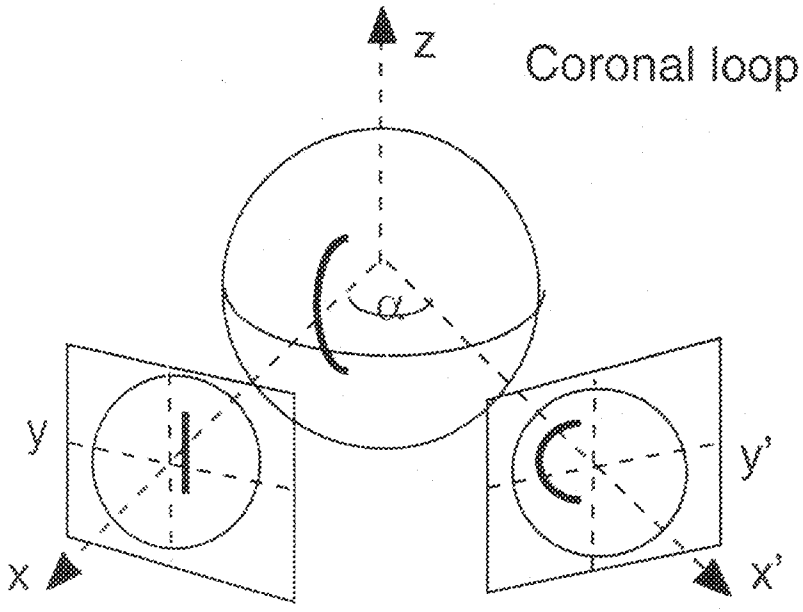
3D Visualization and Analysis Tools at JPL

Eric De Jong, Paulett Liewer, Jeff Hall,
Jean Lorre, Shigeru Suzuki

SECCHI Team Meeting
November 2000

Determination of 3D Geometry from Stereo Image Pairs using Triangulation



Coronal loop viewed from two angles separated by α

Coordinates of two views related by simple rotational transform

$$x = x'\cos\alpha + y'\sin\alpha$$

$$y = y'\cos\alpha - x'\sin\alpha$$

$$z = z'$$

Stereo Images give y,y' , Solve for x,x'

$$x = \frac{y' - y\cos\alpha}{\sin\alpha}$$

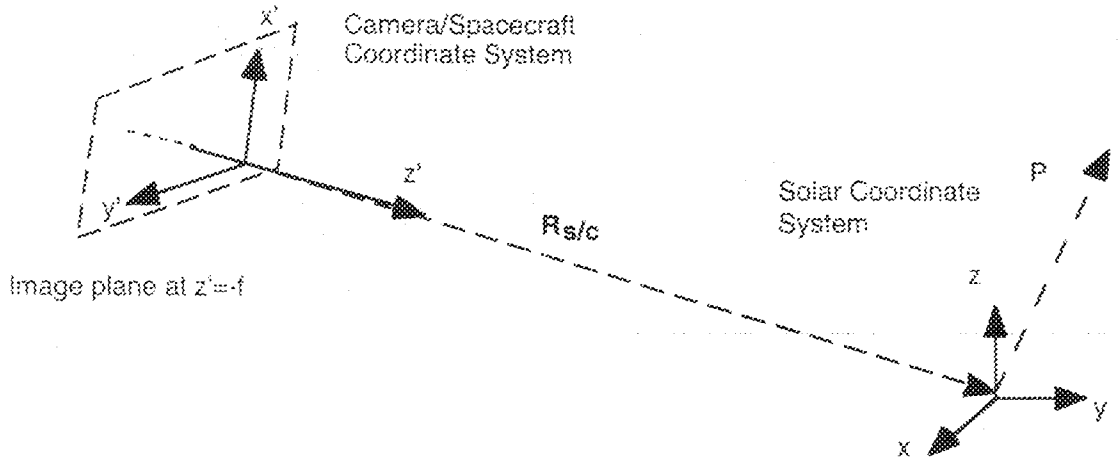
In principle, two view determine completely (x,y,x) solar coordinates of loop

For same "feature" in time sequence of images, determine (v_x, v_y, v_z)

