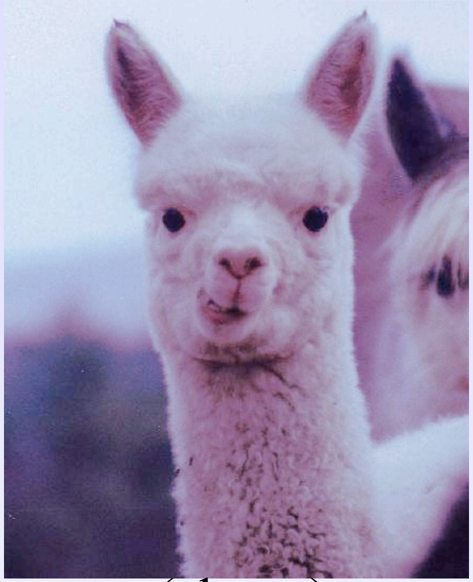
# **A**dvanced
# **L**iquid-mirror
# **P**robe for
# **A**strophysics,
# **C**osmology and
# **A**steroids



(alpaca)

is currently a collaboration between

Columbia University

University of British Columbia

University of Oklahoma

Pont. Universidad Catolica (Santiago)

Cerro Tololo Inter-american Observatory

(Stony Brook University)

(American Museum of Natural History)

## ALPACA is a telescope and survey project consisting of

- 8-meter diameter, mercury primary mirror
- Baker-Paul 3-mirror design with ~3° field
- Zenith-pointing, drift-scan telescope+CCD
- ~ 1 Gigapixel mosaic, 5 simultaneous bands
- ~ 1000 square degree field, at Dec = –30°.16
- Nightly sampling all bands, reaching r ~ 25
- "Real-time" and archival image processing
- Reaching r ~ 28 in 3y survey (~ HDF depth)

# Remarkable aspects of ALPACA include:

- Diverse, superlative science return
- Contains Galactic Center, South Galactic Pole area
- Optimizing SNe Ia probe of dark energy dynamics
- Extremely large $A\Omega$ ("etendue" or "grasp")
- Superlatively deep imaging, multiple bands
- Good time sampling (time resolution $\Delta t$ = 30s, 1d)
- Simple, time-efficient operation
- Simple design (few moving parts)
- Largely established, off-the-shelf technology
- Liquid-mirror technology now in advanced stages
- *Very* cost-effective

# ALPACA Survey Products (P. 1)

- Well-sampled, 5-band SN light curves (to r ~ 25 each night, r ~ 28 each year) to discover and identify ~50000 SNe Ia and ~30000 SN Iab/II per year. SNe Ia mostly over $0.2 < z < 0.8$ range, which is ideal for detailing the evolution and dynamics of dark energy
- Weak Lensing: 700 square degrees with multiband data good for photometric z's
- Galaxy photometric redshift sample to r ~ 28; roughly 1 billion galaxies
- For galaxy clusters, should achieve same richness as SDSS cluster catalog (to z = 0.3) but to z = 1. Sample of ~30000 clusters
- Includes strong QSO lensing e.g., J12514-2914. Monitor 10-20 examples.
- Map of Sculptor supercluster (z = 0.11). Novae, bright variables.
- Should find several orphan GRB afterglows per year.

# ALPACA Survey Products (cont.)

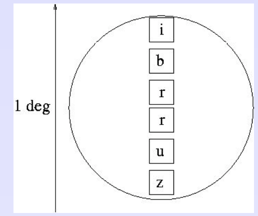
- Monitor 100,000s of AGNe to r ~ 26 for multiband variability.
- Large scale structure over 4 $Gpc^3$ (comoving) to z = 1 and 9 $Gpc^3$ to z = 1.5.
- Includes M83 (7 Mpc away, starburst); two Seyferts: NGC 2997 (17 Mpc), NGC 1097 (17 Mpc). Follow cepheids, miras, novae, eclipsing variables.
- Passes through Galactic Nucleus; will find >5000 Bulge microlensing events per year; superlative extrasolar planet search resource.
- Many 1000s of variable stars: Galactic structure.
- Huge variety of stellar surveys.
- Discover ~50 Kuiper Belt objects per night.
- Trace near-Earth asteroids of 1 km diameter to Jupiter's orbit, reconstruct orbits well within 1 AU and detect 50 m objects at 1 AU.

