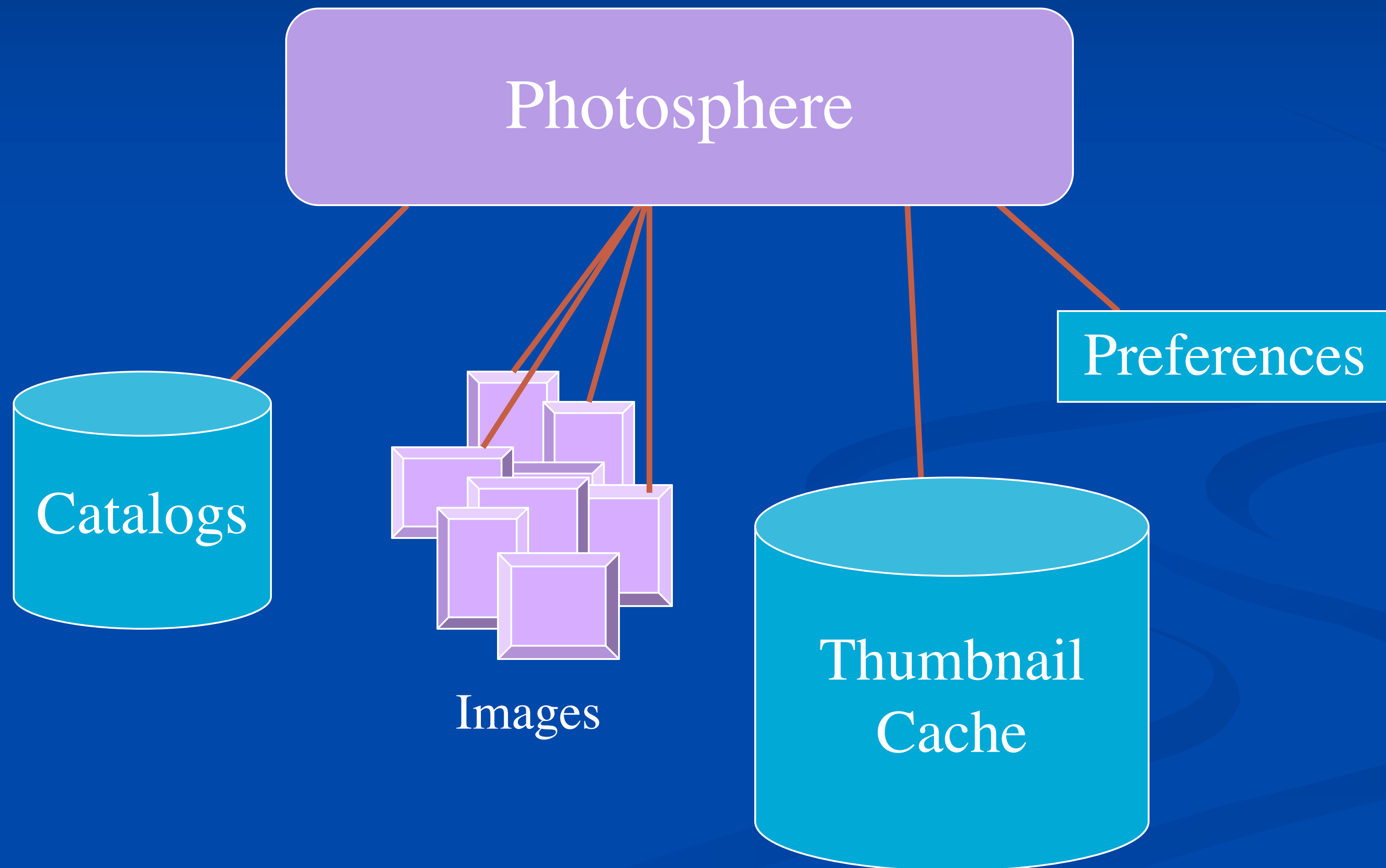
Provides convenient access to individual image settings and information

Most functionality is duplicated in application Set menu, which are more convenient for setting values on multiple images

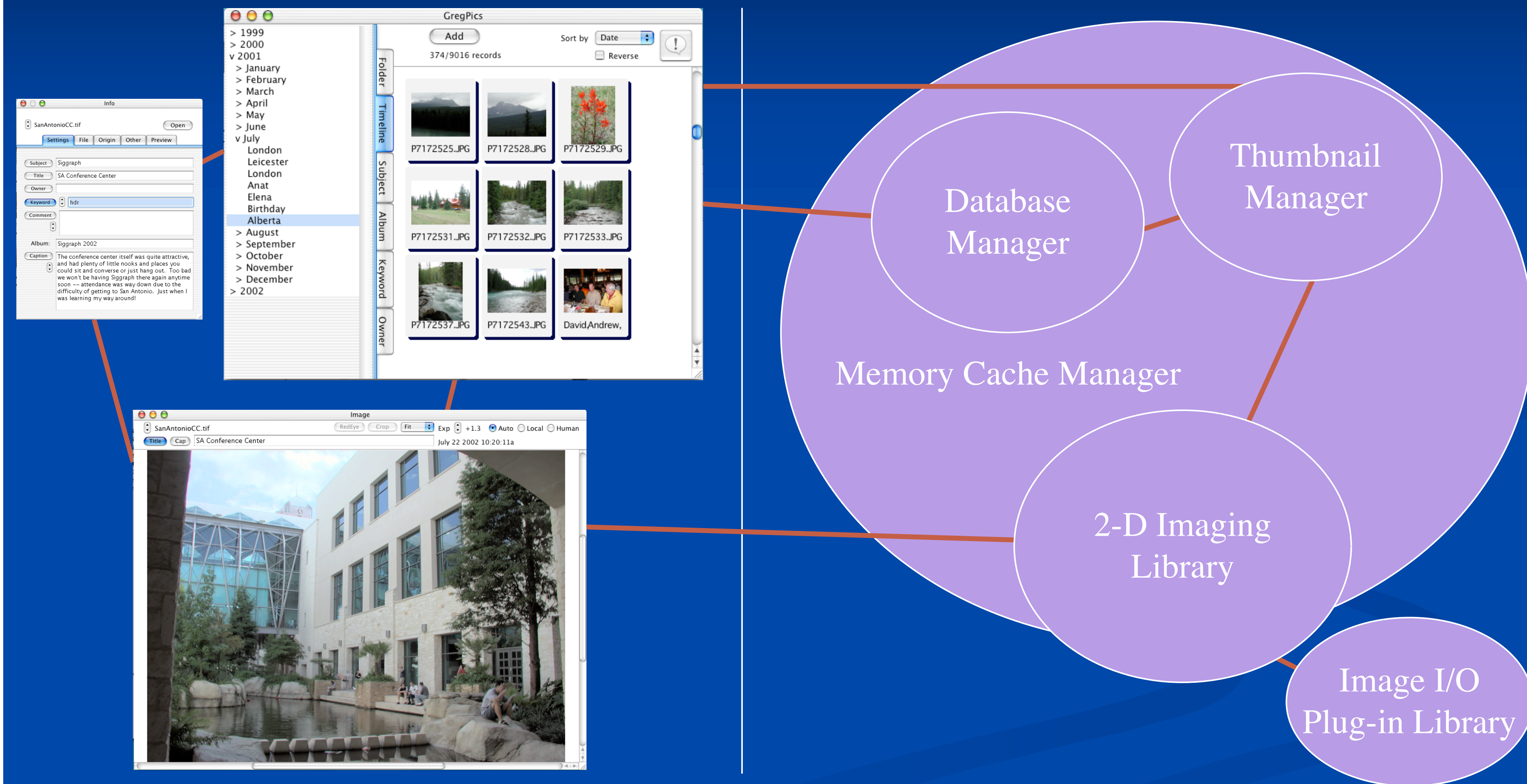
A handy browser “pop-up” feature also provides a preview and detailed image information on any selected thumbnail, and info listing is offered as alternative to thumbnail display