Technique limited by ability to locate same "feature" in both images

XYZSUN - 3D Solar Coordinates from Image Tie - points

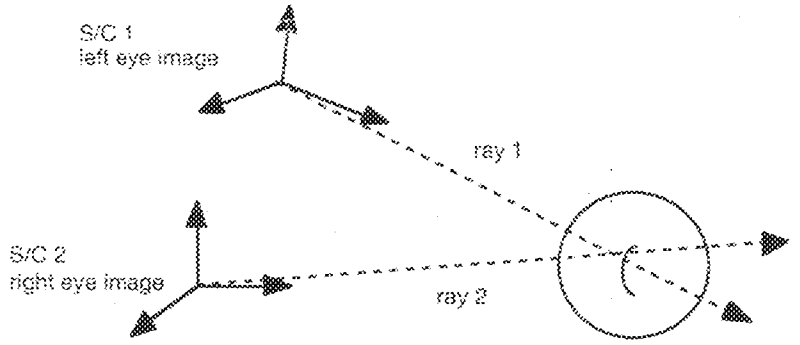
Computes transformation from solar coordinates to telescope coordinates & projection on image plane



$P' = M P + R_{s/c}$

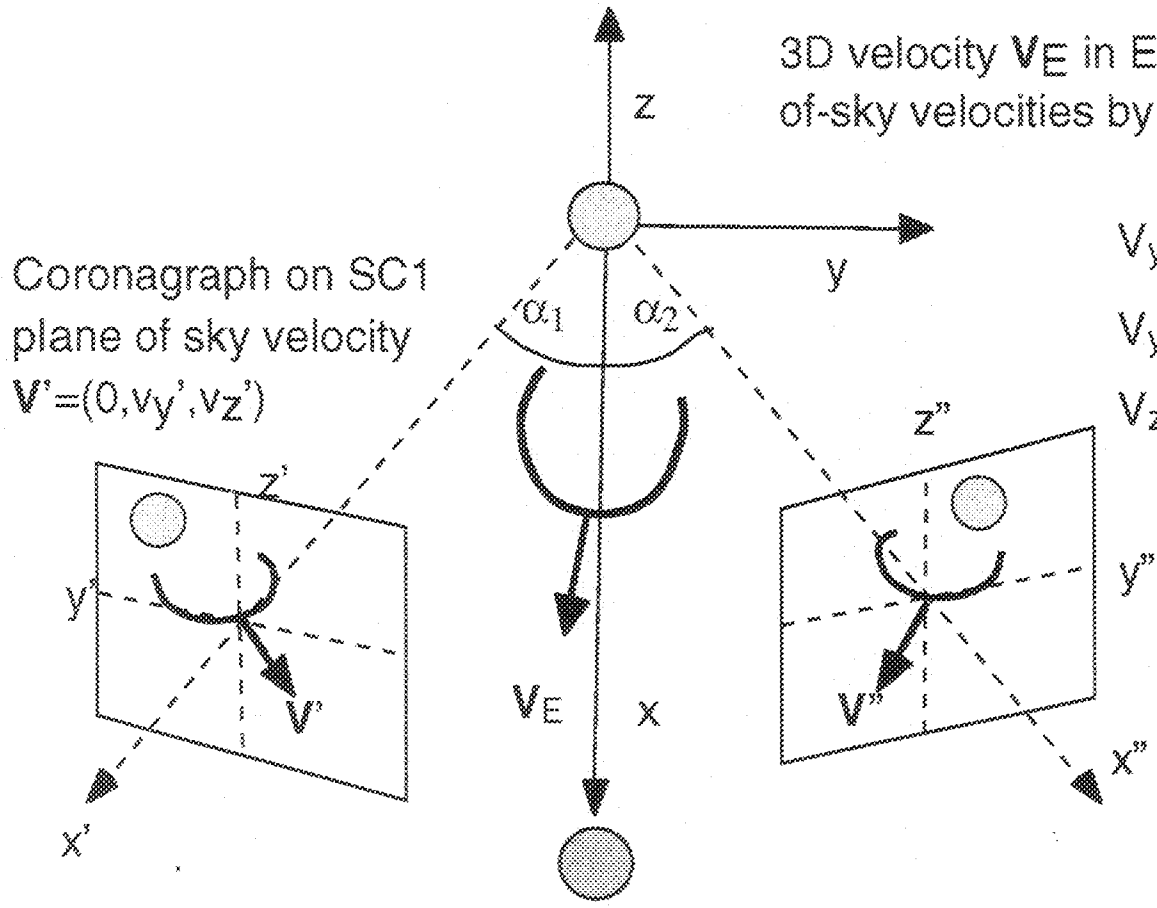
where M is transformation matrix
P' is point P in camera frame