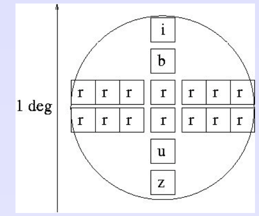
# ALPACA: Comments on Major Components

- ALPACA has no “mount” – the telescope is zenith-looking and is supported without a moving mount. Needs no filter wheel or shutter.
- Rotating 8-m mercury mirror can be constructed for under $1M, usually a $10M item.
- The telescope building is largely a simple tube or silo and need not move with the telescope. It requires a roll-off or clamshell roof and louvers to control airflow for seeing control.

# Proto-ALPACA imaging focal plane

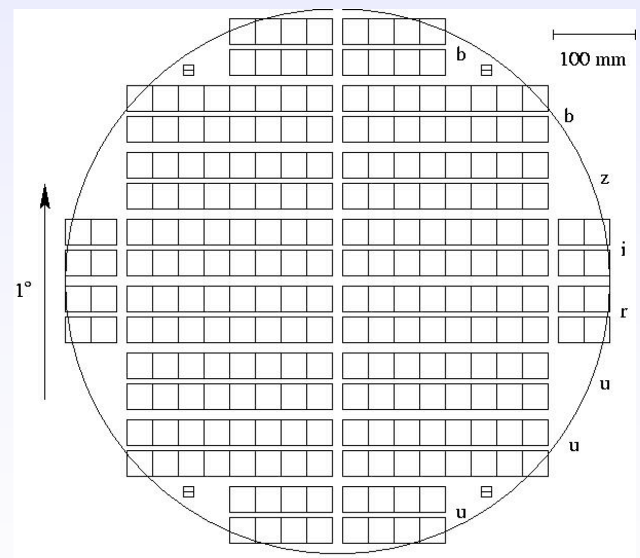
- 0.86 deg diameter field
- 6 CCDs, 6.7 arcmin square, 2048x2048 E2V
- 1 CCD for u,b,i,z; 2 CCDs for r
- NASA NEOs: add two rows (18 CCDs total) for near-Earth asteroids (plus weak lensing, bulge microlensing, LSS, variable stars,  etc.




# full ALPACA imaging focal plane

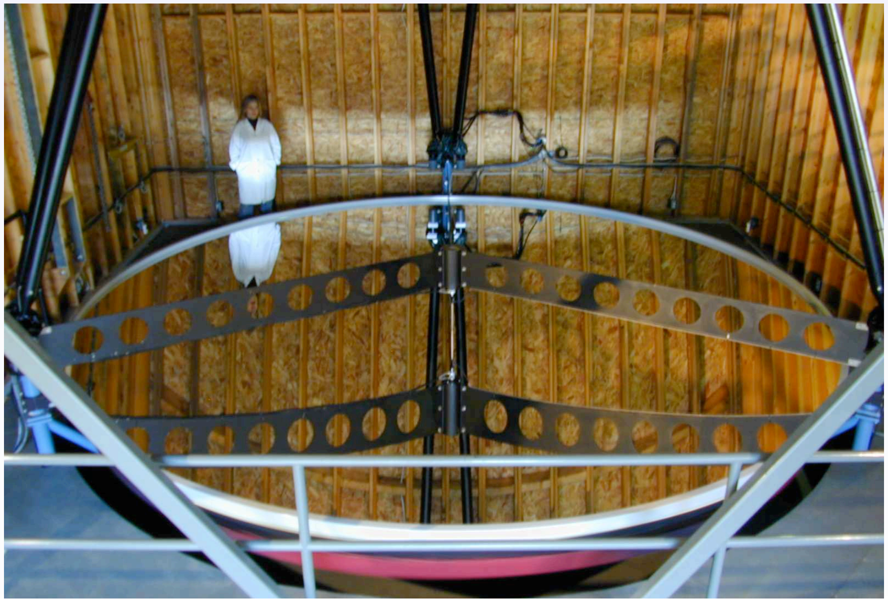
- 3 deg diameter field
- 240 CCDs, 8 arcmin square, 2048x2048 Fairchild
- deep strip, 8 columns with 6 rows of u, 4 b, and 2 each r, i, z
- wide strip, 8 more columns with 4 u, and 2 each b, r, i, z
- NEO “ears”: at least 4 more columns of 2 each of r, i