Browser Files



Browser Architecture



System-Specific GUI

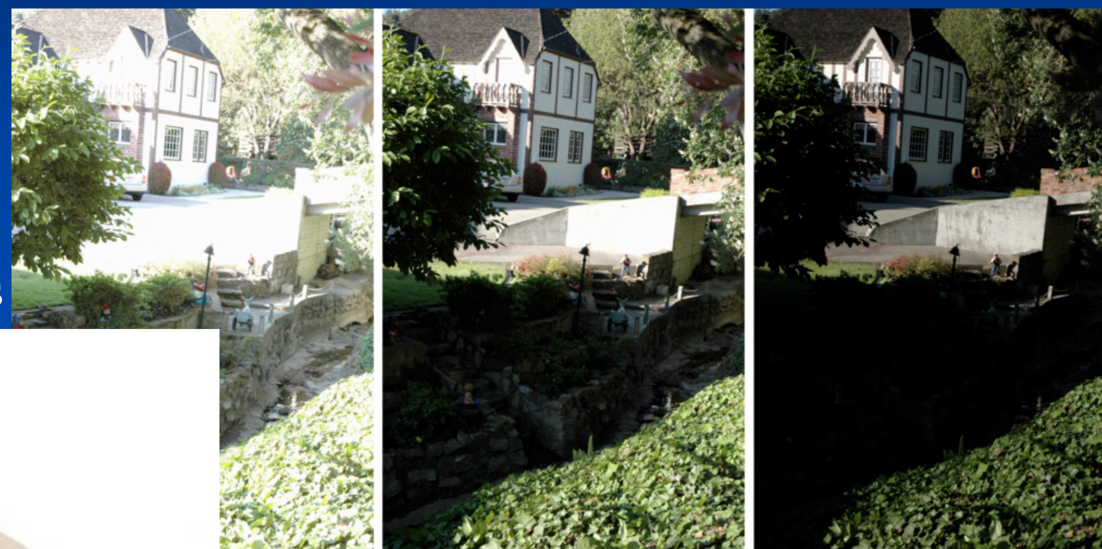
System-Independent Library

High Dynamic Range Photography

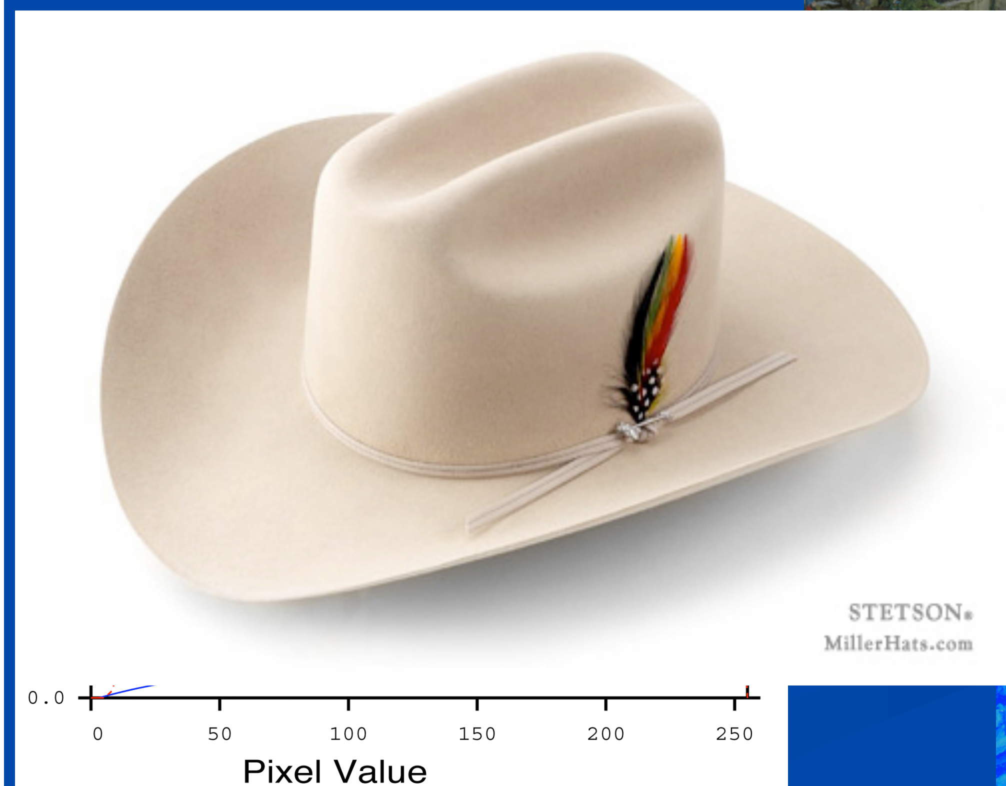
- Most mid-priced digital cameras offer an "exposure bracket" mode
- Exif header includes exposure information
- Photosphere extracts Exif exposure data
- Uses overlapping regions to get response
  - Debevec & Malik invented basic technique, though we use method of Mitsunaga & Nayar
- The trick is image registration (alignment)
- Options to reduce lens flare & ghosting

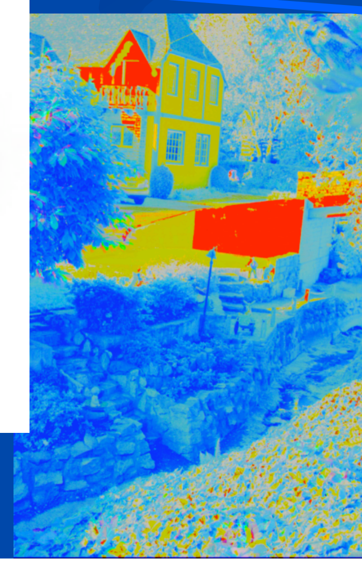
HDR from Multiple Exposures

Input exposures:



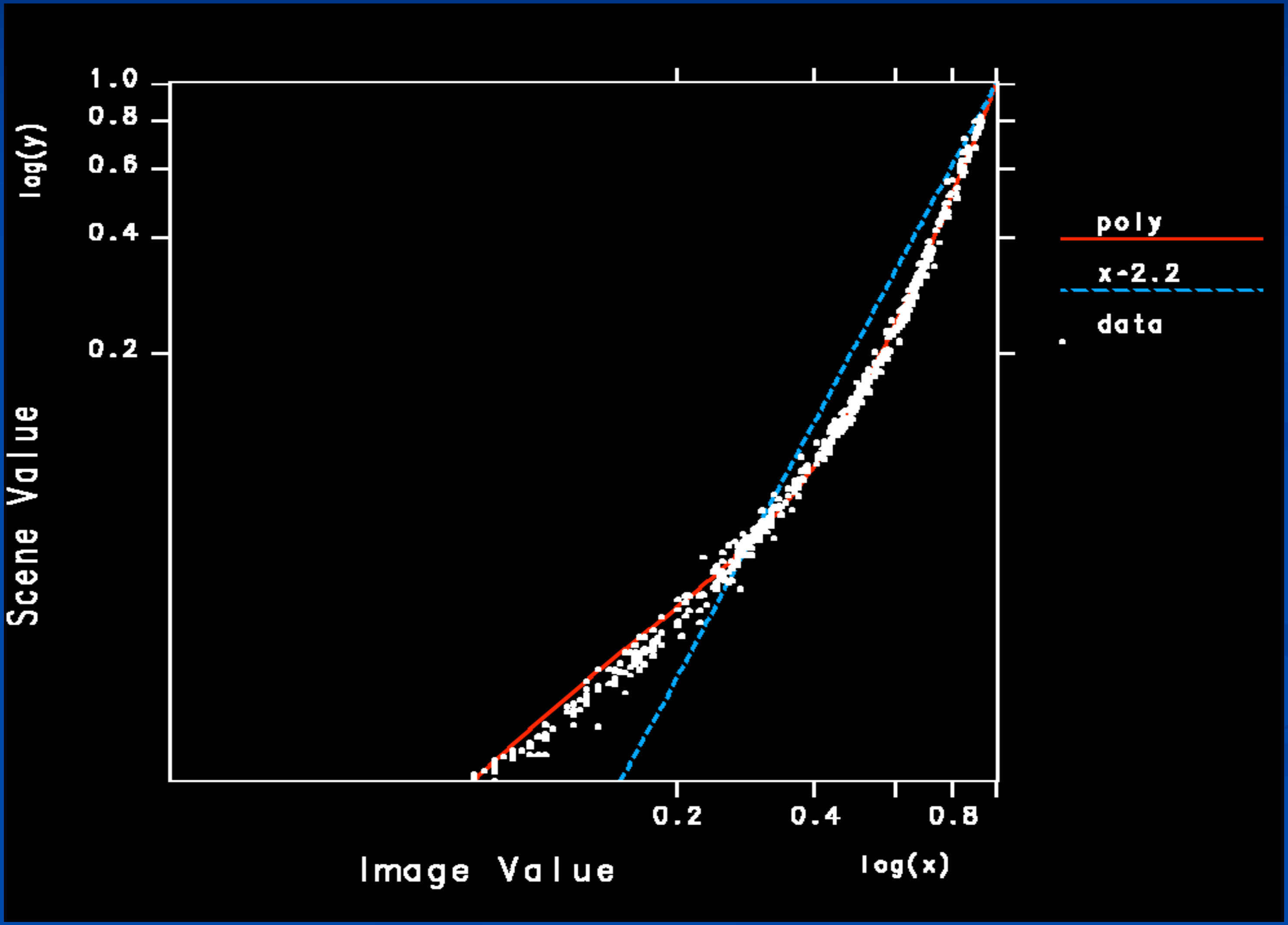
Camera response & weighting functions





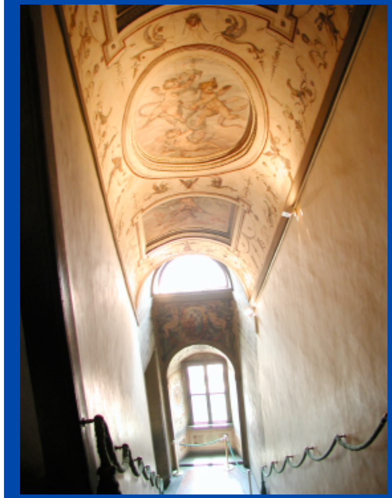
Tone-mapped result

Recovered Response Function



HDR Capture in Photosphere

- Automatic exposure alignment
- "Ghost" removal
- Lens flare removal





LDR Exposure Registration
[Ward 2003, *Journal of Graphics Tools*, 8(2)]

The *median threshold bitmap* (MTB) allows us to quickly compare and align different images, because it is constant with respect to exposure for any camera with a monotonic response function

The same is not true for an edge map, which changes with exposure even with careful normalization and approximate response curves

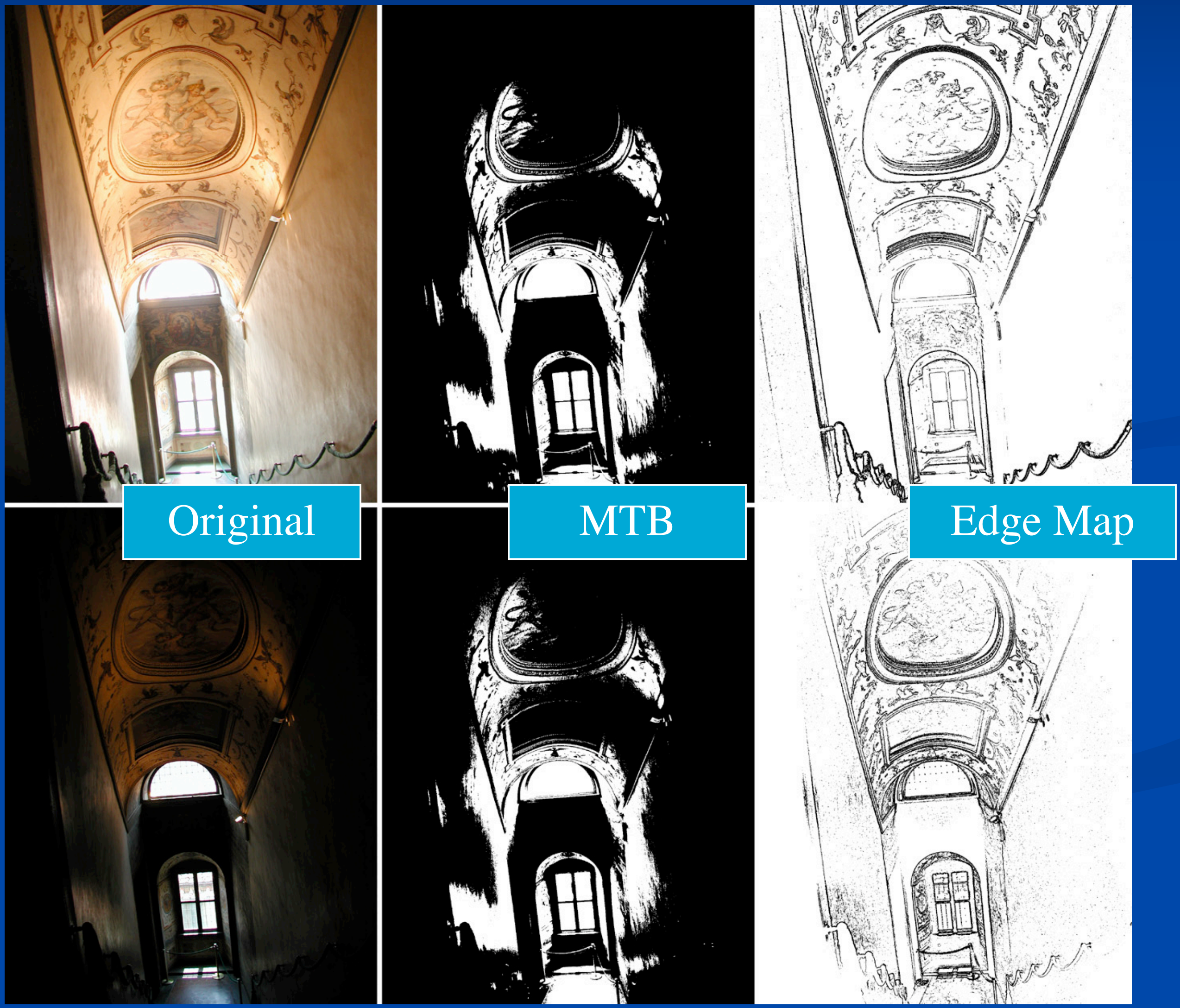


Image Pyramid Alignment

Grayscale images are scaled down repeatedly to create an image pyramid, which is then converted into MTBs for comparison