"Location" is point of closest approach of rays computed from 2 images



Only perfect data would have two tiepoints map to exact same 3D location

STEREO/SECCHI allows determination of 3D direction and velocity of a CME from Two Plane-of-Sky Views



3D velocity $\mathbf{V}_E$ in Earth frame related to plane-of-sky velocities by simple rotational transform

$V_{y'} = -V_yE\sin\alpha_1 + V_yE\cos\alpha_1$

$V_{y''} = -V_yE\sin\alpha_2 + V_yE\cos\alpha_2$

$V_{z'} = V_{z''} = V_zE$

Coronagraph on SC1
plane of sky velocity
$\mathbf{V}'=(0,v_y',v_z')$

Coronagraph on SC 2
plane of sky velocity
$\mathbf{V}''=(0,v_y'',v_z'')$

Given $V_{y'}, V_{y''}$, Solve for $\mathbf{V}_E$

$V_yE = (V_{y'}\sin\alpha_2 - V_{y''}\sin\alpha_1)/(\cos\alpha_1\sin\alpha_2 - \cos\alpha_2\sin\alpha_1)$

$V_xE = (V_{y'}\cos\alpha_2 - V_{y''}\cos\alpha_1)/(\cos\alpha_1\sin\alpha_2 - \cos\alpha_2\sin\alpha_1)$

Thus STEREO/SECCHI can identify Earth-directed CMEs

Analysis Tools for Triangulation of Solar Features

- **2D Manual Feature tie-pointing using commercial software**

  Use ENVI / IDL commercial software to identify & mark the same feature in two 2D images of a stereo pair.

- **3D Manual Feature tie-pointing using Stereo Image Viewer**

  View stereo pair in 3D on SGI using synched shuttered liquid crystal goggles
  Locate the feature with cursor in 3D/stereo image & write out tie-points.

- **TRACKER - Automate Feature tie-pointing**

  Identify criteria for a set of features. Automatic location of features meeting criteria, write out tie-points.

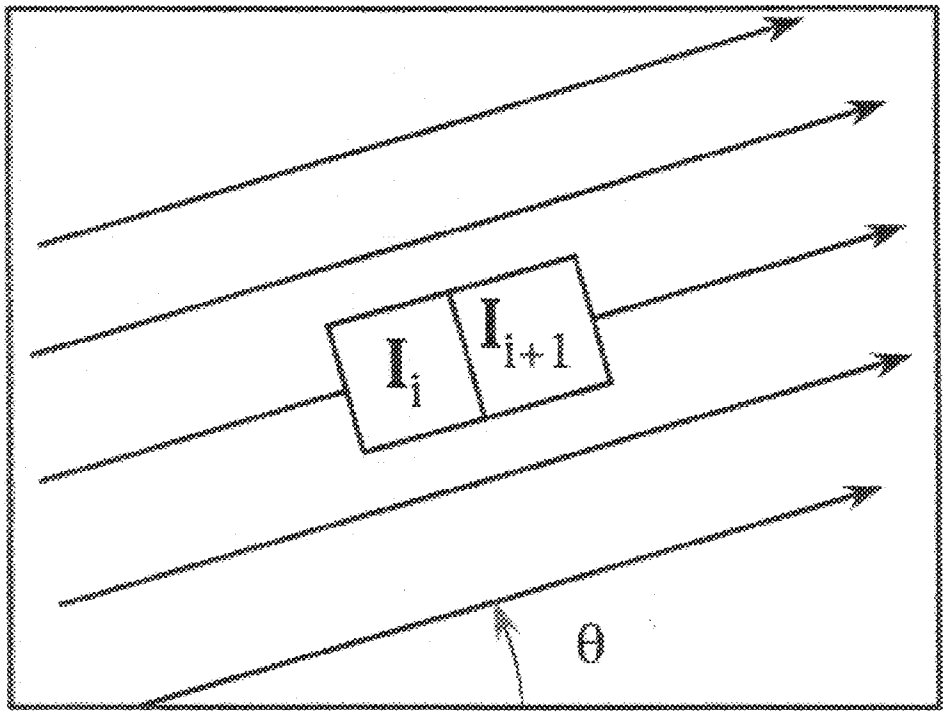
- **XYZSUN - Program to compute 3D solar coordinates of features**

  Input: Feature tie-points from any tie-pointing tool.
  Output: 3D coordinates (solar radius, latitude and longitude) of features.