240 Science CCDs, 4 Focus/Alignment CCDs
1.007 Gpix/32.2s = 2.25 TByte/10h

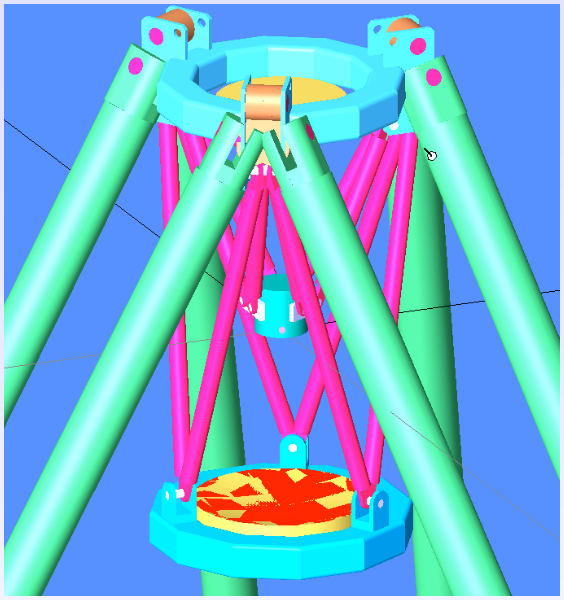
# Comments regarding progress

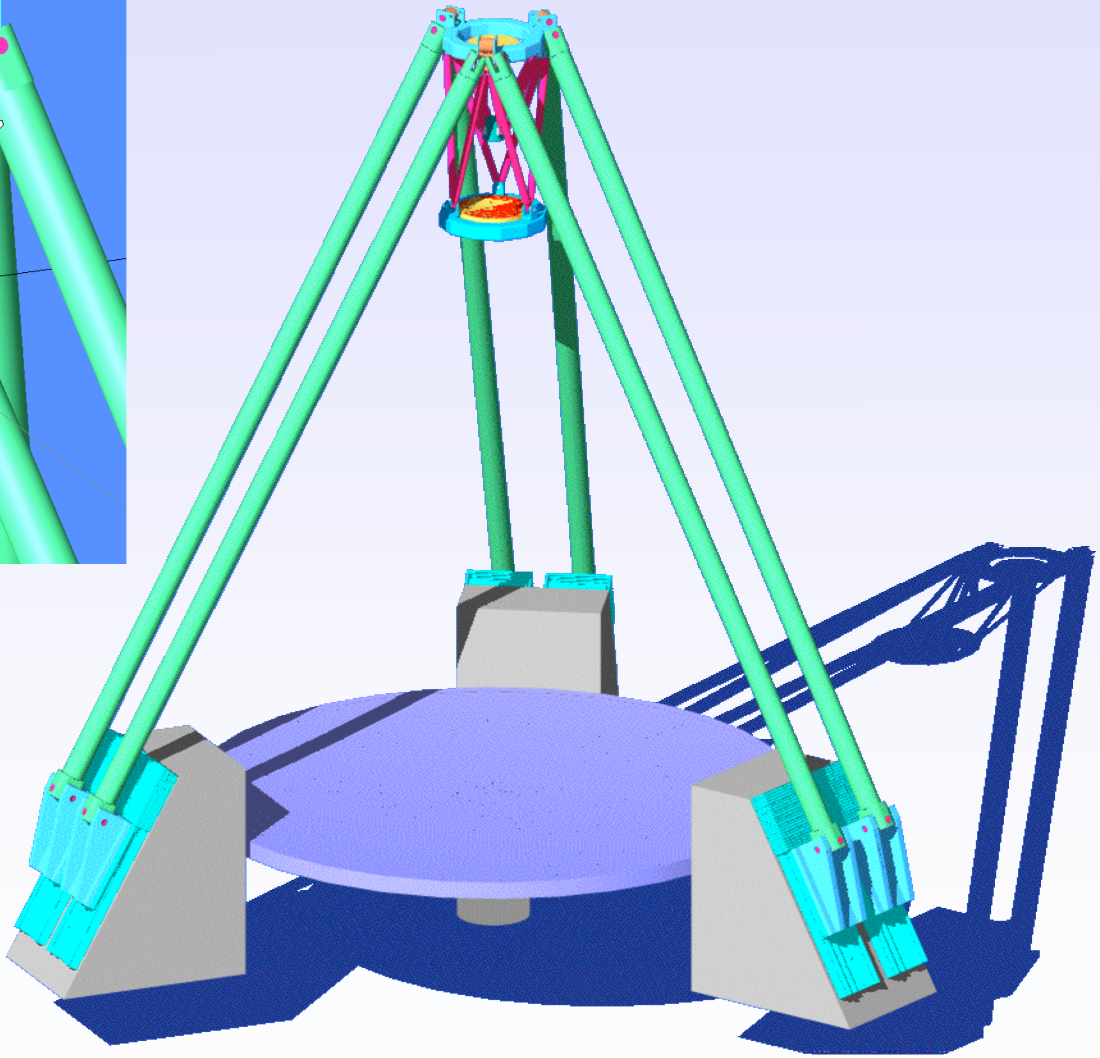
- Seeing tests at CTIO using several monitors, since 2007
- completed Conceptual Design Review (CoDR), approved (for ~$150,000)
- Phase I (Proto-ALPACA) estimated at $8M in 2009 dollars
- liquid mirror saves about $7M over glass mirror e.g., ULE from Corning
- Phase II estimated (roughly) at additional $25M for upgrade to wide field optics, focal plane array, data system, software, operations over 5 years. We need detail these by Preliminary Design Review (PDR) phase.
- Need $300k for PDR
- multiobject spectroscopy needs to be defined for PDR. ($5M-10M spectro. budget?)