The smallest images are aligned first within a ±1 pixel distance, which corresponds to a ±32 pixel distance in the original

This becomes the MSB in the offset, which is shifted and used as the starting point for the next higher resolution alignment, and so on to the top

Alignment Results

5 unaligned exposures Close-up detail MTB alignment

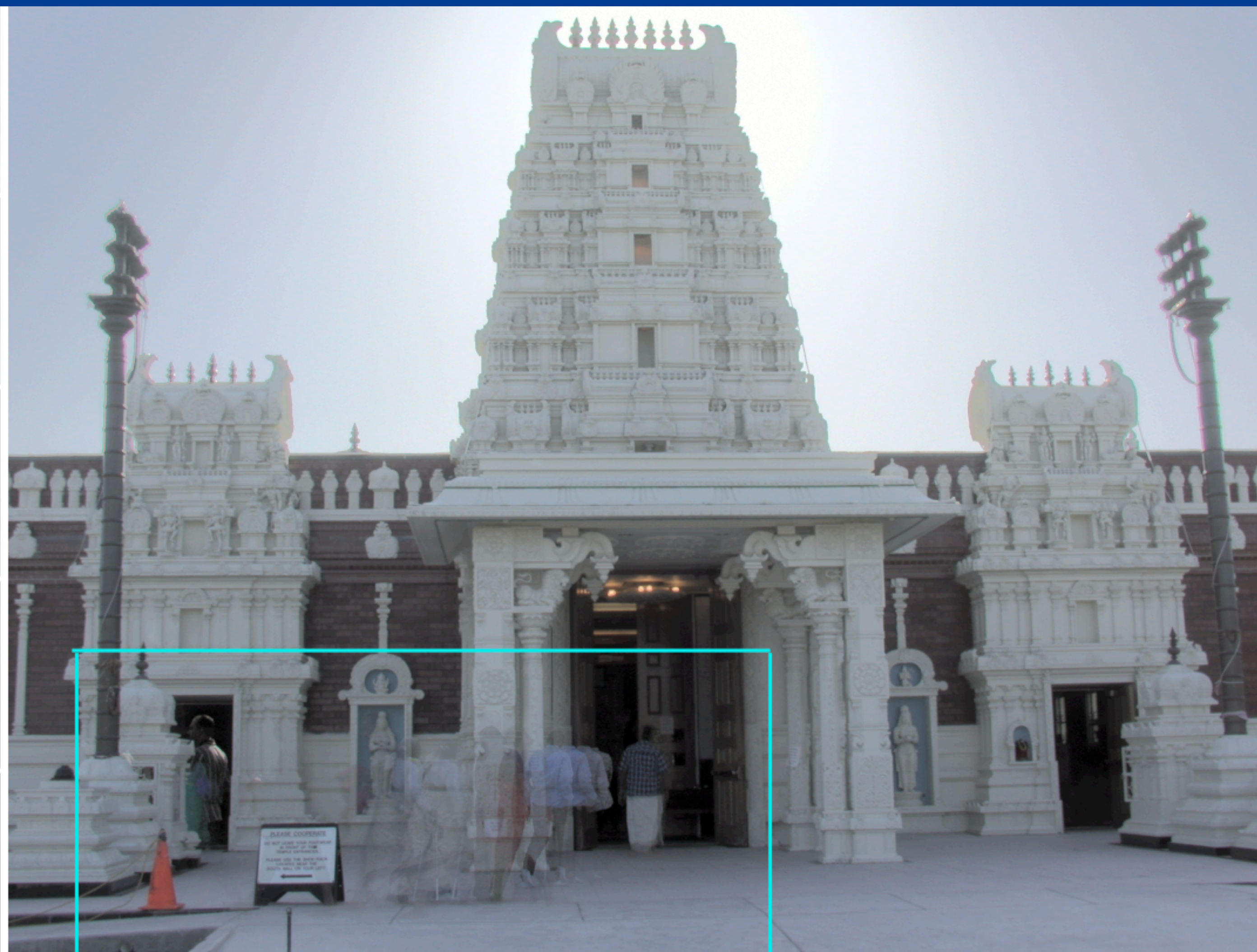
Time: About .2 second/exposure for 3 MPixel image

Automatic "Ghost" Removal

Before

After

Object Movement



Variance-based Detection

Region Masking

Best Exposure in Each Region

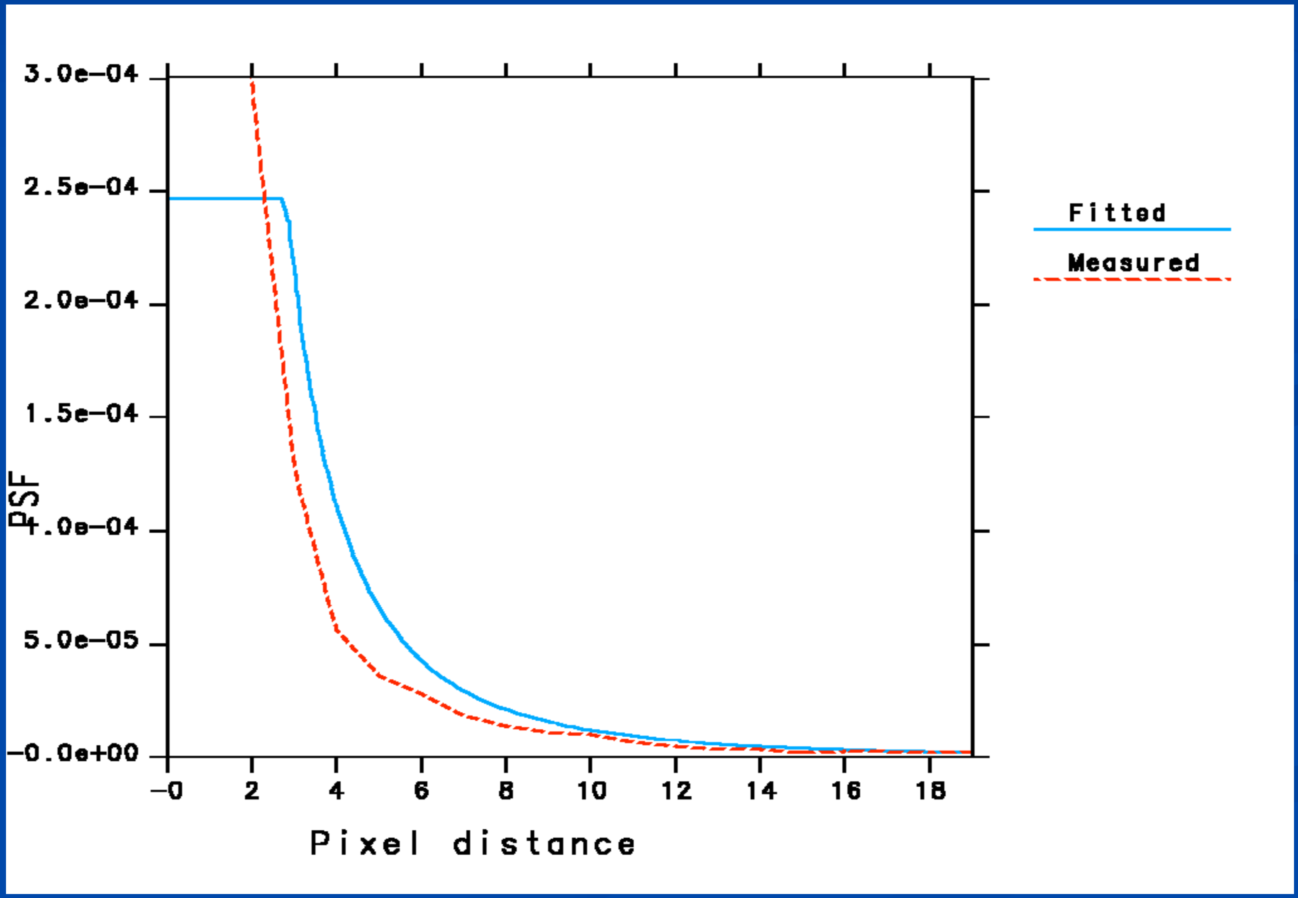
Lens Flare Removal

- From left image, we may directly measure the lens Point Spread Function (PSF)
- PSF is a function of focal length and aperture, so comprehensive measurement is impractical