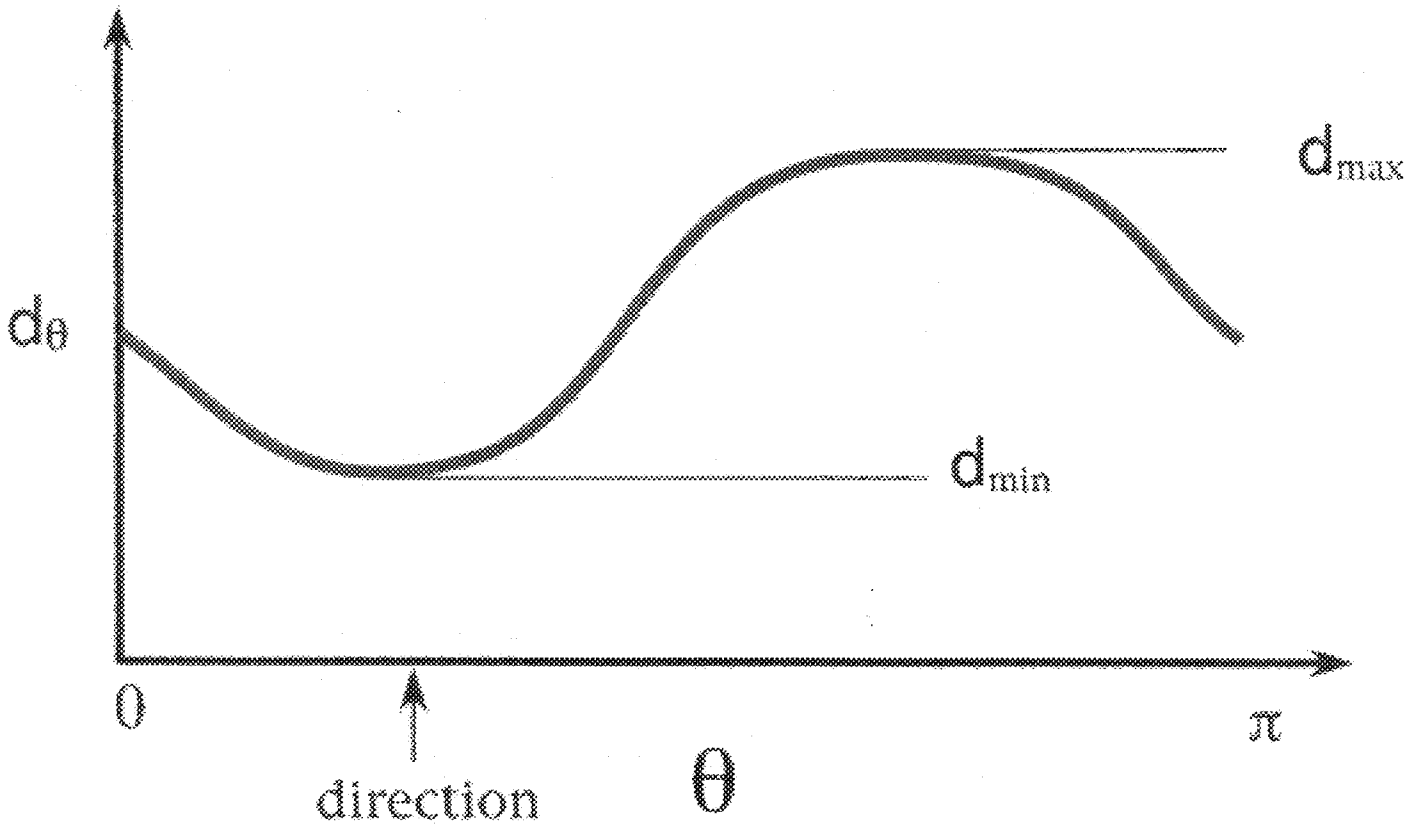
Example 1: Automatic tie-pointing of TRACE image loops