Large Zenith Telescope (6-meter)

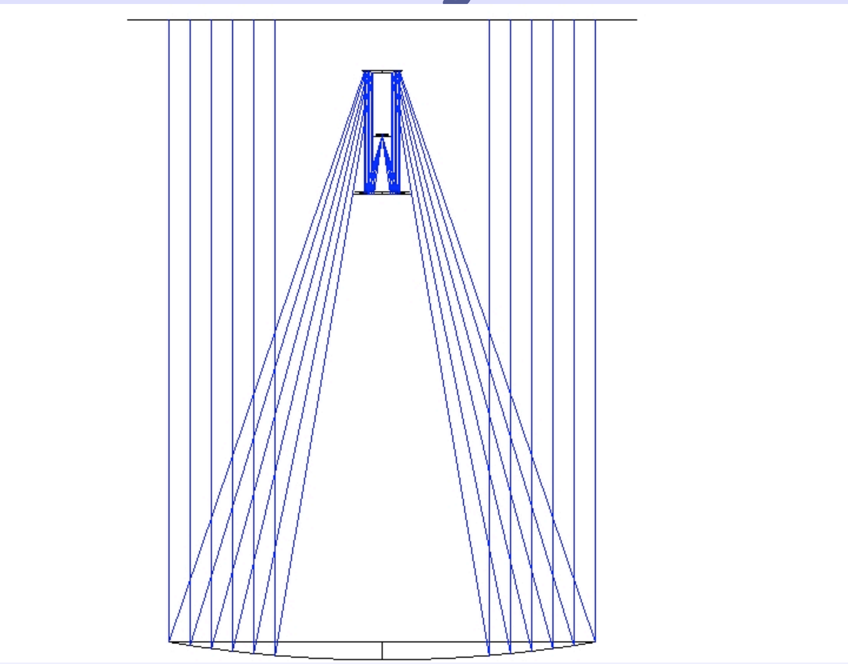
# Proto-ALPACA Telescope Design





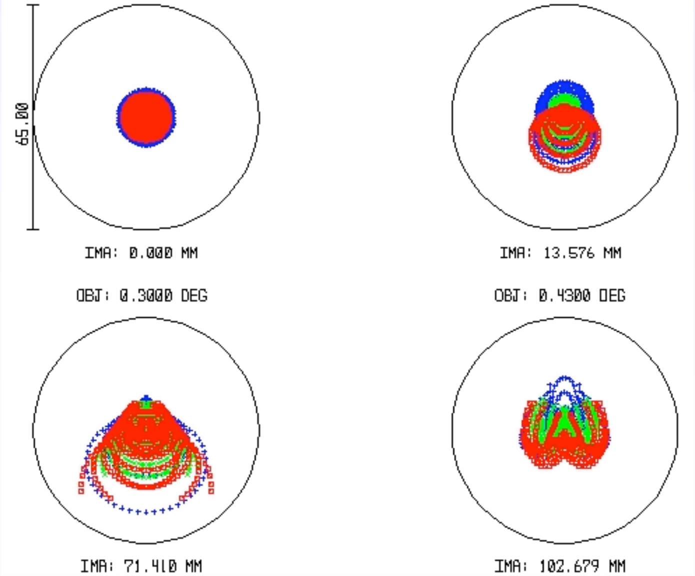
# Proto-ALPACA Modified Baker-Paul Design

- 8 Meter parabolic Primary Mirror
  - Limited (≲10m) by air bearing capacity
- 800 mm Aspheric Secondary
- 1 meter Spherical Tertiary
- Final f/1.7
- FL=13,600mm
- Primary - f/1.5
- Field of view - 0.86°
- Plate Scale - 66 µm/arcsec



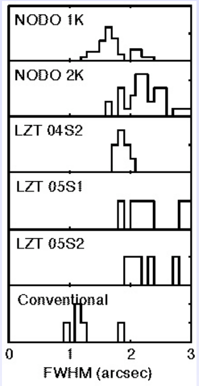
## Image Quality

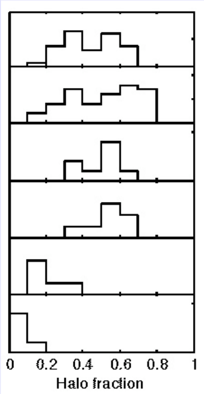
| Wavelength Band | 80% encircled Energy (center) µm | 80% encircled Energy (edge) µm |
|---|---|---|
| **u 3150Å-4100Å** | 9.6 | 11.5 |
| **b 4150Å-5500Å** | 11.0 | 12.0 |
| **r 5600Å-7500Å** | 6.8 | 9.5 |
| **i 7600Å-10,200Å** | 6.0 | 8.75 |
| **z 8800Å-10,200Å** | 4.75 | 8.25 |