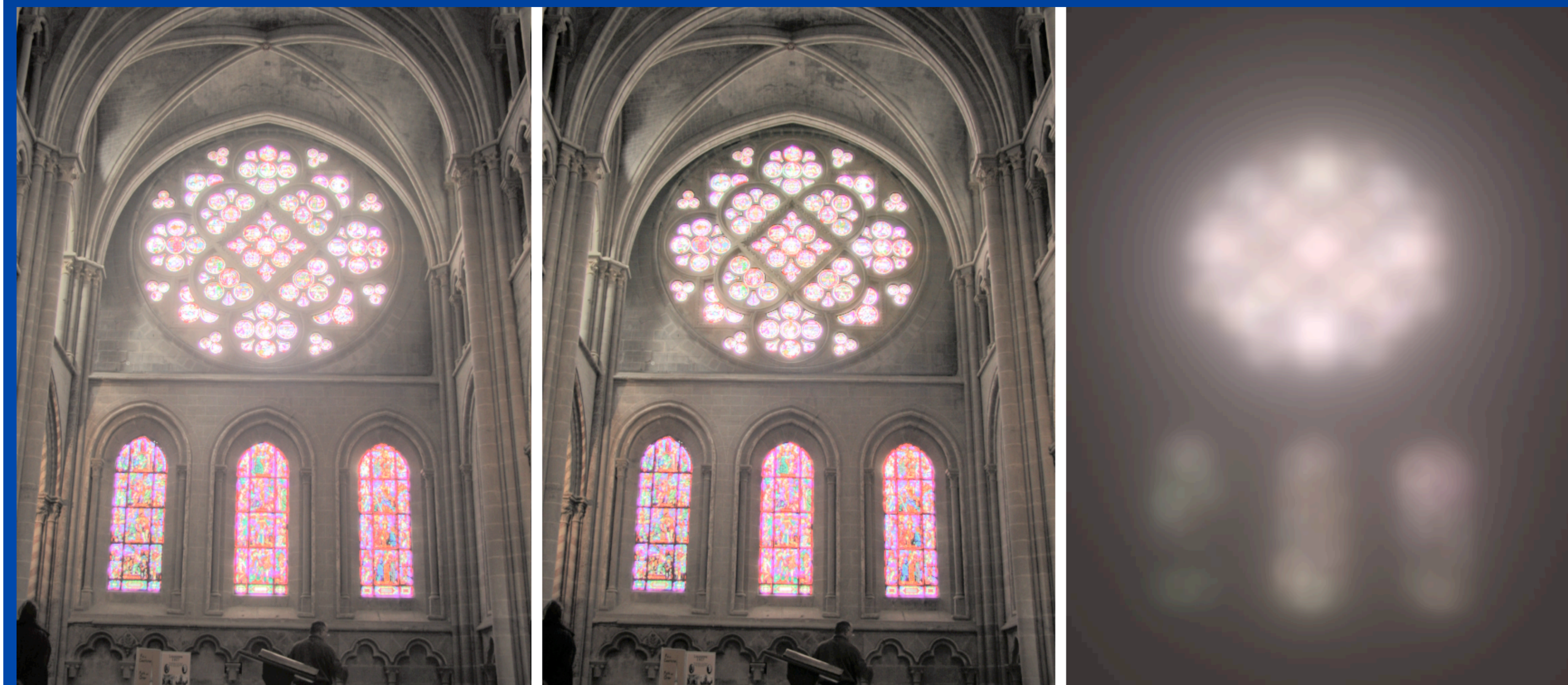
More Usual Input

Fitted vs. Measured PSF

PSF estimate (apt. capture fit vs. tin foil spot)



Apply: Simulate Flare & Subtract

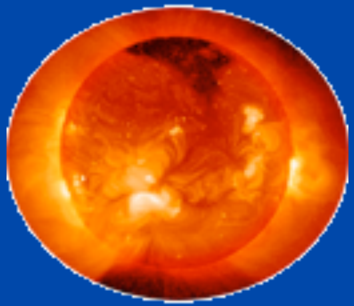


Before After Difference

Details explained in Reinhard et al., *High Dynamic Range Imaging*

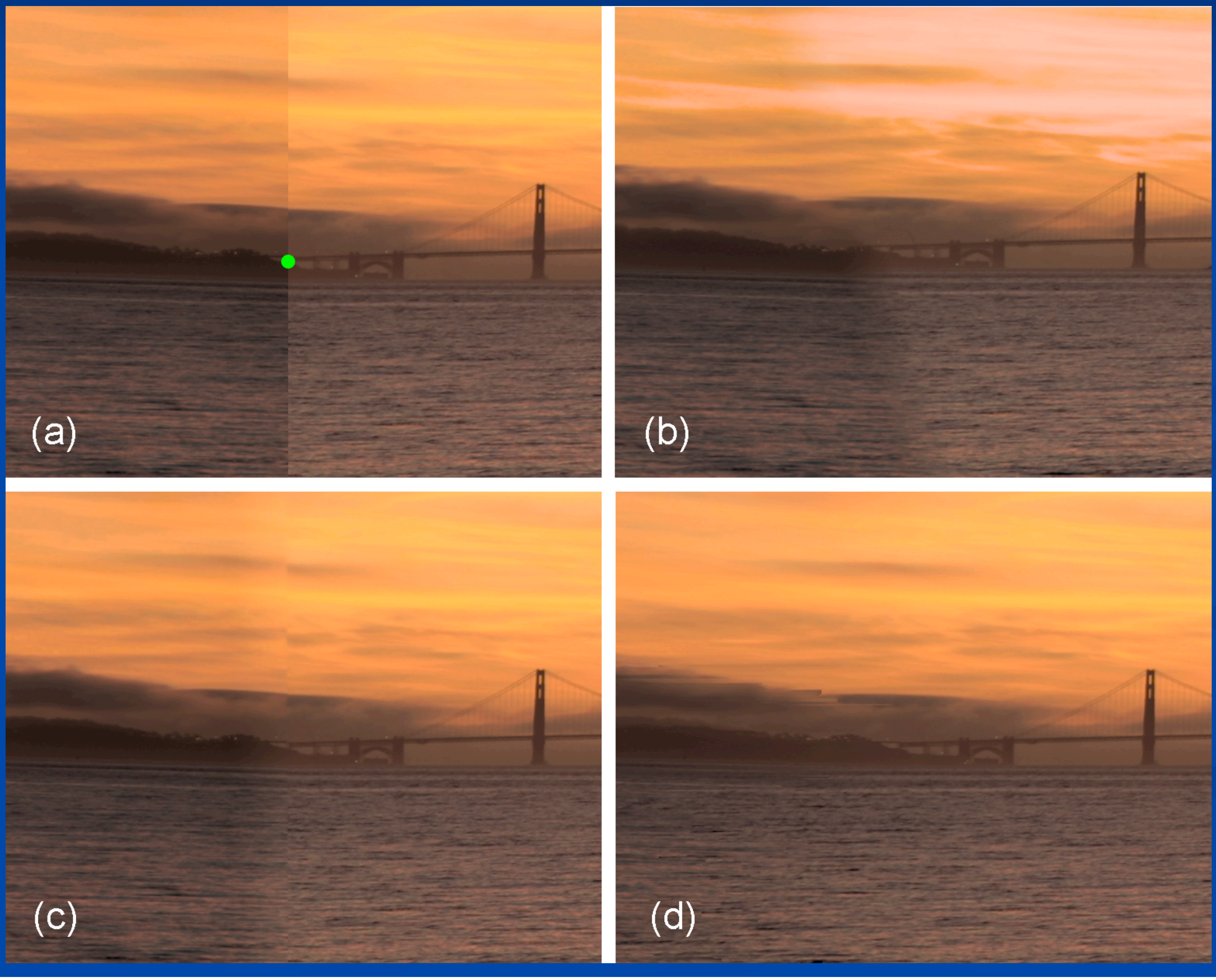
Photosphere Demo

- HDRI Browsing & Cataloging Application
  - Also builds HDRI's from bracketed exposures
- Available from www.anyhere.com
  - Mac OS X app., Linux command-line tool **hdrgen**



Launch Photosphere

HDR Stitching



Splice w/ feature

Photoshop ™

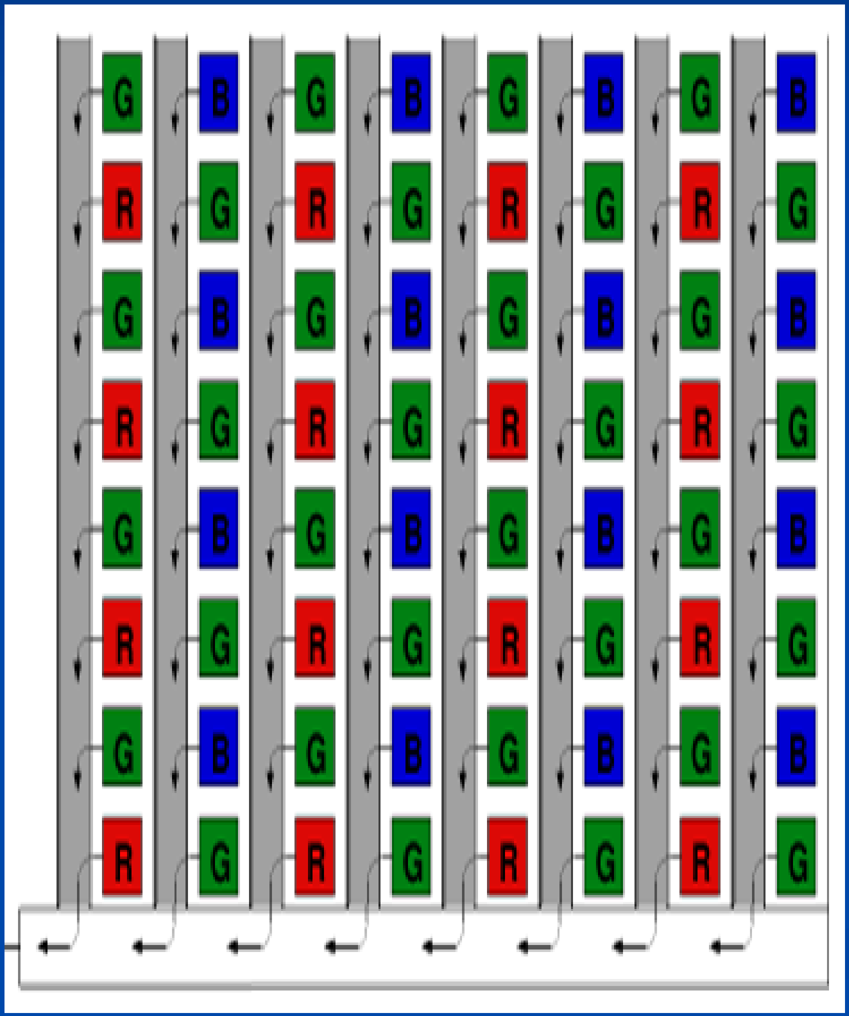
Burt-Adelson

Photosphere

HDR Cameras

- Leverage CMOS Sensor Technology
  - Fuji has sensor with dual-sensitivity pixel
  - SMaL Camera has log sensor
  - Pixim sensor has local pixel exposure
  - Other proprietary sensors in the works
- Unfortunately, most advanced CMOS sensors are VGA or SVGA resolution
- Reprogram CCD Camera Exposure
  - No hardware changes necessary

Interline CCD Scanout



Old Program:

Electronic shutter holds each exposure during scanout

Preview/movie uses electronic shutter, while still capture relies on mechanical shutter

New Program:

Instead, shift pixels under electronic shutter with 1/16th of mechanical exposure still remaining

After scanning out long exposure, shift and scan out short exposure

Result: two exposures separated by 4 f-stops

Two-Exposure HDR

- Compared Results to 5 exp. on 12 Scenes
  - Two exposures was usually sufficient
  - More noise but otherwise good
- Camera Implementation Reduces Artifacts
  - No alignment issues on short exposures
  - Longer exposure akin to "slow flash"
- Marginal Manufacturing Cost: $0.00

Sample Results

5 Exposures

2 Exposures

Licensable Technologies

- HDR image i/o library
- Image database manager
- Thumbnail cache manager
- Fast histogram-based tone-mapping
- HDR image builder
  - Exposure registration algorithm
  - Response function recovery
  - Automatic lens flare removal