Original Image

Moving window centered @ (x,y)



$$d_\theta = \sum_{\text{window}} | I_{i+1} - I_i |$$

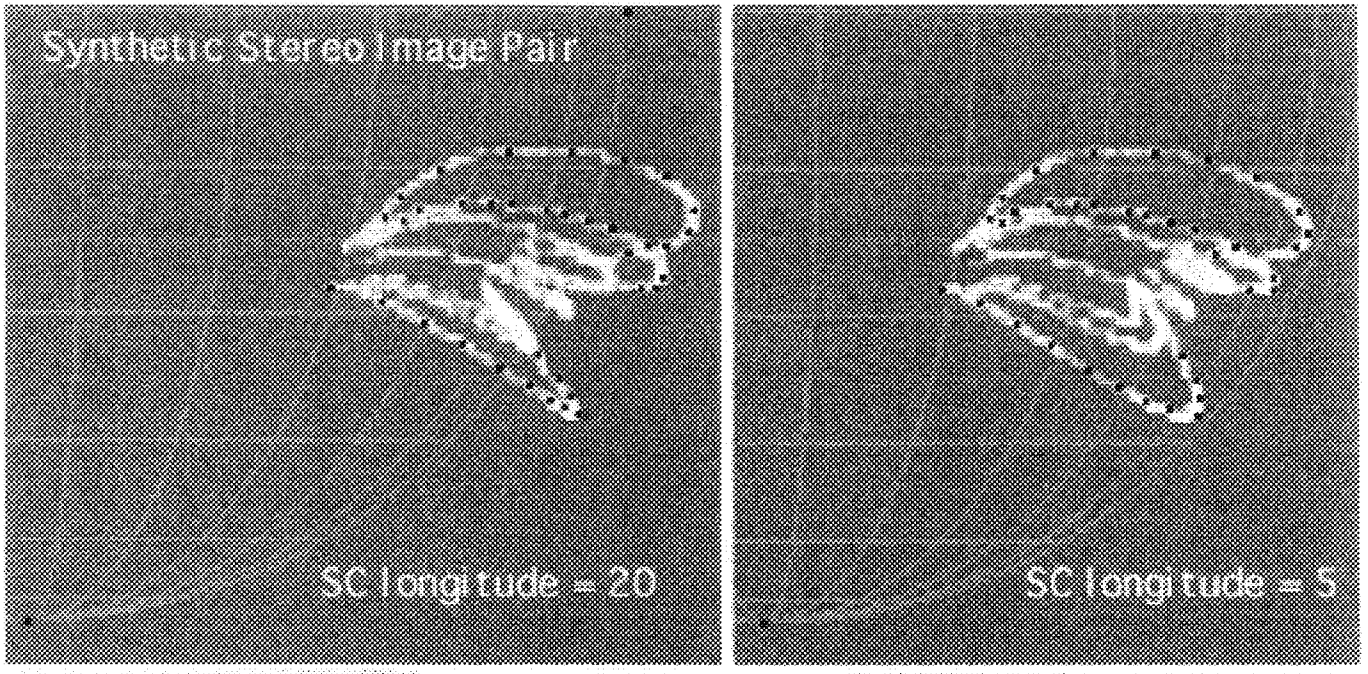


Creating a "Directionality" Image

$$D(x,y) = \text{Directionality} = d_{max} - d_{min}$$

1. Move the center of the window to position (x,y) and calculate the value of D (x,y).
2. Create an image of D (x,y) by encoding the value of D(x,y) as the intensity of the "Directionality" Image at position (x,y).
3. Repeat the process for all values of (x,y) in the Original Image.
4. Correct for any "edge" effects.