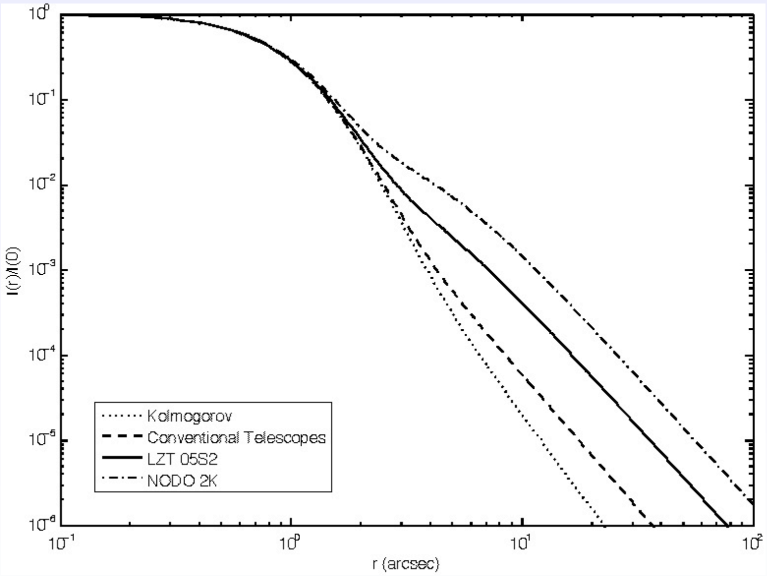


# LZT Image Quality: Reducing Scattering, Bad Site

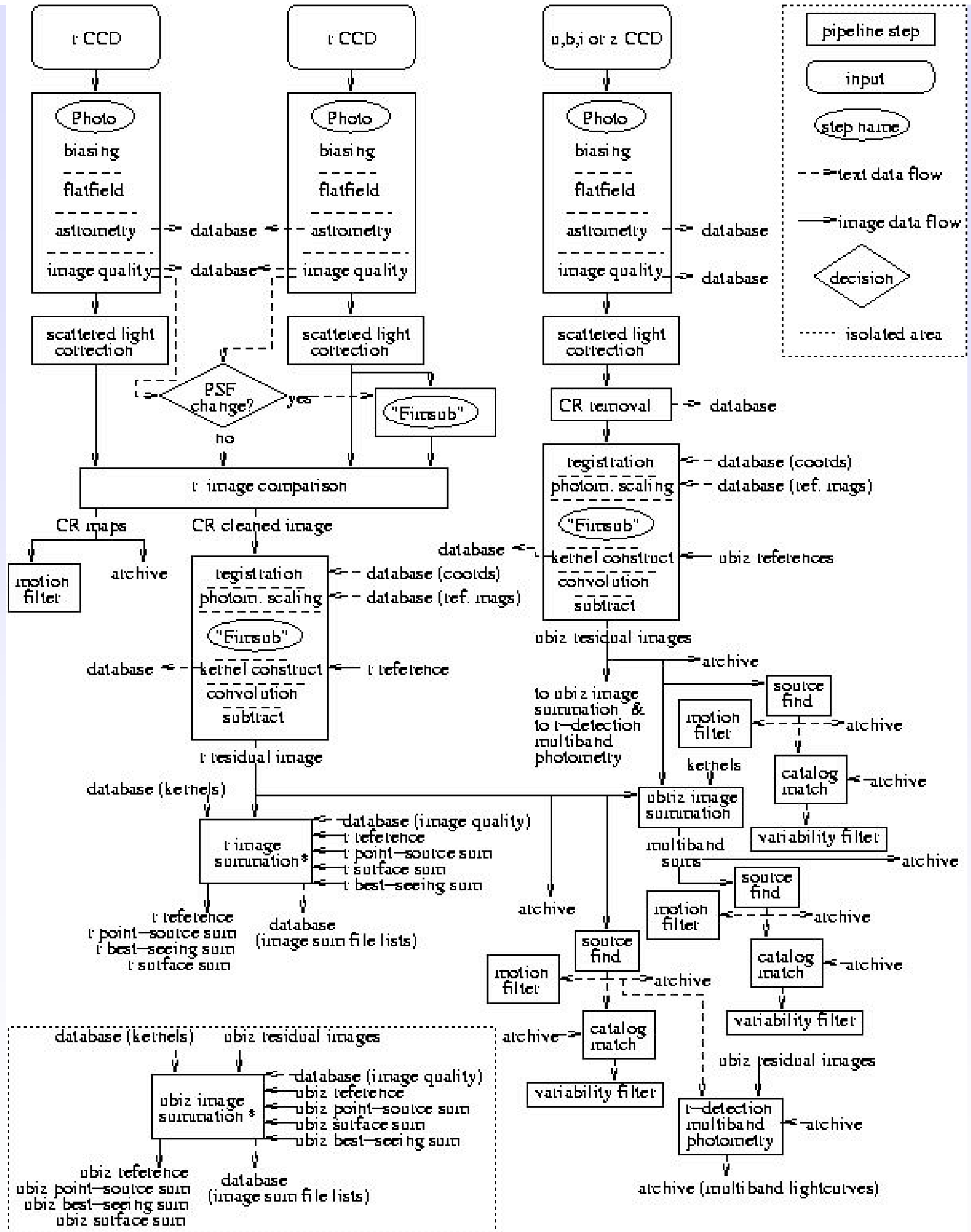
- Best seeing ~ 1.3 arcsec, typical of site. Images are seeing dominated.
- Scattered light component ~ 30%: of which ~10% due to dust, ~20% due to Mylar. Mylar being replaced with better film; expect 10-15% total scattering, close to classical total.
- Light losses with new film will still be ~20% over conventional telescope => ~10% diameter hit (but at < 1/10th the price !).



# Imaging Pipeline




*Reference image and point–source, surface and best–seeing sums are not computed nightly.

# Cerro Tololo Inter-american Observatory

Cerro Tololo is in the southern Atacama desert of Chile, Latitude $-30^{0}.16$. The nights are 80-85% clear, and seeing is typically at or below 1 arcsec. It has developed roads, utilities, shops, offices, dorms and other infrastructure.