File Size & HDR Adoption

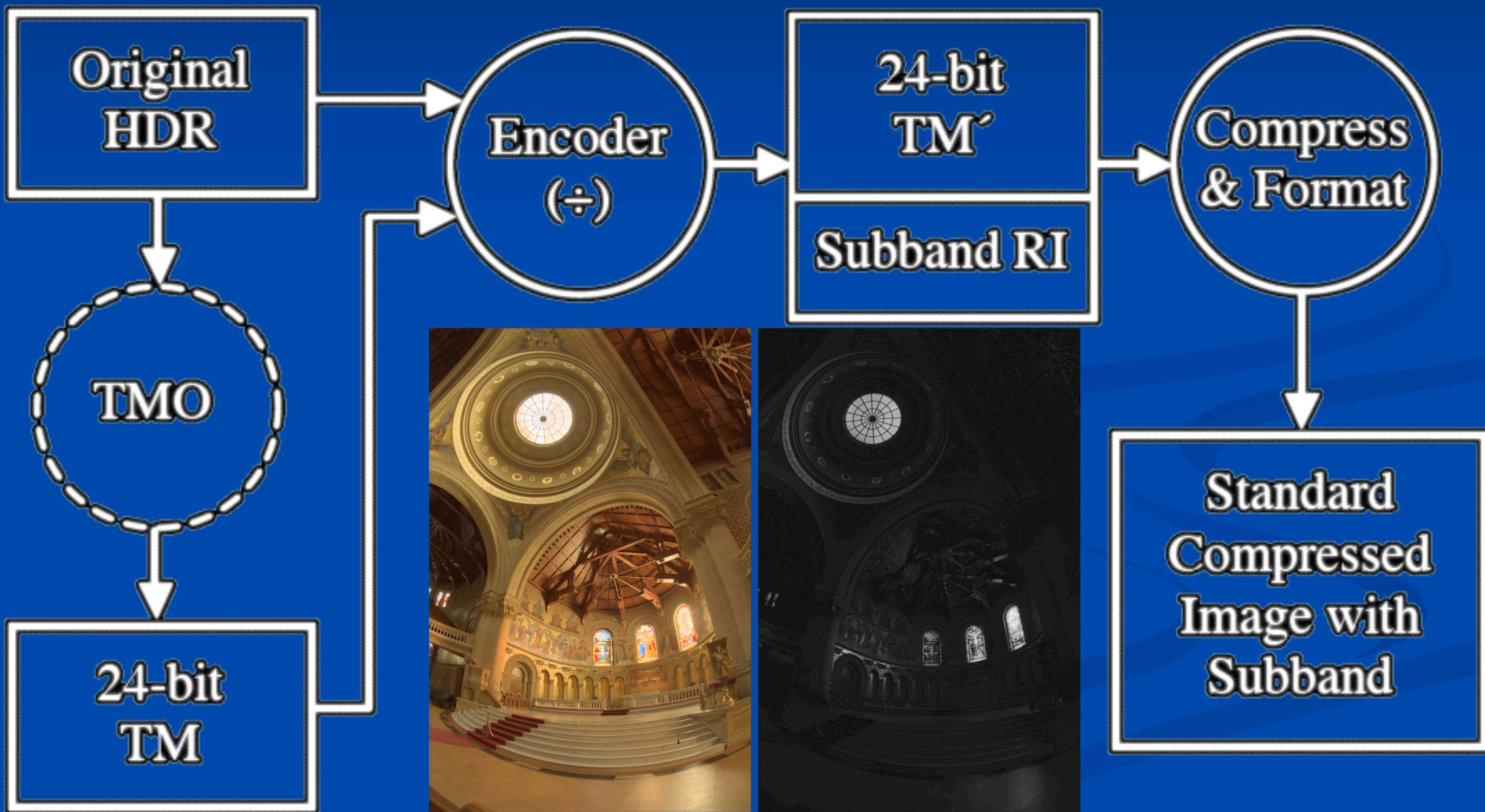
- Intelligent compression can lead to file sizes on par with JPEG images
- Rationale for “lossy” HDR:
  - Lossy encodings are all about perception
  - Why record what the eye cannot see?
  - Lossy HDR would support display to the limits of human vision
  - Required for consumer digital cameras
- What if HDR was backwards-compatible?

JPEG-HDR Encoding

1) Tone-map HDR input into 24-bit sRGB
2) Write as *output-referred* JPEG
3) Record restorative information as metadata (subband)

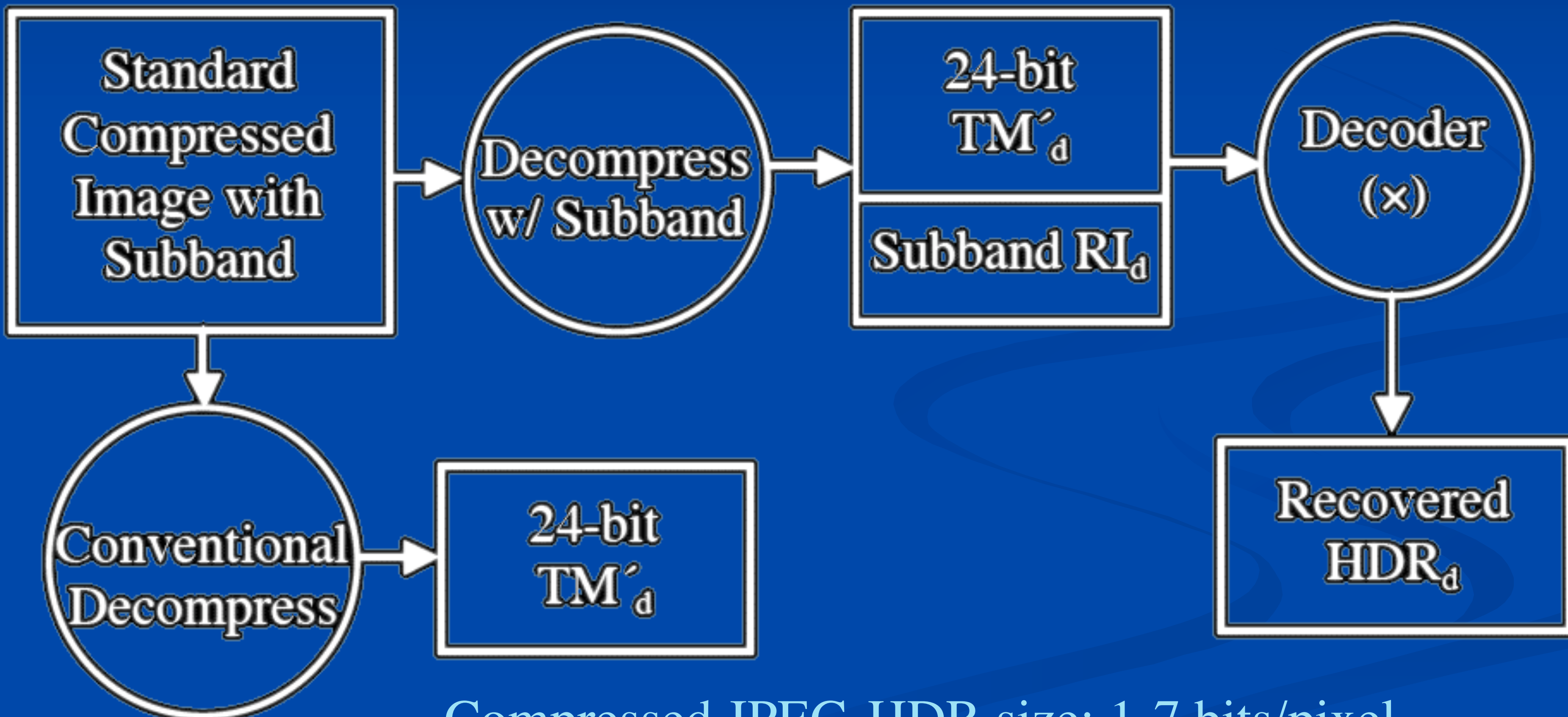
- Naïve applications see tone-mapped image
- HDR applications use subband to recover *scene-referred* original

JPEG-HDR Encoding Process



$$RI(x,y) = Y(HDR(x,y)) / Y(TM(x,y))$$

Decoding Process



Compressed JPEG-HDR size: 1-7 bits/pixel
(between 1/3 & 1/20 size of other HDR formats)