Example 2: Reconstruction of synthetic EUV loops



3D Model -- original and reconstructed loops

x

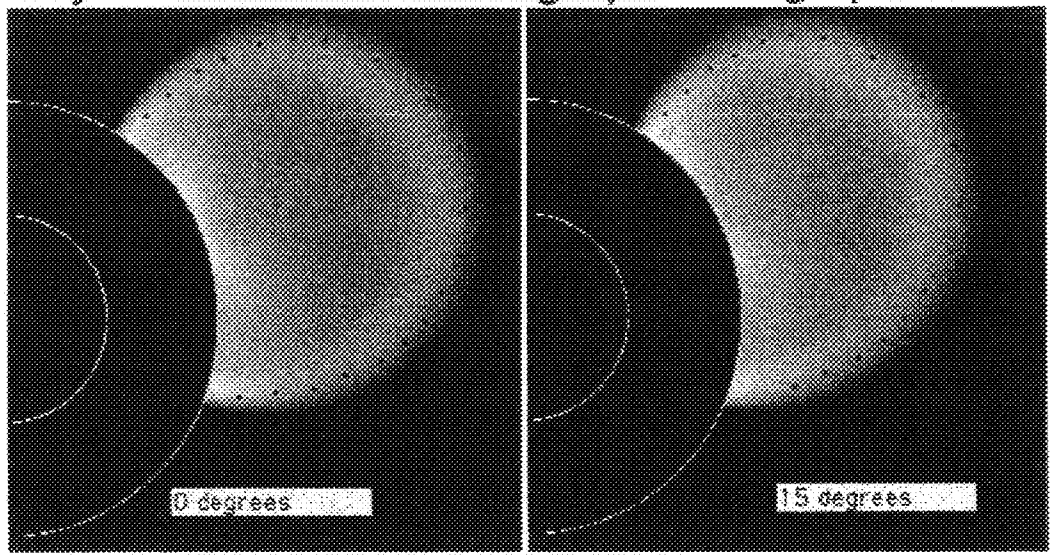
y

Model viewed from 20 degrees

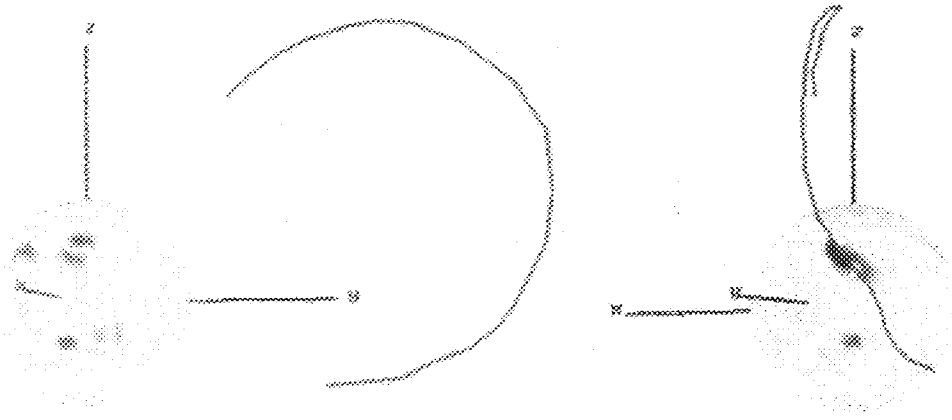
Model viewed from -90 degrees

Example 3: Reconstruction of CME by Triangulation

Synthetic stereo coronagraphic image pair



CME loop reconstructed from above pair



viewed from 15°

viewed from 117°

Technologies for Stereo Visualization and Analysis

- SGI & Goggles for qualitative visualization and for quantitative analysis

  Use SGI monitors with stereo / 3D viewing using interlaced left & right eye images

  View using liquid crystal goggles shuttered electronically in sync with monitor - 60 Hz

  Used in 3D Cursor Triangulation Tool

- Stereo High Definition TV (HDTV) animations of sequences of stereo images can be displayed using an HDTV stereo monitor or projector.

- Several SECCHI team sites will have these capabilities.

High Definition Television for Stereo Data Analysis

High Definition Television (HDTV) provides highest resolution for stereo data analysis

Device	Resolution (eyes-x-y)	Images per sec	Comments
Standard TV	1x640x480	30 interlaced	data storage (video tape) is analog and lossy; not suitable for archiving
Standard TV stereo interlaced	2x640x240	60	interlaced left & right eye (odd/even lines) stereo using 60 Hz synchronized shuttered goggles;
Computer monitor (non-interlaced)	1x1024x768	60	data storage is digital
Standard Computer monitor stereo interlaced	2x1024x384	60	interlaced left & right eye (odd/even lines) stereo using 60 Hz electronically shuttered goggles; data storage is digital
US HDTV Computer Monitor (non-interlaced)	1x1920x1080	60	data storage digital; suitable for archiving. (Also digital tape decks using 1/2" digital tape)
US HDTV stereo interlaced	2x1920x540	60	interlaced left & right eye; stereo using 60 Hz electronically shuttered goggles;
US HDTV stereo non-interlaced	**2x1920x1080**	120	polarized glasses & screen filter(120Hz synchronized); digital data storage; suitable for archiving.