The directorship of CTIO has shown keen interest in attracting ALPACA and is actively studying which of two of best sites on the mountain are most suitable: a site at the summit or one 50 m below (depending on the wind shadow ALPACA would create for other telescopes).

⇦ Prevailing Wind Direction

# Choice of CTIO Sites

Both site are at the “prow” of the mountain looking into the prevailing wind, hence best for seeing. There are no obstructions for many km (if at all), hence one can expect little ground-layer turbulence.

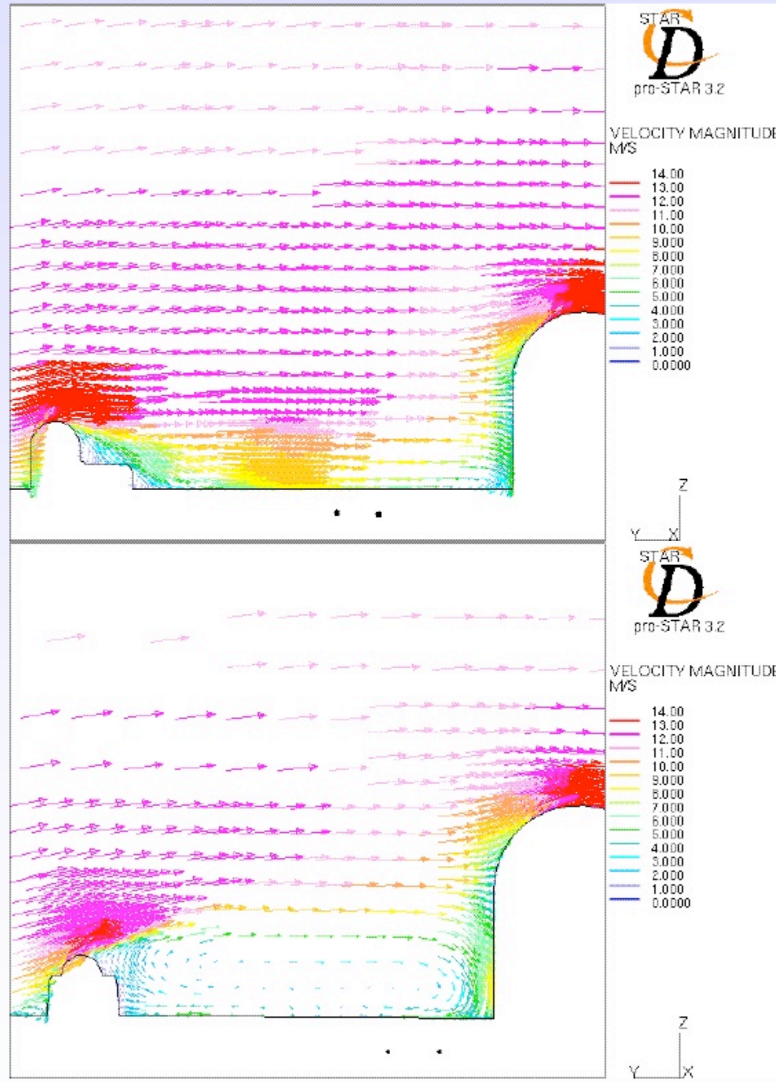
Both sites are adjacent to utility hookups and roads, and far from lights or dust-generating activity.

View from summit site looking NE into prevailing wind

# CTIO Summit Wind Models

- ALPACA enclosure is designed to have minimal aerodynamic effect, restores original windflow pattern within about 20 meters.  Doesn't affect Blanco 4-m.

- 1-m is boxed-shaped and traps volume of air in cell between 1-m and Blanco, including some changes at lip of 4-m dome slit.



# Seeing Monitor Campaign (2007-2010)

- CTIO DIMM: record seeing integrated through atmosphere

- 4 microthermal sensors on 30m (or 21m) tower: sensors at 10, 15, 21, 30m

- Lunar Scintillometer (since 8/2006): senses seeing at ~30-1000m. See: http://www.ctio.noao.edu/diroff/Web%20Covers/SCINTILLOMETER-2.htm

# BACKUP MATERIAL ON ALPACA HARDWARE DESIGN