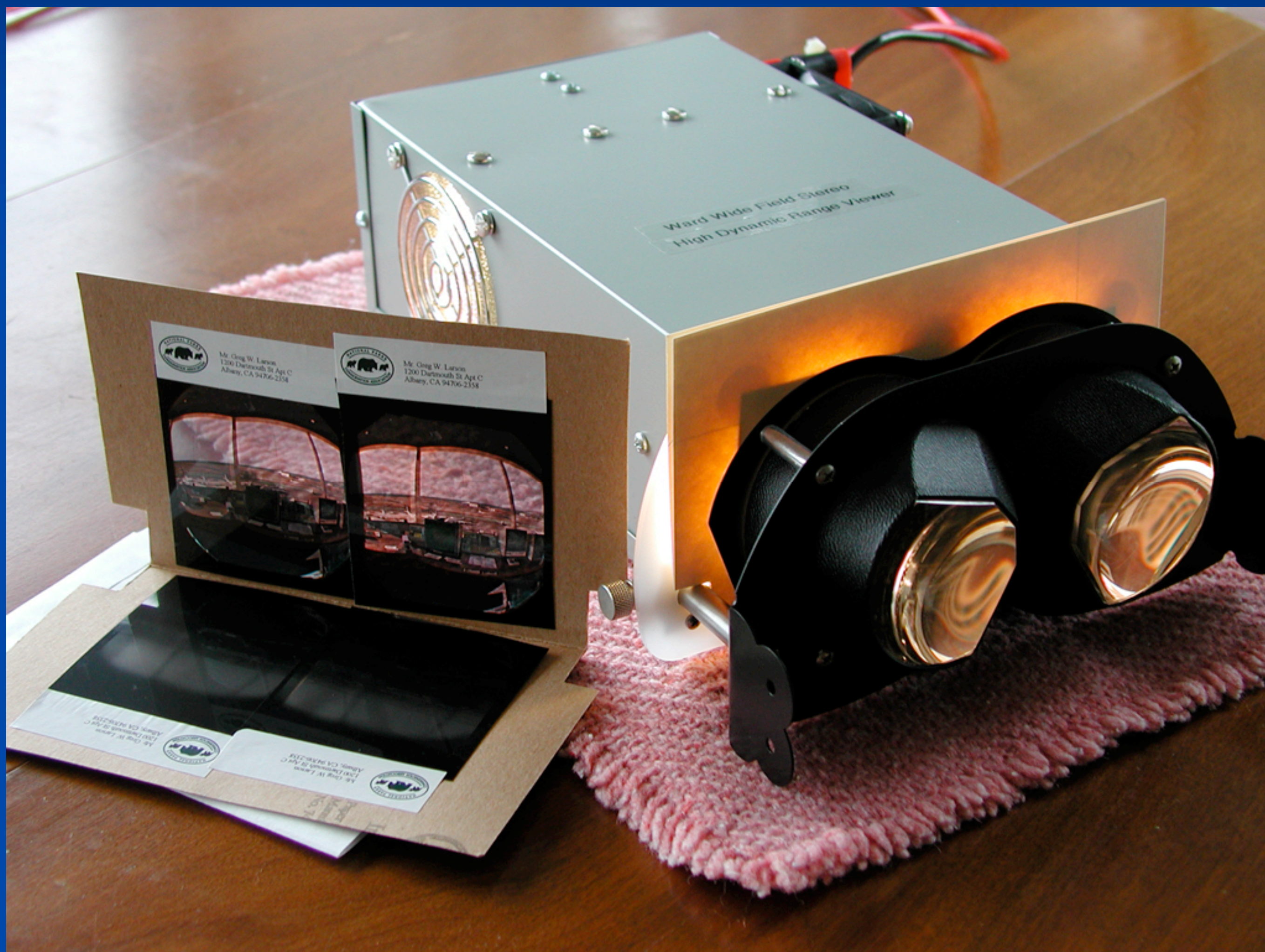
JPEG-HDR Software Availability

- Implemented as extension to Tom Lane's public JPEG library (www.ijg.org)
  - Available for non-commercial use with *High Dynamic Range Imaging* by Reinhard et al.
  - Contact BrightSide Technologies for licensing info. at www.brightsidetech.com/software
- JPEG-HDR included in Photosphere 1.3
  - Handy export function for batch conversion and webpage creation

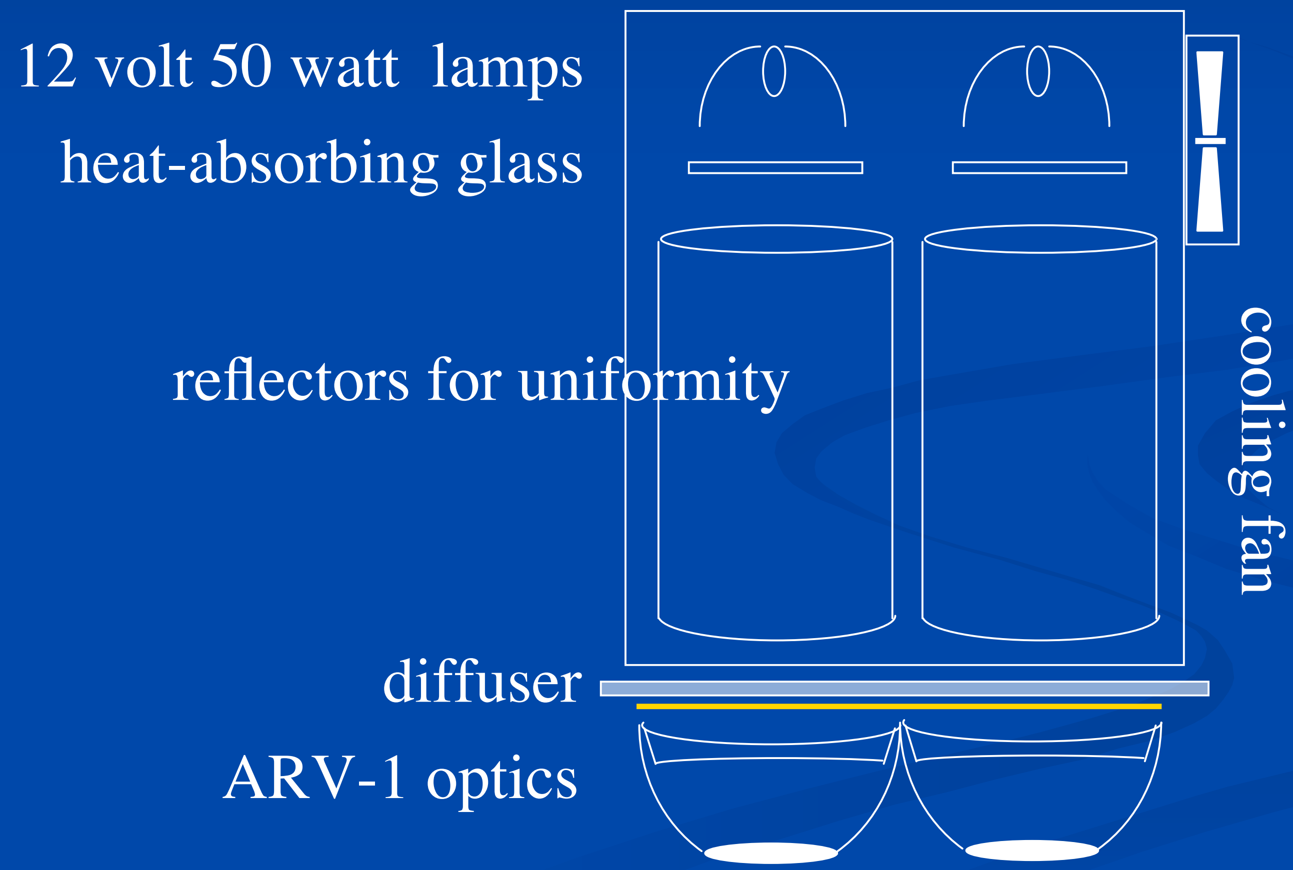
HDR Display Technologies

- Silicon Light Machines Grating Light Valve
  - Amazing dynamic range, widest gamut
  - Still in development
  - Promising for digital cinema
- BrightSide Technologies HDR Display
  - 37" diagonal LED-based production unit

HDR Transparency Viewer



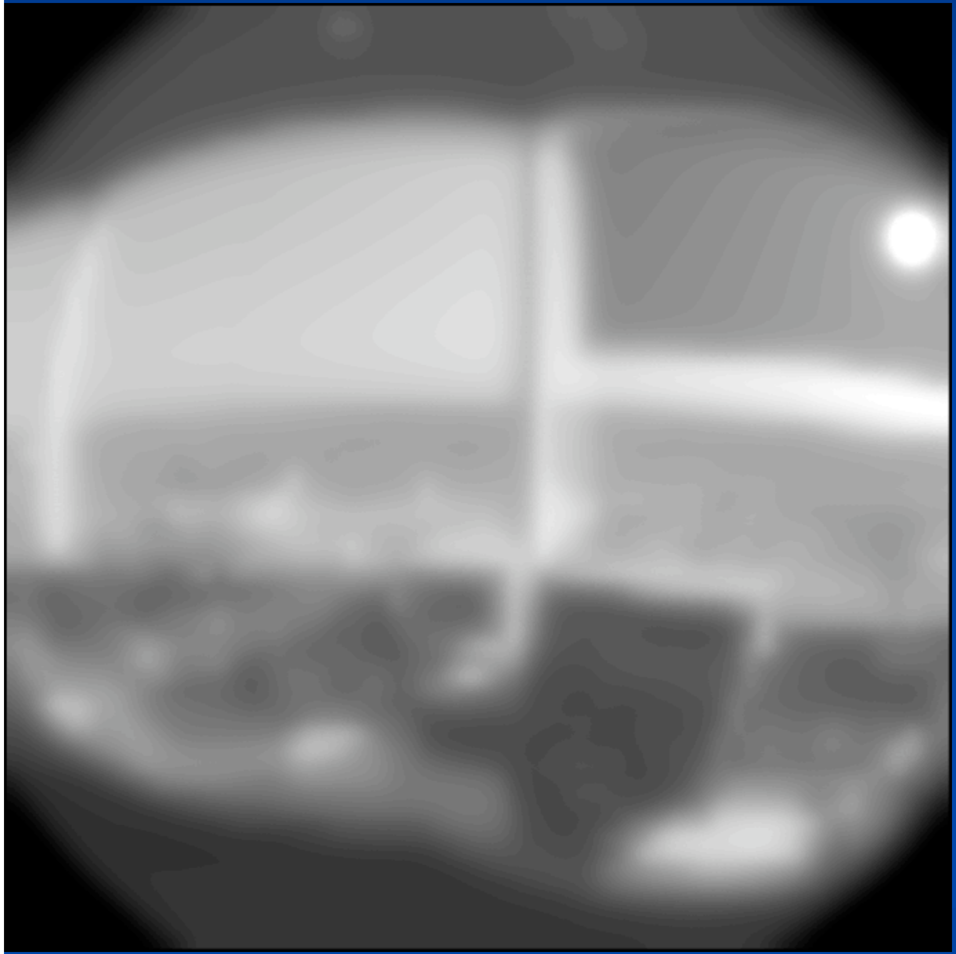
HDR Viewer Schematic



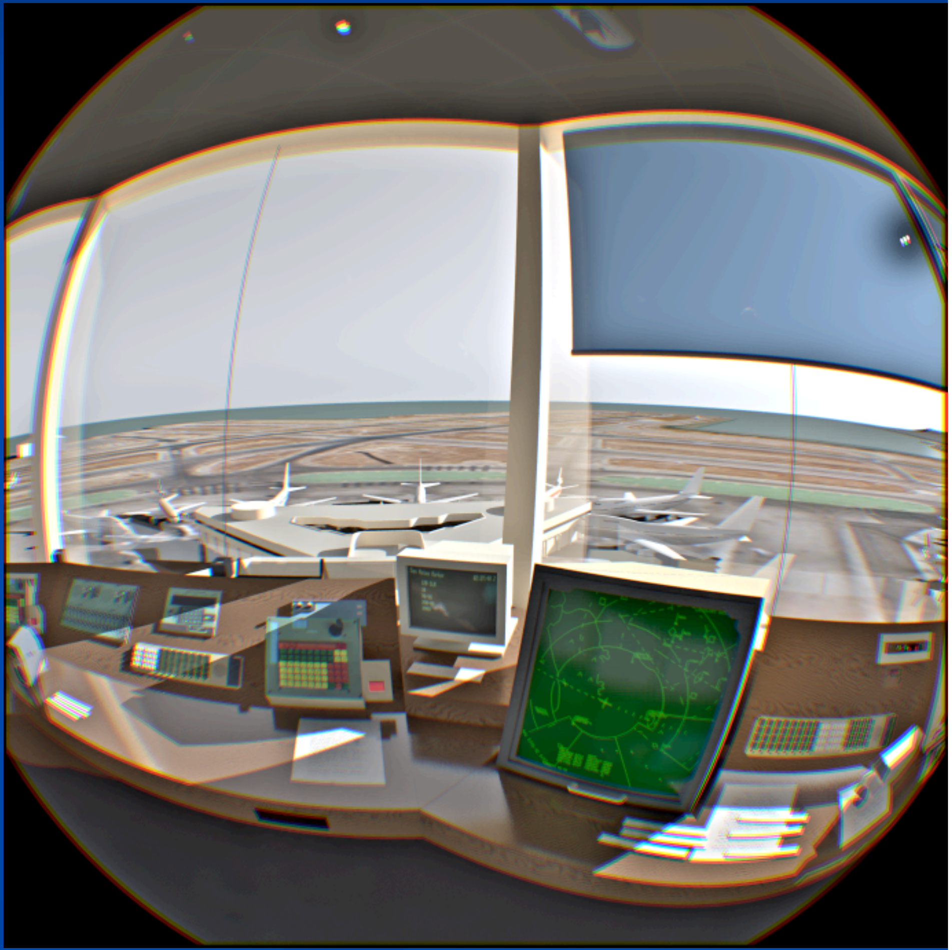
HDR Transparency Preparation

- Two transparency layers yield $1:10^4$ range
  - B&W "scaling" layer
  - Color "detail" layer
- Resolution difference avoids registration (alignment) problems
- 120^o hemispherical fisheye perspective
- Correction for chromatic aberration

Example Image Layers

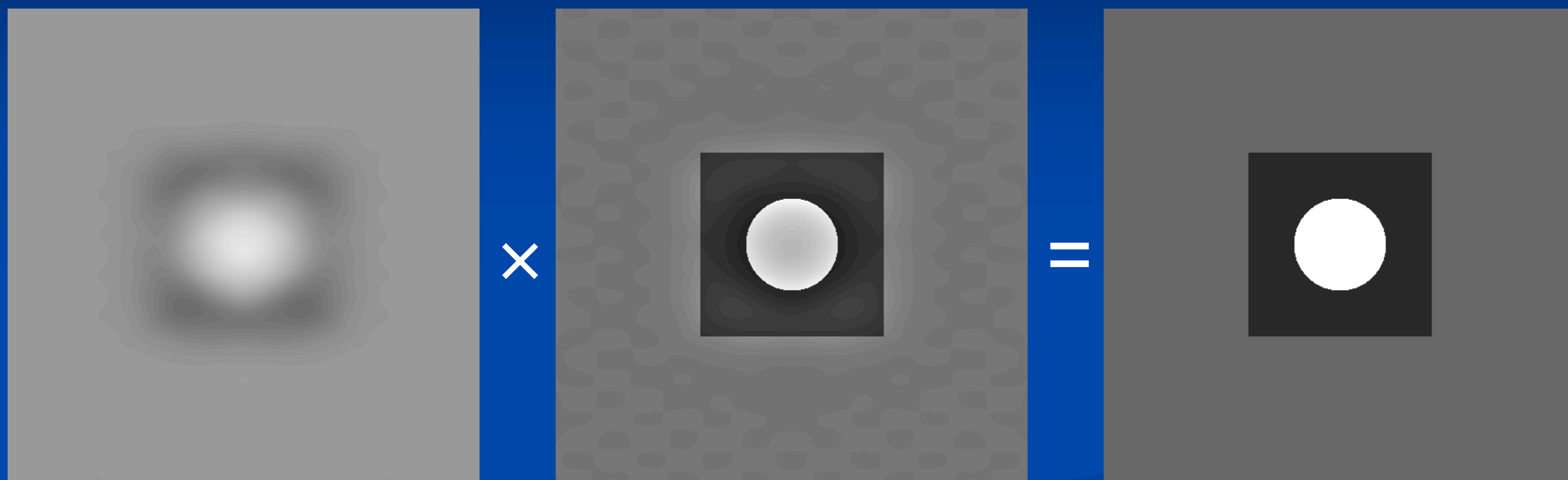


Scaling Layer

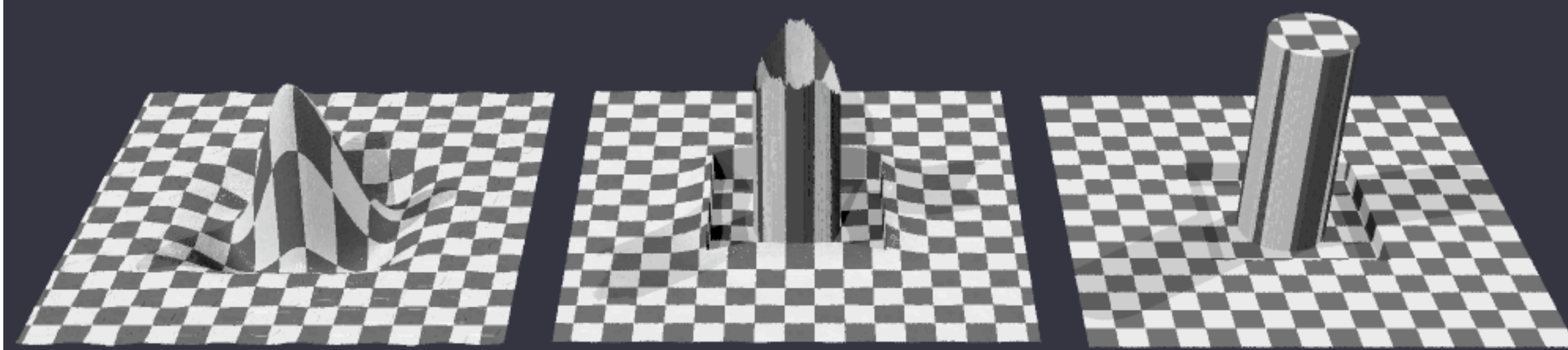


Detail Layer

How It Works

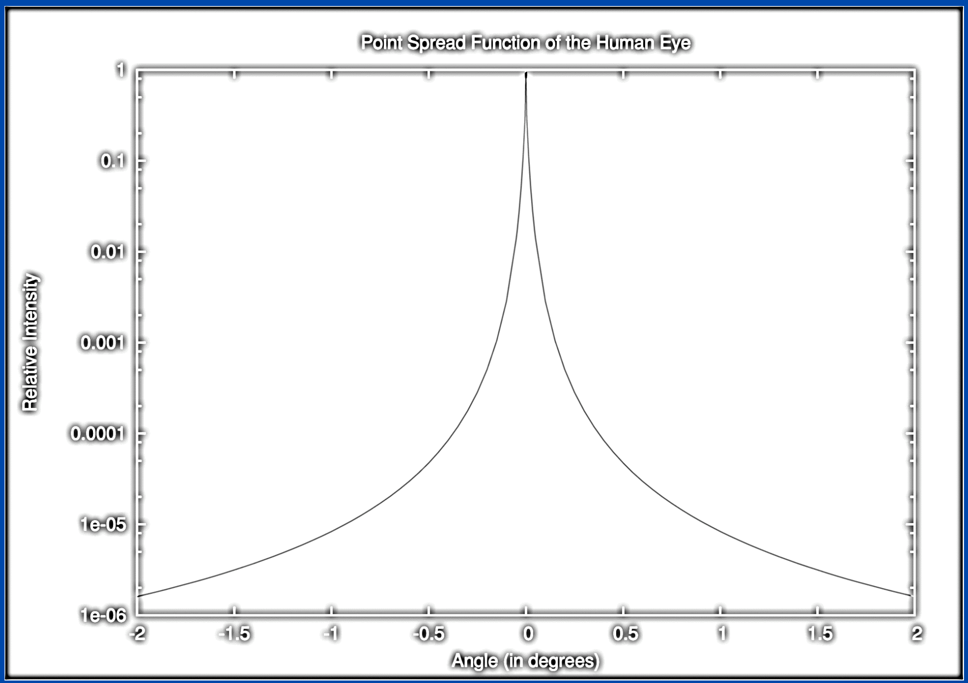


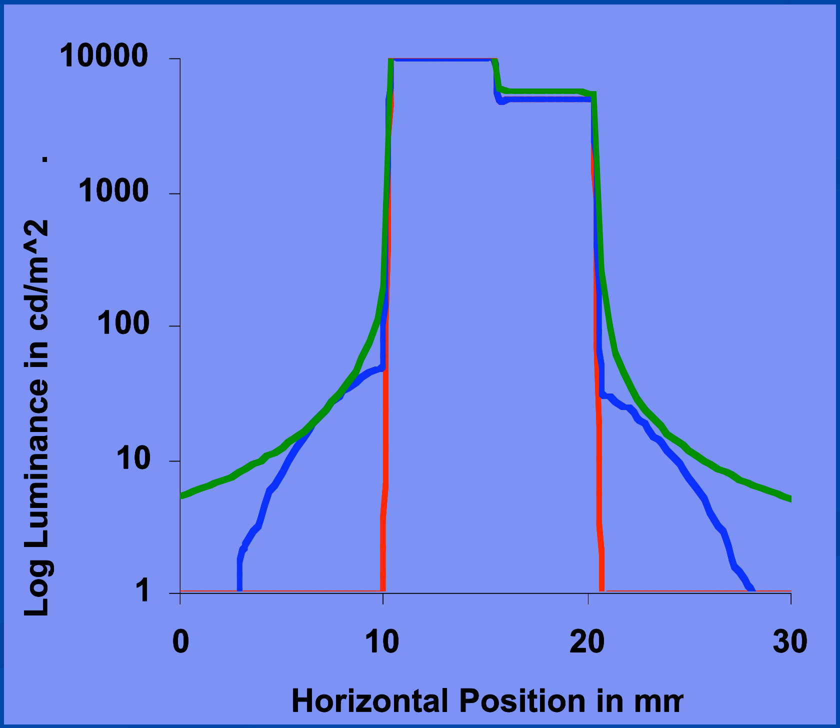
Scaling Layer × Detail Layer = Combined Result



What If Edge Contrast Exceeds Detail Range?

Observers cannot tell when this happens because the eye has limited local contrast capacity due to scattering





See Seetzen et al., SIGGRAPH 2004

BrightSide HDR Displays

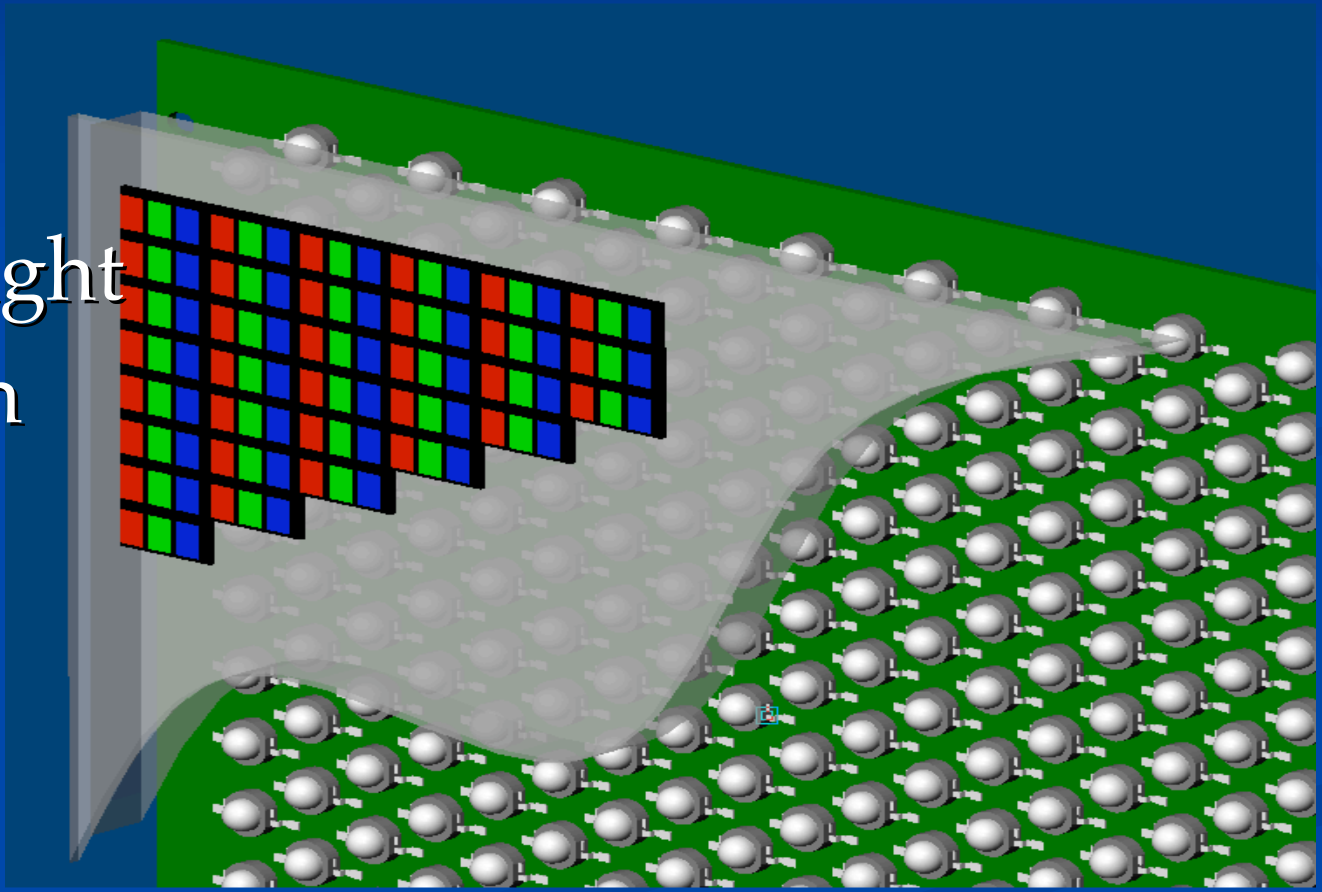
- Use Bright Source + Two 8-bit Modulators
  - Transmission multiplies together
  - Over 10,000:1 dynamic range

HDR Display Prototype

- DLP projector
- LCD screen

LED-Based Display

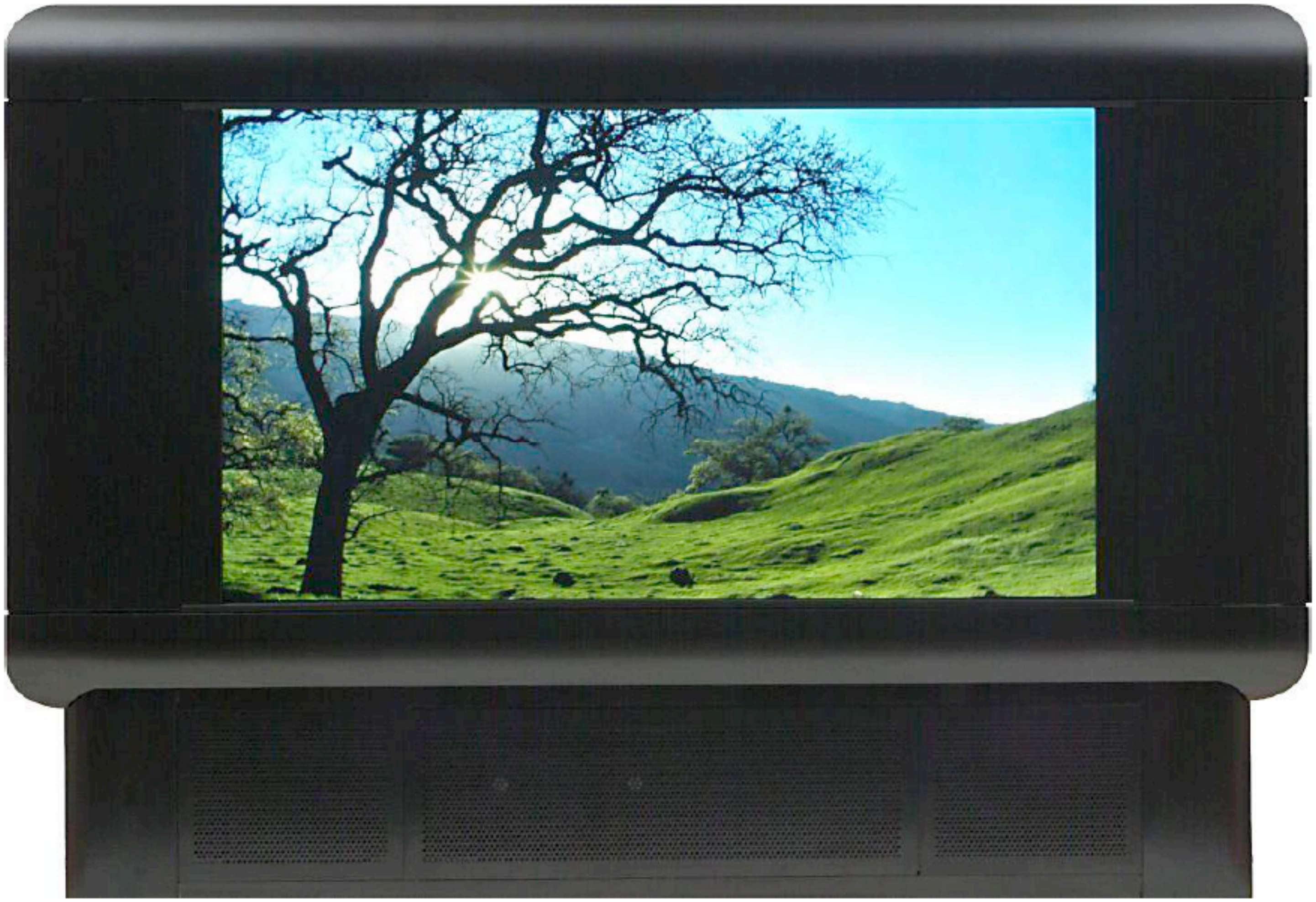
- LED backlight
- LCD screen



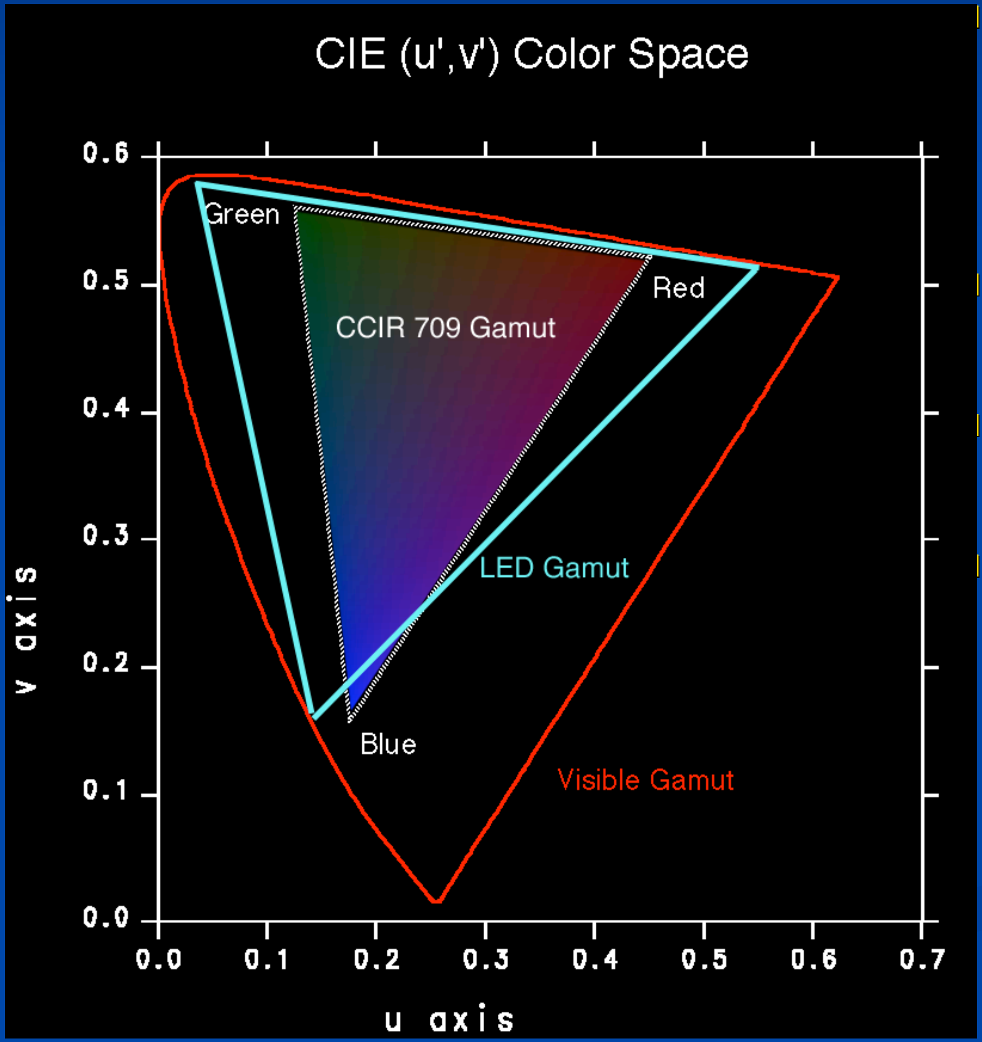
Color Gamut Comparison

- Standard LCD gamut determined by backlight and filters
- HDR display gamut determined by LEDs and filters -- same color, but greater range
- Volumes shown in perceptual color space

37" Diag. Production Unit



Extending HDR Color Gamut



- New RGB LEDs are spectrally pure
  - LCD filters select between them easily
- Result is very wide, laser-like gamut
- Better coverage would require > 3 primaries
- Possible option in upcoming display